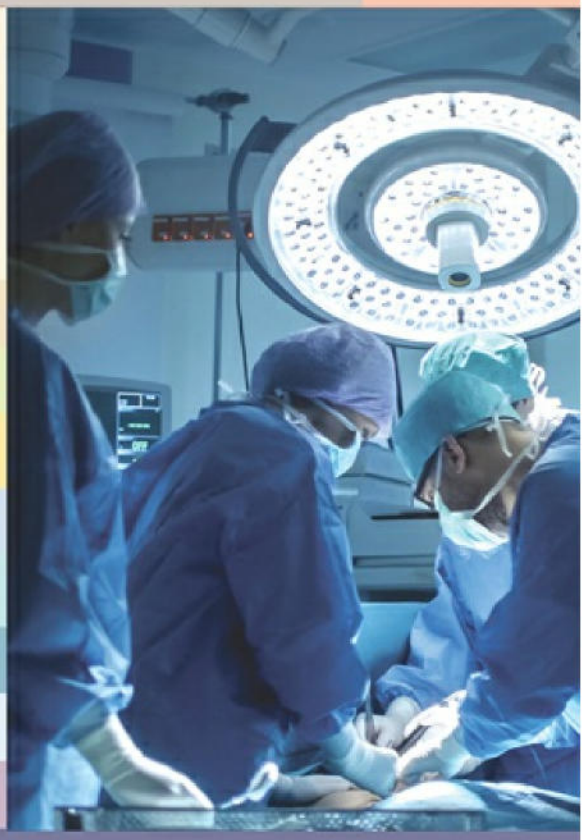
ANESTHESIOLOGIST'S Manual of Surgical Procedures

SIXTH EDITION

Richard A. Jaffe
Clifford A. Schmiesing
Brenda Golianu



SURGICAL CONSIDERATIONS
INDUCTION
MAINTENANCE
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Anesthesiologist's Manual of Surgical Procedures

Sixth Edition

EDITOR

Richard A. Jaffe, MD, PhD
Professor of Anesthesiology and Neurosurgery
Chief, Neurosurgical Anesthesia Service
Stanford University School of Medicine
Stanford, California

ASSOCIATE EDITORS

Clifford A. Schmiesing, MD
Associate Clinical Professor, Anesthesiology, Perioperative and Pain Medicine
Co-Director Anesthesia Preoperative Assessment Clinic
Stanford University School of Medicine
Stanford, California

Brenda Golianu, MD
Assistant Professor of Anesthesiology
Stanford University School of Medicine
Stanford, California

Wolters Kluwer

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Acquisitions Editor: Keith Donnellan
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CONTRIBUTING AUTHORS

Vernon J. Adams Jr., DMD
Staff
Department of Pediatrics
Lucile Salter Packard Hospital
Stanford, California

Rita Agarwal, MD, FAAP, FASA
Clinical Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Timothy P. Angelotti, MD, PhD
Associate Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Martin S. Angst, MD
Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Alexander H. Arzeno, MD
Chief Resident
Department of Orthopaedic Surgery
Stanford University School of Medicine
Stanford, California

Michael J. Bellino, MD
Clinical Associate Professor
Department of Orthopaedic Surgery
Stanford University School of Medicine
Surgeon
Department of Orthopaedic Surgery

Stanford Health Care
Stanford, California

Claudia Benkwitz, MD, PhD
Associate Professor of Anesthesia and Perioperative Care
UCSF Benioff Children's Hospital
San Francisco, California

Melissa T. Berhow, MD, PhD
Associate Professor
Department of Anesthesiology
Stanford University School of Medicine
Stanford, California

David A. Berman, MD
Medical Director, Dermatologic Surgeon
Berman Skin Institute
Palo Alto, California

William E. Berquist, MD
Professor of Pediatrics
Department of Pediatrics
Stanford University School of Medicine
Professor of Pediatrics (Gastroenterology)
Lucile Packard Children's Hospital Stanford
Stanford, California

Mark F. Berry, MD
Professor
Department of Cardiothoracic Surgery
Stanford University School of Medicine
Stanford, California

M. Gail Boltz, MD, FAAP
Clinical Professor of Anesthesiology
Department of Anesthesiology
Stanford University School of Medicine
Stanford, California

C. Andrew Bonham, MD
Associate Professor
Surgery
Stanford University Medical School
Stanford, California

John G. Brock-Utne, MD, PhD
Professor of Anesthesiology (Emeritus)
Department of Anesthesiolgy
Stanford University School of Medicine
Stanford, California

Jessica L. Brodt, MBBS
Clinical Assistant Professor
Division of Cardiac Anesthesia
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Timothy Browder, MD, MACM
Clinical Associate Professor
Department of Surgery
Stanford University Medical Center
Stanford, California

Mark A. Burbridge, MD
Clinical Assistant Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University Medical Center
Stanford, California

Matthew B. Burn, MD
Assistant Professor
Department of Orthopedics
Houston Methodist Hospital
Pediatric Hand and Upper Limb Surgeon
Shriner's Hospital for Children
Houston, Texas

Megan Kennedy Burns, MD, MA
Assistant Professor
Obstetrics and Gynecology
University of Massachusetts Memorial Hospital
Worchester, Massachusetts

Erin Bushell, MD
Anesthesiologist
United States Anesthesia Partners
Swedish Medical Center
Seattle, Washington

Alex J. Butwick, MD, MS, FRCA
Associate Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Natalia F. Callaway, MD, MS
Clinical Instructor
Department of Ophthalmology
Stanford University Byers Eye Institute
Palo Alto, California

Robson Capasso, MD
Associate Professor
Division of Otolaryngology–Head and Neck Surgery
Stanford University School of Medicine
Stanford University Medical Center
Stanford, California

Anthony J. Carden, MD
Minimally-Invasive Surgery Fellow
Surgical Services
Palo Alto VA Health Care System
Palo Alto, California

Brendan Carvalho, MBBCh, FRCA, MDCH
Professor

Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

James Chang, MD
Johnson & Johnson Distinguished Professor
Chief of Plastic & Reconstructive Surgery
Department of Surgery
Stanford University Medical Center
Stanford, California

Jeff Chang, MD
Clinical Instructor of Surgery
University of Southern California
Los Angeles, California

Steven D. Chang, MD
Robert C. and Jeannette Powell Professor
Department of Neurosurgery
Stanford University School of Medicine
Stanford, California

Navjot Chaudhary, BSc, MD, FRCSC
Neurosurgeon
Division of Neurosurgery
The University of British Columbia
Vancouver, Canada

Michael I. Chen, MD
Clinical Associate Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Ivan Cheng, MD
Associate Professor
Department of Orthopaedic Surgery
Stanford University School of Medicine
Stanford, California

Tiffany Cheng, MD
Clinical Instructor
Department of Anesthesiology
Stanford University School of Medicine
Stanford, California

Samuel H. Cheshier, MD
Associate Professor
Department of Neurosurgery
University of Utah
Associate Professor
Pediatric Neurosurgery
Primary Children's Hospital
Salt Lake City, Utah

Emilie V. Cheung, MD
Associate Professor
Orthopedic Surgery
Stanford University School of Medicine
Redwood City, California

Rebecca E. Claure, MD
Clinical Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California
Medical Director Perioperative Services
Lucile Packard Children's Hospital Stanford
Palo Alto, California

Lee Coleman, MD
Assistant Professor
Department of Anesthesiology
Cedars Sinai Medical Center
Los Angeles, California

Waldo Concepcion, MD, FACS
Professor
Department of Surgery

Stanford University School of Medicine
Chief of Clinical Transplantation
Chief of Pediatric Kidney Transplantation
Stanford Hospital and Clinics
Stanford Children's Hospital
Stanford, California

Catherine Curtin, MD
Associate Professor
Department of Surgery
Stanford University School of Medicine
Stanford, California

Michael D. Dake, MD
Professor
Medical Imaging, Medicine and Surgery
The University of Arizona
Senior Vice President for Health Sciences
The University of Arizona Health Sciences
Tucson, Arizona

Edward J. Damrose, MD, FACS
Professor of Otolaryngology–Head and Neck Surgery (Laryngology)
Professor, by courtesy, of Anesthesiology, Perioperative and Pain Medicine
Division of Otolaryngology–Head and Neck Surgery
Stanford University School of Medicine
Stanford University Medical Center
Stanford, California

Charles DeBattista, DMH, MD
Director, Depression Research Clinic
Director of Medical Student Education in Psychiatry
Professor of Psychiatry and Behavioral Sciences
Department of Psych/General Psychiatry and Psychology (Adult)
Stanford University School of Medicine
Stanford, California

Lucia DiFrancesco, MD
Research Fellow

Center for Special Minimally Invasive and Robotic Surgery
Palo Alto, California

Samantha Corey Do, MD
Clinical Fellow
Division of Maternal–Fetal Medicine, Department of Obstetrics and Gynecology
Stanford University School of Medicine
Stanford, California

Robert L. Dodd, MD, PhD
Associate Professor
Departments of Neurosurgery and Radiology
Stanford University School of Medicine
Stanford, California

Sarah S. Donaldson, MD, FACR, FASTRO
Professor
Radiation Oncology
Stanford University School of Medicine
Stanford, California

Genevieve D'Souza, MD
Clinical Assistant Professor
Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Zhenhua Du, MD, PhD
Lecturer
Department of Obstetrics and Gynecology
China Medical University
Physician
Department of Obstetrics and Gynecology
Shengjing Hospital of China Medical University
Shenyang, Liaoning, China

Anne M. Dubin, MD
Professor

Department of Pediatrics
Stanford University School of Medicine
Director of Pediatric Arrhythmia Service
Pediatric Cardiology
Lucile Packard Children's Hospital
Stanford, California

Michael S. B. Edwards, MD, FAANS, FACS, FAAP
Professor of Neurological Surgery and Pediatrics, Emeritus
Department of Neurological Surgery
Stanford University School of Medicine
Stanford, California

Dan Eisenberg, MD, MS, FACS, FASMBS
Associate Professor
Department of Surgery
Stanford School of Medicine
Stanford, California
Director of Minimally Invasive and Bariatric Surgery
Surgical Services
Palo Alto VA Health Care System
Palo Alto, California

Yasser Y. El-Sayed, MD
Professor and Director Maternal-Fetal Medicine & Obstetrics
Department of Obstetrics and Gynecology
Stanford University School of Medicine
Stanford, California

James I. Fann, MD
Professor
Department of Cardiothoracic Surgery
Stanford University School of Medicine
Stanford, California

Ruth M. Fanning, MB, BCh, MRCPI, FFARCSI
Clinical Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine

Stanford, California

Linda E. Foppiano, MD
Clinical Associate Professor
Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Deshka S. Foster, MD, MA
General Surgery Resident
Department of Surgery
Stanford University School of Medicine
Stanford, California

Paige M. Fox, MD, PhD
Assistant Professor
Division of Plastic and Reconstructive Surgery
Department of Surgery
Stanford University School of Medicine
Stanford, California

Louise K. Furukawa, MD
Clinical Associate Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Lucile Packard Children's Hospital
Stanford, California

James G. Gamble, MD, PhD
Professor
Orthopaedic Surgery
Packard Children's Hospital
Stanford University Medical Center

Harcharan S. Gill, MD, FRCS, FACS
Professor
Department of Urology
Stanford University School of Medicine
Kathryn Simmons Stamey Professor of Urology

Program Director
Department of Urology
Stanford University School of Medicine
Stanford, California

Andrew J. Giustini, MD, PhD
Clinical Instructor, Anesthesiology, Perioperative and Pain Medicine
Department of Anesthesiology
Stanford University School of Medicine
Stanford, California

Brenda Golianu, MD
Associate Professor
Anesthesiology Pain and Perioperative Medicine
Stanford University School of Medicine
Stanford, California

Julie Good, MD
Clinical Associate Professor
Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Stuart B. Goodman, MD, PhD, FRCSC, FACS, FBSE, FICORS
Robert L. and Mary Ellenburg Professor of Surgery
Department of Orthopaedic Surgery and (by courtesy) Bioengineering
Stanford University Medical Center
Stanford, California

Gerry A. Grant, MD
Professor
Department of Neurosurgery
Stanford University School of Medicine
Stanford, California
Division Chief
Department of Pediatric Neurosurgery
Lucile Packard Children's Hospital
Stanford, California

Gregory B. Hammer, MD
Professor
Pediatrics and Anesthesiology, Perioperative and Pain Management
Stanford University School of Medicine
Stanford, California
Attending Physician
Pediatrics (Critical Care), Pediatric Anesthesiology
LPCH at Stanford
Stanford, California

Frank L. Hanley, MD
Professor of Cardiothoracic Surgery
Cardiothoracic Surgery
Stanford University School of Medicine
Executive Director
Betty Irene Moore Children's Heart Center
Lucile Packard Children's Hospital
Stanford, California

Gary E. Hartman, MD, MBA
Clinical Professor
Surgery–Pediatric Surgery
Stanford University School of Medicine
Associate VP of Medical Affairs
Lucile Packard Children's Hospital
Stanford, California

Jaimie M. Henderson, MD
John and Jene Blume–Robert and Ruth Halperin Professor
Professor of Neurosurgery
Stanford University Medical Center
Stanford, California

Vincent R. Hentz, MD
Professor (Emeritus)
Department of Surgery
Stanford University School of Medicine
Stanford, California

Jerome E. Hester, MD
Attending Physician
Department of Otolaryngology/Head and Neck Surgery
Stanford University Hospital
Stanford, California

Susan M. Hiniker, MD
Assistant Professor
Department of Radiation Oncology
Stanford University School of Medicine
Stanford, California

Terri D. Homer, MD
Anesthesiologist (Retired)
Associated Anesthesiologists Medial Group
Palo Alto, California

Anita Honkanen, MD, MS, FAAP
Clinical Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Jean-Louis Horn, MD
Professor
Chief of Regional Anesthesia and Acute Pain
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

James I. Huddleston III, MD
Associate Professor of Orthopaedic Surgery
Department of Orthopaedic Surgery
Stanford University School of Medicine
Division Director, Adult Reconstruction Service
Department of Orthopaedic Surgery
Stanford Healthcare
Stanford, California

Peter H. Hwang, MD
Professor and Vice Chair
Department of Otolaryngology–Head & Neck Surgery
Stanford University School of Medicine
Stanford, California

Ibrahim A. Idakoji, MD, MPH
Clinical Assistant Professor
Division of Interventional Radiology
Stanford University School of Medicine
Stanford, California

Jerry Ingrande, MD, MS
Associate Clinical Professor
Department of Anesthesiology
University of California, San Diego
La Jolla, California

Robert K. Jackler, MD
Sewall Professor and Chair
Division of Otolaryngology—Head and Neck Surgery
Stanford University School of Medicine
Service Chief
Department of Otolaryngology—Head and Neck Surgery
Stanford Health Care
Stanford, California

Richard A. Jaffe, MD, PhD
Professor of Anesthesiology and Neurosurgery
Chief, Neurosurgical Anesthesia Service
Stanford University Medical Center
Stanford, California

Sharon Jung, PharmD
PGY2 Critical Care Pharmacy Resident
Department of Pharmacy
Loma Linda University Medical Center
Loma Linda, California

David M. Kahn, MD
Associate Professor
Plastic Surgery
Stanford University Medical Center
Stanford University School of Medicine
Stanford, California

Clayton A. Kaiser, MD
Cardiovascular Surgeon
Department of Cardiac Surgery
Saint Thomas Heart
Saint Thomas Health
Nashville, Tennessee

Komal Kamra, MBBS, MMI
Clinical Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University Medical Center
Stanford, California

Michael J. Kaplan, MD
Professor of Otolaryngology–Head and Neck Surgery
Divisions of OHNS/Head and Neck Surgery
Stanford University School of Medicine
Stanford University Medical Center
Stanford, California

Hadiza S. Kazaure, MD
Fellow
Endocrine Surgery
Duke University
Durham, North Carolina

Andrew Kesselman, MD, RPVI
Assistant Professor
Department of Radiology
Weill Cornell Medicine
New York, New York
Interventional Radiologist

Stanford Hospital and Clinics
Stanford, California

Lisa M. Knowlton, MD, MPH
Assistant Professor of Surgery
Trauma, Acute Care Surgery and Surgical Critical Care
Stanford University Medical Center
Stanford, California

Jonathan Kort, MD
Practice Director
Department of Reproductive Endocrinology and Fertility
Reproductive Medicine Associates of Northern California
San Francisco, California

Vivek Kulkarni, MD, PhD
Clinical Associate Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Chief, Division of Thoracic Anesthesiology
Stanford University Medical Center
Stanford, California

Jamie Kuo, PharmD, BCCCP
Pharmacy Manager of Clinical Effectiveness
Department of Pharmacy
Stanford Health Care
Stanford, California

Amy L. Ladd, MD
Elsbach-Richards Professor of Surgery
Orthopaedic Surgery
Stanford University School of Medicine
Stanford, California

Azeem K. Lakha, DMD
Oral and Maxillofacial Surgeon
Department of Surgery
Stanford University School of Medicine

Stanford, California

C. Philip Larson Jr., MD, CM
Emeritus Professor, Anesthesia and Neurosurgery
Department of Anesthesiology
Stanford University School of Medicine
Stanford, California
Professor of Clinical Anesthesiology (ret)
Department of Anesthesiology
David Geffen School of Medicine at UCLA
Los Angeles, California

Hendrikus J. M. Lemmens, MD, PhD
Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Jacinta Leyden, BS
MD Candidate
Division of Plastic and Reconstructive Surgery
Stanford School of Medicine
Stanford, California

Liong-Bing Liem, DO, FHRS, FACC
Clinical Professor
Medicine
University of California at San Francisco
Electrophysiologist
San Francisco VA Health Care System
San Francisco, California

Dana T. Lin, MD
Clinical Assistant Professor
Department of Surgery
Stanford School of Medicine
Stanford, California

Javier Lorenzo, MD

Clinical Assistant Professor
Department of Anesthesiology, Pain and Perioperative Medicine
Stanford University School of Medicine
Stanford, California

Natalie Shaubie Lui, MD, MAS
Assistant Professor
Department of Cardiothoracic Surgery
Stanford University School of Medicine
Stanford, California

Deirdre Lum, MD
Clinical Assistant Professor
Obstetrics and Gynecology
Stanford University School of Medicine
Stanford, California

Birgit Maass, MD
Clinical Assistant Professor
Pediatric Anesthesiology
Stanford Hospital
Stanford, California

Katsuhide Maeda, MD, PhD
Clinical Associate Professor
Department of Cardiothoracic Surgery
Stanford University School of Medicine
Clinical Associate Professor
Department of Cardiothoracic Surgery
Lucile Packard Children's Hospital
Stanford, California

Hari R. Mallidi, MD
Associate Professor
Department of Surgery
Harvard Medical School
Surgical Director, Heart and Lung Transplant
Divisions of Cardiac and Thoracic Surgery
Boston, Massachusetts

Michael P. Marks, MD
Professor of Radiology and Neurosurgery
Stanford University School of Medicine
Stanford, California

Marc L. Melcher, MD, PhD
Associate Professor
Department of Surgery
Stanford University School of Medicine
Stanford, California

Julianne Mendoza, MD
Clinical Assistant Professor
Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Anna H. Messner, MD
Professor
Department of Otolaryngology/Head & Neck Surgery
Baylor College of Medicine
Chief, Otolaryngology
Texas Children's Hospital
Houston, Texas

Frederick G. Mihm, MD
Professor; Chief, Division of Critical Care Medicine
Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Associate Medical Director, Intensive Care Units
Stanford University Medical Center
Stanford, California

Amin A. Milki, MD
Professor
Department of Obstetrics and Gynecology
Stanford University School of Medicine
Stanford, California

Samuel A. Mireles, MD
Clinical Associate Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

R. Scott Mitchell, MD
Professor Emeritus
Department of Cardiothoracic Surgery
Stanford University School of Medicine
Stanford, California
Attending Surgeon
Department of Surgery
V.A. Hospital
Palo Alto, California

Arash Momeni, MD
Assistant Professor of Surgery
Director, Clinical Outcomes Research
Ryan-Upson Scholar in Plastic and Reconstructive Surgery
Division of Plastic and Reconstructive Surgery
Stanford University School of Medicine
Stanford, California

Darius M. Moshfeghi, MD
Professor, Chief of Retina
Ophthalmology
Byers Eye Institute, Stanford University School of Medicine
Palo Alto, California

Sam P. Most, MD
Professor
Departments of Otolaryngology, Head & Neck Surgery, and Surgery (Plastic)
Stanford University School of Medicine
Chief, Division of Facial, Plastic & Reconstructive Surgery
Division of Facial, Plastic & Reconstructive Surgery
Stanford, California

Claudia Mueller, MD, PhD

Associate Professor
Surgery
Stanford University School of Medicine
Stanford, California

Mastoora Nasiri, MD
Clinical Instructor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Aussama K. Nassar, MD, MSc, FRCSC, FACS
Clinical Assistant Professor
Department of Surgery
Stanford University School of Medicine
Stanford, California

Vladimir Nekhendzy, MD
Clinical Professor
Departments of Anesthesiology and Otolaryngology
Director, Stanford Head and Neck Anesthesia and Advanced Airway Management Program
Stanford University School of Medicine
Stanford, California

Azadeh A. Nezhat, MD, FACOG
Assistant Clinical Professor
Department of Obstetrics and Gynecology
UCSF School of Medicine
San Francisco, California
Co-Director of Fellowship
Department of Gynecologic Surgery
Center for Minimally Invasive & Robotic Surgery
Palo Alto, California

Camran R. Nezhat, MD, FACOG, FACS
Clinical Professor
Department of Obstetrics and Gynecology
University of California, San Francisco School of Medicine

San Francisco, California
Director
Camran Nezhat Institute
Palo Alto, California

Carolyn Nguyen, PharmD
Clinical Pharmacist
Department of Pharmacy
Stanford Health Care
Stanford, California

Jeffrey A. Norton, MD
Professor
Chief of Surgical Oncology
Department of Surgery
Stanford University School of Medicine
Stanford, California

Daryl Oakes, MD
Clinical Associate Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

David Oji, MD
Clinical Assistant Professor
Department of Orthopedic Surgery
Stanford University School of Medicine
Palo Alto, California

Einar Ottestad, MD
Clinical Associate Professor
Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Director of Acute Pain Services
Stanford Health Care
Stanford, California

Christopher J. Painter, MD

Assistant Clinical Professor
Department of Anesthesia
Stanford University School of Medicine
Stanford, California

Ariel Palanca, MD
Assistant Professor
Orthopedic Surgery
Stanford University Medical Center
Stanford, California

Periklis Panousis, MD, PhD
Assistant Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford Health Care
Stanford, California

Lynn Peng, MD
Clinical Associate Professor
Pediatrics, Division of Pediatric Cardiology
Stanford School of Medicine
Director, Cardiac Catheterization Laboratory
Division of Pediatric Cardiology
Lucile Packard Children's Hospital
Palo Alto, California

Lindsay Raleigh, MD
Clinical Assistant Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Lindsey Ralls, MD
Clinical Assistant Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Chandra Ramamoorthy, MD
Clinical Assistant Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Radhamangalam J. Ramamurthi, MD, FRCA
Clinical Associate Professor
Anesthesiology
Stanford University School of Medicine
Stanford, California
Co-Chair–Pediatric Regional Anesthesia
Division of Pediatric Anesthesiology
Stanford Children's Hospital
Stanford, California

Roya Saffary, MD
Clinical Assistant Professor
Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Stephen A. Schendel, MD, DDS, FACS
Professor Emeritus
Department of Surgery
Stanford University Medical Center
Stanford, California

Clifford A. Schmiesing, MD
Associate Clinical Professor
Anesthesiology, Perioperative and Pain Medicine
Department of Anesthesiology
Stanford School of Medicine
Co-Director Anesthesia Preoperative Assessment Clinic
Stanford, California

Donald M. Sesso, DO
Surgeon
Pennsylvania Snoring & Sleep Institute

Philadelphia, Pennsylvania

Jeannie Seybold, MD
Clinical Instructor of Anesthesia (Retired)
Department of Anesthesiology
Stanford University Medical Center
Stanford, California

Steven L. Shafer, MD
Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford Hospital
Stanford, California

Andrew A. Shelton, MD, FACS, FASCRS
Clinical Professor and Chief of Colorectal Surgery
Department of Surgery
Stanford University School of Medicine
Stanford, California

Lawrence M. Shuer, MD
Professor and Associate Chair
Department of Neurosurgery
Stanford University School of Medicine
Stanford, California

Vanila M. Singh, MD, MACM
Clinical Associate Professor
Department of Anesthesiology
Stanford University School of Medicine
Stanford, California
Chief Medical Officer
US Department of Health and Human Services
Washington, D.C.

Samuel K. S. So, MD, FACS
Lui Hac Minh Professor
Department of Surgery

Stanford University School of Medicine
Stanford, California

Gary K. Steinberg, MD, PhD
Bernard and Ronni Lacroute-William Randolph Hearst Professor of
Neurosurgery and the Neurosciences
Chair, Department of Neurosurgery
Stanford University School of Medicine
Chief
Department of Neurosurgery
Stanford Health Care
Stanford, California

Andrew J. Sun, MD
Resident Physician
Department of Urology
Stanford University Medical Center
Stanford, California

Kristin Sun, MD
Assistant Professor
Department of Anesthesiology
Stanford University School of Medicine
Clinical Staff Anesthesiologist
Pediatric Anesthesia
Lucile Packard Children's Hospital
Stanford, California

Nai Yi Sun, MD
Staff Anesthesiologist
Anesthesia and Pain Medicine
The Hospital for Sick Children
Toronto, Ontario

Daniel Y. Sze, MD, PhD
Professor
Division of Interventional Radiology
Stanford University School of Medicine
Stanford, California

Pedro P. Tanaka, MD, PhD, MACM
Clinical Professor
Department of Anesthesiology, Pain and Perioperative Medicine
Stanford University School of Medicine
Stanford, California

Peter H. Tang, MD, PhD
Clinical Instructor
Department of Ophthalmology
Stanford University School of Medicine
Stanford, California

Jordan S. Taylor, MD
Postdoctoral Research Fellow
Division of Pediatric Surgery
Department of Surgery
Stanford University School of Medicine
Stanford, California

Maureen M. Tedesco, MD
The Permanente Medical Group
Kaiser Permanente Santa Clara
Clinical Assistant Professor (Affiliated)
Department of Surgery
Stanford University School of Medicine
Stanford, California
Adjunct Clinical Assistant Professor of Surgery
Boston University School of Medicine
Boston, Massachusetts

Nelson N. H. Teng, MD, PhD
Professor
Department of Obstetrics and Gynecology–Oncology
Stanford University School of Medicine
Stanford, California

Mai Thy Truong, MD
Clinical Associate Professor
Otolaryngology, Head and Neck Surgery

Stanford University School of Medicine
Stanford, California
Fellowship Director
Pediatric Otolaryngology, Head and Neck Surgery
Stanford Children's Hospital
Palo Alto, California

Albert Tsai, MD
Clinical Assistant Professor
Department of Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Anand Veeravagu, MD
Assistant Professor of Neurosurgery
Assistant Professor of Orthopadic Surgery, by courtesy
Stanford University School of Medicine
Stanford, California

Lindsey Vokach-Brodsky, MB, ChB, FFARCSI
Clinical Associate Professor
Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

James Wall, MD, MSE, FACS
Assistant Professor
Pediatric Surgery
Stanford University School of Medicine
Palo Alto, California

David S. Wang, MD
Clinical Assistant Professor
Division of Interventional Radiology
Stanford University School of Medicine
Stanford, California

Ellen Ya-Ping Wang, MD
Clinical Associate Professor

Department of Anesthesiology, Pain and Perioperative Medicine
Stanford University School of Medicine
Palo Alto, California

Irene L. Wapnir, MD, FACS
Professor of Surgery/Chief of Breast Surgery
Surgery
Stanford University School of Medicine
Stanford, California

Lynn M. Westphal, MD
Professor
Obstetrics and Gynecology
Stanford University School of Medicine
Stanford, California

Lisa Wise-Faberowski, MD, MS, FAAP
Associate Professor
Anesthesiology
Stanford University School of Medicine
Lucile Packard Children's Hospital
Palo Alto, California

Olga Wolke, MD
Clinical Associate Professor
Anesthesiology, Perioperative and Pain Medicine
Stanford University School of Medicine
Stanford, California

Sherry M. Wren, MD, FACS, FCS(ECSA)
Vice Chair and Professor
Department of Surgery
Stanford University School of Medicine
Stanford, California

Hsi-Yang Wu, MD
Associate Professor
Urology
Stanford University School of Medicine

Stanford, California
Pediatric Urology Fellowship Program Director
Pediatric Urology
Lucile Packard Children's Hospital
Palo Alto, California

Ann Ming Yeh, MD
Clinical Associate Professor
Pediatric Gastroenterology, Hepatology, Nutrition
Department of Pediatrics
Stanford University School of Medicine
Stanford, California

Stacy Young, MD
Fellow
Department of Obstetrics and Gynecology
Stanford University Medical Center
Stanford, California

Karl Zheng, MD
Clinical Assistant Professor
Department of Anesthesiology
Stanford University School of Medicine
Stanford, California

PREFACE

The goals of this sixth edition remain unchanged from those of the first—that is, to provide an easily accessible source of clinically relevant information about a wide variety of common and not-so-common surgical and nonsurgical procedures requiring anesthesia. As with the first edition, this edition does not pretend to be either a textbook of anesthesia or a textbook of surgery. Indeed, in the formulation of any anesthetic plan, there is no substitute for experience and sound clinical judgment.

Those familiar with the preceding editions will notice that the format and organization of this edition remain largely unchanged. Along with the addition of new procedures, every existing procedure was carefully reviewed and revised to reflect current practice. We continue to expand the use of color to improve readability of the tables and clarity of the figures. New to this edition is an emphasis on common sense enhanced recovery considerations that we believe can be applied perioperatively to most patients undergoing most surgical procedures. Also new to this edition is a chapter reviewing the basic principles and anatomy of common regional anesthetic techniques, an appendix reviewing individual components of enhanced recovery (ERAS) protocols, including fluid management and multimodal pain management, an appendix describing the intraoperative use of Transnasal Humidified Rapid-Insufflation Ventilatory Exchange (THRIVE), and a collection of interesting facts and figures printed on the inside cover pages.

Once again, we have made extensive use of abbreviations, medical symbols, and telegraphic sentence structure to present a large body of information in a condensed format. Although we realized that it may be aesthetically more pleasing to read: "hypoxia or hypercapnia can lead to the development of tachycardia and hypertension", it takes up a lot less space to write: $\downarrow PaO_2$ or $\uparrow PaCO_2 \rightarrow \uparrow HR + \uparrow BP$.

As always the editorial team welcomes comments and suggestions from our readers (e-mail: anesthesiologistsmanual.Jaffe@stanford.edu), and we remain hopeful that this edition will become a useful resource in their training and subsequent clinical practice.

Richard A. Jaffe, MD, PhD
Stanford, California

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This edition is built on the foundation of its predecessors and thus includes material from prior editions. We remain grateful to our many former contributors, some of whose words have survived the test of time and continue to live on in the current edition.

We would like to thank our families for their support, patience, and understanding; our colleagues on both sides of the blood–brain barrier for the time and effort they have generously invested in this educational project; our readers, whose many kind comments have been very much appreciated; Donna J. Allison, PhD, for the difficult job of proofreading under adverse circumstances; our Acquisitions Editor, Keith Donnellan, and our Developmental Editor, Rebeca Barroso, for their patient and enthusiastic support of this project; and finally, our teachers, mentors, and trainees, who have made anesthesiology such an exciting and fulfilling profession for us all.

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ANESTHESIOLOGIST Hendrikus J. M. Lemmens

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ANESTHESIOLOGIST Hendrikus J. M. Lemmens

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ANESTHESIOLOGIST Martin S. Angst

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ANESTHESIOLOGIST Martin S. Angst

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ANESTHESIOLOGIST Lindsay Raleigh

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ANESTHESIOLOGIST Clifford A. Schmiesing

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ANESTHESIOLOGIST Lindsey Vokach-Brodsky

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ANESTHESIOLOGISTS Frederick G. Mihm, Christopher J. Painter, Pedro P. Tanaka

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Intracranial Neuroendoscopy (Endoscopic Third Ventriculostomy, Coagulation of Choroid Plexus, Fenestration of Cyst)
Surgery for Intracranial Arteriovenous Malformation
Craniotomy for Vein of Galen Malformation

12.2 Pediatric Ophthalmic Surgery

SURGEONS Natalia F. Callaway, Darius M. Moshfeghi

ANESTHESIOLOGIST Olga Wolke

Strabismus Surgery
Pediatric Vitreoretinal Surgery

12.3 Pediatric Otolaryngology

SURGEONS Mai Thy Truong, Anna H. Messner

ANESTHESIOLOGISTS Samuel A. Mireles, Ellen Ya-Ping Wang, Gregory B. Hammer

Myringotomy and Tympanostomy Tube Placement
Tonsillectomy and Adenoidectomy
Bronchoscopy/Esophagoscopy/Removal of Foreign Body
Laryngoscopy, Supraglottoplasty, and Excision of Laryngeal Lesions
Removal of Branchial Cleft Cyst or Thyroglossal Duct Cyst
Incision/Drainage of Deep Neck Abscess
Laryngotracheal Reconstruction, Cricotracheal Resection, and Laryngotracheoplasty
Choanal Atresia Repair
Pediatric Tracheostomy

12.4 Pediatric Cardiovascular Surgery

SURGEONS Katsuhide Maeda, Frank L. Hanley

ANESTHESIOLOGISTS Claudia Benkwitz, Lisa Wise-Faberowski, Komal Kamra, M. Gail Boltz, Chandra Ramamoorthy

Surgery for Atrial Septal Defect (Ostium Secundum)
Surgery for Atrioventricular Canal Defect
Surgery for Ventricular Septal Defect
Surgery for Patent Ductus Arteriosus
Surgery for Coarctation of the Aorta
Surgery for Tetralogy of Fallot
Surgery for Total Anomalous Pulmonary Venous Connection
Surgery for Complete Transposition of the Great Arteries
Surgery for Truncus Arteriosus
Surgery for Tricuspid Atresia
Surgery for Double-Outlet Right Ventricle

Surgery for Hypoplastic Left Heart Syndrome

12.5 Pediatric General Surgery

SURGEONS Jordan S. Taylor, James Wall

ANESTHESIOLOGISTS Andrew J. Giustini, Rebecca E. Claure, Brenda Golianu

Resection of Cystic Hygroma, Branchial Cleft Cyst, Thyroglossal Duct Cyst, or Other Cervical Mass
Esophagus—Foreign Body Removal and Dilation
Achalasia, Heller Myotomy, Peroral Endoscopic Myotomy (POEM), and Advanced Endoscopic Surgeries
Repair of Tracheoesophageal Fistula and Esophageal Atresia
Mediastinal Mass—Biopsy or Resection
Neonatal Lung Resection
Drainage of Empyema
Repair of Pectus Excavatum/Carinatum
Esophageal Replacement, Colon Interposition
Repair of Congenital Diaphragmatic Hernia
Pyloromyotomy for Pyloric Stenosis
Abdominal Tumor: Resection of Neuroblastoma, Wilms Tumor, and Hepatic Tumors
Laparotomy for Intestinal Perforation and Necrotizing Enterocolitis
Repair of Biliary Atresia and Choledochal Cysts
Repair of Abdominal Wall Defects: Omphalocele/Gastroschisis
Pull-Through for Hirschsprung Disease
Pull-Through for Imperforate Anus and Cloaca
Repair of Inguinal and Umbilical Hernias and Hydrocele
Surgery for the Undescended Testicle
Resection of Sacrococcygeal Teratoma
Anesthesia for Minimally Invasive Surgery in Pediatric Patients
Ex Utero Intrapartum Treatment (EXIT) Procedure
Pediatric Bariatric Surgery

12.6 Pediatric Urology

SURGEONS Andrew J. Sun, Hsi-Yang Wu

ANESTHESIOLOGIST Radhamangalam J. Ramamurthi

Kidney and Upper Urinary Tract Operations

Percutaneous Stone Procedures
Transurethral Procedures
Simple Open Bladder Operations
Complex Open Bladder Operations
Penile Surgery
Genital Procedures (Clitoroplasty, Vaginoplasty, Urethroplasty)
Inguinoscrotal Procedures
Laparoscopic and Robotic Procedures

12.7 Pediatric Orthopedic Surgery

SURGEONS Amy L. Ladd, Matthew B. Burn, James G. Gamble

ANESTHESIOLOGISTS Genevieve D'Souza, Brenda Golianu, Radhamangalam J. Ramamurthi

Percutaneous Pinning of Displaced Supracondylar Humerus Fracture
Closed or Open Reduction of Displaced Lateral Condyle Humerus Fracture
Aspiration and Injection of Unicameral Bone Cyst
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Posterior Spinal Instrumentation and Fusion
Anterior Spinal Fusion for Scoliosis
Pelvic Osteotomy
Acetabular Augmentation (Shelf) and Chiari Osteotomy
Ober Fasciotomy and Yount-Ober Release
Hip, Open Reduction, and Femoral Shortening
Adductor Release or Transfer and Psoas Release
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Epiphysiodesis
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Tendon Transfer, Lengthening (Posterior Tibial)
Triple Arthrodesis and Grice Procedure (Extra-Articular Subtalar Arthrodesis)

Surgical Correction of Clubfoot
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12.8 Surgery for Craniofacial Malformations

SURGEON Stephen A. Schendel

ANESTHESIOLOGISTS Nai Yi Sun, Rita Agarwal, Louise K. Furukawa

Surgical Correction of Craniosynostosis
Major Secondary Craniofacial Surgical Procedures
Cleft Lip Repair—Unilateral/Bilateral
Palatoplasty
Pharyngoplasty
Alveolar Cleft Repair with Bone Graft
Secondary Cleft Lip/Nasal Surgery
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SURGEON Waldo Concepcion

ANESTHESIOLOGISTS Julianne Mendoza, Louise K. Furukawa, Gregory B. Hammer

Pediatric Renal Transplantation
Pediatric Liver Transplantation

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PROCEDURAL SPECIALISTS Charles DeBattista, Liong-Bing Liem, Michael P. Marks, Daniel Y. Sze, David S. Wang, Andrew Kesselman, Ibrahim A. Idakoji

ANESTHESIOLOGISTS Richard A. Jaffe, John G. Brock-Utne, Timothy P. Angelotti

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Electroconvulsive Therapy
Interventional Neuroradiology
Direct Current Cardioversion
Implantation of Cardioverter-Defibrillator (ICD) or Cardiac Resynchronization Therapy Defibrillator (CRT-D)
Extraction of Pacemaker and Implantable Cardioverter-

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Catheter Ablation of Ventricular Tachycardia
Transjugular Intrahepatic Portosystemic Shunt (TIPS)
Endoscopic Retrograde Cholangiopancreatography
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Tracheobronchial Stenting
Thermal Ablation of Tumors and Other Targets
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PROCEDURAL SPECIALISTS Claudia Mueller, William E. Berquist, Sarah S. Donaldson, Anne M. Dubin, Gary E. Hartman, Susan M. Hiniker, Katsuhide Maeda, Lynn Peng, Ann Ming Yeh

ANESTHESIOLOGISTS Claudia Benkwitz, Erin Bushell, Rebecca E. Claure, Louise K. Furukawa, Brenda Golianu, Kristin Sun, Lisa Wise-Faberowski, Komal Kamra

Pediatric Radiation Therapy
Pediatric Cardiac Catheterization and Electrophysiology
Pediatric Oncologic Procedures
Upper/Lower GI Endoscopy
Anesthesia for the Patient with Epidermolysis Bullosa (EB)
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Surgical Considerations for ECMO
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ANESTHESIOLOGISTS Richard A. Jaffe, Terri D. Homer

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Office Dental Rehabilitation Under Deep IV Sedation
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ANESTHESIOLOGIST Frederick G. Mihm

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ANESTHESIOLOGISTS Jean-Louis Horn, Mastoora Nasiri

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SECTION 1.0

NEUROSURGERY

CHAPTER 1.1

Intracranial Neurosurgery

SURGEONS

Gary K. Steinberg, MD, PhD (Neurovascular surgery)
Robert L. Dodd, MD, PhD (Neurovascular surgery)
Navjot Chaudhary, BSc, MD, FRCSC (General neurosurgery)
Lawrence M. Shuer, MD (General neurosurgery)
Steven D. Chang, MD (General neurosurgery, Stereotactic neurosurgery)

ANESTHESIOLOGISTS

Richard A. Jaffe, MD, PhD
Mark A. Burbridge, MD

CRANIOTOMY FOR INTRACRANIAL ANEURYSMS

SURGICAL CONSIDERATIONS

Gary K. Steinberg and Robert L. Dodd

Description

Intracranial aneurysms are focal protrusions arising from weakened arterial walls usually at major bifurcations of the arteries at the base of the brain (some frequent sites of aneurysms are shown in Fig. 1.1-1) and are most commonly treated by endovascular coiling (>50%) or microsurgical clip ligation. The high rate of mortality (~45% within 30 d) and morbidity from aneurysmal rupture necessitates treatment for symptomatic lesions. Treatment for asymptomatic lesions generally is recommended when the lifetime risk of rupture exceeds the risk of treatment. The most important surgical considerations include clinical presentation, aneurysm size and location, patient age, neurologic status, and medical comorbidities. Aneurysm rupture into the subarachnoid space is the most common clinical presentation; however, symptoms from the mass

effect of enlarging aneurysms or ischemic symptoms from emboli also may occur. Aneurysm morphology, size, and location are important in determining the surgical approach, and these aneurysm characteristics, as well as patient age, condition, and comorbidities, affect the overall outcome. The **Hess and Hunt clinical grading system** (Table 1.1-1) has been proven useful in describing patients with ruptured intracranial aneurysms because it has been shown to have prognostic value in terms of ultimate clinical outcome. Grading is based on the neurologic examination and ranges from grade I (minimal headache, no neurologic deficit) to grade V (moribund) (see Table 1.1-1).

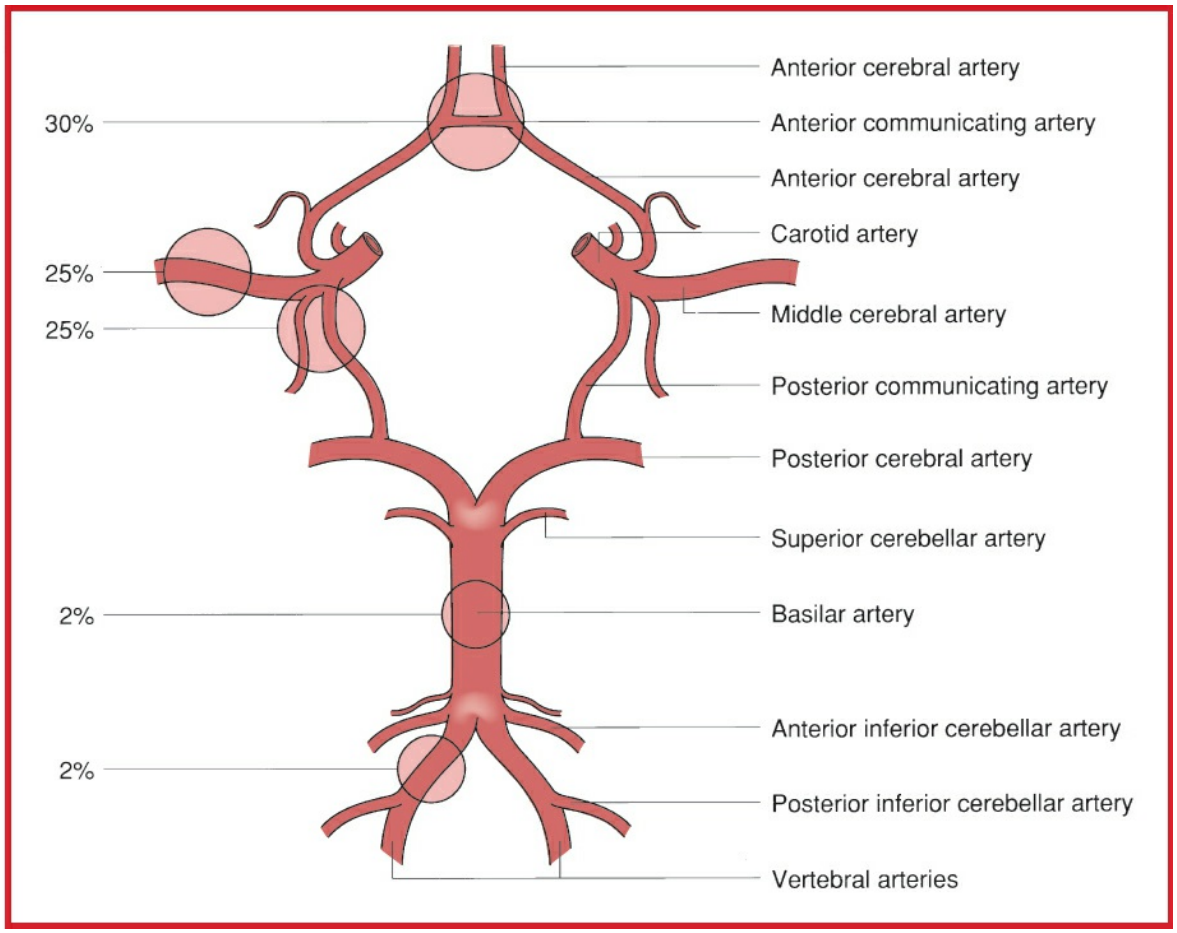

Figure 1.1-1 Locations of aneurysms of the circle of Willis and their relative occurrence. (Reproduced with permission from Greenfield LJ, Mulholland MW, Lillemoe KD, et alSurgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Table 1.1-1 Hunt-Hess Grading System for Aneurysmal SAH*

Grade	Description
I	Asymptomatic or minimal headache and slight neck stiffness (mortality ~2%)
II	Moderate-to-severe headache, neck stiffness, no neurologic deficit

	(except cranial nerve palsy)—(mortality ~5%)
III	Drowsiness, confusion, or mild focal deficit (mortality 15–20%)
IV	Stupor, moderate-to-severe hemiparesis, possible early decerebrate rigidity, and vegetative disturbances (mortality 30–40%)
V	Deep coma, decerebrate rigidity, moribund (mortality 50–80%)

*The presence of serious systemic disease—such as hypertension, diabetes, severe arteriosclerosis, chronic pulmonary disease, and angiographic vasospasm—results in placement in the next less-favorable category.

Patients with ruptured aneurysms require careful preop management to control MAP (CPP), ICP, glucose, and sodium. MAP < 70 or >130, HCO_3 < 20, glucose >180, and hypoxia have been independently associated with ↑ mortality and morbidity. EVD (ventriculostomy or external ventricular drain) or spinal drain may be placed to manage ICP and/or drain CSF. Unless otherwise required, these drains should be closed during patient transport. On arrival in the OR, level drain at tragus, set height relative to tragus as requested by the surgical team and then open drain. Keep surgeons informed of drainage volume at regular intervals throughout the case.

Through a **craniotomy** or **craniectomy**, using microscopic techniques, the parent vessel giving rise to the aneurysm is identified. The aneurysm is isolated, and small, nonferromagnetic alloy spring clips are placed at the origin of the aneurysm, excluding it from the circulation. A **frontotemporal (pterional) craniotomy** normally is used to approach anterior circulation aneurysms. This requires extensive drilling of the medial sphenoid wing (pterion) and allows access to most aneurysms on the anterior and lateral circle of Willis vessels: internal carotid-paraclinoid/superior hypophyseal artery, internal carotid-ophthalmic artery, posterior communicating artery, anterior choroidal artery, internal carotid artery bifurcation, middle cerebral artery, and anterior communicating artery. Posterior circulation aneurysms are approached via a pterional or **subtemporal exposure** (upper basilar artery, posterior cerebral artery, superior cerebellar artery), a **suboccipital exposure** (vertebral artery, posterior inferior cerebellar artery), or a combined subtemporal and suboccipital exposure (basilar trunk, vertebrobasilar junction). Increasingly, aneurysms requiring craniotomy for treatment are complex (see Fig. 1.1-2) and therefore less suitable for endovascular treatment. Clipping these aneurysms can be time consuming and must be accomplished in a way that preserves flow through all the affected vessels and their branches. This may not be possible without a bypass graft to restore flow distal to the aneurysm (Fig. 1.1-2C). The use of temporary clips to eliminate flow to the aneurysm can greatly facilitate the placement of permanent clips and will be required to complete a bypass graft.

Temporary clipping may result in focal ischemic injury, which can be minimized by inducing EEG burst suppression in combination with mild hypothermia to decrease metabolic demand. Increasing MAP is often requested during temporary clipping to improve distal supply through collateral flow. Circulatory arrest under CPB with deep hypothermia (16–20°C) may be used for repairing some giant (>2.5 cm) aneurysms.

Usual preop diagnosis

Cerebral aneurysm; subarachnoid hemorrhage (SAH); intracerebral hemorrhage progressive neurologic deficits (mass effect on cranial nerves or CNS structures); TIAs cerebral infarct

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include continuing chronic pain and AED medications, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, possibility of urinary drain postop. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

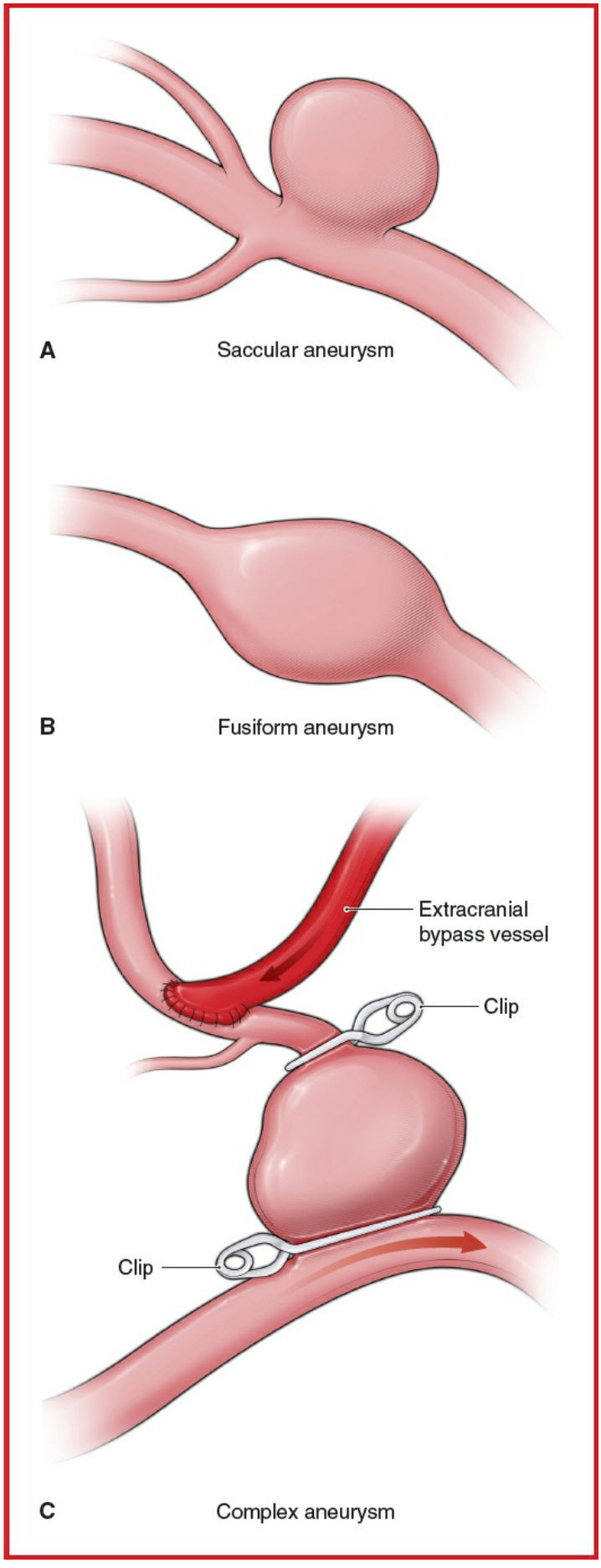
A
Saccular aneurysm
B
Fusiform aneurysm
Extracranial
bypass vessel
Clip
Clip
C
Complex aneurysm

Figure 1.1-2 Aneurysm types. **A:** Saccular; **B:** fusiform; **C:** complex (showing bypass and clip placement).

SUMMARY OF PROCEDURES

	Anterior Circulation Aneurysms	Posterior Circulation Aneurysms	Circulatory Arrest (CPB) W/Deep Hypothermia
Position	Supine, head in Mayfield headrest, turned 30–45° to side away from aneurysm, vertex dropped (Fig. 1.1-6)	⇐ or lateral decubitus, head lateral in Mayfield headrest	⇐ + Both groins must be accessible for arterial + venous cannulation; access to chest for defibrillation
Incision	Frontotemporal	⇐ or temporal, temporosuboccipital, or suboccipital	⇐
Special instrumentation	Operating microscope; aneurysm clips; radiolucent table, and headrest if intraop angiography is planned	⇐ + Aperture clips to accommodate cranial nerves and critical vessels	⇐ + CPB pump; femoral cannulae; defibrillator; CUSA for partially thrombosed aneurysms
Unique considerations	Temporary arterial clipping; mild hypothermia (33°C); intraop angiography with access to femoral artery; electrophysiologic	⇐	⇐ + No manipulation of brain retractors after systemic heparinization; meticulous

	monitoring (SEPs, BAERs, MEPs); brain relaxation; ± lumbar subarachnoid CSF drainage; dexamethasone 8–12 mg iv; indocyanine green for video angiography. LAs with EPI may → ↑ BP and risk of rupture		attention to hemostasis
Antibiotics	Cefazolin 2–3 g iv q6–8h	⇐	⇐
Surgical time	3–5 h	3–6 h	6–8 h
Closing considerations	Rewarming to >35°C may be necessary	⇐	⇐
EBL	250–1000 mL	⇐	2000–4000 mL
Postop care	ICU 1–2 d; postop ± CBF monitoring, transcranial Doppler (TDC) monitor for vasospasm	⇐	⇐ + ICP monitoring
Mortality	Unruptured: 0.5%	1.5%	5–10% (giant aneurysms)
	Ruptured:		
	Hunt and Hess grades I–III: <10% (see Table 1.1-1)	15%	5–15%
	Hunt and Hess grades IV–V: 20–	20–50%	15–50%

	40% (see Table 1.1-1)		
Morbidity	Neurologic: 5–20% Cranial nerve injury Stroke: 5.2% (38% if ruptured) Hydrocephalus: 15–25% Hyponatremia (SIADH vs. CSW) Seizures: 2–20% Respiratory failure: Rare Thromboembolism: Rare CSF leak: Rare Infection: Rare Massive blood loss: Rare	10–30% ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐	10–50% ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐
Pain score	3–4	3–4	4–5

PATIENT POPULATION CHARACTERISTICS

Age range	30–70 yr (Peak incidence in 5th and 6th decades)
Male:Female	44:56
Incidence	8–16/100,000/yr for ruptured aneurysms with SAH (highest in Japan and Finland). Approximately 85% survive initial bleed. Overall incidence of rebleeding is ~11% (4% in the first 24 h).
Etiology	Idiopathic (probably acquired and related to hemodynamic stress at arterial branch points, although may have congenital predisposition to loss of internal elastic lamina); traumatic; infectious; familial
Associated conditions	Polycystic kidney disease; coarctation of the aorta; Marfan syndrome; Ehlers-Danlos syndrome; intracranial AVMs; aortic aneurysm; fibromuscular dysplasia; pseudoxanthoma elastica; Rendu-Osler-Weber syndrome; cocaine/amphetamine use

ANESTHETIC CONSIDERATIONS

(Procedures covered: craniotomy for intracranial aneurysms; craniotomy for cerebral embolectomy)

PREOPERATIVE

Aneurysms may occur in any age group, although they generally become symptomatic and are diagnosed in young or middle-aged adults who are usually in otherwise good health. Most patients have warning Sx before the first major bleed, but these tend to be mild and nonspecific (e.g., headache, dizziness, orbital pain, slight motor or sensory disturbances). The symptoms are generally disregarded by both patients and physicians. Most patients with SAH will be receiving oral nimodipine or iv nicardipine; SBI should be maintained between 120 and 140 mm Hg using vasoactive drug infusions if necessary. Patients with symptomatic vasospasm may benefit from single-H therapy (see below).

Respiratory	Respiratory complications (e.g., neurogenic pulmonary edema [up to 23%], pneumonia, ARDS, PE) are the most common nonneurologic causes of death following SAH. Pulmonary aspiration may have occurred as the result of a neurologic deficit from an intracranial hemorrhage. **Tests:** As indicated from H&P. Elevated cTnI may predict pulmonary complications.
Cardiovascular	Generally, these patients do not have other cardiovascular diseases, although intracerebral aneurysms occur more commonly in patients with certain congenital disorders, such as polycystic disease of the kidneys, coarctation of the aorta, fibromuscular hyperplasia, and Marfan or Ehlers-Danlos syndrome. Patients who have had a recent intracranial hemorrhage (ICH) are prone to develop systemic HTN, hypovolemia, ↓ Mg^{++}, and ECG abnormalities. The HTN is thought to be due to autonomic hyperactivity and is generally treated with antihypertensive medication, which should be

	continued up to the time of anesthesia and surgery. ECG abnormalities occur in many patients following ICH and may represent subendocardial injury 2° catecholamine release from intracardiac nerve terminals (contraction band injury). Dysrhythmias (most commonly PVCs) occur in 30–80% of patients, and ischemic changes (typically T-wave inversion and ST-segment depression) are seen in >50%. Appropriate preop preparation includes ECG characterization of the abnormality. If patient has Hx of ischemic heart disease, ECHO and cardiac enzyme studies may be helpful in determining whether the myocardial injury and consequent ECG changes are likely to be of clinical significance. **Tests:** ECG; cTnI; others (e.g., ECHO) as indicated from H&P
Neurologic	Occasionally unruptured aneurysms produce neurologic Sx by compressing adjacent neural tissue or cause ↑ ICP. If ICH occurs, the neurologic dysfunction will vary, depending on the site and extent of the hemorrhage. Typically, SAH → ↑↑ ICP → sudden severe HA ± confusion and disorientation, ± motor deficit, ± coma. Admission GCS < 12 predicts ↑ mortality. Significant cerebral vasospasm (~30% incidence) and delayed cerebral ischemia (DCI) may cause worsening of the neurologic deficits. Clinically significant vasospasm commonly begins on day 3 reaching a maximum at 7–8 d and usually is resolved within 2–4 wk. The precipitating event is believed to be clot lysis → release of vasospastic substances. Rx vasospasm with support of BP (occasionally, induced HTN), euvolemia, and systemic Ca^{++} antagonists (e.g., nimodipine [60 mg PO q4h] or iv [3–15 mg/h iv]). Triple-H therapy (↑ volume, ↑ BP, ↓ Hct) should be avoided in favor of euvolemia and a trial of ↑ BP for DCI. Occasionally, intra-arterial angioplasty may be necessary to Rx refractory vasospasm. Control of BP is important: any

	substantial ↑ BP may → serious rebleed, permanent neurologic deficits or death; any substantial ↓ BP may → cerebral ischemia and infarction. Arterial catheterization and continuous beat-to-beat monitoring of BP prior to induction of anesthesia is essential in these patients. Post-SAH Sz is not unusual and may require Rx with AEDs. **Tests:** CT; MRI; CTA, which the anesthesiologist should examine preop to identify the nature and site of the aneurysm. DSA is the gold standard for detection of vasospasm.
Hydrocephalus	Acute hydrocephalus occurs in 15–20% of patients within 24 h of SAH. External ventricular drainage may be necessary.
Hematologic	Thrombocytopenia may develop following SAH. DVT prophylaxis (e.g., SCD) is beneficial. **Tests:** Hct; PT; PTT. Target Hb ~ 10 g/dL.
Radiographic findings	CT: Blood in basal cisterns (~95% of patients) or ventricles; CTA (replacing conventional angiography): anatomical characteristics of the aneurysm.
Laboratory	Cardiac enzymes if ECG changes observed (↑ cTnI predicts ↓ neurologic outcome and ↑ mortality); serum Mg^{++} and glucose; others as indicated from H&P. Hyponatremia is common and may be 2° SIADH or CSW. In contrast to SIADH, patients with CSW are hypovolemic (↓ plasma volume, ↓ CVP, ↓ PCWP), ± ↑ K^{+}.
Hepatic	Hepatic dysfunction following SAH is not uncommon (24% in one series). **Tests:** LFTs, as indicated from H&P
Premedication	Small doses of midazolam 1–3 mg iv are preferable to opiates. Detailed discussion with the patient about the anesthetic plan, with appropriate reassurance, is essential. Should an intracranial aneurysm leak or rupture in the immediate preop period, its signs may

	be difficult to distinguish from those associated with excessive response to premedication.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss possibility of scalp block for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water and aprepitant 40–80 mg po with sip of water especially for posterior fossa craniotomies with their high incidence of PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: The goals of anesthesia for this surgery are to (a) maintain optimum CPP (cerebral MAP minus cerebral venous pressure or ICP, whichever is greater); (b) decrease intracranial volume (blood and tissue) to optimize working space for surgeons, thereby reducing the need for surgical retraction; and (c) decrease metabolic rate and $CMRO_2$ with the expectation that the brain will tolerate hypotension and ischemia if sudden decreases in CPP become necessary.

Induction	Smooth induction is essential. Fentanyl 7–10 mcg/kg iv to blunt response to intubation and provide analgesia for the first hours of surgery. Propofol 1–2 mg/kg iv to provide amnesia and ↓ cerebral blood volume by inducing cerebral vasoconstriction. Rocuronium 0.6–1.2 mg/kg or vecuronium 0.15 mg/kg to provide muscle relaxation for tracheal intubation and positioning. Succinylcholine acceptable if RSI required. Patients on nimodipine may require pressors (e.g., phenylephrine) during and after induction. Poor H-H grade patients (IV–V) may not tolerate ↓ MAP during induction. Patients may benefit from moderate hyperventilation during induction.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia. Avoid hypothermia unless indicated for brain protection. Consider preincision placement of scalp blocks. Dexamethasone (4–8 mg iv)

	may ↓ PONV. Avoid long-acting opioids or scopolamine patch, which may confound postop neuro examination. Sequential pneumatic compression devices should be used to ↓ VTE risk.
Maintenance	Isoflurane or sevoflurane (1/2 MAC if EP monitoring is used), inspired with O_2. Avoid N_2O > 50% and entirely in patients with ↑↑ ICP. Propofol (50–100 mcg/kg/min) may be used to replace N_2O and further ↓ cerebral blood volume, ↓ cerebral metabolism, and ↓ $CMRO_2$. If movement is of concern, rocuronium 4–8 mcg/kg/min will provide adequate neuromuscular blockade. A remifentanil infusion (0.05–0.2 mcg/kg/min) can be used to supplement the anesthetic without interfering with EP monitoring. Contrary to popular belief, TIVA is not necessary for monitoring SSEPs or MEPs.
Emergence	H-H grade IV–V patients should be kept intubated and sedated on ventilator support postop. For grade I–III patients, with the start of dural closure, ↓ inhaled anesthetic concentration, stop any propofol infusion, continue 50% N_2O (if used), supplemented with a low-dose remifentanil infusion (e.g., 0.05 mcg/kg/min). As recovery from anesthesia occurs, BP will increase. Titration of β-adrenergic blocking drugs (e.g., labetalol and esmolol) with vasodilators (e.g., clevidipine or SNP) may be needed; if so, the dose should be stabilized before transport to ICU (see Control of BP, below). Inhalation agents can be D/C'd at the time of dressing application. Most patients will breathe spontaneously and can be extubated uneventfully while on the remifentanil infusion. If the brain has not been injured by the surgical procedure, the patient should awaken within 10 min after cessation of remifentanil administration. As the patient is awakening, it is important to ensure full reversal from neuromuscular blockade (consider sugammadex 2–4 mg/kg) and close regulation of BP. If the patient begins to cough on ETT, either it should be removed or cough reflex suppressed with iv lidocaine

	(0.5–1 mg/kg). Patient is placed in bed in a 30° head-up position and transported to ICU for monitoring overnight. Supplemental O_2 should be administered and close regulation of BP maintained. Prophylactic antiemetics (e.g., ondansetron 4–8 mg) should be given 30 min before extubation. Consider iv acetaminophen (1 g) if po dose given >4–6 h ago and scalp block placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >4–6 h ago.	
Blood and fluid requirements	IV: 14–18 ga × 2 BSS @ <3 mL/kg/h + UO > 1 mL/kg/h	Maintain euvolemia (see zero balance fluid management, Appendix K, p. K-2). If blood volume is normal, crystalloid fluid should not exceed 3 mL/kg/h beyond that required to replace UO. Rapid, massive blood loss is possible.
	Expand blood volume with albumin 5% if Hct > 30% Albumin + PRBC if Hct < 30% Maintain colloid oncotic pressure	If blood volume is low (↑ SVV or PPV), albumin 5% is given; combinations of albumin and blood, if Hct is <30%.
	Hetastarch may → coagulopathy and renal dysfunction	Albumin is the preferred colloid.
Brain relaxation	Hyperventilate to $PaCO_2$ = 35 mm Hg ($PetCO_2$ = 30 mm Hg). PaO_2 > 100 mm Hg	↓ $PaCO_2$→ ↓ cerebral vascular volume (better surgical access) + ↑ CBF to ischemic areas ("Robin Hood" effect) + ↓ anesthetic requirements + ↑ lactic acid buffering.
Brain relaxation (cont'd)	Consider propofol infusion (50 mg/kg/h iv) to replace N_2O ↓ isoflurane/sevoflurane	Propofol → cerebrovasoconstriction →↓ ICP. Remifentanil infusion (0.05–

	to <0.5 MAC	0.2 mcg/kg/min) may then be required to provide adequate analgesia.
	Mannitol 0.5–1 g/kg ± Furosemide 0.3 mg/kg Maximum osmolarity = 320 mOsm ± Steroids	Mannitol/furosemide → ↓ K^+; monitor level and replace as necessary. If mannitol is administered too rapidly, ↓ BP may occur, 2° peripheral vasodilation. For example, 8 mg dexamethasone at start of surgery.
	± Lumbar CSF drain Head up to provide venous drainage	CSF drain may be placed after induction of anesthesia, avoid rapid drainage → aneurysm rupture or remote hemorrhage.
	Minimize neck flexion/rotation	Otherwise → ↑ venous pressure →↑ ICP and ↓ CBF and ↑ venous bleeding.
Monitoring	Standard monitors Arterial line Bladder/esophageal temperature Blood glucose (keep <180 mg/dL)	Direct monitoring of arterial BP is essential because marked BP fluctuations may occur, necessitating rapid drug therapy. Transducers should always be leveled at the head.
	UO (Foley catheter) CVP line (subclavian preferred) ± Evoked potentials/EEG	Monitoring CVP is desirable in virtually all patients to assess adequacy of fluid therapy, for infusion of vasoactive drugs both intraop and postop, and for aspiration of VAE. Localization of the catheter can be determined by CXR, ECG tracing (noting P-wave

		changes), or pressure wave morphology as the catheter is withdrawn from the right atrium.
Hypothermia	Water-circulating pads Cold operating room	Mild hypothermia (33–34°C) is used in some centers to ↓ $CMRO_2$ and to ↓ susceptibility to ischemic injury during temporary clip application. $CMRO_2$ decreases ~30% @ 33°C. This level of hypothermia has minimal effect on coagulation or the incidence of cardiac dysrhythmias.
	Bladder irrigation	Rewarming using surface means can be quite slow. The use of bladder irrigation (40–42°C saline) or a heat exchange catheter is useful.
	Thermogard XP®, InnerCool® or equivalent	A heat exchange catheter may be placed in the inferior vena cava (via femoral vein) or superior vena cava via the subclavian vein to facilitate patient cooling and rewarming.
	IHAST study[8]	Although it implied that mild hypothermia was not useful in aneurysm surgery, the IHAST study was not designed to assess the effectiveness of mild hypothermia in the patient group most likely to benefit: otherwise intact patients requiring long temporary clip times. Generalizing the IHAST

		findings to all aneurysm patients is an unfortunate disservice to many of them.
	Delayed response to peripherally administered drugs	Administer drugs through CVP line in hypothermic patients to ensure prompt effect.
Single H therapy (for vasospasm)	Hypertension	Goal: SBP 120–150 mm Hg (preclipping); 160–200 mm Hg (postclipping). Hypervolemia: No benefit. ↑ cardiopulmonary complications, ↑ infection. Euvolemia is recommended. Hemodilution: Not recommended. Optimal Hct is difficult to predict but is probably 30–33% for most patients.
Control of BP	During application of head fixation device (Mayfield): remifentanil: 100–250 mcg iv bolus 1–2 min in advance During aneurysm exposure: ↓ MAP to ~80% of baseline During temporary clipping: ↑ MAP to ~120% of baseline	Control of BP is critical. ↑↑ BP → ↑↑ transmural pressure across the aneurysmal wall → rupture of the aneurysm. Many neurosurgeons apply a temporary clip on the major feeding vessel(s) in advance of clipping the aneurysm. This technique depressurizes the aneurysm and makes clipping easier and less likely to cause inadvertent rupture. During temporary clipping, keep MAP ~20% above baseline to maximize collateral flow. Phenylephrine is preferred because it has minimal dysrhythmogenic potential. EEG/EP monitoring can be useful to guide BP

	Postclipping: MAP typically 70–90 mm Hg	management. If it becomes necessary to ↓ BP, use esmolol 50–200 mcg/kg/min to ↓ HR to 50–60, supplemented as necessary with clevidipine 1–21 mg/h or SNP 0.1–4 mcg/kg/min to desired effect. Labetalol (5–100 mg total dose) is a useful adjunct for postop BP control.
Video angiography	Indocyanine green (ICG) NB: Usually contains iodine	ICG is an iv fluorescent dye for video angiography. Usual dose is 2.5–7.5 mg through a central line depending on tissue thickness. Rarely anaphylactic or other allergic reactions may occur.
Aneurysmal rupture	↓ MAP to 40–50 mm Hg Consider carotid compression	Bolus SNP: MAP will ↓ ~20 mm Hg/15 mcg SNP. Ipsilateral or bilateral carotid occlusion is often effective in controlling hemorrhage while a temporary clip is applied.
	Adenosine via CVP line Hypothermic dose: 12 mg iv Normothermic dose: 0.5–1 mg/kg	Adenosine will produce asystole, allowing time for the application of a temporary clip. Escalate dose until asystole has been achieved ($t_{1/2}$ < 10 sec). An external pacemaker should be available for hypothermic patients.
Positioning	For most aneurysms: Supine, head turned, Mayfield fixation (NB: ↑ BP with use of pins)	Anesthetic circuit and all monitoring and vascular catheter lines are directed to patient's side or feet, where

	Use shoulder roll ✓ and pad pressure points ✓ eyes	the anesthesiologist is positioned during surgery. SCDs used to minimize DVT. Shoulder roll to ↓ brachial plexus stretch. Remifentanil (100–250 mcg bolus) to minimize ↑ BP during skull pinning.
Complications	Aneurysm rupture (intraop)	6–18% incidence; up to 2% rupture during induction.
	Hypothermia (mild)	Most patients can be extubated safely at core T ≥ 35°C with active rewarming in progress.
	DVT	SCDs should be used for DVT prophylaxis.

POSTOPERATIVE

Complications	Intracranial hemorrhage Stroke	New deficits or delayed emergence may necessitate urgent transport to CT scanner and/or return to the OR.
	Cerebral vasospasm SIADH/CSW (less common)	Avoid prophylactic triple-H therapy, usually not evident intraop. Rx:NS.
Multimodal pain management	Acetaminophen 1 g iv	If not given preop or if 4–6 h have elapsed since previous dose.
	± Meperidine (10–20 mg iv prn) ± Fentanyl 25–50 mcg prn	Emphasize multimodal approach (see p. K-5). Meperidine will ↓ postop shivering in hypothermic patients. Minimize opioid use to ↓ PONV and to avoid unnecessary sedation.

	Place/Reinforce scalp blocks	0.5% bupivacaine with epi is as effective as liposomal bupivacaine.
ERAS	Ondansetron 4 mg iv ± Metoclopramide 10–20 mg iv	Encourage early enteral nutrition, Foley catheter removal, and mobilization.
Tests	CT scan, if any change in neurologic status	Be prepared to resecure airway.

Suggested Readings

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2. Chalouhi N, Hoh BL, Hasan D: Review of cerebral aneurysm formation, growth, an rupture. Stroke 2013; 44(12):3613–22.
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4. Garg R, Bar B: Systemic complications following aneurysmal subarachnoic hemorrhage. Curr Neurol Neurosci Rep 2017; 17(1):7.
5. Krishnamoorthy V, Mackensen GB, Gibbons EF, et al: Cardiac dysfunction after neurologic injury: what do we know and where are we going? Chest 2016; 149(5):1325–31.
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8. Todd MM, Hindman BJ, Clarke WR, et al: Mild intraoperative hypothermia durin surgery for intracranial aneurysm. N Engl J Med 2005; 352(2):121–4.
9. Zhou J, Agarwal N, Hamilton DK, et al: The 100 most influential publication pertaining to intracranial aneurysms and aneurysmal subarachnoid hemorrhage. J Clin Neurosci 2017; 42:28–42.

ANESTHETIC CONSIDERATIONS FOR CRANIOTOMY FOR GIANT INTRACRANIAL ANEURYSMS (REQUIRING DEEP HYPOTHERMIC CIRCULATORY ARREST)

PREOPERATIVE

Aneurysms are classified as "giant" when they are >2.5 cm in diameter. These represent ~5% of all aneurysms. They occur twice as often in women, usually become symptomatic in the 4th or 5th decade of life, and present particularly difficult surgical challenges: (a) their large size makes direct visualization of the vascular anatomy difficult; (b) vascular branches essential to maintaining flow to normal brain may arise from the aneurysmal/SAC and cannot be included in the clipping without causing permanent neurologic injury; (c) standard aneurysm clips may not occlude a large, turgid aneurysm, or may slip or move, once applied; and (d) giant aneurysms may easily rupture during dissection or clip application. Many of these aneurysms are amenable to coiling or other interventional radiologic techniques. For those requiring craniotomy, temporary clips applied during mild hypothermia often provide sufficient opportunity to decompress and occlude the aneurysm. Rarely, deep hypothermia to 18°C, achieved with fem-fem CPB/ECMO and temporary circulatory arrest, may be required to safely decompress the aneurysm and protect the brain during circulatory arrest. The duration of asystole may be as long as 45 min.

Respiratory	None unless patient has Hx of smoking or has sustained pulmonary aspiration as a result of a neurologic deficit from an intracranial hemorrhage. **Tests:** As indicated from H&P; elevated cTnI may predict pulmonary complications.
Cardiovascular	Generally, these patients do not have other cardiovascular diseases (see Anesthetic Considerations for Intracranial Aneurysms). **Tests:** ECG; cTnI; others (e.g., ECHO) as indicated from H&P
Neurologic	These patients usually present with complaints of intermittent or persistent headaches or visual disturbances that are probably due to aneurysmal compression of adjacent neural tissue or ↑ ICP. If an intracranial hemorrhage occurs, neurologic dysfunction varies, depending on site and extent of the hemorrhage. Cerebral vasospasm is a major complication of intracranial hemorrhage (see discussion in Anesthetic Considerations for Intracranial Aneurysms). **Tests:** CT; MRI; angiogram. The anesthesiologist should examine the cerebral angiogram preop to

	visualize the size and site of aneurysm.
Hematologic	T&C for 6 U PRBCs. **Tests:** Hct; PT; PTT; CBC; others as indicated from H&P
Laboratory	Other tests as indicated from H&P
Premedication	Premedication is usually desirable, with small doses of midazolam (e.g., 1–2 mg) preferable to opiates. Detailed discussion with patient about the anesthetic plan, with appropriate reassurance, is effective in reducing premedication requirements. Should an intracranial aneurysm leak or rupture in the immediate preop period, it may be difficult to distinguish this event from changes associated with excessive responses to premedication.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss possibility of scalp block for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water and aprepitant 40–80 mg po with sip of water especially for posterior fossa craniotomies with their high incidence of PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: The goals of anesthesia for this procedure are to (a) provide adequate surgical anesthesia; (b) ↓ intracranial volume (blood and tissue) to optimize working space within the cranial compartment, thereby minimizing the need for surgical retraction of brain tissue; and (c) ↑ tolerance of the brain to ischemia by decreasing $CMRO_2$, which occurs with the use of deep hypothermia, barbiturate or propofol therapy, ± isovolemic hemodilution.

Induction	Propofol 2–3 mg/kg iv to provide anesthesia and ↓ CBV by inducing cerebral vasoconstriction. Fentanyl 7–10 mcg/kg iv to blunt the response to laryngoscopy/intubation and provide analgesia for the first hours. Vecuronium 0.15 mg/kg or rocuronium 0.6–

	1.2 mg/kg to provide relaxation for intubation and positioning.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia. Consider preincision placement of scalp blocks. Dexamethasone (4–8 mg iv) may ↓ PONV. Avoid long-acting opioids or scopolamine patch, which may confound postop neuro examination. Sequential pneumatic compression devices should be used to ↓ VTE risk.	
Maintenance	Propofol 100–200 mcg/kg/min administered by constant infusion pump. These doses provide additional amnesia and ↓ CBV and $CMRO_2$. Isoflurane ≤1%. N_2O not used. An additional dose of NMB is administered just prior to the start of CPB.	
Emergence	Because of the length and nature of the operation and the potential for temporary neurologic injury, it is advisable to leave the ETT in place immediately postop and send patient to the ICU on controlled ventilation. If patient begins to cough, the reflex should be suppressed with opiates, NMBs, and/or LTA sprayed down the ETT. The patient is placed in bed in a 30° head-up position and transported to ICU for overnight monitoring. Supplemental O_2 should be administered and close regulation of BP maintained. Prophylactic antiemetic (e.g., ondansetron 4 mg) should be given 30 min before extubation. Consider iv acetaminophen 1 g iv and scalp block placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >4–6 h ago.	
Blood and fluid requirements	IV: 14–16 ga × 2 BSS @ 1–2 mL/kg/h PRBC 4–6 U	Maintain euvolemia. Cold BSS up to 10 mL/kg is administered during surgery. Zero balance or goal-directed fluid management is recommended.
Isovolemic	5% albumin: 1000–2000	Albumin is placed in a

hemodilution	mL CPD bags (for blood collection)	refrigerator at 4°C the night before surgery to be used as necessary for cooling during isovolemic hemodilution. After induction of anesthesia, a 2nd arterial or large-vein cannula is placed for removal of blood into CPD bags. Generally, about 1000 mL of blood is removed and replaced with 1 L of cold albumin 5%. This usually → ↓ Hct to 22–26%. Frequent intraop Hct checks are appropriate. The withdrawn blood is held for reinfusion at the conclusion of operation. In addition, the perfusate from the CPB unit is spun down, and packed cells are returned to patient.
Control of ICP (brain relaxation)	Hyperventilate to $PetCO_2$ = ~30 mm Hg Limit crystalloid <10 mL/kg + UO Limit isoflurane ≤1% ± Mannitol 0.5–1 g/kg ± Furosemide 0.3 mg/kg Dexamethasone 8–12 mg ± Lumbar CSF drainage	Ventilation is controlled and TV and RR adjusted such that $PaCO_2$ = ~35 mm Hg. There are some advantages to mild hypocarbia, including ↓ CBV, and better buffering of brain lactic acid that may form as a result of ischemia.
	Position head to promote venous drainage	Elevate head of bed, and minimize neck flexion/rotation if possible.
Monitoring	Standard monitors Temperature: esophageal, bladder and brain surface Arterial line	Frequent checks are made of Hct, electrolytes, and ACT values, before, during, and after CPB.

	CVP (triple-lumen) line	CVP line is used for infusions of esmolol, SNP, and phenylephrine. Subclavian preferred.
	Blood glucose	Keep glucose between 80 and 180 mg/dL.
	UO	Keep UO > 0.5 mL/kg/h.
Control of BP	Maintain BP normal to 20% below normal Esmolol infusion SNP infusion	↑ BP during induction or prior to CPB will ↑ likelihood of rupture. Prior to CPB, BP is controlled using anesthetic agents ± an esmolol infusion to ↓ HR to a range of 50–60 bpm, ± SNP infusion. SNP facilitates both cooling and rewarming because of its peripheral vasodilatory effect.
	Phenylephrine	If a vasoconstrictor is needed, particularly during CPB while patient is still cold, phenylephrine is preferred because of its minimal dysrhythmogenic potential.
Positioning	Shoulder roll 180° table rotation ✓ and pad pressure points ✓ eyes Mayfield skull fixation (NB: ↑BP)	Anesthetic circuit and all monitoring and vascular catheter lines are directed to patient's feet. Make sure that all will reach the foot of operating table. Remifentanil 100–250 mg bolus will blunt BP response to pinning.
	SCD	SCDs used to minimize DVT.
Deep hypothermia	Initial cooling: Circulating water	Surface cooling and/or central cooling is begun as soon as

and CPB	blankets Ice packs Thermogard®-type device	induction is complete, using either a central venous heat exchange device (e.g., Thermogard XP®) or thermal blankets above and below patient, ice packs, and infusion of cold fluids during establishment of isovolemic hemodilution.
	SNP infusion	An SNP infusion (if tolerated) will promote surface cooling.
	Heparinization ACT monitoring Goal: 3–4× baseline	Once the aneurysm is exposed and the decision is made that CPB is required, systemic **heparinization** (load: 300 U/kg; maintenance: 100 U/kg/h) is established, and patient is put on CPB using fem-fem bypass and cooled to ~18°C. During CPB cooling, the heart will usually fibrillate between 22°C and 26°C. After 18°C is reached, the CPB unit is shut off to deflate the aneurysm; it may be activated and shut off several times during clipping to evaluate adequacy of the surgical occlusion of the aneurysm and to apply additional clips. **Total circulatory arrest time should not exceed 45 min**.
	Rewarming	When clipping is complete, CPB is resumed and warming instituted. Partial CPB is continued until normal

		cardiac rhythm is established and body temperature reaches ~36°C. Once partial CPB is D/C, patient will tend to cool unless vigorous efforts at warming are continued. Warming the OR and iv fluids, use of a Bair Hugger, or a Thermogard®-type device will facilitate the warming process. ACT analysis is performed to establish that heparin reversal is complete 5–10 min after protamine (1 mg/100 U heparin activity). Blood is sent for clotting studies, and Plts, FFP, and calcium gluconate are administered as needed.
Complications	↓↓ BP 2° failure to maintain circulating volume	Restore circulating volume.
	Dysrhythmias 2° ↓ K^+ from diuresis and cold	✓ K^+ level and replace as indicated.

POSTOPERATIVE

Complications	HTN Vasospasm Intracranial hemorrhage, stroke Hypothermia Hypervolemia Coagulopathy DVT Seizures PE	HTN Rx: Esmolol + SNP titrated to effect. Vasospasm Rx: Euvolemia, trial of ↑ MAP; consider nimodipine. Patient should be rewarmed to 36–37°C before terminating CPB. ✓ coag status. SCDs may be useful. Sz Rx: Phenytoin (1 g iv

		slowly to avoid ↓BP) or levetiracetam (Keppra®) 1 g iv. NB: Phenytoin is incompatible with dextrose containing solutions.
Multimodal pain management	Scalp block Acetaminophen 1 g iv ± Fentanyl 25–50 mcg prn	PT usually remains intubated and sedated (e.g., propofol infusion) in immediate postop period. If not given preop or if 4–6 h have elapsed since previous dose.
	Reinforce scalp blocks	0.5% bupivacaine with epi is as effective as liposomal bupivacaine.
Tests	CT scan	If any question about neurologic status arises, a CT scan is performed postop.
	Coag panel	Coagulation studies are needed early postop to assure normal coagulation.
ERAS	Ondansetron 4 mg iv ± Metoclopramide 10–20 mg iv	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

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CRANIOTOMY FOR CEREBRAL EMBOLECTOMY

SURGICAL CONSIDERATIONS

Gary K. Steinberg and Robert L. Dodd

Description

Although endovascular thrombectomy (first choice—see p. 493) and intravenous or endovascular intra-arterial thrombolysis are the current standard therapies for intracranial intravascular clots, embolic occlusion of a major intracranial vessel occasionally requires microsurgical embolectomy. In particular, when the embolus is a large atherosclerotic plaque or foreign body (such as a balloon or microcoil from endovascular treatment), surgery may be the treatment of choice. Because cerebral ischemia often proceeds to irreversible infarction before the surgeon can restore blood flow, early diagnosis is of the utmost importance, and several studies have demonstrated that the best results from embolectomy occur when the procedure is performed within 6–24 h following the onset of a neurologic deficit.

A standard craniotomy is fashioned as previously described for other lesions involving the vasculature at the skull base, and the occluded intracranial artery is exposed using microsurgical techniques. The involved arterial segment is isolated and temporarily occluded with miniature clips, and an arteriotomy is performed to remove the thrombus or embolus (Fig. 1.1-3). The arteriotomy is then closed and blood flow reestablished.

Usual preop diagnosis

Stroke; TIA; intracranial arterial occlusion; catheter embolization to intracranial artery

ERAS: These procedures are usually urgent/emergent and present little opportunity for ERAS considerations.

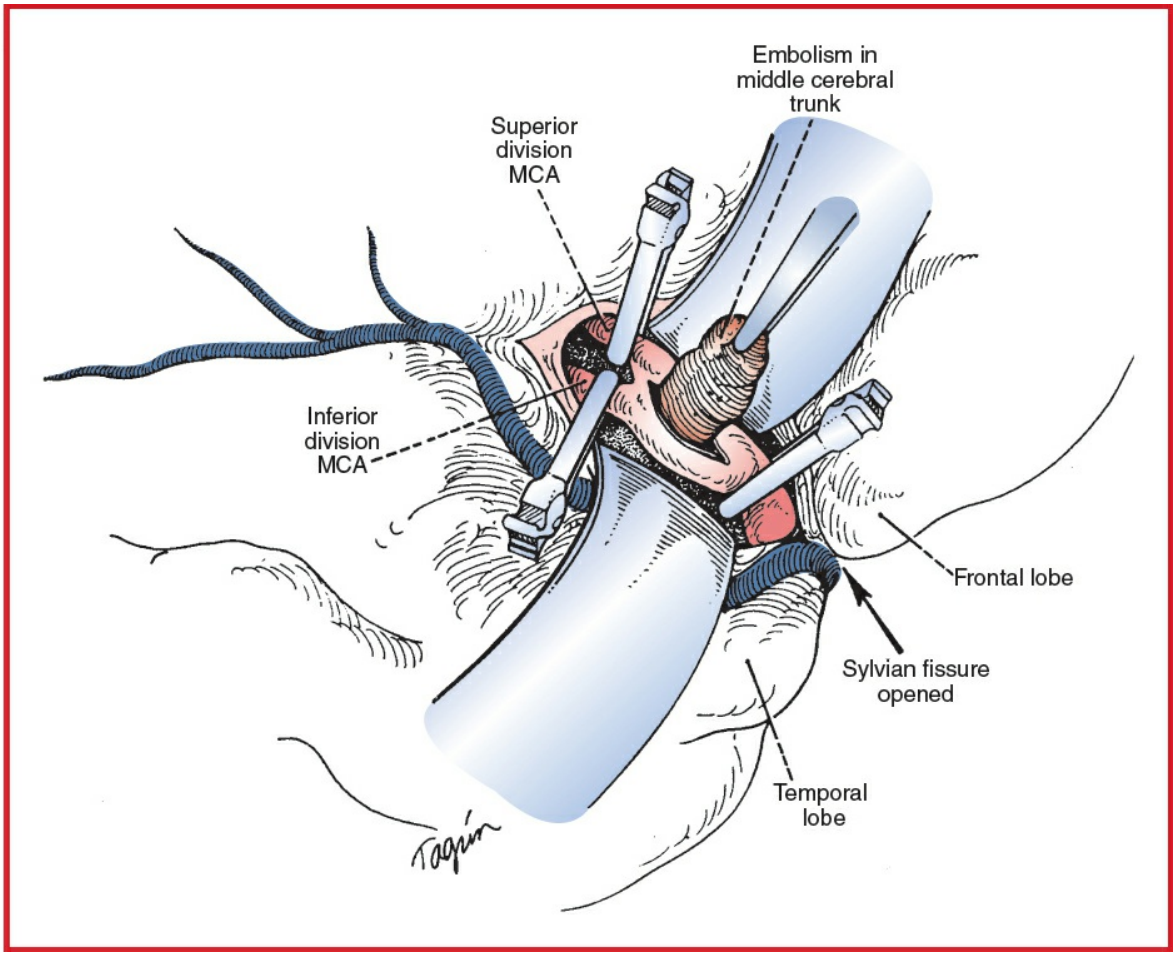

Figure 1.1-3 Middle cerebral artery (MCA) embolectomy. Exposure of right MCA in the sylvian fissure and removal of an embolus from the MI segment. (Reproduced with permission from Ojemann RG, Ogilvy CS, Crowell RM, et al: Surgical Management of Neurovascular Disease, 3rd edition. Williams & Wilkins, Baltimore: 1995.)

SUMMARY OF PROCEDURE

Position	Supine or lateral decubitus
Incision	Frontal, temporal, or occipital
Special instrumentation	Microscopic instruments (fine forceps, miniature vascular clips, operating microscope)
Unique considerations	Neuroprotective agents during arterial segment occlusion (barbiturates, mannitol), mild hypothermia (33°C)
Antibiotics	Cefazolin 2 g iv (30–60 min before incision)
Surgical time	3–4 h
Closing considerations	Avoid ↓ BP (MAP 80–100 mm Hg). Induced mild HTN (MAP 90–110) during temporary arterial occlusion

EBL	100–250 mL
Postop care	Control BP (MAP 80–100 mm Hg); start aspirin postop day 1; ICU: 1–2 d
Mortality	5–10%
Morbidity	Intracerebral hemorrhage Stroke MI: Rare Thromboembolism: Rare Respiratory failure: Rare Infection: Rare
Pain score	3–4

PATIENT POPULATION CHARACTERISTICS

Age range	50–80 yr
Male:Female	1:1
Incidence	Rare
Etiology	Atherosclerosis; carotid artery disease; atrial fibrillation; iatrogenic endovascular catheter complication
Associated conditions	HTN; CAD; PVD; carotid artery disease; hyperlipidemia; smoking; alcohol abuse; obesity; atrial fibrillation

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Craniotomy for Intracranial Aneurysms.

Suggested Readings

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2. Ansari S, Rahman M, Waters MF, et al: Recanalization therapy for acute ischemic stroke, part 1: surgical embolectomy and chemical thrombolysis. Neurosurg Rev 2011; 34(1):1–9.
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CRANIOTOMY FOR INTRACRANIAL VASCULAR MALFORMATIONS

SURGICAL CONSIDERATIONS

Gary K. Steinberg

Description

Intracranial vascular malformations are congenital abnormalities that cause intracranial hemorrhage, seizures, headaches, progressive neurologic deficits, or audible bruits. Intracranial vascular malformations comprise high-flow arteriovenous malformations (AVMs); low-flow angiographically occult vascular malformations (AOVMs) including cavernous malformations (a collection of enlarged capillaries with thin inelastic walls prone to leaking), "cryptic" AVMs, capillary telangiectasias, and transitional malformations; and low-flow venous angiomas (developmental venous anomalies). **Microsurgical resection** is the optimal treatment for these lesions, although preop endovascular embolization and preop or postop focused **stereotactic radiosurgery** (heavy particle or photon) may be useful adjuncts.

Most moderate-sized and large **AVMs** (>3 cm diameter) will have been partially embolized in the cath lab prior to surgery. Resection is accomplished using a standard **scalp flap** and with **craniotomy** centered over the area of the AVM using image guidance techniques. The patient is positioned appropriately to place the craniotomy site uppermost in the field and parallel to the floor. For example, a patient with a left frontal AVM would be positioned supine, head turned to the right, a left frontal or bicranial scalp flap raised, and a left frontal craniotomy bone flap removed. A patient with a right medial occipital AVM would be positioned in the left lateral decubitus position with head turned semiprone and a right occipital scalp flap and craniotomy performed. Smaller AVMs (<3 cm diameter), many low-flow AOVMs, and many deep-seated vascular malformations (AVMs and AOVMs) require only a small **stereotactic craniotomy**. This is performed by attaching fiducial markers or (less frequently) a stereotactic base frame to the patient's skull (using local anesthetic and sedation). Next, a CT or MRI scan is obtained. The location of the AVM in relation to the markers (or frame) is calculated, using a computer and stereotactic geometric principles. The patient is taken to the OR, intubated (fiberoptically if a frame is used), and positioned for surgery. The surgical navigation system reference is attached to the headrest and

microscope and calibrated. A small scalp flap and a small craniotomy (a few cm in diameter) can be fashioned precisely for microscopic exposure of the malformation. Microsurgical resection of brain stem and thalamic vascular malformations often necessitate special positioning. In frame-based surgery, a three-dimensional arc frame is fixed to the base frame, and coordinates are set to localize the vascular malformation within the brain.

Usual preop diagnosis

Cerebral AVM; dural AVM (an A-V shunt within the dura mater); cavernous malformation (low-flow hemangioma); angiographically occult vascular malformation; intracerebral hemorrhage; subarachnoid hemorrhage; seizures; epilepsy; progressive neurologic deficit; migraine or vascular headaches

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include continuing chronic pain and AED medications, limiting NPO duration, alcoho and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, and possibility of urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Standard Craniotomy (High-Flow AVM)	Stereotactic Craniotomy (Low-Flow AOVM)	Brain Stem/Thalamic Vascular Malformations
Position	Supine, lateral, Concorde (modified prone; Fig. 1.1-4)	⇐	Lateral, Concorde, or semisitting (Fig. 1.1-5)
Incision	Frontal, temporal, parietal, occipital, suboccipital, or combination	⇐	Suboccipital (midline), paramedian, or occipital
Special instrumentation	Operating microscope; radiolucent table and headrest. Access to femoral artery for intraop angiography.	⇐	⇐

	Surgical navigation system.		
Unique considerations	Induced hypotension (MAP 60–65 mm Hg) during resection, use of neuroprotective agents. Relaxed brain. Mild hypothermia (33°C); ± lumbar CSF drain.	Use of neuroprotective agents and relaxed brain	⇐
Antibiotics	Cefazolin 2 g iv (30–60 min before incision)	⇐	⇐
Surgical time	4–10 h	2–5 h	3–6 h
Closing considerations	Maintain MAP 65–75 mm Hg to ↓ postresection hyperemia. Avoid ↑ venous pressure. Consider loading dose of phenytoin (1 g iv for adults) if not previously on anticonvulsants.	Keep MAP 70–90 mm Hg ⇐ ⇐	⇐ ⇐ No anticonvulsants necessary
EBL	500–3000 mL	<250 mL	⇐
Postop care	ICU × 1–2 d. Maintain MAP 65–75 mm Hg for 1 d. ICP monitoring, ventricular drain; normovolemic in ICU.	ICU × 1 d; normovolemic in ICU	⇐
Mortality	1–10%, depending on AVM size, location, and venous drainage pattern	<0.5%	<2%
Morbidity	Overall: 5–30% Breakthrough bleeding: <5% Intracranial hemorrhage	<5% ⇐ ⇐ ⇐	10–50% (transient) <5% ⇐

	Cerebral edema Stroke <15% Hydrocephalus Massive blood loss: Occasional Thromboembolism: Rare Infection: Rare	⇐ ⇐ ⇐ ⇐	⇐ ⇐ ⇐ ⇐ ⇐ ⇐
Pain score	3–4	3–4	3–4

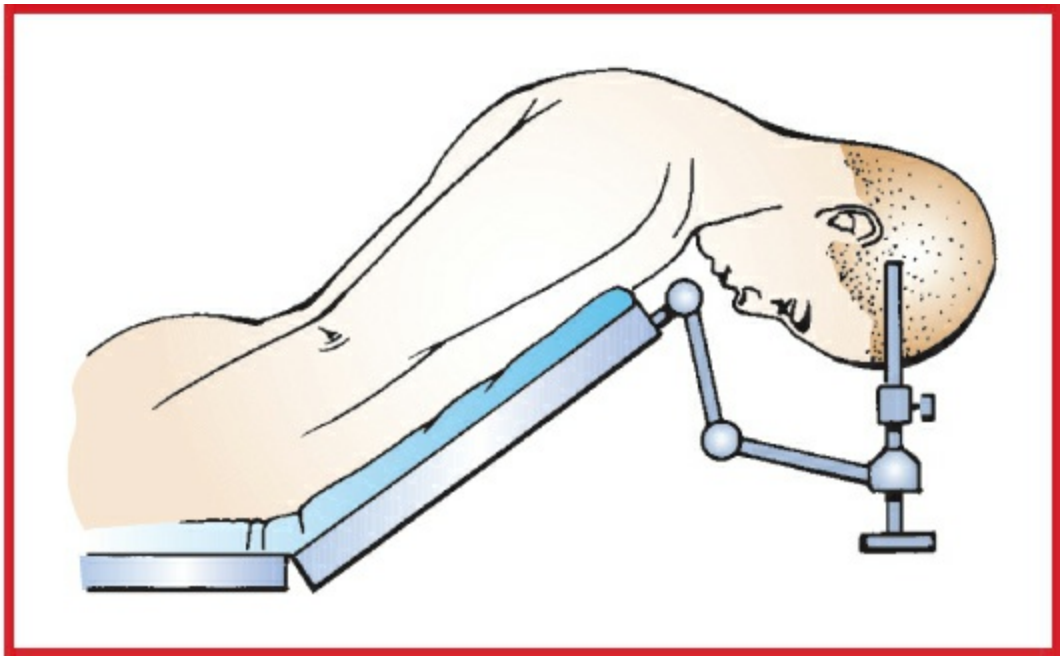

Figure 1.1-4 Concorde (modified prone) position for resection of posterior fossa vascular malformations.

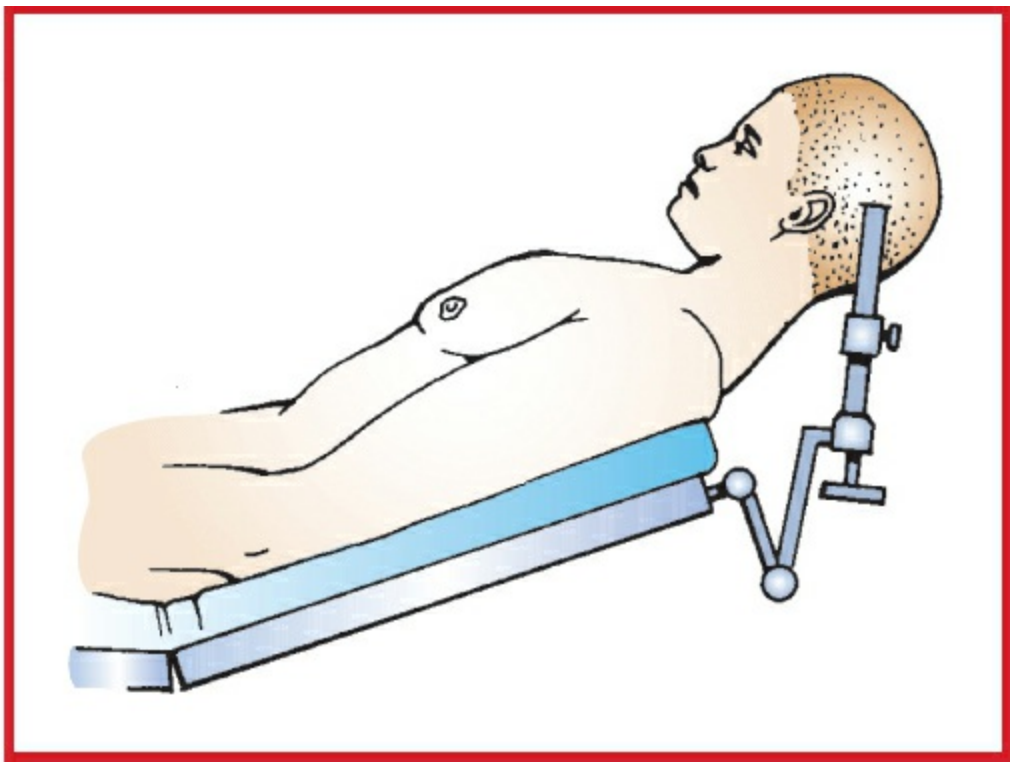

Figure 1.1-5 Semisitting position for resection of deep posterior corpus callosum or thalamic vascular malformations.

PATIENT POPULATION CHARACTERISTICS	
Age range	15–40 yr (most common), 41–60 yr (less frequent). Average age: 33 yr
Male:Female	1:1 (slight male predominance)
Incidence	0.2% of the U.S. population (AVM); 0.1% (cavernous malformation)
Etiology	Congenital; traumatic for dural AVM
Associated conditions	Intracranial aneurysm (~10% of AVM patients [up to 58% in some studies]); von Hippel-Lindau disease; Rendu-Osler-Weber syndrome; familial cavernous malformation syndrome

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

AVMs are typically direct arterial-to-venous communications without intervening normal capillary circulation. On histologic examination, the vessel walls are thin and lack a muscular layer; consequently, the vessels exhibit loss of normal vasomotor

control or responsiveness to changes in $PaCO_2$. **Stereotactic localization** is essential for safe excision of deep-seated AVMs (e.g., those located in the corona radiata, basal ganglia, visual center, cerebellar white matter, or corpus callosum). Untreated, the overall risk of rupture is ~2–4% per year (varies by size). AVMs > 6 cm in maximum diameter and located near eloquent areas of the cortex or with deep venous drainage (grades IV and V) have a high complication rate and may not be suitable for surgical resection without prior partial embolization. Review imaging studies and discuss surgical approach with surgeon.

Respiratory	Not usually significant unless patient has Hx of smoking or has aspiration pneumonitis as a result of a neurologic deficit from an intracranial hemorrhagic or ischemic event. **Tests:** As indicated from H&P
Cardiovascular	Generally, these patients do not have other cardiovascular diseases. Occasionally, ECG changes are noted following intracranial hemorrhage and may represent subendocardial injury 2° catecholamine release. **Tests:** ECG; others as indicated from H&P
Neurologic	Presenting Sx depend on location and size of AVM and whether it is a low- or high-flow lesion. Hemorrhage with resultant headache and/or neurologic deficit is the most common Sx, although patients also may present with intractable seizure disorder, recurrent HAs, or Sx of cerebral ischemia 2° high-flow AV shunts, causing an intracerebral steal. Surgical treatment is essential to prevent future hemorrhage (incidence of 2–4%/yr) with substantial mortality (6–30%) or severe morbidity (15–80%). Unlike hemorrhages from an intracerebral aneurysm (generally subarachnoid), hemorrhages from an AVM are usually ventricular or intraparenchymal; hence, they are seldom associated with cerebral vasospasm. **Tests:** CTA; MRI; cerebral angiogram. Preop cerebral angiogram indicates size and location of the AVM and whether it is likely to be a low- or high-flow lesion.

Hematologic	After surgery for AVM, it is fairly common for surrounding brain tissue to swell and resection sites to bleed. The cause of this is unknown, but it may be related to diversion of former AVM blood flow into the surrounding vasculature, producing a fragile hyperemic state. Thus, it is advisable to attempt embolization of the lesion before surgery; obtain coag studies preop, and consider staging resection over more than one sitting when the residual AVM is large.
Laboratory	**Tests:** Hct; PT; PTT; Plt count CBC; other tests as indicated from H&P
Premedication	If medication is desirable, small doses of midazolam (e.g., 1–3 mg iv) are useful. Detailed discussion with patient about the anesthetic plan, with appropriate reassurance, is essential.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss possibility of scalp block for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water and aprepitant 40–80 mg po with sip of water especially for posterior fossa craniotomies with their high incidence of PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: The goals of anesthesia for this operation are to (a) ↓ $CMRO_2$ to lessen the dependence of normal brain on vessels feeding the AVM; (b) decrease intracranial volume (blood and tissue) to optimize surgical working space within the cranial compartment and minimize the need for surgical retraction; and (c) reduce CPP (10–20% below normal) to lessen blood loss during excision of the AVM (postcraniotomy CPP = cerebral arterial pressure minus cerebral venous pressure). For stereotactic image-guided surgery, scalp localizing markers are attached. The patient is then sent to MR or CT, where the exact coordinates defining the AVM and critical adjacent structures are established. The patient is brought to OR, and anesthesia is induced.

Induction	Propofol 1–2 mg/kg iv provides amnesia and ↓ CBV by

	inducing cerebral vasoconstriction. Fentanyl 7–10 mcg/kg iv blunts the response to laryngoscopy and provides analgesia for the first hours. High-dose opiates used as a primary anesthetic technique do not alter CBF or $CMRO_2$ enough to provide any special benefits. Rocuronium (0.6–1 mg/kg) or vecuronium (0.15 mg/kg) provides muscle relaxation for intubation and patient positioning. Occasionally, the patient may be in a stereotactic frame, and ET intubation must be accomplished before anesthesia is induced because the frame may partially occlude the mouth, making conventional laryngoscopy impossible. Awake oral fiberoptic intubation of the trachea is the easiest method for accomplishing this.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia. Avoid hypothermia unless indicated for brain protection. Consider preincision placement of scalp blocks. Dexamethasone (4–8 mg iv) may ↓ PONV. Avoid long-acting opioids or scopolamine patch, which may confound postop neuro examination. Sequential pneumatic compression devices should be used to ↓ VTE risk.
Maintenance	Isoflurane ≤1% or sevoflurane ≤2% (limit to 1/2 MAC maximum if EP monitoring is used) with 1:1 O_2/N_2O. With EP monitoring, a remifentanil infusion (0.05–0.2 mcg/kg/min) may be necessary to supplement the anesthetic. Propofol (50–150 mcg/kg/min) by continuous infusion may be administered to provide ↓ CBV and ↓ $CMRO_2$ and allow for reduction in inhalation agent concentration or elimination of N_2O. Mild hypothermia (33°C) provides additional cerebral protection (see below). Additional neuromuscular blocking drugs are usually not necessary but can be administered if patient movement is of concern. Induced mild hypotension is often useful during AVM resection. Following resection, induced brief hypertension (e.g., MAP = 90 mm Hg) may be requested to assess hemostasis.

Emergence	With the start of dural closure, consider changing the anesthetic to low-dose sevoflurane (e.g., 0.5%) in 50% N_2O, supplemented with a low-dose remifentanil infusion (e.g., 0.05 mcg/kg/min). A propofol infusion (if used) should be discontinued at the start of the scalp closure. The patient's BP generally will increase, and titration of β-adrenergic blocking drugs (e.g., labetalol or esmolol) and/or vasodilators (e.g., clevidipine or SNP) may be needed (see Control of BP, below). The inhalation agents can be D/C'd at the time of dressing application. Most patients will breathe spontaneously and can be extubated uneventfully while on a 0.05 mcg/kg/min remifentanil infusion. Reverse any residual neuromuscular blockade. If the brain has not been injured by the surgical procedure, the patient should awaken within 10 min after cessation of remifentanil administration. Close regulation of BP is essential. If the patient begins to cough on ETT, either it should be removed or cough reflex suppressed with iv lidocaine (1 mg/kg). Patient is placed in bed in a 20–30° head-up position and transported to ICU for monitoring overnight. Supplemental O_2 should be administered and close regulation of BP maintained (typically at ~10% below baseline values). Prophylactic antiemetics (e.g., metoclopramide 10–20 mg and ondansetron 4 mg) should be given 30 min before extubation. If not given preincision, consider iv acetaminophen (1 g) and/or local anesthetic scalp blocks for intra- and postop analgesia. Consider scalp block reinforcement if initially placed >4 h ago. Consider additional acetaminophen iv if po dose given >4–6 h ago.	
Blood and fluid requirements	IV: 14–16 ga × 2 BSS @ <3 mL/kg/h + UO Massive blood loss possible Maintain euvolemia Maintain colloid oncotic pressure	If blood volume is normal, BSS—not to exceed 3 mL/kg/h beyond that required to replace UO—is given. If hypovolemic, albumin 5% is given, if Hct > 30%; combination of albumin and

		blood, if Hct < 30%.
Hypothermia	Water-circulating blankets Cold OR ± Thermogard®-type device Bladder irrigation	Mild hypothermia (33–34°C) is used in some centers for cerebral protection. This level of hypothermia does not interfere appreciably with coagulation, nor is it generally associated with ↑ SSI or cardiac dysrhythmias. Warming is begun as soon as possible after lesion resection and is greatly facilitated by the use of a central warming device (e.g., Thermogard® or equivalent) or bladder irrigation.
Brain relaxation (control of ICP)	Hyperventilate to $PaCO_2$ = ~35 mm Hg or $PetCO_2$ = 30 mm Hg Limit isoflurane/sevoflurane ≤ 0.5 MAC Maintain euvolemia Consider propofol infusion (50 mg/kg/min) to replace N_2O Mannitol 0.5–1 g/kg Furosemide 10–20 mg q6h Lumbar CSF drainage	↓ $PaCO_2$ → ↓ cerebral vascular volume →↑ working space and lessens need for vigorous retraction of brain tissue. ↓ $PaCO_2$ may also improve the regional distribution of CBF by preferentially diverting blood to potentially ischemic areas of the brain. If AVM is superficial, decreasing brain volume is less important, and the first five techniques listed (at left) are usually sufficient. If AVM is deep, the additional listed therapies may be needed.
Monitoring	Standard monitors Core temp: deep esophageal best Arterial line CVP line, subclavian	Direct monitoring is essential for rapid control of BP. Level transducer at the head. Monitoring CVP via a near right atrial catheter is

	preferred UO Blood glucose (100–180 mg%)	desirable in virtually all patients to assess adequacy of fluid therapy, for infusion of vasoactive drugs and aspiration of VAE. Localization of the catheter can be determined by CXR, ECG tracing, noting P-wave changes, or pressure wave morphology. **NB:** If patient has a high-flow AVM causing a large AV shunt, venous blood may appear arterialized (bright red) during central venous catheterization.
Control of BP	Isoflurane/sevoflurane Esmolol infusion SNP/clevidipine infusion Maintain normovolemia Labetalol (emergence)	Close regulation of BP during induction and prior to excision of AVMs is important, both to prevent bleeding (↑ BP) and to avoid ischemia 2° steal (↓ BP). After surgical excision is underway, however, modest decreases in MAP (≤20% below normal) using esmolol and/or SNP/clevidipine should be achieved to prevent excessive bleeding.
Positioning	Shoulder roll Three-point fixation (Mayfield) ✓ and pad pressure points ✓ eyes 180° rotation SCDs	For most AVMs, patient is supine, head turned laterally in three-point fixation, a roll under the shoulder on the side of operation (Fig. 1.1-6). Anesthetic hoses and all monitoring/vascular catheter lines are directed toward patient's feet or side. Make sure that all will reach the foot of operating table. SCDs

		are used to minimize DVT. Remifentanil (2–4 mcg/kg iv bolus) should be used to minimize ↑ BP during skull pinning.

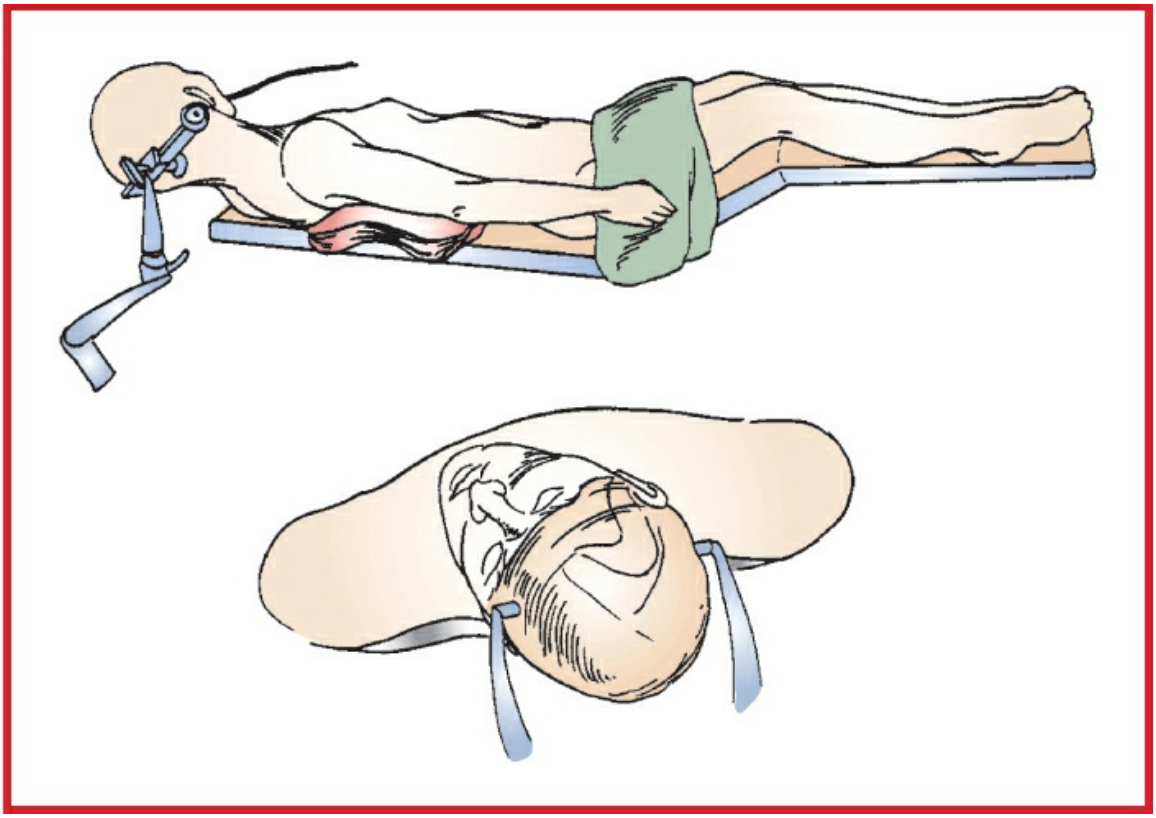

Figure 1.1-6 Supine position, head elevated above heart, turned 30–45° to side, vertex dropped for approach to anterior circulation aneurysms and frontal vascular malformations. (Reproduced with permission from Long DM:Atlas of Operative Neurosurgical Technique, Vol. 1. Williams & Wilkins, Baltimore: 1989.)

POSTOPERATIVE

Complications	Neurologic deficits	If these complications occur, the patient likely will have to be reintubated and transported to the CT scanner for further neurologic evaluation or possible reoperation.
	Cerebral edema and ↑ ICP	Careful regulation of BP is

	Intracerebral hemorrhage	essential to avoid postop hemorrhage.
	Seizures	*Sz Rx: Levetiracetam (1 g) or phenytoin (1-g loading dose). **NB:** Incompatible with dextrose-containing solutions.
Multimodal pain management	Acetaminophen 1 g iv	If not given preop or if 4–6 h have elapsed since previous dose.
	± Meperidine (10–20 mg iv prn) ± Fentanyl 25–50 mcg prn	Emphasize multimodal approach (see p. K-5). Meperidine will ↓ postop shivering in hypothermic patients. Minimize opioid use to ↓ PONV and to avoid unnecessary sedation.
	Place/Reinforce scalp blocks	0.5% bupivacaine with epi is as effective as liposomal bupivacaine.
Tests	CT scan	If neurologic status changes.
ERAS	PONV protocol	Ondansetron 4 mg iv ± metoclopramide 10–20 mg iv. Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Chang SD, Lopez JR, Steinberg GK: The usefulness of electrophysiologic monitorin during resection of central nervous system vascular malformations. J Stroke Cerebrovasc Dis 1999; 8:412–22.
2. Derdeyn CP, Zipfel GJ, Albuquerque FC, et al: Management of brain arteriovenou malformations: a scientific statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke 2017; 48(8):e200–24.
3. Gross BA, Du R: Natural history of cerebral arteriovenous malformations: a meta analysis. J Neurosurg 2013; 118(2):437–43.
4. Miller C, Mirski M: Anesthesia considerations and intraoperative monitoring during surgery for arteriovenous malformations and dural arteriovenous fistulas. Neurosurg

Clin N Am 2012; 23(1):153–64.
5. Morgan MK, Davidson AS, Assaad NNA, et al: Critical review of brain AVM surgery, surgical results and natural history in 2017. Acta Neurochir (Wien) 2017; 159(8):1457–78.
6. Rangel-Castilla L, Spetzler RF, Nakaji P: Normal perfusion pressure breakthrough theory: a reappraisal after 35 years. Neurosurg Rev 2015; 38(3):399–404; discussion 404–5.
7. Solomon RA, Connolly ES Jr: Arteriovenous malformations of the brain.N Engl J Med 2017; 376(19):1859–66.
8. Steinberg GK, Stoodley MA: Surgical management of intracranial arteriovenous malformations. In: Schmidek HH, ed.Operative Neurosurgical Techniques, 4th edition. WB Saunders, Philadelphia: 2000, 1363–91.

CRANIOTOMY FOR EXTRACRANIAL-INTRACRANIAL REVASCULARIZATION (EC-IC BYPASS)

SURGICAL CONSIDERATIONS

Gary K. Steinberg and Robert L. Dodd

Description

Extracranial-intracranial (EC-IC) revascularizationprocedures are performed when (a) deliberate occlusion of a major cervical artery (carotid or vertebral) is necessary and inadequate collateral CBF is available or (b) stenosis orocclusion of major cervical or intracranial arteries causes TIA or stroke, despite the use of maximum medical therapy (e.g., antiplatelet drugs, heparin, or Coumadin). The chief causes of stenosis or occlusion are atherosclerotic disease, radiation injury, and moyamoya disease. The subset of patients who benefit from revascularization are those whose radiographic and metabolism studies demonstrate that they have ↓ CBF and poor or absent vascular reserve. The most important surgical considerations include site of stenosis, adequacy of donor graft, and patient age.

The donor vessel (usually a scalp artery) is identified using ultrasound mapping and microscopically dissected from the surrounding tissue taking care to maintain flow. This portion of the procedure may require 1–2 h. A standard craniotomy is then fashioned as previously described for other lesions involving the vasculature around the skull base, and the intracranial site of anastomosis is exposed using microscopic techniques.

Typically, a donor superficial temporal artery is anastomosed to an intracranial artery (e.g., middle cerebral artery) distal to the site of stenosis. When scalp vessels are inadequate, an interposition vein segment can be sutured to a cervical artery and then anastomosed to the designated intracranial artery. The most common EC-IC procedure is a **superficial temporal artery (STA)-to-middle cerebral artery (MCA) branch anastomosis** (see Figs. 1.1-7 to 1.1-11). Other grafts include STA-to-posterior cerebral artery, STA-to-superior cerebellar artery, occipital artery-to-posterior inferior cerebral artery or interposition saphenous vein segment graft from the cervical external carotid artery to the middle cerebral artery, posterior cerebral artery, or superior cerebellar artery. During anastomosis, the recipient artery must be temporarily clamped for 10–20 min. The potential for ischemic injury during this interval can be minimized by inducing burst suppression on EEG combined with ongoing mild hypothermia (33–34°C).

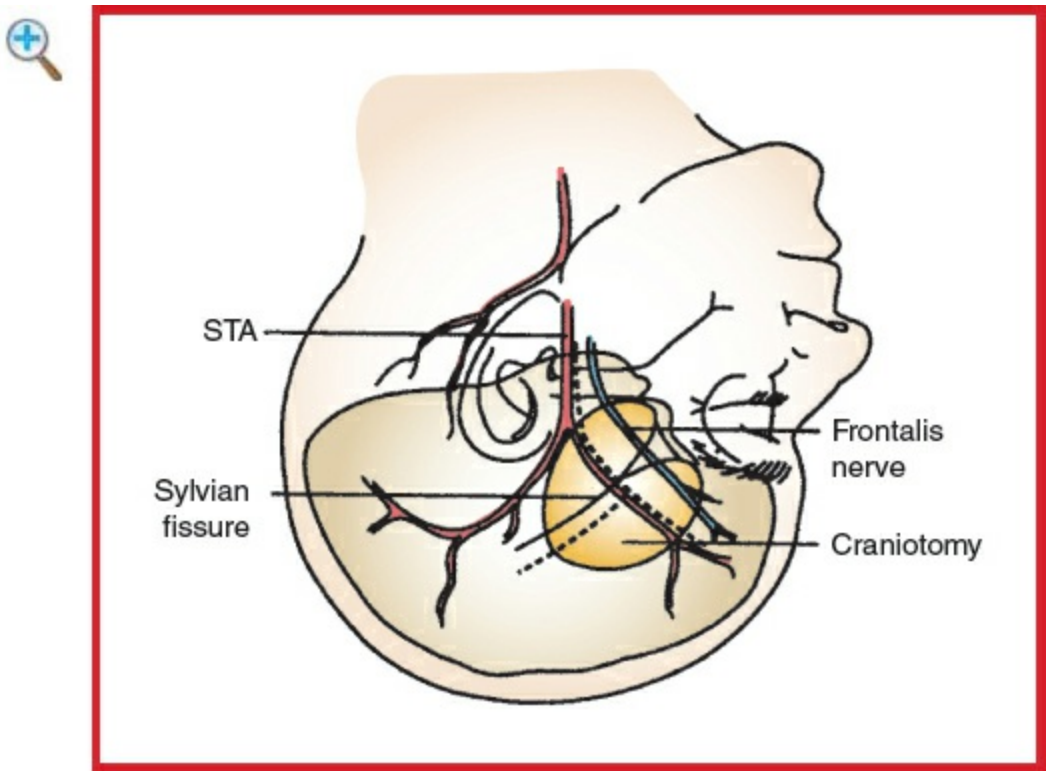

Figure 1.1-7 Typical skin incision for EC-IC bypass. The main incision is planned over the superficial temporal artery (STA) with a T extension to allow exposure of the bone. (Reproduced from Chang SD, Steinberg GK: Superficial temporal artery to middle cerebral artery anastomosis.Tech Neurosurg 2000; 6(2):86–100.)

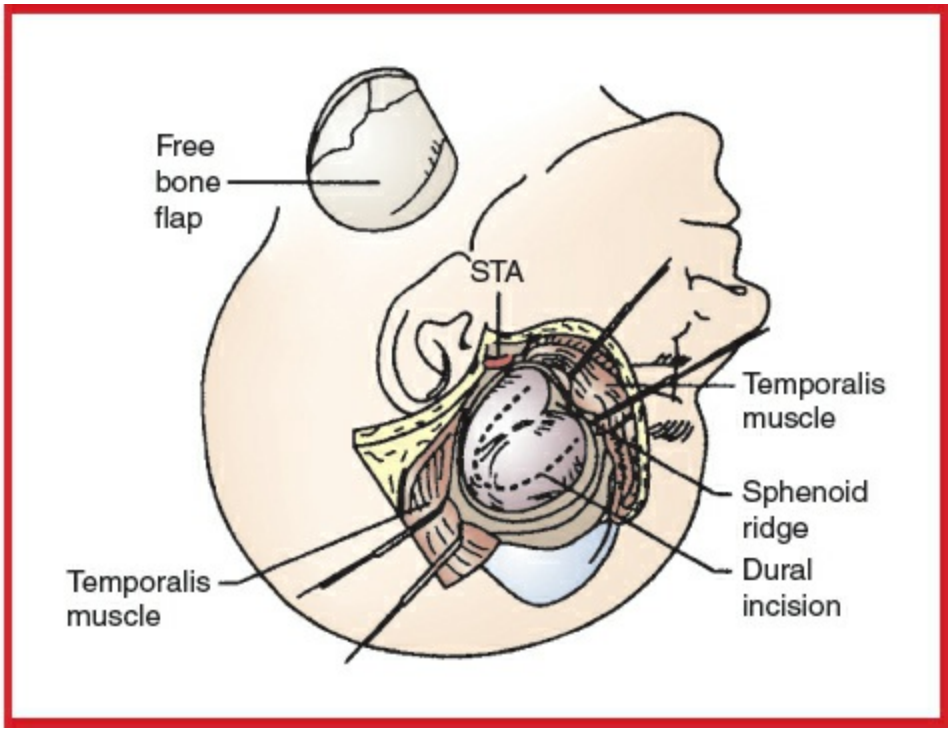

Figure 1.1-8 After the STA is dissected out, the temporalis muscle is divided and the bone flap is made to allow exposure of the brain over the anterior sylvian fissure. (Reproduced from Chang SD, Steinberg GK: Superficial temporal artery to middle cerebral artery anastomosis. Tech Neurosurg 2000; 6(2):86–100.)

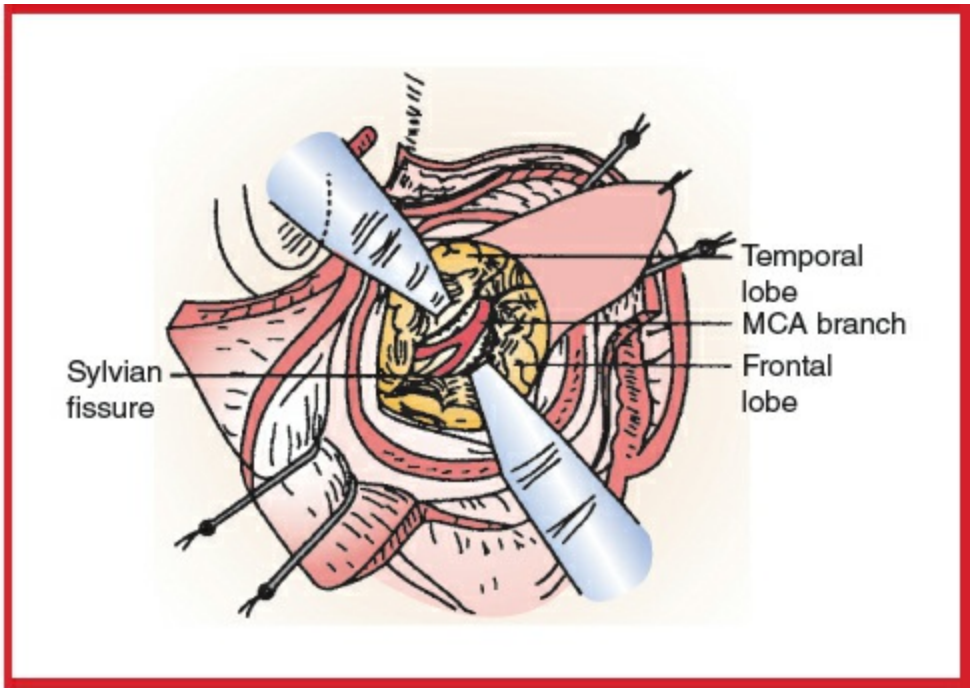

Figure 1.1-9 A middle cerebral artery (MCA) recipient vessel is identified. The sylvian fissure can be split to allow identification of a larger, more proximal branch of the MCA, preferably an M3 branch. (Reproduced from Chang SD, Steinberg GK: Superficial temporal artery to middle cerebral artery anastomosis. Tech Neurosurg 2000; 6(2):86–100.)

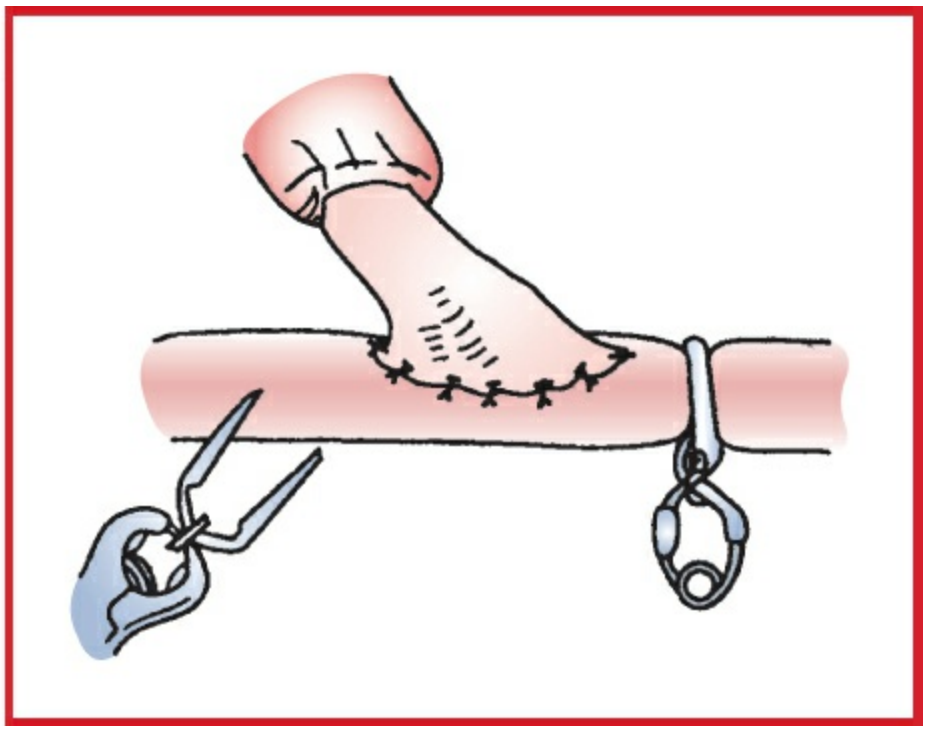

Figure 1.1-10 When the anastomosis is complete, the vascular clips are removed. (Reproduced from Chang SD, Steinberg GK: Superficial temporal artery to middle cerebral artery anastomosis.Tech Neurosurg 2000; 6(2):86–100.)

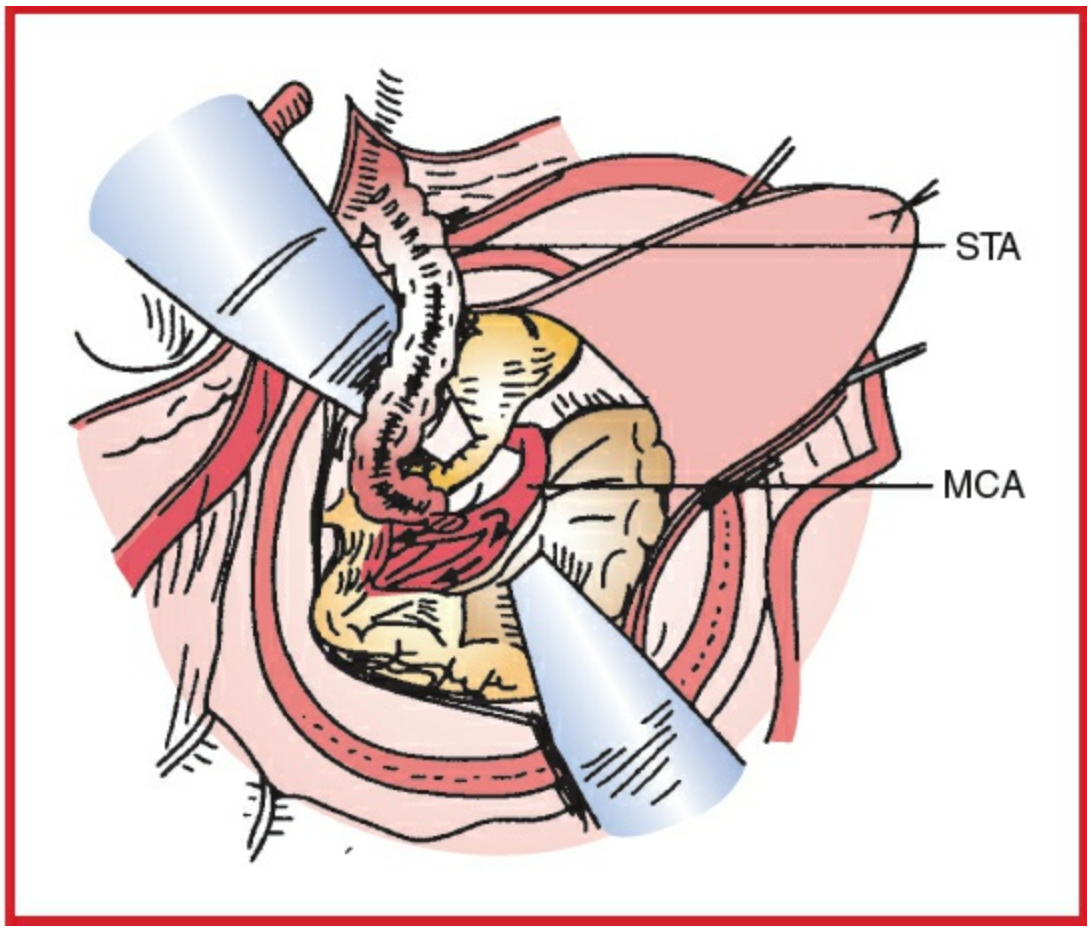

Figure 1.1-11 The completed anastomosis shows the STA positioned such that flow is directed toward

the proximal portions of the MCA. (Reproduced from Chang SD, Steinberg GK: Superficial temporal artery to middle cerebral artery anastomosis. Tech Neurosurg 2000; 6(2):86–100.)

Variant procedure or approaches

Indirect revascularization is commonly employed in patients in whom the graft vessels are too small for direct anastomosis. Vascular source tissues include a temporalis muscle flap and a flap of dura folded under so that its outer vascular surface is apposed to the cortical surface. **Encephalo-duro-arterio-synangiosis (EDAS)** is an indirect variant procedure wherein the STA is dissected circumferentially with its adventitia in the scalp, left in continuity, and laid on the surface of the brain after opening the dura. **Omentum-to-brain transposition** is becoming a more frequently used variant, wherein a portion of the omentum, with its luxuriant blood supply, is isolated using endoscopic technique, left attached to the right gastroepiploic artery, tunneled subcutaneously in the chest and neck, and laid over an area of poorly vascularized cerebral cortex after opening the dura. Revascularization is induced by angiogenesis factors and growth substances secreted by the brain and omentum.

Usual preop diagnosis

Moyamoya disease (cerebral ischemia due to occlusion of vessels at base of the brain); stroke; TIA; carotid artery stenosis (inaccessible to carotid endarterectomy); carotid artery occlusion; middle cerebral artery stenosis or occlusion; vertebral artery stenosis or occlusion; basilar artery stenosis or occlusion

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include continuing chronic pain and AED medications, limiting NPO duration, alcoho and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, and possibility of urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	EC-IC Bypass	EC-IC Bypass with Vein Graft	Indirect Procedures
Position	Supine or lateral decubitus	⇐	⇐
Incision	Frontal, parietal, temporal, occipital, or a combination of	⇐ + Medial aspect of the leg and thigh for	⇐ + possible abdominal incisions for

	these, depending on area to be vascularized.	harvesting greater saphenous vein	endoscopic harvesting omentum and chest/neck incision for tunneling
Special instrumentation	Microscopic instruments; microvascular Doppler to identify scalp donor artery course and confirm graft patency. Videoangiography with indocyanine green	⇐ + Tunneling instruments	⇐
Unique considerations	Neuroprotective agents (propofol) and induced mild HTN (MAP 90–110 mm Hg) during cross-clamp of recipient intracranial artery. Avoid hypocapnia. Mild hypothermia (33°C). Dexamethasone 8–12 mg iv	⇐ + Attention to proper alignment of vein when tunneled to avoid kinking; heparinization if major cervical artery (carotid, vertebral) is temporarily occluded.	⇐ + Avoid devascularizing source tissue during dissection or compromise to blood supply during closure.
Antibiotics	Cefazolin 2 g iv (30–60 min before incision)	⇐	⇐
Surgical time	4–6 h	⇐	⇐
Closing considerations	Careful attention to hemostasis. Avoid compromise of graft with dural closure, bone replacement, or scalp closure	⇐	⇐
EBL	<100 mL	⇐	100–200 mL

Postop care	Start aspirin on POD 1; monitor for subdural hygroma (CSF fluid collection in subdural space); ICU × 1 d	⇐	⇐
Mortality	<0.5%	⇐	⇐
Morbidity	Transient neurologic deficit: 20–40% Subdural hygroma: Rare Wound infection: Rare Stroke: Rare	⇐ ⇐ ⇐ ⇐	 ⇐ ⇐ Abdominal hernia: Rare
Pain score	3	3–5	3–5

PATIENT POPULATION CHARACTERISTICS	
Age range	40–80 yr; 2–20 yr for moyamoya disease
Male:Female	1:1 for atherosclerotic disease; 1:1.4 for moyamoya disease
Incidence	Thromboembolic stroke common, but indications for EC-IC bypass rare; 1/million/yr for moyamoya disease
Etiology	Atherosclerosis; embolism from heart or carotid artery
Associated conditions	HTN; CAD; PVD; hyperlipidemia; smoking; alcohol abuse; obesity; moyamoya disease

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients range in age from pediatric (classic moyamoya disease) to adult. These patients may have significant preexisting neurologic deficits. HTN in these patients is often an adaptation to cerebral vascular insufficiency → hypoperfusion. Inappropriate treatment of this compensatory HTN → cerebral ischemia and stroke. Patients with symptomatic moyamoya disease or bilateral carotid stenosis or occlusion may be good candidates for EC-IC bypass, especially since there are no alternative forms of therapy that have proven to be effective. Most patients present with h/o TIAs or stroke, and most are receiving antiplatelet medication.

Respiratory	None unless patient has Hx of smoking or has sustained pulmonary aspiration 2° neurologic deficit. **Tests:** As indicated from H&P
Cardiovascular	HTN is a common adaptive mechanism to maintain cerebral perfusion; therefore, "normalization" of BP preop may be undesirable. Adult patients may have generalized vascular disease, including CAD, so a careful cardiac Hx, physical examination, and ECG analysis should be done. If findings are positive, consider a more complete evaluation, including ECHO and coronary angiography. Be aware that cardiac insufficiency is the cause of about half of the deaths in patients with cerebrovascular disease. **Tests:** Consider ECG; others as indicated from H&P
Neurologic	Patients present with Sx of focal ischemic lesions. Cerebral angiography is necessary to r/o other causes of TIAs and characterize collateral circulation. Regional CBF studies are generally not helpful because measurement does not distinguish between low flow due to cerebrovascular obstruction and that due to low metabolic demands 2° prolonged cerebral ischemia. Preexisting deficits should be well characterized. **Tests:** CTA; MRI; angiogram; Diamox® scan
Hematologic	For most patients, a platelet-suppressive dose of aspirin should be continued through the day of surgery; drugs affecting PT/PTT should be D/C'd at least 1 wk before surgery to avoid excessive bleeding; clopidogrel (Plavix) should be D/C'd 5 d before surgery. **Tests:** Hct; PT; PTT; C8C
Laboratory	Tests as indicated from H&P
Premedication	If medication is desirable, small doses of midazolam (e.g., 1–3 mg iv) are useful. Detailed discussion with the patient about the anesthetic plan with appropriate reassurance is essential.
ERAS	Check compliance with presurgical ERAS

	recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water and aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: The goals of anesthesia for this procedure are to (a) maximize flow to the ischemic area through collateral channels by maintaining BP at normal or somewhat elevated values; (b) ↑ tolerance of the brain to ischemia by decreasing $CMRO_2$ with the use of mild hypothermia (33–34°C) and anesthesia; (c) ↓ intracranial volume (blood and tissue) to optimize working space within the cranial compartment, thereby minimizing the need for surgical retraction; and (d) provide adequate surgical anesthesia.

Induction	Propofol 1–2 mg/kg iv to provide amnesia and ↓ cerebral blood volume by inducing cerebral vasoconstriction. Fentanyl 7–10 mcg/kg iv to blunt response to intubation and provide analgesia for the first hours of surgery. Rocuronium 0.6–1.0 mg/kg or vecuronium 0.15 mg/kg to provide muscle relaxation for tracheal intubation. Bolus ephedrine and/or phenylephrine are often necessary to maintain CPP during induction.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia. Avoid hypothermia unless indicated for brain protection. Dexamethasone (4–8 mg iv) may ↓PONV. Avoid long-acting opioids or scopolamine patch, which may confound postop neuro examination. Sequential pneumatic compression devices should be used to ↓VTE risk.
Maintenance	Isoflurane ≤0.6% or sevoflurane ≤1% with 1:1 O_2/N_2O and a remifentanil infusion (0.05–0.2 mg/kg/min). A phenylephrine infusion is usually necessary to maintain CPP during the procedure. Continued neuromuscular blockade is usually not necessary. Burst suppression is induced with propofol (~1 mg/kg) just before cross-clamping of the cerebral artery in preparation for

	anastomosis. A bolus dose of phenylephrine and/or ephedrine is usually given concomitantly to offset the hypotensive effects of propofol. If mild hypothermia was employed, rewarming should start as soon as revascularization is complete.	
Emergence	With the start of dural closure, reduce remifentanil infusion to 0.05 mcg/kg/min. A propofol infusion (if used) should be discontinued at this time. The patient's BP generally will increase and titration of β-adrenergic blocking drugs (e.g., labetalol or esmolol) and/or vasodilators (e.g., clevidipine or SNP) may be needed (see Control of BP, below). The inhalation agents can be D/C'd at the time of dressing application. Reverse any residual neuro muscular blockade. Most patients will breathe spontaneously and can be extubated uneventfully while on the remifentanil infusion. If the brain has not been injured by the surgical procedure, the patient should awaken promptly. Close regulation of BP is essential. If the patient begins to cough on ETT, either it should be removed or cough reflex suppressed with iv lidocaine (1 mg/kg). Patient is placed in bed in a 20–30° head-up position and transported to ICU for monitoring overnight. Supplemental O_2 should be administered and close regulation of BP maintained (typically at baseline values). Prophylactic antiemetics (e.g., ondansetron 4 mg ± metoclopramide 10–20 mg iv) should be given 30 min before extubation. Consider iv acetaminophen for postop analgesia if po dose given >4–6 h ago.	
Blood and fluid requirements	IV: 18 ga × 2 BSS @ <1–3 mL/kg/h + UO Zero balance fluid management (see Appendix K, p. K-2)	In hypothermic patients, iv drugs should be administered through the central line to ensure timely entry into the central circulation.
	CVP (triple lumen)	Use low-volume (1 mL) extension for drug infusions. Reserve distal lumen for

		pressure monitoring and air aspiration.
Control of brain volume (ICP)	Avoid hypovolemia ↓ Isoflurane ≤0.6% or sevoflurane <1% N_2O ≤ 50% ± Furosemide 10–20 mg iv ± Mannitol 0.5–1.0 g/kg	Maintain normovolemia. Generally, vigorous control of brain volume is not necessary because surgeon is working with cerebral vessels on the surface of the brain. Keep $PaCO_2$ = ~40 mm Hg. Hypocarbia may cause unwanted cerebral vasoconstriction in these patients.
Monitoring	Standard monitors EEG	Establish burst suppression before X-clamp.
	Core temperature Arterial line	Core temperature is best approximated by a deep esophageal temperature probe. Bladder temp tends to lag behind core temp.
	CVP (triple-lumen catheter) UO	The distal CVP lumen should be used for pressure monitoring.
Control of BP	Maintain normal BP (MAP) Phenylephrine infusion	Maintenance of MAP is important because cerebral perfusion is often impaired in these patients. If a vasoconstrictor is needed, phenylephrine is preferred because it has minimal dysrhythmogenic potential.
	Normovolemia	Responses to vasoactive drugs are much easier to regulate if a normal blood volume has been maintained throughout the anesthetic period.

Positioning	✓ and pad pressure points ✓ eyes Shoulder roll SCDs Mayfield 3-point skull fixation	Anesthetic hoses, monitoring, and vascular lines directed to patient's feet where anesthesiologist is usually positioned during surgery. Used to minimize DVT. Remifentanil (2–4 mcg/kg) should be used to minimize ↑BP during pinning.
Hypothermia	Cold-water circulating blankets Core temp goal: 33–34°C Thermogard®-type device Bladder irrigation	Surface cooling is quite effective in patients with high surface-to-volume ratios and should be started as soon as induction of anesthesia is complete, using a cold-water circulating blanket underneath and above the patient. When anastomosis is nearly complete, vigorous efforts at warming, including bladder irrigation, are initiated. Cooling and especially rewarming can be greatly facilitated by the use of a central heat exchange device (e.g., Thermogard®).
Complications	Seizures Stroke Hemorrhage at anastomosis	*Sz Rx: Levetiracetam (1 g) or phenytoin (1-g loading dose). **NB:** Incompatible with dextrose-containing solutions.
	Brain swelling	May be 2° hyperemia in revascularized territory.

POSTOPERATIVE

Complications	Localized scalp necrosis	Major complications uncommon; localized scalp

		necrosis unique to this procedure.
	Brain swelling	May be 2° to delayed hyperemia. Careful control of BP is important.
Multimodal pain management	Avoid scalp blocks Meperidine (10–20 mg iv prn)	May interfere with donor vessel blood flow. May be useful to suppress shivering. Postop pain is usually not severe.
	Acetaminophen 1 g iv ± Fentanyl 25–50 mcg prn	If not given preop or if 4–6 h have elapsed since previous dose.
Tests	Cerebral angiogram	Cerebral angiography documents patency of graft and collateral flow.
	Regional blood flow studies	Regional blood flow studies are often useful.
	CT scan	If any question about neurologic status, a CT scan is performed.
ERAS	PONV protocol	Ondansetron 4 mg iv ± Metoclopramide 10–20 mg iv Encourage early enteral nutrition, Foley catheter removal, and mobilization.

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CRANIOTOMY FOR TUMOR

SURGICAL CONSIDERATIONS

Lawrence M. Shuer, Steven D. Chang, and Navjot Chaudhary

Description

Many classification systems exist for brain tumors. Generally, brain tumors can be classified by their location, and a differential diagnosis can be generated based on tumor location and patient age. Brain tumors are either supratentorial or infratentorial (Table 1.1-2) or intraaxial or extraaxial (Table 1.1-2). The surgical approach depends on the location of the lesion, the need for brain relaxation, and whether exposure will require brain resection. Patient positioning generally depends on the location and surgical approach to the tumor (Table 1.1-3). Once positioned, the patient's head typically is placed in a Mayfield pin fixation system to prevent head movement during surgery and to allow for intraoperative image-guided stereotactic navigation.

Several types of incisions are used for these procedures. **Linear incisions** can be used to resect small tumors over the convexity or when using a midline approach to the posterior fossa and often have the advantage of a more rapid wound closure. **Curvilinear** or **horseshoe-shaped incisions** are commonly used for larger tumors. After the skull is exposed, burr holes are made with a perforating drill, and the bone flap is

cut with the craniotome. Most surgeons routinely use a **free bone flap**, in which the bone is completely removed and stored for the duration of the case. Other surgeons turn an **osteoplastic flap**, where the bone is left attached to muscle and/or pericranium to keep it partially vascularized. When performing certain posterior fossa resections (e.g., a retromastoid craniotomy or low suboccipital craniotomy), the surgeon may choose to remove the bone without replacement, performing a **craniectomy** instead of a craniotomy. After the bone is removed, a few small holes are drilled near the edge of the craniotomy. These holes are used to suspend the dura using sutures. This helps prevent blood from accumulating in the epidural space during the rest of the case. The dura is then opened either in a stellate or curvilinear fashion. The method of dural opening generally is based on the size of the bone opening and its proximity to venous sinuses. The surgeon then proceeds with tumor removal if it is on the surface or with brain retraction/resection if the tumor is deep to the surface. At this point, the surgeon may request anesthetic interventions for brain relaxation (osmotic diuresis, hyperventilation) and specific BP control. After the tumor is removed, hemostasis is achieved and the dura is closed. The bone flap is replaced and fixated, the galea is closed with sutures, and the skin incision is closed with staples. During closure, the surgeon may ask for specific BP parameters to ensure that there is hemostasis in the resection bed and surgical field. Patients typically are extubated after cranial surgery because it is paramount to obtain a neurologic examination as soon after surgery as possible. Patients undergoing a craniotomy almost always require a postoperative ICU course.

Table 1.1-2 Common Tumor Location

Supratentorial	Infratentorial	Intraaxial Tumors	Extr
Metastatic tumors	Metastatic tumors	Astrocytoma/glioblastoma	Men
Astrocytoma/glioblastoma	Acoustic neuromas	Metastatic tumors	Acou
Oligodendroglioma	Meningiomas	Oligodendroglioma	Cho papi
Ependymoma	Hemangioblastoma	Ependymoma	Cran
Meningioma	Medulloblastoma	Hemangioblastoma	Hem
Choroid plexus papilloma		Medulloblastoma	
Craniopharyngioma		PNET	
Primitive neuroectodermal			

tumor (PNET)			

Table 1.1-3 Common Patient Positions Based on Tumor Location	
Supine:	Most supratentorial tumors in the frontal, temporal, or anterior parietal lobe. Tumors of the lateral ventricles and 3rd ventricle. Tumors of the anterior two-thirds of the interhemispheric fissure
Lateral:	Tumors of the posterior or lateral parietal lobe, posterior temporal lobe, cerebellopontine angle, or lateral cerebellum. Tumors of the posterior ventricular horn
Prone:	Tumors of the occipital lobe, most midline cerebellar tumors, and tumors of the 4th ventricle. Tumors of the posterior one-third of the interhemispheric fissure and the tentorium
Sitting:	Tumors of the pineal region. Tumors of the 4th ventricle or midline cerebellum

Electrophysiologic monitoring detects changes in SSEP, brain stem auditory evoked potentials (BAEP), and motor evoked potentials. Such monitoring is commonly used for tumors of the brain stem and skull base or when resecting tumors in critical locations. Early changes in electrophysiologic monitoring potentials may alert the anesthesiologist to manipulate BP and may help the surgeon to further define the extent of safe retraction and tumor resection to minimize the likelihood of a postop deficit.

Image-guided navigation involves the use of a computerized workstation that can track the position of specific instruments before and during the operation. This allows the surgeon to (a) plan appropriate skin and bone openings, (b) choose an optimal trajectory to the tumor, and (c) achieve a volumetric resection of the tumor. Image-guided navigation involves obtaining a CT or MRI scan prior to the start of the surgical procedure; the time required to obtain this study is usually offset by a shorter operative time. Data from the operative microscope can also be incorporated into the navigation system to aid in tumor dissection.

Mild hypothermia is often utilized when resecting tumors in eloquent areas of the brain because hypothermia has been shown to provide neuroprotection.

CSF drainage usually is accomplished by use of a lumbar drain. Lumbar drainage typically is used for tumors in the cerebellopontine angle, in the pineal region, or tumors associated with significant edema. CSF drainage can also be accomplished by placing a

ventriculostomy or by draining various cisterns during the operation.

Awake craniotomies typically are reserved for tumors adjacent to or within fine motor or speech areas of the language dominant cortex. Patients are sedated during cranial opening and are awakened once the dura is open. Direct cortical stimulation is performed to determine the relationship between the tumor and the speech or motor centers. The surgeon then maps out eloquent and noneloquent areas of the brain prior to beginning the tumor resection. The patient continues to converse during the tumor resection to ensure that language function is not altered.

Interstitial chemotherapy or brachytherapy can be performed after the tumor resection by implanting chemotherapy impregnated wafers or radioactive seeds in the resection cavity. In addition, a catheter can be placed in the resection bed and injected with radioactive material at a later date.

Intraoperative fluorescent dyes can assist in achieving gross or near-total resection. Maximal safe resection is thought to have an important role in improving overall survival and progression-free survival, but identifying tumor borders can be challenging in some glioma cases. For this reason, imaging adjuncts, such as 5-aminolevulinic acid (5-ALA) or fluorescein sodium, have been proposed as strategies for better delineating the limits of surgical resection.

Variant procedure or approaches

Patient position varies depending on tumor location and surgeon preference (Table 1.1-3). Tumors on the convexity, or surface, of the brain may require minimal brain relaxation or exposure. Deep tumors, or tumors around the brain stem or skull base, may require substantial brain relaxation and retraction for optimal exposure. For deep tumors or tumors within or adjacent to critical structures, the operating microscope is commonly used. Large vascular tumors may undergo preop embolization of the tumor blood supply to minimize intraop blood loss.

Minimally invasive techniques exist for tumor resection. Access points include supraorbital ("eyebrow craniotomy"), transnasal, minipterional, retromastoid, and transventricular routes. In addition, MRI-guided laser ablation techniques have provided a method for stereotactic access to thermocoagulate brain tumors through a small twist drill hole placed with the patient in the MRI scanner. Advantages of these minimally invasive techniques include smaller incision, less postop pain, and faster recovery times. Disadvantages include limited access and visibility.

Intraop MRI (iMRI) is an advance, which has allowed surgeons to better define brai

tumor margins in the operating room in conjunction with surgical navigation systems (e.g., StealthStation™). This allows for more accurate confirmation of complete surgical resection of brain tumors. iMRI systems may include those that are moved into the OR or those that require transporting the patient while anesthetized to a nearby location for scanning.

Usual preop diagnosis

Glioma; glioblastoma multiforme; astrocytoma; oligodendroglioma; ependymoma; PNET; meningioma; craniopharyngioma; choroid plexus papilloma; hemangioblastomas; medulloblastoma; acoustic neuroma; brain metastasis; hemangiopericytoma

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include continuing chronic pain and AED medications, limiting NPO duration, alcoho and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, and possibility of urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine, lateral, prone, or sitting, based on location of tumor
Incision	Linear or curvilinear, based on location of tumor
Special instrumentation	Operating microscope, laser, CUSA, electrophysiologic monitoring, image-guided navigation, lumbar drain, ventriculostomy
Unique considerations	ETT must be taped securely in a location satisfactory to the surgeon; anode or RAE tube is helpful in certain situations. Decadron is usually given preop and dosed every 6 h to minimize brain edema. Brain relaxation techniques may be required. The patient with ↑ ICP may require special consideration for induction of anesthesia. Awake craniotomy may be required for tumors involving eloquent brain areas.
Antibiotics	Cefazolin 2 g iv (30–60 min before incision)
Surgical time	3–5 h typically
Closing	Possible requirement for dural graft. Drain often left in the

considerations	epidural or subgaleal space. Good BP control during closing and extubation to prevent hemorrhage into tumor resection bed.
EBL	50–500 mL (Meningiomas and renal cell mets are highly vascular tumors, → blood loss may be substantial.)
Postoperative care	ICU or close observation unit × 1–3 d. Fluid and electrolytes require frequent monitoring. BP may need to be controlled with antihypertensives.
Mortality	0–5% (mortality higher for tumors in critical locations)
Morbidity	Infection: 1% Neurologic: neurologic disability, nerve injury: 0–10% CSF leak: 1–3% Venous sinus injury, air embolus Endocrine disorder Massive blood loss
Pain score	2–7

PATIENT POPULATION CHARACTERISTICS

Age range	Infant to 85 yr (usually 20–60 yr)
Male:Female	~1:1
Incidence	Common neurosurgical procedure (~40,000 dx/yr in the United States)
Etiology	Neoplastic

ANESTHETIC CONSIDERATIONS

(Procedures covered: craniotomy for tumor; craniotomy for skull tumor)

PREOPERATIVE

Typically, this is a healthy patient population, apart from Sx attributable to intracranial pathology (↑ ICP, Sz, HA, N/V, visual disturbances). Review imaging studies and discuss surgical approach, positioning, tumor type, and potential for blood loss with surgeon. These patients are often receiving steroids to ↓ ICP. The patient may have received po 5-aminolevulinic acid 3 h before anesthetic induction. Side effects can

include phototoxic skin reactions (reduce exposure to room light or sunlight for 24 h postop), severe hypersensitivity reactions, lactic acidosis, and N/V.

Respiratory	Occasionally, neurogenic pulmonary edema may occur. H/o chemotherapy or radiation therapy may affect pulmonary function and airway management. Otherwise no special considerations, unless indicated from H&P.
Cardiovascular	Benign or malignant brain tumors cause edema formation in adjacent normal brain tissue, which may → ↑ ICP. If ICP increases sufficiently to cause herniation of the brain stem, patients develop the "Cushing triad" of HTN, bradycardia, and respiratory irregularity. These changes will resolve when ICP is reduced, so vigorous attempts to regulate BP and HR prior to craniotomy are not warranted. After the diagnosis of brain tumor is made, most patients are placed on high-dose steroid therapy to lessen edema in surrounding normal brain. Steroids are extremely effective in this setting, and Sx of ↑ ICP will often abate. **Tests:** Consider ECG; others as indicated from H&P
Neurologic	Patients may present with complaints related to ↑ ICP (e.g., HA, N/V, visual changes, recent onset of Sz), neurologic deficits from compression of motor area, or as a result of hemorrhage from the tumor or edema in surrounding normal brain. Document preop physical findings. **Tests:** A CT scan or MRI will delineate the site and size of the tumor, especially if iv contrast material, such as gadolinium, is administered to enhance the margins of the tumor. Look for intracranial mass effects: midline shift, ↓ ventricular volume, ↓ peri-brainstem (basal cisterns) CSF space, obstructive hydrocephalus.
Laboratory	Coags should be normal. Hct, electrolytes, and other tests as indicated from H&P.

Premedication	Standard premedication (except for patients with the possibility of ↑ ICP: no sedation).
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water and aprepitant 40–80 mg po with sip of water for patients undergoing posterior fossa craniotomy or with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Small tumors, particularly those located in deeper brain structures, may be localized and resected using stereotactic or image guidance techniques. Generally, scalp markers (fiducials) or a stereotactic frame are placed on the patient's head; then, the patient is taken to CT/MR for determination of the exact tumor site. GETA is almost invariably used for tumor removal, although MAC (see Awake Craniotomy) is used on rare occasions when the surgeon needs to assess motor or sensory function during the resection of the tumor adjacent to critical motor or speech areas. Surgeons may visualize certain tumors by utilizing iv fluorescent dyes (e.g., fluorescein—a marker for areas with compromised BBB, or 5-aminolevulinic acid—a Hb precursor that causes the accumulation of fluorescent porphyrins in malignant glioma cells). When used in conjunction with a specialized operating microscope, these compounds allow greater definition of the tumor and its boundaries with normal brain tissue. Anaphylactic reactions can occur with the use of these agents.

Induction	If the patient is in a stereotactic frame, or a difficult intubation is anticipated, orotracheal intubation will need to be accomplished before induction of GA. Awake fiberoptic intubation is the best choice. Ensure adequate airway anesthesia to minimize sudden ↑ICP and ↑MAP. After the airway is secured, anesthesia usually is induced with propofol (1–3 mg/kg) and fentanyl (5 mcg/kg) in combination with an NMR (e.g., rocuronium 0.6 mg/kg or vecuronium 0.1 mg/kg). To minimize ↑↑ BP and ↑ ICP with ET intubation, it is important that the patient be well anesthetized (and paralyzed) before undertaking laryngoscopy. Induction doses of propofol or fentanyl

	may not be sufficient to abolish increases in ICP that may occur with laryngoscopy and tracheal intubation. Consider hyperventilating the patient and using remifentanil (2–3 mcg/kg) as part of the induction technique to further blunt the response to laryngoscopy in patients with ↑ ICP.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia. Consider pre-incision placement of scalp blocks. Dexamethasone (4–8 mg iv) may ↓PONV. Avoid long-acting opioids or scopolamine patch, which may interfere with postop neuro examination. Sequential pneumatic compression devices should be used to ↓VTE risk.
Maintenance	Isoflurane or sevoflurane ≤1 MAC (≤1/2 MAC if EP monitoring is used) inspired with 50:50 O_2/N_2O. Propofol (50–100 mcg/kg/min) can replace N_2O and may be used to further ↓ cerebral blood volume, ↓ cerebral metabolism, and ↓ $CMRO_2$. A remifentanil infusion (0.05–0.2 mcg/kg/min) can be used to supplement the anesthetic without interfering with EP monitoring. Excessive EMG activity can be Rx with 5–10 mg rocuronium bolus.
Emergence	Surgeons should request transient ↑ MAP to 90–100 mm Hg to test hemostasis after the tumor has been resected. With the start of dural closure, D/C propofol infusion if in use, continue a low-dose remifentanil infusion (e.g., 0.05 mcg/kg/min). The patient's BP generally will increase, and titration of β-adrenergic blocking drugs (e.g., labetalol or esmolol) and/or vasodilators (e.g., clevidipine or SNP) may be needed (see Control of BP, below). Reverse NMB as necessary. The anesthetic agents can be D/C'd at the time of dressing application while continuing the remifentanil infusion. Most patients will breathe spontaneously and can be extubated uneventfully while on 0.05 mcg/kg/min remifentanil. If the brain has not been injured by the surgical procedure, the patient should awaken promptly.

	Keep close regulation of BP. Patient is placed in bed in a 20–30° head-up position and transported to ICU for monitoring overnight. Supplemental O_2 should be administered and BP control maintained. Prophylactic antiemetics (e.g., metoclopramide 10–20 mg and ondansetron 4 mg) should be given iv ~30 min before extubation. Consider scalp block placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po or iv dose given >6 h ago.	
Blood and fluid requirements	IV: 16–18 ga × 2 Type and screen (or cross) BSS @ 2–3 mL/kg/h	Brain tumors (e.g., meningioma) can be highly vascular. To minimize postop cerebral edema, limit BSS to ≤3 mL/kg/h + replacement of UO. If volume is needed, administer albumin 5% as required. Zero balance or goal-directed fluid management is recommended.
Monitoring	Standard monitors Arterial line CVP line ± Precordial Doppler	If the head of the OR table is significantly elevated (≥30°) or if the patient is in the seated position, a precordial Doppler monitor is necessary to monitor for VAE.
	± BAER, SSEP, MEP UO	Evoked potentials can be monitored easily in the presence of inhaled anesthetics (e.g., ≤0.6% isoflurane with 50% N_2O), contrary to popular belief.
Positioning	Supratentorial: supine/lateral Posterior fossa: prone/sitting	For brain tumors in the frontal, parietal, or temporal lobes, patient will be supine with head in Mayfield pin

	✓ and pad pressure points ✓ eyes	fixation, turned to the side with a roll under the shoulder on the operative side (Fig. 1.1-6). For occipital or posterior fossa tumors, patient may be prone or, occasionally, sitting (see Anesthetic Considerations for Cervical Neurosurgical Procedures, Positioning). Acoustic neuromas are generally most easily removed with patient in the lateral ("park-bench") position with a roll under the axilla. The patient generally lies on a "beanbag," which holds her/him firmly in the lateral position.
Control of ICP	Maintain normovolemia Control BP in normal range for patient PaO_2 > 100 mm Hg Limit isoflurane or sevoflurane to 1/2 MAC for EP monitoring Steroids: 8–12 mg Decadron iv	Patients with intracranial tumors may be on the steep portion of the intracranial compliance curve such that any increase in intracranial volume may → ↑↑ ICP. Transient increases in ICP—even up to 50–60 mm Hg—are tolerated, provided they are promptly terminated. Sustained increases in ICP > 25–30 mm Hg are associated with severe neurologic injury and poor outcome.
	$PaCO_2$ = 25–30 mm Hg	↓ $PaCO_2$ → ↓ CBV (providing better surgical access) + ↑ CBF to ischemic areas ("Robin Hood" effect).
	Consider replacing N_2O	If further reduction in ICP is

	with propofol infusion	needed, replace N_2O with a propofol infusion.
	Mannitol 0.5–1.0 g/kg ± Furosemide 10–20 mg	Mannitol/furosemide → ↓ K^+; monitor level and replace as necessary. If mannitol is administered too rapidly, profound ↓ BP will occur, probably from peripheral vasodilation.
	± Lumbar CSF drain Head up 20–30°	CSF drain may be placed after induction of anesthesia and may be opened as required to ↓ CSF volume and pressure. Keep surgeon informed of volume drained.

POSTOPERATIVE

Complications	Seizures Neurologic deficits	*Sz Rx: Levetiracetam (1 g) or phenytoin (1-g loading dose). **NB:** Incompatible with dextrose-containing solutions.
	Tension pneumocephalus Hemorrhage requiring reexploration Edema and ↑ ICP	In seated position, additional rare, but possible complications include quadriplegia from excessive flexion of the head or tension pneumocephalus from intracranial air. Severe tension pneumocephalus may delay emergence from anesthesia or cause postop neurologic deficits. CT scan may be necessary for Dx.
Multimodal pain management	Acetaminophen 1 g iv	If not given preop or if 4–6 h have elapsed since previous dose.

	Scalp blocks (see Fig. 1.1-12) ± Meperidine (10–20 mg iv prn) ± Fentanyl 25–50 mcg bolus prn	0.5% bupivacaine with epi is as effective as liposomal bupivacaine. Meperidine reduces postop shivering. Avoid excessive sedation.
Tests	CT scan	If patient exhibits any delay in emergence from anesthesia and surgery, or any new neurologic deficits emerge postop, a CT scan is invariably obtained.
ERAS	PONV protocol	Ondansetron 4 mg iv, ± metoclopramide. Encourage early enteral nutrition, Foley catheter removal, and mobilization.

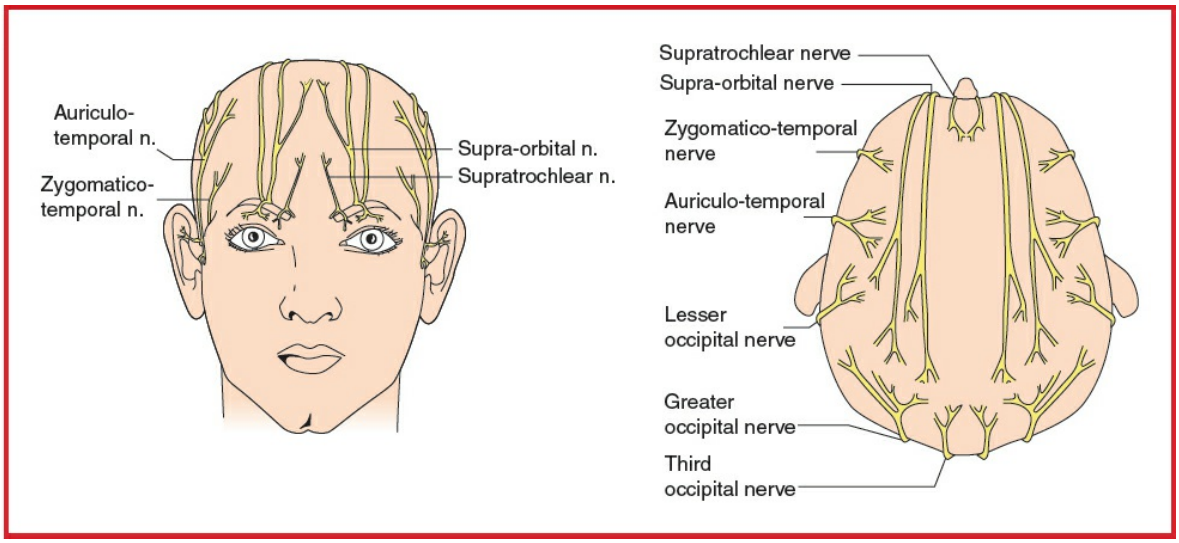

Figure 1.1-12 Scalp innervation. Typically, the supraorbital, auriculotemporal, lesser occipital, and greater occipital nerves are blocked near their scalp origins.

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CONSIDERATIONS FOR AWAKE CRANIOTOMY

PREOPERATIVE

These patients typically are otherwise healthy except for a tumor (or AVM) involving eloquent (speech or motor) areas of the brain. In some centers, awake craniotomies are still used for epilepsy surgery. Awake craniotomies for functional procedures (e.g., deep brain electrode placement) usually involve 1 or 2 burr holes with small dural punctures and are discussed on p. 79.

In addition to the preop anesthetic considerations for brain tumors or vascular malformations, it is essential that these patients (and family) meet with their anesthesiologist and monitoring neurologist to discuss in detail both the anesthetic and surgical aspects of the procedures, as well as the specific speech or motor mapping techniques that will be used. The patient should be told that a Foley catheter will be placed while they are sedated; however, after the sedation is stopped, the catheter will become annoying, and the patient may be convinced that he/she has a full bladder. Intraop cooperation is critical, and there is no pharmacologic substitute for a well-

informed patient.

ERAS: Preop counseling by the surgeon/anesthesiologist should include a detailed description of the awake craniotomy procedure and what to expect. Patients should also be advised to continue chronic pain and AED medications, limit NPO duration, and advised regarding alcohol and smoking cessation, carb loading, postop pain management options, urinary drain postop, description of antimicrobial prophylaxis, and skin preparation. See Appendix K, p. K-1.

Premed	Midazolam 1–3 mg iv is usually tolerated. Beware of respiratory depression → ↑ ICP. Antiemetic: for example, ondansetron 4 mg iv slowly and q4h during the procedure. Patients who are caffeine dependant will benefit from replacement caffeine (100- to 200-mg tablet with sip of water).
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water and aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Although some centers use an asleep-awake-asleep technique with airway control (ETT or LMA) during the sleep phases, we prefer the following technique that minimizes airway manipulation and its inherent risk of coughing and bucking.

Premapping	Most patients with significant space-occupying lesions will benefit from the early administration of mannitol 0.5 g/kg by slow iv infusion (check with surgeon for possible contraindications). With the patient in a lounge-chair position and following the application of standard monitors and nasal prong O_2, initial sedation is provided by incremental midazolam titrated to effect (1–10 mg iv). A loading dose of dexmedetomidine (1 mcg/kg iv over 10–15 min as tolerated) is given while the sites for arterial line and

	central line (subclavian or antecubital PICC line) placement are infiltrated with local anesthetic. Following the loading dose, a maintenance infusion of dexmedetomidine (0.2–0.7 mcg/kg/h) typically 0.4 mcg/kg/h is started. The dexmedetomidine produces cooperative sedation and analgesia without respiratory depression. A ↓ BP and ↓ HR are common and occasionally will require treatment with vagolytics and/or pressors. Sedation is usually deepened with a propofol infusion (25–75 mcg/kg/min) to cover the more invasive aspects of the procedure. A nasal airway or THRIVE device (e.g., Optiflow®) may be useful in some patients with mild airway obstruction. Scalp blocks (supraorbital, temporal, and occipital nerves) are placed using 0.5% bupivacaine with epinephrine (see Fig. 1.1-12). Arterial line, central line, and Foley catheter are placed. The arterial line and iv are ideally placed on the ipsilateral upper extremity to minimize interference with mapping. It is important that the nurse administer intraurethral lidocaine gel, holding it in place for 2–3 min before inserting the Foley catheter. Pin sites for the Mayfield skull fixation are infiltrated with local anesthetic, and the clamp is applied. The incision is infiltrated with local anesthetic, and after patient comfort has been ensured, the craniotomy is allowed to proceed. Drapes should be arranged so that the anesthesiologist and neuromonitoring team have an unobstructed view of, and access to, the patient's face and airway.
Mapping	The dexmedetomidine (and propofol) infusions are stopped at the end of the craniotomy. Initial mapping (e.g., phase reversal localization) can be accomplished while the patient is recovering from the sedation. Some direct cortical stimulation can produce seizures; it is important that sterile, iced saline be immediately available for cortical irrigation

	to suppress the seizure activity. If seizure activity spreads, it will be necessary to administer a bolus dose of propofol (20–30 mg iv) through the central line. Airway support (e.g., LMA) may be necessary in the postictal phase. The patient should be awake and cooperative within 20 min after the dexmedetomidine and propofol infusions have stopped. Occasionally, flumazenil may be necessary to reverse residual midazolam effects. Detailed speech or motor mapping can then be readily accomplished. We use a miniature wireless microphone taped near the patient's mouth to amplify the patient's voice during testing and tumor resection.
Resection	If the lesion is located safely away from the mapped speech or motor areas, the resection can be accomplished after reinstituting the dexmedetomidine and propofol infusions. Otherwise, the patient must be kept awake and talking throughout the resection. Often the patient will benefit from a low-dose remifentanil infusion (e.g., 0.05 mcg/kg/min) to improve ability to tolerate positional discomfort.
Closing	Closing is best accomplished by resuming the previously effective infusions of dexmedetomidine and propofol. The infusions should be stopped during the final phase of wound closure. Careful control of BP may require the use of labetalol, esmolol, and SNP, which should be titrated during emergence. Typically, the patient will be awake and alert for transport to the ICU.
ERAS	Reinforce scalp blocks as necessary. Encourage early ambulation, alimentation, and Foley catheter removal.

Suggested Reading

1. Brown T, Shah AH, Bregy A, et al: Awake craniotomy for brain tumor resection: the

rule rather than the exception? J Neurosurg Anesthesiol 2013; 25(3):240–7.
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CRANIOTOMY FOR SKULL TUMOR

SURGICAL CONSIDERATIONS

Lawrence M. Shuer, Steven D. Chang, and Navjot Chaudhary

Description

Tumors of the skull fall into the classification of other bony tumors. Examples of types of skull tumors often requiring surgery include eosinophilic granuloma, histiocytosis, hemangioma, osteoma, epidermoid, dermoid, metastases, osteosarcoma, fibrous dysplasia, chordoma, chondrosarcoma, and meningioma. These tumors may occur anywhere on the skull, except chordoma and chondrosarcoma, which usually arise from the skull base. The exact positioning of the patient depends on the location of tumor. For example, the sitting or prone position often is used for tumors in the occipital or suboccipital regions, and the supine position is used for frontal, temporal, or parietal tumors. Some surgeons prefer the lateral position for temporal or parietal bone lesions and the prone position for occipital and some suboccipital bone lesions. Complete immobilization of the head is often not necessary, so the patient's head can be placed in a horseshoe or a Shea headrest. If complete immobilization is required, Mayfield pin fixation is used. The tumor is removed by placing burr holes near or around the tumor. Then, the affected skull is removed by cutting a bone flap around the tumor with the craniotome. In a suboccipital or posterior fossa craniectomy, the bone often is removed piecemeal with either a drill or a series of rongeurs. The dura usually is not opened unless it is involved with the tumor. The surgeon may elect to perform a **cranioplasty** to cover the defect, depending on the size and location. The defect can be repaired using a variety of methods, which include the use of a polymer, such as methyl methacrylate, or a bone cement, such as hydroxyapatite. In addition, autologous bone may be harvested from another location on the skull or another site (hip or rib) for reconstruction. Last, the surgeon may elect to repair the cranial defect at a later date, using a custom implant made from titanium, methyl methacrylate, or polyethylethylketone (PEEK). After the tumor is removed and the reconstruction is completed, the skin incision is closed. Occasionally, the skull tumor will be approached intracranially, if its location favors

that approach. Examples include tumors of the petrous portion of the temporal bone, fibrous dysplasia involving the optic canal, or skull base tumors, such as chordomas and chondrosarcomas.

Usual preop diagnosis

Eosinophilic granuloma; histiocytosis; hemangioma; osteoma; epidermoid; dermoid tumor; metastatic tumors; osteosarcoma; fibrous dysplasia; chordoma; chondrosarcoma; meningioma

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, and possibility of urinary catheter postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine, lateral, prone, or sitting, based on the location of the tumor
Incision	Dependent on location of tumor
Special instrumentation	Neuro drill, craniotome, image-guided navigation (if intracranial)
Unique considerations	ETT must be taped securely in a location satisfactory to the surgeon. Reinforced or RAE tube may be helpful in certain situations.
Antibiotics	Cefazolin 2 g iv (30–60 min before incision)
Surgical time	1–4 h
Closing considerations	Drain often left in epidural space. Surgeon often requests control of BP to avoid hemorrhage into the bed of tumor.
EBL	25–500 mL
Postop care	ICU or close observation unit
Mortality	0–2% (higher for tumors in critical locations)
Morbidity	Usually <5% Infection Neurologic disability CSF leak

	Massive blood loss 2° venous sinus injury
Pain score	2–5

PATIENT POPULATION CHARACTERISTICS	
Age range	Infant to 85 yr (usually 20–60 yr)
Male:Female	~1:1
Incidence	Unknown
Etiology	Neoplastic

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Craniotomy for Tumor. Note, however, that patients with skull tumors rarely have problems with ICP.

Suggested Readings

1. Cheng CH, Chuang HY, Lin HL, et al: Surgical results of cranioplasty using three dimensional printing technology. Clin Neurol Neurosurg 2018; 9(168):118–23.
2. Scolozzi P, Martinez A, Jaques B: Complex orbito-fronto-temporal reconstruction using computer-designed PEEK implant. J Craniofac Surg 2007; 18(1):224–8.
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CRANIOTOMY FOR TRAUMA

SURGICAL CONSIDERATIONS

Lawrence M. Shuer, Steven D. Chang, and Navjot Chaudhary

Description

Head injuries occasionally require emergent surgical procedures to evacuate mass lesions or débride contused or contaminated brain. The majority of these injuries are supratentorial. The surgical procedure depends on the exact type and location of the injury (e.g., epidural, subdural, intraparenchymal hematomas, or depressed skull fracture); however, most traumatic injuries can be addressed through a wide frontotemporoparietal craniotomy. Often the entire head is shaved and placed in a headrest (pins, suction cups, or horseshoe). If the C-spine has not been cleared, the

patient may be placed in a lateral position to minimize neck movement. Timing is often important for these procedures because the patient usually has a component of ↑ ICP, either from a hematoma or from cerebral edema due to the trauma. Hyperventilation, mannitol, hypertonic saline, and diuresis may be necessary to control the patient's ICP until the patient can be taken into the OR and undergo a wide decompressive hemicraniectomy (frontotemporoparietal craniectomy). For a standard trauma craniotomy, the scalp incision starts anterior to the tragus and continues superiorly in a question-mark type path, ending in the frontal area (Fig. 1.1-13). This incision can be modified according to the location and extent of the injury. The skin is reflected, and the skull is perforated with a cranial drill. The temporal burr hole should be placed first because if the patient's condition deteriorates rapidly, the temporal burr hole can be enlarged quickly to a craniectomy for decompression before continuing with the craniotomy. A chronic subdural hematoma may be drained through burr holes. However, if there is an acute subdural hematoma, epidural hematoma, intraparenchymal hemorrhage, depressed fracture, or penetrating wound, a craniotomy bone flap is elevated. Wide exposure is used to visualize and control sources of bleeding. Gentle warm irrigation may be used to aid in removal of an acute subdural hematoma. Mass lesions and associated contused brain parenchyma are identified and removed (Fig. 1.1-14). For penetrating head injuries or depressed skull fractures, the wound is débrided, foreign bodies are removed, bleeding is controlled, and the dura is repaired if lacerated. It is important to débride the wound as much as possible, but it is often not possible to safely remove all fragments from the wound. Depending on the injury and the presence of brain swelling, it may be necessary to close the dura with autologous pericranium or fascia lata. If these are not available, a synthetic dural substitute or bovine pericardium can be used. Alternatively, the dura may be left open or multiple relaxing incisions may be made in the dura to allow for brain swelling. The surgeon can often repair and reconstruct a depressed skull fracture after removing a bone flap that surrounds the fracture. In addition, the bone flap may be left out to compensate for brain swelling and replaced later. A subgaleal drain may be inserted and brought out through a separate incision. An ICP monitor or a ventriculostomy may be placed at the end of the procedure.

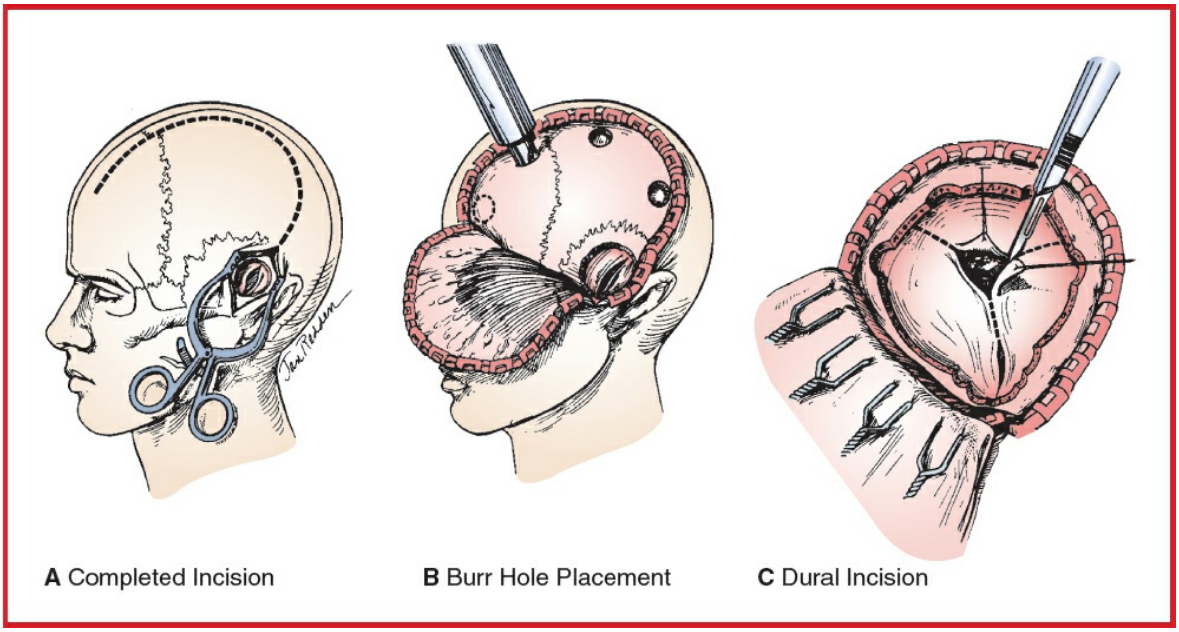

Figure 1.1-13 **A:** In an acute subdural hematoma: burr hole is made, followed by craniotomy, and the incision is extended upward to form a large question mark, the medial extent of which follows the midline. **B:** Additional burr holes are made, with the medial ones 1.5 cm off the midline to avoid injury to the major venous structures and granulations. The anterior burr hole is placed above the frontal sinus (the size of which can be estimated from preop radiographs). **C:** The dura can be opened with a Y- or X-shaped incision, with a flap being based on the superior sagittal sinus. (Reproduced with permission from Grossman RG, Loftus CM·Principles of Neurosurgery, 2nd edition. Lippincott-Raven, Philadelphia: 1999.)

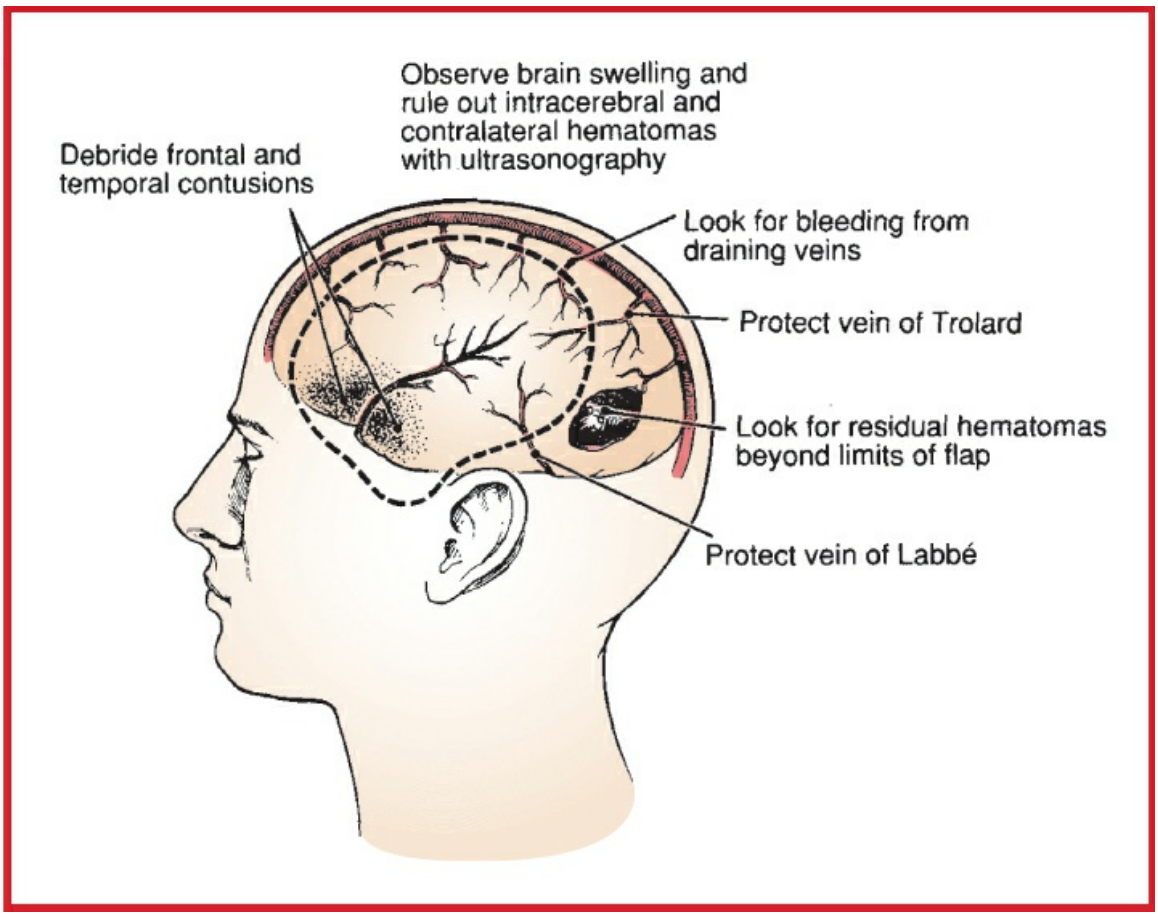

Figure 1.1-14 Precautions to be taken during a craniotomy for subdural hematoma. (Reproduced with permission from Grossman RG, Loftus CM:Principles of Neurosurgery, 2nd edition. Lippincott-Raven, Philadelphia: 1999.)

Frontal sinus fracture

If a skull fracture involves the frontal sinus and/or there is a CSF leak, the sinus may need to be obliterated or cranialized. Obliteration involves removal of the mucosa of the sinus and filling the sinus with antibiotic-soaked Gelfoam® sponges. Cranialization of the frontal sinus involves removing the posterior bony wall of the sinus and removing the mucosa. If there is a CSF leak, the dura will need to be repaired.

Variant indication

Some patients, with a large ischemic stroke, will develop malignant cerebral edema, necessitating a decompressive hemicraniectomy (frontotemporoparietal craniectomy) to control rising ICPs and prevent herniation.

Usual preop diagnosis

Epidural hematoma; acute subdural hematoma; intracerebral hematoma; depressed skull fracture; cerebral contusion; gunshot wound of the brain; malignant cerebral edema

ERAS: These procedures are usually urgent/emergent and present little opportunity for ERAS considerations.

SUMMARY OF PROCEDURE	
Position	Supine, lateral, prone, or sitting, depending on site of injury
Incision	Varies with location of injury (typical incision shown in Fig. 1.1-13)
Unique considerations	The patient may have ↑↑ ICP. Because incipient herniation and/or associated injuries may be a concern, timing is critical. C-spine precautions may be necessary. Patients may also be on anticoagulation medications, necessitating transfusions of blood products or recombinant activated factor VII.
Antibiotics	Cefazolin 2 g iv (within 30–60 min before incision)
Surgical time	1.5–4 h
Closing considerations	Application of head dressing may jostle ETT at end of case → ↑ BP. Patient may stay intubated postop. ICP monitor or external ventricular drain may be placed. Antiepileptic medications may be given for prophylaxis, especially if the patient had a seizure.
EBL	25–500 mL
Postop care	ICU or close observation unit until stable. Fluid and electrolytes require frequent monitoring, as the patient may develop SIADH. BP may need to be controlled with vasodilator and β-blocker infusions.
Mortality	10–50%, depending on lesion; higher for acute subdural hematomas, lower for epidural hematomas.
Morbidity	Morbidity depends on lesion; morbidity from craniotomy itself is low. Infection Neurologic disability Nerve injury CSF leak Endocrine disorders: SIADH, CSW, panhypopituitarism, DI

	Massive blood loss: venous sinus injury
Pain score	2–4

PATIENT POPULATION CHARACTERISTICS

Age range	Infant to 85 yr (usually 15–40 yr); peaks at 0–4 yr and 15–19 yr
Male:Female	2:1
Incidence	Relatively common: >1.7 million TBI/yr in the United States (mostly concussion)
Etiology	Trauma
Associated conditions	Abdominal injuries; C-spine fractures

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Traumatic brain injury (TBI) is the leading cause of death of persons <24 yr old. A penetrating injury of the skull usually will cause major damage to the brain as a result of both focal and diffuse neuronal injury with hemorrhage into brain tissue. Surgery is necessary to evacuate hematomas, control intracranial bleeding, débride the wound, and remove bone fragments, foreign material, and damaged brain so that the cranial vault can better accommodate the brain swelling that inevitably occurs. Epidural hematomas form between the skull and dura and are usually due to bleeding from an artery (e.g., middle meningeal). Hence, time is of the essence, and rapid evacuation and control of the bleeding is essential if permanent neurologic injury is to be avoided. Subdural bleeding occurs between the dura and the leptomeninges lining the brain surface. This bleeding is usually venous in origin and usually occurs more gradually. Focal intracranial hemorrhages may be either arterial or venous, and, as with subdural hematomas, must be evacuated if they are enlarging.

Respiratory	Ensure a secure airway and adequate ventilation. Localized injuries to the frontal or parietal lobes may not cause any respiratory changes. If ↑ ICP, respirations may become phasic (Cheyne-Stokes) or slow (<10 min) and deep resulting in substantial

	hypocapnia. Many patients with head injuries demonstrate partial airway obstruction from the tongue falling back into the posterior pharyngeal space. If this occurs, or if the patient is comatose and unable to protect the airway and prevent aspiration of gastric contents, immediate tracheal intubation should be performed. Head injuries in the region of the occipital lobes may → hypoventilation or apnea. Neurogenic pulmonary edema may occur in up to 20% of TBI patients. **Tests:** As indicated from H&P and as time allows
Cardiovascular	Most patients with head injuries evidence ↑ BP and ↑ HR. Even transient hypotension (SBP < 90 mm Hg) → ↑ morbidity and mortality. If ICP increases sufficiently to cause herniation of brain stem, patients develop the "Cushing triad" of ↑ BP, ↓ HR, ± irregular respiration. These changes resolve when ↑ ICP is relieved, so vigorous attempts to regulate BP prior to craniotomy are not warranted. However, the patient should be taken to OR as quickly as possible. **Tests:** As indicated from H&P and as time allows
Neurologic	Neurologic evaluation of the head-injured patient is based on the Glasgow coma scale (Table 1.1-4). The scale involves evaluation of three functions: eye opening, verbal response, and motor response. Using this scoring system, the severity of brain injury may be classified as mild (13–15 points), moderate (9–12 points), or severe (8 points or less). By definition, any patient having 8 points or less is in a coma. Additional useful neurologic examinations include assessment of pupillary size and reactivity to the light, reflex responses, and evidence of asymmetry or flaccidity of the extremities or decerebrate (e.g., rigid arm extension) or decorticate (e.g., rigid arm flexion) posturing. Head-injured patients whose neurologic function is deteriorating rapidly, and in whom an epidural or subdural hemorrhage is suspected, should be taken to OR immediately.

	Hyperventilation is appropriate if herniation is eminent. **Tests:** CT scan
Hematologic	Severe head injury may be associated with a progressively worsening coagulopathy, resulting in a clinical picture similar to that of DIC. The reason for this is not known, but the brain is rich in thromboplastin and other coagulation factors. **Tests:** Hct; PT; PTT; others as indicated from H&P
Associated injuries	Multiple organ system injury must be considered. ATLS assessment if time permits. Evidence of intrathoracic or intraperitoneal hemorrhage should be sought and repaired first if the patient is hemodynamically unstable. **Tests:** May include MRI, CT, ultrasound, and others as indicated.
Laboratory	Other tests as indicated from H&P, and as time permits
Premedication	Usually none. Steroids are not recommended to ↓ICP in TBI.

Table 1.1-4 Glasgow Coma Scale (GCS)

Category	Score
I. Eyes open:	
Never	1
To pain	2
To verbal stimuli	3
Spontaneously	4
II. Best verbal response:	
None	1
Incomprehensible sounds	2
Inappropriate words	3

Patient disoriented and converses	4
Patient oriented and converses	5
III. Best motor response:	
None	1
Extension (decerebrate rigidity)	2
Flexion abnormal (decorticate rigidity)	3
Flexion withdrawal	4
Patient localizes pain	5
Patient obeys	6
	I + II + III Total = 3–15

INTRAOPERATIVE

Anesthetic technique: GETA

Induction	↑ ICP is likely in most patients with head injury requiring operation, and induction of anesthesia is best accomplished with drugs that ↓ ICP. A mannitol infusion (0.25–1 mg/kg iv over 10–20 min) may be necessary to control ICP. If the patient is hemodynamically stable and not hypovolemic, titrated induction with propofol (1–3 mg/kg) + fentanyl (2–5 mcg/kg) is satisfactory. If hemodynamically unstable, etomidate (0.1–0.4 mg/kg) is suitable for induction. Ketamine is not used because of its ability to ↑ ICP. If the patient is comatose, anesthetic requirement is less, needing only O_2 and muscle relaxant, or low-dose isoflurane (0.5%) or sevoflurane (1%). A nondepolarizing muscle relaxant (vecuronium [0.1 mg/kg] or rocuronium [1 mg/kg]) is administered for ET intubation. Succinylcholine may ↑ ICP transiently but is still appropriate for emergency airway management. A defasciculating dose of a nondepolarizing NMB may attenuate the ICP ↑. Nasotracheal intubation is not recommended for patients

	with the possibility of maxillary and/or basilar skull fractures because of the potential for inserting the tube through the fracture site into the brain. To minimize ↑↑ BP and ↑↑ ICP with ET intubation, consider bolus remifentanil (2–5 mcg/kg iv) 1–2 min before laryngoscopy. In hypovolemic patients, hydration with a mixture of crystalloid (e.g., NS) and colloid (e.g., 5% albumin) should be initiated prior to induction.
Maintenance	The ideal drug for maintenance of anesthesia decreases ICP and $CMRO_2$, maintains cerebral autoregulation, redistributes flow to potentially ischemic areas, and provides protection for the brain from focal ischemia. Unfortunately, there is no ideal anesthetic. Both isoflurane and sevoflurane are good choices for patients undergoing neurosurgical procedures. Although these agents cause dose-dependent increases in CBF and volume, and hence ↑ ICP, these effects tend to be mitigated by the prior administration of propofol, by hyperventilation, and by limiting the inspired concentrations to <1 MAC. At these concentrations, CBF responses to changes in $PaCO_2$ are maintained, and cerebral autoregulation remains intact. N_2O is best avoided in patients with significantly elevated ICP and in patients with potential for pneumothorax or pneumocephalus. A propofol infusion is a reasonable alternative, although its use has been associated with a ↓ CBF > ↓ $CMRO_2$ → ↑ potential for ischemia. Jugular bulb O_2 saturation may be reduced during propofol anesthesia, consistent with an unfavorable supply-demand balance. BP goals: Keep SBP > 100 mm Hg (50–69 yr old), ≥110 mm Hg (15–49 and >70 yr old), and CPP ~70 mm Hg. Avoid prophylactic hyperventilation. Mild hypothermia may be beneficial if maintained >48 h. DVT prophylaxis is recommended. High-dose steroid administration is associated with worsened outcomes. Muscle relaxation can be maintained as necessary.

Emergence	Because recovery from head injury is so unpredictable, it is generally advisable to leave the ETT in place and maintain controlled ventilation until there is sufficient clinical evidence that normal neurologic recovery is occurring. Postop sedation can be accomplished using dexmedetomidine (0.2–0.7 mcg/kg/h) or propofol (20–75 mcg/kg/min) not to exceed 5 mg/kg/h to minimize the occurrence of propofol-related infusion syndrome (including metabolic acidosis, ↑ K^+, rhabdomyolysis).	
Blood and fluid requirements	Possible severe blood loss IV: 14–16 ga × 1–2 BSS @ 1–3 mL/kg/h ± Albumin 5% ± RBCs for Hct < 27	Blood transfusion to keep Hct ~30. Minimize postop cerebral edema by limiting crystalloid volume to <3 mL/kg/h + replacement of UO. Glucose-containing solutions should be avoided; blood glucose levels should be maintained between 80 and 180 mg/dL. If volume is needed, albumin 5% should be administered.
	Coagulopathy is common	Consider Rx with tranexamic acid (load = 1 g over 10 min followed by 1 g over 8 h infusion) for persistent bleeding. Initiate within 3 h of injury.
Control of blood pressure	Keep CPP ~70 mm Hg Keep SBP > 100–110 mm Hg Maintain normovolemia	Controlled hypotension generally is not used unless bleeding becomes profuse and difficult to control. ↓ BP is better treated initially with volume replacement than vasopressors. Target SBP goals are age dependent.
	Vasopressors	Phenylephrine or norepinephrine infusions can be used to maintain CPP.

Monitoring	Standard monitors (p. B-1). Avoid hypothermia Arterial line ± CVP line UO	If the injury is extensive or unknown, or if the patient is unstable, invasive monitoring is mandatory. Monitor for VAE if the head is elevated above the heart. Level the arterial line at the head. EEG, EP, and SjO_2 monitoring may be desirable.
Positioning	✓ and pad pressure points ✓ eyes	For occipital or posterior fossa lesions, patient may be prone or sitting (see Anesthetic Considerations for Cervical Neurosurgical Procedures, Positioning). Otherwise, patient will be supine with head in Mayfield skeletal fixation and turned to the side, with a roll placed under the shoulder on the operative side.
Control of ICP	Adequate anesthesia Head up 20–30° Keep SBP ≥ 90 mm Hg Propofol infusion Hyperventilation to	Transient increases in ICP—even up to 50–60 mm Hg—are generally tolerated, provided they are promptly terminated. Sustained increases in ICP > 25–30 mm Hg are associated with severe neurologic injury and poor outcome. Patients with skull fractures or intracranial bleeding may be on the steep portion of intracranial compliance curve such that any increase in intracranial volume may cause ↑↑ ICP. ↓ CO_2 → cerebral

	$PaCO_2$ = 25–30 mm Hg PaO_2 > 100 mm Hg	vasoconstriction → ↓ CBV, ↓ CBF, and ↓ ICP. Patients with diffuse brain injury may have lost cerebrovascular sensitivity to $PaCO_2$. Despite maintaining adequate ventilation, oxygenation, and BP, patients with diffuse head injury often exhibit arterial and CSF lactic acidosis, a further indication of the metabolic derangement that exists in the brain from the injury.
	Keep CPP ~70 mm Hg	Control MAP and cerebral venous pressure so that CPP = ~70 mm Hg. In severe diffuse head injury with loss of autoregulation, some parts of the brain may exhibit "luxury perfusion," while other areas exhibit severe ischemia.
	Mannitol 0.25–1.0 g/kg	Vigorous diuresis will commence in 20–30 min (if blood volume and renal perfusion are adequate), and brain shrinkage will follow. Max serum osmolarity = 320 mOsm/L. If mannitol is administered too rapidly, profound refractory hypotension will occur.
	Furosemide 10–20 mg	Simultaneous administration of furosemide (10–20 mg) is recommended to avoid the transient ↑ CBV and ↑ ICP

	Hypertonic saline	following mannitol. Hypertonic saline (e.g., 3% @: 2–3 mL/kg) may provide better control of ICP than an equiosmolar dose of mannitol.

POSTOPERATIVE

Complications	Seizures	Sz Rx: Levetiracetam (1 g) or phenytoin (1-g loading dose). **NB:** Incompatible with dextrose-containing solutions.
	Neurologic deficits Hemorrhage	Some patients with severe head injury remain unconscious for weeks or months, without evidencing any substantial neurologic recovery. A late complication of head injury is hydrocephalus requiring a shunt procedure.
	SIADH/CSW DI	These causes of ↓ Na^+ must be differentiated for proper Rx. ↑ UO + ↓ Urine Osm + ↑ serum Na
	NPE ↑ ICP	Neurogenic pulmonary edema may result from massive sympathetic discharge 2° ↑↑ ICP. Rx: ↓ ICP, alpha-blockers to control BP, respiratory support.
	DIC	TBI is a risk factor for DIC.
Multimodal pain management	Propofol or dexmedetomidine infusion	Most patients will remain intubated and sedated postop.

Tests	CT scan ICP monitor	Unless neurologic recovery is rapid, periodic CT scans are obtained postop to follow the intracranial changes. In addition, in many institutions, a device for monitoring ICP postop is placed at the time of operation.

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MICROVASCULAR DECOMPRESSION OF CRANIAL NERVE

SURGICAL CONSIDERATIONS

Lawrence M. Shuer, Steven D. Chang, and Navjot Chaudhary

Description

Microvascular decompression (MVD) is used to treat various disorders of the cranial nerves, including trigeminal neuralgia (TN), hemifacial spasm and, more rarely, glossopharyngeal neuralgia (GN). Trigeminal neuralgia is characterized by brief episodes of intense, stabbing facial pain along the distribution of the trigeminal nerve. This pain usually can be elicited by gentle stimulation of the affected area. Trigeminal neuralgia is further subdivided into type 1 (episodic pain) and type 2 (continuous pain) variants. Continuous pain is a poor prognostic factor when treating trigeminal neuralgia with any modality including surgery. Hemifacial spasm is characterized by paroxysmal repetitive twitching of the facial muscles. The twitching usually starts with the muscles around the eye and can progress to involve the rest of the facial muscles. Glossopharyngeal neuralgia is characterized by paroxysmal pain that involves the ear and throat. Typically, the pain is described as "stabbing" and radiates from one site to the other. Swallowing, drinking cold beverages, talking, or coughing can elicit the pain. A Chiari malformation may mimic the symptoms of glossopharyngeal neuralgia. Combinations of vascular compression syndromes involving multiple nerves and multiple offending vessels have also been reported.

All of these conditions are usually unilateral and are often caused by compression of a cranial nerve by a vascular structure. In trigeminal neuralgia, the superior cerebellar artery is the usual culprit. In hemifacial spasm, the anterior inferior cerebellar or vertebral artery is usually compressing the facial nerve. In glossopharyngeal neuralgia, the posterior inferior cerebellar or vertebral artery is usually the offending artery. Large veins can also compress the cranial nerves. The goal of an MVD is to remove the pressure on the cranial nerve. To perform an MVD, a linear incision is made behind the ear on the affected side (Fig. 1.1-15A). Dissection is taken down to the skull, and several burr holes are made. The burr holes can be enlarged into a **craniectomy** (Fig. 1.1-15B) or used for elevation of a bone flap. The craniectomy is placed below the transverse sinus and medial to the sigmoid sinus to allow access to the cerebellopontine angle. The mastoid air cells are sealed with bone wax to prevent CSF leak. Any venous sinus bleeding is controlled, and the dura is opened (Fig. 1.1-15C). With brain relaxation, the cerebellum is retracted. The operating microscope allows the surgeon to explore the involved cranial nerve. If an offending vessel is identified, it is carefully dissected away from the nerve and shredded Teflon felt or a small plastic sponge is placed to keep the vessel away from the cranial nerve. In the case of trigeminal or

glossopharyngeal neuralgia, if no offending vessel is identified, a **partial section of the nerve** may be performed. Partial section of the 9th or 10th cranial nerve may cause some vasomotor instability. BAERs, facial nerve monitoring, and EMGs can be monitored intraop to protect the cranial nerves. Once the cranial nerve has been decompressed, the dura is closed, and the wound is closed in layers. The main variations in this procedure are in patient positioning and surgeon's preference of monitoring modalities. Patient positioning may be lateral, prone, supine, or rarely sitting. Intraop, mannitol (0.5–1 g/kg) and/or a lumbar drain (for CSF removal) may be needed for brain relaxation. Success rate is typically 75–95%, with a recurrence rate as high as 3.5% per year.

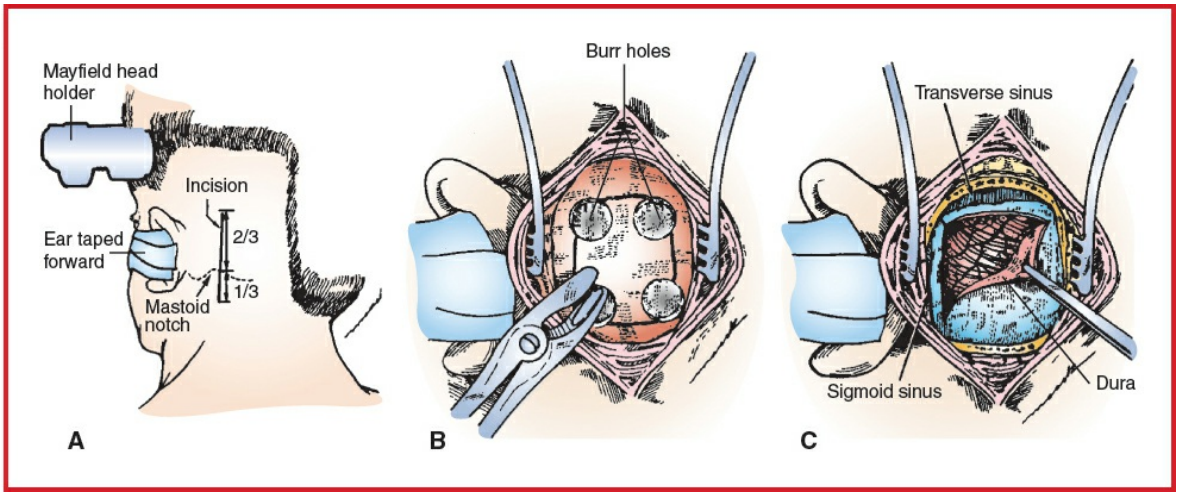

Figure 1.1-15 Microvascular decompression. **A:** Location of incision. **B:** Enlargement of burr holes into craniectomy with a rongeur. **C:** Dural opening on the left side. Note position of venous sinuses. (Reproduced with permission from Wilson CB:Neurosurgical Procedures: Personal Approaches to Classic Operations. Williams & Wilkins, Baltimore: 1992.)

Alternative procedure

Endoscopic-assisted or fully endoscopic approaches to MVD offer the advantage of a panoramic view of the surgical field using a small craniotomy and with less brain retraction. Disadvantages include the need for greater care during exposure and during insertion or withdrawal of instruments to avoid collateral damage. Stereotactic radiosurgery is less effective than microvascular decompression but may be appropriate for patients unwilling or unable to undergo surgery. Other, less frequently used options include radiofrequency rhizotomy, glycerol injection, and balloon compression.

Usual preop diagnosis

Trigeminal neuralgia; tic douloureux; hemifacial spasm; tinnitus; glossopharyngeal neuralgia

ERAS: Preop counseling by the surgeon/anesthesiologist should include continuing chronic pain and other meds, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, and possibility of urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE

Position	Normally, lateral rotation with shoulder roll, head elevated; upper shoulder retracted caudally
Incision	Retroauricular (mastoid) (see Fig. 1.1-15A)
Special instrumentation	Operating microscope; cranial perforator; ± facial nerve monitoring; ± EMG; ± BAER
Unique considerations	Risk of air embolus in head-elevated positions. Precordial Doppler or TEE required for head elevation ≥30°
Antibiotics	Cefazolin 2 g iv (30–60 min before incision)
Surgical time	2–3 h
EBL	25–250 mL
Postop care	ICU or close observation unit. Observe for change in neurologic status (e.g., level of alertness, response to commands), usually for 12–24 h
Mortality	~1%
Morbidity	Facial sensory deficit: 25% (often transient) Aseptic meningitis: ≤20%, usually occurring 3–7 d postop Hearing loss: 3% Diplopia (usually transient) Facial weakness: 2% Deafness: 1% Infection CSF leak Massive blood loss due to vertebral artery injury or venous sinus laceration
Pain score	4–6

PATIENT POPULATION CHARACTERISTICS

Age range	40–85 yr (usually 60–70 yr)
Male:Female	1:2
Incidence	TN: 4.3/100,000/yr; GN: 25.6/100,000/yr at age >70 yr; prevalence: 16/100,000
Etiology	Vascular compression of cranial nerve demyelination; multiple sclerosis plaque; cerebellopontine angle tumor
Associated conditions	HTN; multiple sclerosis; rheumatoid arthritis; Charcot-Marie-Tooth disorder; Sjögren syndrome

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Microvascular decompression involves a full craniotomy for decompression of a cranial nerve that is causing facial pain and/or spasm of facial muscles. Generally, these patients have trigeminal neuralgia or tic douloureux that has not been responsive to medical management (e.g., carbamazepine [Tegretol] therapy), stereotactic radiosurgery (Gamma Knife), and percutaneous rhizotomy or glycerol injection has failed.

Respiratory	None unless the patient has a long-standing Hx of smoking and has COPD.
Cardiovascular	Many patients will have Hx of idiopathic HTN requiring antihypertensive medications. Good preop control of BP is important because it will make intraop and postop management of BP easier. Anticipate exaggerated hemodynamic response to anesthetic medications.
Neurologic	The presenting symptom is usually pain ± muscle spasm in the maxillary and/or mandibular division of the trigeminal nerve, unaccompanied by any motor or sensory deficits. Identify trigger points so that they may be avoided during face mask placement and induction.
Laboratory	None, except for routine preop studies.
Premedication	Generally, patients for these procedures are elderly and do not require any special premedication.

	Midazolam 1–3 mg iv will provide amnesia for the preop events, if that is desired by patient or surgeons.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water and aprepitant 40–80 mg po with sip of water for these patients.

INTRAOPERATIVE

Anesthetic technique

GA is necessary because a full craniotomy is performed. ICP is not increased in these patients. Brain volume reduction (typically using mannitol 0.25–0.5 g/kg), however, is important to provide the surgeon with sufficient space to identify and relieve the pressure on the offending nerve without requiring excessive brain retraction in the process.

Induction	Induction is best accomplished with propofol (1–2 mg/kg), followed by neuromuscular blockade and ET intubation. Facemask placement may trigger intense pain in susceptible patients. Consider O_2 insufflation for preoxygenation.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia. Dexamethasone (4–8 mg iv) may ↓PONV. Avoid long-acting opioids or scopolamine patch, which may interfere with postop neuro examination. Sequential pneumatic compression devices should be used to ↓VTE risk.
Maintenance	Maintain anesthesia with 0.5 MAC sevoflurane or isoflurane with 50 mcg/kg/min propofol. BP is maintained in the normal range during the operation. Hyperventilation to achieve a $PaCO_2$ of 25–30 mm Hg is helpful to ↓ brain volume and ↑ workspace. Once the nerve has been isolated, stop hyperventilation. A spinal drain may be used to remove CSF during the operation and improve exposure. The drain usually is opened at

	the time of dural opening and closed as soon as surgery on the nerve is complete.	
Emergence	Reverse any residual neuromuscular blockade. The ETT is removed following return of protective airway reflexes. Postop HTN may need to be controlled with esmolol and/or clevidipine by continuous pump infusion. Prophylactic antiemetic (e.g., metoclopramide 20 mg and ondansetron 4–8 mg) should be given 30 min before extubation. The incidence of PONV is high following this procedure. Consider acetaminophen (1 g iv) and/or local anesthetic scalp infiltration for postop analgesia. Consider iv acetaminophen if po dose given >4–6 h ago.	
Blood and fluid requirements	Large blood loss is rare IV: 18 ga × 1 BSS @ 1–3 mL/kg/h	Mannitol 0.5–1 mg/kg is sometimes necessary to provide sufficient brain volume reduction to permit adequate surgical exposure. Zero balance or goal-directed fluid management is recommended (see Appendix K, p. K-2).
Monitoring	Standard monitors Arterial line ± CVP line ± EMG and/or SSEP	Invasive monitoring will facilitate intraop and postop BP management. Sometimes EMG and/or SSEP monitoring of the facial nerve is performed.
Positioning	Lateral, rotation with shoulder roll ± Pillow between legs ✓ and pad pressure points ✓ eyes	Patients usually will be positioned with their head in a "far lateral" position. Padding of the shoulder and placing a pillow between the legs may be necessary. A beanbag can be used to hold patient stable in the lateral ("park bench") position.

POSTOPERATIVE

Complications	PONV	PONV is common and usually requires multimodal treatment including aprepitant.
	Bleeding Brain edema	Postop recovery is usually uneventful. On rare occasion, significant brain edema or bleeding may be experienced.
Multimodal pain management	Acetaminophen 1 g iv Fentanyl 25–50 mcg iv prn	If not given preop or if 4–6 h have elapsed since previous dose.
	Reinforce scalp blocks	0.5% bupivacaine with epi is as effective as liposomal bupivacaine.
Tests	CT scan	If neurologic recovery is delayed.
ERAS	Ondansetron 4 mg iv ± Metoclopramide 10–20 mg iv	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Ashkan K, Marsh H: Microvascular decompression for trigeminal neuralgia in the elderly: a review of the safety and efficacy. Neurosurgery 2004; 55(4):840–8; discussion 848–50.
2. Fariselli L, Ghielmetti F, Bosetti D, et al: The role of radiosurgery in trigemina neuralgia. Neurol Sci 2017; 38(Suppl 1):63–5.
3. Meng L, Quinlan JJ: Assessing risk factors for postoperative nausea and vomiting: a retrospective study in patients undergoing retromastoid craniectomy with microvascular decompression of cranial nerves. J Neurosurg Anesthesiol 2006; 18(4):235–9.
4. Minahan RE, Mandir AS: Neurophysiologic intraoperative monitoring of trigemina and facial nerves. J Clin Neurophysiol 2011; 28(6):551–65. Review.
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7. Schaller B: Trigemino-cardiac reflex during microvascular trigeminal decompression in cases of trigeminal neuralgia. J Neurosurg Anesthesiol 2005; 17(1):45–48.
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BIFRONTAL CRANIOTOMY FOR CSF LEAK

SURGICAL CONSIDERATIONS

Lawrence M. Shuer, Steven D. Chang, and Navjot Chaudhary

Description

Trauma (44% accidental; 29% surgical) is the leading cause of CSF leaks. CSF leaks can also be caused by tumors (22%), congenital malformations, or as a result of transsphenoidal surgery. Most CSF leaks involve the floor of the anterior cranial fossa (e.g., cribriform plate: 35%), with drainage through the auditory canal (otorrhea), nasopharynx (rhinorrhea), sinus air cells, or other less common routes. CSF leaks can occasionally stop on their own or by management with a lumbar drain. However, to lessen the risk of meningitis, surgical repair is the usual treatment.

The surgical repair of CSF leaks has changed with the advent of the endoscope. The success rates of endoscopic closure are similar to open surgical approaches while avoiding the morbidity associated with craniotomies. Although it is common to attempt closure of a CSF leak endoscopically before proceeding on to an open repair, selected patients may benefit by proceeding directly to an open surgical approach.

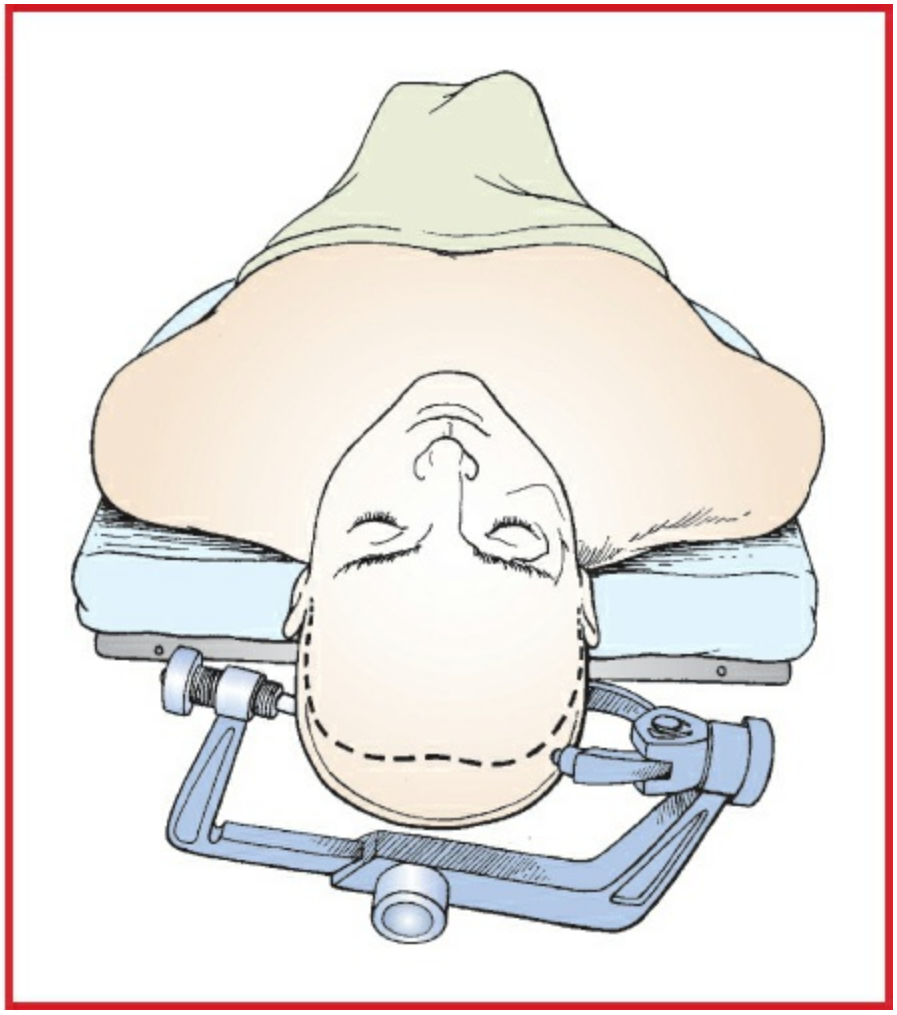

Figure 1.1-16 Patient positioning for bifrontal craniotomy with bicoronal skin incision outlined. This position allows the frontal lobes to separate from the anterior cranial fossa with minimal retraction on the frontal lobes. (Reproduced with permission from Tindall GT, Cooper PR, Barrow DL:The Practice of Neurosurgery. Williams & Wilkins, Baltimore: 1996.)

An open surgical repair is typically done through a bifrontal craniotomy. The patient is placed in a supine position, and the head is stabilized with a Mayfield clamp. A bicoronal skin incision (Fig. 1.1-16) is made, and the pericranium is often turned as a separate flap and kept moist during the case. Next, burr holes are drilled and a bifrontal free bone flap is elevated. Care is taken to avoid injury to the underlying superior sagittal sinus. If the frontal sinuses are entered, the mucosa is stripped and the sinus is packed with antibiotic-soaked Gelfoam. The dura is opened over the inferomedial frontal lobes, and the sagittal sinus is ligated. An intradural exploration is undertaken to determine the site of the leak. Identification of the leak site is essential for successful outcome. The source of the leak may be identified using radioactive tracer or CT metrizamide studies. Brain relaxation is usually necessary to reduce the need for mechanical retraction and may require mannitol, hyperventilation, and/or the placement of a lumbar drain. The frontal lobes are elevated, and the olfactory tracts may be

sacrificed. If the site of the leak can be determined, the dural repair can be performed using fascia lata, pericranium, bovine pericardium, or a synthetic dural substitute. It usually is necessary to strip the dura off the anterior cranial fossa to complete the repair. Defects in the bone can be plugged with a variety of materials (e.g., pericranial flap, fat, temporalis muscle flap, bone, or wax). After the repair is complete, the dura can be closed and the bone flap replaced, often with a drain left in the epidural space. In addition, tissue sealants such as fibrin glue can be sprayed over the dural suture line to help create a watertight seal. At this point, brain relaxation is no longer required. The wound is closed with stitches, and skin is closed with staples.

A combined approach may be used for CSF leaks 2° to a tumor that invades the dura and the cribriform plate. In these cases, the procedure often is performed with an otorhinolaryngologist. The intracranial part of this procedure is identical to the bifrontal craniotomy, except that bone and tumor are removed at the floor of the anterior cranial fossa. The extracranial part of this procedure is performed by the otorhinolaryngologist, who approaches the sinonasal region endoscopically or through a lateral rhinotomy or degloving gingival incision. The extracranial approach is chosen to complement the cranial exposure, and a common space is created between the two operative fields. Closure involves isolating the two operative fields once again. The dural repair is as above. The mucosa of the nasal cavity is replaced with the use of a skin graft.

Alternate procedure

Transnasal endoscopic repair of selected CSF leaks has been shown to be effective with significantly ↓ morbidity compared with craniotomy.

Usual preop diagnosis

CSF leak or rhinorrhea; fracture of the anterior cranial fossa; intracranial encephalocele; cribriform plate tumor; olfactory neuroblastoma (tumor of the olfactory epithelium). β-2 transferrin is a relatively sensitive and specific marker for CSF and can be used to establish the diagnosis

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include continuing chronic pain and other meds, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, postop pain management options, possibility of urinary drain postop, and description of antimicrobial prophylaxis and skin preparation. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE

Position	Supine

Incision	Bicoronal (Fig. 1.1-16); transnasal for endoscopic
Special instrumentation	Operating microscope; endoscope; image guidance system
Unique considerations	Brain relaxation desired; lumbar subarachnoid catheter; fascia lata graft
Antibiotics	Cefazolin 2 g iv (30–60 min before incision)
Surgical time	2–3.5 h, depending on extent of leak or lesion
Closing considerations	Drain often left in epidural space. Anticipate that the application of a full head dressing will jostle patient and ETT → ↑ BP + coughing/bucking.
EBL	75–500 mL
Postop care	ICU or close observation unit; Valsalva maneuver, coughing and vomiting can cause ↑↑↑ ICP → recurring CSF leak.
Mortality	≤5%
Morbidity	Usually <5% for all complications Infection (ascending meningitis) Recurrent CSF leak Neurologic disability Nerve injury Massive blood loss: venous sinus injury
Pain score	3–5

PATIENT POPULATION CHARACTERISTICS

Age range	15–65 yr
Male:Female	~3:2
Incidence	Relatively uncommon neurosurgical procedure
Etiology	Traumatic (73%); congenital; neoplastic

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Transsphenoidal Resection of Pituitary

Tumor.

NB

Positive pressure mask ventilation in patient with an anterior CSF leak may produce severe pneumocephalus.

Suggested Readings

1. Abuabara A: Cerebrospinal fluid rhinorrhea: diagnosis and management. Med Oral Patol Oral Cir Bucal 2007; 12(5):E397–400.
2. Martin TJ, Loehrl TA: Endoscopic CSF leak repair.Curr Opin Otolaryngol Head Neck Surg 2007; 15(1):35–9.
3. Psaltis AJ, Schlosser RJ, Banks CA, et al: A systematic review of the endoscopic repair of cerebrospinal fluid leaks. Otolaryngol Head Neck Surg2012; 147(2):196–203.
4. Sharma SD, Kumar G, Bal J, et al: Endoscopic repair of cerebrospinal fluid rhinorrhoea. Eur Ann Otorhinolaryngol Head Neck Dis 2016; 133(3):187–90.

TRANSORAL OR TRANSNASAL APPROACH TO THE CERVICOMEDULLARY JUNCTION AND ODONTOID

SURGICAL CONSIDERATIONS

Lawrence M. Shuer, Steven D. Chang, and Navjot Chaudhary

Description

The transoral or transnasal approaches provide excellent access to the odontoid process of the C2 vertebral body, as well as the skull base just anterior to the brain stem (Fig. 1.1-17). This is important for conditions where there is pressure on the ventral brain stem or spinal cord → Sx: HA, impaired ambulation, hyperreflexia, paresthesias, neurogenic bladder, etc. Common indications for this approach include basilar impression (upward translocation of the odontoid process; Fig. 1.1-18A), degeneration of the odontoid due to rheumatoid disease (Fig. 1.1-19), fracture of the odontoid, and resection of extradural tumors, such as chordomas and metastases. In these cases, the operation is performed through the oral cavity with an incision in the posterior wall of the pharynx. Special retractors hold the mouth open and keep the tongue out of the way. Fluoroscopic or image guidance helps the surgeon maintain optimal trajectory. Intraop monitoring of evoked potentials (i.e., SSEP or BAER) and use of the operative microscope helps avoid injury to the brain stem and spinal cord. The dissection is

carried down to expose the anterior arch of C1 and body of C2. To decompress the region, the anterior arch of C1 and the odontoid process are removed. For basilar impression, a portion of the clivus may need to be removed to gain access to the dens (Fig. 1.1-18B). For rheumatoid arthritis, the pannus (thickened fibrous tissue) surrounding the dens is also removed (Fig. 1.1-18B). If an extradural tumor is found, it is resected in a piecemeal fashion. If a CSF leak occurs, the dura can be closed with fascia, muscle, fibrin glue, or thrombin-soaked Gelfoam. Upon completion of the decompression, the mucosa is closed. It may be necessary to fuse the occiput to the upper C-spine to correct any cervical instability. This may take place at the same time or at a later date. C-spine precautions normally are used during and after the case. The patient may be in traction with tongs or a halter.

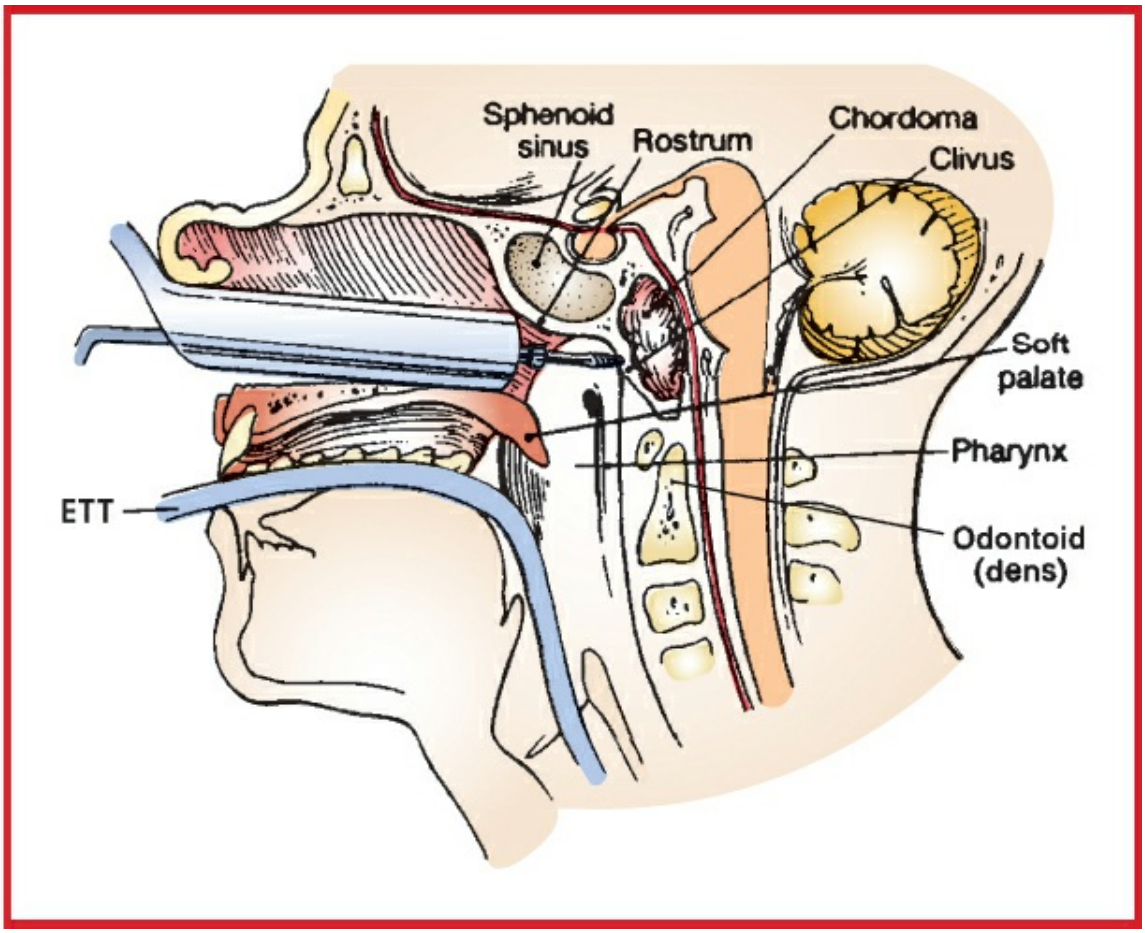

Figure 1.1-17 Transnasal inferior exposure of the clivus and chordoma. This procedure may be performed with endoscopic assistance, eliminating the need for a nasal speculum. (Reproduced with permission from Grossman RG, Loftus CM:Principles of Neurosurgery, 2nd edition. Lippincott-Raven, Philadelphia: 1999.)

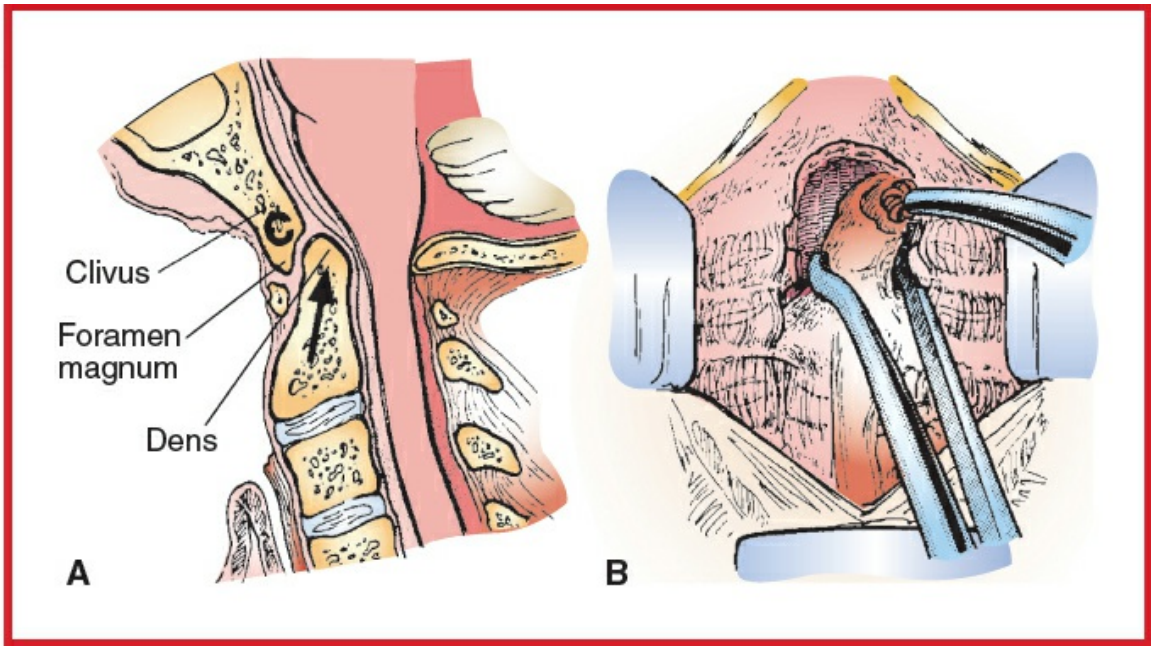

Figure 1.1-18 **A:** Basilar impression. The dens has moved superiorly into the foramen magnum (arrow). **B:** Removal of the dens with a drill. The arch of C1 and a portion of the clivus have been removed. (Reproduced with permission from Donald PJ:Surgery of the Skull Base. Lippincott-Raven, Philadelphia: 1998.)

Variations in procedure

A fiberoptic nasal intubation or tracheostomy may be necessary to gain adequate exposure and maintain ventilation. It also may be necessary to split the soft palate, hard palate, tongue, and/or mandible to obtain adequate exposure. Because of the morbidity associated with a transoral decompression of the craniocervical junction, some surgeons recommend a posterior decompression with stabilization first, followed by an anterior decompression if necessary. An anterior resection of the odontoid creates an unstable craniocervical junction that requires at least a halo stabilization and more commonly an occipital-cervical fusion. This procedure may also be performed endoscopically.

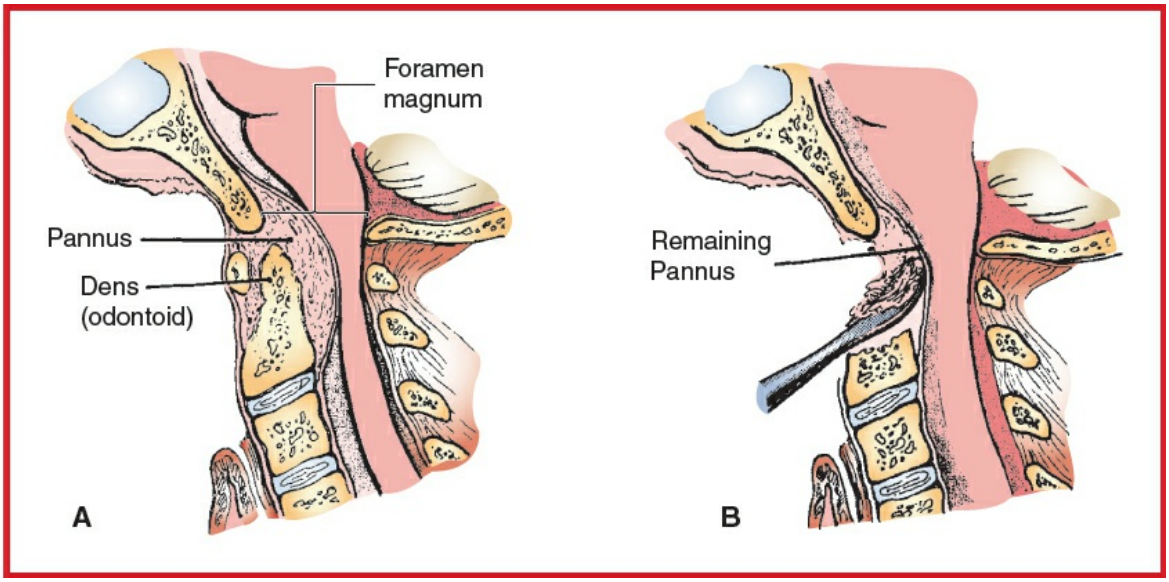

Figure 1.1-19 **A:** Pannus formation in a patient with rheumatoid arthritis. **B:** Removal of pannus. (Reproduced with permission from Donald PJ:Surgery of the Skull Base. Lippincott-Raven, Philadelphia: 1998.)

Usual preop diagnosis

Basilar impression (platybasia); odontoid fracture; rheumatoid arthritis with atlantoaxial instability and anterior impingement of the cord; chordoma; metastatic tumor

ERAS: Preop counseling by the surgeon/anesthesiologist should include continuing chronic pain and other meds, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, and possibility of urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine; head in traction or pins
Incision	Back of oropharynx or nasopharynx
Special instrumentation	Operating microscope; I.I.; intraop monitoring = SSEP or BAER; micro drill; intraoral/intranasal retractors for exposure; image-guided navigation system (optional)
Unique considerations	FOL may be necessary. ETT must be taped securely in a location satisfactory to surgeon. Anode or RAE tube may be helpful. Occasionally, a **tracheostomy** is performed in advance. Odontoidectomy creates an unstable craniocervical junction, which may need to be temporarily

	stabilized with a halo or immediate occipital cervical fusion.
Antibiotics	Cefazolin 2 g iv (30–60 min before incision)
Surgical time	2.5–3 h
Closing considerations	Patient may remain intubated postop. C-spine precautions may be necessary.
EBL	25–250 mL
Postop care	ICU or close observation unit; monitor airway for swelling (✓ for stridor).
Mortality	0–3%
Morbidity	All <5%: Infection CSF leak Neurologic Massive blood loss
Pain score	2–4

PATIENT POPULATION CHARACTERISTICS

Age range	18–85 yr (usually 20–60 yr)
Male:Female	~1:2
Incidence	Rare
Etiology	Neoplastic; traumatic; congenital; degenerative
Associated conditions	Rheumatoid arthritis (atlantoaxial subluxation in 25%; basilar compression in 8%); traumatic injury

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Transsphenoidal Resection of Pituitary Tumor.

Suggested Readings

1. Dlouhy BJ, Dahdaleh NS, Menezes AH: Evolution of transoral approaches endoscopic endonasal approaches, and reduction strategies for treatment of craniovertebral junction pathology: a treatment algorithm update. Neurosurg Focus 2015; 38(4):E8.
2. Seker A, Inoue K, Osawa S, et al: Comparison of endoscopic transnasal and transoral approaches to the craniovertebral junction. World Neurosurg 2010; 74(6):583–602.
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TRANSSPHENOIDAL RESECTION OF PITUITARY TUMOR

SURGICAL CONSIDERATIONS

Robert L. Dodd, Lawrence M. Shuer, and Steven D. Chang

Description

The transsphenoidal approach to the sella turcica is a direct procedure used to gain access to the pituitary gland and sella region and is associated with relatively fewer complications than a craniotomy. The procedure usually is performed transnasally; although a sublabial transseptal approach is out of favor, it may be used in patients with large tumors. An otorhinolaryngologist often will participate in obtaining the exposure, transnasally with an endoscope. Once the sphenoid sinus is reached, it is entered by removing the face and rostrum. The thin bone of the lateral wall of the sphenoid sinus protects portions of the optic nerve and carotid artery. The sella is entered by removing a portion of the sellar floor (Fig. 1.1-20). Under image guidance and with the aid of the operating microscope and/or endoscope, the surgeon can operate safely on the pituitary gland, respecting the midline and avoiding injury to the carotid arteries in the cavernous sinus on either side of the exposure. After the sellar floor is removed, the dura is opened and the tumor is removed with a series of microdissectors and curettes. Following tumor removal, if there is a CSF leak, the surgeon may harvest fat, muscle, or fascia from the thigh or abdomen to pack into the sella to reduce free intrasellar space and serve as a graft to prevent a leak. Resorbable materials, such as Gelfoam and fibrin glue, also may be used to obliterate dead space within the sella. The floor of the sella can be reconstructed with bone salvaged from the exposure or artificial material. During the closure, the sphenoid sinus also may be packed and sealed with the same materials used to close the sella. The nostrils may or may not be packed, depending on the details of the technique used.

Alternative procedure

Endoscopic transsphenoidal approach has several advantages (improved surgical view and access, fewer complications, and more rapid recovery) and is associated with the same success rate as the microscopic approach.

Usual preop diagnosis

Pituitary tumor; prolactin-secreting tumor; growth hormone–secreting tumor (acromegaly); ACTH-secreting tumor (Cushing disease); visual compromise, intrasellar tumor; craniopharyngioma; meningioma; Forbes-Albright syndrome (galactorrhea-

amenorrhea syndrome)

ERAS: Preop counseling by the surgeon/anesthesiologist should include continuing chronic pain and other meds, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, and possibility of urinary drain postop. See Appendix K, p. K-1.

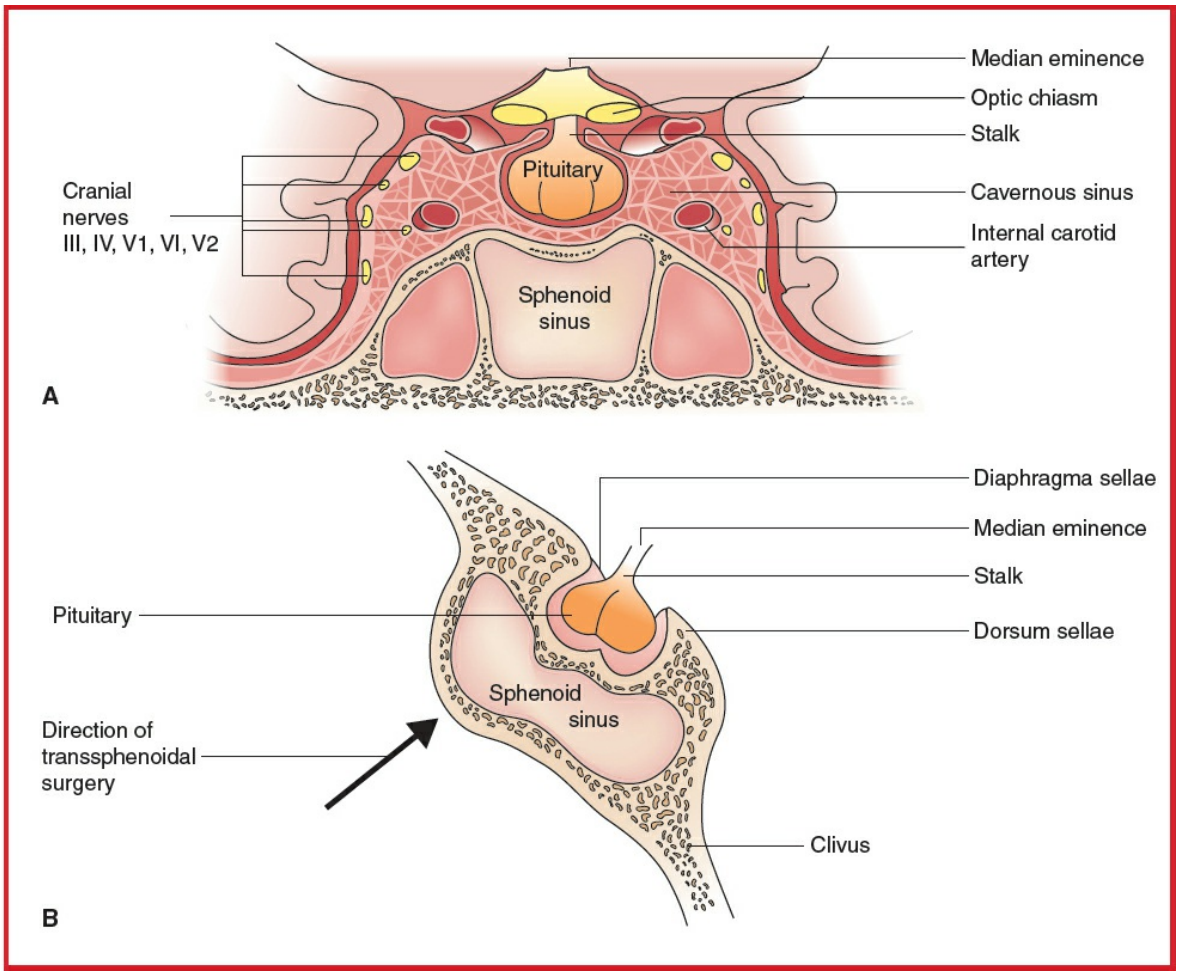

Figure 1.1-20 **A:** Midpituitary coronal view of parasellar region. The sphenoid sinus is below, and the cavernous sinuses are lateral. **B:** Midsagittal view of the pituitary and surrounding bony structures. Note the approach for transsphenoidal surgery. Anterior is to the left.

SUMMARY OF PROCEDURE

Position	Supine, head elevated 20–30°
Incision	Endonasal; +abdomen (or thigh) for fat graft; occasionally sublabial, maxillary gingiva
Special instrumentation	Operating microscope; operating endoscope; micro drill; neuronavigation (image guidance)

	Throat packs may be used but are usually unnecessary.
Unique considerations	ETT must be taped securely in a location away from the surgeon (usually left side of the mouth). Anode or RAE tube may be helpful but is not essential. The generous use of topical vasoconstrictors and the injection of epinephrine-containing solutions may → ↑ BP and dysrhythmias. Dissection in the nasal cavity can be painful → ↑ BP and ↑ ICP. There is a risk of VAE following inadvertent entry into the cavernous sinus. Valsalva maneuver, jugular compression, or injection of saline through a lumbar intrathecal catheter may be requested to facilitate tumor exposure. Injuries to sphenopalatine or carotid arteries are rare but may be dramatic when they occur.
Antibiotics	Cefazolin 2 g iv (30–60 min before incision)
Surgical time	2.5–3 h
Closing considerations	Possible abdominal or thigh fat graft. Closure quite fast. Prevent straining and bucking if there has been an intraoperative CSF leak. Remove any throat pack before extubation.
EBL	25–250 mL
Postop care	Fluid and electrolytes require frequent monitoring as the patient may develop diabetes insipidus (DI), usually transient, following this procedure.
Mortality	1%
Morbidity	Anterior pituitary insufficiency: 19.4% DI: 0.5–31%; SIADH: 9–25% Sinusitis: 8.5% Septum perforation: 3% CSF leak: 3.5% Epistaxis: 3.0% Loss of vision: 1.8% Meningitis: 1.5% Carotid artery injury: 1.1% stroke (rare)

Pain score	2–4

PATIENT POPULATION CHARACTERISTICS

Age range	18–85 yr (usually 30–50 yr)
Male:Female	2:3 (microadenomas)
Incidence	16.7% (autopsy studies); 1.5/100,000/yr diagnosed
Etiology	Neoplastic; traumatic
Associated conditions	Cushing disease (ACTH); acromegaly (GH); amenorrhea/galactorrhea (prolactin); hyperthyroidism (TSH); hypergonadotropism (FSH; LH); multiple endocrine neoplasia I

ANESTHETIC CONSIDERATIONS

(Procedures covered: bifrontal craniotomy for CSF leak; transoral approach to cervicomedullary junction, odontoid; transsphenoidal resection of pituitary tumor)

PREOPERATIVE

Patients presenting with pituitary tumors can be divided into two categories, those with functional (hormone secreting) tumors and those with nonfunctional (nonsecreting) tumors. Nonfunctional tumors are usually large at the time of diagnosis (headache, visual changes, panhypopituitarism), producing Sx as a result of compression. Functional tumors can be subcategorized:

Prolactin secreting: Few anesthetic implications beyond possible mass effect and ↑ ICP.

ACTH secreting: HTN is very common and is often associated with diastolic dysfunction. OSA is common and may have implications for postop airway management. Hyperglycemia is common and should be treated if blood glucose >180 mg/dL. ↑ cortisol → fragile skin and veins → difficult iv access.

Growth hormone secreting: Hypertrophy of the mandible, tongue, and other facial tissues is common and complicates airway management. Hoarseness suggests laryngeal stenosis or recurrent laryngeal nerve dysfunction. OSA is very common with its attendant risk of postop airway compromise. HTN and diastolic dysfunction (with a need for ↑ filling pressure) are very common. The incidence of intraop ventricular ectopy and SVT is higher in these patients. ECG changes (e.g., ST/T

wave changes, conduction abnormality) are common.

Pituitary tumors may present with the sudden onset of Sx (including severe headache, ophthalmoplegia, coma) as the result of hemorrhagic infarction (pituitary apoplexy). This is a life-threatening emergency often requiring urgent transsphenoidal decompression following stabilization with volume and high-dose corticosteroids.

Endocrine	Rarely, the mass effect may cause the clinical picture of panhypopituitarism requiring preop treatment with thyroxine, glucocorticoid, and vasopressin. Functional tumors commonly secrete prolactin (→ lactation), ACTH (→ adrenal hyperplasia), or growth hormone (→ acromegaly). Hyperprolactinemia may occur with any tumor 2° loss of inhibition of prolactin secretion. **Tests:** Preop endocrine studies, including serum and urinary levels of pituitary, thyroid, and adrenal hormones; appropriate replacement therapy established before proceeding with surgery. "Stress-dose" hydrocortisone (e.g., 100 mg iv q8h) is often unnecessary; treatment should be guided by symptoms and periop cortisol levels. Dexamethasone will not interfere with cortisol assays, but some surgeons continue to avoid this steroid.
Respiratory	No special requirements, unless patient has acromegaly, in which case large facial features, long neck, large tongue, and redundant soft tissue in the oropharynx may make mask fit and ET intubation difficult. If these patients evidence hoarseness or inspiratory stridor, they should have a full clinical and radiologic evaluation of the upper airway. **Tests:** As indicated from H&P
Cardiovascular	No special requirements unless patient has acromegaly, in which case they may have refractory HTN, ischemic heart disease, cardiomyopathy, dysrhythmias, valvular disease, and diabetes. **Tests:** As indicated from H&P
Neurologic	Secretory tumors of the pituitary are usually small,

	confined to the sella, rarely cause ↑ ICP (2° direct tumor effects or by obstruction of 3rd ventricle), and commonly produce Sx of endocrine dysfunction early in their growth. In contrast, nonfunctional pituitary tumors may not produce Sx until they extend beyond the boundaries of the sella, causing HAs (the most common presenting symptom) or compression of the optic chiasm, producing visual field defects (temporal or bitemporal hemianopsia). **Tests:** A CT or MRI will delineate the site and size of the tumor, especially if iv contrast material, such as gadolinium, is administered to enhance the margins of the tumor.
Musculoskeletal	If growth hormone is the primary secretant, patient will exhibit Sx of acromegaly, including large hands, feet, head, and tongue. Cushing myopathy (UE proximal muscle weakness) may affect apparent recovery from muscle relaxant. **Tests:** As indicated from H&P
Laboratory	Metabolic panel, Hct, and others as indicated from H&P. ↓ Na^{+} may indicate DI; ↑↑ Ca^{++} may indicate MEN I.
Premedication	If ↑ ICP is not a concern, patients may benefit from midazolam 1–2 mg iv. In patients with ↑ ICP consider pretreatment with mannitol (e.g., 0.25 g/kg 20 min before induction). Acromegalic patients may develop airway obstruction following even small doses of sedatives or narcotics.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water and aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA is required for these operations because the surgical approach is commonly through the nose or rarely through the mouth above the maxillary gum line and behind the nose. A lumbar drain may be placed to permit intraop management of ICP and improve access to the tumor.

Induction	If a difficult intubation is anticipated (e.g., severe acromegalic patients), orotracheal intubation will need to be accomplished before induction of GA. LMA placement may be difficult, and awake FOL is often the best choice. Because pituitary tumors generally are confined to the sella turcica and, hence, ICP usually is not increased, a standard induction technique with standard ETT is appropriate. An oral RAE tube may be preferred by some surgeons. If increased ICP is of concern, induction should be similar to that used for patients with other kinds of brain tumors (see Anesthetic Considerations for Craniotomy for Tumor). Because the surgeon will be working from the patient's right side, the ETT must be positioned at the far left side of the mouth. The surgeon may infiltrate the nasal mucosa with lidocaine and epinephrine →↑ BP + dysrhythmias → possible myocardial ischemia.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia. Consider dexamethasone (4–8 mg iv) may ↓PONV. Sequential pneumatic compression devices should be used to ↓VTE risk.
Maintenance	Standard maintenance with sevoflurane (or propofol infusion) supplemented with remifentanil. Generally, no further NMBs are administered beyond ET intubation. With adequate anesthesia, and the head in a Mayfield clamp, patient movement of any consequence is highly unlikely. Ventilation is controlled with $PaCO_2$ maintained in the normal range. Hyperventilation is not desirable because it makes it more difficult to access the tumor in the sella and establish that it has been removed in its entirety. Following the resection, the surgeon may request a Valsalva maneuver to check for CSF leak.

Emergence	If the patient evidences normal emergence from anesthesia, the ETT should be removed before vigorous coughing ensues. Before removing the ETT, however, make certain that all blood accumulated in the back of the throat is suctioned out and that any oropharyngeal packs that may have been placed in the back of the throat have been removed. An OG tube should be used to suction out the stomach. The surgeon may have packed the nose at the end of operation, making the patient an obligatory mouth breather. If there is any question about airway patency because of a large tongue, small mouth, or soft tissue redundancy in the oropharynx, the ETT should be left in place until patient is fully awake from anesthesia. Prophylactic antiemetics (e.g., ondansetron 4–8 mg and metoclopramide 20 mg) should be given 30 min before extubation. Consider iv acetaminophen if po dose given >4–6 h ago.	
Blood and fluid requirements	Minimal blood loss usual Potential large blood loss IV: 16–18 ga × 1–2 BSS @ 1–3 mL/kg/h	Blood loss is minimal, unless the surgeon inadvertently enters the internal carotid artery or cavernous sinus. Additional iv access is prudent. Zero balance or goal-directed fluid management is recommended (see Appendix K, p. K-2).
Monitoring	Standard monitors ± Arterial line ± UO	Monitor for VAE in semisitting position if >30° head up. Ulnar artery flow may be compromised in acromegaly—document Alan test before placing radial artery catheter.
	± CVP line ± Precordial Doppler	CVP line should be placed in patients at significant risk for VAE or as medically indicated.
Positioning	✓ and pad pressure	The surgeon will use an

	points ✓ eyes Shoulder roll Table turned 90–180°	operating microscope or endoscope, which means that the anesthesiologist will be positioned at the side or foot. Anesthetic hoses and intravascular lines must be long enough to be accessible.
Complications	Carotid injury VAE	Potential for large-volume hemorrhage and intraop stroke. Deliberate hypotension may facilitate repair. Carotid compression may → ↓ CBF → ischemia.

POSTOPERATIVE

Complications	Hypopituitarism Diabetes insipidus (24–48 h postop) CSF leak SIADH Cranial nerve injury	Replacement therapy with steroids is necessary in hypopituitary patients until normal pituitary function returns. Occasionally, patients will develop DI postop → polyuria and ↓ urine specific gravity <1.005. Rarely, this may occur in the PACU necessitating fluid replacement and/or DDAVP.
Multimodal pain management	Acetaminophen Fentanyl 25–50 mcg prn	Frontal HA is the most common complaint. Consider acetaminophen (1 g iv) for postop analgesia if not given preop or if 4–6 h have elapsed since previous dose.
Tests	CT scan Serum cortisol Visual acuity/fields	If a patient exhibits any delay in emergence from anesthesia and surgery, or any new neurologic deficits

		emerge postop, a CT scan is ordinarily obtained.
ERAS	Ondansetron 4 mg iv ± Metoclopramide 10–20 mg iv	Metoclopramide will promote gastric emptying of swallowed blood. Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

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2. Alzhrani G, Sivakumar W, Park MS, et al: Delayed complications afte transsphenoidal surgery for pituitary adenomas. World Neurosurg 2018; 109:233–41.
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4. Lim M, Williams D, Maartens N: Anaesthesia for pituitary surgery.J Clin Neurosci 2006; 13(4):413–8.
5. Murad-Kejbou S, Eggenberger E: Pituitary apoplexy: evaluation, management, and prognosis. Curr Opin Ophthalmol 2009; 20(6):456–61. Review.

VENTRICULAR SHUNT PROCEDURES

SURGICAL CONSIDERATIONS

Lawrence M. Shuer, Steven D. Chang, and Navjot Chaudhary

Description

Many conditions exist where it is necessary to shunt CSF from the ventricles to another body cavity where it can be absorbed readily. The most common condition is hydrocephalus, where there is dilation of the ventricular system due to an obstruction in the flow of CSF (Fig. 1.1-21) or decreased absorption of CSF by the arachnoid villi. Hydrocephalus is commonly treated by diverting CSF to the peritoneal cavity via a ventriculoperitoneal shunt (**VP shunt**). Most shunt systems have a one-way, pressure-dependent valve to regulate the flow of CSF. These valves usually have a preset pressure setting (e.g., low, medium, high) at which they open and allow CSF to flow. Newer valves have externally adjustable opening pressures, flow-regulating devices, and/or antisiphon systems to prevent overshunting. In addition, antibiotic impregnated

catheters can be used to reduce the risk of infection.

To insert a VP shunt, the patient is positioned so that the cranial incision and abdominal incision are aligned in the same plane. The scalp is shaved (usually over the frontal or parietal region), and a continuous surgical field is created from head to abdomen. The cranial incision is made over the intended region of cannulation of the ventricle, and a burr hole is made in the cranium. A subgaleal pocket is created for the valve, usually behind the ear. A separate incision is made in the abdomen, and the dissection is carried down to the level of the peritoneum. A catheter is then passed subcutaneously from the abdominal incision to the cranial incision with a special tunneling instrument (Fig. 1.1-22A). Alternatively, the catheter can be threaded from the cranial incision to the abdominal incision. It may be necessary to use one or more incisions between the head and the abdomen to thread the catheter. The valve is connected to the peritoneal catheter and placed in the subgaleal pocket. A ventricular catheter is then inserted into the ventricle (Fig. 1.1-22B), and a small amount of CSF is drained to check placement and patency of the catheter. The ventricular catheter is then connected to the valve, and CSF flow through the entire shunt system is checked by draining some CSF from the distal end of the peritoneal catheter. The distal end is then placed into the peritoneal cavity and all wounds are closed.

Any component of the shunt may malfunction; thus, it may be necessary to test each component at the time of revision to identify the problem. To test the patency of the ventricular catheter, it is disconnected from the valve, and CSF should flow freely through it. A saline-filled manometer can be attached to the valve to measure the opening pressure of the valve. The manometer should drain spontaneously until the opening pressure of the valve is reached. An elevated opening pressure may indicate a valve malfunction or a distal occlusion. If a distal occlusion is suspected, gentle irrigation may clear it, but externalization may be necessary.

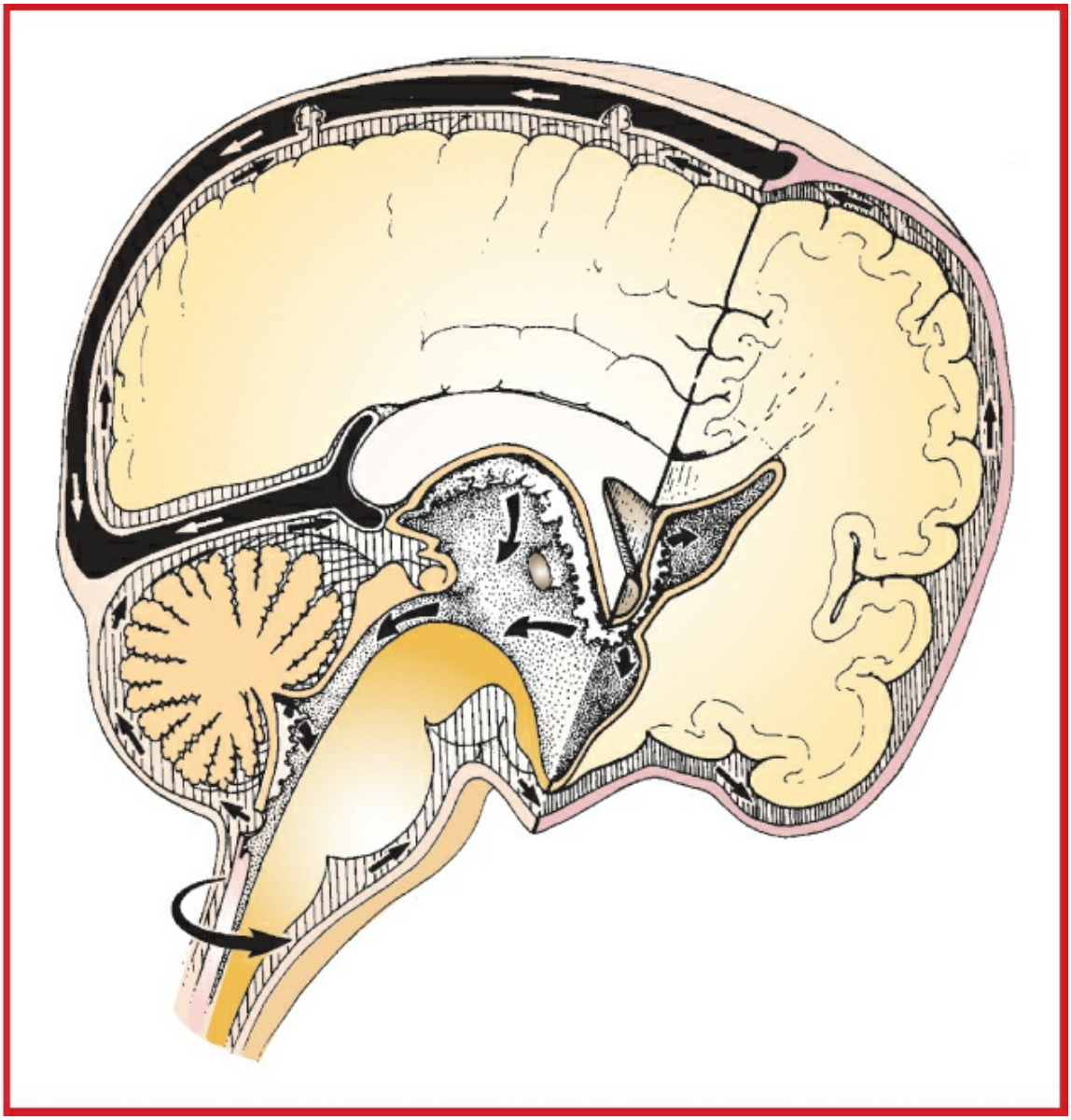

Figure 1.1-21 Pathways of CSF flow and potential sites of obstruction. (Reproduced with permission from Tindall GT, Cooper PR, Barrow DL:The Practice of Neurosurgery, Vol III. Williams & Wilkins, Baltimore: 1996. Originally from Scott RM: Hydrocephalus.Concepts in Neurosurgery, Vol III. Williams & Wilkins, Baltimore: 1990.)

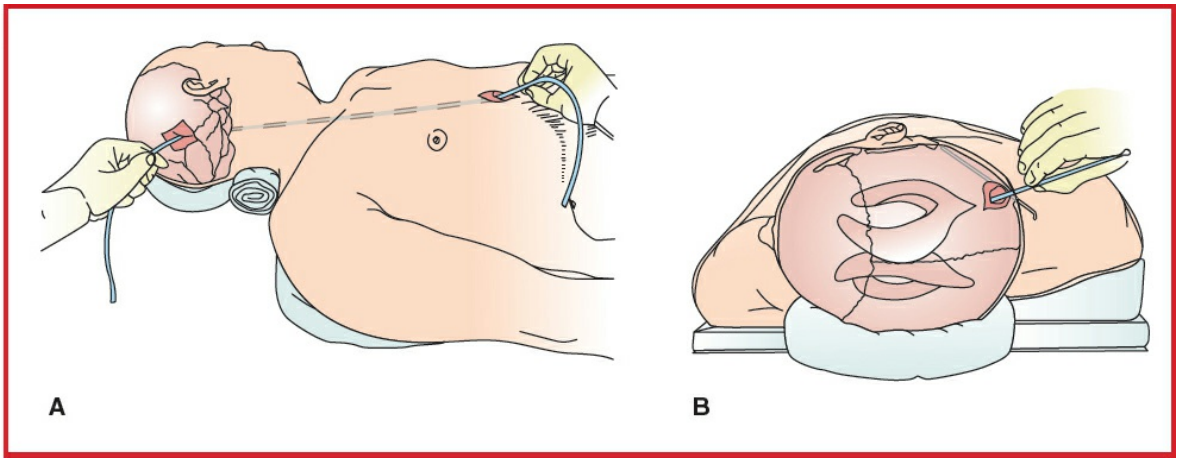

Figure 1.1-22 **A:** The catheter is threaded from the cranial incision to the abdominal incision. **B:** Insertion of the ventricular catheter. (Reprinted from Meyer FB:Atlas of Neurosurgery: Basic Approaches to Cranial and Vascular Procedures, 1st edition. Churchill Livingstone, Philadelphia: 1999. Copyright © 1999 Elsevier. With permission.)

Variant procedure or approaches

Endoscopy, fluoroscopy, ultrasound, image-guided navigation, or intraoperative MRI may be used to help place the catheter into the ventricle. The ventricular catheter can be placed in either lateral ventricle; occasionally, both lateral ventricles are cannulated. This procedure also is used to shunt the 4th ventricle and, sometimes, subarachnoid cysts and subdural hygromas. The distal end alternatively may be placed in the pleural cavity or the right atrium (ventriculoatrial or **VA shunt**). If the distal end of the catheter is placed into the pleural cavity, a Valsalva maneuver is performed upon closure to reinflate the lung. To place the distal end into the atrium, a vein is cannulated in the neck (usually IJ, EJ, or facial vein), and the catheter is fed into the atrium under fluoroscopic guidance. It may be necessary to inject radiopaque contrast to verify proper placement. Rarely, the distal end of the catheter can be placed in an intracranial venous sinus, the gallbladder, or the ureter.

Endoscopic third ventriculostomy (ETV)

Endoscopic third ventriculostomy is being used with increasing frequency to treat both obstructive and communicating forms of hydrocephalus. Head fixation is generally not needed, and the procedure involves a small skin incision over the frontoparietal lobe to gain access to the skull. A small burr hole is then made. The dura is opened over the burr hole, permitting the insertion of the endoscope into the lateral ventricle. Under endoscopic guidance, the tuber cinereum is then fenestrated with a balloon tip catheter. CSF is diverted through the membranous floor of the 3rd ventricle into the basal cisterns. The endoscope is then removed, and the wound is closed.

Usual preop diagnosis

Hydrocephalus; obstructive or communicating hydrocephalus; aqueductal stenosis; Dandy-Walker malformation (cystic dilation of the 4th ventricle and incomplete formation of the cerebellar vermis); occult hydrocephalus; normal pressure hydrocephalus; subarachnoid cyst; subdural hygroma; pseudotumor cerebri

ERAS: Preop counseling by the surgeon/anesthesiologist should include continuing chronic pain and other meds, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, and possibility of urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	VP Shunt	VA Shunt	ETV
Position	Supine, with head turned to contralateral side	⇐	⇐
Incision	Scalp, either coronal and retroauricular or parietal; + neck and abdomen	Scalp, either coronal and retroauricular or parietal; + neck	Scalp over frontoparietal lobe
Special instrumentation	Ventricular endoscope (optional)	⇐ + I.I.	Ventricular endoscope
Unique considerations	Patient to be treated as if there is ↑ ICP	⇐	⇐
Antibiotics	Cefazolin 2 g iv	⇐	⇐
Surgical time	1 h	⇐	⇐
EBL	5–25 mL	⇐	⇐
Postop care	PACU → room; usually kept flat for 24 h	⇐	⇐
Mortality	<1%	⇐	⇐
Morbidity	Infection: <15% Neurologic: Intracranial bleed: <1% Subdural hematoma: <1% Hardware failure: <1%	⇐	⇐ Basilar artery injury ↑↑ ICP → ↓↓ HR or asystole
Pain score	4–6	2–4	2–4

PATIENT POPULATION CHARACTERISTICS

Age range	Newborn-elderly
Male:Female	1:1

Incidence	Common
Etiology	Congenital (3–4/1000 live births); acquired; neoplastic; infectious; posthemorrhagic
Associated conditions	Subarachnoid hemorrhage; myelodysplasia; spina bifida (95% incidence); intraventricular hemorrhage; intraventricular tumor

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Ventricular shunts are inserted to ameliorate hydrocephalus or cyst formation, which may be either congenital or acquired. EVD (if present) may have been clamped by surgical team to enlarge ventricles to facilitate insertion of VP shunt. Resulting ↑ICP may exacerbate N/V and/or drowsiness.

Cardiovascular	↑ ICP → ↑ BP + ↓↓ HR (Cushing response) **Tests:** As indicated from H&P
Neurologic	The most common presenting Sx is HA. If hydrocephalus is severe, Sx of ↑ ICP (>15 mm Hg); for example, N/V, drowsiness, papilledema, Sz, and focal neurologic defects) develop.
Laboratory	Tests as indicated by H&P
Premedication	Usually not required; should be avoided in patients with ↑ ICP.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water and aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique: GETA

Induction	If ↑ ICP, iv induction with propofol (1–2 mg/kg) is preferred because of its ability to ↓ CBV → ↓ ICP. ET intubation is accomplished with the use of an NMB (e.g.,

	rocuronium [0.6–1 mg/kg]).	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia. Dexamethasone (4–8 mg iv) may ↓PONV. Avoid long-acting opioids or scopolamine patch, which may confound postop neuro examination. Sequential pneumatic compression devices should be used to ↓VTE risk.	
Maintenance	Isoflurane ≤1% or sevoflurane <2%, inspired with 50:50 N_2O/O_2 mixture. Depending on duration of operation, additional doses of rocuronium (0.2 mg/kg) may be needed. Maintain normal temperature in children by keeping OR warm (78°F) and using a forced-air warming blanket. Ventilation should be controlled. TV and frequency should be adjusted such that the $PetCO_2$ = 35–40 mm Hg. Hyperventilation and hypocarbia are undesirable because they make cannulation of the ventricle(s) more difficult. Maintain normotension. During endoscopic third ventriculostomy (ETV), puncture of the floor of the 3rd ventricle may be associated with significant ↓↓ HR or asystole. The surgeon should be immediately informed if bradycardia occurs. Catheter tunneling will be stimulating → ↑HR and ↑BP, which can be prevented with bolus propofol or remifentanil.	
Emergence	Ensure reversal of any residual neuromuscular blockade. ETT is removed at the conclusion of the anesthetic. Prophylactic antiemetic (e.g., metoclopramide 10–20 mg and ondansetron 4 mg) should be given 30 min before extubation.	
Blood and fluid requirements	IV: 18–20 ga × 1 BSS @ 1–3 mL/kg/h	Zero balance fluid management (see Appendix K).
Monitoring	Standard monitors	Invasive monitors as indicated.
Positioning	Table turned 180° ✓ and pad pressure points ✓ eyes	Supine with a bolster under the shoulder on the operative side. The head, chest, and abdomen are prepped, so all

		anesthesia equipment and lines must be at the sides of the patient.
Complications	Valve malfunction ↓↓ HR or asystole Basilar artery injury	Major intraop complications from this operation are rare. ETV may be associated with severe bradycardia and injury to the basilar artery or its branches.

POSTOPERATIVE

Multimodal pain management	Children <2 yr: acetaminophen suppositories (10–15 mg/kg q4h) Adults: acetaminophen 1 g iv q6h ± Fentanyl 25–50 mcg prn	If not given preop or if 4–6 h have elapsed since previous dose.
ERAS	Ondansetron 4 mg iv ± Metoclopramide 10–20 mg iv	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

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2. Spennato P, Ruggiero C, Aliberti F, et al: Third ventriculostomy in shunt malfunction. World Neurosurg 2013; 79(2 Suppl):S22.e21–6.
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CRANIOCERVICAL DECOMPRESSION (CHIARI MALFORMATION)

SURGICAL CONSIDERATIONS

Lawrence M. Shuer, Steven D. Chang, and Navjot Chaudhary

Description

Historically, congenital hindbrain abnormalities characterized by cerebellar descent were known collectively as **Arnold-Chiari malformations**; now, they are known as **Chiari malformations**. In these abnormalities, portions of the cerebellum protrude through the foramen magnum and may compress the brain stem and upper cervical spinal cord. Frequently, the malformation is accompanied by **syringomyelia**, a condition in which CSF is located abnormally within the spinal cord. In **type I Chiari** malformation, the cerebellar tonsils are herniated through the foramen magnum. In **type II Chiari** malformation, the tonsils, vermis, 4th ventricle, pons, and medulla are displaced caudally through the foramen magnum. Type II Chiari malformations are usually found in infants and are associated with myelomeningoceles. In **type III Chiari** malformations there is a defect in the back of the head or neck through, which the cerebellum and/or brain stem is herniated. Patients with **type IV Chiari** malformations usually do not survive past infancy.

To make room for the brain stem and caudally displaced cerebellum, decompression of the craniocervical junction is necessary. This procedure may be performed in the prone, three-fourths prone, or seated position. The head is placed in Mayfield pin fixation. A midline incision is made, and the dissection is carried down to the skull and the posterior arch of C1. Paramedian burr holes are placed to aid in the suboccipital craniectomy. The craniotome is then used to remove an ~4 × 3-cm bone flap that includes the foramen magnum. Care is taken to avoid injury to the underlying venous sinuses when performing the craniectomy.

The posterior arch of C1 is removed, and as many upper cervical lamina as are needed to fully decompress the Chiari malformation are removed. Next, any constricting fibrous bands are cut, and the dura is opened. Any subarachnoid adhesions should be lysed to allow the free flow of CSF. The tonsils are dissected apart under microscopic guidance to gain an opening to the 4th ventricle (Fig. 1.1-23). The cerebellar tonsils can be reduced with electrocautery or by resection to facilitate the outflow of CSF from the 4th ventricle. A stent or a shunt may be placed in the 4th ventricle and brought out to the subarachnoid space to ensure adequate drainage of the 4th ventricle. The dura is closed

loosely with autologous pericranium, fascia lata, or bovine pericardium (Fig. 1.1-23B). This creates a widely patent cisterna magna and prevents constriction at the cervicomedullary junction.

Usual preop diagnosis

Chiari malformation I or II or Arnold-Chiari malformation; syringomyelia

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, and possibility of lines and urinary catheter postop. See Appendix K.

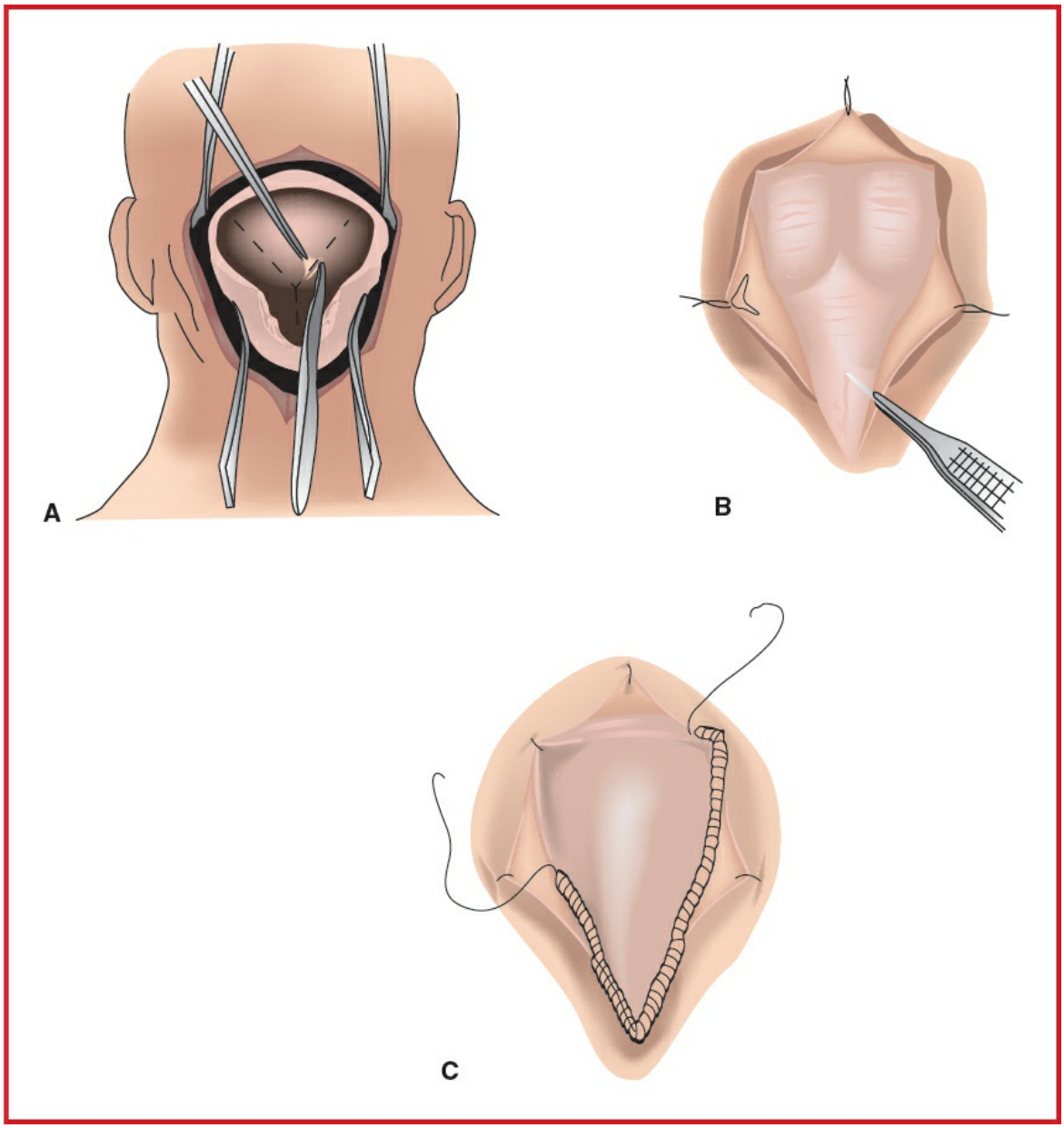

Figure 1.1-23 A and B: Surgical anatomy in Chiari I decompression. The use of the no. 12 blade is demonstrated. Because the cutting surface is drawn up and away from the central nervous system

tissue, the risk of injury is minimized with patch graft. (Adapted with permission from Barrow Neurological Institute.) **C:** Surgical anatomy in Chiari II malformation. Demonstration of the surgical anatomy of the Chiari II malformation showing a low-lying torcular and a medullary kink that is more caudally displaced than the cerebellar vermis.

SUMMARY OF PROCEDURE

Position	Prone or sitting
Incision	Midline posterior, posterolateral thigh for fascia lata graft (optional)
Special instrumentation	Operating microscope
Unique considerations	Risk of air embolus; brain stem manipulation can cause BP and pulse instability; dural patch used to expand dura at foramen magnum
Antibiotics	Cefazolin 2 g iv (30–60 min before incision)
Surgical time	2.5–3.5 h
Closing considerations	BP control to ensure adequate hemostasis
EBL	25–250 mL
Postop care	ICU or constant observation unit; neurologic function monitored
Mortality	0–3% (usually respiratory arrest)
Morbidity	Respiratory depression: 14% up to 5 d postop All others <5%: Infection Neurologic: dysphagia and ↓ gag reflex Aseptic meningitis CSF leak Massive blood loss; vertebral artery or transverse sinus injury
Pain score	5–7

PATIENT POPULATION CHARACTERISTICS

Age range	Infant to 70 yr; Chiari I: average age = 41 yr
Male:Female	~1:1
Incidence	Relatively rare neurosurgical procedure
Etiology	Congenital; acquired, S/P lumboperitoneal shunting
Associated conditions	Hydrocephalus; syringomyelia; scoliosis; myelodysplasia

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Cervical Neurosurgical Procedures.

Suggested Readings

1. Cesmebasi A, Loukas M, Hogan E, et al: The Chiari malformations: a review with emphasis on anatomical traits. Clin Anat 2015; 28(2):184–94.
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STEREOTACTIC NEUROSURGERY

SURGICAL CONSIDERATIONS

Steven D. Chang and Navjot Chaudhary

Description

Stereotaxis applies simple rules of geometry to radiographic images to allow precise localization within the brain. Such techniques can be applied to a variety of neurosurgical procedures, providing up to 1 mm accuracy. This precision makes it possible to perform certain intracranial procedures less invasively. Methods include both frame-based and frameless navigation systems, as well as specific stereotactic applications for functional neurosurgery and radiosurgery.

Frame-based stereotaxy

Stereotactic localization was developed using frames; however, with the widespread use of image-guided, "frameless" stereotactic systems, frame-based stereotaxy is rarely

used. These procedures begin with the attachment of a frame to the patient's head using four screws that anchor it to the skull. This is typically done outside the OR, using local anesthetic and, sometimes, light sedation. In the cooperative adult, frame application takes only 5–10 min; however, GA typically is used for children. Once the frame is in place, access to the patient's airway is restricted. A key for emergency removal of the frame must be kept with the patient at all times. With the stereotactic frame in place, CT, MRI, and/or cerebral angiography are used for target identification and localization. During imaging, a set of fiducials (radiographically visible markers) is attached to the frame. These fiducials provide the geometric reference points needed for localization. Data from imaging studies are used to calculate the spatial coordinates of the target(s). In nearly all cooperative patients, there is no need for sedation or analgesia during this stage of the procedure.

Frame-based stereotaxy is used most frequently for brain biopsies; however, drainage of cystic lesions or placement of a catheter or depth electrodes also can be performed. These common procedures involve relatively minor surgery, usually requiring only light sedation and local anesthesia. After prepping and draping, specialized operating tools are attached to the stereotactic frame. These instruments provide spatial guidance throughout the surgical procedure. A burr or twist drill hole is the usual form of intracranial access. Maximal sedation is needed during drilling and dural opening. Anesthetic considerations include ensuring adequate oxygenation and ventilation, which may be compromised by the sterile drapes. In addition, sedation should be light enough at times to allow the neurosurgeon to test gross neurologic function, such as extremity movement, both during and immediately after biopsy. At the completion of the case, the frame is removed and the patient is brought to the recovery room.

Image-guided "frameless" stereotaxy

Over the last several years, techniques have been developed to provide neurosurgeons with a real-time computer display of position and trajectory. Spatial information is displayed on high-speed computer workstations as two-dimensional images and three-dimensional renderings obtained from CT and/or MRI. These devices have the added advantage of being frameless; instead of a frame providing a system of reference, small markers (fiducials) are affixed to the scalp and forehead with adhesive. Advances in image-guided navigation also allow the incorporation of ultrasound and endoscopy to provide intraoperative updating of the preoperative radiographic images.

Image-guided surgery begins with an imaging study performed with fiducials in place. The remainder of the case is performed in the OR, usually under GA. After the patient's head is appropriately fixed and positioned, the locations of the fiducials are entered into

a computer, using any one of several different commercially available digitizing techniques. The most common system uses triangulation of infrared light from LEDs to determine the position of a pointer in space. The computer calculates the position of the pointer with respect to the patient and displays on the monitor the images from the scan with a representation of the pointer superimposed. Because the process of localization assumes a constant frame of reference, it is important that fiducials do not move between the time of imaging and registration in the OR. A further refinement, the dynamic reference frame, may be affixed to the craniotomy headrest to allow intraoperative repositioning of the patient. The OR must be set up to accommodate the computer and monitor as well as to allow a direct line-of-sight between the operative site and an array of infrared sensors (see Fig. 1.1-24). Care must be taken to avoid patient movement during the initial registration of the fiducials because this introduces a component of error with respect to the accuracy of the navigation system. The camera system can be repositioned during the case and still maintain accuracy.

Robotic stereotaxy: clinical application of robotic systems include stereotactic placement of intracranial electrodes, biopsy needles, laser probes, and intraventricular catheters. ROSA™ (Zimmer Biomet) and Renaissance® (Mazor Robotics), two of the more widely employed robotic systems, have been used for both frame-based (ROSA™) and frameless stereotactic procedures. Targeting errors are reported to be <2 mm. Complication rates are similar to traditional surgery, but robot assistance may offer the benefit of significantly reduced operating time in experienced hands.

The spatial information provided to neurosurgeons by image guidance can be used to access deep or critically located lesions through the most direct trajectory and a smaller craniotomy. These techniques have been used primarily during craniotomy for tumor or vascular malformation; however, image guidance also can be used for brain biopsy, shunt placement, cyst drainage, or other smaller procedures. As with most craniotomies, GA is used. Maneuvers that alter the spatial relationship of the intracranial contents, such as hyperventilation, diuresis, or CSF drainage, will result in brain shift relative to the presurgical images and should be avoided if possible, particularly during the early stages of surgery.

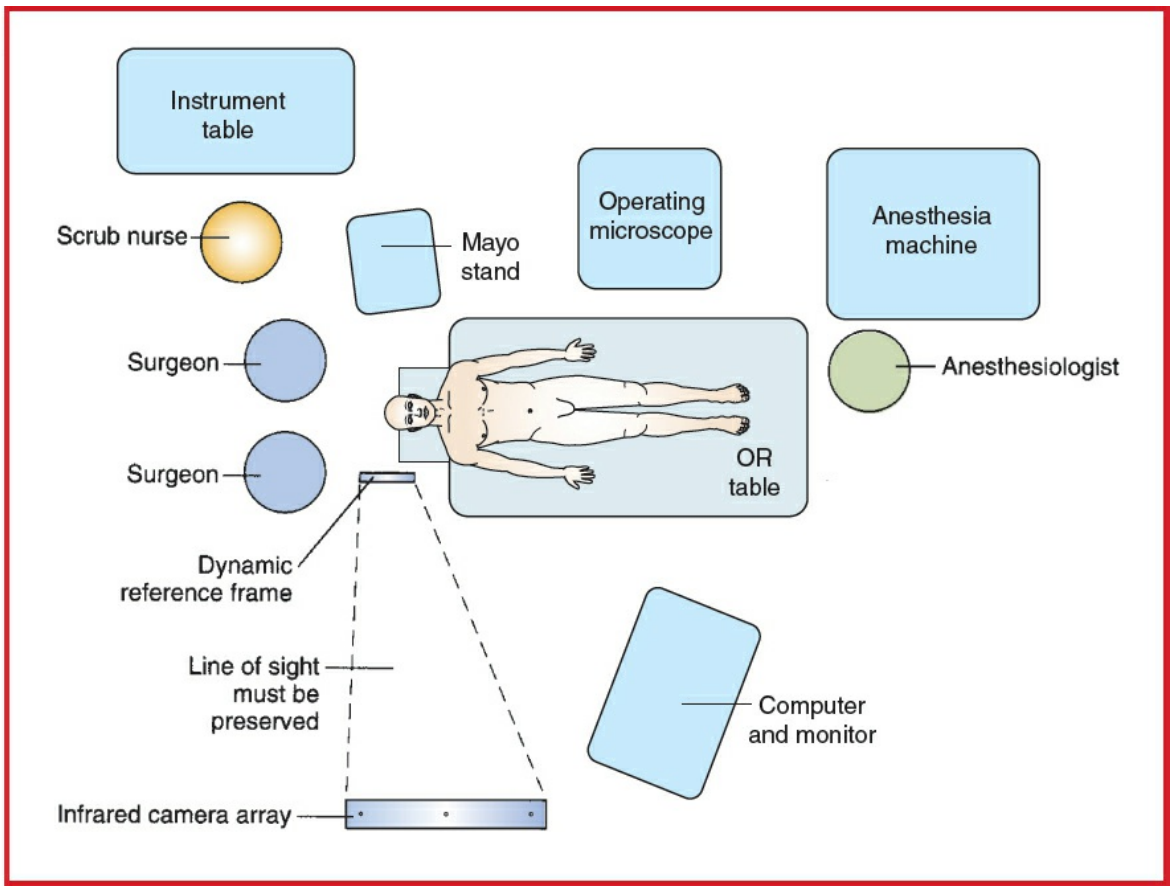

Figure 1.1-24 OR layout for frameless stereotactic surgery.

Radiosurgery

This technique uses focused radiation to ablate small or residual tumors and vascular malformations. It can also be used to treat some pain, psychiatric, and movement disorders. In contrast to other stereotactic operations, radiosurgery is performed outside the OR, using a linear accelerator or other specialized irradiation device. Cooperative adults need little or no sedation during the procedure. Children, however, almost always require GA from the beginning of frame placement through the actual treatment, which may last from 5 to 8 h. Consequently, anesthesia must be administered at several locations in the hospital, as well as during transport between these sites. Ideally, GA is initiated in the imaging suite just prior to frame placement. After transport to the recovery unit, the child is maintained under anesthesia while radiosurgical treatment is being planned, which takes from 1 to 3 h. The patient is then transported to the radiosurgery suite, still anesthetized, and treatment is performed. Depending on complexity, radiosurgery itself may last from 1 to 2 h. At the completion of treatment, the stereotaxic frame is removed and the child is awakened.

Newer, frameless radiosurgical systems can obviate the need for GA, and most children can be set up and treated with iv sedation alone. However, the setup and treatment are

usually performed on different days, and the child can go home while the treatment plan is created. These systems also allow for fractionation of the total dose, which may spare damage to surrounding critical structures.

Functional neurosurgery

Surgery using precisely placed lesions (e.g., **pallidotomy**, **thalamotomy**) or deep brain stimulators for the treatment of movement disorders, pain, and certain psychiatric syndromes are encompassed by the term "**functional stereotaxy**." These techniques depend on absolutely precise localization of specialized instruments. These surgeries traditionally have required the use of a stereotactic frame. However, advances in imaging and image-guided navigation have obviated the need for a stereotactic frame. Concurrent neuroanatomic localization using electrophysiologic techniques is routinely used, regardless of the stereotactic system employed. To preserve neural potentials and allow the patient to cooperate with neurologic testing, GA is not used. Frameless procedures begin with placement of the fiducials (small screws) and imaging. Typically, the fiducials are implanted in the patient's skull using local anesthetic and a special screwdriver. Then, the patient undergoes a CT scan, which is uploaded into the image-guided navigation system. The surgeon can then plan the trajectory in the computer. In the OR, the patient's head is placed in Mayfield pins, and the imaged-guided navigation system is set up and the fiducials are registered. A small skin incision is made, and a burr hole is placed with the patient under iv sedation. The patient is then awakened and must remain awake and cooperative throughout a several-hour procedure, which may require patient participation in various neurologic tests. The recording electrodes are positioned using the image-guided navigation system and the electrophysiologic monitoring. After the proper electrophysiologic position is obtained, the recording electrode is removed and the deep brain stimulator is placed in the exact same position and depth. After the deep brain stimulator is placed, a subgaleal pocket may be created to house the leads until they can be connected to the pulse generator. Frame-based procedures begin with the attachment of a rigid frame to the patient's skull with local anesthesia. The stereotactic frame provides an immobile reference that aids in targeting. The remainder of the procedure is similar to the frameless procedure previously described.

Usual preop diagnosis

Brain disease requiring biopsy; brain tumor; vascular malformation; Parkinson disease; hydrocephalus; pseudotumor cerebri; pain syndromes; psychiatric syndromes; cyst drainage

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should

include continuing chronic pain and AED medications, limiting NPO duration, alcoho and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, and possibility of urinary drain postop. See Appendix K.

SUMMARY OF PROCEDURES

	Frame-Based Stereotaxy	Frameless Stereotaxy	Radiosurgery	Functional Neurosurgery
Position	Supine or prone	Sitting, supine, prone, or lateral	Supine or prone	Supine; frameless or head fixed in frame
Incision	0.5–2 cm, scalp	1–12 cm, scalp	None	1–3 cm, scalp
Special instrumentation	Stereotactic treatment arc ± Robotic assistance	Image guidance system ± Robotic assistance	Linear accelerator (LINAC) CyberKnife	Electrophysiologic monitoring equipment, image-guided navigation, C-arm ± Robotic assistance
Unique considerations	Key for emergency removal of frame	No patient movement during registration. Clear line-of-sight between camera and dynamic reference frame	Extended anesthesia in several different locations for pediatric patients	Patient is usually awake, able to cooperate with testing. Key for emergency removal of frame (if used)
Antibiotics	Cefazolin 2 g iv	⇐	None	Cefazolin 2 g iv
Surgical time	0.5–1.5 h	2–6 h	5–8 h	2–6 h
EBL	<10 mL	20–1000 mL	None	<100 mL
Postop care	PACU	ICU or PACU	PACU	PACU
Mortality	<0.5%	1%	None	<1%
Morbidity	Overall: <1% Symptomatic intracerebral hemorrhage	Infection Air emboli Hemorrhage Stroke Sz Worsening edema	N/V: 2–3%	N/V: 1–10% Intracerebral hemorrhage New neurologic deficits
Pain score	2	4	2	2

PATIENT POPULATION CHARACTERISTICS				
Age range	All ages	⇐	0–12 yr	18–90 yr
Male:Female	1:1	⇐	⇐	⇐
Incidence	Uncommon	Unusual	⇐	Rare
Etiology	Tumor; infection; AIDS; demyelinating syndromes	Tumor; vascular malformations; epilepsy	⇐	Parkinson disease; pain syndromes; psychiatric syndromes

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for specific neurosurgical procedures, e.g., tumor resection, functional neurosurgery, etc.

A variety of neurosurgical procedures are performed using stereotactic guidance especially when the lesion is small and/or is located deep within brain tissue or as a means of obtaining a biopsy of a lesion for diagnosis. For example, focal, deep-seated AVMs may be resected under stereotactic, or image-guided, control. These patients are often otherwise healthy. In adults, fiducial markers or a stereotactic frame are placed, and the patient is taken to the radiologic suite for CT/MRI scan to determine stereotactic coordinates before surgery. The patient is then brought to OR with the frame or fiducial markers in place. The tool for removing the stereotactic frame must be readily available in the event of an airway emergency. Biopsies may be accomplished under local anesthesia with MAC or GETA. If a complete resection is planned (e.g., AVM resection), GETA is used.

Suggested Readings

1. Fomenko A, Serletis D: Robotic stereotaxy in cranial neurosurgery: a qualitative systematic review. Neurosurgery 2018; 83(4):642–50.
2. Holloway KL, Gaede SE, Starr PA, et al: Frameless stereotaxy using bone fiducial markers for deep brain stimulation. J Neurosurg 2005; 103(3):404–13.
3. Kemmerer E, Shah S: An update on radiation therapy of brain metastases. Surg Oncol Clin N Am 2017; 26(3):347–55.
4. Risholm P, Golby AJ, Wells W III: Multimodal image registration for preoperative planning and image-guided neurosurgical procedures. Neurosurg Clin N Am 2011; 22(2):197–206, viii.
5. Venkatraghavan L, Manninen P, Mak P, et al: Anesthesia for functional neurosurgery: review of complications. J Neurosurg Anesthesiol 2006; 18(1):64–7.
6. Woodworth GF, McGirt MJ, Samdani A, et al: Frameless image guided stereotactic brain biopsy procedure: diagnostic yield, surgical morbidity, and comparison with

the frame based technique. J Neurosurg 2006; 104(2):233–7.

Suggested Viewing

Links are available online to the following videos:

Endoscopic Pituitary Surgery: https://www.youtube.com/watch?v=D_UQS345C8w

Adenosine for Temporary Flow Arrest During Intracranial Aneurysm Surgery https://www.youtube.com/watch?v=2KkgbtocnNY

Cavernous Malformations of the Brainstem: A Supracerebellar Infratentorial Approach https://www.youtube.com/watch?v=1jl62S2xH6c

Chronic Subdural Hematoma: https://www.youtube.com/watch?v=_ct7S72NzPQ

Neurosurgery: Craniopharyngioma Supra-Orbital Removal: https://www.youtube.com/watch?v=gyVALlTTFQQ

Superficial Temporal Artery Dissection: https://www.youtube.com/watch?v=djL_utmksEI

Surgery for Giant PCOM Aneurysms Video 1: https://www.youtube.com/watch?v=QhJ8NElcLIw

The Middle Fossa Approach and Extended Middle Fossa Approach Video 1 https://www.youtube.com/watch?v=OLgkeJ1u3kw

Intra-operative Real-time Querying of White Matter Tracts: Frameless Stereotactic Neuronavigation https://www.youtube.com/watch?v=KrGkGPR5hs0

Bypass for Complex Basilar Aneurysms: https://www.youtube.com/watch?v=yQu0w4xr1aU

Neuroendoport (SM) Technique—Minimally Invasive Brain Surgery: https://www.youtube.com/watch?v=z6gidGVkzno

Aneurysm Clip Surgery—Middle Cerebral Artery: https://www.youtube.com/watch?v=8vCBMiEgXQg

Fluorescein for Glioma Surgery: https://www.youtube.com/watch?v=uIjTeU6Y6e4

CHAPTER 1.2

Functional Neurosurgery

SURGEONS
Jaimie M. Henderson, MD
Lawrence M. Shuer, MD

ANESTHESIOLOGIST
Richard A. Jaffe, MD, PhD

FUNCTIONAL NEUROSURGERY—INTRODUCTION: THE SURGICAL TREATMENT OF PAIN, MOVEMENT DISORDERS, AND EPILEPSY

INTRODUCTION

Jaimie M. Henderson, MD

Functional neurosurgery differs from most surgical subspecialties in that it aims to alter the function of the nervous system, rather than addressing anatomical abnormalities. The most common treatment areas include chronic pain, epilepsy, and movement disorders. Each of these disease states has a distinctive anesthetic requirement dictated by the specific pathophysiology and subsequent intraoperative objectives. Procedures may be performed under local anesthesia, conscious sedation, or GA and can be divided into ablative (destructive) or augmentative (nondestructive) techniques. Ablative techniques are less frequently performed because of their unpredictable duration of effect and irreversible nature of the lesion. Neuroaugmentation (electrical stimulation or continuous local drug administration) tends to produce more lasting benefits and, more importantly, can be changed to meet fluctuations in the patient's symptoms.

One of the keys to successful functional neurosurgical therapies is target

identification (Fig. 1.2-1). Many targets can be identified anatomically on appropriate radiographic studies, whereas others may be difficult to visualize even with special techniques. However, even areas that can be targeted anatomically may vary in terms of their physiologic function. Thus, it is important to incorporate physiologic testing in many functional neurosurgical procedures. Most physiologic confirmation techniques require that the patient be awake and cooperative during testing. Thus, the need for physiologic identification often dictates a specific anesthetic technique.

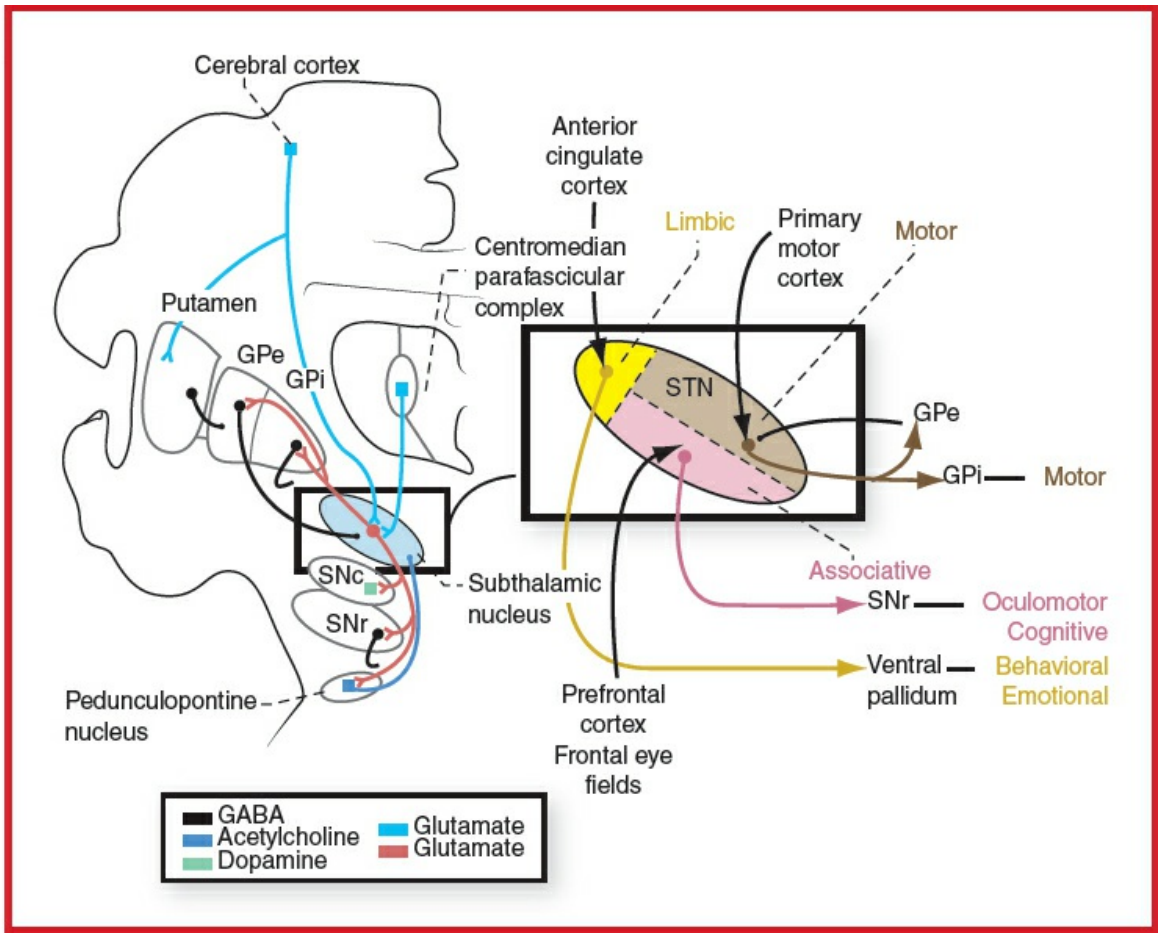

Figure 1.2-1 Topographical anatomy of the ventrolateral thalamus. GPe, external segment of the globus pallidus; GPi, internal segment of the globus pallidus; SNc, substantia nigra pars compacta; SNr, substantia nigra pars reticulata; STN, subthalamic nucleus.

STEREOTACTIC PROCEDURES: DEEP BRAIN STIMULATION, LASER INTERSTITIAL THERMAL THERAPY, AND MR-GUIDED FOCUSED ULTRASOUND

SURGICAL CONSIDERATIONS

Description

Many procedures are currently performed with **frame-based stereotactic techniques**, with intracranial access achieved via a burr hole or twist drill. Recently, the development of **MR-guided focused ultrasound** has allowed precise lesioning of deep brain structures without a cranial opening (see below). There is a growing trend to use "frameless" stereotactic approaches, with two major systems currently in use. Real-time frameless localization can be achieved by replacing the stereotactic frame with rigidly attached skull markers ("fiducials") that provide a fixed reference. Another innovative alternative is to produce a custom-made fixed trajectory guide using rapid prototyping techniques. Both of these approaches have been used successfully and appear to be equivalent in accuracy to a stereotactic frame. Deep brain stimulation (DBS) electrodes and lesioning probes such as lasers can also be placed with real-time guidance in the MRI suite. These procedures are done under GA, with anatomic rather than physiologic target confirmation.

Two approaches to identification of the functional target are used following initial stereotactic CT or MRI radiographic localization; both require patient cooperation. In one approach, the target is confirmed by assessing symptomatic resolution during high-frequency macrostimulation and by identifying surrounding structures using their characteristic stimulation-evoked responses. In the other approach, before stimulation testing, single-neuron recordings are performed to localize the appropriate target through somatotopic kinesthetic and/or somatosensory responses. In an awake patient, appropriate stimulation is delivered to the skin or by passive and active movement of the joints. This technique utilizes specialized high-impedance microelectrodes and amplifiers susceptible to interference from monitoring equipment, which may necessitate manual measurements of BP and clinical assessment of oxygenation. Anesthesia or sedation can modify neuronal activity significantly and, thus, interfere with functional mapping. For example, propofol has been shown to inhibit globus pallidus and subthalamic neurons for several minutes beyond its behavioral effects. In addition, many of these agents have been shown to change evoked potential (EP) responses, raising the possibility that they could alter stimulation thresholds for either the internal capsule or optic tract.

A variety of movement disorders are amenable to surgical treatment. They can be divided into akinetic (e.g., Parkinson's) and hyperkinetic (e.g., dystonias, tremor, spasticity) syndromes. Idiopathic Parkinson disease (PD) is best treated with deep

brain stimulation (DBS) targeted to a functional subcomponent of either the subthalamic nucleus or globus pallidus interna (Fig. 1.2-2). Tremor syndromes are treated by targeting the ventral intermedius (Vim) thalamic nucleus (MR-guided focused ultrasound or stimulation), whereas dystonias are treated by stimulation of the globus pallidus interna. Spasticity is not treated stereotactically but through the administration of intrathecal baclofen (GABA-like synaptic inhibition) in the lumbar cistern via an internalized pump system. Abrupt loss of intrathecal infusion of baclofen, however, can quickly lead to a serious withdrawal syndrome with dysautonomia, circulatory collapse, and death within hours. Spasticity refractory to intrathecal baclofen may be amenable to selective dorsal root rhizotomy performed through an open laminectomy.

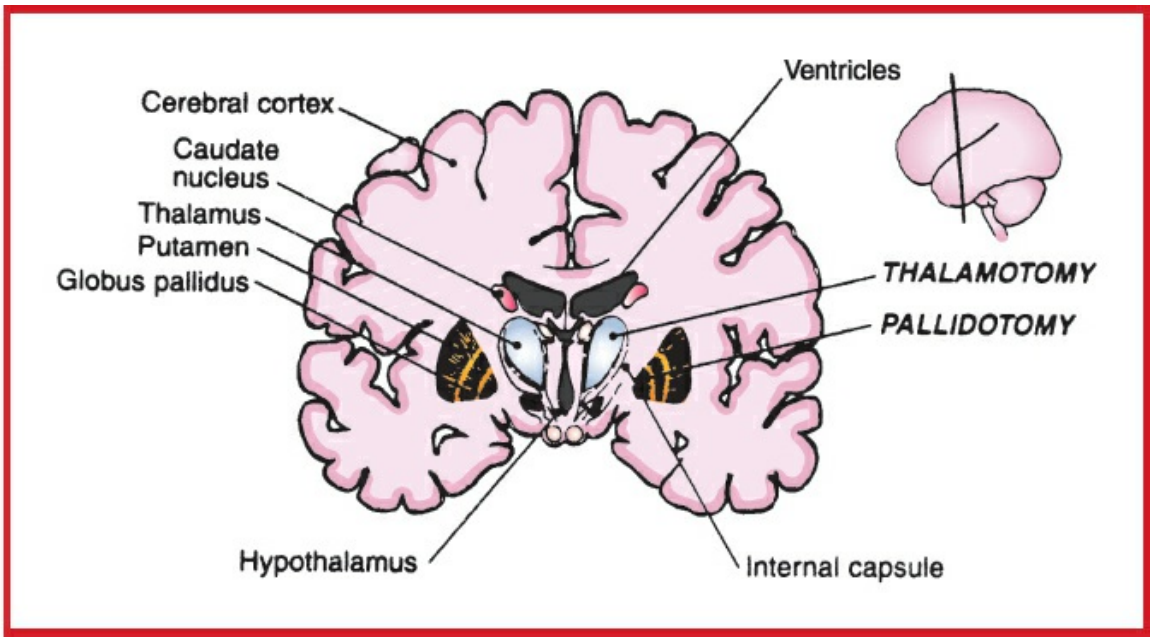

Figure 1.2-2 Anatomical locations for therapeutic lesions (thalamotomy and pallidotomy) for the surgical treatment of Parkinson disease. Inset shows the plane of the coronal section through the diencephalon, identifying the lesions. (Reproduced with permission from Mason LJ, Cojocaru TT, Cole DJ: Surgical intervention and anesthetic management of the patient with Parkinson's disease. In: Jaffe RA, Giffard RG, eds.International Anesthesiology Clinics: Topics in Neuroanesthesia. Little, Brown, Boston: 1996; 4(34):141.)

For DBS, mapping and implantation of the intracranial stimulating electrode is performed under local anesthesia to permit monitoring of behavioral and physiologic responses. A 2- to 3-cm linear incision is placed near the coronal suture and 20–50 mm from the midline. This can be accomplished with local anesthesia under propofol sedation for patient comfort. Subsequently, minimal or no sedation is used, as patient cooperation is necessary during the functional mapping component of the case. If single-neuron recordings are used, propofol should be

discontinued at least 20 min in advance of mapping because it can produce prolonged suppression of target neuronal activity. If analgesia is needed, use a low-dose (0.01–0.05 mcg/kg/min) remifentanil infusion. Local anesthetics should not contain epinephrine. Avoid central-acting β-blockers (e.g., propranolol), which suppress tremor activity in target neurons. Sedation with meperidine in patients taking selegiline is contraindicated. No dopaminergic antagonist (e.g., metoclopramide, droperidol) should be given to parkinsonian patients or patients with dopamine-responsive dystonia. To enhance single-cell responses, withhold medications prescribed for target symptoms for 8–24 h. In some cases (e.g., Parkinson disease), this may result in a rebound HTN requiring active treatment; however, patients will resume their medications postop (often in the postanesthesia recovery area), and the HTN will resolve. Theimplantable pulse generator (IPG) may be placed in an infraclavicular subcutaneous pocket during a separate surgical procedure or at the time of the intracranial electrode implantation. Implantation of the IPG and subcutaneous tunneling of the electrode lead can be done under MAC but is best tolerated under GETA. To facilitate intubation, the calvarial wound is closed temporarily, and the stereotactic localizing apparatus is removed. Closure consists of a single, interrupted suture for stab wounds or two-layer suture/staple closure for a burr hole. IPG pockets are closed in two layers. The subcutaneous layer is closed with absorbable sutures, and the skin is closed with staples or sutures.

MR-guided focused ultrasound is performed in an interventional MRI scanner equipped with an array of several hundred high-intensity ultrasound transducers in a helmet that surrounds the patients head. A stereotactic frame is placed under local anesthetic, following which the patient is placed into the transducer helmet on the scanner table. An elastic membrane allows cooled water to circulate around the head in order to provide a conductive medium for the ultrasound energy. The target in the Vim thalamus is placed at the focal point of the ultrasound array, and a lesion is made by gradually increasing the ultrasound energy over a number of 10- to 20-second sonications. Temperature is monitored in real time using MR thermography, and the patient is frequently evaluated during the procedure for side effects and reduction of tremor. Patients frequently experience near-complete tremor relief immediately following the procedure, with an average reduction in tremor over the long term of ~50%.

Usual preop diagnosis

Medically intractable idiopathic PD with disablingL-dopa-induced dyskinesia, bradykinesia, or rigidity; severe fluctuations in medication responses; dystonia

musculorum deformans; post-CVA dystonia; occasionally, torticollis; tremor; movement disorders

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include continuing chronic pain and other medications (Parkinson medications typically held), limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. See Appendix K: Enhanced Recovery After Surgery, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Linear (burr holes); stab wound (twist drill)
Unique considerations	Minimal/no sedation. BP ↑ in patients who have their antihypertensive medications withheld. Manual vital sign monitoring if electronic monitors interfere with single-cell recordings. Be aware that BP cuff or iv's may produce sensations that distract the patient during awake stimulation testing for sensory side effects.
Antibiotics + other meds	Cefazolin 2 g iv (30–60 min before incision)
Surgical time	3–5 h
EBL	25–150 mL
Postop care	Continue antibiotics at surgeon's discretion, Parkinson medications. BP may ↓. Maintain MAP < 90 mm Hg to prevent postop bleeding. PACU
Mortality	<0.5%
Morbidity	Overall: 8–27% Infection: <10% Hardware failure: Rare Intracranial hemorrhage: 3.3–6% Cognitive disturbances
Pain score	2–3

PATIENT POPULATION CHARACTERISTICS	
Age range	12–80 yr; PD: 45–60 yr at onset
Male:Female	PD: M > F
Incidence	PD: 1% > 60 yr; 4% > 80 yr
Etiology	Idiopathic; genetic (10–15% will have a 1st- or 2nd-degree relative with PD)
Associated conditions	Dystonia; PD: cognitive impairment, depression, dysphagia, orthostatic hypotension

ANESTHETIC CONSIDERATIONS

Parkinson disease (PD) is the most common movement disorder, affecting ~1% of the population >60 yr. It is the result of the loss of dopaminergic neurons in the basal ganglia → ↓ dopamine (dopamine/acetylcholine imbalance) in basal ganglia → movement disorder. Medical treatment is directed primarily to restoring dopamine levels by increasing the availability of the dopamine precursor (L-dopa), by inhibiting liver dopa decarboxylase (carbidopa, usually given in combination with L-dopa as Sinemet), by releasing endogenous dopamine (amantadine [Symmetrel]), and by blocking MAO-B (selegiline [Eldepryl], rasagiline [Azilect]). Medical treatment also may include dopamine agonists (pergolide [Permax], bromocriptine [Parlodel]) and acetylcholine antagonists (amantadine [Symmetrel], benztropine [Cogentin]) to correct the dopamine/acetylcholine imbalance. Patients presenting for surgery usually have failed medical therapy. They will have been taken off their antiparkinsonian medications 8–24 h before surgery. This will maximize their symptoms to help assess treatment effects intraop; thus, preop assessment on the day of surgery may be difficult.

PREOPERATIVE

Respiratory	Autonomic dysfunction → esophageal dysfunction →↑ risk of aspiration. Patients typically have ↓ vital capacity 2° rigidity, dyskinesia →↓ respiratory function, and ↓ cough. Laryngospasm and respiratory failure may occur following abrupt withdrawal of antiparkinsonian medications. **Tests:** CXR; consider ABG; PFTs may be difficult to obtain.

Cardiovascular	Autonomic dysfunction → orthostatic hypotension. Dopamine replacement therapy → cardiac dysrhythmias, ↓ BP, and hypovolemia. In patients taking selegiline (MAOI): avoid meperidine →↑↑ BP, rigidity, agitation; sympathomimetics → exaggerated ↑ BP.
Neurologic	The primary Sx of Parkinson disease includes rigidity, tremor, bradykinesia, and muscle weakness. Secondary symptoms include dementia, depression, and speech difficulty. Patients may alternate between a state of immobility and one of exaggerated tremor (which may interfere with intraop monitoring). PD medications are sedating—modafinil may be used to improve daytime function.
Renal	Urinary retention is common.
Gastrointestinal	Autonomic dysfunction → gastroparesis, ↑ incidence of reflux. Poor nutrition. Pharyngeal muscle dysfunction → dysphagia.
Laboratory	As indicated from H&P.
Premedication	None. These patients may have received small doses of fentanyl and/or midazolam to facilitate placement of the stereotactic frame. For frameless procedures, fiducial markers or mounting screws will have been placed before surgery using local anesthesia.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water if tolerated by the patient.

INTRAOPERATIVE

Anesthetic technique

MAC, with minimal sedation limited to surgical opening and closing, as patient cooperation and typical neuronal activity are essential for intraop mapping and neurologic examination. The surgeon should have generously infiltrated the incision sites with local anesthetic.

Induction	Low-dose propofol (25–75 mcg/kg/min), or dexmedetomidine (0.1–0.4 mcg/kg/h), may be used for sedation during burr-hole placement. If propofol or dex is used, it should be discontinued 20 min before electrophysiologic recording or mapping. In the event of an airway emergency in framed procedures, a means of releasing the patient from the stereotactic frame must be readily available.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia. Avoid hypothermia. Surgeon will place scalp field blocks.	
Maintenance	BP control is essential to ↓ the risk of intracranial hemorrhage during passage of the recording and stimulating electrodes. If not otherwise contraindicated, MAP should be kept ~20% below normal for that patient. This usually can be accomplished without an arterial line by using an infusion of NTG and/or esmolol titrated to effect or by using small doses of atenolol (0.5–1 mg increments iv). Esmolol and atenolol are preferred over other parenteral β-blockers because CNS penetration is limited → minimal effect on central tremor.	
Emergence	Postop BP control can be continued by using atenolol or labetalol titrated to effect at the end of the procedure. The patient is usually transported to the PACU and then to the neurology ward for postop monitoring. Antiparkinsonian medication should be given in the PACU and may result in ↓ BP. Consider iv acetaminophen if po dose not given or given >4–6 h ago.	
Blood and fluid requirements	Minimal blood loss IV: 18–20 ga × 1 BSS @ 1–3 mL/kg/h	For unilateral procedures, iv should be placed in the ipsilateral arm (relative to side of surgery). Zero balance or goal-directed fluid management is

		recommended.
Monitoring	Standard monitors VAE monitoring if head is significantly elevated (≥30°)	Exaggerated tremors and/or neurologic testing in these patients may interfere with monitoring. It may be helpful to place the BP cuff on a leg (less tremor). For unilateral procedures, monitors should be placed on the ipsilateral arm and leg.
Positioning	✓ and pad pressure points ✓ stereotactic frame clearance	Patient comfort may be improved by placing pillows under the knees to relieve lower back strain. A massage therapist can greatly improve patient comfort during the procedure.
Complications	Intracerebral hemorrhage Loss of airway in stereotactic frame VAE	Dx: ↓ mental status and hemiparesis. CT scan usually required to confirm Dx. Emergency craniotomy may be necessary. Rx: may require rapid removal of the stereotactic frame. Sx: cough, pleuritic chest pain, ↓BP, ↑HR.

POSTOPERATIVE

Complications	Intracranial hemorrhage Motor deficit Visual field deficit	Intracranial hemorrhage may require emergency craniotomy. The surgeon

	Aphasia	should be notified immediately if any new deficits are noted.
Tests	None	Unless otherwise indicated.
Multimodal pain management	Usually not necessary Acetaminophen 1 g iv ± Fentanyl 25–50 mcg prn	Acetaminophen po if not given preop or if 4–6 h has elapsed since previous dose.
ERAS	Ondansetron 4 mg iv (no metoclopramide)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Balachandran R, Mitchell JE, Dawant BM, et al: Accuracy evaluation o microtargeting platforms for deep-brain stimulation using virtual targets. IEEE Trans Biomed Eng 2009; 56(1):37–44.
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SURGICAL ANALGESICS: SPINAL CORD STIMULATION, INTRATHECAL PUMPS, AND CORTICAL STIMULATION

SURGICAL CONSIDERATIONS

Description

Chronic pain arises from a variety of etiologies. It can involve both neuropathic and nociceptive processes and occur in a variety of anatomical distributions (e.g., radicular versus a hemibody pattern). Therapeutic interventions are dictated by the pathophysiology of the pain, its qualitative nature, etiology, and the patient's prognosis. Many common procedures for chronic pain are directed at the spinal cord and may consist of epidural or intrathecal medications or electrical stimulation.

For chronic spinal cord stimulation (e.g., postlaminectomy syndrome), an epidural electrode is implanted either percutaneously or via an open laminectomy. Percutaneous electrodes are easier to implant and have less associated surgical pain. The surgical electrode (implanted via laminectomy) confers greater mechanical stability in the epidural space. In addition, given its larger contact size, it can generate higher current densities with less drain on the implanted system. For percutaneous electrodes, a small skin incision is made two to three vertebral levels caudal to the target region of the spinal cord. For "surgical paddle" electrodes, the skin incision is made one to two levels caudal to the target zone of the spinal cord, and a laminectomy is performed to provide access to the epidural space. Incisions are closed in the standard fashion.

Most percutaneous electrode placements and some paddle electrode placements are done awake so that intraoperative test stimulation can be performed. The procedures are done in the prone or lateral position with consequent implications for airway management in the sedated patient. Localization of the electrodes is

accomplished initially based on radiographic criteria; however, these localizations are only approximate, and it is recommended that the electrode placement be confirmed by intraop stimulation. The patient needs to be sufficiently alert to communicate the quality, distribution, and intensity of the stimulation-induced paresthesias. Surgical paddle placement requires a variable extent of muscle dissection and laminectomy, which may be done under general anesthesia or with epidural anesthesia for patient comfort. If done under general anesthesia, response to paddle test stimulation may be measured by manual palpation of musculature stimulated at higher test voltage and/or using intraoperative electrophysiologic monitoring. To assess efficacy, the electrode may be externalized and percutaneous stimulation used for assessment. If there is ≥50% reduction in pain, the patient may return to the OR for internalization of the implantable pulse generator (IPG). Postop, these patients can have an exacerbation of pain particularly if neuropathic in nature. They may require iv lidocaine or ketamine infusions to return them to their preop baseline, even with a functioning and appropriately located stimulating electrode.

For pain of central origin (e.g., post stroke, multiple sclerosis, and trigeminal nerve pathology), surgical procedures are often directed at the thalamus and cortex. Thalamic interventions include stereotactic insertion of stimulating electrodes into sensory thalamus. Thalamic DBS requires awake mapping of the somatotopic representation of the affected body part through either microelectrode mapping or stimulation-induced paresthesias. For medically intractable neuropathic pain syndromes, epidural motor cortex stimulation has shown mixed results. Functional mapping of the motor cortex for epidural stimulation can be done with anatomical and physiologic mapping under GA via a craniotomy, with the anesthetic tailored to minimize interference with EP recording. The incision consists of a 5- to 10-cm linear or 5 × 10-cm trapezoidal incision placed over and paralleling the motor cortex.

Identification of the appropriate location on the motor strip can be done initially with epidural mapping using SSEPs elicited from the part of the body where the pain originates. In cases of denervation syndromes, SSEP may not be present, and the minimum intensity point for epidural stimulation–induced movements is used. In rare cases, the surgeon may elect to perform the surgery awake to facilitate mapping. To assess efficacy, the electrode may be externalized and percutaneous stimulation assessed for overall therapeutic efficacy. If there is ≥50% reduction in pain, the patient will return to the OR for internalization of the IPG. Closure consists of calvarial reconstruction with externalization of leads. The craniotomy

incision is closed in the standard fashion. If a percutaneous trial is done, the IPG implant requires a second GETA with reopening of wounds.

The mainstay of surgical treatment of trigeminal neuralgia is microvascular decompression of the trigeminal nerve in the prepontine cistern. In patients who are poor surgical candidates, treatment is accomplished with ablative procedures aimed at the gasserian ganglion, using chemolytic, mechanical, or RF techniques. Patients who fail gasserian ganglion interventions or have atypical facial pain may be candidates for thalamic DBS or motor cortex stimulation. Stereotactic radiosurgical techniques are increasingly utilized as an ablative treatment for trigeminal neuralgia, particularly in the elderly (>65 yr old) population or in other surgically averse candidates. Radiosurgery employs highly focused beams of radiation to partially ablate the intracisternal portion of the trigeminal nerve while sparing surrounding structures (brain stem and other cranial nerves). The downside to radiosurgery is that the effects and consequent pain relief may take weeks to months to manifest, as opposed to other surgical and ablative treatments whose effects are immediate.

For pain unresponsive to spinal cord stimulation or because of unacceptable side effects of parental medications, continuous intrathecal administration of analgesics can be accomplished with an implantable medication delivery system. An incision is made over the L3-L4, L4-L5, or L5-S1 spinous process and a second incision is placed in the RLQ of the abdomen. An intrathecal catheter is then placed and anchored to the lumbodorsal fascia. A tunneling tool is used to bring the catheter from the lumbar spinal region to the abdomen. This tunneling procedure is rarely tolerated without GETA or deep sedation. A reservoir or continuous-delivery pump is then placed in the abdomen and attached to the catheter. Both incisions are closed in two layers.

Intrathecal narcotics (typically morphine) can produce satisfactory results because therapeutic drug concentrations can be achieved at the level of spinal opiate receptors without influencing higher CNS opiate systems. This therapeutic intervention can be assessed through a percutaneous catheter trial. Patients who experience ≥50% reduction in pain are candidates for a totally implanted pump system. These are low-morbidity procedures (5–10%) with infections and hardware failures constituting the greatest problems. Abrupt cessation of medications—through either patient noncompliance with refill schedules (10–12 wk) or hardware failure—however, can lead to a serious withdrawal syndrome.

Usual preop diagnosis

Chronic pain

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include continuing chronic pain and AED meds, limiting NPO duration alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Prone/lateral
Incision	2–3 levels above target area (spinal cord stimulation) + laminectomy; L3, L4, L5 (intrathecal pump) + 2nd incision RLQ of the abdomen
Unique considerations	Patient communication important; therefore, avoid over sedation. Copious use of local anesthetics (avoid overdosing)
Antibiotics	Cefazolin 2 g iv (30–60 min before incision)
Surgical time	1.5–3 h
EBL	25 mL
Postop care	May have ↑ pain during recovery period
Mortality	<0.5%
Morbidity	Overall: 5–10% Infection Hardware failure Withdrawal Sx
Pain score	3–8

PATIENT POPULATION CHARACTERISTICS	
Age range	20–75 yr
Male:Female	1:1
Incidence	Common
Etiology	Iatrogenic; neuropathic; traumatic

Associated conditions	Opiate dependency

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients with chronic pain often present unique challenges to the anesthesiologist and surgeon. They may be intolerant of any additional pain (e.g., iv placement, positioning on the OR table, postop pain) and seemingly immune to typical doses of systemic analgesics while remaining vulnerable to respiratory depression. In most cases, patients should continue their usual pain medications and co-analgesics until ~2 h before surgery. Typically any transdermal fentanyl patch should be left in place unless its location will be subject to intraop heating, compression, or other manipulation. A detailed h/o of patient pain, effective (and ineffective) pain management techniques and drugs, and the current medication regime (including the use of both over-the-counter and under-the-counter drugs and herbals) is essential.

Respiratory	Chronic pain → ↓ physical activity → ↓ respiratory reserve.
Cardiovascular	Ventricular dysrhythmias have been associated with methadone at doses >200 mg/d. Chronic pain → ↓ physical activity → ↓ cardiovascular reserve.
Neurologic	A careful neurologic assessment is essential to detect preexisting deficits.
Psychological	These patients often benefit from a detailed explanation of the surgical and anesthetic procedures including expectations and contingency plans for intraop pain management if an awake procedure is planned. These patients may have a higher incidence of coexisting psychiatric disease and often have high scores on standardized measures of hysteria and hypochondria. Patients on serotonergic drugs or antipsychotic medication may develop serotonin syndrome or neuroleptic malignant syndrome (hyperthermia, muscle rigidity, encephalopathy, autonomic dysfunction).

Gastrointestinal	Chronic opioid use may →↓ gastric emptying and ↓ GI motility with chronic constipation. Inactivity 2° chronic pain → obesity.
Laboratory	As indicated from H&P. For patients on anticonvulsants, drug levels are useful to exclude toxic effects.
Premedication	Chronic opioid use may make the patients at risk for gastric aspiration 2° ↓ bowel motility. Consider metoclopramide 10–20 mg iv 30-min preinduction with Na citrate 30 mL po on transport to the OR. Midazolam iv titrated to effect can be beneficial.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water.

INTRAOPERATIVE

Anesthetic technique

The placement of epidural electrodes, intrathecal cannulae, and cortical stimulators is often best accomplished under GA using anesthetic techniques appropriate for spinal or intracranial procedures. Accurate electrode placement may require an awake patient during at least a portion of the procedure. For intracranial electrode placement, see the anesthetic technique for awake craniotomy. These same general principles can also be used for spinal cord electrode placement, although regional techniques are usually simpler and just as effective. The following description pertains to the placement of electrodes for spinal cord stimulation.

Thoracic epidural	Following the application of standard monitors and with an iv catheter in place, the patient should be seated carefully on the edge of the operating table. Provide support for feet and arms as necessary. The epidural injection should be at the level of the surgery (usually 2–3 levels below the electrode target site). A single bolus injection of 8–10 mL of 0.75% bupivacaine usually provides excellent surgical anesthesia without compromising the ability

	to map the more rostral portion of the spinal cord. It is important to avoid over sedation and to minimize the use of systemic analgesics in order to ensure patient cooperation with accurate spinal cord mapping.	
Blood and fluid requirements	IV: 18 ga × 1 BSS @ 1–3 mL/kg/h	Zero balance or goal-directed fluid management is recommended. Recommend zero balance fluid management (see Appendix K, p. K-2).
Monitoring	Standard monitors	
Positioning	Prone ✓ and pad pressure points ✓ eyes	The patient should self-position on bolsters (hips and upper chest) or Wilson frame.
Complications	Spinal cord injury Serotonin syndrome (SS) vs. neuroleptic malignant syndrome (NMS)	 May be precipitated by meperidine, droperidol, metoclopramide, oxycodone among others. Ddx can be difficult. Dantrolene may be effective for NMS but not for SS.

POSTOPERATIVE

Complications	Spinal cord injury Epidural hematoma Respiratory distress Drug withdrawal symptoms	Prompt postop neurologic assessment is essential. May occur in response to the patient's usual opiate dose if the spinal stimulation has produced

		significant pain relief.
Tests	None unless otherwise indicated	Surgeons may request specific tests.
Multimodal pain management	Typically complex and multimodal	Patient often intolerant of postop pain while remaining susceptible to narcotic overdose.
	Acetaminophen 1 g iv	Acute pain service consult recommended.
	± Fentanyl 25–50 mcg prn	If not given preop or if 4–6 h has elapsed since previous dose.
	Reinforce scalp blocks	0.5% bupivacaine with epi is as effective as liposomal bupivacaine.
ERAS	Ondansetron 4 mg iv	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Aaronson ST, Sears P, Ruvuna F, et al: A 5-year observational study of patients with treatment-resistant depression treated with vagus nerve stimulation or treatment as usual: comparison of response, remission, and suicidality. Am J Psychiatry 2017; 174(7):640–8.
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VAGUS NERVE STIMULATION

SURGICAL CONSIDERATIONS

Description

The surgical treatment of medically intractable epilepsy consists of either **surgical resection** of the epileptic site or **vagus nerve stimulation (VNS)**. For patients who are not candidates for resective surgery, VNS can be a viable surgical strategy. Although it is a low-morbidity procedure, its efficacy also is low. VNS tends to produce a 50% or greater reduction of Sz in ~48% of patients after 18 mo of stimulation. By contrast, **temporal lobectomy** (often with amygdalohippocampectomy) for patients with medial temporal lobe epilepsy has an 80–85% chance of seizure freedom in carefully selected patients whose seizures are refractory to medications. Surgery for **extra temporal epilepsy** originating in neocortex has a 50% chance of making the patient seizure free, in the absence of a structural lesion. (If an anatomical abnormality is present, then that figure increases to ~75%.) In general, the complication rate is ~7%, dependent on the exact location of the Sz focus and its relationship to eloquent cortex (Fig. 1.2-3).

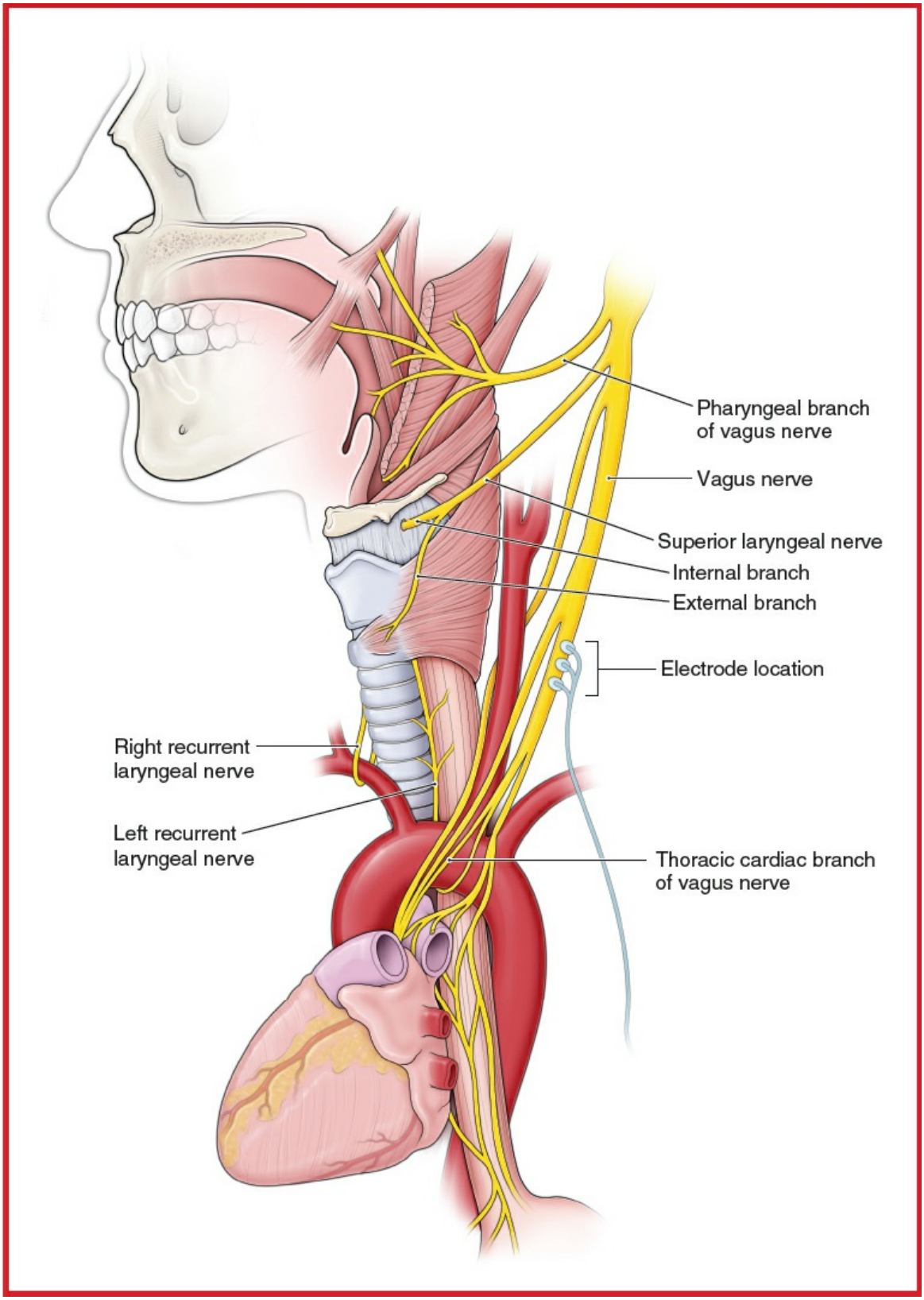

Figure 1.2-3 Surgical anatomy for placement of vagal nerve stimulator electrodes.

Left vagus nerve stimulation is also used to treat some types of medically refractory depression. As with its use in epilepsy, the exact mechanism of action

remains unclear.

Two incisions are used for VNS: one left anterior cervical, placed approximately at the C6-C7 level, with a second incision in the left infraclavicular region for placement of the implantable pulse generator (IPG). Most surgeons perform the procedure through a carotid-type incision and place the IPG caudally through blunt dissection. The left vagus nerve is isolated, and the electrode assembly is wrapped around the nerve below the origin of the superior and inferior cervical cardiac branches. During surgery, the interface between the vagus nerve and the electrode is tested with electrical stimulation. Fortunately, this is associated with a very low incidence of bradycardia and extremely rare reports of asystole. All resolve with cessation of stimulation and administration of atropine. The surgeon should inform the anesthesiologist when vagus stimulation is about to begin. The incisions are closed using the standard technique; however, because many patients are developmentally delayed, the final skin layer is often closed with a subcutaneous technique that does not require subsequent suture removal.

Usual preop diagnosis

Partial-onset seizures refractory to medication; chronic or recurrent depression refractory to other medical treatment

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include continuing chronic pain and AED meds, limiting NPO duration alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Anterior cervical (C6-C7) + infraclavicular pocket (for IPG)
Unique considerations	Possible bradycardia → asystole during stimulation testing
Antibiotics	Cefazolin 2 g iv (30–60 min before incision)
Surgical time	1.5 h
EBL	<50 mL
Postop care	Observe for ↑ Sz activity postop × 8 h

Mortality	<0.5%
Morbidity	Hoarseness: ~50%, may be 2° vagal nerve injury or fatigue, device malfunction Cough: ~40% in first 3 mo after surgery Infection: 2% Dysphagia during stimulation →↑ aspiration risk Dyspnea during stimulation; patients with OSA may have ↑ apneic events Nerve/vascular injury (similar to carotid surgery)
Pain score	1–2

PATIENT POPULATION CHARACTERISTICS

Age range	12–80 yr (≥18 yr for treatment of depression)
Male:Female	1:1
Incidence	20–40% of epilepsy patients are medically refractory
Etiology	Idiopathic, typically
Associated conditions	Developmental delay; severe depression

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Antiepileptic medications can control seizure disorders in most (~70%) patients, but some develop intolerable side effects; others are refractory to medical therapy. Surgical resection of the Sz focus may be the only effective therapy for some patients. For patients who are not candidates for surgical resections, the placement of a vagus nerve stimulator may be a viable alternative. These patients typically take multiple antiepileptic medications that should be continued throughout the morning of surgery. These same general considerations are also applicable to patients with refractory depression.

Neurologic	The only common neurologic finding in epilepsy patients is a Hx of uncontrollable Sz, either focal or generalized. Obtain a description of Sz and any

	prodromal Sx.
Psychiatric	Medications used to treat depression (e.g., MAOIs, SSRIs) may have significant interactions with other drugs (e.g., meperidine → serotonin syndrome). Antiepileptic medications may have additive effects with anesthetics and significantly alter the pharmacodynamics of other drugs (e.g., ↓ duration of NMB).
Gastrointestinal	Abnormal liver function may be associated with use of valproate and carbamazepine. **Tests:** LFT and others as indicated from H&P
Hematologic	Phenytoin/phenobarbital →↓Hct; carbamazepine/valproate/ethosuximide/primidone → ↓ Plt; carbamazepine/primidone → ↓ WBC. **Tests:** CBC and others as indicated from H&P
Laboratory	Tests as indicated from H&P
Premedication	Standard premedication is usually appropriate.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water.

INTRAOPERATIVE

Anesthetic technique

GETA: Chronic use of antiepileptic medications may cause hepatic enzyme induction → accelerated drug metabolism; resistance to muscle relaxants including succinylcholine.

Induction	Standard induction. Once anesthesia is induced, a nondepolarizing NMR is administered.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia. Avoid hypothermia. Consider preincision placement of scalp blocks for open procedures.
Maintenance	Standard maintenance. Generally, no further NMBs

	are administered beyond those used for tracheal intubation. Hyperventilation may promote Sz activity. Sevoflurane and enflurane can induce epileptiform EEG activity.	
Emergence	No special considerations. Prophylactic antiemetic (e.g., ondansetron 4 mg) should be given 30–60 min before extubation. For open procedures, consider scalp block placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >4–6 h ago.	
Blood and fluid requirements	Minimal blood loss IV: 18 ga BSS @ 4–6 mL/kg/h	Possibility of injury to carotid artery or jugular vein may result in significant blood loss. Zero balance or goal-directed fluid management is recommended.
Monitoring	Standard monitors EEG monitoring not necessary	O_2 sat and $ETCO_2$ monitoring will indicate the adequacy of ventilation and oxygenation.
Positioning	✓ and pad pressure points ✓ eyes	Head turned to the right with neck extension.
Complications	Asystole	Rarely (<1%), the SA node is innervated by the left vagus nerve. In those patients, vagal stimulation may result in severe bradycardia or asystole. Rx: stop stimulation; atropine 0.5 mg iv ± CPR.
	Bronchospasm	Bronchospasm may occur

	Sz Vascular injury	as a result at vagal nerve stimulation.

POSTOPERATIVE

Complications	Seizure Vocal cord paralysis Hoarseness Peritracheal hematoma	Sz precautions may be necessary. Monitor carefully for altered mental status. Airway obstruction may occur.
Multimodal pain management	Usually mild discomfort Acetaminophen 1 g iv ± Fentanyl 25–50 mcg prn Reinforce scalp blocks	Rx: If not given preop or if 4–6 h has elapsed since previous dose. 0.5% bupivacaine with epi is as effective as liposomal bupivacaine.
Tests	No routine tests	
ERAS	Ondansetron 4 mg iv	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Aaronson ST, Sears P, Ruvuna F, et al: A 5-year observational study of patients with treatment-resistant depression treated with vagus nerve stimulation or treatment as usual: comparison of response, remission, and suicidality. Am J Psychiatry 2017; 174(7):640–8.
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EPILEPSY SURGERY

SURGICAL CONSIDERATIONS

Lawrence M. Shuer

Description

In the United States, the prevalence of epilepsy is ~5–20/1,000 (0.5–2%), meaning that at least 1.5 million people have epilepsy. In childhood, the incidence and prevalence are higher, with 90% of all new cases occurring before the age of 20. Intractable epilepsy is defined as persistent seizure activity of such frequency or severity that it prevents normal function and/or development. This diagnosis is made only after an adequate trial of anticonvulsant medication(s), with therapeutic levels, has been documented. Of all those with epilepsy, 10–20% prove to be intractable; it is estimated that ~20–30% of patients with intractable epilepsy may benefit from a surgical procedure.

The causes of epilepsy are varied, ranging from idiopathic to neoplastic. Epilepsy surgery is most beneficial in patients with partial epilepsy 2° a structural lesion. Most commonly, this lesion is located in the temporal lobe, and the most common operation is a temporal lobectomy, in both children and adults. Cerebral dominance and, hence, the location of speech may be determined using a preop Wada test (intracarotid amobarbital or other anesthetic injection to localize language function). Functional MRI mapping of speech centers is replacing this invasive test at many centers. Studies to define the epileptogenic focus include simultaneous recordings of video/EEG and high-resolution MRI and PET scans. Temporal lobe surgery may involve removal of only the structural lesion and associated epileptogenic cortex, cortical resection alone, excision of the amygdala and hippocampus, or removal of the entire anterior temporal lobe, with the extent of posterior resection dependent on dominance. Depending on the local protocol, intraop electrocorticography may be used, requiring modification of the anesthetic

technique. In addition, the speech center may need to be identified intraop, necessitating an awake procedure. These differing options will significantly alter the choice of anesthesia and must be established before surgery.

For a standard temporal lobectomy, the patient is placed supine on the operating table with the head turned 90° and held with pin fixation. A "question mark" temporal incision is often used, and hemostasis is achieved with skin clips. A flap—either a free temporal bone flap or an osteoplastic flap, based on the temporalis muscle—is elevated with a high-speed craniotome. A subtemporal craniectomy allows visualization of the entire anterior temporal lobe. The dura is opened, widely exposing the anterior 6–6.5 cm of the temporal lobe. Labbé vein must be preserved. At this point, surface and/or depth electrocorticography may be employed, and inhalation anesthetics must not be used. After mapping the lesion, amygdala and hippocampus or anterior temporal lobe is removed. Temporal lobectomy involves resection of both the lateral and medial temporal structures and is commonly performed in two steps. Often an operating microscope will be used to completely resect medial structures, including the uncus and hippocampal formation. Injury to the brain stem, 3rd and 4th cranial nerves, and either the middle cerebral or posterior cerebral arteries can occur; these are known complications of this surgery. Closure of the dura, bone flap, and scalp concludes the surgery.

Variant procedure or approaches

There are several variant procedures. The first is sectioning of the corpus callosum, known as a **corpus callosotomy**. This is commonly used for patients with atonic seizures or partial seizures with secondary generalization. Either the anterior two-thirds or the entire corpus callosum is divided in the midline. The approach is the same as any transcallosal, intraventricular procedure and uses a bifrontal, paramedian scalp incision and elevation of free-bone flap adjacent to the midline in the region of the coronal suture. Injury to the sagittal sinus is possible and may result in massive VAE or hemorrhage. In addition, numerous bridging veins across the interhemispheric fissure must be preserved to avoid venous congestion and possible infarction. The right cerebral hemisphere is gently retracted from the falx, exposing the paired anterior cerebral arteries and underlying corpus callosum. If an anterior two-thirds transection is performed, an intraop x-ray is required to determine the posterior border.

The second variant involves a frontal, temporal, or occipital craniotomy for resection of a structural epileptogenic focus, such as a tumor or AVM. This procedure may use stereotaxic localization, and the resultant craniotomy may be

performed with image guidance or in a stereotaxic head frame, which affects the method of intubation. The subsequent craniotomy is similar to the excision of any structural lesion, with the exception of intraoperative electrocorticography of surrounding cortex, which if used will affect the choice of anesthetic.

The third variant is most common and consists of a diagnostic procedure involving placement of surface and/or depth electrodes. This may be performed with stereotaxic localization and robotic assistance. Often only burr holes, outlining the future craniotomy flap, are used. After placement, the electrodes are externalized, and postop, the patient's naturally occurring seizures are recorded, in conjunction with video monitoring, to register the clinical presentation with the onset of ictal activity. This recording/observation period may last for several days. The patient is then returned to the OR and the epileptogenic focus resected as described earlier.

The fourth alternative is selective amygdalohippocampectomy, a variation of the standard anterior temporal lobectomy. In this procedure, the surgeon makes a cortical incision in the anterior temporal lobe and exposes and resects the amygdala and hippocampus, sparing the remaining portions of the temporal lobe. This procedure is sometimes used on the dominant side of the brain in an effort to lower the risk of postop speech and language dysfunction.

Stereotactic laser ablation (laser interstitial thermotherapy [LiTT]) is a recent alternative to amygdalohippocampectomy. In this procedure, a 1.65-mm laser catheter/applicator (Visualase®, Medtronic) is introduced stereotactically through a small (3.2-mm) burr hole under general anesthesia in the OR or MRI suite. The patient is then repositioned and moved into the MRI scanner where the laser applicator is advance to target. Thermal ablation is then performed under direct MR thermography visualization. The laser tip may be repeatedly repositioned to treat larger tissue volumes. This technique has the advantages of being minimally invasive and allowing the lateral temporal structures to remain unharmed, thus further decreasing the risk of speech and language dysfunction and other lateral temporal lobe functions. Once ablation is complete, the laser catheter/applicator is removed, the incision is closed (usually with a single suture), and the patient is moved from the scanner, awakened and extubated.

Another option is responsive neurostimulation (RNS): In this procedure, electrodes are stereotactically placed in the seizure-onset zone(s) in the hippocampus or cortex and connected to a battery operated module implanted in the skull. When the neurostimulator module senses preseizure activity, it delivers an electrical

stimulus intended to disrupt the development of that seizure. This technique is particularly useful for bilateral seizure foci or for foci located in eloquent brain areas. Long-term efficacy appears to be comparable to other modalities and with minimal side effects.

Usual preop diagnosis

Temporal lobe epilepsy; partial epilepsy; intractable epilepsy

ERAS: Preop counseling by the surgeon/anesthesiologist should include continuing chronic pain and AED meds, limiting NPO duration, alcohol and smoking cessation review of nutritional status, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine, occasionally prone for occipital lesions; table turned 180°
Incision	Temporal question mark, reverse question mark, paramedian, frontal, or occipital
Special instrumentation	Operating microscope; Cavitron; bipolar cautery; surface electrode grids and strips; depth electrode
Unique considerations	Electrocorticography requiring awake craniotomy; awake procedures for mapping of temporal and/or frontal speech areas; stereotaxic craniotomy for lesion resection
Antibiotics	Cefazolin 2 g iv (30–60 min before incision)
Surgical time	3 h
EBL	Minimal for diagnostic procedures; 250–500 mL with craniotomy (adults)
Postop care	After craniotomy, ICU for 12–24 h
Mortality	<1%
Morbidity	Hemiplegia Dysphasia Ophthalmoplegia Brain stem injury

Pain score	2–4

PATIENT POPULATION CHARACTERISTICS

Age range	New-onset Sz: pediatric (<2 yr) and geriatric (>65 yr) populations most commonly
Male:Female	1:1
Incidence	200,000/yr (new cases of epilepsy): ~10% eventually present for surgery per year
Etiology	Idiopathic (mesial temporal sclerosis); infectious (brain abscess, encephalitis); traumatic (glial scar); vascular (AVM, infarct); neoplastic (glioma, hamartoma, ganglioglioma); congenital (cortical dysplasia)
Associated conditions	Tuberous sclerosis; Sturge-Weber syndrome; infantile hemiplegia; encephalitis; hemimegalencephaly; infections; tumors; trauma

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Epilepsy is a common neurologic disorder among young adults. Antiepileptic medications will abolish seizure disorders in many patients, but some develop intolerable side effects to such medications; others are refractory to any medical therapy. Surgical ablation of the seizure focus may be the only effective therapy for these patients. Several operations may be done, the most common being placement of surface or depth electrodes to determine the focus of the Sz, with subsequent temporal lobectomy or amygdalohippocampectomy for removal of the focus. In some cases, the lesion may be very focal and amenable to stereotactic localization and removal. At some centers, both seizure mapping and resection are carried out during the course of an awake craniotomy. If wake-up testing is planned, the procedure should be explained to the patient in detail, including what the patient can expect to hear and feel during the test. More recently, less invasive procedures (stereotactic laser ablation and responsive neurostimulation) have been shown to be beneficial in select patient populations.

Neurologic	Usually the only neurologic finding is a Hx of uncontrollable seizures, either partial or generalized.

	Obtain a description of Sz and any prodromal Sx. Sz medications should be continued through the morning of surgery. Antiepileptic medications may have additive effects with anesthetics and significantly alter the pharmacodynamics of other drugs (e.g., ↓duration of NMB). **Tests:** Preop fMRI mapping and/or a Wada test (intracarotid injection of anesthetic) is performed to determine whether the area of proposed surgery has any cerebral dominance or speech function.
Gastrointestinal	Abnormal liver function may be associated with valproate and carbamazepine use. Vomiting is associated with levetiracetam. **Tests:** LFT and others as indicated from H&P
Hematologic	Phenytoin/phenobarbital →↓ Hct Carbamazepine/valproate/ethosuximide/primidone →↓ Plt Carbamazepine/primidone/levetiracetam →↓ WBC **Tests:** CBC and others as indicated from H&P
Laboratory	Tests as indicated from H&P
Premedication	Standard premedication is usually appropriate.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water.

INTRAOPERATIVE

Anesthetic technique

GETA (± wake-up testing), conscious sedation or local anesthesia (awake craniotomy). Typically, the placement of surface or depth electrodes is done under GETA, as is a temporal lobectomy in the nondominant hemisphere. If the seizure focus is in the dominant hemisphere and/or if there is any question about possible injury to speech or motor areas, the procedure may be performed under local anesthesia (awake craniotomy), with intraop localization of the seizure focus.

Induction	Standard induction. After anesthesia is induced, a nondepolarizing neuromuscular relaxant is administered. If a difficult intubation is anticipated (e.g., stereotactic frame), orotracheal intubation is best accomplished before induction of GA. An awake fiberoptic intubation is the best technique.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia. Avoid hypothermia. For open procedures, consider preincision placement of scalp blocks.
Maintenance	Standard maintenance. Generally, no further NMBs are administered beyond that used for tracheal intubation. With adequate anesthesia, and the head fixed in pins (Mayfield-Kees skeletal fixation), patient movement of any consequence is highly unlikely. Furthermore, it may be useful to see movement of an extremity as an indicator of inadequate depth of anesthesia.
Emergence	No special considerations. Prophylactic antiemetic (e.g., ondansetron 4 mg iv, ± metoclopramide 10–20 mg iv) should be given 30 min before extubation. Surgeon should infiltrate wound with 0.5% bupivacaine (max = ~30 mL) or 0.75% ropivacaine (max = ~40 mL) with epinephrine (1:200K) to improve postop analgesia. For open procedures, consider scalp block placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >4–6 h ago.
Conscious sedation	Most commonly accomplished using infusions of propofol (25–75 mcg/kg/min) with remifentanil (0.02–0.05 mcg/kg/min) or dexmedetomidine (1 mcg/kg load over 10 min + 0.2–0.7 mcg/kg/h infusion).

Wake-up testing

At some institutions, an asleep-awake-asleep technique is used in which the patient is

placed under GETA for positioning and craniotomy. After surgical exposure of the seizure area, the patient is allowed to awaken to assess neurologic function while areas of the brain are stimulated. When the seizure focus has been adequately delineated, GA is reinstituted for the remainder of the operation. An excellent anesthetic technique under these circumstances includes the use of sevoflurane (±50% N_2O) for amnesia and remifentanil (0.05–2 mcg/kg/min) by continuous infusion for analgesia. The advantage of these drugs is that they are quickly eliminated, allowing for rapid emergence for the awake component of the procedure, followed by rapid reinduction of anesthesia when the testing period is over. To allow the patient to talk during the awake portion of the procedure, the ETT must be removed. This is best accomplished by inserting a small or medium-sized tube changer through the ETT before it is removed. The tube changer can then be used as a guide for reinsertion of the ETT, and it will not prevent normal vocalization by the patient during the awake phase. Alternatively, an LMA can be used to secure the airway initially, removed for the awake testing and reinserted for closure.

Blood and fluid requirements	Moderate blood loss IV: 18 ga × 2 BSS @ 4–6 mL/kg/h	Two iv cannulae are useful: one for fluid administration and another for infusion of anesthetic and other drugs. Alternatively, one peripheral iv and a CVP catheter are inserted. Blood transfusions are seldom needed. Zero balance or goal-directed fluid management is recommended (see Appendix K, p. K-2).
Monitoring	Standard monitors. Arterial line ± CVP line UO	O_2 sat and $ETCO_2$ monitoring will indicate the adequacy of ventilation and oxygenation in awake patients.
Positioning	Table rotated 180° ✓ and pad pressure	Semisitting position with head held in Mayfield-

	points ✓ eyes	Kees 3-pin clamp and rotated laterally with a roll under the shoulder on the operative side. Anesthetic hoses and intravascular lines must be long enough to be accessible.
Complications	Anxiety/agitation Sz	Local anesthetic toxicity may produce agitation and seizures. Iced NS should be immediately available to flood cortical surface for Sz control.

POSTOPERATIVE

Complications	Seizure/cerebral edema Bleeding	Monitor carefully for altered mental status. May require urgent reexploration and removal of electrode grid if present.
Multimodal pain management	Acetaminophen 1 g iv	Avoid oversedation. LA infiltration of the incision effectively reduces postop pain.
	± Fentanyl 25–50 mcg prn	If not given preop or if 4–6 h has elapsed since previous dose.
	Reinforce scalp blocks	0.5% bupivacaine with epi is as effective as liposomal bupivacaine.
	PCA (selected patients)	Hydromorphone PCA (e.g., 0.2–0.4 mg, 5- to 10-min lockout) combined with ondansetron 4 mg iv

		q4h.
Tests	CT scan	If a patient exhibits any delay in emergence from anesthesia and surgery, or any new neurologic deficits appear, a CT scan is invariably obtained.
ERAS	Ondansetron 4 mg iv	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Bloor M, Nandi R, Thomas M: Antiepileptic drugs and anesthesia.Paediatr Anaesth 2017; 27(3):248–50.
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SURGERY FOR SPASTICITY

SURGICAL CONSIDERATIONS

Description

Neurologic conditions associated with spasticity of the extremities include spinal cord injury, multiple sclerosis, stroke, etc. The spasticity is often managed with oral medications and botulinum toxin treatment. An alternative approach is to infuse baclofen (GABA agonist that decreases frequency and amplitude of tonic impulses to the muscle spindles) into the spinal subarachnoid space via an implanted pump. When these therapeutic modalities fail, it may be necessary to perform surgery. Some of the procedures are destructive in that a lesion is placed in certain nerves or the spinal cord to destroy the reflex arc that is contributing to the spasticity. There are both percutaneous and open techniques for placing the lesion. In the **open procedures**, a **laminectomy** is performed (see Posterior Lumbar Spine Surgery). In a case where a **myelotomy** is to be performed, the lower spinal cord is exposed and incised at the appropriate location to interrupt the reflex arc. In certain cases, selective electrical stimulation can be performed on isolated dorsal rootlets from the involved extremity. Abnormal responses in the extremities are monitored via EMG and direct observation When abnormal responses are detected, that particular rootlet is divided (**selective dorsal rhizotomy**). This procedure is somewhat tedious and requires that stable anesthetic conditions be maintained so that motor and sensory nerve monitoring can be carried out during the procedure. The surgeon usually must sacrifice 50–75% of the dorsal rootlets in cases of spastic diplegia found in cerebral palsy. Selective dorsal rootlet rhizotomy reduces spasticity by decreasing facilitatory input to spinal motor neurons.

Variant procedure or approaches

Percutaneous **RF rhizotomy** is another procedure used for spasticity. A thermal lesion is placed in the appropriate dorsal roots with an RF generator. Needles are passed into the neural foramen via a posterolateral trajectory for levels L1-L5 and then from a midline approach to the S1 root. The needle position is determined by A-P and lateral fluoroscopy and by stimulus mapping. Stimulating current is delivered via an electrode passed through the needle. A low-level stimulating current causes muscle twitching in the appropriate leg if the needle is in the proper location. Once placed and verified, the

RF generator is used to produce the lesion. At the termination of this procedure, the patient's legs should be flaccid. Patients with spinal cord injury producing anesthesia below T10 may not require additional anesthetic for the procedure.

Usual preop diagnosis

Spasticity; multiple sclerosis; spinal cord injury

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include continuing chronic pain and other meds, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Open Rhizotomy or Myelotomy	RF Rhizotomy
Position	Prone	⇐
Incision	Midline	Needles placed in lumbar region
Special instrumentation	EMG monitor; nerve stimulator	RF generator; fluoroscope
Unique considerations	Anesthetic that allows EMG recordings/no muscle relaxation	May not require anesthesia if anesthetic below waist (2° spinal cord surgery)
Antibiotics	Cefazolin 2 g iv (30–60 min before incision)	None
Surgical time	4 h	2 h
Closing considerations	Surgeon may wish to test dural closure with Valsalva maneuver	
EBL	50–250 mL	Negligible
Postop care	Head flat; PACU room	⇐
Mortality	<1%	⇐

Morbidity	All <5%: CSF leak Infection Hemorrhage Neurologic impairment	⇐
Pain score	4	2

PATIENT POPULATION CHARACTERISTICS

Age range	3–55 yr
Male:Female	~3:2
Incidence	Relatively uncommon neurosurgical procedure
Etiology	Hyperactivity of gamma stretch reflex
Associated conditions	Multiple sclerosis; cerebral palsy; spinal cord injury

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Surgical Correction of Spinal Dysraphism, Pediatric Neurosurgery.

Suggested Readings

1. Aquilina K, Graham D, Wimalasundera N: Selective dorsal rhizotomy: an old treatment re-emerging. Arch Dis Child 2015; 100(8):798–802.
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PERCUTANEOUS PROCEDURES FOR TRIGEMINAL NEURALGIA

SURGICAL CONSIDERATIONS

Lawrence M. Shuer

Description

Three percutaneous procedures are commonly used to treat trigeminal neuralgia (a well-defined pain disorder of the face). Each involves placing a needle percutaneously from the cheek into the foramen ovale at the base of the skull under iv anesthetic (Fig. 1.2-4). For **glycerol injection** (rarely used), it is necessary for the surgeon to verify that the needle is placed in the cistern of the trigeminal (AKA gasserian) ganglion. This usually is done via I.I. or x-ray films with contrast instilled into the cistern by the surgeon. There should be free flow of CSF through the needle. The patient is then placed in the seated position with head flexed, and sterile glycerol is injected into the cistern (a painful event). The patient is taken to the recovery room sitting up with the head still flexed for 1 h. The glycerol damages neurons in the ganglion, which usually causes mild sensory loss and relieves the tic pain in most cases. **Percutaneous balloon compression** of the ganglion is a procedure done in some centers for this condition. The needle is placed similarly to the previously mentioned procedure, but in this case, a balloon catheter is placed through the needle, and the balloon is inflated after it is successfully located in the gasserian ganglion cistern. The patient may be kept sedated throughout this procedure. Compression of the ganglion will relieve the pain in many patients.

Radiofrequency (RF) rhizotomy is the most common percutaneous procedure used for trigeminal neuralgia. This procedure differs from glycerol injection in that an RF generator is used to place a thermal lesion (sparing the less heat-sensitive sensory neurons) in the appropriate portion of the gasserian ganglion. The needle is actually an insulated electrode with a portion of the tip exposed. The proper needle position is determined by applying stimulating current, with the patient awake, while assessing patient's responses. Multiple brief periods of anesthesia will be required to adjust the needle position or to lesion the nerve. It is important for the patient to awaken quickly and be able to cooperate with the stimulus localization throughout this procedure. This same approach may be used to place a stimulating electrode in the ganglion (ganglionic stimulation) with the leads subsequently tunneled to an implantable pulse generator. Direct stimulation has been shown to provide pain relief in many patients.

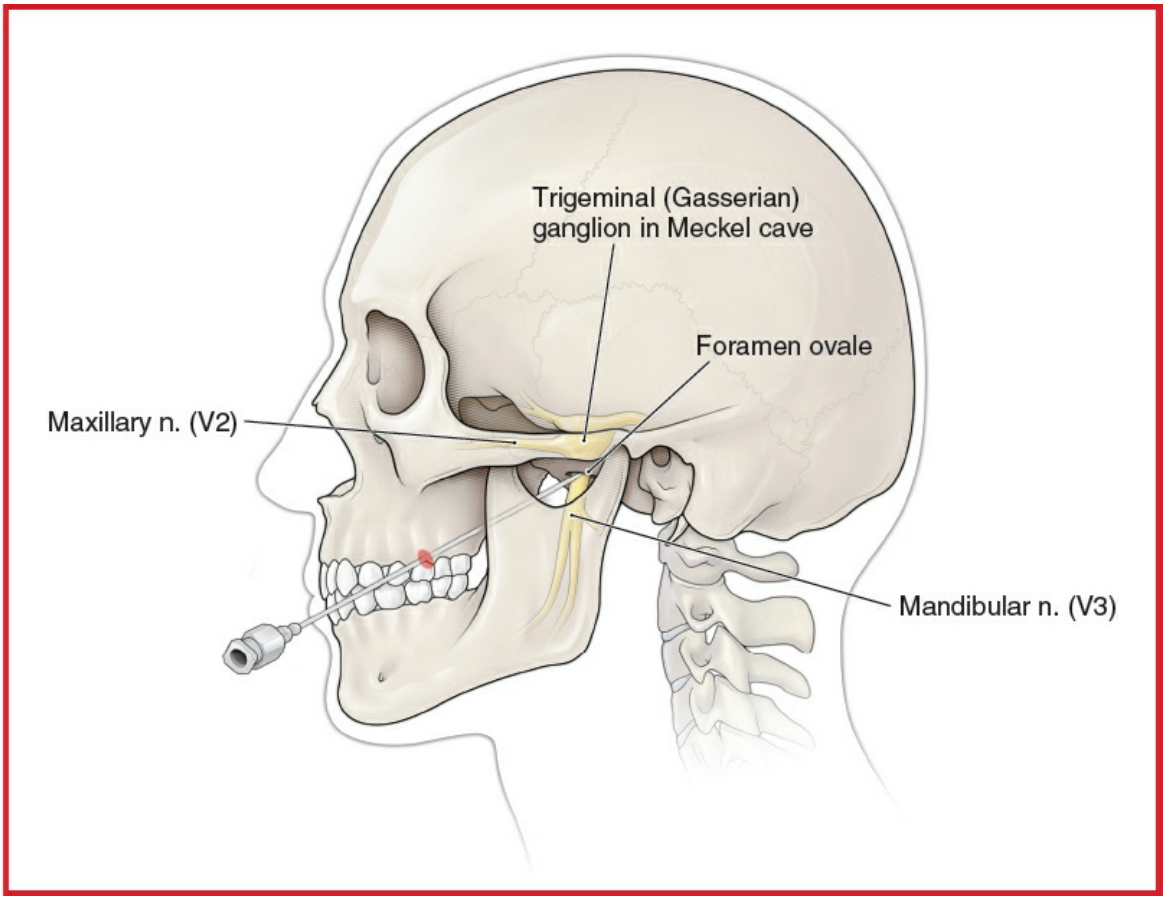

Figure 1.2-4 Percutaneous approach to the foramen ovale and the trigeminal (gasserian) ganglion used in the RF ablation procedure for trigeminal neuralgia.

RF neuromodulation is a nondestructive variant of RF ablation. Both percutaneous RF electrode placement at the trigeminal ganglion and treatment using pulsed RF energy can be accomplished under MAC with fluoroscopic control. This technique has a much lower complication rate compared to RF ablation but is also much less efficacious.

Usual preop diagnosis

Trigeminal neuralgia; tic douloureux; hemifacial spasm

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include continuing chronic pain and other meds, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Balloon Compression

	Glycerol Injection		RF Rhizotomy
Position	Supine	⇐	⇐
Incision	Needle placed lateral to mouth on cheek	⇐	⇐
Special instrumentation	I.I.	⇐	⇐ + RF generator
Unique considerations	Hypertensive response to needle placement	⇐	⇐ + Requirement for periodic deep sedation with rapid awakening for RF lesioning
Antibiotics	Usually none	⇐	⇐
Surgical time	0.5 h	1 h	1–1.5 h
EBL	None	⇐	⇐
Postop care	Seated position with head flexed for 1 h	PACU	PACU
Mortality	rare	⇐	⇐
Morbidity	Infection: rare	⇐	⇐
	Complete facial numbness or anesthesia dolorosa: ~4%	⇐	⇐
	Extraocular muscle paresis (diplopia): <4%	⇐	⇐
	CSF leak: rare	⇐	⇐
	Masticatory problem: common	⇐	⇐
	Facial hematoma	⇐	⇐
	Sensory loss:	⇐	⇐

	common Recurrence: >50% in 5 yr	~50% in 5 yr	⇐
Pain score	3–7	2–4	2–4

PATIENT POPULATION CHARACTERISTICS	
Age range	40–85 yr (usually 60–70 yr)
Male:Female	1:2
Incidence	Trigeminal neuralgia: 4.3/100,000/yr (25.6/100,000/yr > 70 yr)
Etiology	Vascular compression of trigeminal nerve → demyelination; multiple sclerosis plaque; cerebellopontine angle tumor; AVMs
Associated conditions	HTN; multiple sclerosis; rheumatoid arthritis; Charcot-Marie-Tooth disorder; Sjögren syndrome; hemifacial spasm

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Trigeminal neuralgia, or tic douloureux, is a condition that develops in adults usually >60 yr old. It is more common in women in whom an intermittent, severe, lancinating pain arises over the maxillary and/or mandibular divisions of the trigeminal nerve. The ophthalmic division of the trigeminal nerve is rarely involved. The pain is unilateral and often can be precipitated by stimulating a trigger point, such as by contact with the cheek, mastication, or brushing teeth. The cause of this condition is not known. Medical management consists of therapy with carbamazepine (Tegretol) or oxcarbazepine (Trileptal), anticonvulsants, and analgesics specific for this condition. The failure rate for medical treatment is 50–60%. Stereotactic radiosurgery (dose = ~60 Gy) has been shown to have long-term effectiveness in ~50% of patients who failed drug therapy. Surgery is considered when medical or radiotherapy management fails to control pain or complications of drug therapy develop (anemia, bleeding disorders, dizziness, etc.). One of three types of percutaneous procedures is performed: **glycerol injection**, **RF rhizotomy** (or pulsed RF treatment) of the symptomatic branches of the trigeminal ganglion, or direct **ganglionic stimulation**. If these treatments fail, microvascular

decompression of the trigeminal nerve is considered (see p. 50).

Respiratory	No common associations or special considerations, unless patient has a long-standing Hx of smoking and has COPD. **Tests:** As indicated from H&P
Cardiovascular	Most patients have Hx of idiopathic HTN and take antihypertensive medications. Good control of BP preop is important because most patients become hypertensive during the operative procedure. Intraop HTN is often unavoidable because of the surgical need to have the patient awake during much of the procedure. **Tests:** As indicated by H&P
Neurologic	The presenting symptom is pain (shock-like = better outcome) in the maxillary and/or mandibular division of the trigeminal nerve, unaccompanied by motor or sensory deficits. (Dx should be questioned in the presence of sensory deficits). Patients likely will have failed first-line Rx and now be partially treated with second-line drugs including phenytoin, baclofen, gabapentin, and various antidepressants, which may have anesthetic management implications.
Laboratory	As indicated from H&P. CBC/platelets if Rx carbamazepine. Anticonvulsant drug levels
Premedication	Midazolam (1–4 mg iv)
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water.

INTRAOPERATIVE

Anesthetic technique

GA, regardless of which percutaneous technique is to be used. O_2 by nasal cannula should be administered before induction of anesthesia. Patients with OSA may benefi

from the use of high-flow nasal cannulae (THRIVE device, e.g., OptiFlow™). To keep the O_2 cannula out of the surgeon's field, supply tubing must be taped above the eye on the side of operation.

Induction	Because the surgeon will want the patient awake to check pain distribution as soon as the needle or electrode is in place, the induction drug must be potent, but short acting. Methohexital (0.5 mg/kg) is preferred for this purpose, but propofol (1 mg/kg) alone or at a reduced dose in combination with remifentanil (0.5 mcg/kg) has been used successfully. The drug should be injected by bolus into a rapidly flowing iv to achieve a high concentration in the brain quickly. Continuous infusion is not satisfactory because it fails to achieve a high brain concentration quickly, and its continuous administration prolongs the time before the patient is sufficiently able to communicate with the surgeon. In experienced hands, the needle is placed within a matter of 2–3 min. If difficulty is encountered in placing the needle, additional bolus doses of WW drug ± midazolam may be needed. Patients may develop apnea for 1–2 min, followed by partial or total airway obstruction while the surgeon has his hand in the mouth positioning the needle. Prior to induction of anesthesia, therefore, it is essential that the anesthesiologist optimize ventilation and oxygenation by asking the patient to take a series of deep breaths through the nose with the mouth closed. This will ↑ the O_2 level and ↓ the CO_2 level in the lungs before induction. To maintain adequate spontaneous ventilation and oxygenation, it may be necessary to institute forward displacement of the mandible while the surgeon inserts the needle. Another alternative is to insert a nasal airway. If **glycerol injection** is used, needle position is verified by radiologic imaging, using a radiopaque dye. Patient is awakened and placed in a seated

	position with head flexed. The glycerol is injected, causing transient severe pain. Patient is then moved to recovery room still in seated position with the head forward to keep the glycerol localized to the region of the trigeminal ganglion. Fortunately, this procedure is now rarely used. If **RF rhizotomy** electrode placement is performed, the patient is awakened and the position of the electrode is verified by stimulating the ganglion with heat or directly and determining the site of pain. The patient is then reanesthetized with a smaller bolus of the same drug to permit electrode adjustment or local heating for ~1 min. This process may be repeated several times. Each time, the patient needs less anesthetic because of both the cumulative effects of the drug and the fact that the ganglion is becoming damaged by the heat and manipulation.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia. Avoid hypothermia.	
Emergence	Following glycerol injection, patients are maintained in a seated position with an ice pack on the cheek at the site of needle insertion to minimize postop bleeding and swelling. These patients often complain of pain in the face, requiring opiate analgesics. Following RF rhizotomy, the affected area of the face is usually numb, which is the end point for concluding the operation.	
Blood and fluid requirements	IV: 18–20 ga × 1 BSS @ 1–3 mL/kg/h	Zero balance fluid management is recommended (see Appendix K, p. K-2).
Monitoring	Standard monitors.	HTN patients may require an arterial line.
Control of BP	Labetalol Esmolol bolus dose	Patients almost invariably become hypertensive

	Clevidipine infusion may be necessary	during this therapy. Attempts to lessen these episodes with a clonidine patch preop or use of intermittent doses of esmolol or labetalol prophylactically or therapeutically are only partially successful.
Positioning	Table turned 180° ✓ and pad pressure points ✓ eyes	Patient in reclining position with head in the midline.
Complications	Failure of needle placement Bleeding Respiratory arrest (glycerol effect) Oculocardiac reflex	Major complications from this operation are uncommon but include (a) failure to identify the foramen ovale, through which the needle must be inserted to reach the trigeminal ganglion. If the needle cannot be placed within 30–40 min, the procedure usually is delayed pending additional imaging studies. (b) Bleeding into cheek from puncture of a branch of the facial artery. (c) Apnea from spillover of the glycerol solution into CSF, presumably affecting the respiratory center in the 4th ventricle.

POSTOPERATIVE

Multimodal pain management	Parenteral opiates Acetaminophen 1 g iv ± Fentanyl 25–50 mcg prn Reinforce scalp blocks	Usually needed for postglycerol pain Rx. If not given preop or if 4–6 h has elapsed since previous dose.
ERAS	Ondansetron 4 mg iv	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

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Suggested Viewing

Links are available online to the following videos:

Microvascular Decompression for Atypical Hemifacial Spasm:
https://www.youtube.com/watch?v=4aOuANvc2-g

Deep Brain Stimulation (DBS) Parkinson's (Australia 60 Minutes segment):
https://www.youtube.com/watch?v=j3NjNKm0pio

CHAPTER 1.3

Spinal Neurosurgery

SURGEONS

Anand Veeravagu, MD
Lawrence M. Shuer, MD

ANESTHESIOLOGISTS

Karl Zheng, MD
C. Philip Larson, Jr., MD, CM
Martin S. Angst, MD

INTRODUCTION: GUIDELINES FOR THE INTRAOPERATIVE MANAGEMENT OF PATIENTS UNDERGOING SPINE SURGERY

Karl Zheng and Martin S. Angst

Anesthesia for spine surgery today is more common and more complicated than ever before. Many different surgical approaches, OR tables, frames, and operative systems are used in spine procedures, each with their own set of anesthetic considerations. Some of these patient positions can decrease venous return, alter pulmonary compliance, drastically restrict iv access, or introduce significant measurement errors in noninvasive blood pressure (NIBP) measurements. Some spine surgeries are performed with navigation technology including CT guidance and robotic systems like Mazor X and Mazor Renaissance, while minimally invasive techniques are replacing larger incisions and more invasive procedures. While these changes may increase fidelity of pedicle screw placement and decrease patient recovery times, they also increase technical complexity, potentially increase surgical times, and require more radiation exposure. There are spine surgeries that are so extensive they require multiple positions or are staged across more than 1 d of surgery. Patients for spine surgery have changed as well. Chronic pain and opioid tolerance is particularly increased in the spine surgery patient population, making management of postop analgesia more

challenging than before. Anesthesiologists today need to be able to navigate this evolving landscape of spine surgery by identifying relevant details and adapting their anesthetic plans. A good rule of thumb is always to communicate with the surgeon ahead of time to avoid any mismatch of expectations.

GENERAL CONSIDERATIONS

Surgical procedures are divided into three classes based on the extent of surgery: minor, major, and complex. Considerations for the intraop management of patients undergoing spine surgery are class specific. Procedures are listed in the table:

Minor (EBL < 200 mL)	Major (EBL 200–1000 mL)	Complex (EBL 1–10 L)
• 1–2 level ACDF • ≤2 level decompression or microdiscectomy without instrumentation	• 3–4 level ACDF/PCDF • 1–3 level ALIF/XLIF • 1–2 level TLIF • 1–2 level anterior/posterior • Degenerative corpectomy	• 6–18 level instrumentation • ≥3 level anterior/posterior fusion • Pedicle subtraction osteotomy (PSO) • Vertebral column resection (VCR) • Tumor corpectomy • Tumor debulking

Access

Consider establishing vascular access as suggested:

- Minor surgery: 18- to 20 ga iv cannula, A-line only if medically indicated
- Major surgery: 16- and 18- to 20 ga iv cannulas, A-line recommended
- Complex surgery: 2× 14–16 ga iv cannulas or central venous line (Cordis), A-line

Fluid management

The overall aim is to keep patients euvolemic, avoiding excessive fluid administration. Fluids should be titrated on an "as-needed basis" to maintain euvolemia. Integration of various clinical indicators status (arterial blood pressure, pulse pressure variation, acid/base balance, clinical assessment of peripheral perfusion, trends in central venous pressure [CVP]) will allow assessment of fluid. Consider using colloids early in major and complex surgery (after administration of 1–2 L crystalloids) to avoid tissue edema.

- Crystalloids: Balanced solutions (e.g., LR) are preferred in combination with normal saline to limit sodium and chloride load.
- Colloids: Colloids preferentially expand intravascular volume and limit volume load of the interstitial space. This is particularly relevant in patients who are in prone position for extended periods of time. These patients have an increased risk of postop

visual loss. Significant tissue edema is also associated with slower bowel recovery and airway edema. The use of albumin 5% is recommended. The use of hetastarch is discouraged in major and complex surgery as it may impair renal function and worsen coagulopathy.

Blood pressure management

The overall aim is to avoid decreases in mean arterial pressure (MAP) >20% from baseline (typical blood pressure at rest without stress). Elevated MAP (≥80–90 mm Hg) may be required in patients with myelopathy or trauma to the spine. Consider taking the following sequential actions if MAP decreases >20%:

- ↓ Anesthetic level (use age-adjusted monitored anesthesia care [MAC] and evaluate individual patients' true anesthetic requirements). The use of 50% nitrous oxide (minimal impact on systemic vascular resistance [SVR]) is suggested to spare volatile anesthetics. A total of 0.7–1.0 MAC is often sufficient to prevent awareness and provide adequate surgical conditions.
- Opioids are mainly used to control hemodynamic variables during GETA. Opioids do not exert preemptive analgesic effects. Toward the end of surgery, opioids should be titrated to provide a component of postop pain control.
- Consider starting a continuous infusion of phenylephrine at a rate ≤0.4 mcg/kg/min. The use of higher rates has to be balanced against the risk of concealing intravascular volume depletion. This is particularly important in patients with significant blood loss. Fluids should be used to restore euvolemia if a decrease in MAP >20% is due to intravascular volume depletion (normal SVR).

Transfusion of blood products

Unexpected significant bleeding can occur during any spine surgery from direct vascular injury, for example, of the common iliac vessels during an anterior lumbar approach. During a routine prone decompression surgery, injury to epidural veins can also result in abrupt unexpected blood loss. However, surgeries where potentially life-threatening bleeding is expected typically fall into two major categories. The first is a large fusion surgery that involves many levels (>8) and subsequently a large incision and many hours to complete. Bleeding potential is always higher if the surgery involves revising a previous fusion. The second is a major osteotomy (e.g., corpectomy) of a vertebral body (for tumor metastasis or traumatic fracture), pedicle subtraction osteotomy (full-thickness osteotomy for deformity correction), or vertebral column resection (major deformity correction). Tumor metastases, renal cell carcinoma and breast cancer in particular, can be highly vascular and often benefit from preop embolization if time permits.

While there is some controversy regarding the threshold Hct/Hb that should trigger administration of blood, a threshold of 24% (Hct) or 8 g/dL (Hb) is suggested for major and complex surgeries. Consider administering blood at Hct ~27% or Hb ~9 g/dL if blood loss is rapid and continuous to provide a margin of safety. If blood loss is rapid and large, administering blood products may be dictated by hemodynamic parameters rather than specific Hct or Hb targets.

- Prophylactic use of tranexamic acid (10 mg/kg bolus) should be considered for major surgery (discuss with surgeons) and is strongly recommended for complex surgery (10 mg/kg bolus followed by an infusion of 1 mg/kg/h). Use with caution in patients with a history of thromboembolic events or malignancy.
- A cell saver should be available for major and complex surgery except for cancer-related surgeries.
- Consider the use of fresh frozen plasma (FFP) after administering 4–6 units of packed red blood cells (PRBCs) or as clinically indicated. Administration of FFP and PRBCs in a ratio of 1:1–2 is suggested.
- Consider administration of platelets (one apheresis product) after transfusion >6 PRBCs, a platelet count <100,000/mcL, or as clinically indicated. Consider administration of platelets for each additional 6 PRBCs.
- Consider administration of cryoprecipitate (10 U) after transfusion of 10 PRBCs to maintain a plasma fibrinogen level >100 mg/dL.
- Consider calling for help and initiating massive transfusion protocol in case of massive and/or uncontrollable bleeding.

Prophylaxis for PONV

A special consideration concerns the use of steroids (dexamethasone). Steroids have to be avoided in patients undergoing spinal fusion as they may impact bone healing. Discussing the use of dexamethasone with surgeons is strongly recommended. PONV prophylaxis should follow guidelines using risk stratification (see Appendix B: Standard Adult Anesthetic Protocols, p. B-1). The risk for developing PONV is increased by the use of postop opioids, being a nonsmoker, being female, and having a history of PONV or motion sickness. Each factor adds 1 point to a maximum score of 4. The number of agents for preventing PONV is equal to the risk score. Agents to consider include the following:

- Ondansetron (4 mg)
- Dexamethasone (4 mg) in nonfusion procedures
- Propofol-based anesthetic
- Scopolamine patch (1.5 mg)
- Haloperidol (1 mg)
- Metoclopramide (10–20 mg)

Pain management

The major aim is to provide adequate pain control (pain at rest ≤3/10, pain during movement ≤5/10) using a multimodal approach. While opioids are an important component of the multimodal approach, opioid-sparing techniques are encouraged. Certain components of a typical multimodal approach require special considerations in patients undergoing spine surgery. In particular, the use of NSAIDs and COX2 inhibitors (e.g., celecoxib) are usually avoided in patients undergoing spinal fusion.

- Patients should be started on acetaminophen (1 g po) before surgery, then 1 g po q6h postop until they are switched to an oral combination product containing an opioid and acetaminophen. Dose adjustments may be necessary in the very elderly and in patients with impaired liver function.
- Consider the use of celecoxib (200 mg po) before surgery for nonfusion procedures.
- Consider the use of an intraop ketamine infusion (0.5 mg/kg bolus followed by an infusion rate of 0.25 mg/kg/h). Stopping the infusion 30–45 min before the end of surgery is recommended to facilitate emergence from anesthesia. The use of ketamine is encouraged in patients undergoing major and complex surgeries and in patients with history of chronic pain complaints. Consider the use of an intraop lidocaine infusion (100 mg bolus followed by an infusion rate of 1–2 mg/kg/h). A lidocaine infusion is recommended for patients undergoing major or complex surgery.
- The use of gabapentin before surgery is controversial. Gabapentin can cause postop drowsiness and impair early mobilization. Consider preop administration of gabapentin (600 mg po) in patients with a history of chronic pain.

Neuromonitoring

The use of neurophysiologic monitoring during spine surgery is highly dependent on surgeon preference. Patients requiring neuromonitoring including motor evoked potentials (MEPs) should not receive neuromuscular blockers, except for tracheal intubation. EMG is primarily performed to assess electrical stimulation thresholds for pedicle screw placement as an indicator of proximity to the spinal canal or exiting nerve structures. If baseline potentials will be recorded before turning a patient prone use succinylcholine to facilitate intubation. A standard anesthetic plan not interfering with the monitoring of evoked potentials includes the use of 0.5 MAC of a volatile anesthetic, <50% N_2O, and a remifentanil infusion or TIVA targeted to a patient's anesthetic needs. Patients requiring EMG monitoring (Nuvasive XLIF, MIS TLIF) should only receive succinylcholine for intubation.

Perioperative visual loss (POVL) is a rare surgical complication (estimated incidence: <1 in 1000) that primarily occurs after prone spine surgery. This is due to ischemic injury to the optic nerve by either one of two mechanisms. The less common

etiology is central retinal artery occlusion (CRAO) whereby direct pressure on the eye leads to retinal ischemia. This is almost always due to poor positioning and can be avoided by ensuring that there is no direct pressure on the eyes. The more common etiology of POVL today is ischemic optic neuropathy (ION). ION is essentiall compartment syndrome within the optic nerve canal because of venous congestion that restricts perfusion of the optic nerve leading to ischemic injury. POVL due to ION wil most likely affect both eyes, whereas CRAO typically leads to unilateral vision loss Should any visual loss occur, the change is usually permanent.

A landmark publication by the ASA in 2011 looking at POVL after prone spine surgery identified the following risk factors as statistically significant: male gender, obesity, diabetes, duration of surgery, blood loss during surgery, and use of Wilson frame. Additionally, the use of colloid in combination with crystalloid for resuscitation was found to be protective presumably due to less edema. General guidelines for reducing the risk of POVL would be to minimize periods of hypotension and anemia particularly near the end of a lengthy case when presumably edema would be most severe. The technique of deliberate hypotension during major spine surgery is no longer advised.

ANTERIOR FUSION/FIXATION OF THE UPPER CERVICAL (C1-C2) SPINE

SURGICAL CONSIDERATIONS

Description

Transoral odontoid excision: The **transoral approach** is indicated primarily to relieve ventral irreducible compression of the cervicomedullary junction due to extradural lesions involving the lower part of the clivus, C1 and C2 vertebral bodies. This approach provides direct access to the C1 anterior arch and odontoid process of C2. The anesthetized patient is positioned supine usually with cervical traction. A Dingman or similar retractor is used to facilitate surgical access. The soft palate is retracted upward with stay sutures. Through a posterior midline incision over the pharyngeal wall, the C1 anterior arch and C2 vertebra are exposed (Fig. 1.3-1). Using fluoroscopic guidance, bony decompression of the clivus, C1 anterior arch, odontoid process, and C2 vertebral body is performed. Instrumentation of C1-C2 may be performed with plate and screws. The wound is closed in two layers after securing hemostasis. As the procedure often results in significant instability at the craniovertebral junction, posterior occipitocervical fusion often is required.

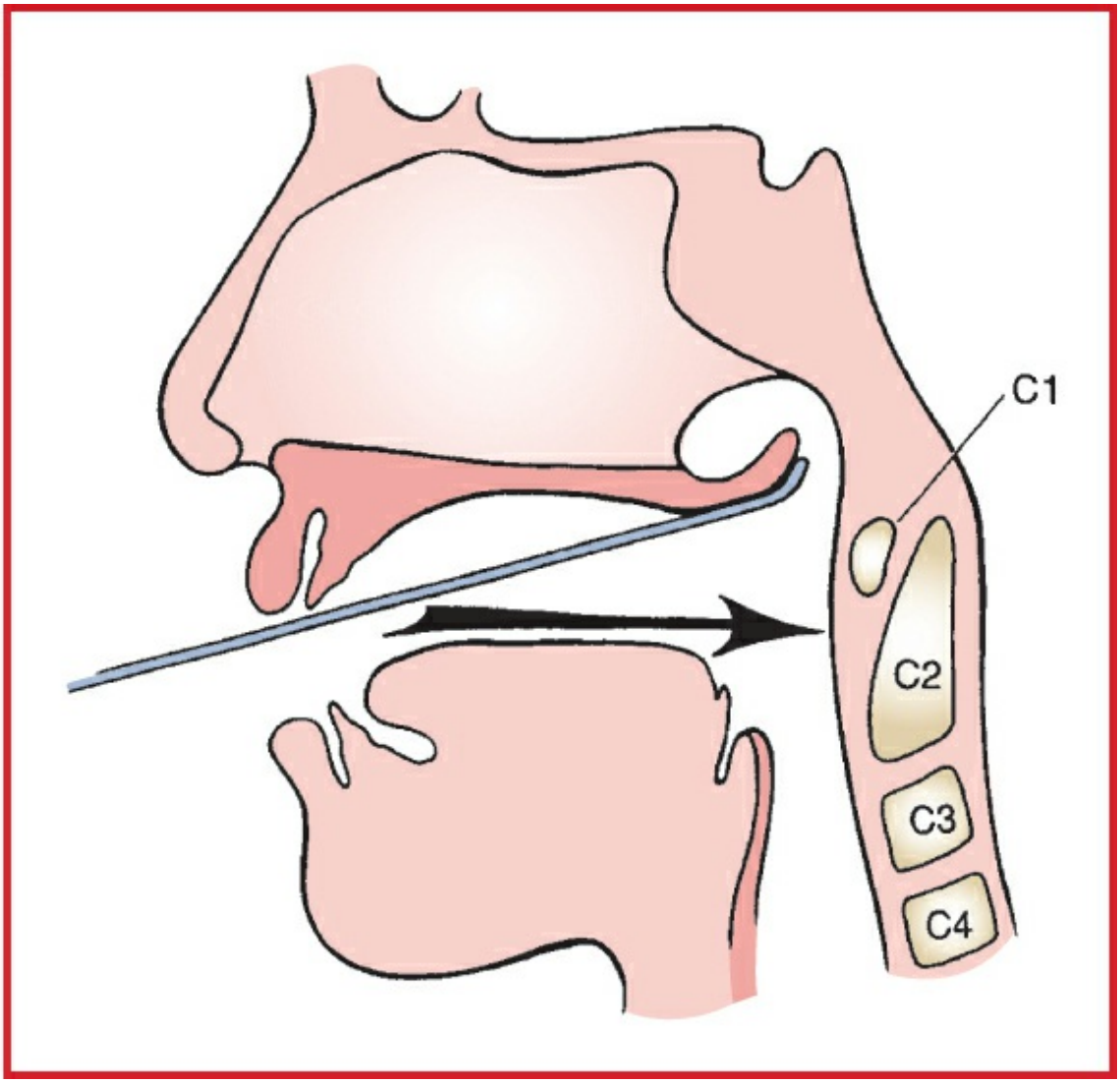

Figure 1.3-1 The transoral approach. (Reproduced with permission from An HS, Cotler JMSpinal Instrumentation. Williams & Wilkins, Baltimore: 1992.)

Variants of the transoral procedure

Transpalatal exposure with removal of hard palate or a **tongue-splitting transmandibular approach** may be required for adequate exposure of the clivus or upper C-spine, respectively. A **high cervical anterior retropharyngeal approach** is rarely used to approach C1-C3 without traversing the oral cavity and with less destabilization. A transcervical approach to the C2 body can be performed using an endoscope and a highly beveled tubular retractor.

Transodontoid screw fixation

Fractures of the odontoid process of C2 account for 10–20% of all C-spine fractures and are classified (**Anderson and D'Alonzo**) into three types, based on anatomical location. **Type I fractures**, which occur at the tip of dens, are treated conservatively. **Type II fractures**, which occur through the waist of the odontoid process, are the most

common and are often inherently unstable, requiring surgical treatment. Internal instrumented fixation is the ideal treatment for type II fractures because it provides immediate stability while preserving C1-C2 rotation. **Type III fractures** occur through the body of C2 and can be treated surgically or with external immobilization.

The anesthetized patient is placed in a supine position with traction of 5–10 lb. The mouth may be kept open using a radiolucent jaw distractor. A horizontal skin incision is made at approximately C5 level, and the platysma is cut along the skin incision. The anterior C-spine is exposed by opening the natural plane between the trachea and esophagus medially and carotid sheath laterally. Using a guide tube, a hole is drilled under fluoroscopy through the body of C2, the odontoid process, and its apex, through the fracture. The drilled hole is tapped, and an appropriately sized screw is placed (Fig. 1.3-2). At this point, fluoroscopy of the patient's neck in flexion and extension is done to exclude C1-C2 instability.

Usual preop diagnosis

Basilar impression (telescoping of the C-spine into the posterior fossa); odontoid fracture; rheumatoid arthritis with atlantoaxial instability; traumatic irreducible atlantoaxial instability; type II odontoid fractures (recent or remote)

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol and smoking cessation, review of nutritional status, and postop pain management options. See Appendix K: Enhanced Recovery After Surgery, p. K-1.

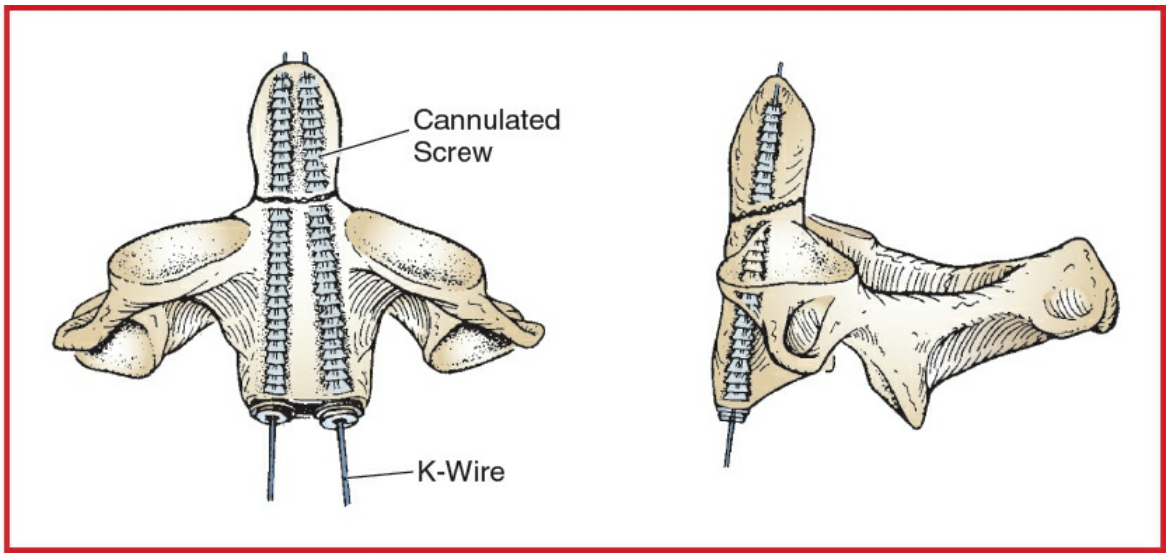

Figure 1.3-2 Screw fixation technique, using cannulated screws. K-wire provides provisional stabilization and allows guided tapping and screw placement. (Reproduced with permission from An HS, Cotler JM: Spinal Instrumentation. Williams & Wilkins, Baltimore: 1992.)

SUMMARY OF PROCEDURES

	Transoral	Transodontoid Screw Fixation
Position	Supine; head in mild extension with traction	Supine; head in mild extension with traction
Incision	Posterior oropharynx	Transverse skin incision in the anterolateral neck at C5 level
Special instrumentation	Operating microscope, I.I., Dingman retractor	K-wire, drill, odontoid screw instrumentation
Unique considerations	Requires ≥3 cm mouth opening; armored ETT must be taped securely away from the surgical field. Tracheostomy is needed occasionally. Fiberoptic intubation may be required.	Fiberoptic intubation in patients with C1-C2 instability; biplanar fluoroscopy is mandatory.
Antibiotics	Cefazolin 2 g iv (30–60 min before incision)	⇐
Surgical time	2–4 h	2–3 h
Closing considerations	Extubation may be delayed due to lingual swelling	Routine wound closure
EBL	25–200 mL	25–200 mL
Postop care	ICU or close observation unit. Monitor airway for respiratory obstruction. ± postop immobilization. Will require leaving NG tube in postop	PACU → room; cervical collar
Mortality	0–3%	1%

Morbidity	All: <20%: CSF leak/dural tear Infection Neural injury Pharyngeal wound dehiscence	All: <15% Hardware failure (screw pullout, screw fracture): 10% Nonunion: 5–10% Superficial wound infection: 2%
Pain score	3–5	3–5

PATIENT POPULATION CHARACTERISTICS		
Age range	18–85 yr (usually 20–60 yr)	15–90 yr (usually 20–60 yr)
Male:Female	1:2	1.5:1
Incidence	Rare	Common (10–20% of C-spine fractures)
Etiology	Neoplastic; traumatic; congenital; degenerative	Traumatic
Associated conditions	Rheumatoid arthritis	—

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Cervical Neurosurgical Procedures.

Suggested Readings

1. Apelbaum RI, Lonser RR, Veres R, et al: Direct anterior screw fixation for recen and remote odontoid fractures. J Neurosurgery 2000; 93:227–36.
2. Fountas KN, Kapsalaki EZ, Nikolakakos LG, et al: Anterior cervical discectomy an fusion associated complications. Spine 2007; 32(21):2310–7.
3. Shriver MF, Kshettry VR, Sindwani R, et al: Transoral and transnasa odontoidectomy complications: a systematic review and meta-analysis. Clin Neurol Neurosurg 2016; 148:121–9.
4. Vender JR, Harrison SJ, McDonnell DE: Fusion and instrumentation at C1–3 via th high anterior cervical approach. J Neurosurgery 2000; 92:24–9.

POSTERIOR FUSION/FIXATION OF THE

UPPER CERVICAL SPINE

SURGICAL CONSIDERATIONS

Description

Craniocervical (occipitocervical, craniovertebral) fusion/fixation or instrumentation involves stabilization of the occiput and upper three or four cervical vertebrae, whereas **atlantoaxial fusion/fixation** involves stabilization of the atlas (C1) and axis (C2). Instability may be caused by congenital, traumatic, degenerative, neoplastic, or infectious conditions resulting in compression of the lower brain stem or cervical spinal cord. Symptoms may include paresthesias and/or weakness of the upper and lower extremities.

Atlantoaxial techniques

Atlantoaxial (C1-C2) fusion is performed in the prone position, with or without traction. Through a posterior midline incision, the occiput and upper C-spine are exposed. A posterior iliac or rib graft may be harvested and fashioned appropriately. The bone graft can be secured with wires to the decorticated segments to be fused. Traditionally, the fixation has been performed with sublaminar wires alone; however, other fixation techniques—such as **C1-C2 transarticular screw fixation** and more recently the **C1-C2 lateral mass fusion** techniques are being used more often because they are biomechanically stronger and permit early ambulation with minimal orthotic support.

In **C1-C2 posterior wiring techniques**, the posterior arches of C1 and C2 laminae are exposed through a midline incision. Of the various wiring techniques used, **Gallie's** and **Brooks'** are the most widely accepted. In **Gallie fusion** (Fig. 1.3-3A), a wire loop or cable is passed underneath the C1 arch and brought over a bone graft wedged between C1 and C2 and then tightened over the C2 spinous process. In **Brooks technique** (Fig. 1.3-3B), wires are passed beneath the C2 lamina and C1 posterior arch on each side and tightened over a bone graft placed between C1 and C2. The posterior aspects of C1 and C2 are decorticated to facilitate the bony fusion. Wiring techniques are simpler, but carry the risk of cord injury during wire placement.

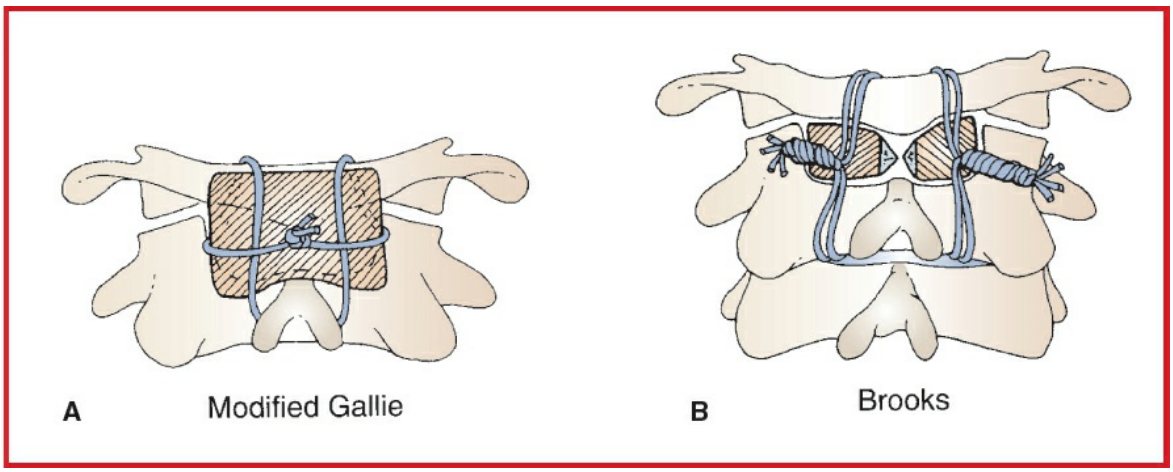

Figure 1.3-3 Posterior wiring techniques. **A:** Modified Gallie using an H-shaped bone graft from the iliac crest, contoured to fit over the posterior arches of C1 and C2. A double U-shaped 18- or 20-ga wire is passed under the arch of C1 from inferior to superior. **B:** Brooks-type fusion with doubled-twisted 24-ga wires passed under the arch of C1 and then under the lamina of C2. Rectangular iliac crest bone grafts are fitted in the intervals between the arch of C1 and each lamina of the axis. (Reproduced with permission from An HS, Cotler JM: Spinal Instrumentation. Williams & Wilkins, Baltimore: 1992.)

C1-C2 transarticular screw fixation was initially popular because of its greater biomechanical stability, higher fusion rates (87–100%), and superior fixation of atlantoaxial rotation. The occiput and C1-C3 vertebrae are exposed by a conventional posterior approach. Screws are placed from each lateral mass toward the anterior tubercle of C1 under fluoroscopic guidance. The major risks of this technique include injury to the vertebral artery (4.1%), malposition of screws, or instrumentation failure. Twenty percent of patients will have an anomalous vertebral artery, demonstrated by radiographic studies, precluding use of this technique.

In **C1-C2 lateral mass fusion**, the C-spine is exposed subperiosteally from occiput to C3-C4 vertebrae by a conventional posterior approach. In this technique, polyaxial screws are passed into the lateral mass of C1 (Fig. 1.3-4). In addition, C2 pedicle screws are also placed and then attached to the C1 screws by connecting rods (Fig. 1.3-5). If required, a reduction maneuver is carried out by repositioning the head or by direct manipulation of the C1 and C2 vertebrae. C1-C2 interfacetal fusion or posterior interlaminar fusion may be performed with wiring. The C1-C2 construct can be combined with cervical decompression. Because of the superior and medial placement of C2 pedicle screws, the risk of injuring the vertebral artery is less than with a transarticular fusion.

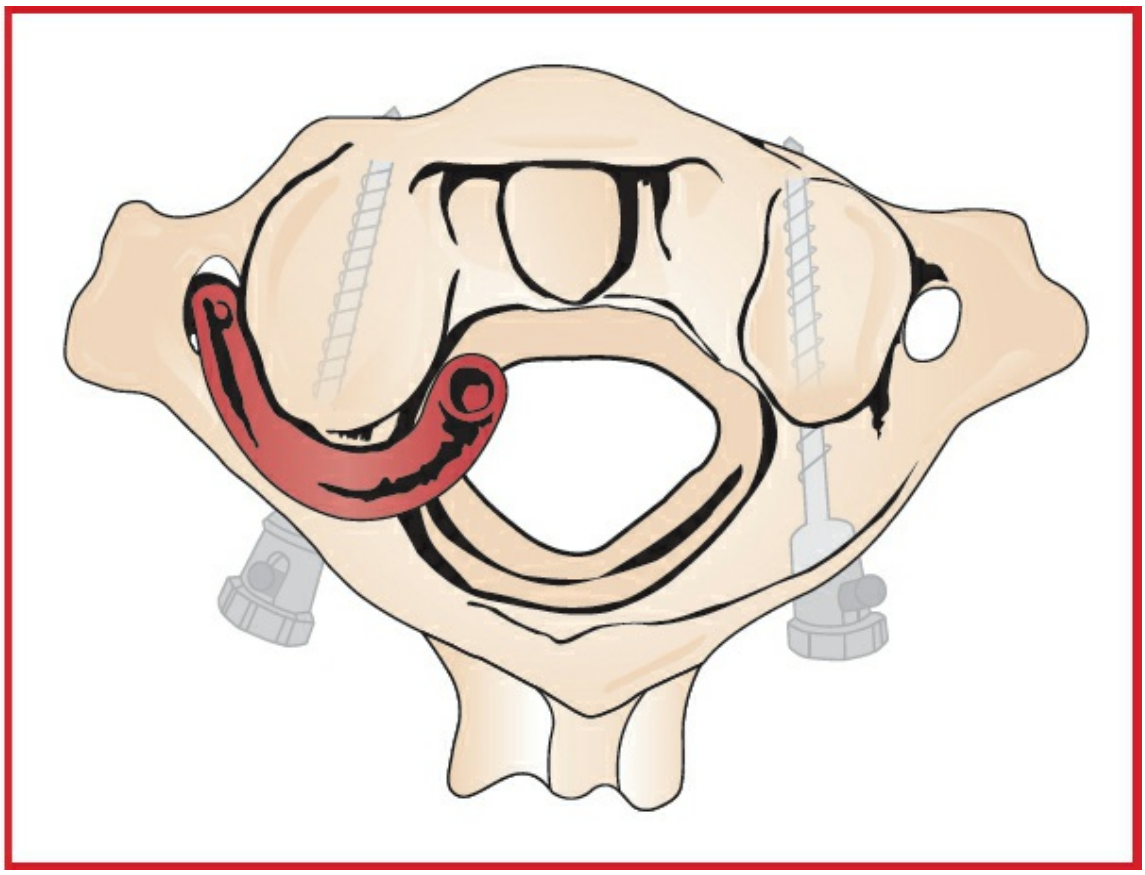

Figure 1.3-4 Axial view of C1 lateral mass screws. (Reproduced with permission from Harms J, Melcher RP: Posterior C1-C2 fusion with polyaxial screw and rod fixation. Spine 2001; 26(22):2467–71.)

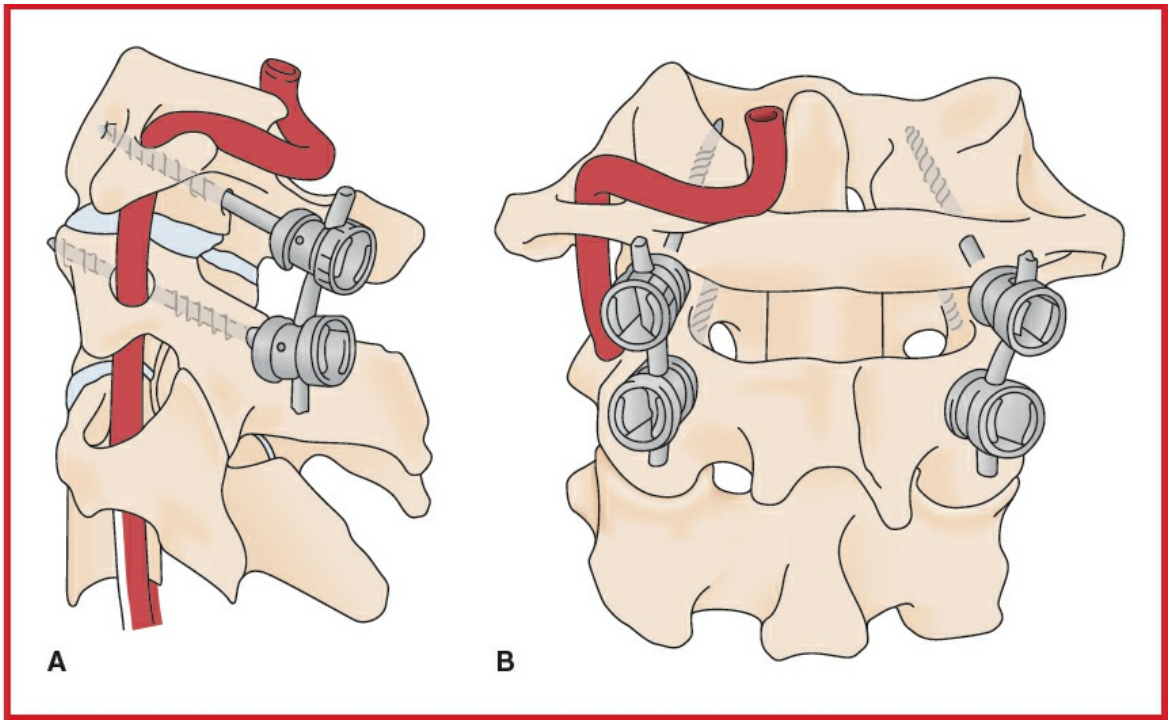

Figure 1.3-5 Lateral **(A)** and AP view **(B)** of C1-C2 fusion. (Reproduced with permission from Harms J, Melcher RP: Posterior C1-C2 fusion with polyaxial screw and rod fixationSpine 2001; 26(22):2467–71.)

Craniocervical techniques

Occipitocervical fusion involves a surgical exposure similar to that of atlantoaxial fusion, except that a more extensive exposure of the occipital bone is required. In the past, fixation was performed with a **Luque rectangle/contoured rod and wiring** or plate and screws. An appropriately fashioned rib or iliac crest graft was then secured in place.

I n **occipitocervical contoured rod fixation**, the occiput and posterior C-spine are exposed through a posterior incision, and trephines are made 2.5 cm to either side of the midline and about 2 cm above the foramen magnum. Wires or cables are passed from these occipital holes through the foramen magnum on both sides. Sublaminar wires are passed beneath laminae of the atlas, axis, and C3 vertebrae on each side and are tightened over a rod. Other cervical vertebrae may be included in the fixation as required. A tricorticate iliac or rib graft is fixed with wires over the occipitocervical region. Decortication of occipital bone and laminae of the atlas, axis, or C3 vertebrae is essential for bony fusion.

Occipitocervical plate fixation can be performed by using a T- or Y-shaped plate fixed by screws to the occiput and lateral masses of the cervical vertebrae. C1-C2 transarticular screws, lateral mass screws, or wiring techniques can be added for additional stability. Occipitocervical plating techniques are biomechanically stable, often obviating the need for postop halo immobilization; however, they can be technically challenging. The major concerns include possible dural penetration by occipital screws and obtaining adequate contouring of the construct.

Usual preop diagnosis

Transoral odontoid resection; occipitoatlantal instability; atlantoaxial instability; odontoid fractures; spinal fractures; cervical instability; previous failed fusions

SUMMARY OF PROCEDURES

	Atlantoaxial (C1-C2) Fusion/Fixation	Occipitocervical Fusion/Fixation
Position	Prone, head in tong traction or pins	⇐
Incision	Posterior midline incision	⇐
Special instrumentation	Fluoroscopy; drills; wires/cables; lateral mass	Fluoroscopy; drills; rods, wires/cables; plates and

	plate and/or screws; transarticular screws	screws
Unique considerations	Iliac/rib autograft ± posterior ilium for graft. Fiberoptic intubation and SSEPs	⇐
Surgical time	2–3 h	3–4 h
Closing considerations	Routine wound closure	Halo vest may be needed in selected cases.
EBL	100–500 mL	⇐
Postop care	PACU, then → room	⇐
Mortality	<1%	⇐
Morbidity	Vertebral artery injury: 4.1% CSF leak Instrumentation failure Nonunion	Neural injury ⇐ ⇐ ⇐
Pain score	5–9	5–10

PATIENT POPULATION CHARACTERISTICS	
Age range	18–85 yr (usually 20–60 yr)
Male:Female	1:2
Incidence	Rare
Etiology	Neoplastic; traumatic; congenital; degenerative; infections; rheumatoid arthritis

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Cervical Neurosurgical Procedures.

Suggested Readings

1. Menendez JA, Wright NM: Techniques of posterior C1-C2 stabilization Neurosurgery 2007; 60(Suppl 1): S103–11.
2. Wright N, Lauryssen C: Vertebral artery injury in C1–2 transarticular screw fixation:

results of a survey of the AANS/CNS section on disorders of the spine and peripheral nerves. J Neurosurg 1998; 88:634–40.

ANTERIOR FUSION/FIXATION OF THE MID AND LOWER CERVICAL SPINE

SURGICAL CONSIDERATIONS

Description

The first description of the anterior approach for excision of a cervical disc was made by Smith and Robinson in 1958. This approach permits easy and safe access to the entire C-spine below C2. **Anterior cervical discectomy** is commonly indicated for the removal of herniated discs or osteophytes compressing the spinal cord or nerve roots. Multisegmental cervical spondylosis (narrowing of spinal canal) may require single- or multilevel corpectomy (removal of a vertebral body). During anterior cervical discectomy, an approach from the left side of the neck is often preferred because it minimizes the chances of injury to the recurrent laryngeal nerve. The dissection is carried along the avascular plane between the trachea and esophagus medially and the carotid sheath laterally (Figs. 1.3-6 and 1.3-7). The fascia is incised to expose the longus colli muscles and anterior C-spine. The disc level is confirmed using fluoroscopy. The annulus is incised, and the disc is removed in piecemeal fashion with the use of an operating microscope. **Fusion and instrumentation** are often performed after discectomy to maintain disc space height, restore normal cervical lordosis, prevent graft extrusion, facilitate early ambulation, and possibly prevent delayed deformity and pain due to collapse of the disc space. After the discectomy, osteophytes are removed from the vertebral bodies, and an appropriately sized bone graft or prosthesis is placed in the intervertebral space. PEEK and carbon fiber cages are radiolucent and allow good assessment of bony fusion. Fusion with instrumentation is often essential for immediate stability and early ambulation.

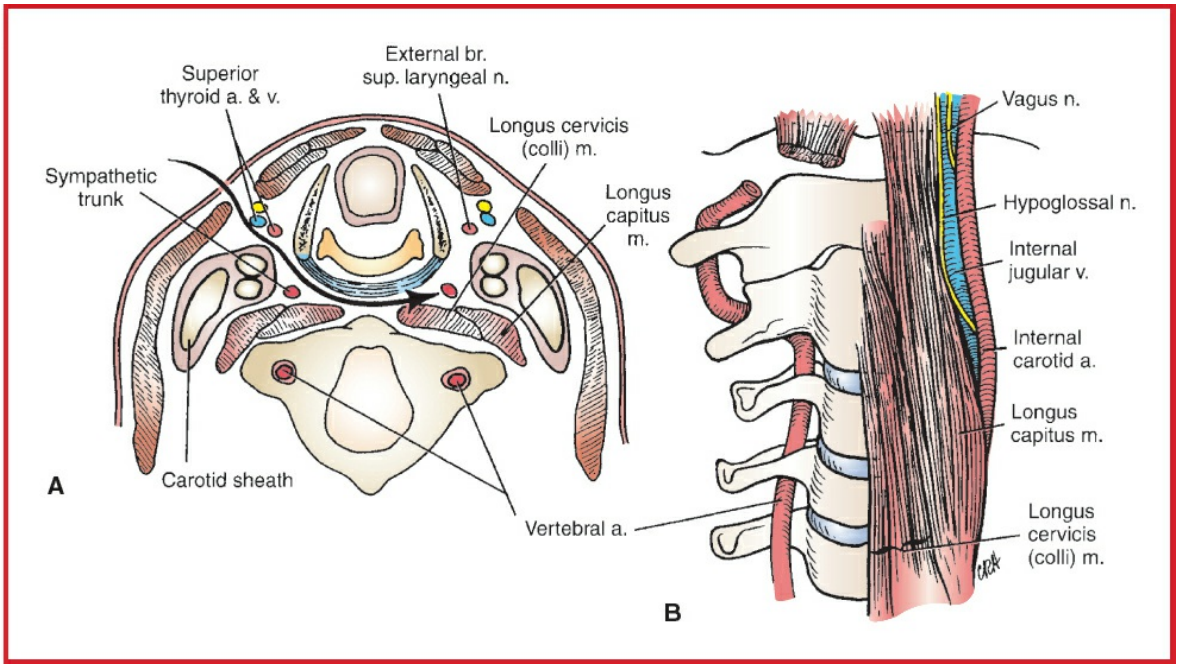

Figure 1.3-6 Upper C-spine. **A:** Cross-section showing the anteromedial approach. **B:** Anterior aspect, after stripping the longus colli muscle. (Reproduced with permission from An HS, Cotler JMSpinal Instrumentation. Williams & Wilkins, Baltimore: 1992.)

Anterior screw-plate fixation (with MRI-compatible titanium) is the preferred method of fixation for C2-C7. It provides stable fixation after discectomy or corpectomy, prevents bone graft migration, improves fusion rate, corrects spinal deformities, and may restore anterior and middle column function following cervical trauma. Plates and screws are placed under fluoroscopic guidance to prevent dural penetration or malposition. Hemodynamic changes should be monitored closely during the procedure, because ↓ HR or ↓ BP during the instrumentation may suggest cord compression.

Usual preop diagnosis

Cervical radiculopathy (nerve root compression due to disc herniation or osteophytic compression); cervical myelopathy (spinal cord compression by disc/osteophytes); cervical instability (ligamentous laxity or disruption)

Variant procedures

Cervical (vertebral) corpectomy and fusion are used to treat conditions in which there is anterior impingement of the spinal cord or narrowing of the spinal canal at the level of the vertebral body, including multisegmental cervical spondylitic compression, ossification of the posterior longitudinal ligament (OPLL), tumors, infections (e.g., TB osteomyelitis), or C-spine injury. The surgical exposure is similar to that for anterior cervical discectomy. A transverse neck incision is preferred for corpectomy involving two or three vertebrae; however, a vertical skin incision along the anterior border of the

sternomastoid may be used if more than three vertebrae are involved. Before the removal of a vertebral body, adjacent discs are resected. The posterior part of the vertebra and osteophytes at the posterior margins are excised. Reconstruction is accomplished with an autograft, allograft, or cages (metal or carbon fiber spaces filled with bone fragments). Some of the newer cages are expandable, facilitating a good fit. Supplemental fixation with plates and screws is essential to prevent graft extrusion, to facilitate fusion, and to permit early ambulation.

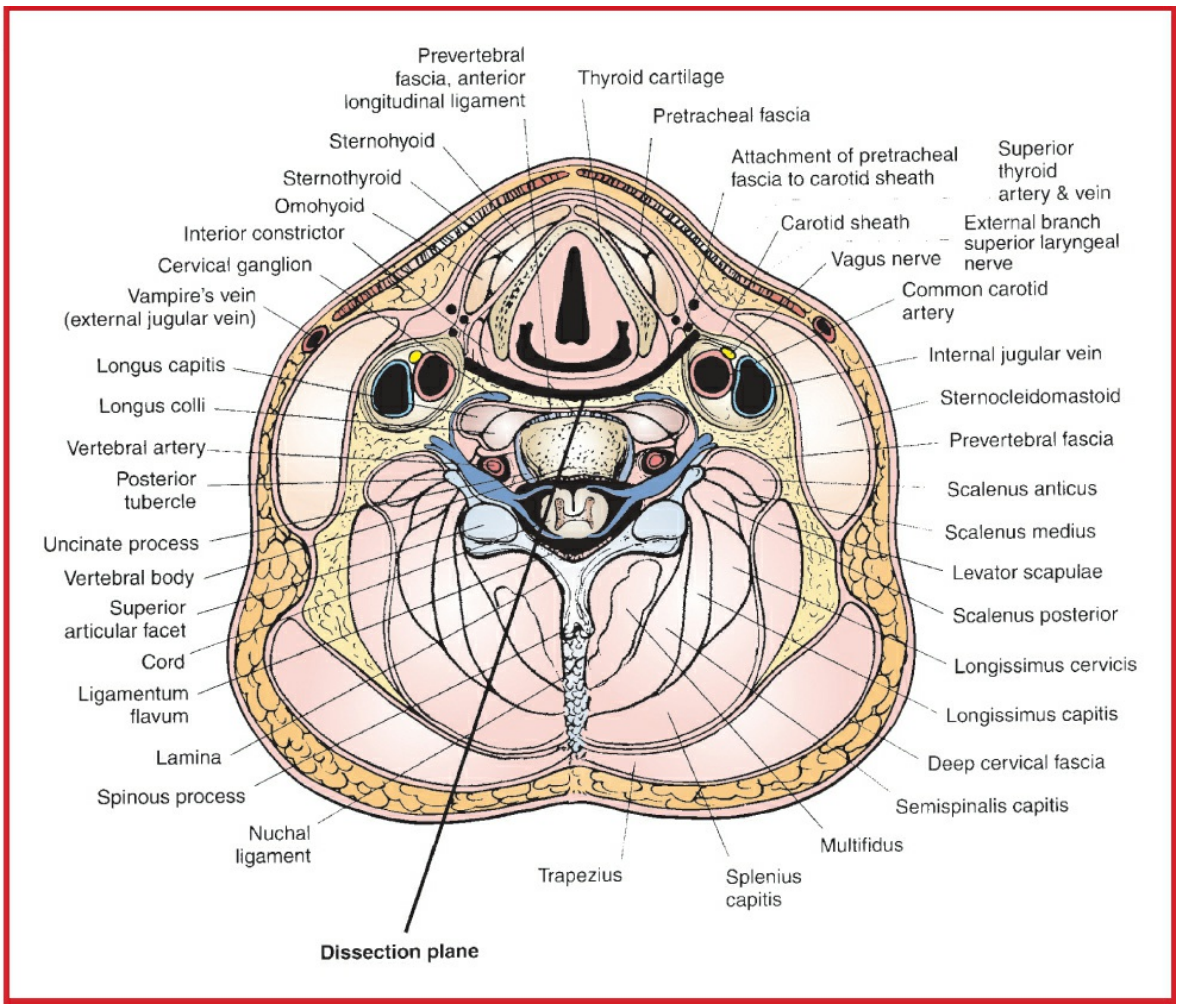

Figure 1.3-7 Cross-section of the C-spine at C5 level. Note the deep cervical fascia, the pretracheal fascia, and the prevertebral fascia. Note the relationship of the pretracheal fascia to the carotid sheath. Dissection plane is shown. (Modified with permission from Hoppenfeld S, deBoer P Surgical Exposures in Orthopaedics: The Anatomic Approach, 2nd edition. J.B. Lippincott, Philadelphia: 1994.)

A **cervical artificial disc** can be placed via an approach that is similar to that of an ACDF but instead of placing a bone graft or cage, a mobile prosthetic disc is placed according to manufacturer's instruction. No additional stabilization or bone grafting is required. Accurate placement of this disc is absolutely critical to the success of this procedure. Fluoroscopy is used extensively to ensure this. There is immediate stability

and because motion is preserved, early mobilization is recommended.

Usual preop diagnosis

Cervical myelopathy (spinal cord compression) 2° fracture of the C-spine (traumatic or pathologic); narrowing of the spinal canal due to congenital conditions; degenerative conditions, such as severe disc disease with osteophyte formation; OPLL; cervical instability (ligamentous laxity or disruption or destruction of bone due to tumor or infection); failed previous spinal fusion

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Cervical Discectomy ± Fusion and Plating; Artificial Disc Placement	Cervical Corpectomy ± Fusion and Plating
Position	Supine, head extended on headrest	⇐
Incision	Transverse anterolateral	⇐ or vertical anterolateral
Special instrumentation	Operating microscope; anterior cervical plates	⇐
Unique considerations	Fiberoptic intubation may be necessary; ± cervical traction	⇐
Antibiotics	Cefazolin 2 g iv	⇐
Surgical time	1–2 h (+1 h for fusion/plating)	1.5–3 h for single level; add 20–30 min for each additional level
Closing considerations	Cervical collar (soft/hard)	⇐
EBL	25–250 mL	50–1000 mL
Postop care	PACU → room	⇐

Mortality	<1%	0–5%
Morbidity	Esophageal perforation: <1%	⇐
	Infection: <1%	⇐
	Massive blood loss–carotid or jugular injury: <1%	⇐
	Myelopathy: <1%	⇐
	Nerve injury:	⇐
	Recurrent laryngeal nerve: 5%	⇐
	Root: <1%	1–15%
	Sympathetic chain: <1%	⇐
	Postop instability: <1%	
	Instrument failure: <1%	
	Slipped graft: <1%	
Pain score	3–5	3–5

PATIENT POPULATION CHARACTERISTICS		
Age range	18–85 yr (usually 20–60 yr)	⇐
Male:Female	1:2	⇐
Incidence	Rare	⇐
Etiology	Neoplastic; traumatic; congenital; degenerative; OPLL	⇐

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Cervical Neurosurgical Procedures.

Suggested Readings

1. Brislin BT, Hilibrand AS: Avoidance of complications in anterior cervical spine revision surgery. Curr Opin Orthop 2001; 12(3):257–64.
2. Tasiou A, Giannis T, Brotis AG, et al: Anterior cervical spine surgery-associated complications in a retrospective case-control study. J Spine Surg 2017; 3(3):444–59.

POSTERIOR FUSION/FIXATION OF THE MID AND LOWER CERVICAL SPINE

SURGICAL CONSIDERATIONS

Description

Posterior cervical laminectomy (removal of lamina), **foraminotomy** (opening of the neural foramina), and **laminotomy** (removal of a portion of the lamina) are posterior procedures for decompression of the neural elements in the C-spine. These procedures are used to treat cervical radiculopathy 2° degenerative disc disease (e.g., herniated discs, osteophytes). The major advantage of **foraminotomy** over an anterior approach is that it does not require fusion and, thus, preserves the motion of the involved vertebral segments and obviates the need for immobilization for fusion. It also permits decompression of multiple levels, if required. Disadvantages of foraminotomy include an increased incidence of neck pain and the fact that it is not an effective approach to midline disc herniation. **Decompressive laminectomy** can be used to treat cervical canal stenosis (congenital or degenerative) and for removal of intraspinal masses (tumors, AVMs, infective granulomas), which may be extradural, intradural, extramedullary, or intramedullary. Depending on the location of the tumor, the surgeon may need to open the dura and/or spinal cord. Obviously, the intradural intramedullary tumors involve more risk and are more delicate to remove. Many laminae may be removed to expose and excise the tumor. Surgical adjunctive tools (e.g., CUSA, laser, surgical microscope) may be used to aid in removal of the tumor. Intraop evoked potential monitoring may be used during these procedures to test the integrity of the dorsal columns. After the tumor has been removed, the wound is closed in layers, as in a simple laminectomy.

Surgery is performed in the prone or sitting position through a posterior midline incision over the involved vertebrae. The paraspinal muscles are dissected off the spinous processes, and lamina and bone are removed piecemeal. The extent of the procedure depends on the indications for treatment. Hemostasis is achieved with bipolar cautery, and raw bone surfaces are sealed with bone wax. Topical hemostatic agents are used to aid in hemostasis in the epidural gutters. If the patient has an intradural tumor or process, such as syringomyelia, the dura is opened, and the operating microscope is used for this portion of the procedure. After the intradural procedure is complete, the dura is closed, and the surgeon may wish to test the integrity of the closure with a Valsalva-like maneuver (sustained inspiration to 30–40 cm H_2O). The wound is closed in layers, and a drain may be left in the epidural space. Multilevel laminectomies with

foraminotomies (involving partial removal of cervical facet joints) can result in late-onset cervical kyphosis, an extremely difficult condition to treat. These patients are usually considered for concomitant posterior fusion and instrumentation, especially in the presence of cervical segmental instability.

Newer less traumatic techniques can be used to perform foraminotomies and discectomies in the cervical spine in a **minimally invasive (MIS)** fashion. These use one of many tubular retractor systems (e.g., **METRx** [Medtronic, Memphis, TN, USA]) These afford similar exposure but minimize blood loss, scar, and pain by spreading the muscles. The disadvantage is unfamiliar exposure, difficulty with retractor placement, and potential of neurologic injury by inadvertent penetration of the interlaminar space.

Posterior cervical wiring techniques include (a) **interspinous wiring** (Fig. 1.3-8) (wires are passed through drilled holes in the base of adjacent spinous processes and then tightened), (b) **sublaminar wiring** with Luque rods or rectangles (sublaminar wires are passed at each level on both sides and are tightened over the rods or rectangles), and (c) **a triple-wire technique** with the first wire being passed through drill holes at the base of each spinous process and the second and third wires passed through the same holes and then through drill holes in the previously placed bone grafts. This latter technique is biomechanically sound because it places the bone grafts in compression. Wiring techniques, although stable in flexion, however, are less stable in extension and rotation, and they cannot be performed in patients with prior laminectomy or requiring laminectomy.

In the **posterior cervical lateral mass screw fixation** technique, the C-spine is exposed through a midline incision over the involved vertebral segments. The lateral mass (bony column between facet joints) is identified, drilled, and tapped. Cortical screws are passed into the lateral mass and fixed with plates or rods. The trajectory of the screws in the lateral mass is to the upper outer corner in the classic Magerl technique. The entry point should be ~1 mm medial to the midpoint of the lateral mass (Fig. 1.3-9). The axial trajectory angulation should be 25°, and the sagittal angulation should be 45°, which is in-line with the facet joints (Figs. 1.3-10 and 1.3-11). Adjacent facet joints are decorticated, and bone grafts are placed. Lateral mass plating provides a rigid multisegmental fixation and can be performed in patients with prior laminectomy. The major risks involved with this procedure are nerve root and vertebral artery injuries.

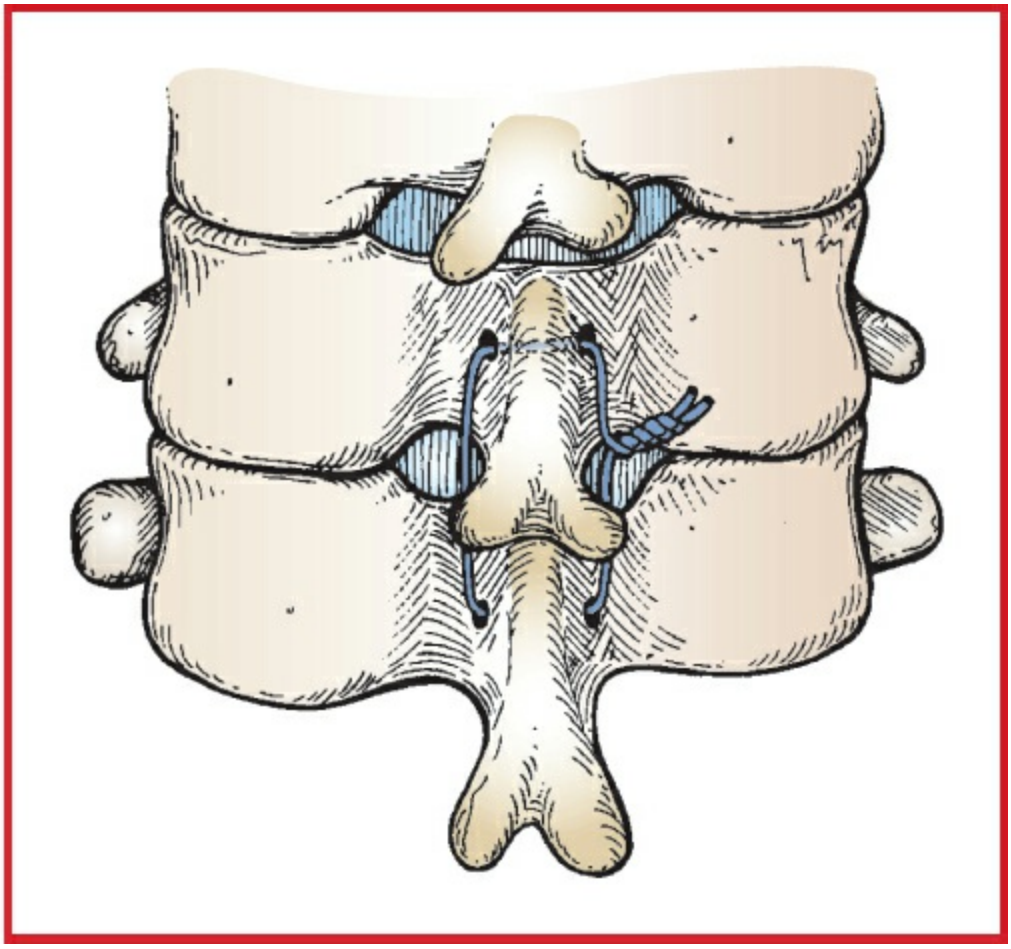

Figure 1.3-8 Intraspinous wiring. Wires passed through drilled holes in base of adjacent spinous processes and tightened. (Reproduced with permission from An HS, Cotler JM Spinal Instrumentation, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 1999.)

Cervical pedicle screw plate fixation is an effective alternative to lateral mass fixation. In this technique, screws are passed under fluoroscopic guidance into the cervical pedicles and secured to plates or rods. This procedure is technically demanding, as the cervical pedicles are narrow and in close proximity to nerve roots, vertebral artery, and spinal cord, and their trajectories are typically unfamiliar. This technique is biomechanically stable and permits the correction of deformity by application of compression or distraction forces. It is most commonly performed at C2 where the pedicles are relatively larger.

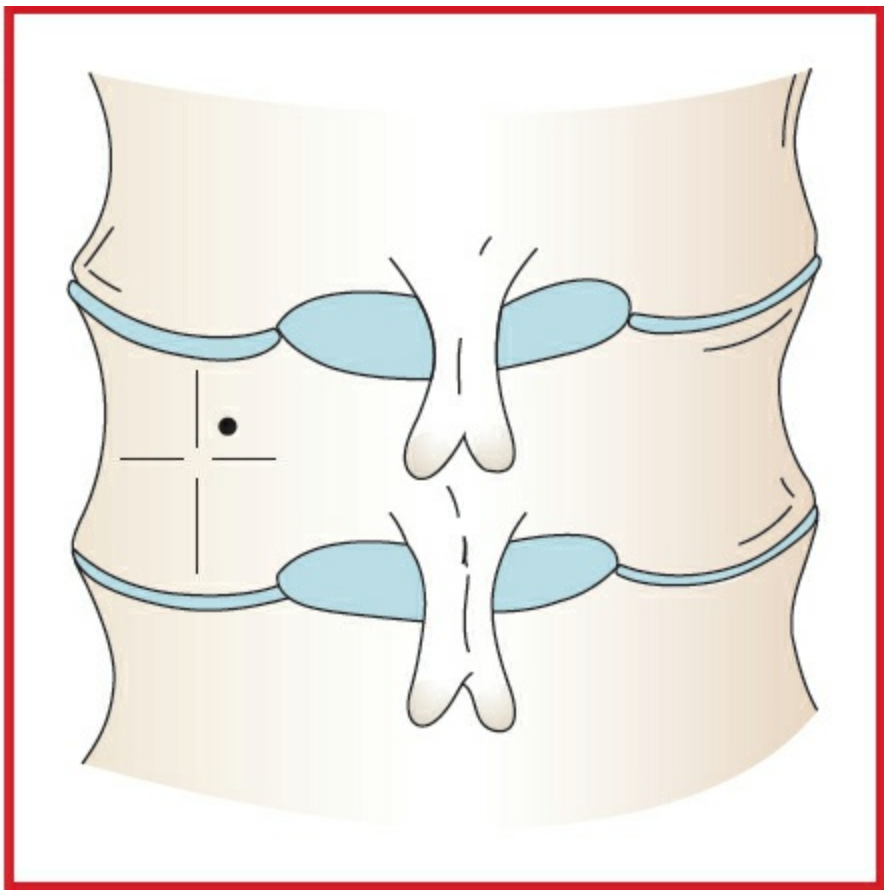

Figure 1.3-9 Magerl technique lateral mass screw entry point. (Reproduced with permission from Barrey C, Mertens P, et al: Quantitative anatomic evaluation of cervical lateral mass fixation with a comparison of the Roy-Camille and the Magerl screw techniques. Spine 2005; 30(6):E140–7.)

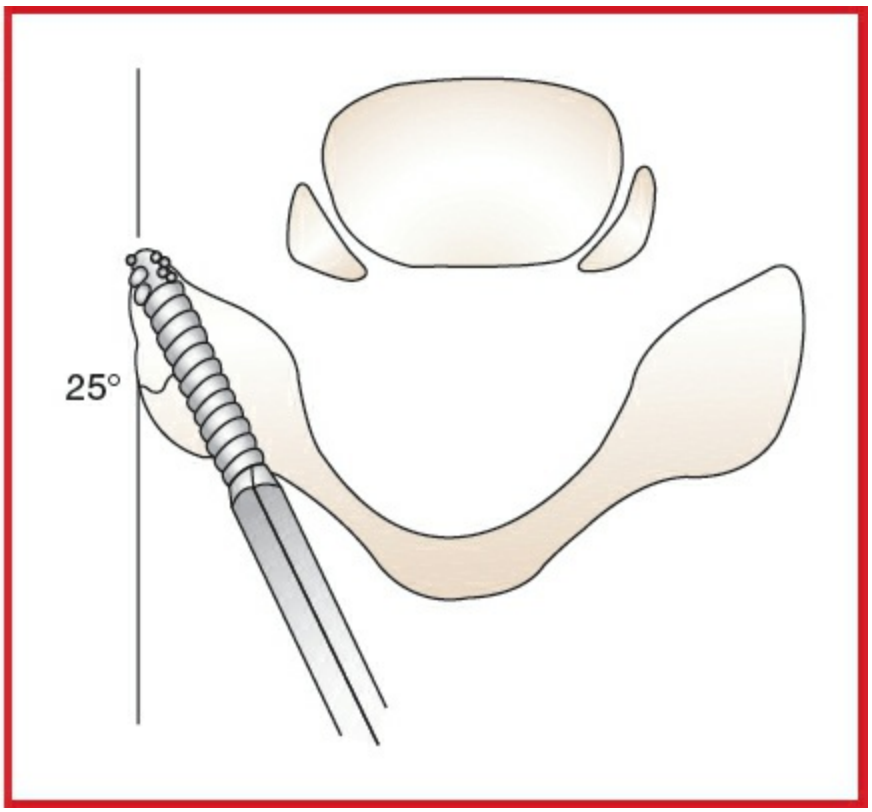

Figure 1.3-10 Magerl technique lateral mass screw axial trajectory angulation. (Reproduced with permission from Barrey C, Mertens P, et al: Quantitative anatomic evaluation of cervical lateral mass fixation with a comparison of the Roy-Camille and the Magerl screw techniques. Spine 2005; 30(6):E140–7.)

Usual preop diagnosis

Cervical radiculopathy (nerve root compression); cervical myelopathy (spinal cord compression); cervical disc disease (herniation or degeneration of one or more cervical discs); C-spine injury

Variant procedures

Patients with panvertebral disease (involving anterior and posterior elements of the spine) and three-column spinal instability often require **combined anterior and posterior decompression, reconstruction, and instrumentation**. Anterior screw plates provide a strong tension band to resist vertical/horizontal translation and neck extension; however, they are less able to resist flexion or rotation. By contrast, posterior cervical plates strongly resist flexion or rotation but are less able to resist extension. Thus, in the presence of three-column spinal instability, combined anterior and posterior instrumentation often is required. This technique provides rigid fixation of spinal segments and avoids the need for rigid external orthotic devices.

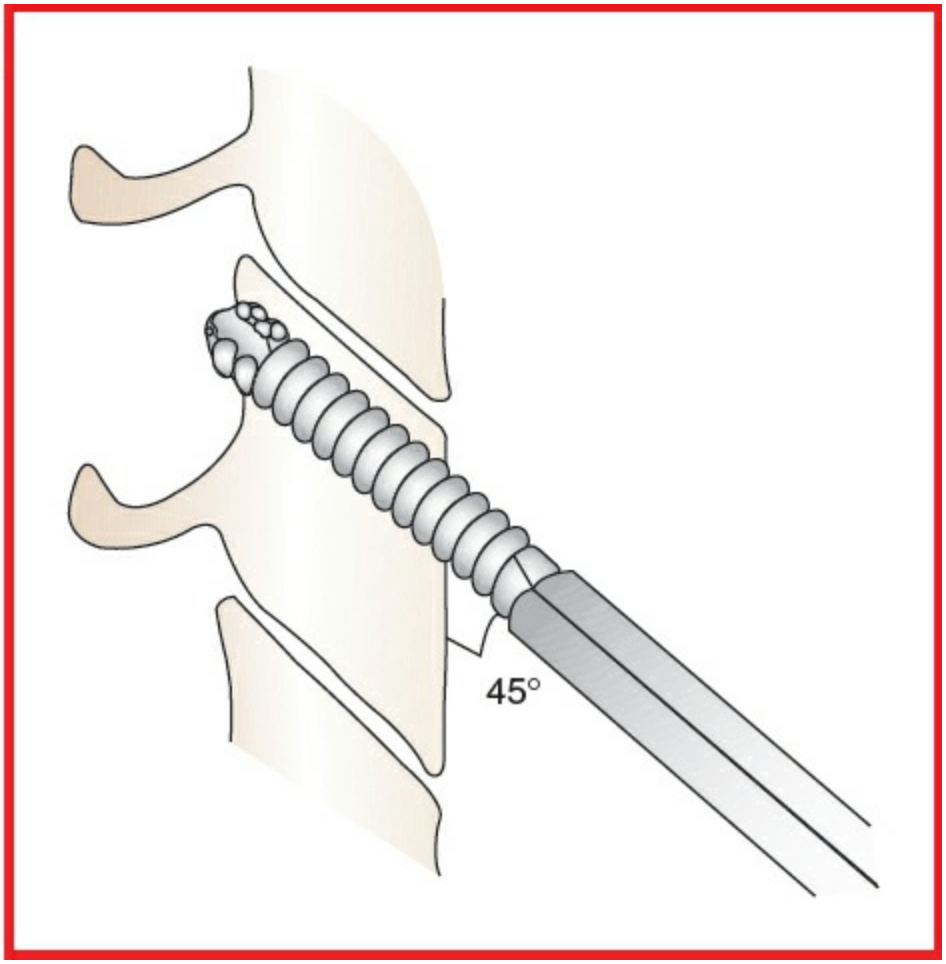

Figure 1.3-11 Magerl technique lateral mass screw sagittal trajectory angulation. (Reproduced with permission from Barrey C, Mertens P, et al: Quantitative anatomic evaluation of cervical lateral mass fixation with a comparison of the Roy-Camille and the Magerl screw techniques. Spine 2005; 30(6):E140–7.)

Combined instrumentation techniques are challenging and require several special considerations. Patients with any unstable C-spine may require fiberoptic intubation, intraop cervical traction, and electrophysiologic monitoring. **Anterior and posterior cervical instrumentation** is usually carried out in a single surgical session although may be staged. The transition between the anterior and posterior approaches requires a specialized operating table (e.g., Jackson spinal table or Stryker frame) and careful coordination among the entire OR team. The long duration of surgery may be associated with increased incidence of respiratory complications, blood loss, and prolonged ICU stays. In rare instances, an additional anterior or posterior approach may be performed ("540-degree procedure").

Usual preop diagnosis

C-spine injury causing three-column (severe, unstable) injuries; cervicothoracic junctional pathologies; correction of kyphotic deformities; panvertebral disorders

involving C-spine (neoplasms, infection, spondylitic myelopathy); failed symptomatic anterior cervical fusions

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol and smoking cessation, review of nutritional status, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Cervical Laminotomy/Foraminotomy	Cervical Laminectomy with Instrumentation	Combine Anterior/ Cervical Instrume
Position	Prone or sitting; pin fixation or horseshoe headrest	Prone; pin fixation or horseshoe headrest	⇐ + supine
Incision	Posterior midline neck	⇐	⇐ + transv longitudina anterolate
Special instrumentation	Operating microscope for intradural procedures	⇐ + Implants, pedicle screws with plates	Implants; and poste plates wit
Unique considerations	Fiberoptic intubation; I.I. to assess correct level	⇐; I.I. for screw placement	Implants; and poste plates wit
Antibiotics	Cefazolin 2 g	⇐	⇐
Surgical time	1.5–2 h	⇐ Add 30–45 min/level of instrumentation	4–5 h
EBL	25–500 mL	⇐	250–600
Postop care	PACU → room	⇐	⇐; someti needs sho stay
Mortality	0–3%	⇐	⇐

Morbidity	All <5%: Neurologic deterioration Myelopathy Nerve root injury CSF leak Postop instability Infection	⇐ ⇐ Additionally: Instrumentation failure Vascular injury Nerve root injury 2° screws	5–10% ⇐ Additior Bone graf dislodgem Respirato problems
Pain score	2–6	5–10	7–10

PATIENT POPULATION CHARACTERISTICS	
Age range	18–85 yr (usually 20–60 yr)
Male:Female	1:2
Incidence	Rare
Etiology	Neoplastic; traumatic; congenital; degenerative; infections; rheumatoid arthritis

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Cervical Neurosurgical Procedures.

Suggested Readings

1. Cason GW, Herkowitz HN: Cervical intervertebral disc replacement.J Bone Joint Surg Am 2013; 95(3):279–85.
2. Leven D, Meaike J, Radcliff K, et al: Cervical disc replacement surgery: indications technique, and technical pearls. Curr Rev Musculoskelet Med 2017; 10(2):160–9.

ANTERIOR CERVICOTHORACIC SPINE SURGERY

SURGICAL CONSIDERATIONS

Description

The **anterior approach** to the **cervicothoracic junction** (CTJ, C7-T3) is performed for discectomy, stabilization of spinal fractures, tumor resection, spinal reconstruction, and instrumentation. Anterior approaches to the CTJ often are challenging, as this area represents a rapid transition from cervical lordosis to thoracic kyphosis, resulting in

abrupt increase in the depth of the wound. The confluence of great vessels and visceral (trachea, esophagus) and neural structures at the thoracic inlet makes them susceptible to injury. The modified anterior approach utilizes a "hockey-stick" incision to allow greater access to the lower cervical and upper thoracic spine. This technique does not require any additional bone resection during the approach. The **transsternal** approach involves a longitudinal incision along the anterior border of the sternomastoid, extended over the midline of the sternum to the xiphisternum. The sternum is divided using an oscillating saw and retracted to expose the anterior aspect of the CTJ. The wide exposure available with this approach permits vertebral resection, reconstruction, and instrumentation. The **transclavicular** approach involves a T-shaped incision over the clavicles, with a vertical limb extending down the midline of the sternum. Subplatysmal flaps are elevated, and the sternal and clavicular heads of the sternomastoid are detached from their origin and retracted superolaterally. The medial third of the clavicle and manubrium are resected to provide an excellent direct anterior approach to the CTJ for vertebral decompression, reconstruction, and stabilization.

Variant procedure and approaches

Axillary thoracotomy and high transthoracic thoracotomy approaches permit an anterolateral exposure to CTJ. As these procedures involve entering the thoracic cavity, they typically require one-lung ventilation (OLV) during the procedure.

Usual preop diagnosis

C7-T3 disc disease, fracture, tumor, and deformity

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Transsternal Approach	Transclavicular Approach	Axillary/High Thoracotomy
Position	Supine	⇐	Lateral
Incision	Longitudinal incision along anterior border of sternomastoid	T-shaped incision over clavicles with a vertical limb down the midline of sternum	Lateral chest wall

Special instrumentation	Anterior cervical plates Special oscillating saw for sternal opening	⇐ Special blades for clavicular resection	⇐
Unique considerations	OLV not necessary	⇐	OLV necessary
Antibiotics	Cefazolin 2 g iv	⇐	⇐
Surgical time	3–4 h	⇐	⇐
Closing considerations	Soft cervical collar	⇐	⇐
EBL	200–500 mL	⇐	⇐
Postop care	PACU → room	⇐	⇐
Mortality	1–2%	⇐	⇐
Morbidity	Wound infection/breakdown Injury to great vessels at thoracic inlet	⇐ ⇐ Cosmetic deformity	⇐ ⇐ Respiratory problems
Pain score	7–10	7–10	7–10

PATIENT POPULATION CHARACTERISTICS	
Age range	30–50 yr
Male:Female	1:1
Incidence	Uncommon
Etiology	Disc herniations; trauma; tumor; infections

ANESTHETIC CONSIDERATIONS FOR CERVICAL NEUROSURGICAL PROCEDURES

(Procedures covered: anterior/posterior fusion/fixation of upper and mid/lower C-spine and anterior cervicothoracic spine surgery)

PREOPERATIVE

Surgery of the C-spine is common primarily because of the frequency of herniation of a cervical intervertebral disc causing compression of the adjacent spinal nerve roots. Other less frequent indications for cervical surgery include acute or chronic instability of the neck requiring fusion, removal of a tumor of the spinal cord, or craniocervical decompression for Arnold-Chiari malformation.

Respiratory	Trauma to the head and high C-spine may be associated with loss of consciousness and/or acute respiratory failure resulting in severe hypoxemia and hypercapnia. These cases require immediate airway control. While efforts should be made to minimize neck movement, these concerns should not be allowed to delay the restoration of adequate ventilation and oxygenation. Direct laryngoscopy with manual in-line stabilization is a rapid and reasonable approach to emergently securing the airway without producing excessive neck motion. If a video laryngoscope or a fiberoptic bronchoscope is immediately available, these techniques may allow airway control with less motion of the neck but may also take more time to perform. C-spine trauma patients should be assessed for the presence of other injuries such as pulmonary contusion, pneumo- or hemothorax, tracheal injury, or facial injury that may affect pulmonary function, impede ventilation, or make airway control difficult. **Tests:** Consider ABG to quantify the degree of respiratory impairment, if present.
Cardiovascular	Acute fractures of the C-spine and associated spinal cord trauma may → ↓ sympathetic tone → ↓ BP and ↓ HR (neurogenic or spinal shock). Generally, this condition can be treated effectively with crystalloid and/or colloid infusion and atropine to ↑ HR. Rarely is it necessary to use vasopressors to maintain BP or HR. If spinal cord injury is suspected, an A-line must be placed, and MAP should be >80 mm Hg at all

	times to avoid vascular insufficiency of the spinal cord. Severe cervical spine disease may compromise blood flow through the vertebral arteries. If present, careful positioning and maintenance of adequate MAP are essential. **Tests:** As indicated from H&P
Neurologic	Patients with herniation of a cervical disc generally complain first of pain in the neck, particularly with lateral rotation of the head. The pain may radiate down one or, rarely, both arms. As nerve compression continues, patients begin to develop weakness and atrophy of specific muscle groups in the arm. These Sx, however, are not specific to herniation of a disc and may be caused by a spinal cord tumor or cyst. Patients with acute fractures of the neck and attendant spinal cord trauma at the T1 level may be paraplegic to some degree, whereas fractures above C5 may result in quadriplegia and loss of phrenic nerve function. Injuries between these two levels result in variable loss of motor and sensory functions in the upper extremities. A careful documentation of preop sensory and motor deficits is important. Be aware that changes in the head or neck position may alter patient signs and symptoms. **Tests:** MRI is the primary diagnostic test to evaluate disease affecting the spinal cord. Patients with suspected acute cervical trauma are usually evaluated with multiple imaging techniques.
Hematologic	Antiplatelet agents should be stopped 5 d before elective surgery. At least 2 U of PRBCs should be cross-matched if large blood loss is anticipated. Expect more blood loss during surgeries involving multiple levels, tumor resection (especially metastases), or at C1 and C2. **Tests**: Hct; T&C; others as indicated from H&P
Laboratory	Other tests as indicated from H&P

Premedication	Elective cases for chronic disease should be premedicated as usual. Acute trauma victims demand extreme caution with premedication since the possibility of intoxication, brain, chest, and/or spinal cord trauma may predispose the patient to serious adverse effects. Proper topicalization and cautious sedation (consider dexmedetomidine: load 0.5–1 mcg/kg over 10 min) are critical when attempting awake intubation to prevent coughing and gagging-induced motion of the neck.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water and aprepitant 40–80 mg po with sip of water.

INTRAOPERATIVE

ANESTHETIC TECHNIQUE: GETA

Induction	It is important to discuss the severity of the surgical lesion and the planned intubation with the surgeon before proceeding. The ideal technique for airway management in patients with cervical spine disease remains a topic of debate. All airway management techniques (including mask ventilation) will likely result in some C-spine movement, but direct laryngoscopy seems to result in more motion than other intubation techniques. Minimizing neck motion during airway management is an important goal. For patients with a stable neck, orotracheal intubation using standard laryngoscopy is acceptable. Manual in-line stabilization will likely reduce neck motion but will also make direct laryngoscopy more difficult. Alternative techniques should be employed in patients with an unstable C-spine, if a difficult airway is anticipated or if neck manipulation exacerbates symptoms. Depending on the clinical situation,

	fiberoptic intubation before or after induction (with or without an LMA), a lighted stylet device, or a video laryngoscope (e.g., a GlideScope®) might be most appropriate (with care being taken to minimize neck motion). An awake intubation has the advantage of permitting a neurologic assessment after intubation and positioning. Whether it is done before or after intubation, induction is typically accomplished with propofol 0.5–2.5 mg/kg. If MEP monitoring will be used, consider succinylcholine or low-dose rocuronium (0.5 mg/kg) vs. deep anesthesia and remifentanil bolus (1.5 mcg/kg) to facilitate intubation yet permit the rapid return of neuromuscular transmission.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Avoid hypothermia. Dexamethasone (4–8 mg iv) may ↓ PONV. Sequential pneumatic compression devices should be used to ↓ VTE risk. Consider ketamine (0.25 mg/kg/h) and/or lidocaine (1–2 mg/kg/h) infusions as components of MMPM especially in chronic pain patients.
Maintenance	If no neurophysiologic monitoring is used, then standard maintenance is sufficient. Neuromuscular blockade with rocuronium 0.6 mg/kg or vecuronium 0.1 mg/kg is helpful for positioning the patient and insertion of the Dingman retractor. After muscle dissection is complete and the retractors are in place, further use of relaxants is usually not necessary. When EP monitoring is used the anesthetic plan must be adapted to ensure optimal monitoring conditions. Standard NMB doses will completely abolish MEPs and must be avoided although small NMB doses may be needed to suppress interfering EMG activity. Doses >0.5 MAC each of a volatile anesthetic and N_2O interfere with MEP and, to a lesser extent, SSEP monitoring. An anesthetic consisting of 50% N_2O in

	O_2 with up to 0.6% isoflurane in combination with a remifentanil infusion (0.05–2 mcg/kg/min) will provide anesthesia while permitting both MEP and SSEP monitoring. TIVA may be preferred by local custom when monitoring EPs but is not necessary. The neurophysiology monitoring team must be updated when conditions that affect the evoked potentials change (depth of anesthesia, anesthetic agent, blood pressure, PCO_2, PO_2). As soon as neuromonitoring is complete, switching to an inhaled anesthetic and stopping the propofol will allow for a timely emergence. In general, keep MAP > 80 mm Hg to ensure adequate perfusion pressure to the cord.
Emergence	If a cervical fusion has been performed and the patient has been returned to a halo device or body jacket, it is desirable to leave ETT in place until the patient is fully awake, responding to commands, and able to manage his/her own airway as reintubation is likely to be difficult. **NB:** Immediate airway obstruction 2° soft tissue occlusion or superior laryngeal nerve damage may occur on extubation. A useful way to test for airway patency is to deflate the cuff of the tracheal tube and determine that the patient is able to breathe around the tube as well as through it. If there is any question about adequacy of the airway, it is prudent to leave the ETT in place and spray lidocaine 4% 4 mL down the trachea using a laryngotracheal anesthesia device (LTA) before emergence. This technique will usually prevent or minimize coughing or bucking on the ETT for about 15–30 min. One also should consider inserting an airway exchange catheter (AEC) through the ETT before its removal. AECs are well tolerated and can be left in place until one is confident that no further airway compromise will occur. So long as the AEC is not touching the carina, it will not induce coughing or bucking, and the patient can talk without difficulty.

	This catheter will provide a conduit for immediate reinsertion of an ETT if airway obstruction from early or delayed swelling, bleeding, or hematoma formation should occur. Remifentanil will not provide postop analgesia and a longer-acting opioid (e.g., hydromorphone 0.2–0.6 mg iv) must be administered prior to emergence. Suggest wound infiltration with LA. Consider iv acetaminophen 1 g if po dose given >4–6 h ago and hydromorphone (0.2–0.6 mg iv). Discuss possible use of ketorolac or celecoxib.	
Blood and fluid requirements	16–18 ga × 1 BSS/LR @ 1–3 mL/kg/h T&C 1–2 units depending on type of surgery	While blood transfusion is rarely needed for operations on the C-spine, expect more blood loss during surgeries involving multiple levels, tumor resection (especially metastases), or C1 and C2. Suggest goal-directed fluid management (see Appendix K, p. K-4). Zero balance or goal-directed fluid management is recommended.
Monitoring	Standard monitors ± Arterial line ± Urinary catheter ± BIS monitor MEP/SSEP	If a standard BP cuff is to be used, consider placing it on a leg at the ankle. If placed on an arm without rigid protection (e.g., sleds), the surgeons tend to lean on the cuff, making it difficult to take consistent, reliable measurements. If the patient has a CV, respiratory, or metabolic

		disorder (e.g., insulin-dependent diabetes), consider inserting an arterial catheter. For patients with spinal cord injury or severe stenosis, an arterial line should be placed prior to induction when hypotension is most likely.
	± CVP line	If a posterior surgical approach with patient in seated position is planned, arterial and CVP catheters should be placed. If a CVC is placed for the purpose of aspirating air from the RA, then its location must be confirmed before the start of surgery by x-ray, transcatheter ECG, or echocardiography.
	± Precordial Doppler	A precordial Doppler flow probe also should be placed on the anterior chest wall; confirm position by injecting 1 mL of agitated NS into CVP line and listening for the characteristic change in Doppler sound, alternatively by transcatheter ECG or by x-ray.
Positioning	Supine: ✓ and pad pressure points	For **anterior cervical discectomy** and/or fusion, patient is

	✓ eyes Shoulder roll ± Cervical traction	positioned supine with a roll under the shoulders or neck, and the head is moderately extended. A cervical strap may be placed below the chin and behind the occiput and attached to a weight of 5–10 lb hung over the head of the bed. If patient is in a halo or tongs, 5–10 lb of weight is attached to the device. Alternatively, the surgeon may request traction intermittently during insertion of bone plugs for fusion. The surgical incision can be made on either side of the neck at the discretion of the surgeon.
	Prone: ✓ and pad pressure points ✓ eyes ✓ genitalia	The head will usually be placed in a Mayfield three-point attachment. Ensure that there is no posterior pressure on the ETT, as it can injure the uvula or soft palate. Ensure a neutral C-spine position. Malpositioning, when maintained for several hours, may result in catastrophic damage to the spinal cord. If there are signs of cord dysfunction on evoked potential monitoring with

		no obvious physiologic or surgical explanation, consider adjustments to the position of the head to try to relieve any occult malpositioning.
	Sitting: ✓ and pad pressure points ✓ eyes VAE monitoring: ✓ ETT position	Although seldom used today, there are some advantages to the sitting position compared to the prone position. For the surgeon: (a) easier access to the lesion, (b) less blood loss, (c) less interference from CSF, and (d) lower incidence of neurologic injury. For the anesthesiologist: (a) less chance of ETT and line dislodgement, (b) less chance for inadvertent pressure injury, (c) easier assessment and management of ventilation, and (d) easier access to patient for insertion of additional catheters, if necessary. NB: measure (or calculate) blood pressure at the level of the head to avoid cerebral hypoperfusion. The previous notes of caution about malpositioning of the neck apply in the sitting position as well.

Complications	VAE	The major disadvantage of the sitting position is the risk of VAE, particularly paradoxical air embolism through a PFO (or, rarely, through the pulmonary circulation) → CNS or coronary emboli. Incidence of VAE is up to 76% in patients operated on in the seated position. VAE is easily detected using a combination of Doppler, $ETCO_2$, and ETN_2 analysis and complications are rare. If VAE is suspected (Sx =↓ $ETCO_2$, ↑ ETN_2, ↓ BP, dysrhythmias), notify the surgeon to flood the field, d/c N_2O, lower the head if possible, and aspirate the right atrial catheter using a syringe. This generally will confirm the Dx as well as provide treatment. If VAE continues, and the surgeon has difficulty identifying the site of air entrainment, consider using PEEP ≤ 10 cm H_2O or bilateral jugular compression to increase cerebral venous pressure. PEEP may promote paradoxical air embolism.

	In cases of massive systemic air embolism, hypothermia and hyperbaric oxygen therapy should be started ASAP.
Esophagus perforation	A possible complication of anterior cervical surgery is esophageal perforation. One way to assess for this type of injury is to flood the operative field with saline and then force air though the oropharynx and look for any signs of bubbling. These can be occult and manifest postop as fistulas as well.
Retraction nerve injury	Another potential complication of anterior surgery is retraction injury to various nerves including the recurrent laryngeal. Pressure can be taken off the nerve by reducing the ETT cuff pressure once the retractors are in place to mitigate any compression due to the nerve being trapped between the retractor and the ET cuff.
Hypotension (calculate MAP at head level)	↓ BP caused by venous pooling, inadequate venous return → ↓ CO can be treated by wrapping lower extremities while patient

		is supine, infusing adequate fluid volume to maintain right heart filling pressure, and avoiding excessive depth of anesthesia. Any acute drop in MAP may be due to a vascular injury, either obvious (vertebral artery injury) or occult (deep great vessel injury) until proven otherwise. The source of bleeding should be identified. Again, be sure to measure (or calculate) blood pressure at the level of the head to avoid cerebral hypoperfusion.

POSTOPERATIVE

Complications	Airway obstruction, edema Hematoma Neurologic deficit	Airway obstruction is usually the result of soft tissue falling back against the posterior pharyngeal wall, which may be difficult to correct by forward displacement of the mandible. Tissue edema from prone positioning and surgical manipulation, vocal cord paresis from recurrent laryngeal nerve injury, or hematoma formation may also contribute.

		Obstruction may require oral or nasal airway or reintubation. Consider inserting an airway exchange catheter before removing the ET tube. If a hematoma is suspected as the cause of respiratory distress, the wound must be opened immediately for evacuation. This should be done before any attempts at intubation, because direct laryngoscopy may not be possible if tracheal compression distorts the view. Emergent tracheostomy or cricothyrotomy can be lifesaving in patients with extreme soft tissue swelling.
	Tension pneumothorax	Delayed respiratory insufficiency usually is caused by either development of a tension pneumothorax or from bleeding into the neck at the surgical site, with progressive compression of the airway. If a tension pneumothorax is suspected and circulatory signs are stable, immediate CXR should confirm the Dx. If

circulation is failing, an 18- or 20-ga needle catheter should be inserted immediately anteriorly at the 2nd intercostal space on the suspected side to relieve the pneumothorax. If the Dx is airway obstruction from bleeding into the neck, the wound should be opened immediately and clots and blood removed. This should be done before any attempts at intubation because direct laryngoscopy may not be possible if tracheal deviation distorts the view. Emergent tracheostomy or cricothyrotomy can be lifesaving. It is sometimes difficult to distinguish airway obstruction from tension pneumothorax by physical signs. One useful way is to check for the "puff sign." With airway obstruction from any cause, what gas moves in and out of the airway does so very slowly because of an obstruction. In contrast, with tension pneumothorax, gas moves out of the airway

		with great speed because of high intrapleural pressure. By applying positive pressure to the airway and listening at the patient's mouth for the sound of gas escaping as airway pressure is released, one hears either a puff or jet of air escaping (tension pneumothorax) or slow, gradual exit of air (airway obstruction).
Multimodal pain management	IV hydromorphone IV acetaminophen Consider PCA ± Fentanyl 25–50 mcg prn	0.2–0.6 mg iv before emergence 1 g q6h for adults, 15 mg/kg q6h if ≤50 kg or ≤12 yr. If not given preop or if 4–6 h has elapsed since previous dose.
	± Ketorolac (30 mg iv) or celecoxib (200 mg po)	Consult with surgeon regarding possible hemostasis concern.
ERAS	Ondansetron 4 mg iv ± Metoclopramide 10–20 mg iv	Encourage early enteral nutrition, Foley catheter removal, and mobilization with physiotherapy.
Tests	CXR (as indicated) Hct	Repeat neurologic exam prior to discharge from PACU.

Suggested Readings

1. Aziz M: Airway management in neuroanesthesiology. Anesthesiol Clin 2012; 30(2):229–40.
2. Cason GW, Herkowitz HN: Cervical intervertebral disc replacement. J Bone Joint Surg Am 2013; 95(3):279–85.

3. Cavallone LF, Vannucci A: Review article: extubation of the difficult airway and extubation failure. Anesth Analg 2013; 116(2):368–83.
4. Chen CJ, Saulle D, Fu KM, et al: Dysphagia following combined anterior-posterio cervical spine surgeries. J Neurosurg Spine 2013; 19(3):279–87.
5. Crosby ET: Airway management in adults after cervical spine trauma. Anesthesiology 2006; 104:1293.
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9. Joglekar SB, Mehbod AA: Surgeon's view of pedicle screw implantation for the monitoring neurophysiologist. J Clin Neurophysiol 2012; 29(6):482–8.
0. Nowicka A, Ungureanu N, Balasubramanian S, et al: Tracheal extubation of patients with cervical spine injury: a case report and review of literature. A A Case Rep 2017; 8(2):21–5.

ANTERIOR THORACIC SPINE SURGERY

SURGICAL CONSIDERATIONS

Description

The **anterior approach** to the mid and lower thoracic spine (T4-T12/L1) is performed for spinal fracture, scoliosis/kyphosis, tumor, and infection. The **anterior transthoracic approach** provides a wide and easy exposure of the thoracic spine from T4-T10. The patient is placed in a lateral decubitus position (right or left, based on spinal pathology). An incision is made over the involved vertebrae and extended rostrally one or two intercostal spaces. The muscles and ribs are retracted, the pleura are opened, and lungs retracted to expose the vertebral bodies. Discectomy, corpectomy, bony reconstruction, and stabilization can be performed as required under radiographic guidance. The risk of spinal cord injury depends on the extent of surgery and reconstruction. The complex vasculature can be challenging. Hemostasis is vital to prevent hemothorax. Chylothorax and lymphatic injury are rare.

The **transition zone** at the thoracolumbar (TL) spine (T11-L1) is somewhat difficult to

expose and requires a combined transthoracic and retroperitoneal approach through the diaphragm **(thoracolumbar transdiaphragmatic approach)**. A left-sided approach is preferred because it is easier to retract the spleen and stomach than the liver. The skin incision is made over the 10th rib, down to thoracic muscles, and the rib is resected subperiosteally to provide wide exposure. Blunt dissection separates the peritoneum from the undersurface of the diaphragm and lateral and posterior abdominal walls. With gentle retraction of the lung and abdominal contents, the diaphragm is well visualized and is sectioned circumferentially from the chest wall. This provides an excellent exposure of the anterior aspect of the TL junction. Most procedures can be performed with minimal retraction of lung tissue at this level; thus, OLV is not typically required. Vertebral resection, reconstruction, and stabilization are performed with radiographic guidance. Reconstruction of the diaphragm is important to prevent herniation. This is rare with pure retroperitoneal approaches.

Variant procedure or approach

An 11th rib extrapleural-retroperitoneal approach offers an alternative approach to the TL junction. It provides excellent exposure without the need to incise the diaphragm, resulting in less morbidity and reduced risk of pulmonary complications. Because the pleural cavity is not entered, chest drains and OLV are not needed.

Thoracoscopic spine surgery

This technically challenging procedure is performed in the lateral position with GA, using OLV. Four or more 10–15-mm portals are made, with the working portal centered over the target vertebra. The optical (scope) portal is placed two or three intercostal spaces cranial to the target vertebra. Separate portals anterior to the working channel allow suction/irrigation and retraction. When using **thoracoscopic instrumentation**, hardware is placed through the portals in the chest wall under fluoroscopic guidance. Blood loss must be minimized as hemostasis is difficult with this approach. Because instrumentation requires a wide exposure of the spine, OLV is essential. The major advantages of thoracoscopic surgery include minimal rib retraction; minimal blood loss, with consequent early removal of chest drain; reduced wound pain; early ambulation; and low morbidity. These factors combine to reduce hospital stay.

Usual preop diagnosis

Fractures (usually at the TL junction); scoliosis; primary and metastatic tumors of the spine; pyogenic and tuberculous osteomyelitis; Scheuermann kyphosis

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol and smoking cessation, review of nutritional status, and postop pain

management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Transthoracic (T4-T10)	Transdiaphragmatic (T11-L1), 10th Rib	Thoracosc
Position	Lateral decubitus + axillary roll	⇐	⇐
Incision	Over involved vertebrae	Along 10th rib	3–4 portals (10–15 mm
Special instrumentation	Anterior thoracic instrumentation/cages	⇐	Thoracosco spinal instrumenta
Unique considerations	DLT ± OLV	⇐	DLT; OLV mandatory
Antibiotics	Cefazolin 2 g iv	⇐	⇐
Surgical time	2–6 h	⇐	⇐
Closing considerations	Transfer to bed before emergence. **NB:** sudden movement may dislodge grafts or implants	⇐ + May need closure of diaphragm	⇐
EBL	200–5000 mL; nontumor cases: 200–400 mL	⇐	50–200 mL
Postop care	Chest tube to water seal	⇐	⇐
	Chest physiotherapy/incentive spirometer Short ICU stay is usual. Bleeding >200 mL/h → re-exploration		Shorter per of chest drain/ICU st

Mortality	3–5%	⇐	⇐
Morbidity	Overall: 5–15%	⇐	⇐ + Probler with OLV
	DVT	⇐	—
	—	—	Conversion open surge 4%
	Neurologic: 1–2%	⇐	—
	Infection	⇐	—
	Vascular injury	⇐	—
	Sepsis	⇐	—
	Atelectasis	⇐	⇐
	Pneumonia	⇐	⇐
Pain score	7–10	7–10	5–8

PATIENT POPULATION CHARACTERISTICS	
Age range	12–30 yr (scoliosis surgery); >40 yr (tumor and infection surgery)
Male:Female	1:1; except for > scoliosis surgery in females
Incidence	20,000/yr
Etiology	Scoliosis, idiopathic (50%); trauma (20%); scoliosis, neuromuscular (15%); infections, tumors (10%); scoliosis, congenital (5%)
Associated conditions	See Etiology (above)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Thoracolumbar Neurosurgical Procedures.

Suggested Readings

1. Foreman PM, Naftel RP, Moore TA II, et al: The lateral extracavitary approach to the

thoracolumbar spine: a case series and systematic review. J Neurosurg Spine 2016; 24(4):570–9.
2. Sundaresan N, Shah J, Feghali JG: A transsternal approach to the upper thoracic vertebrae. Am J Surg 1984; 148:473–7.
3. Sunderesan N, Shah J, Foley KM, et al: An anterior approach to upper thoracic vertebrae. J Neurosurg 1984; 61:686–90.

POSTERIOR THORACIC SPINE SURGERY

SURGICAL CONSIDERATIONS

Description

Thoracic laminectomy (midline removal of the lamina) and **costotransversectomy** (off midline removal of the rib head and transverse process) are procedures for decompressing the neural elements of the thoracic spine via a posterior approach. (Commonly used approaches are shown in Fig. 1.3-12.)

Thoracic laminectomy is used to treat spinal cord compression due to disc herniation, neoplasm, or trauma. It also is used to gain access to the spinal canal or spinal cord for various intradural mass lesions, including syringomyelia. Thoracic laminectomy is done through a posterior midline incision centered over the involved vertebrae. The paraspinal muscles are retracted subperiosteally from the spinous processes and laminae on both sides. Laminae are removed piecemeal with rongeurs or drills. Extensive laminectomy involving several segments or requiring removal of facet joints may require stabilization with transpedicular screws or hooks. Intradural procedures are performed with an operating microscope and microneurosurgical instruments. After completion of the intradural procedure, watertight closure of the dura is obtained and tested with Valsalva maneuver (sustained inspiration at 30–40 cm H_2O).

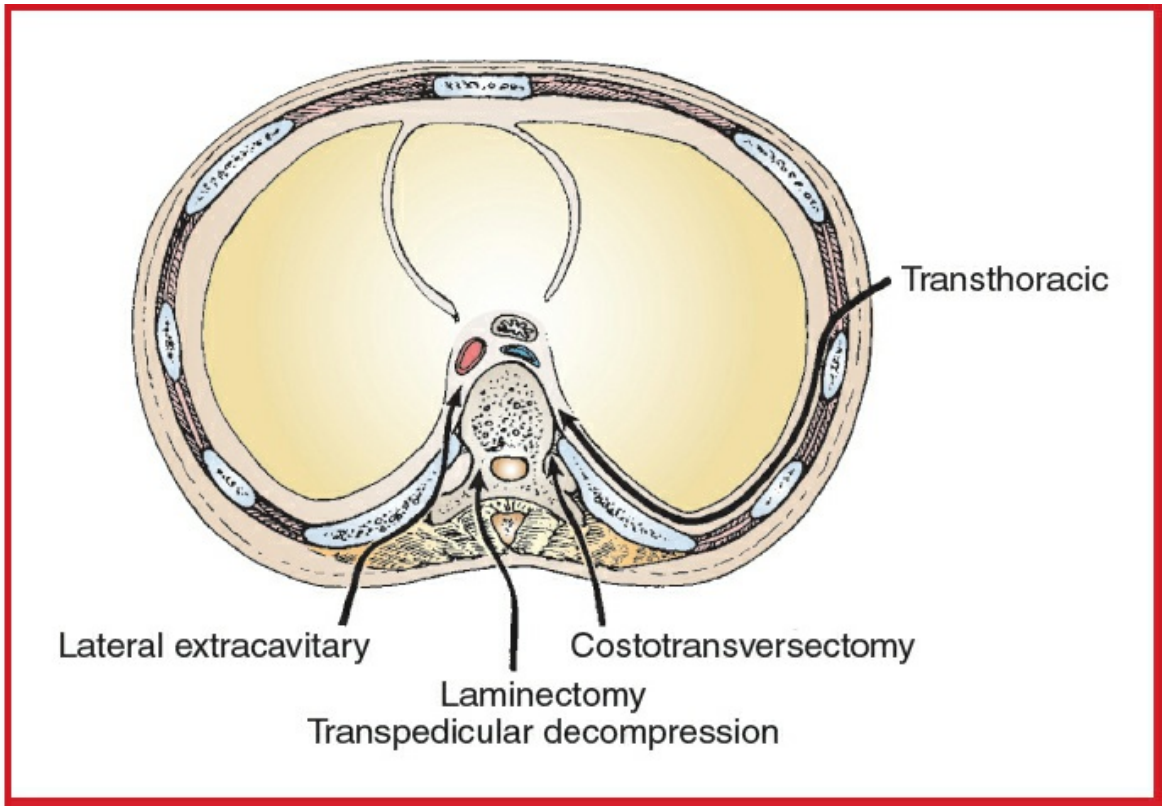

Figure 1.3-12 Surgical approaches to the thoracic spine. (Reproduced with permission from Tindall GT, Cooper PR, Barrow DL: The Practice of Neurosurgery, Vol. II. Williams & Wilkins, Baltimore: 1996.)

A **transpedicular approach** may be indicated for removal of herniated discs, excision or decompression of tumors, and the treatment of infection involving vertebral bodies. This procedure is performed in the prone position through a posterior midline incision centered over the affected vertebrae. The paraspinal muscles are retracted subperiosteally on both sides to expose laminae and facet joints. Facet joints and the superior half of the involved pedicle are drilled out to expose the lateral limits of the thecal sac and the nerve roots. A laterally herniated disc can be removed in a piecemeal fashion. If required, total removal of the pedicle is done to facilitate adequate bony decompression. Posterior instrumentation by pedicle screws, sublaminar wiring with rods, or a hook-rod construct may be performed.

The **lateral extracavitary approach** is a modification of a **costotransversectomy** and provides access to the anterior and posterior elements of the spine, thereby avoiding the need for a thoracotomy. This approach is performed with the patient in the prone position. A midline skin incision is made three levels above and below the involved vertebrae. The lower part of the incision may be curved over the involved side, if needed. A myocutaneous flap is developed by dissecting the scapular muscles (trapezius, rhomboids, etc.) laterally. Paraspinal muscles are freed from the spinous processes and dorsal spinal elements to enable retraction, which exposes the entire rib

cage and dorsal vertebral elements. Subperiosteal resection from its costovertebral tip to the posterior bend of the appropriate rib is done. The parietal pleura is gently separated from the ribs and the vertebrae to expose the posterolateral aspect of the vertebral bodies. The transverse process, pedicle, and laminae are removed, as required, to permit direct visualization of the cord during decompression of the vertebral body. Discectomy/corpectomy, vertebral reconstruction, and instrumentation are performed as required. Complete spondylectomy and anterior reconstruction are possible with this approach with minimal retraction to the cord. Combined anterior-posterior instrumentation can be used to leverage off each other for deformity correction. At the end of the procedure, the operative field is filled with saline to check for any evidence of air leak. A small chest tube can be placed if an air leak is present. A layered wound closure with drain is performed.

Thoracic pedicle screws have largely replaced the older hook-rod construct and **Harrington** rods as the fixation of choice. These can be technically challenging because the thoracic pedicles tend to be rather narrow and variable. Potential complications include injury to surrounding nerves, spinal cord, blood vessels (both local and great vessel), and lung parenchyma.

Usual preop diagnosis

Thoracic radiculopathy (nerve root compression); thoracic disc disease (herniation or degeneration of thoracic disc); thoracic myelopathy (spinal cord compression); thoracic canal stenosis (degenerative); infections (TB, pyogenic osteomyelitis) and tumors to spine (primary bone tumors or metastatic); intraspinal tumors; syringomyelia

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol and smoking cessation, review of nutritional status, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Thoracic Laminectomy	Transpedicular Approach	Lateral Extracavitary Approach
Position	Prone	⇐	⇐
Incision	Posterior midline	⇐	⇐; with/without hockey-stick extension
Special instrumentation	Operating microscope	⇐	⇐ ± anterior and posterior spinal

	± EP monitoring ± Pedicle screws/hooks		instrumentation
Unique considerations	I.I. localization	⇐	⇐
Antibiotics	Cefazolin 2 g iv	⇐	⇐
Surgical time	2–3 h	⇐ Add 30–45 min for bony/tumor decompression	3–7 h, based on need for anterior bony resection/reconstruction
Closing considerations	Often no cast	TL support/orthosis	⇐
EBL	100–1000 mL	200–1000 mL	300–3000 mL
Postop care	PACU → room	⇐	⇐ ± ICU
Mortality	0–5%	⇐	⇐
Morbidity	All <5% Neurologic: Myelopathy Nerve root injury Massive blood loss CSF leak	⇐ ⇐	⇐ ⇐
Pain score	6–10	6–10	8–10

PATIENT POPULATION CHARACTERISTICS

Age range	18–85 yr (usually 20–60 yr)
Male:Female	1:2
Incidence	Rare
Etiology	Neoplastic; traumatic; congenital; degenerative

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Thoracolumbar Neurosurgical Procedures.

Suggested Readings

1. Sairyo K, Chikawa T, Nagamachi A: State-of-the-art transforaminal percutaneous endoscopic lumbar surgery under local anesthesia: discectomy, foraminoplasty, and ventral facetectomy. J Orthop Sci 2018; 23(2):229–36.
2. Yu L, Chen X, Margalit A, et al: Robot-assisted vs freehand pedicle screw fixation in spine surgery—a systematic review and a meta-analysis of comparative studies. Int J Med Robot 2018; 14(3):e1892.

ANTERIOR LUMBAR/LUMBOSACRAL SPINE SURGERY

SURGICAL CONSIDERATIONS

Description

The use of anterior procedures is steadily increasing among spine surgeons. Most procedures permit short-segment instrumentation of the spine, which often obviates the need for subsequent posterior fixation. The most significant disadvantage of these procedures involves the risk of injury to the great vessels; thus, these procedures are commonly done in association with a vascular or general surgeon. There is also risk of injury to the peritoneal contents and the neural plexus around the lumbosacral spine. Anterior instrumentation systems generally fall into three categories: (a) **plating systems** (e.g., Z plating, anterior locking plates, and MACS-TL), (b)**rod systems** (e.g., Kostuik-Harrington, Kaneda, and Moss-Miami), and (c)**interbody devices** (e.g., cages and allografts).

An **anterior lumbar interbody fusion** (ALIF) can be done with artificial cages or bone After exposure of the disc space, the exact midline of the space is marked and verified with fluoroscopy. A spacing guide determines the exact position for pilot holes, and a partial discectomy is performed through these pilot holes, which are distracted and later reamed. Bone or cage is then attached to a specialized implant driver for insertion under fluoroscopic guidance. Harvested bone chips and other fusion enhancers are placed into the cages or around the bone dowel. ALIF provides immediate mechanical stability and long-term load support, with the ability to heal through the disc space. Its primary disadvantages include bleeding and possible major vessel injury.

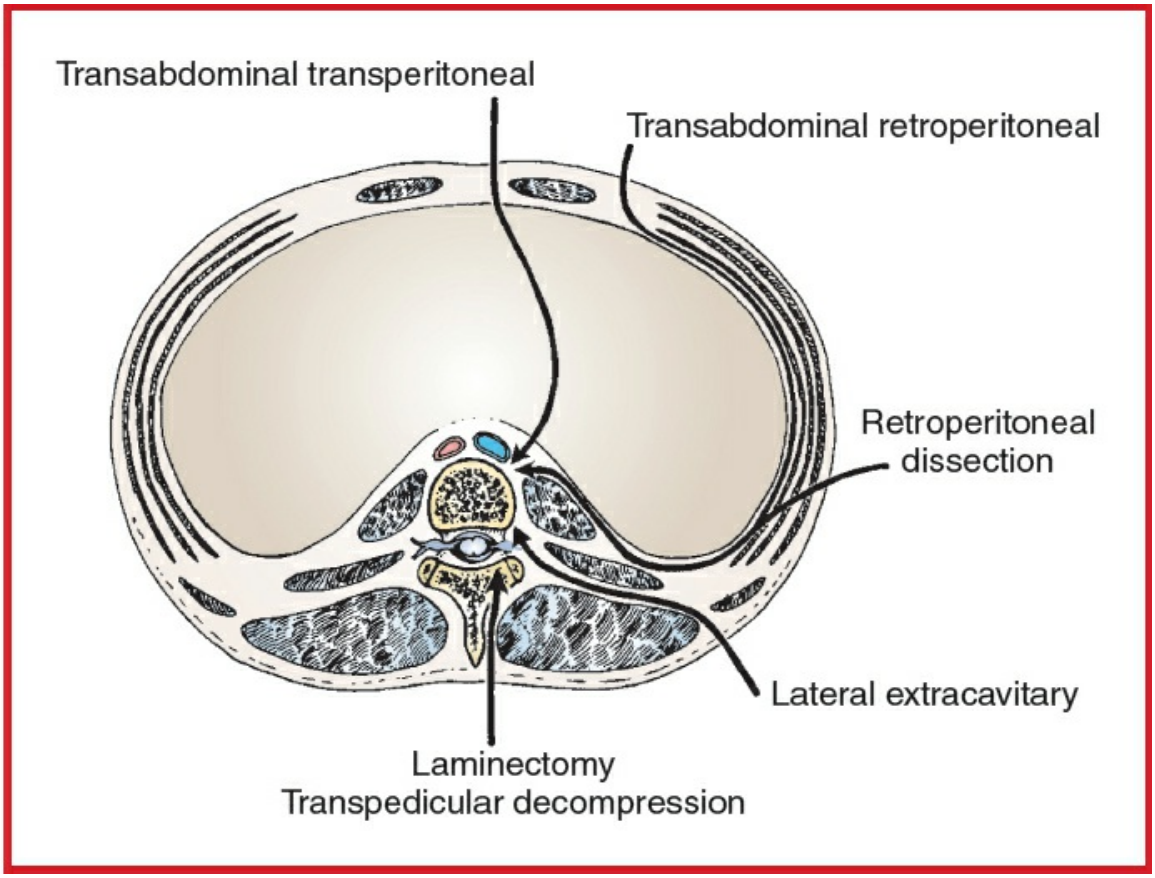

Figure 1.3-13 Surgical approaches to the lumbar spine. (Reproduced with permission from Tindall GT, Cooper PR, Barrow DL: The Practice of Neurosurgery, Vol. II. Williams & Wilkins, Baltimore: 1996.)

A **lumbar artificial disc** can be placed via this approach. The approach is similar to that of the ALIF but instead of placing a bone graft or cage, a mobile prosthetic disc is placed according to manufacturer's instruction. No additional stabilization or bone grafting is required. Accurate placement of this disc is absolutely critical to the success of this procedure. Fluoroscopy is used extensively to ensure this. There is immediate stability, and because motion is preserved, early mobilization is recommended.

Anterior instrumentation after ALIF can be done with a variety of screws and/or plates. These include a screw and screw/plate combination to buttress the graft from falling out. Other devices provide plate stabilization across interspaces. These can be used alone or with a posterior stabilization surgery. These add time to the anterior case and run the risk of hardware failure, but have the advantage of potentially improving the overall fusion rate and decreasing the graft related complications.

A **transperitoneal approach** involves laparotomy through a Pfannenstiel or subumbilical vertical midline incision. After opening the peritoneum, intestines are retracted to expose the anterior aspect of the lower lumbar and lumbosacral spine, an exposure that is often difficult to achieve with the retroperitoneal approach. Exposure of

L4-L5 disc spaces requires mobilization of the aorta and inferior vena cava, along with its bifurcations.

Variants of the transperitoneal approach

A laparoscopic transperitoneal approach often is used at the L5-S1 level. With the patient supine, Trendelenburg position is used to move the small intestine away from the operative field. The procedure is performed through one 10-mm portal for a 30° endoscope, two 5-mm portals for retraction, and one 20-mm working portal for instruments. For access to the L5-S1 level, the posterior peritoneum is incised at the base of the sigmoid mesocolon with endoscopic scissors. Laparoscopic interbody fusion and instrumentation are performed as required, using specially designed long-alignment tubes, distraction plugs, and a reamer, as in the open procedure. The peritoneum is closed with endoscopic sutures or clips. The major advantages of this technique are related to the minimal manipulation of abdominal viscera required and minimal trauma to the abdominal wall. In addition, postop pain, recovery time, and length of hospitalization are often less, permitting an early return to the patient's normal activities.

Variants of the retroperitoneal approach

A lateral retroperitoneal approach provides an excellent exposure of the lumbar spine from L1-S1 through a flank incision. The procedure is performed in the lateral decubitus position. The skin incision is made from the lateral border of the paravertebral muscles at the midlumbar level to the lateral border of the rectus abdominis. The incision is angulated below the umbilicus for exposure of the lower lumbar and lumbosacral junction and is carried down to the peritoneum.

The **supine retroperitoneal approach** is accomplished through a left paramedian incision, and the peritoneum and abdominal contents are retracted. This is one of the most common approaches. Ligation of lumbar intersegmental arteries and tributaries of the iliac vein may be required to allow a direct anterior exposure from L3-S1. An approach surgeon trained in vascular or general surgery can often expose even more. With blunt dissection, the peritoneum is peeled off the lateral and posterior abdominal walls, diaphragm, and iliopsoas, exposing the anterior aspect of the lumbar spine. Vertebral resection and reconstruction are carried out in the routine manner. During this procedure, the great vessels, ureter, and sympathetic trunk need to be protected. Monopolar cautery is avoided because it can cause injury to the presacral plexus, which can result in retrograde ejaculation.

A **laparoscopic retroperitoneal approach** can be used for performing an ALIF following discectomy in patients with lumbar segmental instability. This procedure is

performed in the right lateral decubitus position. A 10- to 12-mm port is made in the posterior axillary line midway between the 12th rib and iliac crest, and a trochar is advanced into the peritoneum. Retroperitoneal dissection is accomplished by balloon inflation, with 1000 mL of air or saline, through a trochar. This procedure is carried out under direct vision through the laparoscope. Discectomy, fusion, or instrumentation requires two additional working portals. Retroperitoneal insufflation with CO_2 may be required during the procedure.

Usual preop diagnosis

Degenerative disc disease; segmental instability; vertebral fractures; benign and neoplastic diseases of the lumbar spine; vertebral osteomyelitis; TB

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol and smoking cessation, review of nutritional status, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Transperitoneal Instrumentation	Retroperitoneal Instrumentation	Endoscopic Approach
Position	Supine	Supine/lateral decubitus	Right lateral decubitus
Incision	Pfannenstiel's/vertical subumbilical	Flank incision	3–4 ports
Special instrumentation	Z plates, Kaneda instrumentation, MACS-TL, femoral rings, cages; intervertebral disc replacements	⇐	Endoscopic instrumentation; balloon dissector
Unique considerations	NG tube, preop bowel prep	⇐	⇐
Antibiotics	Cefazolin 2 g iv	⇐	⇐
Surgical time	3–4 h	⇐	⇐
Closing considerations	Transfer to bed while anesthetized. Smooth	⇐	Rapid closure of ports

	emergence necessary to avoid graft/implant disruption		
EBL	200–600 mL	200–5000 mL; nontumor cases: 200–400 mL	100–500 mL
Postop care	PACU → ward; patients with infections/tumors → ICU. Postop ileus common	⇐	⇐
Mortality	Malignancy and sepsis: 1–2% Elective: <1%	⇐ ⇐	—
Morbidity	Neurologic injury: 2–6% Vascular injury: 2–15% Retrograde ejaculation: 5–35%	⇐ ⇐ <5%	— — —
Pain score	6–7	6–7	4–6

PATIENT POPULATION CHARACTERISTICS

Age range	Variable, infant–adult (usually 20–60 yr)
Male:Female	1:1 (usually)
Incidence	Uncommon
Etiology	Degenerative; lumbar segmental instability; neoplastic; traumatic; infectious

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Thoracolumbar Neurosurgical Procedures.

Suggested Reading

1. Kozak JA, O'Brien JP: Simultaneous combined anterior and posterior fusion. A independent analysis of a treatment for the disabled low-back pain patient. Spine 1990; 15(4):322–8.

POSTERIOR LUMBAR SPINE SURGERY

SURGICAL CONSIDERATIONS

Description

Lumbar laminotomy (partial removal of lamina) and **laminectomy** (complete removal of lamina) are procedures for decompressing the neural elements of the lumbar spine via a posterior approach. They can be used to treat lumbar radiculopathy 2° degenerative disc disease (e.g., herniated discs or osteophytes). **Decompressive laminectomy** can be used to treat compression of the cauda equina, usually 2° degenerative disease, congenital stenosis, neoplasm, and, occasionally, trauma. Lumbar laminectomy is also used to gain access to the spinal canal for dealing with intradural tumors, arteriovenous malformations (AVMs), and other spinal cord lesions.

Through a vertical midline incision, the lumbodorsal fascia is exposed, and then the paraspinal muscles are dissected off the spinous process and lamina of the segments intended for decompression. The level may need to be checked by intraop x-ray or fluoroscopy if the surgeon is not able to identify location based on visual confirmation of anatomic level. The bone landmarks are identified and ligamentous attachments are cut. The bone is removed piecemeal with rongeurs, gouges, or power drills. Care is taken not to injure the underlying dura. If a dural tear is found, it usually must be repaired. The surgeon may want a **Valsalva-like maneuver** (sustained inspiration at 30–40 cm H_2O) performed to test the integrity of the repair. If disc is to be removed, the dura is retracted and the annulus incised. The disc is removed piecemeal with a series of curettes and disc-biting rongeurs. There is a risk of damage to retroperitoneal structures (e.g., great vessels or intestines) during this portion of the procedure. More commonly, there may be troublesome epidural bleeding, which may be difficult to control and will necessitate transfusion. Hemostasis is obtained prior to closure. The wound is closed in layers, and a drain may be left in the epidural space. The patient is rolled supine onto a bed at the completion of the procedure.

Minimally invasive surgery (MIS) lumbar surgery is performed through a shor

paramedian incision at the level of the affected disc. Under radiographic guidance, a series of soft tissue dilators are inserted over a previously placed guide wire to create an operative corridor through the paraspinous musculature. A tubular retractor is inserted over the dilators and connected to a flexible support arm assembly. Endoscope or microscope is used to perform laminotomy and discectomy and/or decompressive laminectomy. As the retractor is withdrawn at the end of the procedure, the paraspinal muscles resume their normal anatomic position, obliterating the dead space. Skin margins are closed with subcuticular sutures. Although all the major risks of surgery are still present, the blood loss, postop pain, and hospital stay are reduced. In theory, less trauma to the paraspinous muscles should improve the postop function of the spine.

Usual preop diagnosis

Lumbar radiculopathy (nerve root compression); lumbar disc disease (herniation or degeneration of the lumbar discs); lumbar canal stenosis; lateral recess stenosis; neurogenic claudication; herniated disc; metastatic tumor to the spine; lumbar spine tumor; lumbar spondylosis (degeneration of the lumbar spine); spondylolysis (structural defect in the pars interarticularis of the vertebra); spondylolisthesis (slipping of one vertebra over another)

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol and smoking cessation, review of nutritional status, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Lumber Laminectomy	Lumbar Laminotomy	MIS
Position	Prone	⇐	⇐
Incision	Posterior midline	⇐	Paramedian port over disc
Special instrumentation	± Operative microscope	⇐	Endoscopic instrumentation (optional)
Unique considerations	I.I. localization to assess the correct level	⇐	⇐
Antibiotics	Cefazolin 2 g iv	⇐	⇐

Surgical time	1–2 h for single level; add 0.5–1 h/additional level	2 h for single level; add 0.5 h/additional level	⇐
EBL	25–500 mL	50–1000 mL	10–50 mL
Postop care	PACU → room	⇐	⇐
Mortality	0.5%	⇐	⇐
Morbidity	All <5%:	⇐	⇐
	CSF leak	⇐	⇐
	Nerve root injury	⇐	⇐
	Infection	⇐	—
	Postop instability	—	—
	Massive blood loss	—	—
	Injury to retroperitoneal structures	⇐	⇐
Pain score	4–7	4–9	3–6

PATIENT POPULATION CHARACTERISTICS

Age range	15–85 yr (usually 30–60 yr)
Male:Female	3:2
Incidence	Common
Etiology	Degenerative; traumatic; neoplastic; infectious

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Thoracolumbar Neurosurgical Procedures.

Suggested Readings

1. Blamoutier A: Surgical discectomy for lumbar disc herniation: surgical techniques. Orthop Traumatol Surg Res 2013; 99(1 Suppl):S187–96.
2. Overley SC, Cho SK, Mehta AI, et al: Navigation and robotics in spinal surgery where are we now? Neurosurgery 2017; 80(3S):S86–99.
3. Wu Y, Vázquez-Barquero A: Stimulus-evoked electromyographic monitoring during minimally invasive transpedicular implantation of screws in lumbosacral spine: threshold value, methodology and clinical effectiveness. World Neurosurg 2017;

98:146–51.

POSTERIOR LUMBAR FUSION AND INSTRUMENTATION

SURGICAL CONSIDERATIONS

Description

Posterior lumbar spinal fusion may relieve low back pain resulting from intervertebral movement. This surgery is often indicated for segmental lumbar instability, spondylolisthesis, or iatrogenic instability due to extensive laminectomy or facetectomy.

The **pedicle screw stabilization** technique provides rigid three-column spinal fixation and is the preferred mode of instrumentation in lumbar spinal surgery (Fig. 1.3-14). Pedicle screws are passed after tapping the entry site and are fixed with rods or plates on each side of each vertebral segment. The major risks with pedicle screw fixation include screw malposition and nerve root injury. Pedicle screws may be combined with hooks to provide fixation of the lumbar/thoracolumbar spine, an approach that improves the stability of the construct and minimizes the risk of instrumentation failure. Facet screw stabilization can also be performed to fix levels together. This is usually not used in a stand-alone fashion but in combination with anterior fixation. Instrumentation can be placed via percutaneous techniques that decrease blood loss and patient pain; however, complications often go undetected and unseen.

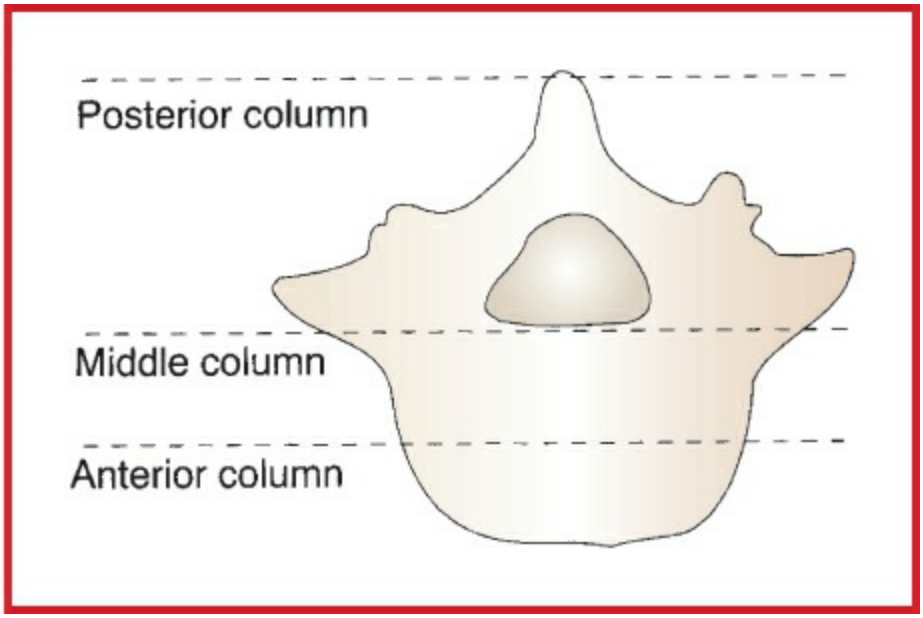

Figure 1.3-14 Spinal three-column model developed by F. Denis. Disruption of elements of two or more columns renders the spine unstable. (Reproduced with permission from Tindall GT, Cooper PR, Barrow DL: The Practice of Neurosurgery, Vol. II. Williams & Wilkins, Baltimore: 1996.)

Posterolateral fusion (PLF) is performed through a posterior midline incision, with the paraspinal muscles retracted subperiosteally from the affected lumbar vertebrae. Decompressive laminectomy and discectomy are performed as needed. PLF is performed by decorticating the facet joints and transverse processes. Bone graft is then placed over the decorticated bone. Instrumentation with pedicle screws and plate/rod constructs often is done for stability and to facilitate fusion.

Posterior lumbar interbody fusion (PLIF) consists of a bilateral laminectomy and removal of the inferior facet and the medial portion of the superior facet. The dural sac is retracted, and a total discectomy, together with the removal of cartilaginous end plates, is performed. The anterior disc space is packed with bone graft. Appropriately sized rectangular bone grafts or cages are inserted into the posterior half of the disc space on both sides to provide structural support close to the center of rotation. The nerve roots above and below the disc space should be visualized during the procedure to avoid excessive retraction. Instrumentation with pedicle screws and a rod/plate construct is often added to facilitate early fusion and ambulation while preventing the extrusion of the graft. The major advantage of this procedure is that it provides the ability to achieve combined anterior and posterior spinal fusion while avoiding the significant morbidity often associated with anterior lumbar surgery. Its major disadvantages include the potential risk of nerve root injury and compromise of the structural integrity of both facet joints.

Transforaminal lumbar interbody fusion (TLIF) is a modification of the PLIF, using a unilateral posterolateral approach. A **hemilaminectomy and total facetectomy** is performed on one side. A near total discectomy is performed and the first bone graft or cage is inserted across the disc space to the contralateral side. A second bone graft may be inserted into the ipsilateral posterior disc space, and satisfactory placement of the bone grafts is confirmed by fluoroscopy. Supplemental pedicle screw stabilization is indicated as in PLIF. This approach has been adopted to be performed with MIS techniques to afford circumferential lumbar decompression and stabilization via an all posterior approach.

Direct/extreme lateral interbody fusion (DLIF/XLIF) is an MIS procedure performed by having the patient positioned on his/her side where the surgeon's approach to the spine will be directly laterally through the retroperitoneal cavity. A specialized retractor is used with multiple long blades that allow for visualization of the spine

through the deep layers of tissue. **Neuromonitoring** (EMG nerve root mapping) is essential in the procedure to help avoid nerve injury. Therefore, minimal or no paralytic should be used as it may confound monitoring.

Transaxial lumbosacral fusion (Trans1) is an **MIS** procedure performed by having the patient positioned prone. A complete L5-S1 discectomy and fusion with screw instrumentation is performed. This is done via a 1-cm incision at the base of the sacrum. Specialized tubular dilators and shims protect the visceral contents while a reamer and disc remover tools are used to remove the disc. There is minimal blood loss, but occult injury to peritoneal contents including the viscera and blood vessels can occur acutely or present in a delayed fashion.

Usual preop diagnosis

Lumbar segmental instability; spondylolisthesis; iatrogenic lumbar instability; lumbar disc disease; spondylolysis; mechanical back pain syndrome

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Posterolateral Fusion	PLIF	TLIF (DLIF/XLIF)
Position	Prone	⇐	⇐ (DLIF/XLIF: Lateral)
Incision	Posterior midline	⇐	⇐ (DLIF/XLIF: Lateral)
Special instrumentation	Drills, pedicle screws, or hooks	⇐; osteotomes, curettes, bone plugs, or cages	⇐; angled curettes, angled impactors
Unique considerations	I.I. localization and guidance	⇐	⇐ (DLIF/XLIF: EMG)
	Cefazolin 2 g iv	⇐	⇐

Antibiotics			
Surgical time	2 h for single level + 0.5 h/additional level	3–4 h for single level + 1 h/additional level	2–3 h for single level + 1 h/additional level
Closing considerations	No brace/lumbosacral corset	⇐	⇐
EBL	250–500 mL	250–1000 mL	250–750 mL (less with MIS)
Postop care	PACU → room	⇐	⇐
Mortality	0–5%	⇐	⇐
Morbidity	Nonunion: 20–30% Nerve root injury CSF leak Infection Massive blood loss	10–20% ⇐ ⇐ ⇐	⇐ ⇐ ⇐ ⇐
Pain score	6–10	6–10	6–10 (4–7 with MIS)

PATIENT POPULATION CHARACTERISTICS	
Age range	15–85 yr (usually 30–60 yr)
Male:Female	3:2
Incidence	Common
Etiology	Degenerative; traumatic; neoplastic; infectious

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Thoracolumbar Neurosurgical Procedures.

COMBINED ANTERIOR AND POSTERIOR INSTRUMENTATION OF THE THORACIC AND

LUMBAR SPINE

SURGICAL CONSIDERATIONS

Description

Patients with multilevel vertebral collapse, unstable three-column injuries, severe kyphosis or scoliosis, and/or neoplastic or infective conditions involving multiple spinal levels often require **combined anterior and posterior instrumentation**. This approach provides (a) complete circumferential neural decompression, which facilitates maximal neuronal recovery; (b) rigid short-segment spinal fixation, which facilitates early ambulation with minimal orthotic support; and (c) maximal correction of deformities with low instrumentation failure and high fusion rates. The combined approach maximizes the possibility of complete resection of the neoplastic or infective process. Patients with major systemic disease or poor marrow reserve may require staged procedures. Combined instrumentation procedures are often lengthy, requiring 5–10 h of surgery. Major related morbidities include infection, wound breakdown, respiratory complications, and significant blood loss. The transition between anterior and posterior procedures should be performed carefully to minimize disruption of the instrumentation.

Usual preop diagnosis

Lumbar segmental instability; spondylolisthesis; iatrogenic lumbar instability; spondylolysis; mechanical back pain syndrome

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol and smoking cessation, review of nutritional status, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Prone + supine/lateral
Incision	Posterior midline skin incision + transverse
Special instrumentation	Anterior and posterior spinal implants and instrumentation sets
Unique considerations	OLV for anterior thoracic approaches; radiologic localization; intraop EP monitoring (optional)
Antibiotics	Cefazolin 2 g iv

Surgical time	4–10 h
EBL	500–5000 mL
Postop care	PACU → room; sometimes needs short ICU stay
Mortality	0–3%
Morbidity	Respiratory problems: atelectasis, pneumonia Infection Bone graft dislodgement
Pain score	7–10

PATIENT POPULATION CHARACTERISTICS	
Age range	15–85 yr (usually 30–60 yr)
Male:Female	3:2
Incidence	Common
Etiology	Congenital; degenerative; traumatic; neoplastic; infectious

Suggested Readings

1. Denis FF: The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. Spine 1983; 8:817–31.
2. Lowe TG, Tahernia D: Unilateral transforaminal posterior lumbar interbody fusion Clin Ortho 2002; 394:227–36.

ANESTHETIC CONSIDERATIONS FOR THORACOLUMBAR NEUROSURGICAL PROCEDURES

(Procedures covered: anterior/posterior thoracic spine surgery, anterior lumbar/lumbosacral spine surgery, posterior lumbar spine surgery, posterior lumbar fusion and instrumentation, and combined anterior/posterior instrumentation of the thoracic and lumbar spine)

PREOPERATIVE

Surgery of the lumbar or thoracic spine is common as a result of a variety of spinal disorders, including herniation of lumbar or thoracic intervertebral discs causing

compression of the adjacent spinal cord or nerve roots, spinal stenosis from bony overgrowth causing compression of the nerve roots or spinal cord, spondylolisthesis, traumatic injury to the spine, and removal of a spinal tumor or AVM. Because these diseases span a wide age range, the patients may be healthy, or they may have severe cardiovascular and/or respiratory disorders. Generally, the surgical incision is made in the posterior thoracic or lumbar region, but the surgeon may elect to use an abdominal (transperitoneal) or flank (retroperitoneal) approach. Sometimes, both anterior and posterior approaches are used sequentially. Finally, some anterior abdominal or thoracic procedures are performed endoscopically.

Neurologic	Patients with a herniated disc or spinal stenosis generally complain of pain, often in the pelvis or radiating down one or both legs. As nerve or spinal cord compression continues, patients develop motor weakness and atrophy of muscle groups in the legs as well as sensory deficits and/or bowel/bladder dysfunction. These changes can also result from a spinal cord tumor, vascular malformation, or cyst. MRI helps delineate the etiology of the neural compression. **Tests:** MRI
Hematologic	Blood loss may be substantial if the surgeon plans both an anterior and posterior approach in the same patient, or if the operation includes both spinal cord decompression and posterior spinal instrumentation. For these operations, 2 U of blood should be available at all times. Consideration should also be given to using a red cell salvage device. Generally, the anticipated blood loss will be proportional to the number of levels involved in the surgery. Prepare for significant blood loss in tumor resection cases.
Laboratory	Preop Hct, platelet count, and coagulation studies—to assess baseline. Other tests as indicated from H&P.
Premedication	Anxiolysis (e.g., midazolam 2–4 mg iv) and analgesia (e.g., meperidine 25 mg iv) as necessary. These patients may be experiencing an exacerbation of

	their chronic pain because they have likely been off NSAIDs and may have skipped their normal AM meds.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water.

INTRAOPERATIVE

Anesthetic technique

GA is almost invariably used for these operations because it maximizes patient comfort, provides airway control, and permits use of controlled hypotension. Spinal and epidural anesthesia are, in principle, excellent techniques for lumbar surgery, particularly for removal of a lumbar intervertebral disc, but they are seldom used because of the medicolegal concern that the regional anesthetic may be blamed for a new neurologic deficit, if one should occur as a result of the surgery. Regional anesthesia is generally not suitable for lumbar fusion or removal of a spinal cord tumor or cyst because of the potentially prolonged duration of the surgery.

Induction	Standard induction unless MEP monitoring will be used. If the surgeon selects a transthoracic approach, one-lung ventilation will be necessary to deflate the lung on the operative side, and a compatible airway technique must be employed (e.g., DLT, bronchial blocker). If MEP monitoring will be used, consider succinylcholine vs. low-dose rocuronium (0.5 mg/kg) vs. deep anesthesia and remifentanil bolus (1.5 mcg/kg) to facilitate intubation yet permit the rapid return of neuromuscular transmission.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Avoid hypothermia. Dexamethasone (4–8 mg iv) may ↓ PONV. Sequential pneumatic compression devices should be used to ↓ VTE risk. Consider ketamine (0.25 mg/kg/h) and/or lidocaine (1–2 mg/kg/h) infusions as components of MMPM

	especially in chronic pain patients.
Maintenance	Standard maintenance will suffice if no neurophysiologic monitoring is used. Once exposure is completed with the posterior approach, muscle relaxation is no longer needed. For thoracoscopic or anterior abdominal approaches, neuromuscular blockade should be maintained until spine surgery is complete and closure is under way. When evoked potential monitoring is used, the anesthetic plan must be adapted to ensure optimal monitoring condition. Standard NMB doses will completely abolish MEPs and must be avoided although small NMB doses may be needed to suppress interfering EMG activity. More than 0.5 MAC each of volatile anesthetics and N_2O interferes with MEP and, to a lesser extent, SSEP monitoring. An anesthetic consisting of 50% N_2O in O_2 with up to 0.6% isoflurane in combination with a remifentanil infusion (0.05–2 mcg/kg/min) will provide anesthesia while permitting MEP and SSEP monitoring. TIVA (see Appendix B, p. B-3) may be preferred by local custom when monitoring MEPs but is not necessary. The propofol infusion should be tapered as the drug saturates the various compartments of distribution. The neurophysiology monitoring team must be updated as conditions that affect the evoked potentials change (depth of anesthesia, anesthetic agent, blood pressure, PCO_2, PO_2). After the baseline SSEP and motor-evoked potentials have been established, some surgeons will request paralysis during dissection of the muscles from the bones. This can be accomplished safely with rocuronium (20–40 mg).
Emergence	Standard emergence, after the patient has been returned to the supine position on a bed or gurney. If the intubation was difficult or the operation was prolonged and airway edema or respiratory

	depression is possible, it may be advisable to leave the patient's trachea intubated overnight. Consider performing a leak test if there is concern for airway edema and extubate over an airway exchange catheter. Keep in mind that remifentanil will not provide postop analgesia and that another longer-acting opioid (e.g., hydromorphone 0.2–0.6 mg iv) must be administered prior to emergence. Suggest wound infiltration with LA. Consider iv acetaminophen 1 g if po dose given >4–6 h ago and hydromorphone (0.2–0.6 mg iv). Discuss possible use of ketorolac or celecoxib.	
Blood and fluid requirements	14–18 ga × 1–2 BSS/LR @ 3–5 mL/kg/h up to a maximum of 40 mL/kg. Use goal-directed fluid management (see Appendix K, p. K-4)	To ↓ the chance of ischemic optic neuropathy in the prone position, do not administer >40 mL/kg of crystalloid regardless of EBL or duration of surgery. If additional fluid is needed, administer albumin 5% or blood. Blood transfusion is often necessary when there has been extensive bony decompression and fusion. Consider the use of a red cell salvage device if large blood loss is anticipated in noncancer surgery. Some tumors, particularly metastases, can bleed profusely. Epidural venous bleeding, particularly during an anterior approach, can also be severe and difficult to control. Zero balance or goal-directed fluid management is recommended.
Control of blood loss	Controlled	In the absence of cord

	hypotension	compression, modest ↓ in BP may be helpful to ↓ blood loss when extensive surgery is anticipated. This may be accomplished with anesthetics and opiates or by the use of α- and β-blockers (e.g., labetalol, esmolol) and clevidipine infusion. BP should not be <60 mm Hg MAP in young adults or <80 mm Hg in elderly patients. After the bony dissection is complete, any possible benefit of deliberate ↓ BP wanes, and a more normal BP is advisable.
Monitoring	Standard monitors ± Arterial line ± CVP line	For simple back surgery, standard monitors are sufficient. If controlled ↓ BP or if an extensive posterior or anterior and posterior approach are planned, an arterial catheter is essential to monitor BP, and a CVC is recommended for infusion of vasoactive drugs and monitoring of CVP.
	± Urinary catheter ± BIS monitor (for TIVA)	A urinary drainage catheter is also desirable if surgery is expected to last several hours or substantial fluid shifts are anticipated. Do not administer excessive crystalloid volume to promote urine output. Urine output is often less than expected when patients are positioned prone. Increased intra-

		abdominal pressure may → ↓ GFR.
	± Neuromonitoring	SSEPs + MEPs should be used to monitor posterior and anterior cord pathways if there is a risk of cord injury during surgery.
Positioning	✓ and pad pressure points ✓ eyes and ears frequently ✓ breasts and genitals ✓ free abdominal movement Neutral C-spine	Usually, patients are positioned prone on a Jackson table, Wilson frame, or bolsters. Less commonly, the knee-chest position on an Andrews table is necessary. For anterior approaches, the patient will be supine; for retroperitoneal or transthoracic approaches, the patient will be positioned lateral or semilateral with some flexion in the table. When prone, the head is placed in a neutral position using a foam pillow with cutouts for the eyes, nose, and chin. Whenever possible, maintain the patient's head at or above the level of the heart to lessen the development of facial or intracranial edema. If the patient also has cervical spine disease, it is advisable to place a cervical collar before turning the patient prone. If an anterior approach and then posterior approach are to be used in the same patient, either move the

patient to a gurney after the anterior portion is completed, and then roll the patient back onto the same operating table, or transfer the patient from one OR table to another. Alternatively, perform the operation on a Jackson table, which allows the patient to be turned from supine to prone without having to move them. If this table is used, the anesthesiologist must pay careful attention to all lines and wires so they are not inadvertently pulled out during the 180° rotation.
Other options are to use a horseshoe headrest or place the head in Gardner-Wells tongs or in a Mayfield head clamp. When placed in a headrest, the breathing circuit should be supported so that the ET tube is strain-free to prevent gradual extubation due to gravity or pressure injury to the posterior oropharynx.
Typically, the arms are abducted; they should be limited to <90° at the shoulder and extended <90° at the elbow. When the arms are tucked, take special care to ensure that all stopcocks under the drapes are secured in the desired position and

		capped to prevent bleeding or leakage and padded to prevent pressure injury. Elbows, knees, feet, and arm pressure points need padding.
Complications	↓ BP Bowel or ureteral injury Hemorrhage	↓ BP may be 2° abdominal compression and ↓ venous return. ↑ blood loss may occur 2° epidural vein engorgement, abdominal compression, or vascular injury. Any acute ↓ BP may be due to a vascular injury, either obvious (segmental artery or epidural vein) or occult (deep great vessel injury) until proven otherwise. The source of bleeding should be identified. If ↓ BP persists despite vigorous blood and fluid administration, suspect bleeding into the retroperitoneal space or abdomen. Alert the surgeon of this possibility and prepare for immediate exploration. Tumor resection, especially of metastases, can result in massive blood loss.

POSTOPERATIVE

Complications	↓ BP Hemorrhage Nerve injury	Postop bleeding may persist. Drain output and vital signs should be monitored closely. As above, acute hypotension

		may be the result of ongoing hemorrhage. Rarely, an epidural hematoma can form, resulting in evolving neurologic symptoms. In either case, emergent surgical re-exploration should be considered. Intubation may be more difficult if airway edema has accumulated during the initial operation.
	Blindness	Postop blindness is a rare but devastating complication of surgery in the prone position. Risk factors include prolonged duration of surgery, large blood loss, and large volume crystalloid administration.
Multimodal pain management	Epidural opiate IV acetaminophen (1 g) PCA	Some surgeons may place a mixture consisting of Duramorph® ± fentanyl, ± steroid, in Avitene® hemostat into the epidural space before closing. This provides excellent postop analgesia for 12+ h.
	Acetaminophen 1 g iv	If not given preop or if 4–6 h has elapsed since previous dose.
	± Fentanyl 25–50 mcg prn ± ketorolac (30 mg iv) or celecoxib (200 mg po)	Consult with surgeon regarding possible hemostasis concern.
ERAS	Ondansetron 4 mg iv ± Metoclopramide	Encourage early enteral nutrition, Foley catheter

	10–20 mg iv	removal, and mobilization with physiotherapy.
Tests	Hct; document neurologic status	If postop bleeding is suspected, serial Hct determinations are useful.

Suggested Readings

1. Aziz M: Airway management in neuroanesthesiology. Anesthesiol Clin 2012; 30(2):229–40.
2. Elgafy H, O'Brien P, Blessinger B, et al: Challenges of spine surgery in obese patients. Am J Orthop (Belle Mead NJ) 2012; 41(3):E46–50.
3. Kurd MF, Kreitz T, Schroeder G, et al: The role of multimodal analgesia in spine surgery. J Am Acad Orthop Surg 2017; 25(4):260–8.
4. Lachiewicz PF: The role of intravenous acetaminophen in multimodal pain protocols for perioperative orthopedic patients. Orthopedics 2013; 36(2 Suppl):15–9.
5. Lee LA: Perioperative visual loss and anesthetic management. Curr Opin Anaesthesiol 2013; 26(3):375–81.
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8. Rabai F, Sessions R, Seubert CN: Neurophysiological monitoring and spinal cord integrity. Best Pract Res Clin Anaesthesiol 2016; 30(1):53–68.
9. Sugrue PA, Halpin RJ, Koski TR: Treatment algorithms and protocol practice in high-risk spine surgery. Neurosurg Clin N Am 2013; 24(2):219–30.
10. Willner D, Spennati V, Stohl S, et al: Spine surgery and blood loss: systematic review of clinical evidence. Anesth Analg 2016; 123(5):1307–15.

Suggested Viewing

Links are available online to the following videos:

Anterior Cervical Decompression and Fusion (ACDF): https://www.youtube.com/watch?v=yfSkOF_DAfA

Dr. Ali Bydon Performs a Minimally Invasive Lumbar Discectomy: https://www.youtube.com/watch?v=2j9QyiOxVF4

Minimally Invasive Tubular Microdiscectomy: 3-D Video: https://www.youtube.com/watch?v=Cpkr_oy5Enc

Scoliosis Spinal Fusion Animation: https://www.youtube.com/watch?v=WBIf4AQj5s0

C1 Lateral Mass Fixation: A Comparison of Constructs: https://www.youtube.com/watch?v=ZRcafQ3xLSs

Dr. Ali Bydon Removes an Intramedullary Spinal Cord Tumor: https://www.youtube.com/watch?v=HoWWRQfWYTo

Posterior Spinal Instrumentation & Fusion for Idiopathic Scoliosis: https://www.youtube.com/watch?

v=TbQaT7z54E4

Transforaminal Lumbar Interbody Fusion (TLIF) Surgery: https://www.youtube.com/watch?v=1I5j4EPOmW4

L5 S1 Fusion TLIF Back Surgery Video: https://www.youtube.com/watch?v=I2lHCdX28D0

Posterior Cervical Foraminotomy Herniated Disc Neck Surgery: https://www.youtube.com/watch?v=0edUnIJpg3o

CHAPTER 1.4

Carotid Endarterectomy

SURGEONS

Gary K. Steinberg, MD, PhD
Robert L. Dodd, MD, PhD

ANESTHESIOLOGIST

Richard A. Jaffe, MD, PhD

CAROTID ENDARTERECTOMY

SURGICAL CONSIDERATIONS

Gary K. Steinberg and Robert L. Dodd

Description

Carotid endarterectomy (CEA) is frequently used to treat severe atherosclerotic occlusive disease involving internal carotid arteries at the common carotid artery bifurcation. Atherosclerotic carotid artery disease commonly causes thromboembolic or hemodynamic stroke and transient ischemic attacks (TIAs). Recent studies proved the efficacy of this operation, compared with medical treatment for symptomatic high-grade stenosis (70–99%), symptomatic moderate stenosis (50–69%), and asymptomatic high-grade stenosis (≥60%).

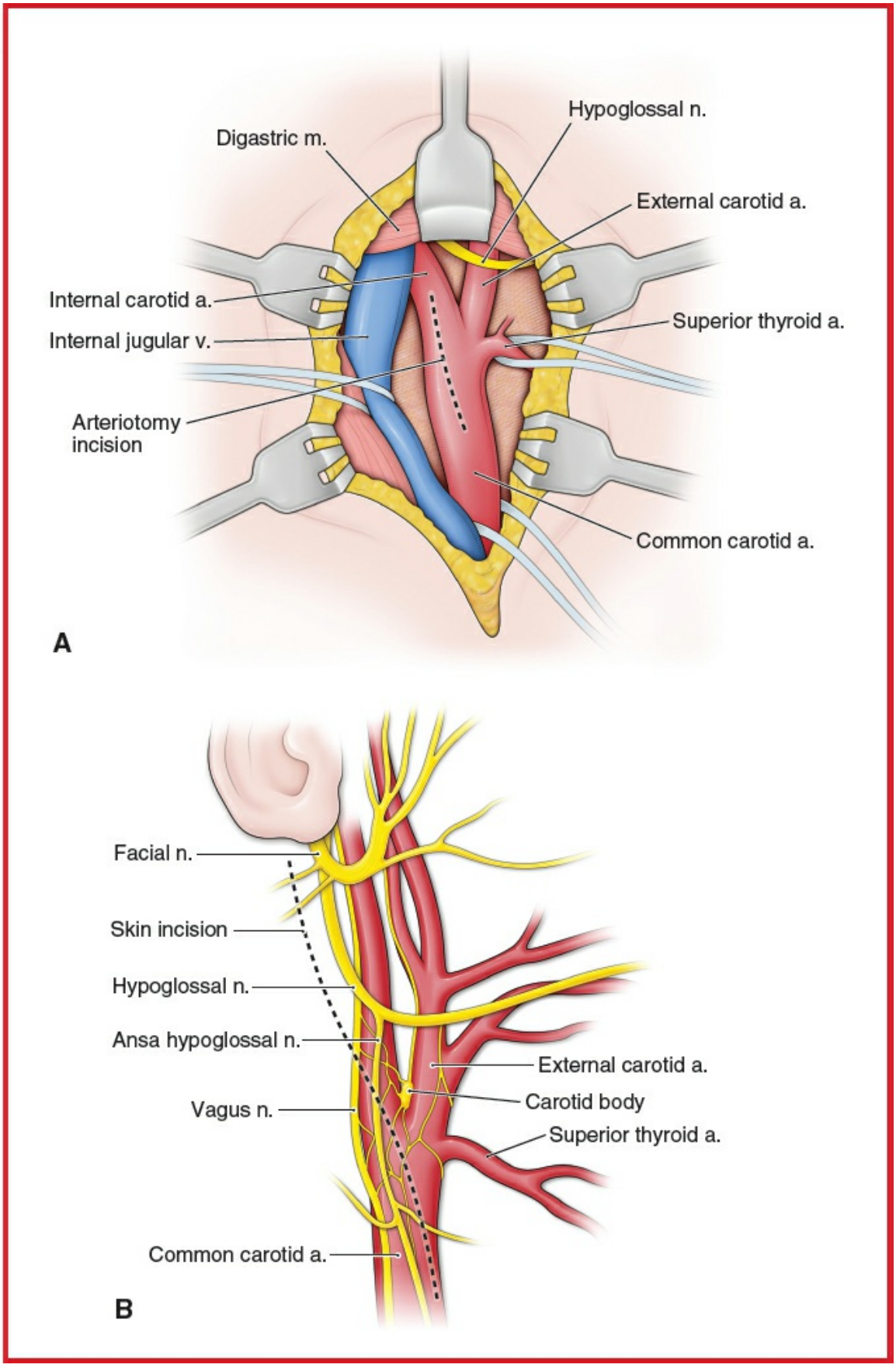

Figure 1.4-1 **A:** Exposure and control of the carotid artery. **B:** Nerves at risk during carotid endarterectomy.

The operation involves opening the common carotid artery and the proximal internal carotid artery in the neck (Fig. 1.4-1), removing atherosclerotic plaque from the inside of the artery, and repairing the wall of the arteries (media and adventitia). Opening the carotid artery (**arteriotomy**) requires temporary occlusion of the proximal common carotid artery, distal internal carotid artery, external carotid artery, and, usually, its first branch, the superior thyroid artery. The entire procedure can be achieved under continued occlusion of these vessels if the collateral blood flow to the territory supplied by the occluded internal carotid is deemed adequate (on the basis of intraop EEG monitoring, internal carotid artery back-bleeding, stump pressures, testing in an awake patient, CBF studies, or angiography). Alternatively, an internal shunt between the proximal common carotid artery and distal internal carotid artery can be placed in an appropriately heparinized patient after the arteriotomy for use during the endarterectomy. Often a synthetic graft (e.g., Dacron) or, occasionally, a vein graft is used to reconstruct ("patch") the arteriotomy site and increase the luminal diameter.

Variant procedure or approaches: The vascular surgeon's approach to CEA is described in Chapter 6.3. Carotid stenting is described in Interventional Neuroradiology, Section 13.1. Stenting appears to be inferior to CEA in outcome studies (↑ stroke, ↑ death) but is associated with ↓ MI. EC-IC bypass for treatment o carotid occlusion is described in Section 1.1.

Usual preop diagnosis

Stroke; TIAs; carotid artery stenosis; carotid artery dissection

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, possibility of lines, and urinary catheter postop. See Appendix K: Enhanced Recovery After Surgery, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Parallel and anterior to the sternocleidomastoid centered at the level of the thyroid cartilage; occasionally, if "patching" arteriotomy, may have to harvest portion of greater saphenous vein from the leg.
Special	Magnification loupes; vascular instruments ± shunt

instrumentation	(Bard, Javid, Pruitt-Inahara)
Unique considerations	Techniques for monitoring cerebral perfusion: EEG-spectral analysis or raw EEG, somatosensory- and motor-evoked potentials, back-bleeding, internal carotid artery stump pressure (>50 mm Hg), or transcranial Doppler. CEA under regional anesthesia permits direct patient testing. Full anticoagulation with heparin (typically 100 U/kg iv) during arterial occlusion ± reversal with protamine (typically 0.5 mg/kg iv) 10 min after repair and reopening of carotid arteries. Maintaining ↑ BP during internal carotid artery occlusion (MAP 90–110). The use of neuroprotective agents just before internal carotid artery occlusion (e.g., iv propofol 1–2 mg/kg as necessary to produce EEG burst suppression).
Antibiotics	Cefazolin (2 g iv q6h)
Surgical time	~3 h
Closing considerations	Avoid ↑ BP or ↓ BP (typical MAP 80–100), meticulous hemostasis
EBL	50–150 mL
Postop care	Control of BP (MAP 80–100 mm Hg); start aspirin on postop d 1; PACU, ICU, or other monitored bed × 3–24 h
Mortality	0.3–1.1% (if combined CABG/CEA: up to 17.7%)
Morbidity	Postop MI: 0.5–4% Nerve injury: up to 39% (typically 8%) • Vagus, recurrent/superior laryngeal nerve (hoarseness): 4% • Hypoglossal nerve (the tongue deviates to the side of injury): 4% • Mandibular branch of the facial nerve (lower lip weakness): 2% • Glossopharyngeal nerve (loss of gag reflex, dysphagia): <1% • Transverse cervical and greater auricular nerves

	(cutaneous anesthesia): 12% Cerebral hyperperfusion syndrome (if postop BP is not well controlled) Intraop MI: 1–2% Postop bleeding: 1.7–2.7% Wound infection: rare
Pain score	3

PATIENT POPULATION CHARACTERISTICS

Age range	50–90 yr
Male:Female	1:1
Incidence	~140,000 CEAs/yr in the United States (steadily declining)
Etiology	Atherosclerosis; occasionally, traumatic (dissection)
Associated conditions	HTN; CAD; PVD; smoking; obesity; alcohol abuse; hyperlipidemia

ANESTHETIC CONSIDERATIONS

(Procedure covered: carotid endarterectomy)

PREOPERATIVE

The incidence of occlusive or ulcerative lesions of the extracranial or intracranial vasculature increases with advancing years. Generally, these lesions are asymptomatic until the cross-sectional area of the vessel is decreased by at least 50%. This is because in most patients the cerebral vasculature has excellent collateral circulation, most importantly the circle of Willis (normal in only 50% of patients), but also persistent anastomoses from the basilar artery and extra- to intracranial collateral flow via the ophthalmic artery or branches of the vertebral artery. Patients presenting for CEA generally fall into one of three categories: (a) those with TIAs, presenting with symptoms that may be focal or generalized, (b) patients with completed stroke (If the stroke is recent (<2–4 wk), some surgeons will not operate on the patient for fear of converting an ischemic infarct into a hemorrhagic infarct; however, if the infarct is small and clinical deficit minor, early surgery may be beneficial. Most studies recommend immediate implementation of best medical therapy followed by CEA (or

stenting) within 2 wk of a related TIA/stroke.), and (c) patients with asymptomatic bruit, which usually is found during a routine physical examination of the neck. These bruits are of concern because they may signal the development of carotid stenosis that could benefit from surgical intervention.

Respiratory	Patients should be asked to stop smoking prior to anesthesia, even if only the night before. Although cessation of smoking for such a short time will not lessen the volume of secretions appreciably or make the airways less irritable to a foreign body, such as an ETT, it will provide sufficient time for the carbon monoxide levels in the blood to decrease, thereby enhancing O_2-carrying capacity. Any Hx of pulmonary disease should be evaluated with spirometry, ABGs, and CXR. If there is evidence of pulmonary infection, appropriate antibiotic therapy should be instituted. If secretions are excessive, preop pulmonary physiotherapy, including bronchodilator therapy, may be indicated. **Tests:** ABGs; spirometry; CXR, if indicated from H&P
Cardiovascular	Careful evaluation of cardiovascular status is essential and should include a detailed Hx of cardiovascular function and serial determinations of BP in both arms to establish the range of pressures that normally occur and whether there are regional differences. If BP is different in the two arms, it should be measured intraop and postop in the arm with the higher values. Also, a preop ECG is mandatory. The reason for concern about cardiovascular function is twofold: (a) it is often necessary to administer vasoactive drugs to regulate BP during CEA, either to maintain it at a normal value or sometimes to increase it as much as 20% above the highest resting pressure to maintain optimal collateral circulation during intraop carotid occlusion. (b) The incidence of perioperative MI in this surgical population is >1% and represents the most common major postop complication. Except in

	the case of emergencies, anesthesia and surgery should not proceed in the face of severe, uncontrolled HTN, diabetes, or recent MI. Antihypertensive medications should be continued up to the time of anesthesia. **Tests:** ECG; others as indicated from H&P
Neurologic	The Sx of cerebrovascular insufficiency are due to either critical stenosis or occlusion of cerebral vessels, combined with inadequate collateral circulation. The degenerative plaques or mural thrombi readily break off from the vessel wall and cause focal ischemic lesions. Manual occlusion of the carotid arteries is not an appropriate test of tolerance to temporary circulatory occlusion, as it may endanger the patient by precipitating embolization from an ulcerative lesion or by inducing bradycardia and ↓ BP from activation of the carotid sinus reflex. It is desirable, however, to position the patient's head in the operative position as a test of the effect of that position on CBF. It is well documented that hyperextension and lateral rotation of the head may occlude vertebral-basilar flow and, if sustained, contribute to postop cerebral ischemia. Sx of dizziness or diplopia will emerge with this maneuver if CBF is compromised. **Tests:** Carotid and cerebral angiography will identify the type of lesion (ulcerative or stenotic), its location, and extent of collateral circulation. Other commonly used techniques include MR or CT angiography and duplex ultrasonography. The anesthesiologist should examine the angiograms of the patient or discuss the case with the surgeon to understand the type, location, and extent of the lesion.
Hematologic	Aspirin or other anti-Plt therapy usually is begun preop to ↓ the risk of periop thromboembolic complications. Aspirin may be continued up to the

	day of surgery. **Tests:** PT; PTT
Laboratory	Tests as indicated from H&P
Premedication	The use of premedication in patients undergoing CEA is controversial. Should a new TIA or stroke occur in the immediate preop period, its Sx may be difficult to distinguish from those associated with excessive responses to premedication. In this population, detailed discussion about the anesthetic and surgical plan, with appropriate reassurance, is usually sufficient. If medication is desired, midazolam 1–3 mg is preferable to opiates.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water and aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique (regional)

Historically, regional anesthesia—in the form of superficial and deep cervical plexus blocks, supplemented as needed by a local field block—was used for most CEAs. I provided the opportunity to evaluate cerebral function during a trial occlusion of 2–3 min. If the patient showed no adverse effects, the operation was completed under regional anesthesia. If the patient developed neurologic changes, a shunt was inserted or GA was induced and ET intubation performed, following which the operation was completed. Regional anesthesia, however, has several disadvantages: this may cause the absence of cerebral protection, patients may tolerate carotid occlusion for 10 min or more before suddenly losing consciousness or developing a Sz, and conversion to GETA may be technically difficult. Nevertheless, the technique still has some advocates among anesthesiologists and surgeons. It is claimed that (a) it decreases the need for a surgical shunt and, thereby, avoids the complications of shunt insertion; (b) it decreases the length of stay in the hospital; and (c) as an anesthetic technique, it is well accepted by some patients with fast surgeons.

Anesthetic technique (GETA)

GETA offers both direct and indirect advantages for patients undergoing CEA: cerebra

protection by decreasing $CMRO_2$ and redistributing flow toward the potentially ischemic area; greater patient comfort; and the ability to regulate PO_2, PCO_2, and MAP. Despite these arguments favoring GA, recent studies comparing regional and GA suggest that there is no clear outcome advantage of one technique over the other, although GA may be associated with a slightly higher risk for postop MI.

Induction	Propofol (1–2 mg/kg), when carefully titrated, is suitable for induction, as arterial BP will generally remain at acceptable levels (±20% of baseline) in normovolemic patients. Propofol will ↓ $CMRO_2$, constrict normally reactive cerebral vessels, and → a redistribution of CBF toward potentially ischemic areas. Etomidate (0.1–0.4 mg/kg) may be useful for induction of anesthesia in hemodynamically unstable patients. A muscle relaxant (e.g., vecuronium 0.15 mg/kg or rocuronium 0.6 mg/kg) is administered for tracheal intubation. An analgesic (e.g., fentanyl 2–5 mcg/kg or remifentanil 1–3 mcg/kg) may be given to minimize the cardiovascular responses to ET intubation. These opiates have minimal effects on CBF or $CMRO_2$.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider dexamethasone (4 mg iv) to ↓ PONV. Avoid long-acting opioids or scopolamine patch, which may confound postop neuroexam. Sequential pneumatic compression devices should be used to ↓ VTE risk.
Maintenance	Isoflurane (up to 0.6%) or sevoflurane (up to 1%) inspired, in combination with N_2O 50% and remifentanil (0.05–0.2 mcg/kg/min), is satisfactory and will not interfere with EEG or EP/MEP monitoring. TIVA offers no advantages but may be comforting to the neuromonitoring team. Just before cross-clamping of the carotid artery, an additional dose of propofol sufficient to produce burst suppression on the EEG (usually 0.5–1 mg/kg propofol) may be

	administered for cerebral protective effects. A low-dose NTG infusion may be beneficial for patients at high risk for MI. Before cross-clamp, the surgeon will request heparin, usually 100 mg/kg iv. Recheck ACT (goal: 2× baseline).	
Emergence	Total carotid occlusion time should be noted on the anesthetic record. After 10 min and once bleeding from the arteriotomy site has been controlled, protamine (typically 0.5 mg/100 U heparin) is administered iv slowly. If ↓ BP occurs, the rate of protamine administration should be slowed. If vasopressors were used during surgery, patient should be weaned from them during emergence because HTN is likely as patient awakens from anesthesia. The need to control BP with labetalol and/or a combination of esmolol and NTG is likely in the emergence phase. Antiemetic prophylaxis (e.g., ondansetron 4 mg iv 30 min before end of case) is usually appropriate. Prophylactic β-blockers may be useful in this patient population. Consider iv acetaminophen if preop po dose is not given.	
Blood and fluid requirements	IV: 16 ga × 2 NS/LR @ 5–10 mL/kg/h	Blood replacement is seldom an issue. Studies indicate that blood glucose > 180 mg/dL may ↓ tolerance of the brain to ischemia; thus, it is prudent to avoid glucose-containing solutions and treat levels >180 mg/dL. One iv is dedicated to drug infusions. Zero balance fluid management is recommended (see Appendix K, p. K-2).
	Albumin 5%	If volume expansion is

		needed, albumin stays in the intravascular compartment longer than crystalloid solutions.
Monitoring	Standard monitors Arterial line (preinduction for symptomatic patients) UO PPV/PVI ±Stump pressure transducer	Marked fluctuations in BP may occur, necessitating vasoactive drug therapy. The arterial pressure transducer should be placed at the level of the head (tragus) to accurately assess CPP. A CVP catheter is seldom necessary. Vasoactive drugs usually can be given safely through a second iv placed in the proximal arm. A second pressure transducer setup may be needed for stump pressure measurements. Monitors incorporating EASI ECG analysis technology can emulate 12-lead ECGs using only five actual leads. ETT cuff pressure should be monitored and kept at the minimum required to prevent leak. This will minimize ischemic injury to the tracheal mucosa and to the recurrent laryngeal nerve, which may be trapped between the cuff and surgical retractor.
Cerebral perfusion	rCBF	Regional CBF (rCBF) ≥ 25

monitoring		mL/min/100 g brain is satisfactory, and <20 mL/min/100 g suggests cerebral ischemia; however, rCBF measurements are not generally available in OR.
	EEG (multilead)	Common BIS-type monitors are inadequate for detecting most ischemic events. Even multilead EEG may not identify small focal areas of ischemia. The depth of anesthesia and arterial CO_2 must be stable, or the EEG may not be interpretable. There is a significant incidence of false positives and negatives with EEG monitoring.
	Stump pressure (back pressure)	Stump pressure (pressure distal to the carotid clamp) is used to evaluate the adequacy of cerebral perfusion. Cerebral ischemia rarely occurs at stump pressures >40 mm Hg. False positives are not uncommon and result in a shunt being placed when none is needed. The simplicity of the measurement and its relative validity when pressure is >40 mm Hg

	still make it a useful clinical method for ensuring adequate perfusion.
Cerebral oximetry (rSO_2)	Cerebral oximetry (e.g., Somanetics Invos) is often used to evaluate superficial frontal cortex perfusion during CEA. With carotid occlusion, ipsilateral rSO_2 values may decrease suggesting inadequate cerebral perfusion. The method is nonquantitative, and an unknown portion of the signal may originate from structures superficial to the cortex perfused by branches of the external carotid artery. Postop increased rSO_2 may predict onset of cerebral hyperperfusion syndrome.
SSEP/MEP	SSEPs/MEPs are being used with increasing frequency as a means of determining the adequacy of cerebral perfusion during temporary occlusion of the carotid artery. This technique requires continuous monitoring by personnel with special training. Areas of focal ischemia may not be detected.

		False-positive and false-negative results can occur.
	Transcranial Doppler (TCD)	TCD scanning alone or combined with EEG monitoring is a useful method for detecting microemboli (air or particulate matter) during CEA. It also has been suggested that TCD can be used as a guide for regulating BP postop to minimize the occurrence of post-CEA cerebral hyperperfusion states. This technique requires continuous monitoring by personnel with special training and is technically difficult to implement intraop.
Control of BP	Keep MAP ≥ awake levels Autoregulation Vasopressors: phenylephrine infusion	It is desirable to maintain MAP at or slightly above the patient's recorded resting pressure while awake. Volatile anesthetics impair autoregulation; therefore, the higher the pressure, the more likely it is that cerebral perfusion will be adequate during surgical occlusion. A pure α-adrenergic agonist (e.g., phenylephrine) is ideal to support BP because it has minimal dysrhythmogenic

		potential. A V-4 or V-5 lead usually will reveal myocardial ischemia induced by ↑ BP.
	Coronary vasodilation NTG infusion	A simultaneous infusion of NTG (0.2–0.4 mcg/kg/min) may improve coronary flow during periods of induced ↑ BP. If hypertensive episodes occur during surgery, infusions of esmolol ± NTG/clevidipine work well to control BP.
	Labetalol (pre-emergence)	Long duration effect (2–10 h) makes intraop titration difficult.
Positioning	✓ pad pressure points ✓ eyes	
Complications	Sudden ↓ HR or ↓ BP	Surgical stimulation of carotid baroreceptors. Rx: have surgeon apply 2–3 mL of 1% plain lidocaine to carotid bulb.

POSTOPERATIVE

Complications	Circulatory instability: ↓ BP	Circulatory instability is common. ↓ BP may be due to hypovolemia, residual anesthetic, dysrhythmias, or exposure of the carotid sinus baroreceptors to a new higher pressure, causing an exaggerated

	reflex response. Rx by volume expansion and/or pressors.
HTN MI Stroke	HTN may be due to loss of the normal carotid baroreceptor mechanism. It may → excessive bleeding, ↑ myocardial O_2 consumption, dysrhythmias, MI, intracerebral hemorrhage, and ↑ ICP from cerebral edema.
Loss of carotid body function	Ipsilateral chemoreceptor function is lost in most patients after CEA → ↓ ventilatory and circulatory responses to hypoxia and a modest increase in resting arterial $PaCO_2$. These patients should be given supplemental O_2 postop. Special attention must be directed toward preventing atelectasis or other pulmonary or circulatory abnormalities that might cause hypoxemia.
Respiratory insufficiency Tracheal compression Vocal cord paralysis Tension pneumothorax	Acute respiratory insufficiency may occur 2° hematoma formation with tracheal deviation, vocal cord paralysis from surgical traction on laryngeal nerves, or tension pneumothorax from dissection of air

		through the wound into the mediastinum and pleural space. A hematoma that causes respiratory distress should be evacuated before reintubation is attempted if possible.
	Circulatory insufficiency MI Tension pneumothorax	If there is evidence of circulatory insufficiency, consider MI or tension pneumothorax and treat appropriately.
	Intimal flap → stroke	Should a patient emerge from anesthesia with a new neurologic deficit, immediate surgical exploration of the operative site or immediate cerebral angiography should be performed to determine if an intimal flap or thrombosis has formed at the site of operation. These are surgically correctable lesions and, if corrected immediately, may lessen the severity of the subsequent neurologic deficit.
Multimodal pain management	Acetaminophen (1 g iv) ±Fentanyl 25–50 mcg prn	Complaints of "sore throat" are common and rarely require opiate treatment. If not given preop of if 4–6 h has elapsed since

		previous dose.
ERAS	Ondansetron 4 mg iv	Encourage early enteral nutrition, Foley catheter removal, and mobilization.
Tests	As indicated by Sx	Consider urgent carotid ultrasound or cerebral angiography for delayed emergence.

Suggested Readings

1. Hye RJ, Voeks JH, Malas MB, et al: Anesthetic type and risk of myocardia infarction after carotid endarterectomy in the Carotid Revascularization Endarterectomy versus Stenting Trial (CREST). J Vasc Surg 2016; 64(1):3–8.e1.
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7. Poi MJ, Echeverria A, Lin PH: Contemporary management of patients wit concomitant coronary and carotid artery disease. World J Surg 2018;42(1):272–82.
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10. Sejersten M, Wagner GS, Pahlm O, et al: Detection of acute ischemia from the EASI derived 12-lead electrocardiogram acquired in clinical practice. J Electrocardiol 2007; 40:120–6.

Suggested Viewing

Links are available online to the following video:

Carotid Endarterectomy: https://www.youtube.com/watch?v=9lDf3sx_ZrE

SECTION 2.0

OPHTHALMIC SURGERY

SURGEONS

Peter H. Tang, MD, PhD
Darius M. Moshfeghi, MD

ANESTHESIOLOGISTS

Richard A. Jaffe, MD, PhD
Lindsey Ralls, MD

CATARACT EXTRACTION WITH INTRAOCULAR LENS INSERTION

SURGICAL CONSIDERATIONS

Description

Cataract—the leading cause of treatable blindness in the world—is defined as opacification of the crystalline lens. **Cataract surgery** is the most common surgical procedure, with more than 3 million performed in the United States each year. Several approaches to cataract removal have evolved as a result of advances in both instrumentation and artificial intraocular lenses (IOL). Most modern cataract surgery is performed using a variation of the **extracapsular technique,** which involves removal of the crystalline lens through an opening made in the anterior lens capsule (known as a **capsulotomy**). Removal of the lens nucleus can then be accomplished intact, which requires an 8–10-mm corneal incision, or more commonly by **phacoemulsification** wherein ultrasound energy is used to fragment the lens, allowing aspiration of the lens material. The advantages of phacoemulsification are that the entire procedure can be performed through a much smaller, clear corneal incision (usually 2.8 mm in length) and is associated with fewer adverse events. With both approaches, the softer, more peripheral cortical lens material is then removed by aspiration, leaving the posterior capsular bag intact to support an IOL implant (Fig. 2.1). If the lens capsule is torn or is for any reason unable to support an IOL, the lens can be fixated with sutures in the posterior chamber (behind the iris), or an anterior chamber IOL can be placed in front of the iris. Presently, the most popular materials for IOL implants are polymethyl methacrylate, silicon, and acrylic. Only silicon and acrylic are foldable, which allows their insertion through a small corneal incision and, therefore, are the most commonly used. The wound is typically sealed by hydrating the adjacent corneal stroma to induce mild edema; however, it may be further closed with a nylon suture (9-0 or 10-0) to achieve a watertight seal.

Variant procedure or approaches

Intracapsular cataract extraction involves removal of the crystalline lens with its surrounding capsular bag intact. To accomplish this, the zonules that normally stabilize and center the lens must be broken, and a cryoprobe often is used to remove the lens from the eye through a large incision. This procedure is performed infrequently, given the superior visual outcomes of extracapsular techniques. It may be indicated in situations where capsular bag support has been compromised by trauma, malignancy, or inherited disorders.

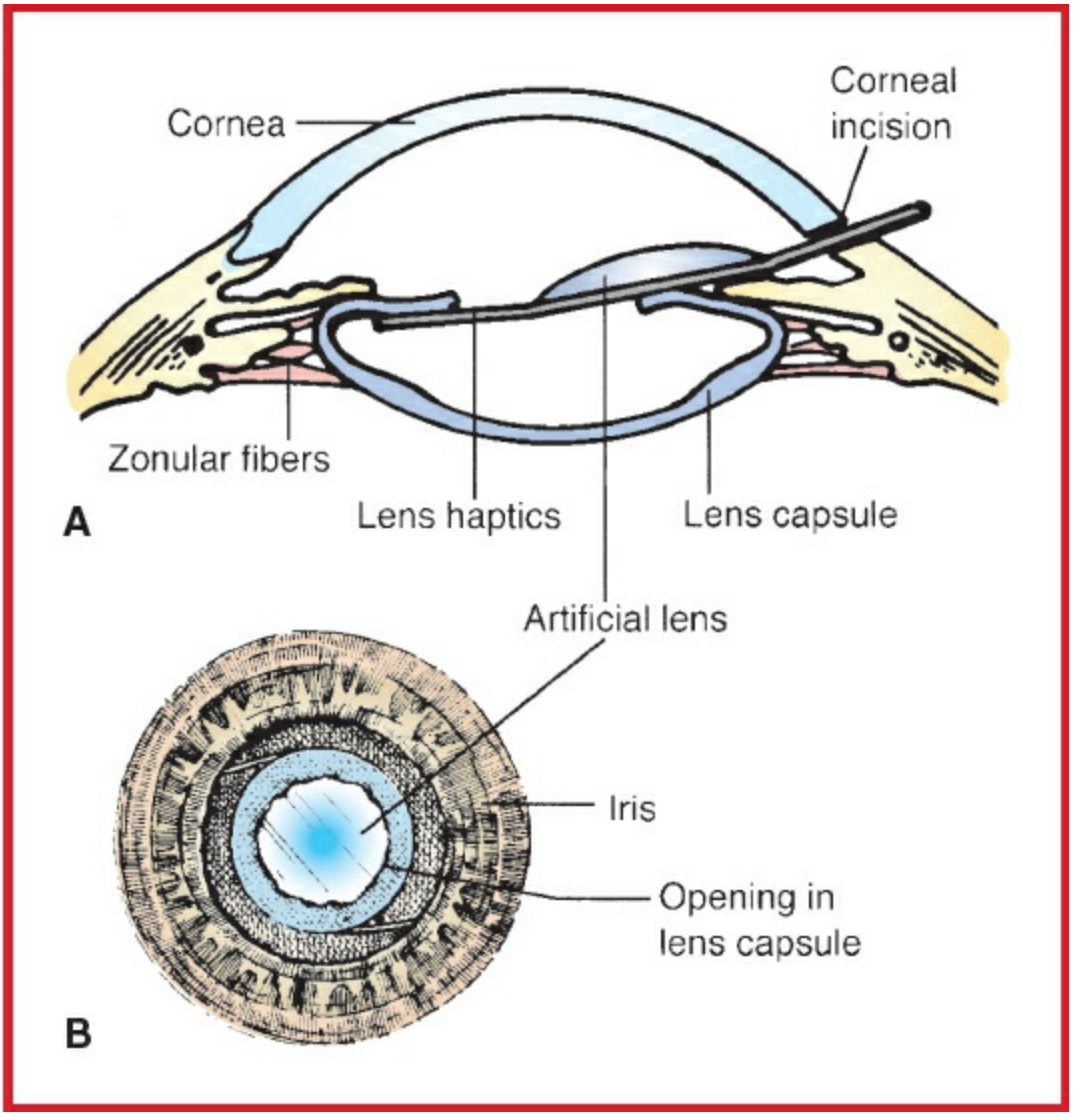

Figure 2.1 **A:** Placement of intraocular lens into remaining capsular bag. **B:** "In-the-bag" insertion.

Usual preop diagnosis

Cataract

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, carb loading, and postop pain management. See Appendix K: Enhanced Recovery After Surgery, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine, table rotated 90–180°
Incision	2.8-mm peripheral cornea (phacoemulsification) or 8–10 mm (corneoscleral junction)

Special instrumentation	Surgical microscope; phacoemulsification machine
Antibiotics	Subconjunctival cefazolin (50–100 mg) or gentamicin (20–40 mg) or a topical fluoroquinolone
Surgical time	10–60 min
EBL	None
Postop care	Possible eye patch/shield for 24 h, topical medications
Mortality	Rare
Morbidity	Posterior capsule opacification: ~25% (may require Nd:YAG laser treatment) Posterior capsule rupture: 3.1% Corneal edema: <2% Macular edema: 1–2% Retinal detachment: <1% Choroidal hemorrhage: 0.3% Endophthalmitis: <0.2%
Pain score	1–2

PATIENT POPULATION CHARACTERISTICS

Age range	3 mo to 80+ yr (depends on type of cataract)
Male:Female	1:1
Incidence	>1,000,000/yr in the United States. Prevalence: 50% @ 65–74 yo, 70% @ 75+ yo
Etiology	90% age-related; congenital (1/250 newborns); metabolic; traumatic; medication-induced (steroids); previous vitrectomy
Associated conditions	Systemic diseases of elderly patients—common; cardiovascular disease; diabetes; HTN Genetic: Marfan disease; metabolic disorders Patients may be on antiplatelet or anticoagulant therapy. It is generally accepted that these drugs do not need to be discontinued before cataract surgery (especially if INR ≤ 1.5).

ANESTHETIC CONSIDERATIONS

At the present time in the United States, cataract surgery is most commonly performed using only topical anesthetic agents (e.g., preservative-free tetracaine 0.5%, lidocaine 2–4%) to block trigeminal nerve endings in the cornea and conjunctiva. Iris and ciliary body anesthesia depend on local anesthetic penetration into the anterior chamber. Thus, in a few patients, there may be a need for supplemental anesthetic administration (e.g., intracameral, 1% lidocaine) and less commonly systemic analgesic and sedative drugs. Inadvertent eye and lid movement should be expected. Adverse reactions to topical anesthetics are extremely rare and typically allergic in nature. High concentrations or prolonged exposure to local anesthetics can be toxic to the corneal epithelium (delayed wound healing; corneal erosion) and to the retina. A prospective randomized double-blind series demonstrated that combining topical anesthesia with intracameral lidocaine anesthesia was safe and effective in phacoemulsification with intraocular lens implantation. This technique avoided potential sequelae of retrobulbar or peribulbar anesthesia for cataract surgery. However, one study of patients undergoing cataract surgery using topical anesthesia reported greater intraop and postop discomfort than those given a sub-Tenon block. Use of intravenous sedation increased the incidence of adverse events as compared with topical anesthesia without sedation. All local anesthetic techniques should be avoided in patients with uncontrolled movement disorders or an inability to cooperate. Retrobulbar or peribulbar anesthesia combined with sedation may be indicated for patients who are otherwise suitable for surgery under monitored anesthesia care (MAC) but have limited ability to cooperate with maintaining akinesia of the eye during surgery.

Anesthesia-trained personnel monitored most patients during cataract surgery, and the most commonly used local anesthetic was lidocaine. The anesthetic method associated with the lowest degree of pain, dissatisfaction, drowsiness, or nausea and vomiting was a regional block technique with administration of sedatives and diphenhydramine.

See Anesthetic Considerations for Ophthalmic Surgical Procedures Under MAC (adult).

Suggested Readings

1. Borazan M, Karalezli A, Akova YA, et al: Comparative clinical trial of topical anaesthetic agents for cataract surgery with phacoemulsification: lidocaine 2% drops, levobupivacaine 0.75% drops, and ropivacaine 1% drops. Eye 2008; 22(3):425–9.
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CORNEAL TRANSPLANTATION

SURGICAL CONSIDERATIONS

Description

Patients with corneal pathology who have failed stem-cell techniques may require **corneal transplantation (penetrating keratoplasty [PKP] or lamellar keratoplasty)**. Corneal transplantation involves replacing a portion of the host cornea with tissue from a donor eye (allograft). The primary goals of this procedure are to both restore the integrity of the cornea and establish a clear visual axis. The ideal death-to-preservation time of the donor cornea is <18 h, and the donor cornea can be stored for up to 2 wk before transplantation. The procedure often begins with the placement of a scleral fixation ring (Flieringa ring) just beyond the corneoscleral junction, which is secured with 7-0 Vicryl sutures. This provides additional scleral support that is especially helpful in children or patients who have undergone previous cataract surgery. The donor corneal button is removed from the surrounding corneoscleral rim with a trephine and kept in storage medium until the recipient bed is prepared. The host cornea is then

trephined in a previously marked central location, using either manual or vacuum-assisted techniques, while the anterior chamber is maintained with viscoelastics. After the eye is opened, it is critical to avoid patient movement, coughing, bucking, or any Valsalva maneuvers to prevent expulsion of the intraocular contents through the wound. The size of the donor button is generally cut ~0.25 mm larger than the host bed. The donor cornea is then sutured in place with the endothelial side down using 10-0 nylon sutures. This can be accomplished using 16 interrupted sutures (generally preferred with corneas that are inflamed, thinned, or vascularized), running sutures, or a combination, depending on a number of factors unique to each patient. Great care is taken during manipulation of the allograft to avoid trauma to the inner surface of the graft, as damage to the endothelial cells in this location can result in primary graft failure.

Variant procedure or approaches

PKP may be combined with **cataract extraction** or exchange of a previously placed IOL. In addition, PKP may be combined with **limbal stem-cell transplantation** (autograft from less injured eye) in cases where the most superficial corneal epithelial layer is unable to regenerate following damage (e.g., chemical burn injuries) to the limbal stem cells. **Partial-thickness transplants**, called **lamellar keratoplasty**, can also be performed in certain clinical situations. PKP may be combined with glaucoma filtration procedures and/or retinal surgeries.

Usual preop diagnosis

Persistent corneal edema; inherited corneal dystrophy; keratoconus; corneal scar; infectious keratitis; chemical injury

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol and smoking cessation, carb loading, and postop pain management. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine, table rotated 90–180°
Incision	Corneal
Special instrumentation	Surgical microscope
Unique considerations	Open-globe precautions may be necessary: avoid coughing, bucking, or Valsalva maneuvers to prevent expulsion of intraocular contents.

Antibiotics	Subconjunctival cefazolin (50–100 mg) or gentamicin (20–40 mg)
Surgical time	60–90 min
EBL	Minimal
Postop care	Patch/shield for 24 h, long-term topical immunosuppression to prevent graft rejection
Mortality	Rare
Morbidity	Graft rejection: ~5% Suprachoroidal hemorrhage: <1% (higher for MAC: ~4%) Infection: <1%
Pain score	2

PATIENT POPULATION CHARACTERISTICS	
Age range	Any age
Male:Female	1:1
Incidence	>40,000 cases/yr in the United States and Canada
Etiology	Corneal opacity or decompensation resulting from endothelial failure; inherited dystrophy; keratoconus; scarring related to trauma/chemical burn/infection
Associated conditions	Congenital malformations; sleep apnea; atopic disease/asthma; Down syndrome

ANESTHETIC CONSIDERATIONS

Full-thickness corneal transplants commonly require GA or a retrobulbar/peribulbar block to prevent movement of the eyelids or extraocular muscles that could lead to distortion of the globe during the procedure. However, in patients with significant coagulopathy, a history of perforated corneal ulcers, severe systemic disease, or other conditions that make the use of these forms of anesthesia less preferable, corneal transplant can be performed with topical anesthesia in cooperative patients. Partial-thickness transplants are often done under MAC.

See Anesthetic Considerations for Ophthalmic Surgical Procedures Under MAC (adult).

Suggested Readings

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TRABECULECTOMY

SURGICAL CONSIDERATIONS

Description

Glaucoma is a chronic disorder characterized by progressive and irreversible optic neuropathy with visual field defect. Glaucoma can develop at any intraocular pressure (IOP), but most current treatments are targeted at lowering IOP. It is the second mos common cause of blindness in the United States and accounts for more than 5.1 million cases of blindness throughout the world. **Trabeculectomy** (glaucoma filtration procedure) is the most common surgical procedure used to reduce IOP and is often undertaken only after maximal medical therapy has failed. In trabeculectomy, a drainage fistula (ostium) is created from the anterior chamber to the subconjunctival space, allowing aqueous humor to drain from the eye. (Normal anatomy relevant for aqueous fluid production is shown in Fig. 2.2.) First, a limbus-based or fornix-based incision is created in the conjunctiva and Tenon layer, exposing the underlying bare sclera. A partial-thickness (4–5 mm) scleral flap, hinged at the limbus, is then created. Because scarring (secondary to inflammation) is the most common cause of surgical failure, antimetabolites, such as mitomycin-C or 5-fluorouracil, are often applied to the surgical site to slow or prevent fibroblast proliferation. Next, an incision into the anterior chamber is created at the base of the scleral flap and converted to a sclerotomy by removing an ~1 × 4 mm piece of corneoscleral tissue. To prevent the iris from entering the ostium as well as to protect against future angle closure, an **iridectomy** is performed, followed by closure of the overlying scleral flap with 10-0 nylon sutures. Before closure, it is important to avoid coughing, bucking, or Valsalva maneuvers, which might cause suprachoroidal hemorrhage or expulsion of intraocular content. The conjunctiva is then reapposed, using running 8-0 or 9-0 absorbable or nylon sutures.

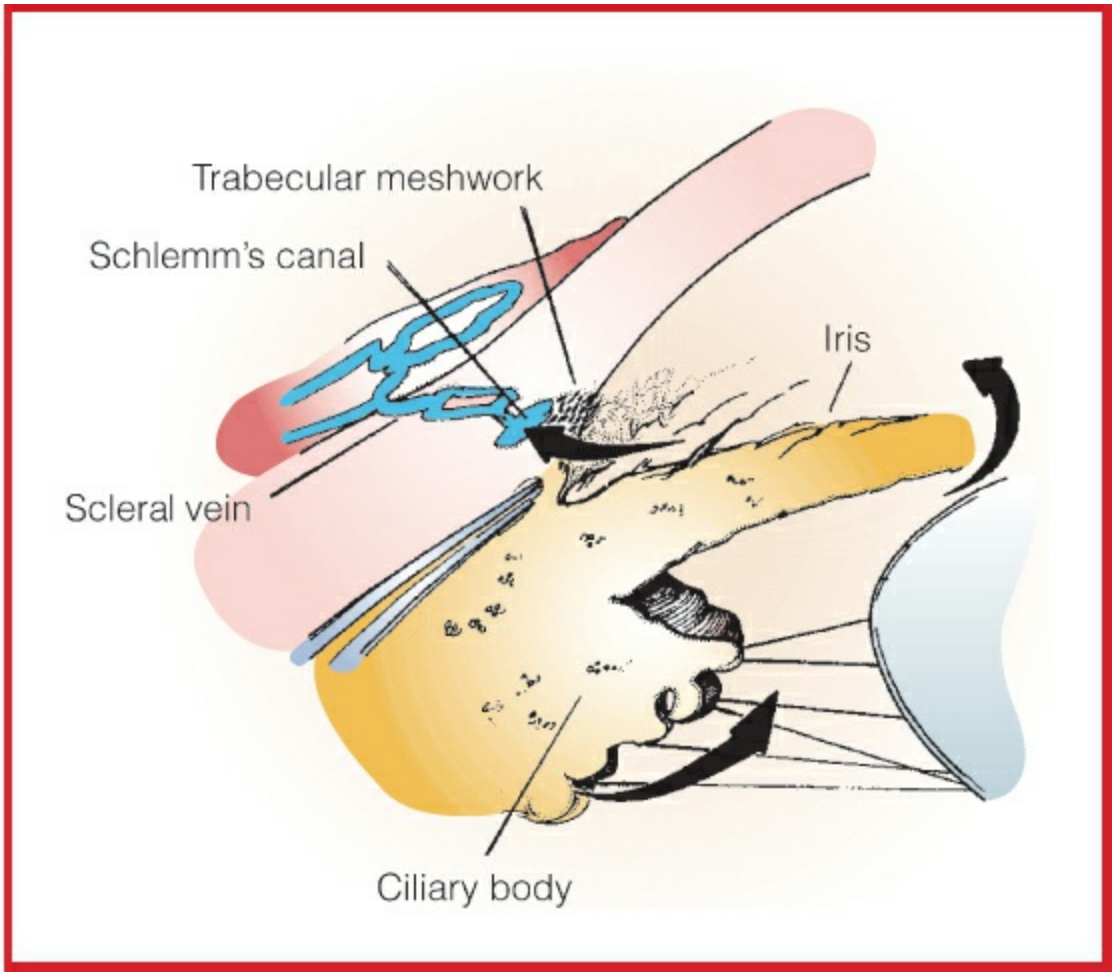

Figure 2.2 Ocular anatomy concerned with control of IOP. (Reproduced with permission from Barash PG, Cullen BF, Stoelting RK, et al., eds:Clinical Anesthesiology, 7th edition. Wolter Kluwers Health/Lippincott Williams & Wilkins, Philadelphia: 2013.)

Variant procedure or approaches

In patients for whom trabeculectomy has failed, a variety of drainage implants have been created to maintain the patency of the drainage ostium. These devices (e.g., **Ahmed, Molteno, Krupin, Baerveldt**) consist of plastic reservoirs that are placed in the sub-Tenon space and are connected to a tube that enters the anterior chamber (Fig. 2.3). These devices differ in implant size and whether or not there is an internal valve to prevent excessive drainage. Long-term IOP reduction with drainage implants is not as successful as trabeculectomy.

In infants and children with congenital glaucoma, the anterior chamber angle, which normally allows outflow of aqueous, develops abnormally and often requires surgical intervention. **Goniotomy** (opening Schlemm canal) is usually the initial procedure of choice. An alternative procedure is a **trabeculotomy** performed by exposing Schlemm canal (the drainage system) in a corneoscleral cutdown. A trabeculotome is then

threaded into this canal and is rotated, creating a tear in the trabecular meshwork and allowing direct communication between the anterior chamber and Schlemm canal.

Usual preop diagnosis

Glaucoma

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol and smoking cessation, carb loading, and postop pain management. See Appendix K, p. K-1.

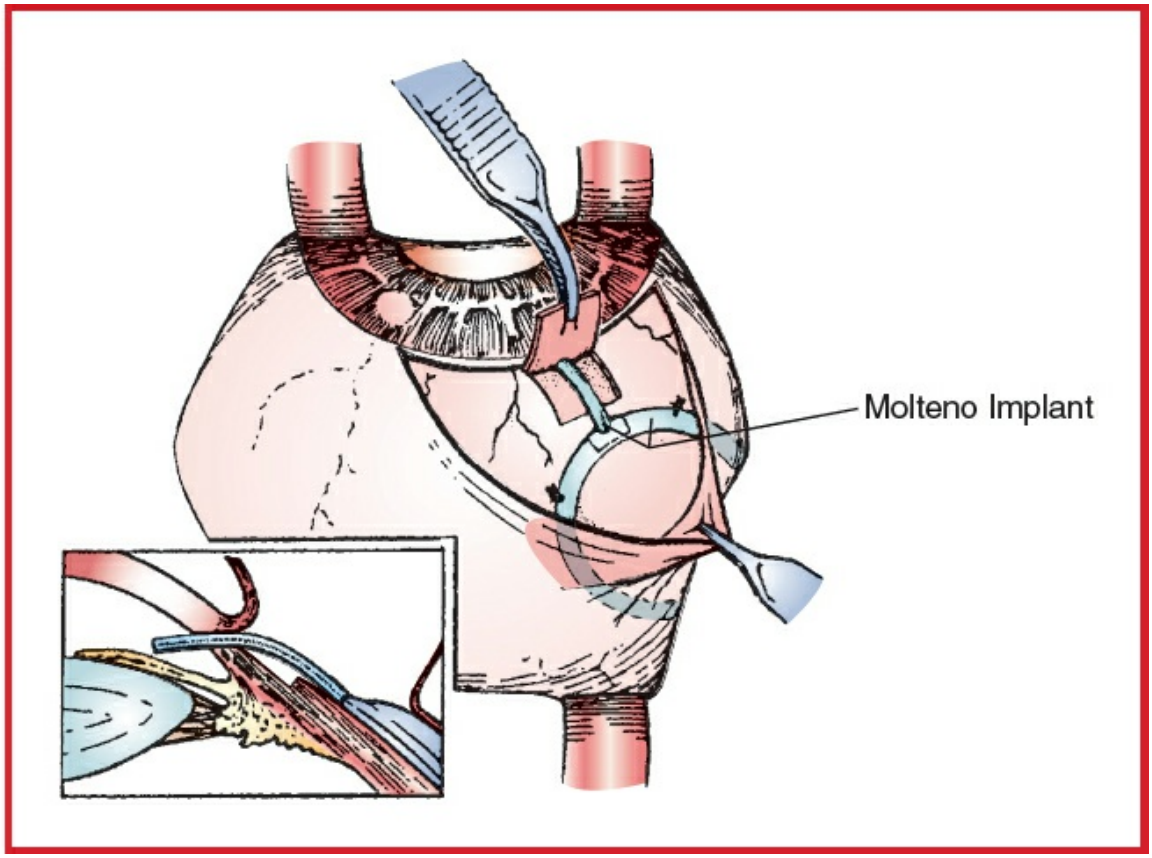

Figure 2.3 Basic technique of inserting Molteno implant. Silicone tube is inserted into anterior chamber via needle track and is connected to a subconjunctival acrylic plate that is attached to the sclera near the equator. (Reproduced with permission from Allingham RR, ed: Shield's Textbook of Glaucoma, 6th edition. Wolter Kluwers Health/Lippincott Williams & Wilkins, Philadelphia: 2010.)

SUMMARY OF PROCEDURE	
Position	Supine, table rotated 90–180°
Incision	Superior portion of eye
Special instrumentation	Surgical microscope

Unique considerations	Prevent coughing, bucking, and Valsalva maneuvers while globe is open, to prevent expulsion of intraocular contents.
Antibiotics	Subconjunctival cefazolin (50–100 mg) or gentamicin (20–40 mg)
Surgical time	30–60 min
EBL	Minimal
Postop care	Patch/shield × 24 h; long-term topical corticosteroids to reduce scarring. Topical antibiotics for the fistula. Scleral flap sutures can be cut with a laser postop to increase flow. Patient advised to wear patch at night × 1–2 wk
Mortality	Rare
Morbidity	Overfiltration causing hypotony Leaking bleb Fistula scarring Infection Anterior chamber bleeding/hyphema Serous choroidal detachment/effusion Persistent corneal edema Suprachoroidal hemorrhage
Pain score	1–2

PATIENT POPULATION CHARACTERISTICS	
Age range	Any age; more common in the elderly
Male:Female	1:1
Incidence	1.7% Caucasians; 5.6% African Americans
Etiology	Impaired aqueous outflow. Cause of primary open-angle glaucoma unknown, but elevated IOP is the strongest risk factor. Many secondary causes, including angle closure, trauma, inflammation, neovascularization, and congenital abnormalities
Associated	Diseases of the elderly, including cardiovascular

conditions	disease, HTN, and diabetes. Children may have multiple congenital anomalies.

ANESTHETIC CONSIDERATIONS

Trabeculectomy is typically accomplished using sub-Tenon anesthesia, which allows monitoring of conjunctival mobility when selecting the surgical site. Alternatively, it can be done using topical anesthetics. GA is usually reserved for pediatric patients and patients unlikely or unable to cooperate during the procedure or if low IOP from anesthesia is desirable.

Subconjunctival anesthesia at the bleb site may be associated with a poorer outcome, because it may stimulate fibroblasts to cause scarring due to hemorrhage and tissue damage. Peribulbar and retrobulbar injections in patients with advanced glaucoma may be associated with increased IOP, which can be prevented by decreasing anesthetic volumes and avoiding the use of orbital Honan balloons.

Topical and intracameral anesthesias are being increasingly employed for trabeculectomy to avoid injection pain and potential complications, such as conjunctival button holes and hemorrhage. However, topical agents have the following limitations: inferior duration and intensity of anesthetic effect and lack of ocular akinesia, which is necessary to prevent globe compression in patients with prominent eyelid squeezing. Intracameral lidocaine as a supplement to topical anesthesia has the theoretical advantage of increasing depth of anterior chamber, but it poses the risk of damaging the phakic lens and excessive iridectomy enlargement. To avoid these possible complications, intracameral acetylcholine or topical pilocarpine can be used in conjunction with intracameral lidocaine.

See Anesthetic Considerations for Ophthalmic Surgical Procedures Under MAC (adult).

Suggested Readings

1. Kumar CM, Eid H, Dodds C: Sub-Tenon's anaesthesia: complications and thei prevention. Eye (Lond) 2011; 25(6):694–703.
2. Sauder G, Jonas JB: Topical anesthesia for penetrating trabeculectomy. Graefes Arch Clin Exp Ophthalmol 2002; 240:739–42.
3. Theventhiran A, Shabsigh M, Moraes CG, et al: A comparison of retrobulbar versus topical anesthesia in trabeculectomy and aqueous shunt surgery. J Glaucoma 2018; 27(1):28–32.
4. Yook E, Vinod K, Panarelli JF: Complications of micro-invasive glaucoma surgery Curr Opin Ophthalmol 2018; 29(2):147–54.

ECTROPION REPAIR

SURGICAL CONSIDERATIONS

Description

Ectropion is a malposition of the eyelid often due to laxity in the tarsoligamentous sling, in which the lid margin is everted away from the globe. The surgical approach depends on the underlying anatomic abnormality, which can be congenital, involutional, or cicatricial (scarring) or due to mechanical traction from masses or facial nerve palsy. A lateral **tarsal strip procedure** is often used, with the lateral canthal tendon first released by performing a **lateral canthotomy and cantholysis** of the crus (Fig. 2.4). A lateral portion of tarsus is then dissected free of overlying skin, muscle, and conjunctiva. This strip of tarsus is trimmed to the appropriate length and is secured to the periosteum of the lateral orbital rim with suture. Excess skin is removed and the defect is closed. If punctal malposition is present, the tarsal strip procedure may be combined with a **medial conjunctival spindle procedure**.

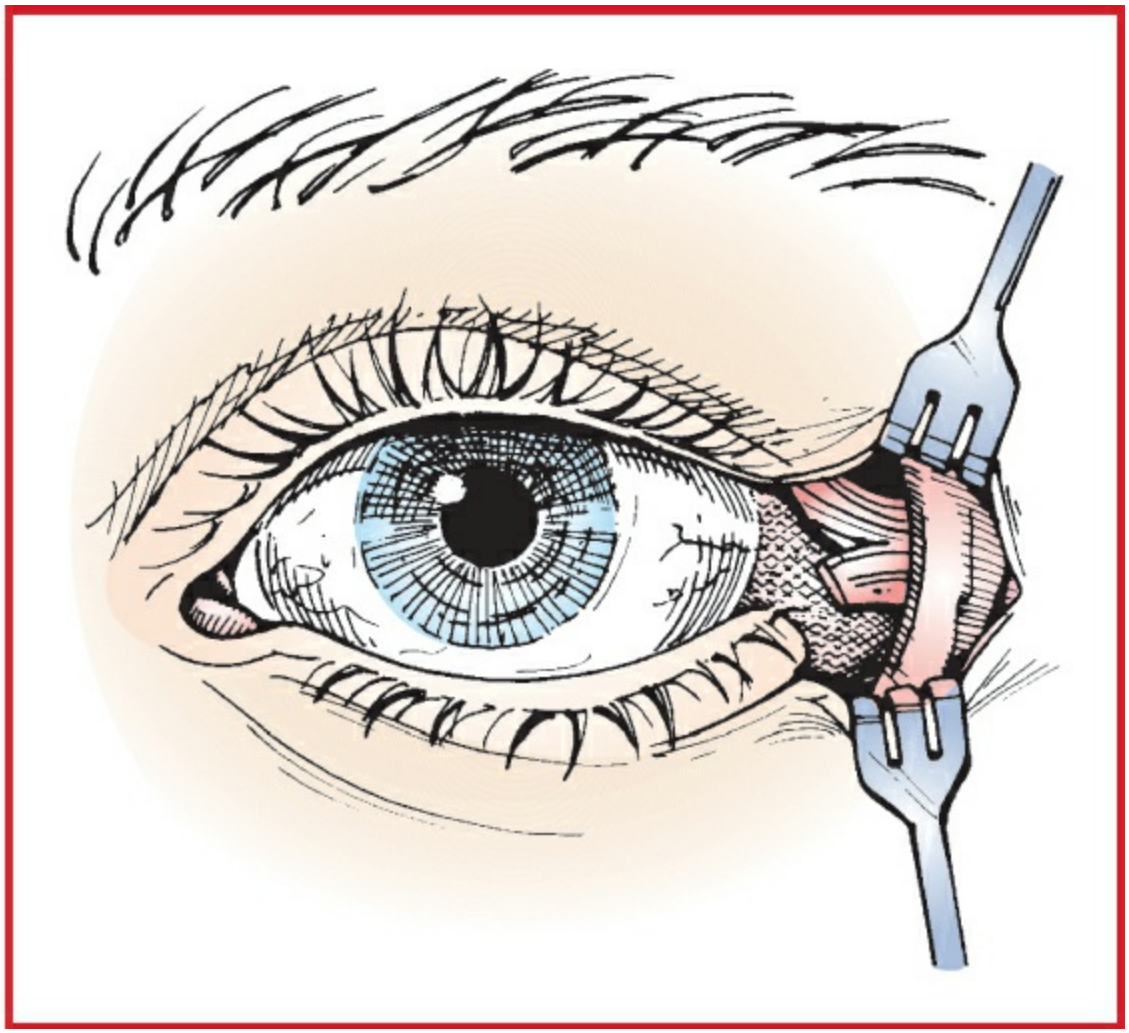

Figure 2.4 In the tarsal strip procedure, the lower eyelid is incised laterally. The entire lower crus of the canthal tendon must be severed. (Redrawn with permission from Tasman W, Jaeger EA, eds:Duane's Ophthalmology, Wolter Kluwers Health/Lippincott Williams & Wilkins, Philadelphia: 2013.)

Variant procedure or approaches

Cicatricial ectropion from a contracting scar can sometimes be released with a Z-plasty incision that releases vertical skin tension. Alternatively, a full-thickness skin graft may be required and can be harvested from the upper lid or the postauricular or supraclavicular regions.

Usual preop diagnosis

Ectropion of the eyelid

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol and smoking cessation, carb loading, and postop pain management. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine, table rotated 90–180°
Incision	Lateral canthal region or area of scarring
Special instrumentation	Surgical loupes
Antibiotics	None intraop
Surgical time	0.5–1 h
EBL	Minimal
Postop care	Topical antibiotic ointment
Mortality	Rare
Morbidity	Lid malposition Infection: Very rare Corneal injury Local postop bleeding
Pain score	1–2

PATIENT POPULATION CHARACTERISTICS

Age range	Any age, but most common in older adults
Male:Female	1:1
Incidence	Common in elderly patients
Etiology	Congenital; aging; malignancy; facial nerve palsy
Associated conditions	Systemic diseases of elderly patients are common, such as cardiovascular disease, diabetes, HTN, and neurologic disease

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Ophthalmic Surgical Procedures Under MAC (adult).

Suggested Reading

1. See Suggested Readings following Ophthalmic Surgery section.

ENTROPION REPAIR

SURGICAL CONSIDERATIONS

Description

Entropion is a condition characterized by an inward rotation of the eyelid margin. The surgical approach depends on the underlying anatomic abnormality, which can be congenital, spastic, involutional, or cicatricial (scarring). For the more common involutional or age-related cases, the primary defect involves horizontal lid laxity, disinsertion of the lower lid retractors, and/or an overriding orbicularis muscle. Correction often involves use of the **lateral tarsal strip procedure** (see description under Ectropion Repair) to achieve tightening of the lower lid. Reattachment of the eyelid retractor muscles/aponeurosis may also be used in certain cases, either alone or in addition to a tarsal strip procedure.

Variant procedure or approaches

Cicatricial entropion results from a contracting scar of the tarsus and/or conjunctiva pulling the lid margin inward. Correction requires release of this tension and a **lid-splitting procedure** with tarsal advancement, rotational grafts, or free mucosal grafts harvested from the hard palate. In the latter case, nasal intubation will be required to allow access to the graft site. **Quickert procedure** involves the placement of 2-3

sutures under local anesthesia to evert the eyelid. Entropion frequently recurs after this procedure.

Usual preop diagnosis

Entropion of eyelid

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol and smoking cessation, carb loading, and postop pain management. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine, table rotated 90–180°
Incision	Lateral canthal region or area of conjunctival scarring. Mucosal graft may be harvested from the hard palate.
Special instrumentation	Surgical loupes
Antibiotics	None intraop
Surgical time	0.5–1 h
EBL	Minimal
Postop care	Topical antibiotic ointment
Mortality	Rare
Morbidity	Infection: Very rare Lid malposition Local bleeding Corneal injury
Pain score	1–2

PATIENT POPULATION CHARACTERISTICS	
Age range	Any age
Male:Female	1:1
Incidence	Common
Etiology	Congenital; aging; inflammation

Associated conditions	Cicatricial entropion can be associated with pemphigoid; Stevens-Johnson syndrome (a sometimes fatal form of erythema multiforme); chemical burns; trachoma.

ANESTHETIC CONSIDERATIONS

Entropion repair can usually be accomplished as an outpatient procedure using local anesthesia and MAC.

See Anesthetic Considerations for Ophthalmic Surgical Procedures Under MAC (adult).

Suggested Reading

1. See Suggested Readings following Ophthalmic Surgery section.

PTOSIS REPAIR

SURGICAL CONSIDERATIONS

Description

Ptosis (drooping of the upper eyelid margin) can be severe enough to obstruct the visual axis. Causes include congenital maldevelopment, mechanical traction, myogenic conditions (e.g., dystrophies, myasthenia gravis), neurogenic conditions (e.g., Horner syndrome, cranial nerve III palsy), actinic skin changes, and aponeurotic dehiscence. The surgical approach depends primarily on the presence or absence of adequate levator muscle function that is responsible for elevating the upper eyelid. The most common etiology is age-related dehiscence or disinsertion of the levator aponeurosis from its normal attachment to the tarsus. Because levator muscle function is usually satisfactory in these patients, surgical correction involves reinserting the aponeurosis to the anterior tarsus alone or in combination with shortening of the aponeurosis by advancement or resection. Access is obtained by an incision in the upper eyelid crease. Removal of excess skin and orbicularis muscle (**blepharoplasty**) may be performed simultaneously. Although several formulas have been devised to determine the amount of aponeurotic shortening, intraop measurement usually is performed to ensure that the appropriate lid position and contour are achieved. This requires that the procedure be performed under local anesthesia and that the patient be positioned and draped in a way that allows him/her to sit upright during surgery. Incisions are closed, and crease reformation can be performed if desired.

Variant procedure or approaches

In patients with levator muscle function that is not adequate to achieve eyelid elevation, a **frontalis sling procedure** is performed to elevate the upper eyelid (Fig. 2.5). More commonly required in children with congenital ptosis, this allows the patient to open the eye by elevating the brow. A variety of materials can be used to accomplish this suspension, including silicone rods or fascia. In children <3 yr, autologous fascia lata can be harvested from the outer thigh from hip to knee. The material is tunneled beneath the skin and muscle from the brow incisions to the anterior tarsal region of the eyelid using Wright needles. After appropriate contour and height are achieved, the sling is secured and incisions are closed. Frontalis suspension usually is performed under GA in both adults and children.

Usual preop diagnosis

Ptosis

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol and smoking cessation, carb loading, and postop pain management. See Appendix K, p. K-1.

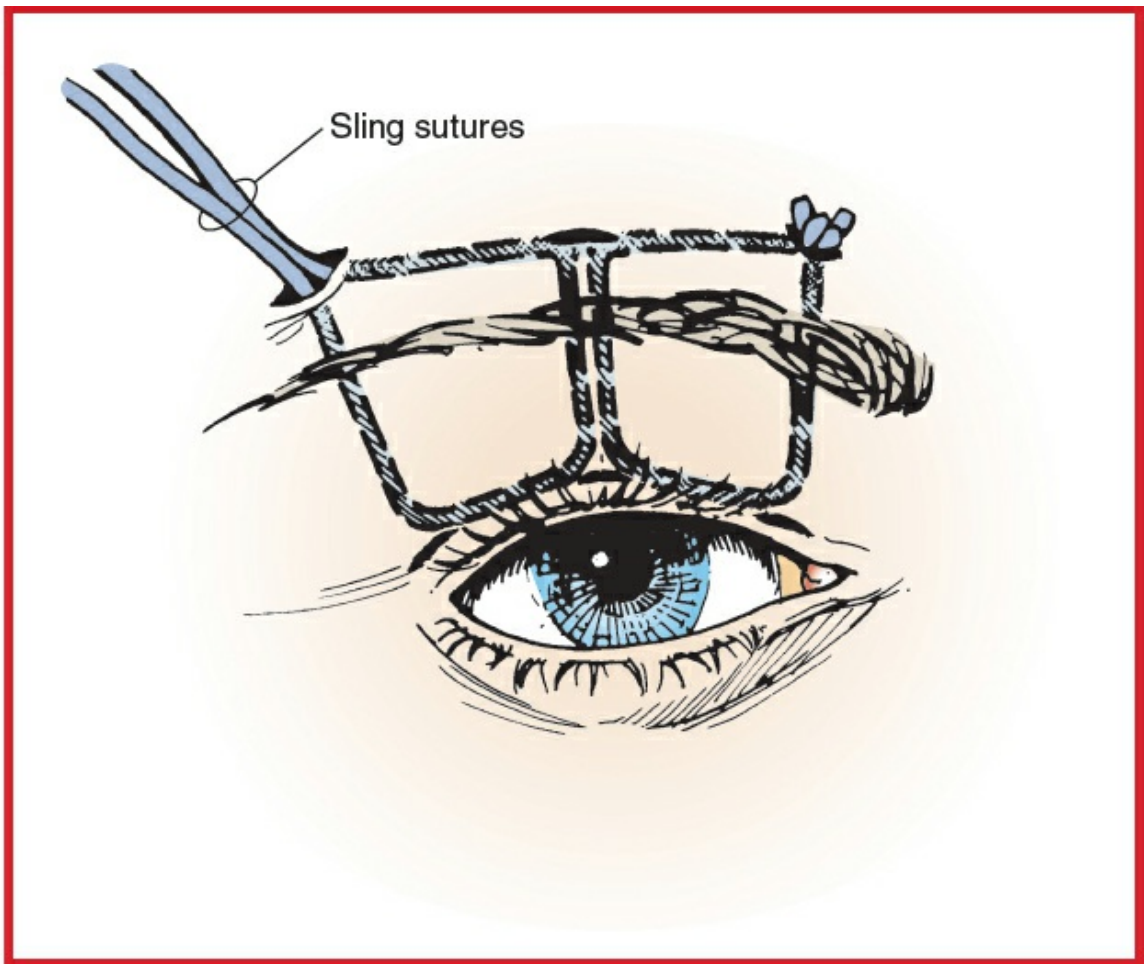

Figure 2.5 Frontalis sling (modified Crawford technique). Note location of brow and lid incisions and double rhomboid fascial slings. (Redrawn with permission from Tasman W, Jaeger EA, eds:Duane's Ophthalmology, Wolter Kluwers Health/Lippincott Williams & Wilkins, Philadelphia: 2013.)

SUMMARY OF PROCEDURE

Position	Supine, table rotated 90–180°
Incision	Upper eyelid crease; brow; and lateral thigh (frontalis sling)
Special instrumentation	Surgical loupes
Antibiotics	Cefazolin 2 g iv
Surgical time	0.5–1 h
EBL	Minimal
Postop care	Topical antibiotic ointment; cool compresses
Mortality	Rare
Morbidity	Lid malposition (overcorrection, undercorrection, asymmetry) Corneal exposure (lagophthalmos) Infection: More common with silicone rods Numbness below incision
Pain score	1–2

PATIENT POPULATION CHARACTERISTICS

Age range	Any age
Male:Female	1:1
Incidence	Common
Etiology	Congenital; aponeurotic; neurogenic; myogenic; mechanical; aging
Associated conditions	Neurogenic causes associated with myasthenia gravis; myogenic causes include chronic external ophthalmoplegia (can have dysrhythmias and Sz disorders); oculopharyngeal dystrophy

ANESTHETIC CONSIDERATIONS

Ptosis repair typically requires GA for infants and children and can be accomplished with local anesthesia (± subcutaneous epinephrine) and MAC as an outpatient procedure in adults. The need for patient cooperation during the surgery should be discussed with the surgeon and patient in advance.
See Anesthetic Considerations for Ophthalmic Surgical Procedures Under MAC.

Suggested Reading

1. Parikh M, Kwon YH: Vision loss after inadvertent corneal perforation during lid anesthesia. Ophthalmic Plast Reconstr Surg 2011; 27(5):e141–2.

EYELID RECONSTRUCTION

SURGICAL CONSIDERATIONS

Description

Given the relatively small tissue area of the eyelids and their importance in both ocular health and cosmesis, excision of lid tumors often requires some form of reconstructive surgery. For lesions suspected of being malignant, **frozen sections** are often performed prior to closing the defect. In addition, **Mohs technique** (microscopically controlled serial excision) may be performed (usually by a dermatologist) to achieve clear margins, with reconstruction undertaken during a separate operation. During closure of full-thickness defects that involve the eyelid margin, attention is focused on aligning the lid in all dimensions (Fig. 2.6), while avoiding exposed sutures on the conjunctival surface that might damage the cornea. For small lid defects involving <¼ of the lid length, direct closure often can be accomplished with release of the lateral canthal tendon (**canthotomy and cantholysis**) to reduce wound tension, if necessary.

Variant procedure or approaches

Larger excisions often require grafting techniques that are designed to replace both the anterior (skin/orbicularis) and posterior (tarsus/conjunctiva) lamellae of the eyelid. This can be accomplished with rotational grafts, a tarsoconjunctival advancement flap or free grafts of cartilage, hard palate, and cadaver sclera; or composite grafts as posterior lamellar replacement materials.

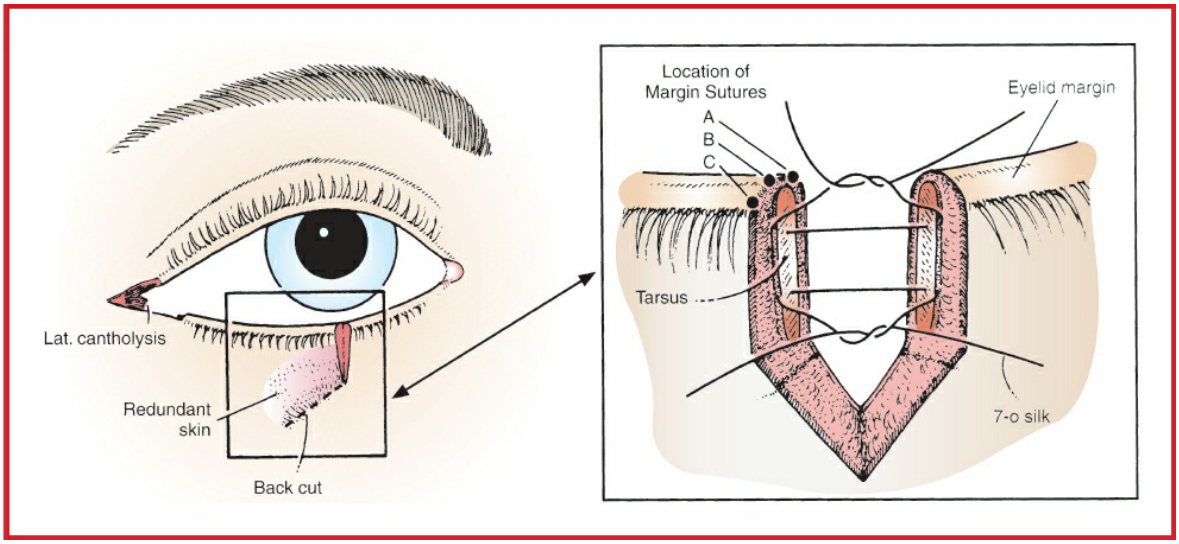

Figure 2.6 Closure of full-thickness defect in the lower lid. The tarsal sutures and half-thickness tarsus are placed first, with the secondary closures at points A, B, and C and the eyelid margin. (Reproduced with permission from McCord CD, Tanenbaum M, eds:Oculoplastic Surgery, 2nd edition. Raven Press, New York: 1987.)

Usual preop diagnosis

Basal-cell carcinoma; squamous cell carcinoma; melanoma; sebaceous carcinoma; or trauma

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol and smoking cessation, carb loading, and postop pain management. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine, table rotated 90–180°
Incision	Upper and/or lower eyelid. Postauricular, supraclavicular, or hard palate if graft harvesting required
Special instrumentation	Surgical loupes
Antibiotics	Cefazolin 2 g iv
Surgical time	0.5–2 h
EBL	Minimal
Postop care	Topical antibiotic ointment; cool compresses; pressure dressing

Mortality	Rare
Morbidity	Graft failure Lid deformity Corneal exposure Infection: <1%
Pain score	2–3

PATIENT POPULATION CHARACTERISTICS	
Age range	Usually elderly
Male:Female	1:1
Incidence	Common
Etiology	Sun exposure–related malignancy
Associated conditions	Diseases of the elderly, including cardiovascular disease, HTN, and diabetes

ANESTHETIC CONSIDERATIONS

Eyelid reconstruction can often be accomplished with local anesthesia and MAC. For patients presenting for eyelid reconstruction immediately following Mohs surgery, ensure that their NPO status has been maintained.

See Anesthetic Considerations for Ophthalmic Surgical Procedures Under MAC.

Suggested Readings

1. Codner MA, Weinfeld AB: Comprehensive eyelid reconstruction. ANZ J Surg2007; 77(Suppl 1):A71.
2. See Suggested Readings following Ophthalmic Surgery section.

PTERYGIUM EXCISION

SURGICAL CONSIDERATIONS

Description

Pterygia are fibrovascular growths that originate in the limbal conjunctiva within the

palpebral fissure and grow into the superficial layer of the cornea. They often produce refractive changes and/or obstruct the central visual axis and, thus, require removal. Although this procedure is often performed in the clinic or minor-procedure room, larger lesions may require an OR. In both settings, local anesthesia is applied both topically (tetracaine 0.5%) and subconjunctivally (lidocaine 2%). The lesion is dissected from the cornea and from the surrounding healthy conjunctiva, leaving a bed of bare sclera that may or may not be closed primarily (Fig. 2.7).

Variant procedure or approaches

For larger excisions and to decrease the rate of recurrence, **conjunctival transposition** or **free-graft techniques** can be used to cover the area of bare sclera. Topical antimetabolites, such as mitomycin-C, also may be applied to prevent recurrence. Recently, a method known as PERFECT (pterygium extended removal followed by extended conjunctival transplant) has been employed to reduce the long-term recurrence rate.

Preop diagnosis or indications

Pterygium

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, carb loading, and postop pain management. See Appendix K, p. K-1.

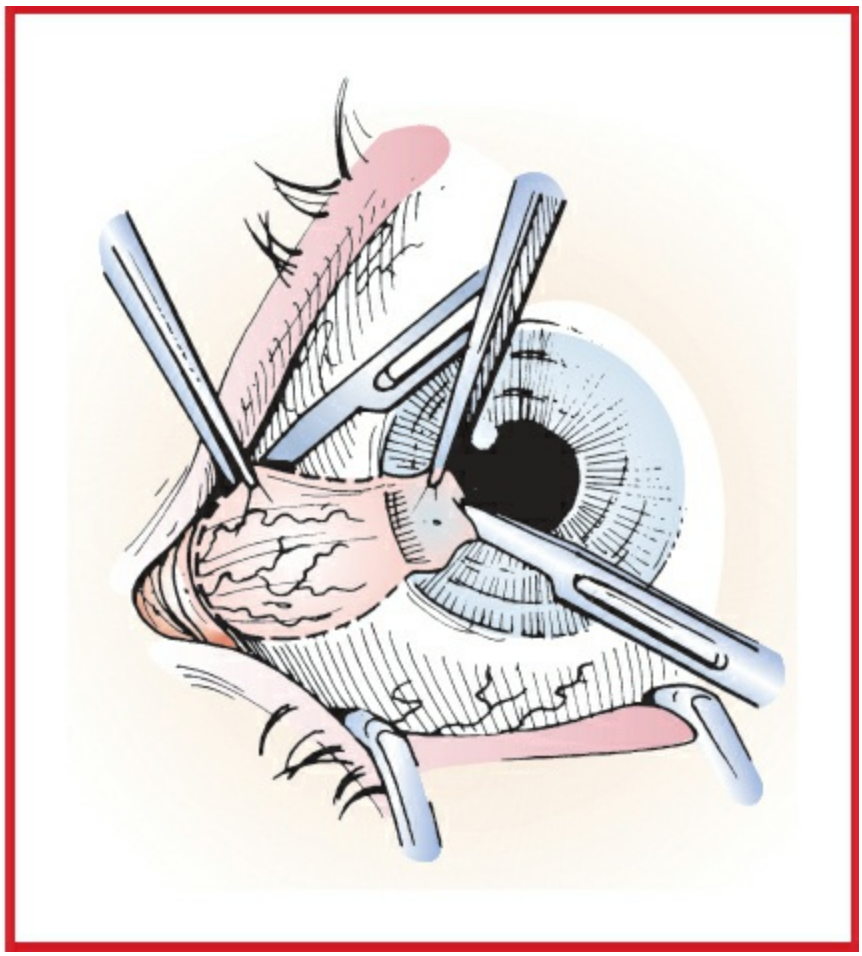

Figure 2.7 Bare sclera excision can be started from the corneal apex or by incising around the conjunctival body of the pterygium. (Redrawn with permission from Tasman W, Jaeger EA, eds: Duane's Clinical Ophthalmology, Vol 6. Lippincott Williams & Wilkins, Philadelphia: 2000.)

SUMMARY OF PROCEDURE	
Position	Supine, table rotated 90–180°
Incision	Interpalpebral area adjacent to involved limbus
Special instrumentation	Operating microscope
Antibiotics	Topical postop
Surgical time	15–45 min
EBL	Minimal
Postop care	Topical antibiotic ointment
Mortality	Rare
Morbidity	Recurrence: 37% without adjunctive therapy or

	grafting, <1% with PERFECT (**p**terygium **e**xtended **r**emoval **f**ollowed by **e**xtended **c**onjunctival **t**ransplant) method Extraocular muscle injury (higher risk in reop eyes) Cyst Local bleeding Infection
Pain score	1–2

PATIENT POPULATION CHARACTERISTICS	
Age range	Usually young to middle age
Male:Female	1:1
Incidence	Common
Etiology	Related to sun exposure with higher rate in latitudes near the equator

Suggested Readings

1. Hirst LW: Recurrent pterygium surgery using pterygium extended removal followed by extended conjunctival transplant: recurrence rate and cosmesis. Ophthalmology 2009; 116(7):1278–86.
2. Hovanesian JA, Starr CE, Vroman DT, et al; ASCRS Cornea Clinical Committee Surgical techniques and adjuvants for the management of primary and recurrent pterygia. J Cataract Refract Surg 2017; 43(3):405–19.

ANESTHETIC CONSIDERATIONS FOR OPHTHALMIC SURGICAL PROCEDURES UNDER MAC

(Procedures covered: cataract extraction and other procedures; corneal transplant; trabeculectomy; ectropion-entropion repair; ptosis surgery; eyelid reconstruction; pterygium excision)

PREOPERATIVE

Ophthalmic procedures that are of relatively short duration and those that result in minimal blood loss are being performed increasingly more often on an outpatient basis, usually with topical or regional anesthesia (e.g., retrobulbar or peribulbar blocks) under

MAC. **Retrobulbar and peribulbar injections** achieve excellent anesthesia and provide equal degrees of akinesia. Given the associated risk of inadvertent intrathecal injection of anesthetic, orbital hemorrhage, need for heavy sedation during injection, and delayed return of visual function postop, most cataract surgeries are performed using **topical anesthesia**. An additional benefit is that the bleeding risk is lower and the procedure can be performed safely in most patients taking anticoagulants or with bleeding disorders. Although satisfactory pain relief usually is achieved with this method, the lack of akinesia requires a highly cooperative patient to prevent sudden eye movements during surgery. Some surgeons will supplement topical anesthesia with **intracameral lidocaine** (injections into the anterior chamber), although any further reduction in pain perception will be quite modest. **Sub-Tenon injection** is another anesthetic technique used by many surgeons as a compromise between topical application and orbital injections. After preop application of topical anesthetics, a small incision is made in the bulbar conjunctiva, exposing the episcleral (sub-Tenon) space. A blunt cannula is inserted under direct visualization and local anesthetic injected into the episcleral space. The main benefit is that no sharp needle is used, thereby reducing the risk of intrathecal injection and orbital hemorrhage from vessel injury. The onset of akinesia, however, is often delayed, and this technique still has the disadvantage of delayed return of postop visual function.

The pain on injection is slightly less with peribulbar blocks or sub-Tenon blocks as compared with retrobulbar techniques. For many patients, placement of the intravenous cannula was the most painful event during eye surgery, suggesting that some eye blocks are well tolerated. Intraoperative pain is significantly less with retrobulbar or peribulbar blocks than with topical anesthesia. Rates of ocular perforation following injection blocks are low (1 in 1000–10,000).

Because the majority of ocular procedures are performed on elderly patients, multiple coexisting medical illnesses are often present. A thorough preop H&P along with appropriate ancillary studies are mandatory even though local anesthesia/MAC is planned. Contraindications to regional anesthesia/MAC for ocular surgery may include uncontrolled movement disorder, bleeding diathesis, open-eye injuries, claustrophobia, chronic cough (or other Valsalva-producing conditions), symptomatic gastric reflux, inability to lie flat, inability to communicate or cooperate, or patient refusal.

Respiratory	Elderly patients have increased incidence of hiatal hernia and, therefore, are at increased risk for pulmonary aspiration. Assess the patient's ability to lie flat for the duration of the procedure. Patients

	with chronic cough may require GA. **Tests:** As indicated from H&P
Cardiovascular	Hx of HTN, CAD, CHF, or poor exercise tolerance should prompt a thorough investigation into the patient's cardiac status, including efficacy of current medications and recent ECG (compared with previous ECGs). Consultation with a cardiologist may be appropriate to optimize the patient's condition before surgery. Patients on antithrombotic drugs may be at higher risk for bleeding complications. The decision to stop these drugs and institute heparin bridge therapy should be made in consultation with both the surgeon and the prescribing physician. **Tests:** ECG; others (e.g., ECHO) as indicated from H&P
Diabetes	Diabetic patients are at increased risk for silent myocardial ischemia. Pulmonary aspiration 2° diabetic gastroparesis is also a risk in this population. Patients taking sc insulin should take two-thirds of their usual dose the evening before surgery and one-half of their usual NPH dose on the morning of surgery. Any morning dose of regular insulin should be held. Fasting blood sugar is checked; consider an iv infusion of D5 LR if glucose <90 mg/dL or regular sc insulin if glucose >200 mg/dL. Blood glucose is often checked intraop and postop. Patients on insulin pumps should reduce their overnight infusion rate by 30% and eliminate preprandial boluses. The insulin pump may be removed before surgery for safety reasons. The anesthesiologist should ask the patient about their insulin sensitivity (the amount of insulin necessary to ↓ blood glucose by 50 mg/dL). Blood glucose should be monitored hourly.
Musculoskeletal	Arthritic changes make lying flat difficult for some patients. Careful positioning and padding are essential. A low-level remifentanil infusion (0.025–

Neurologic	0.05 mcg/kg/min) may be helpful in some cases. Patients with tremor, agitation, severe anxiety, cognitive impairment, or inability to cooperate are not appropriate candidates for regional anesthesia/MAC.
Hematologic	✓ for antiplatelet or anticoagulant drug use, particularly in patients undergoing lid or orbital procedures where both the risks and consequences of hemorrhage may be significant **Tests:** As indicated from H&P (e.g., PT if patient is on anticoagulant)
Laboratory	As indicated from H&P
Premedication	Patients will benefit from a detailed explanation of events prior to surgery (including iv placement, application of monitors, performance of local block, ocular compression, prepping eye, draping of the whole face, and provision of supplemental air/O_2) and the assurance that the anesthesiologist will always be present, monitoring them. Midazolam (0.5–1 mg iv) is often beneficial. For patients with increased risk of aspiration (e.g., with hiatal hernia or diabetic gastroparesis) and for obese and/or very anxious patients, metoclopramide 10 mg iv may enhance gastric emptying. Many patients will receive topical ocular medications during the immediate preop period to produce, for example, mydriasis or to ↓ IOP (see Table 2.1). Some of these medications may have significant cardiovascular effects and should be avoided in poorly controlled hypertensive patients.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water. Topical anesthesia will often be started in the preop holding area.

INTRAOPERATIVE

Anesthetic technique

MAC: Topical anesthesia typically is accomplished by the ophthalmologist, often using long-lasting LA, supplemented with 2% lidocaine with epinephrine, injected subconjunctivally. Placement of retrobulbar or peribulbar blocks may be painful, and very-short-acting agents (e.g., remifentanil 0.25–1 mcg/kg, alfentanil 5–7 mcg/kg, or propofol 30–50 mg) should be administered to minimize patient discomfort. Dose requirements vary significantly among patients, and the anesthesiologist should be prepared to treat sudden ↓ BP and apnea. Usually, further sedation is unnecessary and may result in snoring with head movement or otherwise interfere with patient cooperation during the surgery. Coughing, or other Valsalva maneuvers, should be avoided during the procedure, and the anesthesiologist must always be prepared to administer GA if necessary. If it is possible that cautery may be used during the surgery, then the delivered FiO_2 should be <0.3 to minimize fire hazard when using open oxygen delivery methods (e.g., nasal prongs, mask, etc.).

Retrobulbar block

Using a 25- or 27-ga needle (1.5 inches), the retrobulbar space is approached from the infratemporal quadrant of the orbit. The eye should be in a neutral position. Once the needle is positioned and there is no return of blood or cerebrospinal fluid (CSF) or aspiration, 3–5 mL of anesthetic solution is injected slowly. A facial nerve block is necessary to prevent eyelid movement. This can be accomplished by injecting 4–8 mL of anesthetic solution above and below the lateral aspect of the orbit. Typically, the anesthetic solution consists of a 50:50 mixture of 0.5–0.75% bupivacaine and 2% lidocaine ± hyaluronidase, ± epinephrine 1:400,000.

Table 2.1 Commonly Used Ophthalmic Drugs and Their Systemic Effects	
Phenylephrine	An α-adrenergic agonist that causes mydriasis (pupillary dilation) and vasoconstriction to aid ocular surgery; however, it also can precipitate significant HTN and dysrhythmias.
Echothiophate	An irreversible cholinesterase inhibitor used in glaucoma treatment to cause miosis and ↓ IOP. Its systemic absorption can reduce plasma cholinesterase activity and thereby prolong paralysis 2° to succinylcholine (usually not more than 20–30

	min).
Timolol	A nonselective β-blocker that decreases production of aqueous humor → ↓ IOP. Rarely, it may be associated with atropine-resistant bradycardia, asthma, CHF, and ↓ BP.
Acetazolamide	A carbonic anhydrase inhibitor used to ↓ IOP. It also can cause diuresis and a hypokalemic metabolic acidosis.
Betaxolol	A relatively oculospecific β-blocker used to ↓ IOP. Effects may be additive to systemic β-blockers.
Cyclopentolate	A commonly used mydriatic with the potential for CNS toxicity, including Sz, psychotic reactions, and dysarthria.
Atropine	An anticholinergic that produces mydriasis to aid with ocular examination and surgery. It also can precipitate central anticholinergic syndrome. (Sx range from dry mouth, tachycardia, agitation, delirium, and hallucinations to unconsciousness.) Physostigmine 0.01–0.03 mg/kg will increase central acetylcholine and reverse the symptoms. (It may be repeated after 15–30 min.)
Apraclonidine	An α-2 adrenergic agonist used to treat glaucoma (↓ aqueous formation + ↑ outflow). Systemic absorption → sedation and drowsiness. Hypotension is possible.

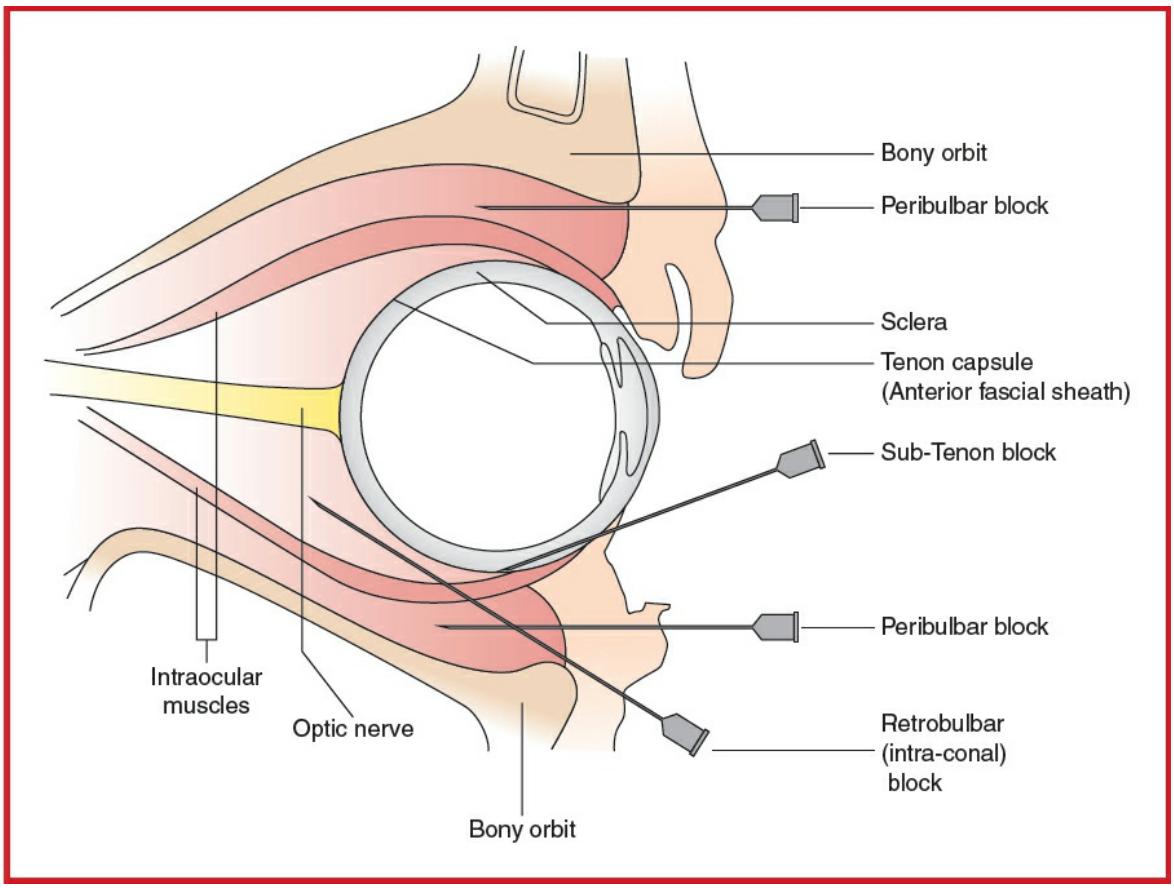

Figure 2.8 Horizontal section of the orbit illustrating regional blocks. There is continuum between the episcleral (sub-Tenon) space and the rectus muscle sheaths.

Peribulbar block

Using a 25- or 27-ga needle (5/8–1 inches), 6–8 mL of anesthetic solution is injected into the peribulbar space, entering just superior to the inferior rim of the orbit at the junction of the lateral and middle thirds of the lower lid. Orbital compression is usually applied to facilitate spread of local anesthetic. Although perforation of the globe and hemorrhage are still possible, direct injury to the optic nerve and subdural injection are not likely due to the length and position of the needle. Peribulbar blocks generally have a slower onset than retrobulbar blocks and are more likely to cause conjunctival swelling, which may interfere with surgery.

Sub-Tenon anesthesia

Injection of LA (often 1% lidocaine ± epi) through a 22-ga cannula into the space below Tenon capsule (episcleral membrane) produces ocular anesthesia in many ways similar to retrobulbar block. However, the onset is slower and akinesia is less reliable. The usual injection volume is 3–5 mL with more necessary if akinesia is required. Unlike retrobulbar block, significant complications with the technique are extremely rare.

Blood and fluid requirements	IV: 18–20 ga × 1 NS/LR @ 1.5–3 mL/kg/h	Excessive fluids → bladder distension → ↑ BP, agitation. See Zero Balance Fluid Management, Appendix K, p. K-2 and p. K-4
Monitoring	Standard monitors Verbal response	It is important to remain in communication with the patient throughout the procedure (Take care to avoid evoking head movement.)
Positioning	✓ and pad pressure points ✓ nonoperated eye	Place pillows under knees to relieve back strain.
Complications	Dysrhythmias, especially ↓ HR	Usually 2° traction or pressure on ocular/periocular tissues. Rx: stop surgical stimulation
	↑ BP	2° anxiety, pain, and phenylephrine eye drops. Rx: reassurance, local anesthetics, labetalol 5 mg, or hydralazine 2.5-mg increments, as appropriate
	Retrobulbar hemorrhage (1–3%)	Rx: pressure bandage; usually cancel surgery
	Globe perforation	If a needle perforation, usually no repair is necessary
	Convulsions 2° iv local anesthetic	Supportive treatment with IPPV; cancel surgery
	Respiratory/circulatory arrest	2° subarachnoid anesthetic injection. Rx:

	Oculocardiac reflex (OCR)	CPR, IPPV OCR: traction on EOMs → ↓↓ HR, ↓↓ BP, ventricular ectopy, and asystole. Rarely occurs during GA or following adequate retrobulbar block. Rx: stop surgical manipulation, atropine for persistent bradycardia, and CPR

POSTOPERATIVE

Complications	Myocardial ischemia Corneal abrasion Photophobia N/V Diplopia	Rx: Provide O_2; ✓ BP; ✓ ECG; cardiology consultation. Rx may include sublingual NTG, aspirin, β-blocker, and MS Rx: ondansetron 4 mg iv
Multimodal pain management	Acetaminophen 325–1000 mg po	Emphasize nonopioid analgesics including acetaminophen and NSAIDs if not contraindicated (see p. K-5).
ERAS	PONV protocol (see p. B-1)	Encourage early enteral nutrition and mobilization. Consider DVT prophylaxis if early mobilization is not possible.

Suggested Readings

1. Assam JH, Bernhisel A, Lin A: Intraoperative and postoperative pain in catarac

surgery. Surv Ophthalmol 2018; 63(1):75–85.
2. Chronopoulos A, Herbert J, Thumann G, et al: Avoiding complications from patient positioning for intraocular surgery. Anesth Analg 2018; 126(4):1206–11.
3. Malik A, Fletcher EC, Chong V, et al: Local anesthesia for cataract surgery. J Cataract Refract Surg 2010; 36(1):133–52.
4. Nanji KC, Roberto SA, Morley MG, et al: Preventing adverse events in cataract surgery: recommendations from a Massachusetts expert panel. Anesth Analg 2018; 126(5):1537–47.
5. Rogers GM, Goins KM: Cataract surgery in the patient that cannot lie flat. Curr Opin Opthalmol 2010; 21(1):71–4.
6. Sanmugasunderam S, Khalfan A: Is fasting required before cataract surgery? A retrospective review. Can J Ophthalmol 2009; 44(6):655–6.

REPAIR OF RUPTURED OR LACERATED GLOBE

SURGICAL CONSIDERATIONS

Description

A ruptured globe involves a tear of either the corneal or scleral layers of the eye and can occur in the setting of blunt, penetrating, or perforating trauma. The primary goal of surgical repair is to replace extruded intraocular contents, close defects, and remove any foreign body. Orbital CT scans are performed preop to aid in the identification of the latter. To reduce the risk of causing further damage, complete examination of the eye is often delayed until the patient is in the controlled setting of the OR under GA. Although anterior injuries are readily identifiable, posterior injuries may require extensive exploration that can require a 360° opening of the conjunctiva and isolation of each extraocular muscle to allow adequate inspection of the entire scleral surface. Corneal lacerations usually are closed with 10-0 nylon sutures, while 8-0 nylon or Vicryl may be used for scleral tissue. Until these wounds are closed, it is crucial that Valsalva maneuvers (which raise IOP) be avoided to prevent further extrusion of intraocular contents.

Variant procedures or approaches

After globe integrity has been established, other associated injuries may be addressed, including repair of conjunctival lacerations, extraocular muscle injuries/detachments, retinal detachments, or removal of a traumatic cataract.

Usual preop diagnosis

Ruptured globe

ERAS: These are usually emergency procedures with little opportunity to benefit from preop ERAS considerations.

SUMMARY OF PROCEDURE	
Position	Supine, table rotated 90–180°
Incision	Conjunctival peritomy (360° conjunctival incision) to allow exposure of the posterior sclera
Special instrumentation	Operating microscope
Antibiotics	IV gentamicin (80 mg) and cefazolin (1 g), subconjunctival and topical antibiotics
Closing considerations	Avoid Valsalva-like maneuvers (coughing, bucking, etc.)
Surgical time	1–2 h
EBL	Minimal
Postop care	Hospital admission for iv antibiotics
Mortality	Rare
Morbidity	Wound leak Infection: Rate depends on injury Sympathetic ophthalmia: Rare Retinal detachment Suprachoroidal hemorrhage
Pain score	4

PATIENT POPULATION CHARACTERISTICS	
Age range	Usually <40 yr
Male:Female	8:1 (as a result of recreational and occupational preferences)
Incidence	Common (~2 million eye injuries in the United States per year with ~40,000 resulting in vision loss)

Etiology	Work- or sports-related injury; motor vehicle accidents
Associated conditions	Intoxication; orbital/facial trauma; head injury

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

This is a generally healthy patient population; however, patients with penetrating eye injuries present the anesthesiologist with two special challenges: (a) they invariably have full stomachs, resulting in risk of aspiration; (b) they are at risk of blindness 2° ↑ IOP → loss of ocular contents, which may be a result of coughing, crying, and/or struggling during induction. Normal IOP ranges from 10 to 22 mm Hg, depending on the rates of formation and drainage of aqueous humor, choroidal blood volume, scleral rigidity, extraocular muscle tone, as well as extrinsic pressure on the eye (e.g., a poorly fitting mask or retrobulbar hematoma). Patient movement, coughing, straining, vomiting, hypercarbia, hypertension (HTN), and endotracheal (ET) intubation may ↑ IOP to 4(mm Hg or more.

Full-stomach precautions	Consider patient to have a full stomach if the injury occurred within 8 h of the last meal. Pain and anxiety due to trauma will delay gastric emptying. Goal is to minimize the risk of aspiration pneumonitis by decreasing gastric volume and acidity. Consider premedication with metoclopramide (10–20 mg iv), antacids such as Na citrate (15–30 mL po, immediately prior to induction), and H_2-histamine receptor antagonists (ranitidine [50 mg iv, ~15 min before induction]). H_2-histamine receptor antagonists, however, have no effect on the pH of gastric secretions present in the stomach prior to administration and are, therefore, of limited value in patients presenting for emergency surgery. If patient has Hx of smoking or is an asthmatic, consider preop use of inhalers such as albuterol (2–4 puffs).
Associated injuries	A ruptured globe may be only one of multiple injuries to the head and neck or other structures. Other injuries should be excluded preoperatively.

Laboratory	Tests as indicated from H&P
Premedication	Patients often are very anxious and may benefit from benzodiazepines (e.g., for pediatric population, midazolam 0.5–0.75 mg/kg po in cola or apple juice, 15–30 mL). Avoid narcotic premedication, which may ↑ nausea and possibility of emesis.

INTRAOPERATIVE

Anesthetic technique

GETA: Regional anesthesia (e.g., retrobulbar block) is contraindicated in patients with open-eye injury because of ↑ IOP, which may accompany injection of local anesthetic behind the globe. Thus, despite the increased risk of aspiration from a full stomach, general endotracheal anesthesia (GETA) is recommended. In patients where the risk of GA is unacceptably high (e.g., extensive pulmonary or unstable cardiac disease), surgical repair can be accomplished using topical anesthesia (see Auffarth GU, et al.).

Induction	To protect the airway and prevent ↑ IOP, a rapid-sequence induction with cricoid pressure and a smooth intubation are required. Although the choice of induction agent is relatively straightforward—propofol 1–2 mg/kg—the choice of neuromuscular blocking agents for facilitating intubation is controversial. Succinylcholine provides a rapid onset, short duration of action, and excellent intubating conditions, but it also transiently increases IOP (~9 mm Hg). This minor ↑ IOP is usually attenuated by pretreatment with a nondepolarizing agent (e.g., rocuronium) followed by propofol induction. Rocuronium (1.2 mg/kg) produces muscle relaxation in 1–2 min and may be a satisfactory alternative to succinylcholine; however, a premature attempt at intubation may significantly ↑ IOP as a result of coughing and straining. Of interest, there are no reports in the literature documenting exacerbation of eye injuries with the use of succinylcholine following pretreatment with a NMR. Given that the anesthesiologist's main concern is safe airway

	management, the following is a suggested induction plan: 1. Preoxygenation, avoiding external pressure on the eye from face mask 2. Pretreatment with a nondepolarizing relaxant (e.g., rocuronium 0.06–0.12 mg/kg or equivalent), followed by iv lidocaine (1 mg/kg) and fentanyl (2–3 mcg/kg) to blunt the cardiovascular response to laryngoscopy and intubation 3. 4 min later, with cricoid pressure, induce with propofol (1–2 mg/kg) and succinylcholine (1.5 mg/kg). Intubate with oral RAE tube. Note: for pediatric patients, it might be appropriate to induce with sevoflurane while maintaining cricoid pressure and intubating when the patient is deeply anesthetized. Trying to start an iv prior to induction may precipitate struggling and crying, leading to further eye injury.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance or TIVA. Avoid hypercapnia, which → ↑ IOP. Muscle relaxation is mandatory until the eye is surgically closed. Humidify gases for pediatric patients. Avoid N_2O in patients receiving intraocular gas injection.
Emergence	Decompress the stomach with OG tube. Goal is smooth emergence and extubation with patient awake with intact airway reflexes. IV lidocaine (1.5 mg/kg) 5 min before extubation; posterior pharyngeal suctioning with patient deeply anesthetized, combined with a small amount of narcotic (remifentanil ~1 mcg/kg), may blunt cough reflex prior to extubation. The common occurrence of PONV requires administration of intraop antiemetics (e.g., dexamethasone 4 mg iv and/or ondansetron 4 mg iv 30 min before the end of surgery).

Blood and fluid requirements	IV: 18–20 ga × 1 (adult) 20 ga × 1 (child) NS/LR @ 5–10 mL/kg/h	Warm fluids if large volume will be administered. See Zero Balance Fluid Management, Appendix K, p. K-2 and p. K-4
Monitoring	Standard monitors	Neuromuscular blockade must be monitored closely and additional relaxant given as necessary to prevent patient movement during surgery.
Positioning	✓ and pad pressure points ✓ nonoperated eye	
Complications	↑ IOP with extrusion of intraocular contents Aspiration of gastric contents	IOP (normal = ~10–22 mm Hg) increased by blink = 10–15 mm Hg and forced lid closure = >70 mm Hg

POSTOPERATIVE

Complications	N/V	Rx: metoclopramide 10–20 mg iv, droperidol 0.625 mg iv (with due respect to the black-box warning), ondansetron 4 mg iv
	Aspiration pneumonitis Photophobia Diplopia Hemorrhagic retinopathy Corneal abrasion	Provide O_2 by face mask, if not intubated. Follow O_2 sat. ✓ CXR
Multimodal pain management	Acetaminophen	Occasionally, parenteral opiates. Emphasize

		nonopioid analgesics including acetaminophen and NSAIDs if not contraindicated (see p. K-5)
ERAS	PONV protocol (see p. B-1)	Encourage early enteral nutrition and mobilization. Consider DVT prophylaxis if early mobilization is not possible.

Suggested Readings

1. Auffarth GU, Vargas LG, Klett J, et al: Repair of a ruptured globe using topica anesthesia. J Cataract Refract Surg 2004; 30(3):726–9.
2. Boscia F, La Tegola MG, Columbo G, et al: Combined topical anesthesia anc sedation for open-globe injuries in selected patients. Ophthalmology 2003; 110(8):1555–9.
3. Chidiac EJ, Raiskin AO: Succinylcholine and the open eye.Ophthalmol Clin North Am 2006; 19(2):279–85.
4. Kelly DJ, Farrell SM: Physiology and role of intraocular pressure in contemporary anesthesia. Anesth Analg 2018; 126(5):1551–62.
5. Palte HD: Ophthalmic regional blocks: management, challenges, and solutions.Local Reg Anesth 2015; 8:57–70.

DACRYOCYSTORHINOSTOMY

SURGICAL CONSIDERATIONS

Description

Dacryocystorhinostomy (DCR) is performed for patients with symptomatic obstruction of the nasolacrimal duct (NLD) and is commonly associated with chronic dacryocystitis. The procedure is designed to create a fistula from the common canaliculus to the nasopharynx, which bypasses the site of obstruction. This involves removal of bone adjacent to the nasolacrimal sac and incorporating the sac with the lateral nasal mucosa. DCR can be performed under GA or local anesthesia (subcutaneous [equal mixture of 1–2% lidocaine and 0.5% bupivacaine with 1:100k epinephrine] and nasal cavity cocaine 4%) with most patients preferring local

anesthesia. Intranasal phenylephrine and/or cocaine pledgets are often placed to decrease mucosal bleeding. A skin incision is made below the medial canthal tendon that is extended to the lacrimal fossa with blunt dissection. Bleeding can be excessive if the angular vessels are injured. The now exposed periosteum is incised, and a 1.5 × 1.5 cm osteotomy is created with a burr and/or Kerrison punch, exiting at the level of the middle meatus. A Crawford lacrimal probe attached to silicone tubing is inserted into the superior punctum and advanced into the lacrimal sac, which is then opened along its medial wall. Following incision of the nasal mucosa through the osteotomy, the posterior flap of the lacrimal sac is sutured to the posterior nasal mucosa flap. The probe is advanced through the osteotomy and into the middle meatus, where it is retrieved through the nare. The second end of the probe is advanced along the same path but beginning through the inferior punctum. The ends of the silicone tubing are tied together in the nare, and the anterior flaps of the lacrimal sac and nasal mucosa are sutured together. Thrombin and gel foam can be used to control mucosal bleeding, and the skin is reapproximated after ensuring hemostasis. Meticulous hemostasis is essential to a successful outcome.

Variant procedures or approaches

If the lacrimal obstruction is more proximal to the lacrimal sac, a **Jones tube** can be placed (Fig. 2.9), creating an artificial lumen from the conjunctiva to the nasopharynx to bypass the entire nasolacrimal drainage system. An endonasal approach using a rigid endoscopic ± laser offers the advantage of no skin incision, good visualization of intranasal pathology, and less postop discomfort. The endoscopic approach is more common in children and young adults where the absence of skin creases makes scar concealment difficult.

Usual preop diagnosis

NLD obstruction

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol and smoking cessation, carb loading, and postop pain management. See Appendix K, p. K-1.

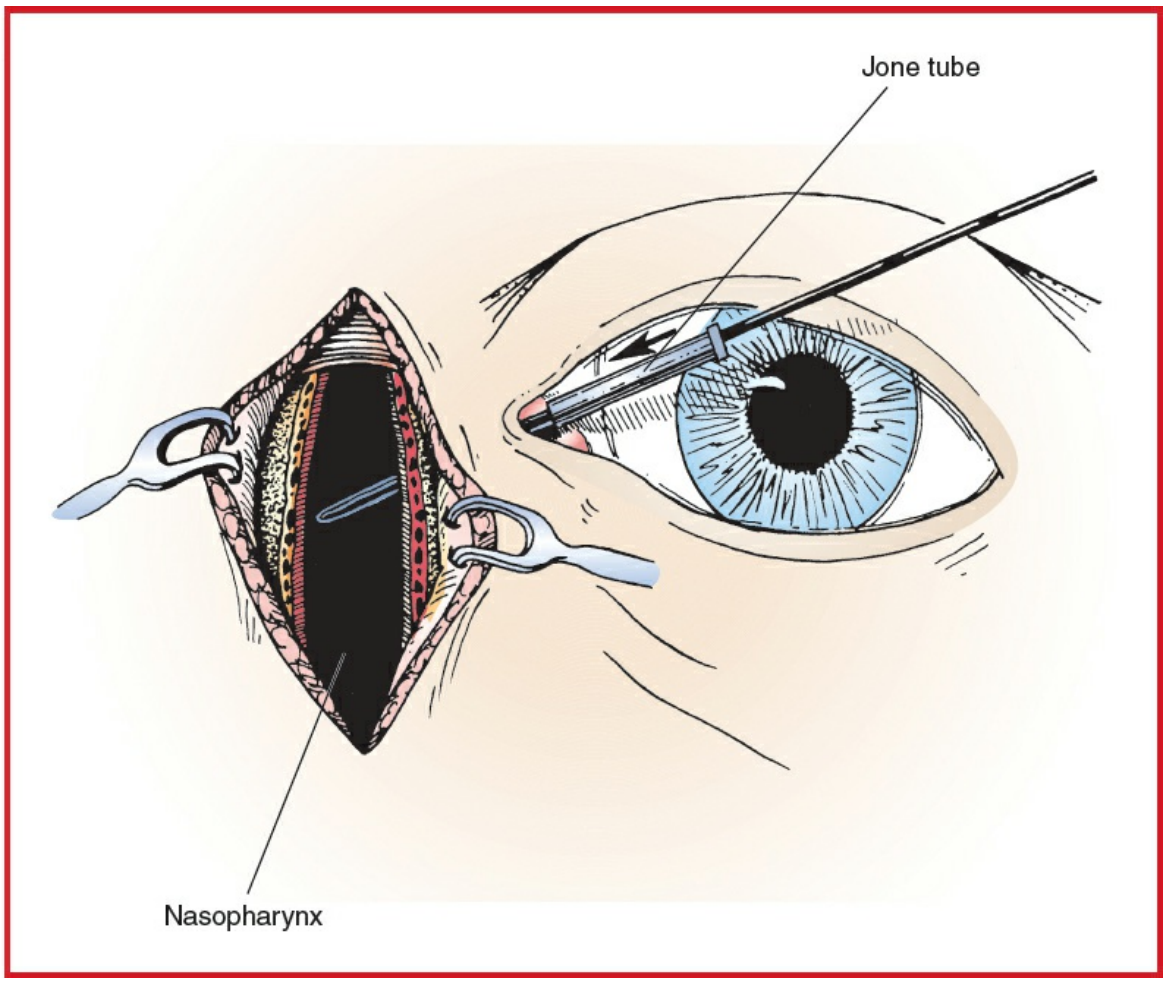

Figure 2.9 Insertion of a Pyrex Jones tube. (Reproduced with permission from McCord CD, Tanenbaum M, Nunery WR, eds: Oculoplastic Surgery, 3rd edition. Raven Press, New York: 1995.)

SUMMARY OF PROCEDURE

Position	Supine, table rotated 90–180°
Incision	15 mm, just below medial canthus (Fig. 2.10)
Special instrumentation	Headlight; surgical loupes
Unique considerations	Nasal packing with phenylephrine/4% cocaine/lidocaine. Blood may drain into upper airway during surgery.
Antibiotics	Cefazolin 2 g iv
Surgical time	1–1.5 h
EBL	100–200 mL

Postop care	Outpatient tube removal required
Mortality	Rare
Morbidity	Failure to drain Bleeding: 5% Infection: <1% Cerebrospinal fluid leak
Pain score	3–4 (Pain scores are lower following local anesthesia compared to GA.)

PATIENT POPULATION CHARACTERISTICS

Age range	30–70 yr
Male:Female	1:1
Incidence	Common
Etiology	Adults: Usually scarring from prior infection or trauma Children: Congenital or prior infection
Associated conditions	Deviated septum; nasal polyps, nasopharyngeal masses, congenital anomalies

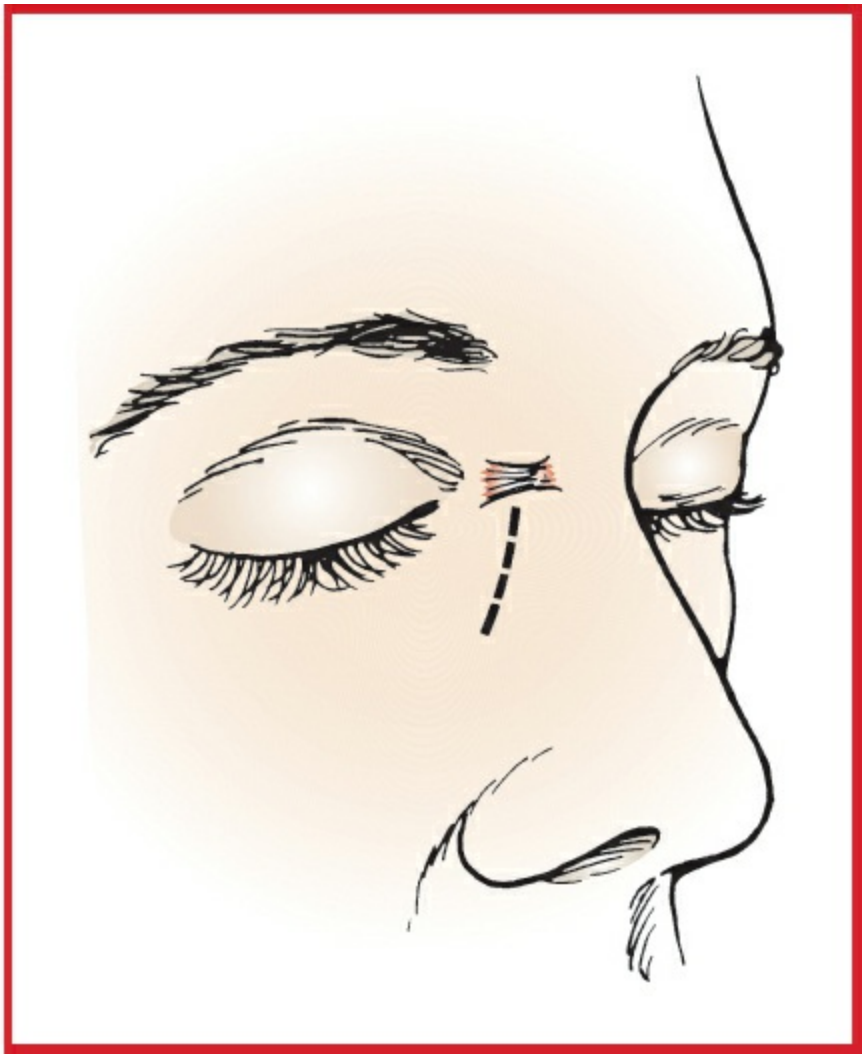

Figure 2.10 Linear skin incision for a standard DCR. (Reproduced with permission from Wright KW: Textbook of Ophthalmology, Williams & Wilkins, Baltimore: 1997.)

ANESTHETIC CONSIDERATIONS

DCR can be performed with local anesthetic and MAC or under GA depending on patient and surgeon preferences. See Anesthetic Considerations for Ophthalmic Surgical Procedures Under MAC or GA.

Suggested Readings

1. Choi WC, Paik JS, Doh SH: Results of endoscopic dacryocystorhinostomy under local anesthesia with minimal sedation. J Ophthalmol 2017; 2017:6712491.
2. Madge SN, Selva D: Intubation in routine dacryocystorhinostomy: why we do what we do. Clin Experiment Ophthalmol 2009; 37(6):620–3.
3. Watkins LM, Janfaza P, Rubin PA: The evolution of endonasal dacryocystorhinostomy. Surg Ophthalmol 2003; 48(1):73–84.
4. See Suggested Readings following Ophthalmic Surgery section, p. 193.

ENUCLEATION

SURGICAL CONSIDERATIONS

Description

Enucleation involves removal of the entire globe and a portion of the optic nerve. It usually is performed for painful blind eyes or intraocular tumors (e.g., retinoblastoma, melanoma). If possible, the surrounding ocular adnexa, including the conjunctiva, Tenon connective tissue, and extraocular muscles, are left in place to secure an orbital implant. The procedure begins with a 360° conjunctival incision (**peritomy**) at the limbus, allowing exposure of the underlying extraocular muscles and the sclera. Each of the recti muscles is isolated with a muscle hook and secured with fixation sutures before disinsertion from the globe. The oblique muscles are cut and allowed to retract into the orbit (Fig. 2.11). A curved clamp is closed across the optic nerve ~3–10 mm posterior to the globe, and the nerve is cut and the globe removed. After hemostasis has been ensured, an orbital implant (polymethylmethacrylate or hydroxyapatite) is placed into the socket. The overlying muscles, connective tissue, and conjunctiva are closed to improve motility and prevent extrusion.

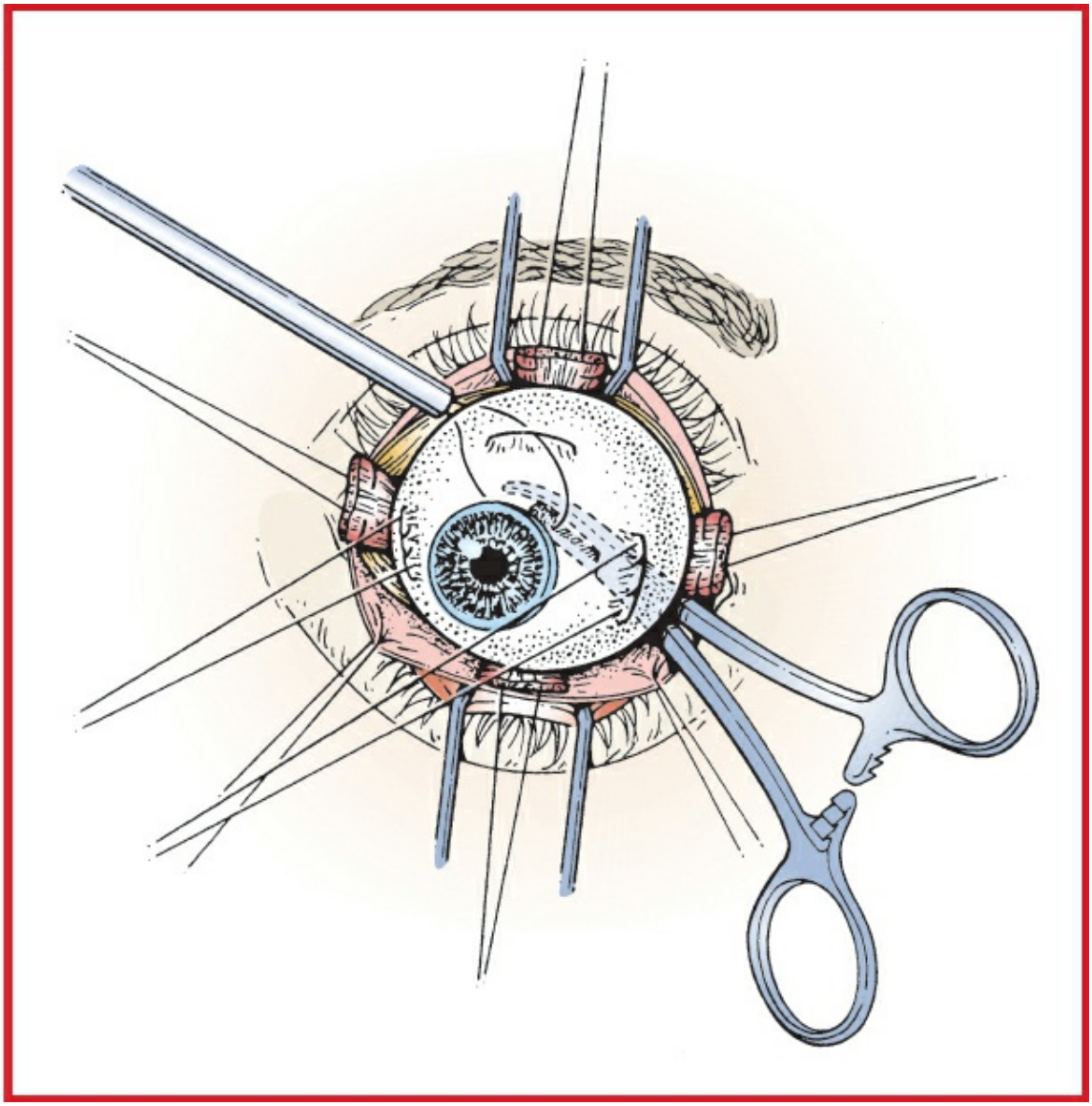

Figure 2.11 Each of the four recti is isolated with 6-0 Dexon suture. The superior oblique tendon is detached. The inferior oblique is sutured to the inferior border of the lateral rectus. 4-0 silk traction sutures are in place over the medial and lateral rectus stump. The globe is rotated laterally, while a curved clamp is introduced from the medial direction. Either curved scissors or an enucleation snare may be used to transect the optic nerve. (Reproduced with permission from McCord CD, Tanenbaum M, Nunery WR, eds: Oculoplastic Surgery, 3rd edition. Raven Press, New York: 1995.)

Variant procedure or approaches

Evisceration involves removing all intraocular contents through a corneoscleral incision, leaving the scleral shell with the attached adnexa in place. This usually is performed in cases of endophthalmitis, but never if malignancy is suspected. **Exenteration** is a more extensive procedure for the management of aggressive malignant tumors or infections where all orbital tissue, often including surrounding orbital bone and adjacent sinuses, is removed. If the extent of orbital tumors is unknown, frozen sections from the surgical margins will be used to determine if

exenteration is needed.

Usual preop diagnosis

Painful blind eye; intraocular tumors; sympathetic ophthalmia; trauma

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol and smoking cessation, carb loading, and postop pain management. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine, table rotated 90–180°
Incision	360° conjunctival (peritomy)
Special instrumentation	Surgical loupes
Antibiotics	Irrigate socket with gentamicin postop
Surgical time	1 h
EBL	<100 mL
Postop care	Outpatient
Mortality	Rare
Morbidity	Extrusion of implant Infection: <1%
Pain score	3–4

PATIENT POPULATION CHARACTERISTICS	
Age range	Any age
Male:Female	Male > female
Incidence	3–5 per 100,000
Etiology	Trauma; infection; glaucoma; tumors (e.g., retinoblastoma, melanoma); inflammation; intractable pain
Associated conditions	Diabetes mellitus

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Ophthalmic Surgical Procedures Under GA.

Suggested Reading

1. See Suggested Readings following Ophthalmic Surgery section.

ORBITOTOMY—ANTERIOR AND LATERAL

SURGICAL CONSIDERATIONS

Description

Surgical access to the orbit is required for biopsy/excision of masses, drainage of orbital abscesses, removal of a foreign body, or repair of orbital fractures, among other procedures. The orbit may be divided into several compartments, and the surgical approach will vary by the location and size of the lesion. In general, an **anterior orbitotomy** is used for small tumors in the anterior orbit and can be approached from a transconjunctival, transseptal, or transperiosteal incision. By contrast, a **lateral orbitotomy** allows for removal of larger masses located further posteriorly in the orbit, as well as those lesions involving the lacrimal gland. In this procedure, the skin incision can be placed just under the brow (**Stallard-Wright**), in the lid crease with lateral extension, or higher in the eyebrow (**coronal**). The dissection is carried down to the periosteum, which is then incised and reflected. The lateral orbital wall is exposed, and an osteotomy is performed using an oscillating saw, after preplacing suture holes with a power drill. The section of bone is removed with a clamp, and the periorbita is opened, allowing intraorbital dissection. After biopsy or removal of the mass, the periorbita is closed and the bone fragment replaced.

Variant procedures or approaches

A **medial orbitotomy** is often required to access lesions that are located medial to the optic nerve.

Usual preop diagnosis

Orbital mass; fractures; foreign body; abscess

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol and smoking cessation, carb loading, and postop pain management. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine, table rotated 90–180°
Incision	Variable (see above)
Special instrumentation	Surgical loupes
Antibiotics	Cefazolin 2 g iv
Surgical time	1–3 h
EBL	Usually minimal, unless vascular tumor
Mortality	Rare
Morbidity	Orbital hemorrhage (retrobulbar → proptosis, retinal ischemia) Impaired ocular motility, strabismus Perforation of the globe: <1:1000 needle blocks Loss of vision, optic nerve injury Infection: <1%
Pain score	3–6

PATIENT POPULATION CHARACTERISTICS	
Age range	Any age
Male:Female	1:1
Incidence	Fairly common
Etiology	Tumor, such as hemangioma, lymphangioma, and lymphoma; lacrimal gland tumors; infection; fracture; foreign body

ANESTHETIC CONSIDERATIONS

(Procedures covered: dacryocystorhinostomy [DCR], enucleation, anterior and lateral orbitotomy)

PREOPERATIVE

Patients presenting for DCR, enucleation, and orbitotomy represent a diverse

population. These patients are generally healthy, aside from the infection, tumor, or trauma underlying their ocular or periocular pathology. Preop evaluation should focus on possible coexisting disease and the systemic manifestations of previous therapeutic interventions (e.g., chemotherapy and drugs used to treat glaucoma). NB: Always verify that surgery is performed on the correct side.

Laboratory	Tests as indicated from H&P
Premedication	Standard premedication
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water.

INTRAOPERATIVE

Anesthetic technique	GETA ± local anesthetic block	
Induction	Standard induction. An oral RAE ETT may be preferred.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance. Muscle relaxation is not required.	
Emergence	No special considerations. The common occurrence of PONV requires the administration of intraop antiemetics (e.g., dexamethasone 4 mg iv and/or ondansetron 4 mg iv).	
Blood and fluid requirements	Blood loss variable IV: 18–20 ga × 1 NS/LR @ 4–6 mL/kg/h	See Zero Balance Fluid Management, Appendix K, p. K-2 and p. K-4
Monitoring	Standard monitors	
Positioning	Table rotated 90° ✓ and pad pressure points ✓ nonoperated eye	

Complications	Oculocardiac reflex (OCR)	OCR: tractions on EOMs → ↓↓ HR, ↓↓ BP, ventricular ectopy, and asystole. Rarely occurs during GA or following adequate retrobulbar block. Rx: stop surgical manipulation, atropine for persistent bradycardia, and CPR.
	Brainstem anesthesia	Onset <20 min → ↓ HR, ↓ BP, apnea, agitation, and asystole. Rx: may require CPR, intubation, and prolonged ventilation

POSTOPERATIVE

Complications	PONV	Rx: metoclopramide 10–20 mg iv and/or ondansetron 4 mg iv
Multimodal pain management	Acetaminophen	Occasionally parenteral opiates. Emphasize nonopioid analgesics including acetaminophen and NSAIDs if not contraindicated (see p. K-5).
ERAS	PONV protocol (see p. B-1)	Encourage early enteral nutrition and mobilization. Consider DVT prophylaxis if early mobilization is not possible.

RETINAL SURGERY

SURGICAL CONSIDERATIONS

Description

Retinal surgery is performed for a wide variety of conditions (see Usual preop diagnoses, below). Most **retinal detachments** are due to one or more small tears in the retina. Retinal detachments are classified as traction, exudative (not usually treated with surgery), or rhegmatogenous (rupture, tear). Children, especially those with retinopathy of prematurity (ROP) or trauma, may develop retinal detachments. In adults, retinal detachments are most frequently associated with diabetes, myopia, trauma, and previous cataract surgery. Rhegmatogenous retinal detachments (more common in adults) start off with a small retinal tear, which allows the vitreous to seep in between the retina and pigment epithelium, forcing retinal separation. Sx range from floaters and flashing lights to showers of black specks and, ultimately, to a dark shadow that impinges on the field of vision. Retinal detachments may be complicated by proliferative vitreoretinopathy (PVR), in which scar tissue grows along the surface of the retina, rendering it stiff and difficult to reattach. Less commonly, retinal detachments are induced by other forms of vitreoretinal traction, or by trauma involving an open globe. Care must be taken to avoid any increase in IOP in an eye that may be ruptured. On rare occasion, retinal detachments are due to the formation of a giant retinal tear. Just as rarely, retinal surgery may be done on premature infants in an effort to prevent or repair retinal detachments. The ultimate aim of retinal surgery is the preservation or recovery of vision through the restoration of normal posterior segment anatomy. (Anatomy of the eye is shown in Fig. 2.12.)

Retinal surgery may involve various procedures alone or in combination, including scleral buckling, vitrectomy, gas-fluid exchange, and injection of vitreous substitutes. **Scleral buckles** are silicone rubber appliances sutured to the sclera to indent the eye wall, thereby relieving vitreous traction and functionally closing retinal tears. This is an external procedure in which the eye may either not be entered at all or entered with a small needle puncture through the sclera for drainage of subretinal fluid or injection of gas.

Cryotherapy or lasers are used frequently to establish chorioretinal adhesions around retinal tears. Cryotherapy is applied to the sclera; a laser is applied with a fiber-optic cable introduced into the vitreous cavity during vitrectomy surgery, often in combination with a wide-field viewing system. It also can be administered with an indirect ophthalmoscope delivery system for those eyes not undergoing vitrectomy.

Simple detachments frequently can be repaired by a pneumatic retinopexy, in which

retinal tears are treated with cryotherapy and/or laser and an expanding gas is injected into the vitreous cavity. This technique usually is done in phakic eyes (eyes with intact lens) with tears between the 9 o'clock and 4 o'clock positions. Pneumatic retinopexy usually is done as an outpatient office procedure, with local anesthesia or, less commonly, MAC. The other procedures discussed usually are done with MAC, althougl GA may be used, according to surgeon's preference and the patient's systemic condition. Some surgeons inject retrobulbar or subconjunctival bupivacaine at the end of a procedure done under GA to decrease postop pain.

Vitrectomy (removal of vitreous) is commonly performed to reduce traction on the retina (↓ retinal detachment), clear blood and debris, and remove scar tissue. It is an intraocular procedure in which three 20–25-ga openings are made into the vitreous cavity with a myringotomy blade 3–4 mm posterior to the limbus (junction of the cornea and sclera). One of these openings in the inferotemporal quadrant is used for infusion of balanced salt solution via a sutured or transconjunctival trocar–based cannula. The remaining openings are at the 9:30 and 2:30 o'clock positions. One is used for a handheld fiber-optic light, and the other for insertion of a variety of manual and automated instruments, including suction cutters, scissors, and forceps, used to remove and section abnormal tissue within the vitreous cavity.

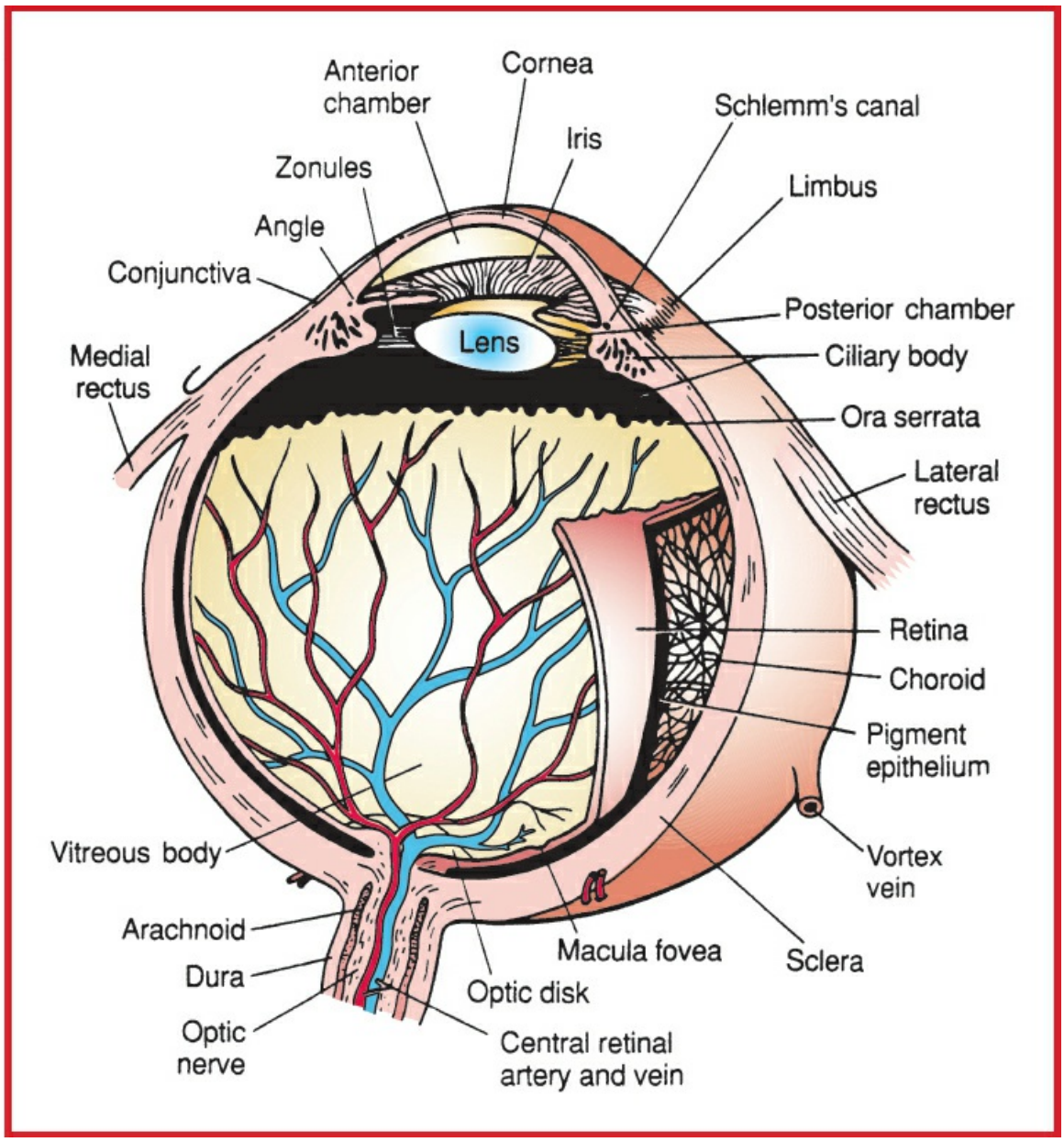

Figure 2.12 Eye anatomy. (Reproduced with permission from Langston D, ed:Manual of Ocular Diagnosis and Therapy, 2nd edition. Little, Brown, Boston: 1985.)

Visualization of the retina during vitrectomy is made possible by a contact lens, which is either sutured to the eye or held in position by an assistant. Some of these lenses provide a wide-field, inverted view of the retina, necessitating an image inverter on the microscope. Alternatively, a noncontact, wide-field lens may be positioned just above the cornea, suspended from the microscope. Balanced salt solution gas, silicone oil, or liquid perfluorocarbon replaces the vitreous and other tissues removed during the operation. A bubble of gas (e.g., sulfur hexafluoride or perfluoropropane mixed with air) is sometimes introduced into the vitreous cavity during a scleral buckle or a vitrectomy when the surgeon wants an internal tamponade of retinal tears that cannot be closed adequately by a scleral buckle alone. N_2O must be discontinued before a gas-

fluid exchange to avoid an intraop or postop change in gas bubble size, possibly accompanied by abnormal IOP.

In the case of a giant retinal tear, a **gas-fluid exchange** formerly was performed with the patient in the prone position toward the end of the operation. This required that the patient be on a Stryker frame, so that he or she could be moved from the supine to the prone position for the gas-fluid exchange. Perfluorocarbon liquids now obviate the need for a Stryker frame.

Liquid vitreous substitutes, such as perfluorocarbon liquids or silicone oil, are sometimes introduced into the vitreous cavity during a vitrectomy. Perfluorocarbon liquids are heavier than water and are used as an intraoperative tool to unfold the detached retina; they are removed at the end of the procedure. Perfluorocarbon liquids make possible repair of giant retinal tears in the supine position, thus eliminating the need for a Stryker frame. They also facilitate reattaching the retina when PVR is present, by allowing a relaxing retinotomy for those situations where the retina is too stiff and foreshortened to be reattached by less-invasive measures. Silicone oil is used for complex detachments in which a long-term, internal tamponade of retinal tears is deemed necessary to prevent redetachment. It usually is removed a few months postoperatively with a second operation.

Usual preop diagnosis

Simple and complex retinal detachment; diabetic retinopathy; vitreous hemorrhage or opacification; macular epiretinal membranes; other surgically correctable macular conditions, such as macular holes or macular degeneration with subfoveal choroidal neovascularization or hemorrhage; dislocated IOL; endophthalmitis; macular degeneration with posterior segment trauma, including repair of ruptured globes and removal of intraocular foreign bodies; ROP; high myopia; trauma

ERAS: For elective surgery, counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, carb loading, and postop pain management. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Transconjunctival
Special instrumentation	Vitrectomy machine; cryoprobe; laser; indirect ophthalmoscope; microscope

Unique considerations	Ruptured globe—avoid ↑ IOP. Stop N_2O 5–10 min before a gas-fluid exchange. Retinal detachments often require urgent surgery (<24 h).
Antibiotics	May use iv antibiotics at the start of surgery, in addition to subconjunctival antibiotics at conclusion of surgery
Surgical time	Pneumatic retinopexy: 20 min Scleral buckle: 30 min to 2 h Vitrectomy: 1–4+ h
Closing considerations	Try to avoid postop coughing, bucking, vomiting, or other Valsalva-like events. Specific head positioning may be required following intraocular gas injection.
EBL	None
Postop care	Prone positioning may be necessary if gas was injected. Alternatively, the surgeon may permit recovery in a sitting position with face down.
Mortality	Extremely rare
Morbidity	Hemorrhage: <5% Retinal detachment: <5% Infection: <1% Proliferative retinopathy
Pain score	4–6

PATIENT POPULATION CHARACTERISTICS

Age range	Usually adults; occasionally premature infants (ROP), and children (retinal detachment or trauma)
Male:Female	3:2
Incidence	1/10,000/yr phakic, 1–3% of patients postcataract extraction with placement of intraocular lens
Etiology	Majority idiopathic possibly related to anatomic predisposition; some related to systemic disease or induced by trauma or cataract surgery

Associated conditions	Idiopathic: retinal detachment, epiretinal membrane, macular hole Diabetic retinopathy: vitreous hemorrhage or traction retinal detachment Macular degeneration: subfoveal choroidal neovascularization or hemorrhage Trauma: vitreous hemorrhage, retinal detachment, ruptured globe Intraocular foreign body (IOFB) HTN: vitreous hemorrhage Extreme prematurity: ROP Proliferative sickle-cell retinopathy

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

In MAC cases, the need for anxiolytics can often be reduced or eliminated by discussing in detail what will happen to the patient during the procedure and by addressing patient concerns (e.g., claustrophobia, positional pain, supine dyspnea). Most vitreous and retinal procedures can be accomplished using regional anesthetic techniques (retrobulbar, peribulbar, or sub-Tenon block) with MAC. Procedures requiring more than 2 h and patients (or surgeons) with special needs (e.g., claustrophobia, uncooperative, immature) may benefit from GA. With MAC, the anesthesiologist's goal should be a comfortable, cooperative patient who can lie completely still without falling asleep (thereby avoiding uncontrolled movement when suddenly awakened) for 1–2 h while avoiding Valsalva-like events (e.g., coughing).

Cardiovascular	Mannitol decreases IOP by increasing plasma oncotic pressure relative to aqueous humor pressure. It may be given just before or during surgery. Total dosage should not exceed 1.5–2 g/kg iv over a 30–60-min period. Rapid infusion of large doses of mannitol may precipitate ↓ BP, CHF, pulmonary edema, electrolyte abnormalities, and, possibly, myocardial ischemia, hence, the importance of a thorough evaluation of the patient's renal and cardiovascular status prior to administering mannitol. Patients on antithrombotic drugs may be at higher risk for bleeding

	complications. The decision to stop these drugs and institute heparin bridge therapy should be made in consultation with both the surgeon and the prescribing physician. **Tests:** As indicated from H&P
Diabetes	Diabetic patients are at increased risk for silent myocardial ischemia. Pulmonary aspiration 2° diabetic gastroparesis is also a risk in this population. Patients taking sc insulin should take two-thirds of their usual dose the evening before surgery and one-half their usual NPH dose on the morning of surgery. Any morning dose of regular insulin should be held.
Renal	Acetazolamide, a carbonic anhydrase inhibitor, decreases secretion of aqueous humor. It also inhibits renal carbonic anhydrase, thereby causing loss of HCO_3, Na^+, K^+, and water. Thus, patients on chronic therapy may be acidotic, hypokalemic, and hyponatremic. **Tests:** Electrolytes; others as indicated from H&P
Hematologic	Sickle-cell disease → retinopathy. Sickle-cell trait is not commonly associated with periop complications. Patients with sickle-cell anemia should be well hydrated and transfused preop, as necessary to increase HbA concentration >40%.
Laboratory	Tests as indicated from H&P
Premedication	Midazolam 0.5 mg/kg po for pediatric patients (~30 min to peak effect, ~30-min duration of effect) and midazolam 1–2 mg iv incrementally for adults will help alleviate anxiety. Avoid excessive sedation (respiratory depression) in sickle-cell patients. Surgeons prefer a normal IOP during retinal reattachment surgery, and therefore, patients may be given acetazolamide or mannitol to decrease IOP.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status.

	Consider preop acetaminophen 1000 mg po with sip of water. Topical anesthesia will often be started in the preop holding area.

INTRAOPERATIVE

Anesthetic technique

Retinal detachment surgery may be performed under regional anesthesia (e.g., retrobulbar or peribulbar block); however, if the surgery is expected to be >2 h, GETA may be preferable. Increased discomfort may occur during scleral buckle placement. Rx with short-action analgesics. If it is possible that cautery may be used during the surgery, then the delivered FiO_2 should be <0.3 to minimize fire hazard when using open oxygen delivery methods (e.g., nasal prongs, mask, etc.).

Induction	Standard induction is appropriate for these patients with care being taken not to put pressure on the affected eye with the face mask.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. The ophthalmologist may place nerve blocks.
Maintenance	Standard maintenance. Ophthalmologists, however, may use expanding gases, such as sulfur hexafluoride (SF_6) or perfluoropropane (C_3F_8), for internal tamponade of the retinal tears, and, if N_2O is used, the injected bubble may expand rapidly, causing a dramatic rise in IOP. This can impair retinal blood flow. N_2O, if used at all, should be D/C'd at least 15 min before gas injection. For any subsequent surgery, N_2O should be avoided for at least 14 d after an air injection, 30 d after a SF_6 injection, and 90 d after C_3F_8. Given the importance of patient immobility, nondepolarizing muscle relaxants may be advantageous, especially if N_2O is D/C'd.
Emergence	Use narcotics for pain control and consider iv lidocaine 1.0–1.5 mg/kg 5 min prior to extubation to

	provide smooth emergence. The common occurrence of PONV requires the administration of intraop antiemetics (e.g., metoclopramide 10–20 mg iv and ondansetron 4–8 mg iv 30 min before the end of surgery).	
Blood and fluid requirements	IV: 18–20 ga × 1 (adult) 20 ga × 1 (child) NS/LR @ 4–6 mL/kg/h	See Zero Balance Fluid Management, Appendix K, p. K-2 and p. K-4
Monitoring	Standard monitors	Processed EEG may be useful in monitoring level of sedation. Care should be taken to avoid CO_2 accumulation under the drapes in MAC cases. The unheated output from a Bair Hugger™ hose or similar air source can be used to improve air circulation under the drapes.
Positioning	✓ and pad pressure points ✓ and pad nonsurgical eye	For long MAC cases, short "time-outs" should be taken to allow patients to reposition themselves.
Complications	Oculocardiac reflex (OCR)	OCR: traction on EOMs → ↓↓ HR, ↓↓ BP, ventricular ectopy, and asystole. Rarely occurs during GA or following adequate retrobulbar block. Rx: stop surgical manipulation, atropine for persistent bradycardia, CPR

POSTOPERATIVE

Complications	PONV Corneal abrasion Vitreous hemorrhage Glaucoma Ptosis Diplopia Loss of vision Infection	Rx: ondansetron 4–8 mg iv ± metoclopramide 10–20 mg iv; however, eye pain (e.g., 2° to corneal abrasion) may also cause N/V. If this is the case, treat eye pain (ophthalmology consult). Persistently low BP → retinal ischemia and central retinal artery occlusion
Multimodal pain management	Acetaminophen 1 g po or iv if not given within previous 4–6 h	PO narcotics may be needed, especially when retrobulbar anesthesia was contraindicated. Emphasize nonopioid analgesics including acetaminophen and NSAIDs if not contraindicated (see Appendix K, p. K-5).
ERAS	PONV protocol (see p. B-1)	Encourage early enteral nutrition and mobilization. Consider DVT prophylaxis if early mobilization is not possible.
Tests	None routinely required	

Suggested Readings

1. Bryant JS, Busbee BG, Reichel E: Overview of ocular anesthesia: past and presen Curr Opin Ophthalmol 2011; 22(3):180–4.
2. Charles S, Fanning GL: Anesthesia considerations for vitreoretinal surgery Ophthalmol Clin North Am 2006; 19(2):239–43.
3. Cruz-Iñigo YJ, Acabá LA, Berrocal MH: Surgical management of retinal diseases proliferative diabetic retinopathy and traction retinal detachment. Dev Ophthalmol

2014; 54:196–203.
4. Kumar CM, Eld H, Dodds C: Sub-Tenon's anaesthesia: complications and thei prevention. Eye (Lond.) 2011; 25(6):694–703.
5. Nouvellon E, Cuvillon P, Ripart J: Regional anesthesia and eye surgery Anesthesiology 2010; 113(5):1236–42.
6. Palte HD. Ophthalmic regional blocks: management, challenges, and solutions. Local Reg Anesth 2015; 8:57–70.

General Ophthalmic Surgery Suggested Readings

1. Ahmad S, Ahmad A: Complications of ophthalmologic nerve blocks: a review. J Clin Anesth 2003; 15(7):564–9.
2. Barton JG: Enhanced recovery pathways in pancreatic surgery. Surg Clin North Am 2016; 96(6):1301–12.
3. Hughes MJ, McNally S, Wigmore SJ: Enhanced recovery following liver surgery: systematic review and meta-analysis. HPB (Oxford) 2014; 16(8):699–706.
4. Kelly DJ, Farrell SM: Physiology and role of intraocular pressure in contemporary anesthesia. Anesth Analg 2018; 126(5):1551–62.
5. Mahajan D, Sain S, Azad S, et al: Comparison of topical anesthesia and peribulbar anesthesia for 23-gauge vitrectomy without sedation. Retina 2013; 33(7):1400–6.
6. Mason J, Gupta S, Compton C, et al: Comparison of hemorrhagic complications o warfarin and clopidogrel bisulfate in 25-gauge vitrectomy versus a control group. Ophthalmology 2011; 118(3):543–7.
7. Pędziwiatr M, Mavrikis J, Witowski J, et al: Current status of enhanced recovery after surgery (ERAS) protocol in gastrointestinal surgery. Med Oncol 2018; 35(6):95.
8. Pokhrel PK, Loftus SA: Ocular emergencies. Am Fam Physician 2007; 76(6):829–36.

Suggested Viewing

Links are available online to the following videos:

Scleral Buckle and Vitrectomy for Retinal Detachment:
https://www.youtube.com/watch?v=CJy8qjNojAc

Vitrectomy for Vitreous Opacities (Floaters): https://www.youtube.com/watch?v=zryk1Ys7td8

Advanced Cataract Surgery—"In Simple English":
https://www.youtube.com/watch?v=aohAHNYpAOs

SECTION 3.0

OTOLARYNGOLOGY—HEAD AND NECK SURGERY

SURGEONS

Michael J. Kaplan, MD (Head & Neck Surgery)
Edward J. Damrose, MD, FACS (Laryngology)
Robert K. Jackler, MD (Otology & Neurotology)
Robson Capasso, MD (Otology—Head & Neck Surgery)
Peter H. Hwang, MD (Endoscopic Sinus Surgery)
Sam P. Most, MD (Nasal Surgery)
Donald M. Sesso, DO (Sleep-disordered breathing)
Jerome E. Hester, MD (Sleep-disordered breathing)

ANESTHESIOLOGISTS

Vladimir Nekhendzy, MD (All topics)
Tiffany Cheng, MD (Sleep-disordered breathing)

We gratefully acknowledge the past contributions of surgeon, Nikolas H. Blevins, MD.

INTRODUCTION—SURGEON'S PERSPECTIVE

Interdisciplinary cooperation is nowhere more important than where the priority of a secure and sustainable airway maintenance is confronted with adjacent surgical goals. An anesthesiologist skilled in the management of the difficult airway and with an ability to anticipate the issues confronting the surgeon is critical. Similarly, a communicative surgeon fully aware of the problems the anesthesiologist is likely to encounter is essential to minimizing complications. Important issues that require mutual understanding include the following:

1. Airway management: anesthesia induction, endotracheal tube (ETT) size, head range of motion with shared airway space, a well-secured ETT, postop airway edema, and smooth emergence from anesthesia
2. Muscle relaxation, patient immobility, patient positioning
3. Deliberate relative hypotensive anesthesia and management of bradycardia
4. Antiemetics and pain management postop
5. Patient population considerations: frequent cardiac and pulmonary issues associated with older patients, especially with alcohol and tobacco use; degenerative C-spine issues; and prior irradiation affecting neck mobility.

Airway management

An initially compromised airway is not uncommon in many otolaryngology head and neck procedures. Many others may develop airway loss at induction or if premature extubation occurs. Communication between the surgeon and anesthesiologist is essential, as is a discussion of a plan and backup plan should an emergency arise. Availability of a sliding Jackson scope and tracheotomy equipment, as well as plans for fiberoptic intubation, awake intubation, or retrograde intubation, should be discussed as indicated.

For procedures within the airway, an ETT no larger than 6 mm should be adequate and will reduce postop airway edema. An armored tube is helpful when the surgical procedure is intraoral and the tube may be compressed. A nasotracheal intubation should be discussed as an alternative in this situation. If laser surgery is planned, maintaining the FiO_2 at <0.3 is indicated. If fiberoptic bronchoscopy is planned, then a 7.0- or 7.5-mm ETT will facilitate passage of the bronchoscope through the ETT, after which for a longer case, changing to a smaller tube may be warranted.

As the patient is generally turned 90° or 180° away from the anesthesiologist, a very secure airway is important. If the surgeon needs access in the mouth, securing the tube

via a wire to several teeth may work better than tape.

Muscle relaxation and patient positioning

Avoidance of muscle relaxation is important if a motor nerve, such as the facial nerve, is to be dissected. Muscle relaxation is important, on the other hand, in esophagoscopy and tongue surgery. Communicate and coordinate timing of drug administration. Frequently, the surgeon will need to turn the patient's head during surgery. Anticipating this movement when initially securing the ETT and its connections will prevent disconnection. In neck surgery, the neck is often rotated away from the surgeon; overrotation presents the risk of brachial plexus stretch injuries. If a radial free flap is anticipated, then positioning of the arm as well as rotation of the head should be carefully coordinated to avoid injury while still providing needed access and a secure airway.

Deliberate relative hypotensive anesthesia, to a systolic blood pressure (SBP) of <100 mm Hg, depending on individual patient's needs, is often a boon to the surgeon operating in the highly vascular fields of the head and neck or operating with a microscope. For selected cases, the patient also will have had preop embolization of a tumor and its blood supply (e.g., angiofibromas and skull base paragangliomas). **Bradycardia** may occur if the surgeon operates near the vagus nerve or carotid bifurcation. If this occurs, it is usually sufficient for the anesthesiologist to communicate this, and the surgeon can desist for a period of time. Occasionally, topical or locally injected anesthetics will be necessary.

INTRODUCTION—ANESTHESIOLOGIST'S PERSPECTIVE

PATIENT POPULATION

Many ENT patients are smokers and elderly and have ↑ incidence of coronary artery disease (CAD), hypertension (HTN), chronic renal insufficiency (CRI), and chronic obstructive pulmonary disease (COPD). Careful H&P must be performed to ensure that the patient's functional status is optimized. In patients with significant CAD, HTN and/or associated CRI, controlled hypotension techniques should be avoided. Chronic cigarette smoking and alcohol use also cause an induction of cytochrome P450 multienzyme system → ↑ opioids and ↑ neuromuscular blocker (NMB) requirements.

AIRWAY

ENT patients often present with H&P findings associated with a difficult airway including (a) anatomic characteristics (e.g., ↓ C-spine ROM, large tongue, receding jaw), (b) Hx of stridor and hoarseness (airway narrowing and possible vocal cord [VC] dysfunction), (c) previous Hx of neck surgery, trauma, or x-ray therapy (XRT) (↓ compliance of the tissues, ↓ neck ROM, ↓ mouth opening), (d) previous Hx of difficult intubation, and (e) infections (e.g., epiglottitis, retropharyngeal abscess, Ludwig angina).

Meticulous examination of the airway must be performed, and there should be a low threshold for an awake intubation if the airway is questionable. The awake versus asleep approach to tracheal intubation should be guided by the presence of predictors of difficult or impossible mask ventilation and their association with difficult direct laryngoscopy (DL) (Tables 3.1 and 3.2). Oxygenation-centered approach to difficult airway management is paramount, and the use of the high-flow nasal oxygen (transnasal humidified rapid-insufflation ventilatory exchange, THRIVE) should be strongly considered when potentially difficult airways are encountered.

Table 3.1 Predictors of Difficult and Impossible Mask Ventilation

Difficult Mask Ventilation	Impossible Mask Ventilation
Mallampati grade 3–4	Mallampati grade 3–4
Decreased mandibular protrusion	Male sex
Presence of beard	Presence of beard
Obesity (BMI ≥ 30)	OSA*
Age > 57 yo	Neck radiation changes
Lack of teeth	
History of snoring	

At least three predictors should be present in any category for a reasonably high probability of the event.

*Moderate-to-severe obstructive sleep apnea (OSA), associated with the use of CPAP/BiPAP or a history of OSA surgery.

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Table 3.2 Predictors of Combined Difficulty with Mask Ventilation and Direct Laryngoscopy

Predictors of Difficult/Impossible Mask Ventilation	Additional and Modified Predictors
Mallampati grade 3–4	Age ≥ 46 yo
Decreased mandibular protrusion	Presence of teeth
Presence of beard	Neck radiation changes or a neck mass
Obesity (BMI ≥ 30)	Thick or obese neck
Male sex	Unstable neck or decreased neck extension
OSA*	Decreased thyromental distance

A total of at least five predictors should be present for a reasonably high probability of both, difficult mask ventilation (DMV) and difficult direct laryngoscopy (DL). Class III patients (five risk factors) constitute 5% of all DMV+DL cases, and patients from class IV (six risk factors) and class V (seven to eleven risk factors) constitute the largest group (85%) of these cases.

*Moderate-to-severe obstructive sleep apnea (OSA), associated with the use of CPAP/BiPAP or a history of OSA surgery.

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A team approach to an anticipated difficult airway is essential. Thorough understanding of upper airway anatomy, concurrent pathology, and all steps of the surgical procedure are necessary for devising a safe and rational perioperative airway management strategy. Video laryngoscopy (e.g., GlideScope™) usually improves airway visualization and should be considered for the initial approach to tracheal intubation when difficulty is anticipated. The LMA-Fastrach™ provides rescue ventilation with a 95–100% success rate in difficult airway situations. If a conventional DL was chosen as a first approach, the patient's head positioning should be optimized, and simple intubating aids (e.g., stylets, gum elastic bougie) as well as the ETTs of different sizes made readily available. The number of DL intubation attempts should be limited to two; repeated intubating attempts are associated with increased incidence of airway trauma, unanticipated ICU admission, and "cannot ventilate-cannot intubate" events.

For most ENT surgical procedures, the patient's airway is shared with the surgeon, and immediate access to the airway may be difficult or impossible. The ETT must be secured diligently to prevent an accidental extubation or pullout of the ETT to the subglottic area, which may result in exerting direct pressure on the recurrent laryngeal nerves by the ETT cuff. For certain procedures (e.g., excision of tumors of the base of the tongue [BOT]), nasal intubation may be required to facilitate surgical access, and

the surgeon should be consulted before induction. Specialized types of ETTs are required for laser surgery of the airway and for surgeries requiring monitoring of the recurrent laryngeal nerve function (e.g., thyroidectomy).

ANESTHETIC MANAGEMENT

Some of the essential anesthesia management requirements for ENT surgery include (a) assurance of good intraop and postop analgesia (most of the procedures are performed on highly reflexogenic areas); (b) quiet surgical field (the operated areas are highly vascular), and moderate controlled hypotension is widely employed: ↓ SBP < 100 mm Hg, MAP = 60–70 mm Hg, unless contraindicated; (c) immobility (for certain procedures profound muscle relaxation may be required, while for others administration of NMB must be avoided); and (d) smooth emergence from anesthesia. The latter constitutes one of the most challenging tasks, as every attempt should be made to avoid or minimize the patient's reaction to the ETT during tracheal extubation. Straining, bucking, or coughing may provoke early postop bleeding (↑ venous and arterial pressure), disrupt delicate suture lines (e.g., facial nerve repair), dislodge surgical grafts (e.g., tympanoplasty), or cause additional trauma to the vocal cords after VC surgery. Many ENT surgeons have their own "list" of the procedures where the patient's reaction to the ETT should be completely avoided during extubation, and an anesthesiologist should be familiar with the surgeon's preferences.

Opioid-based anesthetic techniques are especially advantageous and result in significant ↓ monitored anesthesia care (MAC) while providing sufficient blunting of the tracheal responses to the in situ ETT. In an opioid-naive patient, the choice of an opioid analgesic depends primarily on the anticipated degree of surgical stimulation and postop pain, duration of surgery, and coexisting medical conditions. High-dose opioids (fentanyl, loading dose 3–10 mcg/kg iv; sufentanil, loading dose 0.5–1.5 mcg/kg iv), followed by either intermittent boluses or continuous infusion, are the author's preferred choice for major ENT surgery. For procedures that may be highly stimulating, but associated with minimal postop discomfort (e.g., laser surgery of the airway), a short-acting opioid is preferred: remifentanil (loading dose 0.5–1.0 mcg/kg iv, infusion 0.1–0.3 mcg/kg/min iv).

Total intravenous anesthesia (TIVA) is commonly employed, especially for endoscopic procedures. Most studies demonstrate that, compared to inhalational and balanced inhalational techniques, TIVA offers improved hemodynamic stability, quicker recovery times, decreased incidence of postoperative nausea and vomiting (PONV), and

improved patient satisfaction.

Maintenance of moderate **controlled hypotension** (MAP, 60–70 mm Hg) is useful for maintaining optimal operating conditions. A variety of pharmacologic approaches have been successfully employed for this purpose. The use of remifentanil is particularly effective in that regard and is equally useful with both inhalational and TIVA techniques. The use of esmolol 0.5–1 mg/kg iv bolus, followed by continuous iv infusion 100–300 mcg/kg/min, represents another attractive therapeutic option.

GETA is most widely employed. Use of a **laryngeal mask airway** (LMA) for ENT surgery, when feasible, is beneficial (↓ coughing, ↓ laryngospasm; see Table 3.3). Furthermore, the use of an LMA does not require NMB and facilitates the resumption o spontaneous ventilation. When used appropriately in selected patients, absence of immediate access to the patient's airway is not a deviation from the standard of care.

A flexible laryngeal mask airway (FLMA), but not an LMA Classic™, LMA ProSeal™, or LMA Supreme™, is most frequently used in ENT anesthesia, because it shaft can be bent away from the surgical field without causing cuff displacement. Close communication between the surgeon and anesthesiologist is essential, as even a properly placed FLMA can become dislodged during surgical manipulations. The LMA ProSeal/LMA Supreme is preferred whenever central positioning of the LMA can be safely maintained (e.g., otologic surgery). Proper LMA insertion technique is crucial for minimizing the risk of aspiration or gastric insufflation, especially if positive pressure ventilation (PPV) is planned. An increased number of FLMA insertion attempts and low airway seal pressure (ASP) constitute independent risk factors for FLMA failure. We recommend selecting the largest FLMA size suitable for the patient to improve ASP and minimize the air leak during PPV. We also recommend performing tracheal intubation if adequate ASP (≥12 cm H_2O in patients without associated gastroesophageal reflux disease [GERD] and ≥15 cm H_2O in patients with GERD) cannot be achieved within three FLMA insertion attempts. Gastric insufflation is further minimized by ↓ Vt to 6–10 mL/kg and by keeping PIP < 20 cm H_2O. The absence of gastric insufflation during PPV when LMA is used should be documented in the anesthesia record after auscultating the epigastric area.

Table 3.3 Advantages of the LMA Compared with the ETT

Adverse Event ETT/LMA	ETT %	LMA %	Ratio
Clinically significant problems	3.4	0.9	3.8

Laryngeal spasm	0.38	0.12	3.2
Aspiration	0.017	0.02	0.85
Sore throat	50	10	5
Laryngeal trauma	6.2	<1	>6
Coughing on emergence	60	2	30

Modified from Brimacombe JR, Brain AJ: The Laryngeal Mask Airway. A Review and Practical Guide, 1st edition. WB Saunders, Philadelphia: 1997. Copyright © 1997 Elsevier. With permission.

Smooth emergence from anesthesia constitutes a particularly challenging task when GETA is used. Deeper stages of anesthesia are usually required until the very end of the procedure to blunt laryngotracheal responses. A low-dose remifentanil infusion to blunt the tracheal responses and promote smooth extubation may be helpful. Current data indicate that EC_{95} of effect site concentration of remifentanil for blunting tracheal reflexes after balanced desflurane or sevoflurane anesthesia is 2.3–2.9 ng/mL, which corresponds to an infusion rate of 0.08–1.0 mcg/kg/min. This is higher than that observed with TIVA, where a target concentration of 1.5–2.1 ng/mL, corresponding to an infusion rate of 0.05–0.07 mcg/kg/min is usually sufficient.

Antiemetic prophylaxis should be routine and is most commonly achieved by iv administration of a 5-HT_3 blocker. This is further facilitated by 4–8 mg dexamethasone iv, which is commonly requested by the surgeon to reduce postop airway edema. Multimodal antiemetic prophylaxis should be employed for patients at high risk for PONV. The addition of metoclopramide (10–20 mg iv) may be beneficial for the patients who had undergone the procedures resulting in accumulation of the passively swallowed blood in the stomach (e.g., nasal or intraoral surgery).

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LARYNGOSCOPY/BRONCHOSCOPY/ESOPHAGOSCO

SURGICAL CONSIDERATIONS

Description

Laryngoscopy is used for inspection of the pharynx, hypopharynx, or larynx for diagnostic and/or therapeutic benefit. The patient is supine with cervical spine flexed and atlantoaxial joint extended (this position is best achieved with a headrest), and the teeth are protected with a mouth guard. The laryngoscope is introduced (Fig. 3.1); then, with a lifting motion, a thorough examination of the oropharynx, hypopharynx, and larynx is carried out, with biopsies if indicated. Bleeding typically is minor, easily controlled with cotton pledgets soaked in epinephrine or cautery. Laryngoscopy often is combined with flexible esophagoscopy and bronchoscopy to survey the aerodigestive tract for malignancy. If the procedure is diagnostic, the surgeon may need to see the airway before intubation and/or muscle relaxation. If a laser is to be used, a special

laser ETT, <30% FiO_2, and avoidance of N_2O are required.

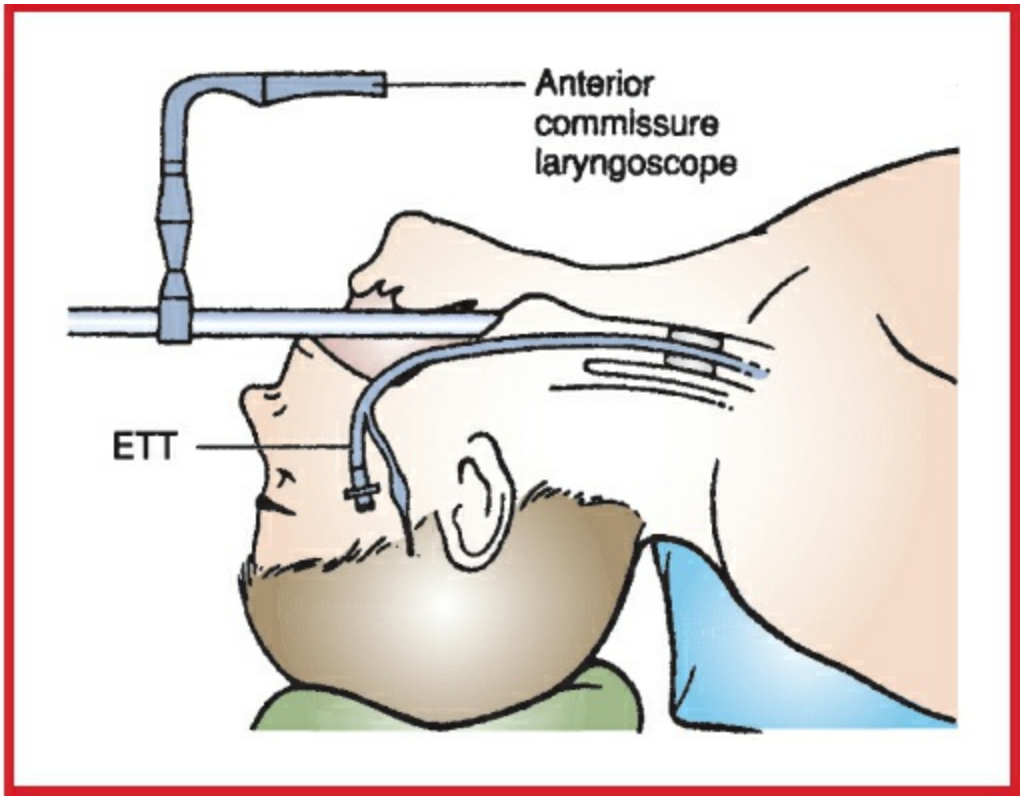

Figure 3.1 Placement of anterior commissure laryngoscope for laryngoscopy.

Usual preop diagnosis

Oropharyngeal, hypopharyngeal, or laryngeal tumors

Description

Operative microlaryngoscopy. Many laryngeal lesions (such as papilloma, cysts, polyps, selected malignancies) can be removed endoscopically. Specialized endoscopes are deployed transorally to allow the surgeon a binocular view of the vocal fold and the target lesion. They can be suspended from a Mayo stand to free both of the surgeon's hands for operating. Using the microscope, a variety of specialized endoscopic instruments, and lasers, the surgeon may be afforded excellent unobstructed access to the vocal folds for diagnostic and therapeutic purposes. Operative microlaryngoscopy may necessitate several hours of work. Because of the precision involved in such procedures and the high degree of stimulation to the patient, general anesthesia (± jet ventilation) with muscle relaxation is required. Intubation with a small-caliber microlaryngeal or laser-safe tube (5 or 6 mm) may be required for these procedures. In cases where jet ventilation is to be performed, an endoscope suitable for this technique should be available. Intermittent apneic ventilation is also a possibility,

although this involves periodic interruption of surgery, which can be cumbersome and distracting.

Usual preop diagnosis

Vocal fold neoplasm; vocal fold paralysis

Description

Bronchoscopy inspects the tracheobronchial tree for diagnostic and therapeutic purposes. The patient is supine with head elevated and neck extended at the upper cervical level. The bronchoscope is directed along the right side of the tongue forward toward the midline to visualize the epiglottis. Next, the bronchoscope tip is used to lift the epiglottis and advance the bronchoscope through the VCs, into the trachea and bronchus (Fig. 3.2). With the aid of telescopes, the bronchoscope can be directed for inspection of the carina, main bronchi, and the segmental bronchi. Rigid bronchoscopes provide a large working channel through which to introduce grasping and biopsy forceps. As such, rigid bronchoscopes may provide a more stable platform for removal or retrieval of foreign bodies, tumors, and stents than flexible fiberoptic bronchoscopes.

Flexible fiberoptic bronchoscopy is more commonly performed than rigid bronchoscopy. The endoscope with biopsy channels is connected to a monitor, suction, and irrigation. Spontaneous ventilation can be maintained, which may allow the procedure to be performed without an ETT in place (or the bronchoscope may be introduced through a large enough ETT, such as a 7.5-mm one), affording unobstructed inspection of the upper airway. A bite block is placed to protect the endoscope from dental trauma and to facilitate advancement through the oropharynx into the larynx.

Usual preop diagnosis

Head and neck squamous cell carcinoma; foreign body (FB) in the bronchus

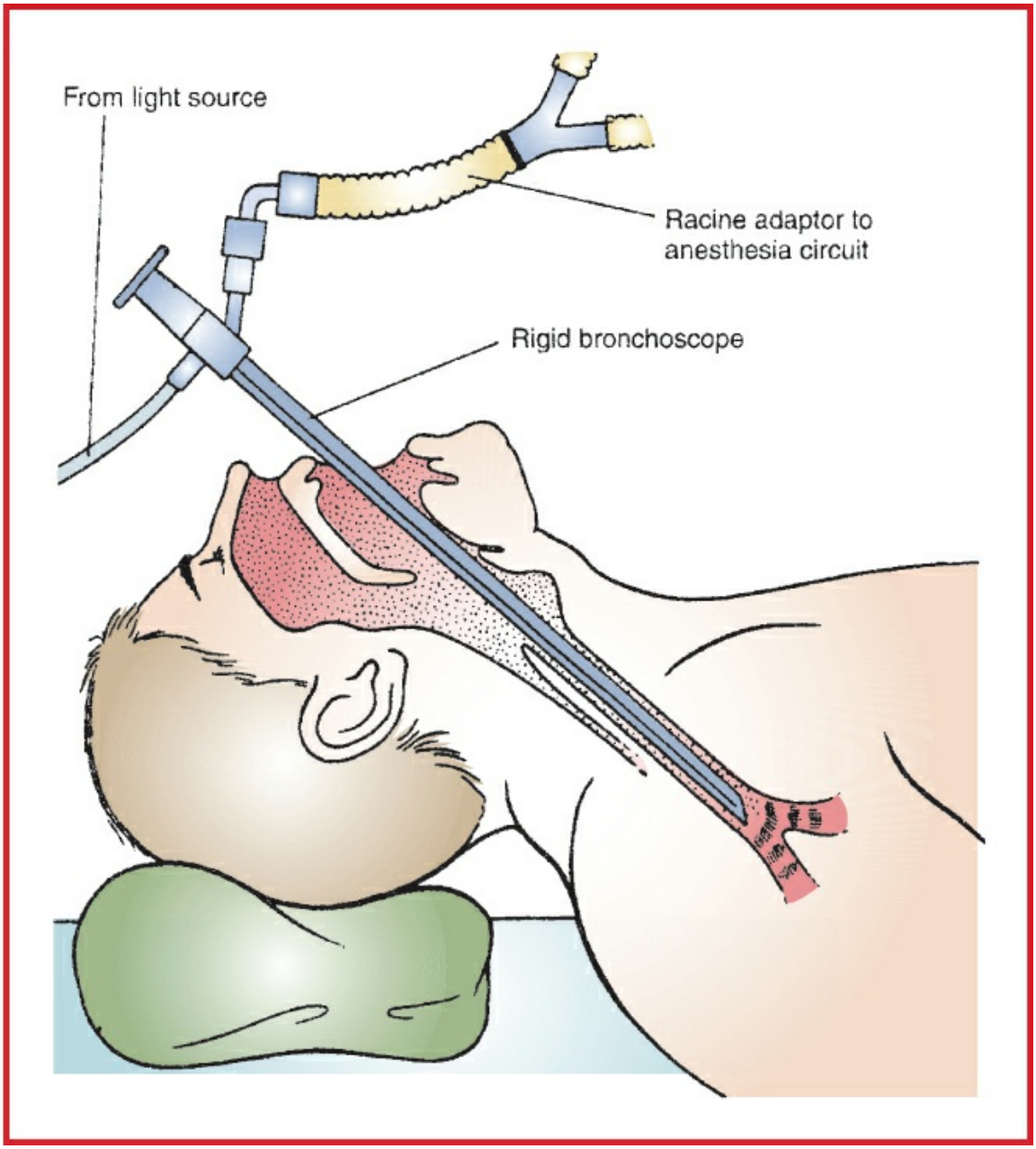

Figure 3.2 Rigid bronchoscopy showing adaptor (Racine) for anesthesia machine. Note neck flexion and head extension to align oropharyngeal and tracheal axes.

Description

Esophagoscopy inspects the esophagus for either diagnostic or therapeutic benefit. The patient is supine with head elevated and neck extended at the upper cervical level. The esophagoscope (held in the dominant hand) is advanced through the mouth behind the arytenoids, gently using the thumb of the nondominant hand. The bevel of the scope is then used to advance through the cricopharyngeal muscle (upper esophageal sphincter) with an upward lifting movement, entering the cervical esophagus. As the scope advances, the head may have to be lowered or the neck extended and the scope directed slightly toward the left. The scope is advanced to the gastroesophageal junction with

great care to ensure a visible lumen is seen at all times to avoid inadvertent perforation.

Flexible fiberoptic esophagoscopy today is far more common because of superior optics and is performed in an essentially identical manner. Biopsies may be taken and percutaneous gastrostomy tubes may be placed.

Usual preop diagnosis

Head and neck squamous cell carcinoma; FB ingestion

Description

Panendoscopy, or triple endoscopy, is the combination of laryngoscopy, bronchoscopy, and esophagoscopy. It is usually performed as part of the evaluation of patients with newly diagnosed cancer of the head and neck and may be done just prior to planned resection, assuming no unexpected findings. Goals of panendoscopy include (a) evaluating extent of a primary tumor and assessing resectability, (b) checking for synchronous second tumors in other locations within the upper aerodigestive tract, and (c) searching for the source of the primary lesion in patients who present with neck squamous cell carcinoma in whom a primary has not been identified by clinical examination or imaging including MRI and PET/CT. In the latter case, endoscopy may be supplemented with transoral robotic surgery (TORS) to resect the lingual tonsils or one or both palatine tonsils.

Usual preop diagnosis

Head and neck squamous cell carcinoma

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting nothing by mouth (NPO) duration and alcohol and smoking cessation. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

SUMMARY OF PROCEDURES

	Laryngoscopy	Bronchoscopy	Esophagoscopy	If Therapeutic Procedure Added
Position	Supine	⇐	⇐	⇐
Special instrumentation	Endoscopes, video monitors, suction	⇐	⇐	Laser, laser-safe ETT, gastroscope and G-tube (abdominal prep)
Unique considerations	Dexamethasone 4–8 mg if airway edema	⇐	⇐	⇐ if laser ablation, keep O_2 <30%
Antibiotics	None	None	None	Cefazolin 2 g and metronidazole 500 mg or clindamycin 600 mg
Surgical time	10–30 min	⇐	⇐	30–120+ min
EBL	Minimal	⇐	⇐	Typically minimal
Postop care	PACU; rarely 23 h stay 2° airway issues	⇐	⇐	⇐; depends on specific intervention; if G-tube, monitor for abdominal signs
Mortality	<1%	⇐	⇐	⇐
Morbidity	With MDL, incisor trauma <1%	⇐	Perforation <1%	⇐; if G-tube placement, <2% Abdominal bleed or free air; if MDL with laser or laser bronchoscopy, <1% pneumothorax, <5% airway compromise
	Airway obstruction or postprocedure edema requiring reintubation: <1%	⇐	⇐	
	Laryngospasm: <5%	⇐	⇐	
Pain score	1–2	1–2	1–2	1–2

PATIENT POPULATION CHARACTERISTICS

Age range	Newborn–90+	⇐	⇐	⇐
Male:female	1:1	⇐	⇐	⇐
Incidence	Common	⇐	⇐	⇐
Etiology	Tumors, foreign bodies, congenital webs	⇐	⇐	⇐; nutritional need (G-tube)
Association conditions	Other congenital issues; if malignancy, prior RT or chemotherapy and the conditions associated with that malignancy	⇐	⇐	⇐

ANESTHETIC CONSIDERATIONS

(Procedures covered: bronchoscopy, esophagoscopy, panendoscopy, operative microlaryngoscopy, Zenker diverticulectomy, laser surgery of the airway.)

PREOPERATIVE

Many of these patients are elderly and have a history of smoking and alcohol abuse with corresponding implications for intraop management. Patient fluid and nutritional status may be further compromised by preexisting malignancy. Meticulous attention to airway management is paramount in these procedures, and close communication with the surgeon is essential. Some patients presenting for esophagoscopy may have obstructing lesions of the esophagus or **Zenker diverticulum** or active gastrointestinal bleeding or require the removal of an FB, putting them at increased risk of aspiration.

Airway	Although rare, the airway may be compromised in these patients at both the upper and lower airway levels; thus, a thorough preop airway assessment is essential. A clear backup plan for securing the airway should be devised and discussed with the surgeon before induction of GA. Stridor at rest suggests an airway narrowing ≤4.5 mm, although the airway diameter can be seriously reduced even without stridor being present. Patients with lesions in the mediastinum may have involvement of the recurrent laryngeal nerve, presenting with hoarseness and potential airway management problems (e.g., difficult mask ventilation, difficult intubation, ↑ aspiration risk). (See also Anesthetic Considerations for Laryngectomy.)
Respiratory	These patients may have a high incidence of COPD and ↓ respiratory reserve. The nature and characteristics of a productive cough must be noted. Wheezing on exam must be treated with bronchodilators before induction. Patients presenting with vocal cord (VC) paralysis or achalasia may have had repeated episodes of pulmonary aspiration.

	Patients with significant lung disease may not be the candidates for specialized ventilation techniques, including jet ventilation (JV) or apneic intermittent ventilation (AIV). **Tests:** CXR; other tests as indicated from H&P
Dental	Physical exam should include a careful dental assessment and documentation of any missing, loose, or damaged teeth. Patients (or parents, as appropriate) should be informed that dental trauma may occur as a result of surgical instrumentation of the patient's mouth during the procedure.
Cardiovascular	Adrenergic responses during endoscopy may be associated with up to a 4% incidence of myocardial ischemia. Careful preop Hx and thorough physical exam should be undertaken in patients with Hx of CAD and CHF or those with cardiac risk factors (including age >40 yr, male, HTN, hypercholesterolemia, long Hx of smoking, obesity, and family Hx). The volume status of debilitated patients who are unable to eat because of obstructing lesions of the esophagus should be assessed by measuring orthostatic BP changes. **Tests:** ECG; other tests as indicated from H&P
Neurologic	Some patients may have Hx of ETOH abuse, which may result in ↑ anesthetic requirements 2° hepatic enzyme induction. Symptoms of alcohol withdrawal (e.g., tremulousness, ↑ sympathetic activity, and altered mental status), if present, should be controlled before surgery.
Hematologic	Patients with malignancy or chronic disease may have evidence of anemia or coagulopathy. **Tests:** CBC; coagulation studies as indicated from H&P
Gastrointestinal	In some patients (e.g., with malignant tumors), significant electrolyte abnormalities may be present 2° malnutrition. Hypokalemia and hypomagnesemia

	should be corrected preop. In patients with Hx of ETOH abuse, liver disease and cirrhosis may be present. **Tests:** Electrolytes; BUN; Cr; LFT; coagulation studies, as indicated from H&P
Premedication	An antisialogogue (e.g., glycopyrrolate 0.2 mg iv) may be desired by the surgeon to facilitate panendoscopy, especially in patients with copious secretions. Sedative premedication is routine but should be minimized or avoided in the elderly and avoided completely in patients with symptoms of upper airway obstruction.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: Airway management requires careful planning and continuous communication with the surgeon. Surgical requirements include adequate muscle relaxation (movement, coughing, or bucking during endoscopy may have disastrous consequences) and immobile VCs for VC surgery. Cardiovascular stability is important: laryngeal, tracheal, and cranial reflexes may provoke severe ↑ BP and ↑ HR, which can be detrimental in some patients. Adequate depth of anesthesia is essential, but the requirements for rapid awakening and return of laryngeal reflexes present additional challenges in anesthetic management. Short-acting β-blockers (e.g., esmolol) may be indicated to treat breakthrough sympathetic responses, especially in patients with cardiac disease. Remifentanil or alfentanil (see Introduction) is useful for these procedures, which, although highly stimulating, are characterized by minimal or absent postop pain, and the majority of patients are discharged home from the recovery room.

Special considerations

If **flexible bronchoscopy** is planned, the patient's trachea is intubated with a large-diameter ETT (7.5–8.0 mm ID) to accommodate a flexible video bronchoscope. The ETT is usually taped midline. As an alternative, in selected patients, flexible

bronchoscopy can be performed without tracheal intubation through the **Patil-Syracuse mask** during manual bag-mask ventilation. Placement and manipulation of the flexible bronchoscope by the surgeon will be facilitated by the concomitant use of one of the hollow oral airways used for the fiberoptic intubation (e.g., **Williams airway**). The patient can then be tracheally intubated with a smaller diameter ETT (e.g., 6.0-mm ID) to facilitate surgical access.

Flexible esophagoscopy is rarely performed as an isolated procedure but, if done, would also be facilitated by tracheal placement of a small-diameter (e.g., 6.0-mm ID) ETT. The ETT is usually moved over to the left corner of the mouth and taped to the lower jaw, to provide more room for esophagoscope advancement and manipulation.

If **rigid bronchoscopy** is planned first, GA is induced, and the patient is hyperventilated through the face mask with FiO_2 = 1.0. Following muscle relaxation, the surgeon may proceed, without securing an airway. Quick and gentle DL for application of topical lidocaine to the larynx and upper trachea (lidocaine tracheal anesthesia [LTA], 4% lidocaine 3–4 cc) before rigid bronchoscopy may help blunt hemodynamic responses to the subsequent surgical manipulation. DL with LTA should be avoided in patients with tumors at the base of the tongue (↑ risk of bleeding; see Anesthetic Considerations for Glossectomy) or when preexisting copious secretions or bleeding are present in the upper airway 2° ↑ risk of pulmonary aspiration on emergence from anesthesia. It is advisable to demonstrate to the surgical team and document in the chart absence of dental damage after DL has been performed.

After the rigid bronchoscope is introduced into the patient's trachea, it is connected to an anesthesia circuit through a flexible side port adapter (Racine, Fig. 3.1), and the patient is ventilated manually. High flows are usually required because of the leak around the bronchoscope. Close communication with the surgeon is essential for adjusting ventilation when the bronchoscope is introduced into the mainstem bronchus to avoid high inflating pressures and to ensure complete exhalation (↓ risk of barotrauma). After rigid bronchoscopy is completed, mask ventilation with FiO_2 = 1.0 before intubation is advisable to ensure adequate oxygenation and normocapnia. A reinforced ETT is useful for **rigid esophagoscopy** to avoid possible compression of the ETT. The ETT should be moved to the left side of the patient's mouth to facilitate introduction of the surgical instruments and taped to the lower jaw because full opening of the patient's mouth is required.

For **operative microlaryngoscopy**, a small-diameter (usually 5.0-mm ID), cuffed long microlaryngeal tube (MLT) is most commonly used to facilitate visualization of the

larynx but will interfere with posterior glottis lesions, for which jet ventilation (see below) is most commonly employed. The CO_2 laser, which can precisely vaporize superficial tissue, is widely used for VC **laser surgery**, whereas the Nd:YAG (neodymium-yttrium-aluminum-garnet) laser is usually employed for airway tumor debulking because of its ability to coagulate deeper lesions. The Nd:YAG can be used through the suction channel of the fiberoptic or video bronchoscope, whereas the CO_2 laser must be aimed directly at the targeted tissue. Both the CO_2 and Nd:YAG wavelengths lie outside the visible spectrum, and a separate, lower-energy visible beam is used for aiming. The patient must be motionless, the patient's eyes must be protected with tape and moistened gauze, and OR personnel must wear protective goggles.

An **intermittent apnea technique** involves hyperventilation, followed by intermittent tracheal extubation for 1–5 min, during which the laser is used. This approach is time consuming and may be associated with a higher incidence of airway trauma and edema 2° repeated intubations. Careful pulse oximeter monitoring is essential for this technique.

Manual low-frequency jet ventilation (Fig. 3.3) or **automated high-frequency jet ventilation** (HFJV) may be necessary when an ETT cannot be used (e.g., some posterior glottic and subglottic lesions). For supraglottic manual jet ventilation, the operating laryngoscope is most commonly employed. The axis of the jet should be in line with the trachea, and full egress of air (complete chest deflation) should be ensured between the jet ventilator "puffs." Close communication with the surgeon is essential. The jet should be triggered during pauses between laser firings to keep the VCs immobile. If jet ventilation is used for laser resection of papillomas, there is a risk of spreading the virus to OR personnel, and special face masks should be worn in the OR. Jet ventilation generally provides adequate ventilation without introducing flammable material into the airway or obstructing the surgical field. Its use, however, may be associated with potentially severe complications, including barotrauma, pneumothorax, and gastric distension (risk of regurgitation), and is hindered by ↓ chest wall, airway or lung compliance. Full muscle relaxation is usually required to facilitate precise laser targeting. Automatic HFJV is preferred to manual JV and can be delivered through either an operating laryngoscope or specialized subglottic catheter (e.g., LaserJet or Hunsaker tube).

A recent introduction of the **THRIVE technique** (see Introduction, above) has made it possible to conduct short laryngeal surgical procedures using high-flow nasal oxygen insufflation as the sole means of oxygenation and ventilation.

For laser cases, precautions must be taken to prevent **airway fire**, including the following:

- Use special laser ETT (e.g., Mallinckrodt Laser-Flex), although none of them provides 100% protection from all types of lasers. Small (5.0 mm ID and smaller) diameter laser ETTs are preferred to facilitate surgical access.
- Use the lowest possible FiO_2 ($\leq$0.3) that will ensure adequate oxygenation (dilute O_2 with air, N_2, or helium) and avoid N_2O (both O_2 and N_2O promote combustion).
- Use colored (methylene blue–tinged) NS in the ETT cuff (will immediately alert the surgeon in case of a laser hit).
- Place the ETT sufficiently deep into the trachea to reduce the risk of laser contact with ETT cuff.

Similar considerations apply in patients undergoing endoscopic **Zenker diverticulectomy**, when the CO_2 laser is used.

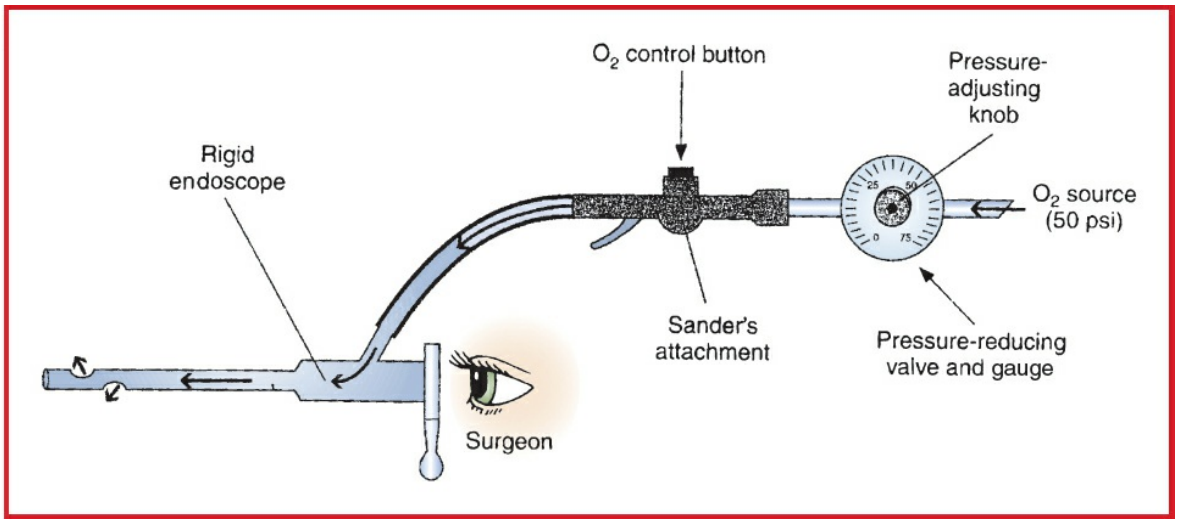

Figure 3.3 Rigid endoscope with modified Sanders jet ventilation technique. The oxygen supply at 50 psi is connected to a reducing valve that allows the pressure to be adjusted from 0 to 50 psi. The side port of the endoscope is used as the Venturi injector site, and the open end can be used for continuous viewing by the endoscopist.

Induction	Patients at risk for aspiration may require RSI with cricoid pressure (CP) if symptoms of active gastroesophageal reflux disease are present. Otherwise, anatomical location of the diverticulum (above the cricoid cartilage) makes application of CP largely ineffective. With the possible exception of endoscopic Zenker diverticulectomy, fentanyl use should be minimized (1–2 mcg/kg) or even

	completely avoided in favor of the short-acting opioids (remifentanil or alfentanil iv; see Introduction), 2° minimal postop pain. Propofol (1–2 mg/kg) is the ideal induction agent. Patients with mobile, floppy, supraglottic tumors (e.g., papillomatosis, epiglottic cancer, large vocal cord polyps) are at ↑ risk for complete airway obstruction after induction of GA with or without neuromuscular blockade. Anesthetic management of these patients requires careful planning and meticulous preparation (see Anesthetic Considerations for Laryngectomy). The surgeon should be consulted about the extent of the disease and the potential need for a tracheostomy. If the disease is severe, the surgeon should be present during induction for the possible need to perform urgent or emergent rigid bronchoscopy or cricothyrotomy/tracheostomy.
ERAS	Maintain normovolemia and normothermia.
Maintenance	TIVA (e.g., propofol: 80–180 mcg/kg/min; remifentanil 0.1–0.25 mcg/kg/min) is widely used, especially when rigid bronchoscopy or jet ventilation/intermittent apnea techniques are planned. Compared to alfentanil, the use of remifentanil during TIVA is associated with the increased hemodynamic stability, reduction in propofol dose and faster respiratory recovery. When the ETT is used throughout the case, delivery of anesthetic gases may be used instead of a propofol infusion, especially if a bronchodilating effect is desirable. Desflurane and sevoflurane are the preferred agents because of their low blood-to-gas solubility; sevoflurane may be favored in patients with preexisting cardiac disease to minimize the risk of a dose-dependent tachycardia. Breakthrough sympathetic responses can be managed safely by administration of β-blockers iv or small boluses of a short-acting opioid (see Introduction). With intermittent apnea or jet ventilation techniques, it

	may be difficult to avoid hypercapnia and hypoxemia, which may provoke intraop dysrhythmias. Full muscle relaxation is routine: vocal cord immobility is essential for microlaryngeal and laser surgery. Monitoring the neuromuscular blockade may be more accurate at the facial nerve (orbicularis oculi muscle), than the ulnar nerve (adductor pollicis muscle) because the recovery of the former better reflects the recovery of the laryngeal muscles. Care should be taken to avoid inadvertent prolonged neuromuscular blockade by coordinating administration of additional doses of muscle relaxants with the surgeon. As the surgery approaches its end, deepening the level of anesthesia may be the preferred approach to minimize VC movement. A succinylcholine infusion (2–6 mg/min iv) can be used safely in selected patients (limiting the total dose of succinylcholine ≤4–6 mg/kg will help avoid phase 2 block).	
Emergence	Patient should have full return of protective airway reflexes prior to extubation. The patient's stomach may need to be decompressed following jet ventilation. Smooth emergence from anesthesia is obligatory to avoid additional trauma to the vocal cords. For this reason, some surgeons request deep extubation after vocal cord surgery, which presents extra challenges to the anesthesiologist (see Emergence for Tonsillectomy, Adenoidectomy).	
Blood and fluid requirements	IV: GI bleeder: 14–16 ga × 2 Others: 20 ga × 1	Blood loss is usually minimal; however, in patients with ↑ risk of GI bleed, blood loss may be massive. See Goal-Directed Fluid Management, Appendix K, p. K-4.

	BSS @ 2–3 mL/kg/h	T&C these patients for 2 U PRBC with blood immediately available in OR.
Monitoring	Standard monitors ± arterial line	In patients with ↑ risk of GI bleed, an arterial line is desirable.
Positioning	OR table rotated 90° or 180° away from the anesthesiologist ✓ and pad pressure points ✓ eyes	A shoulder roll is placed and the patient's neck is extended to facilitate endoscopy. Special attention should be paid to prevent compression of the patient's shoulder by the vertical bar of the Mayo stand, which is frequently employed for suspending the operating laryngoscope or endoscope.
Complications	Inadequate ventilation Loss of airway	Hypoxia and hypercarbia may be difficult to avoid with jet ventilation.
	Perforation of airway Dysrhythmias	Mechanical or laser perforation of the airway may → bronchospasm or uncontrollable hemorrhage.
	Pneumothorax	Dx: ↑ RR, ↓ BP, ↑ CVP, wheezing, ↓ O_2 saturation, ↑ PIP, SOB, chest pain, ↓ breath sounds, ↓ ECG amplitude, dullness on percussion. Rx: chest tube or needle aspiration, FiO_2 = 1.0, ventilation and volume

		expansion.
	Eye trauma Bleeding postbiopsy	Eye trauma from surgical instruments used during endoscopy may require ophthalmology consult.
Airway fire (steps taken **simultaneously** by the anesthesiologist and surgeon)	Disconnect the inspiratory limb of the anesthesia circuit Remove ETT Extinguish fire with oral NS Remove all burning material Resume ventilation by face mask with 100% O_2. Consider reintubation Flexible fiberoptic bronchoscopy Save ETT for later examination	This is an acute, life-threatening emergency. NB: turning ventilator off only may not be sufficient due to continued delivery of fresh gas to the patient's lungs. Rigid or flexible bronchoscopy is required to ✓ extent of damage, presence of ETT fragments, and airway edema. All inhaled gases should be humidified. Patients are usually reintubated and monitored in the ICU. To assess lower airway damage and to remove ETT fragments.

POSTOPERATIVE

Complications	Dental trauma Bleeding Eye trauma	Dental trauma may result from surgical manipulation of the airway, and the anesthesiologist must check the teeth immediately after airway access is gained. If dental trauma is detected, notify

		the surgeon to discuss management options, both immediate and subsequent.
	Postop airway compromise	Has a higher incidence than in general surgery patient population. Patients with T3 lesions and those with associated laryngeal biopsy (↑ airway swelling) after panendoscopy may be at high risk for reintubation in PACU. Delayed upper airway edema after laser surgery has been described, when the coagulation (Nd:YAG) laser is used.
	Esophageal perforation	Complaints of painful swallowing as well as fever, tachycardia, neck/chest/back pains postop may suggest an esophageal perforation.
Complications (cont'd)	Pneumothorax Pneumomediastinum Hemothorax Aspiration	Pneumothorax (see above), mediastinal air or hemothorax from esophageal perforation may present as ↓ BP and cardiovascular collapse.
Multimodal pain management	Short-acting opioid	Fentanyl 25–50 mcg iv prn is usually sufficient.
Tests	✓ CXR	For evidence of pneumothorax, hemothorax, mediastinal

ERAS	PONV protocol (see Appendix B, p. B-1)	air. Encourage early enteral nutrition and mobilization.

Suggested Readings

1. Abdelmalak B, Ryckman JV, AlHaddad S, et al: Respiratory arrest after successful neodymium:yttrium-aluminum-garnet laser treatment of subglottic tracheal stenosis. Anesth Analg 2002; 95:485–6.
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6. Jaquet Y, Monnier P, Van Melle G, et al: Complications of different ventilation strategies in endoscopic laryngeal surgery: a 10-year review. Anesthesiology 2006; 104:52–9.
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TRACHEOTOMY/TRACHEOSTOMY AND CRICOTHYROIDOTOMY

SURGICAL CONSIDERATIONS

Description

When an airway needs to be obtained right away and intubation is not an option, a cricothyrotomy is indicated. A vertical incision is made in the midline through the cricothyroid membrane, an initial influx of air is facilitated if the patient is spontaneously breathing, and a small ETT is placed. It is wise to convert this to a tracheostomy as soon as it is convenient to do so as this reduces the subsequent incidence of subglottic stenosis and cricoid chondritis.

A tracheotomy is generally done in a controlled setting, under general anesthesia in an intubated patient or under local anesthesia; using a short transverse incision 1–2 cm inferior to the cricoid or a midline vertical incision beginning at the same location. Strap muscles are retracted laterally, the anterior tracheal wall inferior to the thyroid isthmus identified (divided the isthmus if necessary), and, in adults, an inferiorly based tracheal flap consisting of the 2nd or 3rd tracheal ring is made and secured to the skin inferiorly. In small children, it is better to make only a vertical midline incision to reduce the risk of subsequent tracheal stenosis; left and right stay sutures are instead placed to assist in reintubation in the event of accidental dislodgment of the tracheotomy tube. The tracheotomy tube is sutured in all patients to the skin. Trach ties supplement this securing of the tube unless these circumferential ties would interfere with venous drainage of a microvascular free flap used in head and neck reconstruction.

When prolonged need for a tracheotomy without mechanical ventilation is anticipated, there are specialized silicon tracheotomy tubes with minimal intraluminal plastic and may be associated with fewer intraluminal potential complications. Extended length tracheotomy tubes are available and may be needed in obese patients or those with tracheal narrowing distal to the tracheotomy site.

Usual preoperative diagnosis

Indications for tracheostomy are numerous but share the common theme of securing a safe airway either in anticipation of postop airway edema or inability to protect the airway from aspiration or as an urgent need to obtain an upper airway in pending obstruction. The fastest way to obtain an airway in an outright emergency when intubation is not an option is a cricothyrotomy. Another third general indication is to protect the larynx from injury if prolonged intubation is anticipated, such as in a prolonged ICU setting or in paralysis associated with cervical spinal cord trauma. Rarer indications are bilateral vocal cord paralysis or a history of recurrent allergy associated with laryngospasm.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Tracheostomy	Cricothyrotomy
Position	Supine, head extended	⇐

Incision	Transverse or vertical	Stab incision through cricothyroid membrane
Special instrumentation	None (most institutions have a “trach set”)	Scalpel is all that is initially needed in this emergency setting
Unique considerations	Local or general, intubated or not. Specialized equipment and silicon trach cannulas selectively arranged for	⇐
Antibiotics	None	⇐
Surgical time	3–20 min	30 sec–2 min
EBL	Minimal	⇐
Postop care	Warm humidification; suctioning; changing inner cannula; skin care; monitor for bleeding and dislodgement; in emergency remove entire tracheotomy tube	⇐; convert to tracheotomy as soon as convenient
Mortality	<1%	⇐
Morbidity	Bleeding <5% cellulitis/tracheitis <5% tracheal stenosis <1%	Subglottic stenosis risk if not converted
Pain score	1–2	2–4

■ PATIENT POPULATION CHARACTERISTICS		
Age range	All	⇐
Male:Female	Dependent on underlying condition	⇐
Incidence	Common	⇐
Etiology	Anticipated or actual airway obstruction, prolonged	Trauma

	intubation	
Associated conditions	Dependent on underlying condition, but typically cardiopulmonary or neurologic conditions	Trauma

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Typically, there are three patient populations presenting for tracheostomy: (a) critically ill intubated patients in chronic respiratory failure or following major trauma, (b) patients for whom tracheostomy is part of a scheduled procedure (e.g., laryngectomy), and (c) patients with impending or total upper airway obstruction (e.g., Ludwig angina, retropharyngeal abscess). If the latter constitutes life-threatening emergency, tracheotomy/cricothyroidotomy may be the preferred approach. Aside from an occasional otherwise healthy patient in the third category, all patients presenting for tracheostomy are usually debilitated, have associated cardiac or pulmonary disease, and frequently present with neurologic and metabolic abnormalities.

Respiratory	Patients in group One usually require mechanical ventilation with PEEP to maintain adequate oxygenation. The continued application of PEEP may be an important consideration during their transport from ICU to OR. Patients in group Two require a careful airway evaluation (see Anesthetic Considerations for Neck Dissection, and Laryngectomy). Based on the assessment, the anesthesiologist must decide whether to choose a DL, an awake FOI, or a tracheostomy under local anesthesia to secure the airway. Patients in group Three will usually require semiemergent or emergent tracheostomy. Patients in all three groups should be evaluated for the presence of possible recurrent aspiration. **Tests:** CXR; ABG, as indicated from H&P
Cardiovascular	All patients may have significant cardiac risk factors, including smoking, ETOH abuse, male gender, ↑

	cholesterol, family Hx, and HTN. Some patients may have recently undergone major cardiac surgery and may be on pharmacologic inotropic support, with full invasive monitoring, including PA line. **Tests:** ECG, and other tests as indicated, in patients of the second group.
Neurologic	Preop neurologic deficits should be fully documented.
Hematologic	In cases of malignancy or chronic disease, coagulopathies or anemia may be present. **Tests:** CBC; coagulation studies
Laboratory	Other tests as indicated from H&P
Premedication	Standard premedication in elective cases. Premedication is best avoided in critically ill patients and patients with symptoms of upper airway obstruction.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of superficial cervical plexus nerve blocks for postop pain management. Consider preop acetaminophen 500–1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA in intubated patients or in patients who pose no problems for conventional DL and tracheal intubation. In the presence of significant airway compromise or anticipated very difficult intubation, local anesthesia may be required. Most tracheostomies are elective or semiurgent and are performed under GA. Patients with ↑ mucosal swelling (e.g., generalized edema, prolonged intubation) and ↑ tissue fragility (e.g., chronic steroid therapy) are at risk for tracheal mucosal separation → creation of a false passage during tracheostomy. This will constitute a true emergency (see Postoperative Complications, below).

Induction	If already intubated (group One, above), convert preexisting

	sedation to GA, using a carefully titrated inhalational agent. intubated, and no airway problems are anticipated, a standa induction may be appropriate. If airway problems are anticip an awake FOI or tracheostomy performed under local anesth may be the techniques of choice (see Anesthetic Considerati for Neck Dissection, and Laryngectomy). In any event, the anesthesiologist should be prepared to deal with a failed intubation and have a surgeon immediately available to perf cricothyrotomy/tracheostomy if ventilation proves impossible use of THRIVE during intubation attempts, and even during conversion of a failed tracheal intubation into the surgical ai may be advisable to maximize oxygenation and prolong the window.
ERAS	Verify preincision antibiotics. Assess volume status (see App K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Standard maintenance. Full muscle relaxation is required. Fi 1.0 usually is required before insertion of the tracheostomy t This high O_2 concentration, combined with electrocautery, m precipitate airway fire (see Postoperative Complications, bel cuffed ETT should be used to prevent O_2 from leaking into th surgical site. In order to avoid inadvertent ETT cuff puncture consider advancing the ETT closer toward the carina, before trachea is opened. The trachea is usually opened above the and the ETT is slowly retracted cephalad, under direct vision the surgeon. (Note: Do not remove the ETT completely.) Ste gas sampling tubing, extra ETTs, and anesthesia circuit shou readily available (see Maintenance for Laryngectomy). After tracheostomy tube is secured, it should be suctioned and connected to the anesthesia circuit. Verify the $ETCO_2$ tracing the inflation pressures, and remove the ETT.
Emergence	Considerations for group Two and Three patients are describ above. Patients in the first group will continue on ventilatory support in the ICU. The tracheostomy tube must be carefully suctioned, and the delivered O_2 should be humidified. Opioic sedation will minimize reaction to suctioning in the early pos period. Tracheostomy tubes should not be removed for at le

	first 5–7 d until a track is formed. Discuss with surgeon local wound infiltration or nerve block (e.g., superficial cervical pl block) placement or reinforcement if initially placed >4 h ag Consider iv acetaminophen if po dose given >4–6 h ago. PO prophylaxis should include dexamethasone and ondansetron	
Blood and fluid requirements	IV: 18 ga × 1 BSS @ 2–3 mL/kg/h	EBL is typically minimal, when the tracheostomy is performed as an isola procedure. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	Avoid ECG pad placement in the prepp area. Invasive monitoring may be appropriate depending on the patient' condition.
Positioning	Shoulder roll ✓ and pad pressure points ✓ eyes	A shoulder roll is usually placed, and patient's neck extended, which may re ETT cuff migrating cephalad, closer to incision site (danger of inadvertent perforation by the surgeon on enterin trachea). Make sure the ETT is positio the sufficient depth and taped securel
Complications	Pneumothorax Pneumomediastinum Hemorrhage Aspiration of blood	Pneumothorax may occur with a low n dissection, or if a false passage (see P Complications, below) has been create during the tracheostomy tube insertio and Rx—see Anesthetic Considerations Laryngoscopy/Bronchoscopy/Esophag
	False tracheal passage/tracheal disruption	This is an airway emergency and must quickly recognized (absent CO_2, ↑ PIP, absent or very distant breath sounds). Reintroduction of the existing ETT fror proximal trachea should be attempted
	Difficult ETT insertion/reinsertion	Rigid bronchoscope should be availabl reestablish the airway, in case of a fai reintubation. An alternative approach insert a large-bore iv catheter into the tracheal lumen distal to the tracheost site and jet ventilate the patient. Inse

	Airway fire	of an airway exchange catheter throug bronchoscopy elbow adapter attached existing ETT has been advocated prior tracheostomy tube insertion in patient high risk for this complication. Tracheostomy fires are usually not catastrophic, possibly because the tracheostomy acts as a vent. Rx: immediately disconnect the patient fro anesthesia machine, extinguish the fir NS, and ventilate the lungs with room using a self-inflating bag. Removing or changing the existing ETT at this point be more risky than leaving it in, espec the patient was previously difficult to intubate or the airway has become edematous.

POSTOPERATIVE

Complications	Pneumothorax Pneumomediastinum Hemorrhage	See Postoperative complications after Laryngoscopy/Bronchoscopy/Esophago
	Occlusion of the tracheostomy tube	This could be due to secretions, mucus blood, or positioning of the tube in the mainstem bronchus or against the trac wall.
	Tracheostomy tube displacement	Reintubate orally or through the tracheostomy site.
Multimodal pain management	PCA IV opioids	Emphasize multimodal approach comb nonopioid and bolus/PCA opioid analge with peripheral local anesthetics (see Appendix K, p. K-6).
Tests	CXR	✓ tracheostomy tube position and ✓ f evidence of either pneumothorax or pneumomediastinum.

ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition and mobilization.

Suggested Readings

1. Akhtar N, Ansar F, Baig MS, et al: Airway fires during surgery: Management and prevention. J Anaesthesiol Clin Pharmacol 2016; 32(1):109–11.
2. Atkins JH, Mirza N: Anesthetic considerations and surgical caveats for awake airway surgery. Anesthesiol Clin 2010; 28(3):555–75.
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4. Mcguire G, El-Beheiry H, Brown D: Loss of the airway during tracheostomy: Rescue oxygenation and re-establishment of the airway. Can J Anesth 2001; 48:697–700.
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INTUBATION FOR EPIGLOTTITIS

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Epiglottitis is an acute inflammation and swelling of the epiglottis, associated with a generalized systemic toxicity, usually due to Haemophilus influenza type B. It also can be caused by β-hemolytic streptococci, staphylococci, pneumococci, or unusual pathogens among immunocompromised individuals and drug/alcohol abusers. It occasionally results in total laryngeal obstruction and death 2° asphyxia. At one time, the typical patient was a previously healthy child 3–5 yr old; however, since the advent of the H-flu vaccine, epiglottitis is more common in adults (predominantly males). The most common presenting symptoms are sore throat, dysphagia/odynophagia, fever, respiratory difficulty, and drooling. Pediatric patients may appear toxic on presentation.

Airway	Enlarged epiglottis seen frequently on neck x-ray. Neck tenderness or swelling also observed in some patients. Patients with stridor are at high risk for upper airway obstruction.

Respiratory	The patient, typically sitting upright, may display hoarseness, muffled voice, dyspnea, and chest wall retractions. **NB:** Rapid treatment should be instituted instead of performing time-consuming investigations. The sudden development of respiratory obstruction in the x-ray suite could have a disastrous outcome.
Hematologic	A high leukocyte count usually is found in these patients. **Tests:** Blood drawing before the airway is secured may be inadvisable.
Premedication	None

INTRAOPERATIVE

Anesthetic technique

GETA: Patients presenting with imminent or actual airway obstruction should be intubated immediately. Airway management for **adult** patients presenting with **mild-to-moderate** symptoms is controversial. Although routine prophylactic intubation of these patients may not be necessary, 18% subsequently develop complete airway obstruction; thus, close monitoring is mandatory if intubation is deferred. It is imperative to realize that total airway obstruction can occur suddenly and without warning.

An experienced anesthesiologist should be present for this procedure. In the pediatric patient, it is critical that neither visualization of the epiglottis nor other maneuvers be attempted to confirm the Dx before anesthesia. In adults, it has been suggested that indirect laryngoscopy or fiberoptic bronchoscopy (FOB) may be performed without the risk of precipitating complete airway obstruction, although this approach is controversial.

Induction	If an iv is in place, atropine 0.02 mg/kg may be given to the pediatric patient to prevent vagal reflexes resulting from manipulation of the inflamed epiglottis. If no iv access is available, inhalation induction (sevoflurane in FiO_2 = 1.0) with the patient in the sitting position should be used. Intramuscular injection should be avoided to prevent agitation, crying, and subsequent total airway obstruction (iv line is placed after induction of anesthesia). An

	experienced ENT surgeon, ready to perform an emergency tracheostomy, must be present at induction. Early application of CPAP is essential to maintain the upper airway patency. Inhalation induction may be prolonged and intubation extremely difficult. Different sizes of ETTs must be available.	
ERAS	Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance.	
Emergence	The patient will remain intubated for 24–48 h and should be kept sedated and restrained to prevent accidental extubation.	
Blood and fluid requirements	IV: 18–20 ga (adult) 22–26 ga (child) BSS @ 3–5 mL/kg/h (adult); @ 1.5 mL/kg/h (child)	Minimal blood loss Fluid requirements may be ↑ 2° fever and dehydration. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes	
Complications	POPE (postobstructive pulmonary edema)	A short-lived POPE occasionally occurs after relief of the obstruction and must be treated with IPPV.

POSTOPERATIVE

Complications	Accidental extubation ETT blockage	These complications can prove fatal. The blockages are sometimes

		due to crusting of the ETT 2° insufficient humidification.
Multimodal pain management	PCA IV opioids	Postop sedation and manual restraints are often required.
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition and mobilization.

Suggested Readings

1. Chroboczek T, Cour M, Hernu R, et al: Long-term outcome of critically ill adul patients with acute epiglottitis. PLoS One 2015; 10(5):e0125736.
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ZENKER DIVERTICULECTOMY (OPEN APPROACH)

SURGICAL CONSIDERATIONS

Description

Zenker diverticulum is a herniation of mucosa through the posterior hypopharyngeal wall immediately above the cricopharyngeus muscle and below the inferior constrictor in an area called Killian dehiscence. This is an acquired disorder, usually seen in the sixth to ninth decades of life and felt secondary to tonic spasm or achalasia of the cricopharyngeus muscle. Clinically, patients may experience dysphagia, globus, coughing, and regurgitation of undigested food. Weight loss and aspiration pneumonia can be seen in severe cases. Barium swallow is usually diagnostic. Endoscopy will reveal the presence of a pouch of variable size posterior to the cricopharyngeus muscle

often filled with undigested debris. Cricopharyngeal achalasia may present in the absence of a well-formed diverticulum with much the same symptom complex. Treatment is usually aimed at division of the cricopharyngeus muscle and eradication of the pouch.

Variant approaches

Open: Under GA with muscle relaxation, an incision is made in the left side of the neck to expose the diverticulum and cricopharyngeus muscle. The muscle is cut, the diverticulum resected, and the hypopharyngeal defect closed. In patients with pure cricopharyngeal spasm, the muscle alone is cut. A drain is placed, and the wound is closed. A nasogastric tube may be placed for postop feeding. Aspiration precautions should be observed at both induction (consider awake intubation in severely symptomatic patients) and reversal of anesthesia, as this is a common comorbidity in patients with Zenker diverticulum. **Endoscopic:** Selected patients may be candidates for endoscopic treatment of a Zenker diverticulum. This is better described as diverticulotomy rather than diverticulectomy because the redundant hypopharyngeal mucosa is not removed, and the cricopharyngeus muscle is not divided in its entirety. Rather, the common wall separating the diverticulum from the esophagus is reduced to prevent food and debris from collecting within the confines of the diverticulum. With the patient under general anesthesia and muscle relaxation, an esophagodiverticuloscope is placed transorally and advanced into the hypopharynx. The endoscope is deployed to visualize clearly the opening into the diverticulum. The common wall separating the diverticulum from the true esophageal inlet is then cut, either with a stapler or with a CO_2 laser.

Usual preop diagnosis

Dysphagia; Zenker diverticulum; cricopharyngeal spasm

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Open	Endoscopic
Position	Supine; table 90°; head extended	Supine

Special instrumentation	Anode or laser ETT; microscope	⇐; endoscopic stapler or CO_2 laser
Unique considerations		Keep O_2 < 30% and avoid N_2O if lasering
Antibiotics	Cefazolin 2 g and metronidazole 500 mg; clindamycin 600 mg	
Surgical time	1–2 h	30 min–1 h
EBL	<25 mL	0–25 mL
Postop care	Reflux precautions should be observed; patients may require nasogastric tube feeding for several days	Reflux precautions should be observed
Mortality	<1%	<1%
Morbidity	Fistula formation <5% Vocal cord paralysis Hematoma 1–5% Infection 1–5% Aspiration	Perforation <5% Aspiration
Pain score	3–5	3–5

PATIENT POPULATION CHARACTERISTICS

Age range	60–90
Male:Female	1.5:1
Incidence	1 in 50,000; Caucasians
Etiology	GERD; neurogenerative disorders
Associated conditions	GERD

ANESTHETIC CONSIDERATIONS

(See p. 204)

Suggested Readings

1. Dzeletovic I, Ekbom DC, Baron TH: Flexible endoscopic and surgical management of Zenker's diverticulum. Expert Rev Gastroenterol Hepatol 2012; 6(4):449–65.
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LARYNGEAL FRAMEWORK SURGERY (THYROPLASTY, ARYTENOID ADDUCTION, INJECTION LARYNGOPLASTY)

SURGICAL CONSIDERATIONS

Description

Thyroplasty is a surgical technique of medializing a paralyzed vocal fold via placement of an implant inserted through the cartilage of the thyroid ala. Under local anesthesia with intravenous sedation, a skin incision is made at the level of the larynx and the thyroid cartilage exposed. Using a small saw, drill bit, or knife, a window is cut in the cartilage to the level of the inner perichondrium. Lateral pressure is then applied to the paralyzed side to gauge the amount of medialization necessary to improve phonation. Because the shape and size of the implant are created based on the location and degree of medialization needed to improve the voice, it is important for the patient to be awake and able to phonate during the procedure. Often, the patient is kept in a state of deeper sedation in the beginning of the case and then is lightened as the case proceeds to allow the patient to be responsive and interactive with the surgeon. This can be a challenge for the anesthesiologist to strike a happy medium between patient comfort and coherence. After the desired degree of medialization is obtained, the implant is secured in place and the wound closed over a drain.

Description

Arytenoid adduction is often performed in conjunction with thyroplasty. This involves placement of a suture around the muscular process of the arytenoid cartilage, which, when tightened, causes posteromedial rotation of the vocal process and adduction of the vocal fold. Usually, the technique is employed when there is a persistent gap between the vocal folds posteriorly.

Description

Injection laryngoplasty refers to medialization of a paralyzed vocal fold by means of injection, whether percutaneous or endoscopic. Its minimally invasive nature is its chief advantage over thyroplasty or arytenoid adduction. However, the longevity of the injected material and its side effect profile are major determinants as to whether or not this procedure should be considered. Traditionally, Teflon was the injectable material of choice. However, because of the potential for an FB reaction, Teflon has been replaced by more biocompatible materials, such as acellular human dermis, fat, Gelfoam™, and calcium hydroxylapatite to name a few. Because of the low viscosity of some of these injectables, many patients are candidates for percutaneous injection, which can be performed in the office or procedure room under simple topical anesthetic. The patient is seated upright and the nasal cavity topically anesthetized with lidocaine 2% and Neo-Synephrine. A fiberoptic rhinolaryngoscope attached to a camera and television monitor is then passed transnasally to the level of the glottis. Through a 25- or 27-gauge needle, the desired material is injected either transcartilagenously, through the cricothyroid membrane, or under the thyroid ala into the paraglottic space. Observing on the monitor, the material is injected until the desired degree of medialization is obtained. This is well tolerated by patients with minimal pain. Airway obstruction or bleeding is exceedingly rare.

For those who request or require injection under GETA, a 5.0 MLT is desirable. Je ventilation and apneic techniques can also be used. An operating laryngoscope is advanced to the level of the glottis and suspended from a Mayo stand. The paralyzed vocal fold is then injected, usually at the mid and posterior aspects, until adequate medialization is seen. Usually, this entails slight overcorrection such that the medialized fold will now be slightly across midline. Hemostasis if needed is usually obtained with epinephrine-soaked pledgets placed directly on the vocal fold. The scope is then withdrawn and the procedure terminated.

It is important for the anesthesiologist to be aware if a patient has undergone a prior medialization procedure. This is not a contraindication to orotracheal intubation for subsequent procedures requiring GETA. However, traumatic intubation or the use of a tube larger than 6 mm may cause trauma to the adducted fold. A laceration of the vocal fold can potentially expose or dislodge a thyroplasty implant, making it more likely to become infected and potentially extrude.

Usual preop diagnosis

Vocal fold paralysis

ERAS: **Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options.** **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Thyroplasty	Arytenoid Adduction	Injection Laryngoplasty
Position	Supine	⇐	⇐
Special instrumentation	Head and neck set; headlights	–	Operating laryngoscope; laryngeal injection needles; jet ventilation setup
Unique considerations	Overmedialization of the vocal fold can potentially cause stridor and dyspnea; coordination between the surgeon and anesthesiologists is essential to time lightening of anesthesia; stimulation can cause coughing	If GETA is requested, intubate with 5.0 microlaryngeal tube	Overmedialization of the vocal fold can potentially cause stridor and dyspnea
Antibiotics	Cefazolin 2 g	⇐	⇐
Surgical time	2 h	⇐	30 min
EBL	<10 mL	10–20 mL	Minimal
Postop care	Decadron intravenously for 24 h; racemic epinephrine; cool	⇐	Racemic epinephrine; cool mist as needed

	mist		
Mortality	Rare	⇐	⇐
Morbidity	Need for revision: 10–20% Transient dyspnea or laryngospasm Infection: <5% Airway obstruction requiring tracheostomy: 1% Extrusion: rare	⇐ ⇐ ⇐ ⇐	Need for repeat injection common 5–10% Rare ⇐
Pain score	3–4	4–5	1–2

PATIENT POPULATION CHARACTERISTICS	
Age range	18 and over
Male:Female	1:1
Incidence	Common
Etiology	Surgical trauma to recurrent laryngeal nerve; cancer; trauma; idiopathic
Associated conditions	Cancer; coronary artery disease; lung disease; tumors of skull base

Suggested Readings

1. Costello D: Change to earlier surgical interventions: contemporary management of unilateral vocal fold paralysis. Curr Opin Otolaryngol Head Neck Surg 2015; 23(3):181–4.
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ANESTHETIC CONSIDERATIONS

PREOPERATIVE

The laryngeal framework surgery (LFS) is the surgery of choice for dysphonias resulting from incomplete glottic closure or inadequate vocal fold tension. With thyroplasty, direct surgery on the vocal folds is avoided, eliminating the possibility of scarring and voice aggravation. Type I (medialization) thyroplasty is most commonly performed for the unilateral VC paralysis or bowing (in elderly patients) and involves placement of a small silicone implant within the larynx on the affected side.

Airway	No airway problems are usually encountered in these patients.
Cardiovascular	Elderly patients may present with advanced cerebrovascular, cardiovascular, or pulmonary disease. Preop pulmonary aspiration due to glottic incompetence is uncommon but may be seen when the VC paralysis is of central origin, affecting both motor and sensory components of the VC innervation.
Tests	EKG; other tests as indicated from H&P.
Laboratory	Tests, as indicated from H&P.
Premedication	Standard premedication with iv midazolam can frequently be reduced or avoided, especially in the elderly.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of superficial cervical plexus nerve blocks for postop pain management. Consider preop acetaminophen 500–1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Most commonly, thyroplasty is performed under MAC, which allows the surgeon to achieve optimal improvement in the patient's voice quality (sometimes facilitated by visualization of the VC movement through a nasally introduced flexible endoscope) before locking the laryngeal implant in place. It can also be performed under GA, when the concomitant use of the LMA and flexible scope allows a real-time assessment of VC positioning. **Arytenoid adduction** and **injection laryngoplasty** are usually performed under GETA with the use of a small (5.0-mm ID) MLT ETT.

The surgical requirements for **thyroplasty** performed under MAC include patient immobility during injection of local anesthetic; different levels of sedation depending on the phase of surgery (deep during the surgical approach to the cartilage, light for implant placement, and deep again during the surgical closure); absence of straining/bucking/coughing during the implant placement. Manipulation of the thyroid cartilage may necessitate the use of iv opioids.

GETA for **arytenoid adduction** and **injection laryngoplasty** requires full muscle relaxation with quick return of protective airway reflexes and smooth emergence from anesthesia.

When providing MAC for thyroplasty, a quick patient transition to the "light" state for the implant placement is required. A combination of a small dose (1–2 mcg/kg) of iv fentanyl with the iv propofol infusion, or iv midazolam with iv remifentanil infusion (typically, 0.05–0.1 mcg/kg/min to avoid severe respiratory depression), will achieve the stated objective. For a thyroplasty performed under GA, as well as for the GETA employed for an **arytenoid adduction** and **injection laryngoplasty** surgery, the use of TIVA (see Introduction, Anesthesiologist's Perspectives) has been shown to be highly beneficial. **Injection laryngoplasty** procedures are short and can be effectively and safely performed under THRIVE in selected patients.

Tracheal intubations in patients who have undergone thyroplasty should be performed with special care: the use of an ETT stylet should be avoided, a smaller ETT size should be used, and tracheal extubation should be performed smoothly and atraumatically.

Blood and fluid Requirements	IV: 20 ga × 1 LR @ 2 cc/kg/h	EBL is minimal during all the LFS procedures.
Monitoring	Standard monitors ± arterial line	Even in patients with preexisting significant CV disease, A-line monitoring

		is usually not necessary.
Positioning	Table may be turned 90–180° ✓ and pad pressure points ✓ eyes	To prevent claustrophobia, inform the patient presenting for thyroplasty under MAC that his/her face will be partially covered with surgical towels.
Complications	Overmedialization Stridor and dysphonia	Can be quickly corrected by the surgeon.

POSTOPERATIVE

Complications	Wound hematoma Airway obstruction Stridor Extrusion of the prosthesis	
Multimodal pain management	Short-acting opioids	For example, fentanyl 25–50 mcg bolus is usually sufficient. Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with peripheral local anesthetics (see Appendix K, p. K-6)
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition and mobilization

Suggested Readings

1. Hoffman H, McCabe D, McCulloch T, et al: Laryngeal collagen injection as a adjunct to medialization laryngoplasty. Laryngoscope 2002; 112(8 Pt 1):1407–13.
2. Lundy DS, Casiano RR, Xue JW: Can maximum phonation time predict voic outcome after thyroplasty type I? Laryngoscope 2004; 114:1447–54.
3. Remacle M, Lawson G, Jamart J, et al: Treatment of vocal fold immobility by injectable homologous collagen: short-term results. Eur Arch Otorhinolaryngol 2006;

263:205–9.
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5. Rosero EB, Ozayar E, Mau T, et al: A sequential anesthesia technique for surgical repair of unilateral vocal fold paralysis. J Anesth 2016; 30(6):1078–81.

TRACHEAL AND CRICOTRACHEAL RESECTION

SURGICAL CONSIDERATIONS

Description

Prolonged endotracheal intubation and complications from tracheotomy account for most cases of subglottic or tracheal stenosis. Wegener disease commonly affects the subglottic airway, and secondary dyspnea may be the first presenting sign of the disease. In females in the fourth to sixth decades of life, subglottic stenosis can be idiopathic. Whatever the etiology, subglottic and tracheal stenosis can be a major source of morbidity for afflicted patients, resulting in dyspnea, dysphonia, and tracheostomy dependence. In selected individuals, resection of the stenotic region with primary repair can often produce marked and sustained relief of symptoms in a single-stage procedure, often without need for a temporary tracheostomy.

Tracheal resection is the treatment of choice in patients with isolated tracheal stenosis. Up to four to five rings of cartilage can be resected, more if releasing maneuvers to mobilize the larynx and intrathoracic trachea are performed. Induction of anesthesia is simplest in patients with preexisting tracheostomies. For those patients who present without a tracheostomy, a tracheostomy under local anesthesia can be performed at or immediately below the stenotic segment. If possible, it is preferable to dilate the stenosis and proceed to endotracheal intubation to avoid further injury to the trachea with a fresh tracheotomy. With the patient in the supine position, a transverse cervical incision is made. The thyroid isthmus is divided and separated from the cervical trachea. Careful blunt dissection on the lateral aspects of the diseased segment is performed to avoid injury to the recurrent laryngeal nerves. A vertical incision is made along the face of the stenotic segment until a healthy complete ring of cartilage is identified above and below the stenotic segment. The anesthesiologist withdraws the ETT up into the subglottis, and the diseased segment of the trachea is resected. At this time, the surgeon may intubate the distal segment of trachea to afford better access to the superior aspect of the diseased segment. In this case, the breathing circuit will need to be switched from the orotracheal tube to the distal tube. The distal trachea can be more

easily mobilized superiorly following blunt finger dissection along the anterior tracheal wall into the mediastinum. The orotracheal tube is then advanced inferiorly into the distal healthy segment. The healthy distal and proximal segments of trachea are then reanastomosed over the ETT using interrupted sutures. The wound is closed and a drain placed. If the patient is to remain intubated overnight, it is important to ensure that the cuff of the ETT remains inferior to the suture line so as not to put tension on the repair. If the patient is to be extubated in the OR, care should be taken to minimize coughing or bucking so as not to rupture the repair site. Endoscopy can be performed prior to transport from the operating room to ensure that at least one vocal fold is mobile. If neither vocal fold is mobile, a bilateral recurrent laryngeal nerve injury should be suspected and a tracheostomy performed. Regardless of whether or not the patient is extubated immediately or later, fiberoptic laryngoscopy to assess vocal fold motion postop is standard of care. Voice quality is not an adequate assessment of vocal fold function. A paralyzed vocal fold can be midline with complete compensation by the mobile fold and no overt dysphonia. In bilateral vocal fold paralysis, the voice is often normal, and the patient's only symptoms will be dyspnea and stridor.

Cricotracheal resection allows single-stage repair of subglottic or a combined subglottic/tracheal stenosis. The procedure is similar to that of tracheal resection with several caveats. It is important to carefully gauge the relationship of the stenosis to the vocal folds. Stenosis that involves the vocal folds is a contraindication to cricotracheal resection. The anterior arch of the cricoid cartilage is usually resected, along with the subglottic soft tissue component of the stenosis, preserving the cricoid plate. This creates a cradle into which the trachea will slide superiorly. No more than one-third of the inferior aspect of the cricoid plate can be resected. More than this will disrupt the posterior cricoarytenoid muscles and prevent vocal fold abduction during inspiration. As resection proceeds, the ETT will be withdrawn above the glottis. It is helpful at this point to attach an umbilical tape to the distal tip of the ETT to allow the surgeon to assist the anesthesiologist in advancing the tube back through the glottis and into the trachea when the resection is complete. The trachea is sutured to the thyroid cartilage anteriorly and the cricoid ring laterally; the wound is closed; and a drain may be placed. The patient is extubated in the OR and vocal fold mobility checked. Tracheostomy is only required in the setting of bilateral vocal fold paralysis and should otherwise be avoided. As with tracheal resection, a preop assessment of vocal fold motion is critical in planning surgery. If unilateral paralysis is present preop, great care is needed to minimize potential injury to the contralateral recurrent laryngeal nerve.

Usual preop diagnosis

Subglottic stenosis; tracheal stenosis

ERAS: **Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options.** **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Tracheal Resection	Cricotracheal Resection
Position	Supine	Supine
Incision	Transverse cervical	Transverse cervical
Special instrumentation	Major head and neck tray; headlights	⇐
Unique considerations	Intubation may be difficult owing to degree of stenosis; dilation may be required prior to intubation; awake tracheostomy under local anesthesia may be necessary in select cases	⇐
Antibiotics	Cefazolin 2 g iv with metronidazole 500 mg; clindamycin 600 mg; vancomycin 1 g; piperacillin/tazobactam 3.375 g	⇐
Surgical time	3 h	⇐
EBL	50–100 mL	⇐
Postop care	Most patients can be extubated at the conclusion of surgery; coughing and stimulation should be minimized; if significant edema is expected, patients may remain intubated for 24–48 h and then extubated; patients may require temporary NG tube feedings if laryngeal releasing maneuvers performed; monitoring in the ICU setting for airway	⇐

	compromise or subcutaneous emphysema required postop	
Mortality	1–2%	⇐
Morbidity	Restenosis: 10% Vocal cord paralysis: 2–3% Dehiscence: 5% Subcutaneous emphysema: 1–2% Airway edema requiring tracheotomy: 2%	10–15% 3–5% <5% 1–2% 5%
Pain score	5–6	5–6

PATIENT POPULATION CHARACTERISTICS	
Age range	All ages
Male:Female	2:1
Incidence	1% of all patients requiring intubation
Etiology	Prolonged intubation; prior tracheostomy; Wegener disease; external trauma; neoplasm; radiation; gastroesophageal reflux; idiopathic
Associated conditions	Atherosclerosis; asthma; gastroesophageal reflux

Suggested Readings

1. Akhtar N, Ansar F, Baig MS, et al: Airway fires during surgery: Management and prevention. J Anaesthesiol Clin Pharmacol 2016; 32(1):109–11.
2. Chee WK, Benumof JL: Airway fire during tracheostomy: Extubation may be contraindicated. Anesthesiology 1998; 89:1576–8.
3. Hobai IA, Chhangani SV, Alfille PH: Anesthesia for tracheal resection and reconstruction. Anesthesiol Clin 2012; 30(4):709–30.
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LARYNGECTOMY: PARTIAL AND TOTAL

SURGICAL CONSIDERATIONS

Description

Radiation, chemoradiation, and surgery are commonly employed as primary treatment alternatives for laryngeal squamous cell carcinoma. Selected tumors can be removed endoscopically, as reviewed above. Open procedures may be primary or following recurrence after irradiation and are tailored to fit tumor extent. If at least one cricoarytenoid unit (innervated posterior cricoarytenoid muscle and working cricoarytenoid joint) is uninvolved by tumor, the patient may be a candidate for less than a total laryngectomy (TL).

A **vertical partial laryngectomy** (VPL) involves removal of the affected true and false vocal folds and up to one-third of the contralateral folds including the anterior commissure. The contralateral cricoarytenoid unit is preserved, and reconstruction often includes a pedicled sternohyoid flap and thyroid cartilage perichondrium. Exposure and anesthetic considerations are similar to that of a TL (discussed below) other than the fact that a temporary tracheotomy is necessary for any partial laryngectomy.

A **supraglottic laryngectomy** (Figs. 3.4 and 3.5) or **anterior horizontal partial laryngectomy** (AHPL; Fig. 3.6) involves removal of laryngeal structures superior to the true VCs. Both cricoarytenoid units remain. The resection may include some of the base of the tongue. Exposure and anesthetic considerations are the same as for a VPL including a temporary tracheotomy.

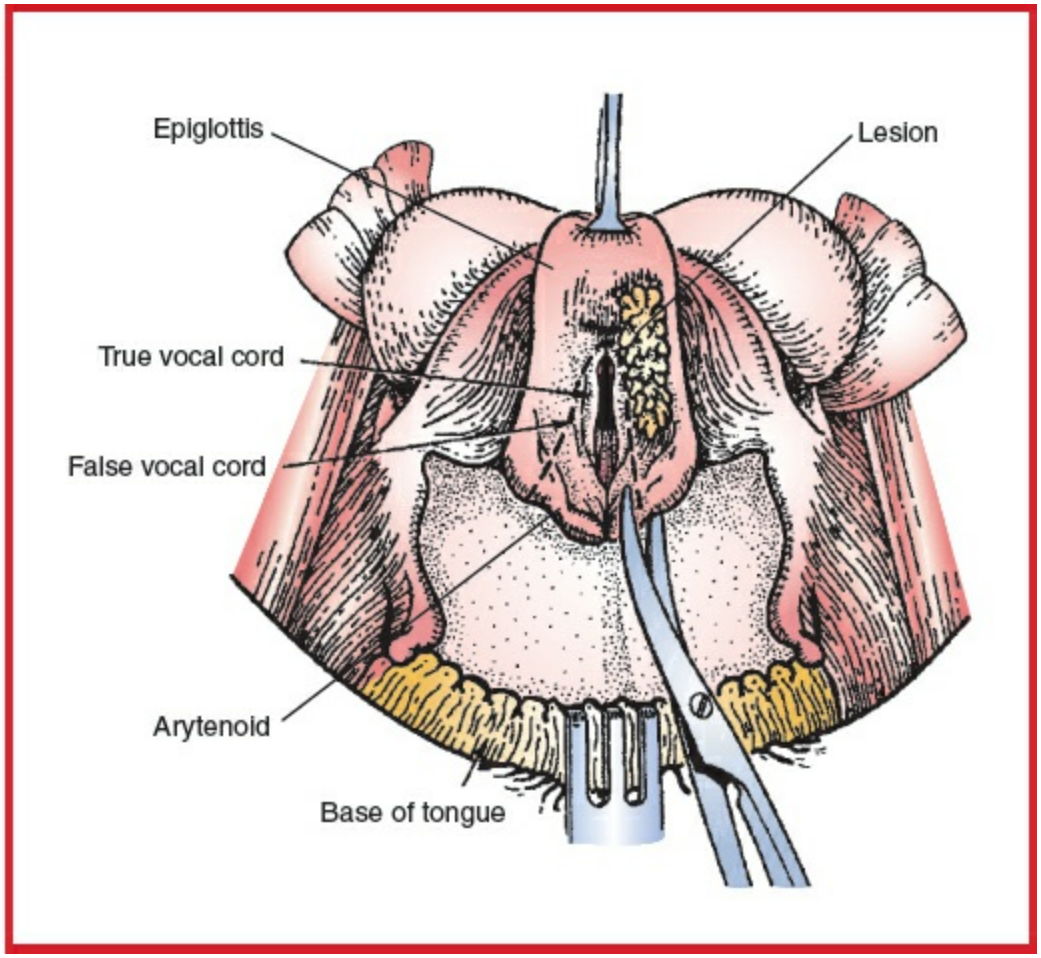

Figure 3.4 The larynx is viewed from the midline, as seen by the surgeon standing at the head of the operating table. Unless the lesion extends posteriorly to the arytenoid, the aryepiglottic fold is transected on each side by placing one blade of the dissecting scissors into the laryngeal ventricle or above the false vocal cord and the other blade in the pyriform sinus. The arytenoid on one side can be resected if the tumor extends posteriorly to involve this structure. (Reproduced with permission from Montgomery WW: Surgery of the Upper Respiratory System, 3rd edition. Williams & Wilkins, Baltimore: 1996.)

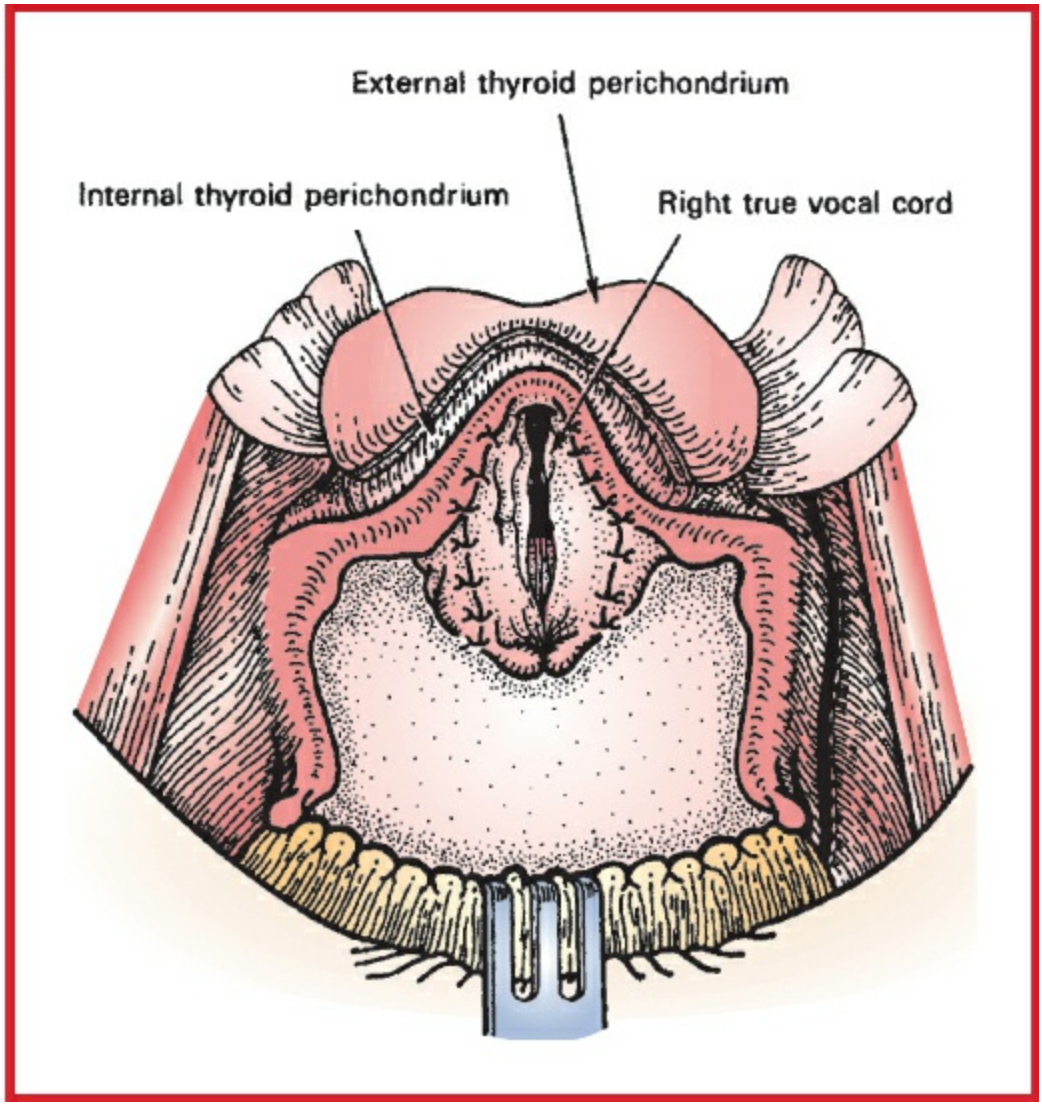

Figure 3.5 The repair following supraglottic partial laryngectomy begins by carefully approximating the margin of the mucous membrane of the pyriform sinus to the lateral margin of the laryngeal ventricle or to the margin of resection above the false vocal cord. There is usually some distortion of the true vocal cord when the repair is accomplished, as is shown on the patient's right side. The repair is continued anteriorly by placing multiple interrupted 3-0 chromic catgut sutures. (Reproduced with permission from Montgomery WW: Surgery of the Upper Respiratory System, 3rd edition. Williams & Wilkins, Baltimore: 1996.)

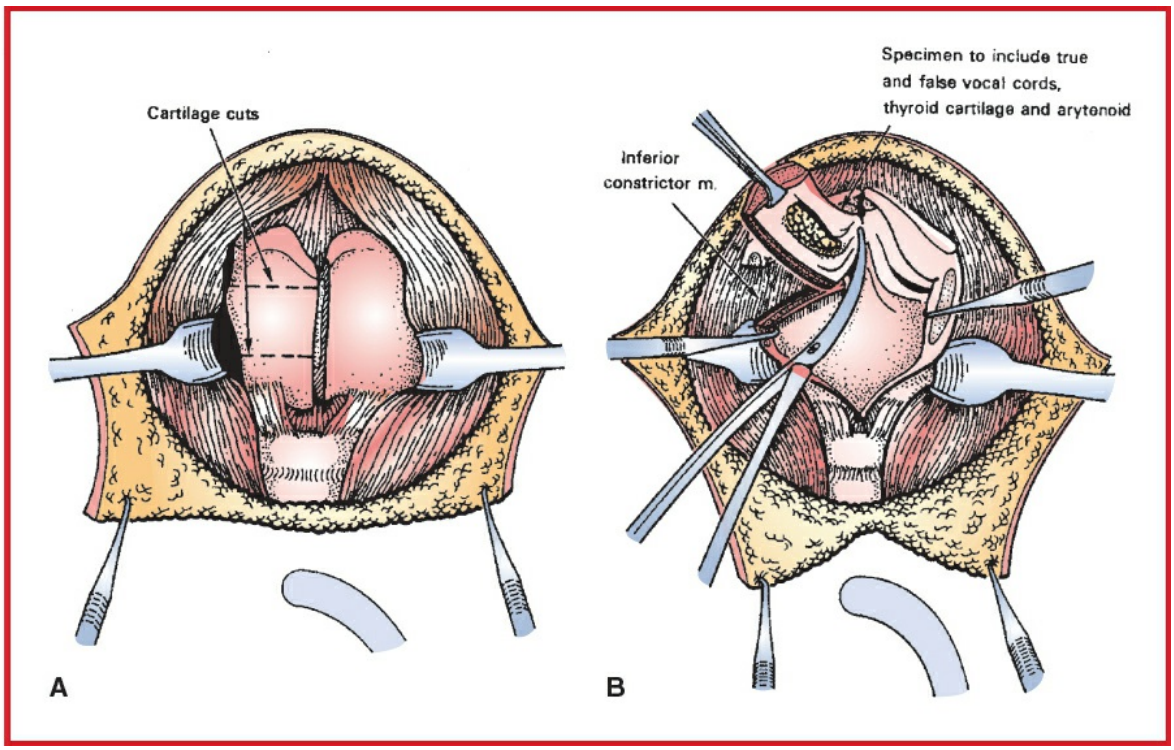

Figure 3.6 **A:** Horizontal incisions, corresponding to the mucosal incision, are made through the thyroid lamina. **B:** The specimen—including true and false vocal cords, the arytenoid, and a portion of the thyroid lamina—is resected en bloc. (Reproduced with permission from Montgomery WW:Surgery of the Upper Respiratory System, 3rd edition. Williams & Wilkins, Baltimore: 1996.)

A **supracricoid laryngectomy** involves removal of the larynx from the top of the cricoid ring to the hyoid bone with preservation of one arytenoid. A temporary tracheostomy is required. Cuts are made superior to the thyroid ala, through the cricothyroid membrane, and anterior to the arytenoid cartilages. The epiglottis may be included in the resection, depending upon the extent of tumor. Blunt dissection anterior to trachea into the mediastinum facilitates superior tracheal mobilization. A cricohyoidopexy (CHP), involving suturing the cricoid to the hyoid bone, is then done with three heavy sutures. If the epiglottis has been preserved, a cricohyoidoepiglottopexy (CHEP) is done. The strap muscles are then used to reinforce the closure, and drains placed.

A **total laryngectomy** involves the resection of the entire larynx, via a transverse 8-cm low midline neck incision, extended via apron incision toward a mastoid tip if a level 2–5 neck dissection is planned. The thyroid gland is often preserved, pedicled on its superior and inferior vasculature after dividing the isthmus; but a partial thyroidectomy may be included. The neopharynx is then closed (after the tracheoesophageal puncture [TEP] [see below], if that is to be done). A nasogastric tube is used for nutrition. As the remaining trachea is sutured to the anterior skin in a true tracheostoma, no tracheotomy tube or ETT is required postop unless there is marked stomal edema or mechanical

ventilation is required, which is uncommon.

A **tracheoesophageal puncture** is often done at the time of a TL. This involves the creation of a tract between the trachea and the esophagus for placement of a voice prosthesis (a one-way valve that allows airflow from the trachea into the pharynx for alaryngeal speech). The voice prosthesis may be placed at the time of the laryngectomy or later. If performed later, it is often placed using the rigid esophagoscopy (see previous section). If TEP is performed at the time of laryngectomy, the valve is generally placed simultaneously. Some surgeons prefer to place a red rubber catheter initially instead, allowing the patient to be fed via this route in lieu of a nasogastric tube, and insert the voice prosthesis later once peroral nutrition obviates the need for a tube. If a rubber catheter is used, the tube will protrude from the stoma, and care must be taken not to dislodge it during suctioning or while removing or replacing the laryngectomy tube if one is temporarily used.

A TL can be extended to include part of the hypopharynx or oropharynx. If flap reconstruction is necessary because of the extent of the tumor, options include a pectoralis major myocutaneous flap or a free flap, such as a radial free flap, to reconstruct less than a circumferential defect. If a circumferential defect following resection exists (e.g., after resection of the superior cervical esophagus and the larynx), options for reconstruction include use of a laparoscopically harvested jejunal free flap, gastric pull-up, or a tubed radial free flap possibly reinforced with a pectoralis major myogenous flap.

Postop care

Inpatient admission for 5–10 d, monitored bed for tracheostomy or free flap care, and a cuffed tracheostomy tube (and a temporary tracheotomy) will usually be required for partial laryngectomy patients or if the patient will require postop mechanical ventilation. A short tracheostomy tube following a TL may be needed if there is significant peristomal edema or if mechanical ventilation is required. General and drain management is similar to that of a neck dissection.

Usual preop diagnosis

Cancer of the larynx; intractable aspiration with resultant pneumonia unresponsive to other techniques

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Total or Partial	Pharyngolaryngectomy
Position	Supine, head extended	⇐
Special instrumentation	Major head/neck set; headlights	⇐
Unique considerations	Laryngeal tumors may distort airway. Fiberoptic intubation or other management of the difficult airway should be considered. May be combined with neck dissection	⇐
Antibiotics	Cefazolin 2 g and metronidazole 500 mg; clindamycin 600 mg	⇐
Surgical time	2–4 h; 4–8 if neck dissection added	8+ h; reconstruction required +/– free flap
EBL	50–150 mL With neck dissection: up to 250 mL Transfusions: rare	⇐ ⇐ ⇐
Postop care	Tracheotomy care, drain management, tube feedings	⇐
Mortality	<1%	⇐
Morbidity	Fistula formation: 5%: 15–20% if prior irradiation Hematoma: <4% Infection: <5% DVT/PE: <1%	1% ⇐ ⇐ ⇐
Pain score	4–6	4–7

PATIENT POPULATION CHARACTERISTICS	
Age range	40–80, occasionally older and younger
Male:Female	3:1
Incidence	Common
Etiology	Smoking; alcohol
Associated conditions	COPD; atherosclerosis; diabetes

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

See preop considerations for Neck Dissection.

Airway	If a stridor at rest is present, its severity must be carefully evaluated. Patients with symptoms and signs of severe obstruction (complaints of difficulty breathing, nocturnal symptoms, sleeping upright, use of accessory muscles on inspiration at rest) will likely be difficult to ventilate and intubate.
Respiratory	Patients with severe stridor may manifest baseline hypoxemia (with or without hypercarbia) 2° ↓ airway diameter and atelectasis caused by ↓ ability to effectively handle secretions.

INTRAOPERATIVE

Anesthetic technique

GETA: Although tracheostomy is universally performed in TL patients, smooth emergence is still important 2° delicate suture lines. Full muscle relaxation is essential. Moderate ↓ BP (see Introduction) is desirable but may be limited by concomitant cardiovascular disease.

Induction	Slow-growing upper airway tumors can cause a high-grade airway obstruction without significant associated symptoms. Accommodated respiratory

muscles can sustain adequate alveolar minute ventilation at rest through a 3-mm orifice, but acute deterioration occurs when a critical narrowing is reached. A preop endoscopic airway examination (PEAE) should be performed in all ENT patients with symptoms of upper airway obstruction. It is the only technique that allows visualizing the lesion and degree of obstruction directly, and assessment of respiratory mechanics and tumor mobility.

There is no universal recipe for management of advanced airway obstruction occurring at supraglottic, glottic, or subglottic levels. An awake flexible scope intubation, inhalation induction, and intravenous induction with muscle relaxants have been used successfully, but none should be considered fail-safe. The patient with a partially obstructed airway requires a team approach with cooperation of the ENT surgeon for devising optimal airway management strategies. The use of THRIVE during intubation attempts should be strongly considered in these patients.

If stridor is **absent** and airway assessment is normal, standard induction followed by DL may be appropriate. The use of VL is strongly recommended to maximize laryngeal exposure. A combined video intubation technique can be highly effective in these patients, as it permits continuous visualization of the intubation procedure both from above and below the lesion, minimizing the chance of tumor disturbance. An awake flexible scope intubation may fail with obstructing glottic lesions, either because of the inability to displace the tumor or because ETT simply would not pass. A forceful advancement of ETT off the flexible scope may cause tumor fragmentation, bleeding, and contamination of the lower airway and may precipitate complete airway obstruction.

Patients with **moderate stridor** and a significant lesion seen on PEAE, but who are considered

	possible to intubate, can be managed with an awake flexible scope intubation or an inhalation induction. Inhalation induction is best reserved for noncollapsing lesions that can be rescued by mask ventilation. A sufficiently deep and stable plane of anesthesia is essential to avoid loss of the airway (e.g., cough, laryngospasm). The ENT surgeon should be present in the OR, ready to perform rigid bronchoscopy or emergent tracheostomy. If the airway cannot be secured after two attempts, tracheostomy must be performed under controlled conditions with the patient anesthetized and breathing spontaneously. In patients with **severe stridor** and low probability of successful intubation, a preliminary tracheostomy should be performed under local anesthesia without any sedation. Other anesthetic considerations are similar to those in neck dissection.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	See Anesthetic Considerations for Neck Dissection. After tracheostomy, a sterile reinforced ETT (6.0–7.0-mm ID) is inserted by the surgeon and connected to an anesthesia breathing circuit. Proper ETT placement should be confirmed by presence of $ETCO_2$ equal bilateral breath sounds and normal airway compliance. Following tracheostomy, ↑ FiO_2 to at least 50% because the surgeon will continue working around the ETT, occasionally removing it from the patient's trachea for suture application. The position of the ETT in the tracheostoma should be monitored closely to prevent the ETT from slipping into the right mainstem bronchus.
Emergence	See Anesthetic Considerations for Neck Dissection. Discuss with surgeon about local wound. Consider iv

acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.

For further discussion, see Intraoperative Considerations for Neck Dissections.

POSTOPERATIVE

See Postop Considerations for Neck Dissections.

Suggested Readings

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10. See Suggested Readings for Neck Dissection.

TONSILLECTOMY AND/OR ADENOIDECTOMY

SURGICAL CONSIDERATIONS

Description

The dissection for **tonsillectomy** is carried out with the patient supine, shoulders elevated on a small pillow (Fig. 3.7). A mouth gag is inserted, and if an **adenoidectomy** is being done concurrently, adenoids are removed first with a curette, and the nasopharynx packed. The palatine tonsil is dissected from underlying constrictor and removed. Hemostasis is secured with various techniques, such as electrocautery. Tonsillectomy may be combined with **palatopharyngoplasty** for obstructive sleep apnea (OSA). If an oropharyngectomy ("radical tonsillectomy") is being done for oncologic reasons, TORS may be used, the resection is more extensive, and the procedure may be combined with a level 2–4 neck dissection.

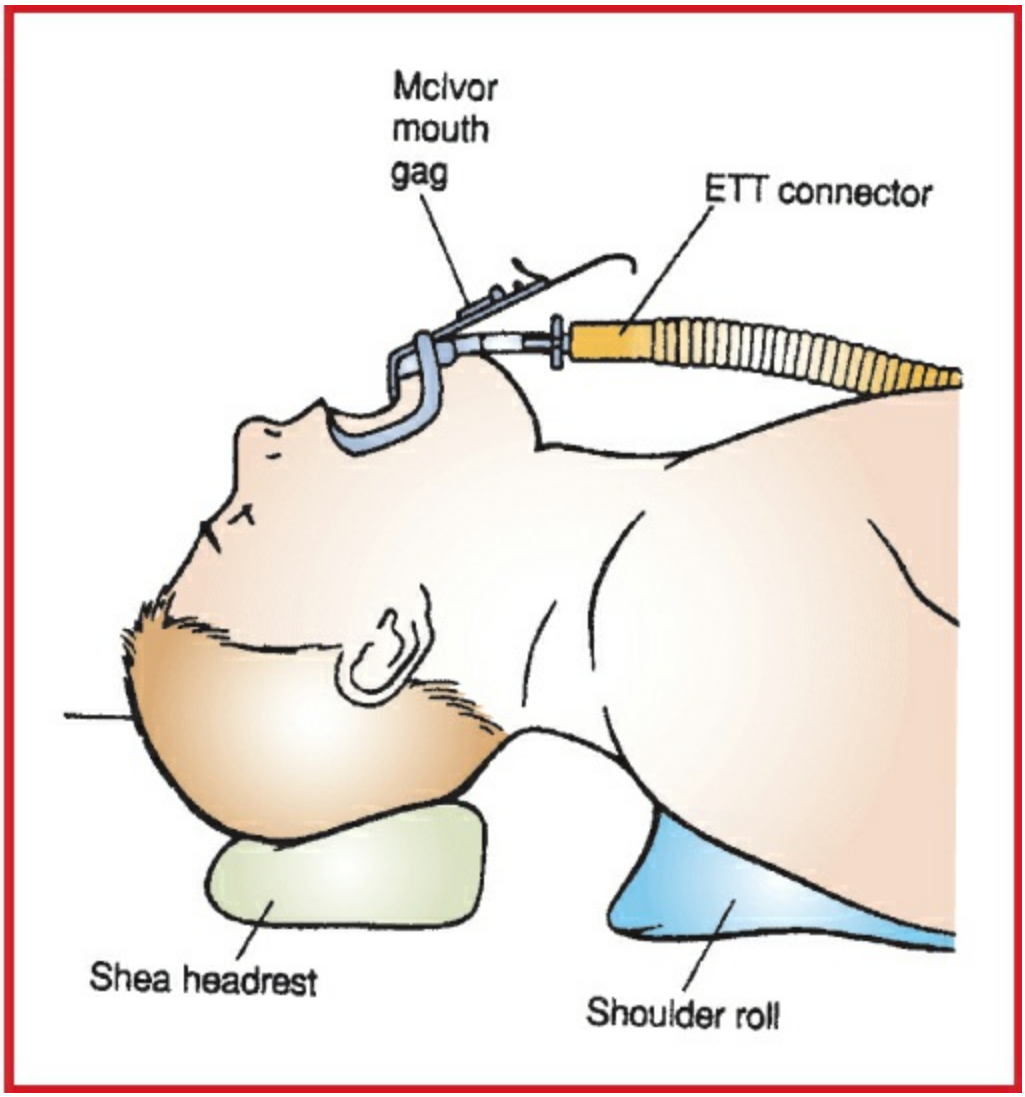

Figure 3.7 The "Rose" position for tonsillectomy.

Variant procedure or approaches

Guillotine technique (rarely used)

Usual preop diagnosis

Chronic tonsillitis and/or adenoiditis (most common); OSA; asymmetric enlargement o tonsils (to r/o cancer); nasal airway obstruction; snoring; peritonsillar abscess

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	"Rose" (supine, shoulder roll, head extended); surgeon at head of table (turned 90–180°)
Incision	Intraoral mucosal
Special instrumentation	Mouth gag (McIvor)
Unique considerations	Use of armored ETT prevents compression of tube by mouth gag. Tube should be secured to lower lip in midline
Antibiotics	Amoxicillin po
Surgical time	30–60 min
Closing considerations	If patient has OSA, a heightened sensitivity to narcotics and sedatives may make emergence more difficult. Avoid hypercapnia on emergence to prevent vasodilation and resultant bleeding. Awake extubation will provide maximum airway protection
EBL	25–200 mL. Monitor suction bottle contents and irrigation as an indication of blood loss
Postop care	Lateral position; head down; gentle suctioning
Mortality	Rare
Morbidity	Bleeding: 4% Infection: 4% Delayed bleeding: 3.2% Aspiration: Rare

	Tooth damage: Rare
Pain score	4–6

PATIENT POPULATION CHARACTERISTICS

Age range	2+ yr
Male:Female	1:1
Incidence	50 per 10,000 children in the United States
Etiology	Chronic infection; OSA (most common indication); peritonsillar abscess; snoring; cancer
Associated conditions	Nonspecific

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Most patients are young and otherwise healthy; however, a subset of both pediatric and adult patients may present with OSA or URI. For many children, this is their firs anesthetic; therefore, it is imperative to ✓ family Hx for anesthetic problems. Most adult and pediatric patients are discharged from the hospital on the day of surgery. If TORS is being done, a neck dissection may also be planned.

Airway	In patients with Hx of snoring or OSA, the probability of difficult mask ventilation and/or intubation may be high, 2° airway characteristics peculiar to these patients (see Introduction and Anesthetic Considerations for Reconstructive Surgery for Sleep-Disordered Breathing). In children with short-stature syndrome, including achondroplastic dwarfism and selected cases of Down syndrome, atlantoaxial subluxation and stenosis of the spinal canal may be present, and neck extension in these patients should be avoided.
Respiratory	In patients presenting with Sx of acute URI (purulent sputum or nasal secretions, fever, etc.), the general recommendation is to postpone any elective

	procedure until symptoms have abated, usually within 7–14 d. **Tests:** As indicated from H&P
Dental	The presence of chipped, loose, or broken teeth should be documented preop, and the patient (or parents, if appropriate) should be informed that there is a possibility of further tooth damage/dislodgement by the mouth gag applied by the surgeon.
Cardiovascular	Rarely, chronic airway obstruction (e.g., OSA) with hypoxemia may → pulmonary HTN and right heart failure. Patients with Down syndrome may have concomitant CHD. **Tests:** As indicated from H&P
Hematologic	✓ for recent aspirin use and Hx of excessive bleeding following minor trauma or tooth extraction.
Laboratory	CBC; other tests as indicated from H&P
Premedication	Sedative premedication is routine but should be avoided in OSA patients and patients with Sx of upper airway obstruction. Some surgeons request preop administration of an antisialagogue to achieve a dry surgical field.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 500–1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Balanced GETA is most commonly used in adults. Adequate muscle relaxation is an essential surgical requirement: it facilitates surgical exposure and prevents patient from swallowing. Continuous control and protection of the airway is another major objective, along with smooth emergence from anesthesia and prevention of early postop laryngospasm. Specific airway considerations include the possibility of difficult mask

ventilation and/or difficult intubation 2° large tonsils and ↓ pharyngeal space, as well as the possibility of intraop obstruction of the ETT with the mouth gag placed by the surgeon.

Induction	An **intravenous induction** with propofol (2 mg/kg) and fentanyl (2–3 mcg/kg) is suitable for the majority of patients. If difficulty with mask ventilation is encountered, an oral airway is preferred to a nasal airway, 2° the possibility of trauma to the hypertrophied adenoid tissue and the resultant brisk bleeding. Patients with peritonsillar abscess may have trismus, which usually resolves after induction of anesthesia and administration of a muscle relaxant. Great care should be exercised with introduction and manipulation of laryngoscope blade to avoid bleeding 2° inadvertent trauma to the enlarged tonsils and to prevent soiling of the airway in patients with a peritonsillar abscess. The lightwand technique of tracheal intubation should be avoided in these patients. The use of a small (6.0 mm ID) reinforced ETT is preferred over an oral RAE ETT because of better resistance to kinking/obstruction by the mouth gag. The use of an FLMA can safely protect the airway during adenotonsillectomy and reduce the incidence of postextubation complications in adults and children. Its use for this procedure, however, has not become popular in the United States.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Opening of a mouth gag and the tonsillectomy itself constitute powerful noxious stimuli; therefore, an adequate depth of anesthesia must be maintained. It is essential to verify the ETT position before and after Boyle-Davis or McIvor mouth gag application (e.g., chest movement, bilateral and equal breath

	sounds, and normal PIP) since the ETT may be obstructed, dislodged, kinked, or inadvertently advanced into a mainstem bronchus, or the patient's trachea can be prematurely extubated when the mouth gag is repositioned/removed. Moderate ↓ BP is desirable but not obligatory; and judicious use of vasoactive drugs (see Introduction) is preferred to deep levels of anesthesia 2° short duration of the procedure. Low-dose remifentanil infusion (see Introduction) as part of either balanced or TIVA technique will provide superior hemodynamic stability and facilitate smooth emergence from anesthesia. For a balanced inhalational technique, desflurane and sevoflurane are the preferred agents for these short surgical procedures. Isoflurane may be favored in pediatric patients 2° ↓ agitation on emergence. The mouth gag may be repositioned several times during the procedure and is removed only at the end of the case. Vigorous patient movement while the mouth gag is hooked on the Mayo stand may cause C-spine injury; thus, neuromuscular blockade should usually be maintained until the end of the surgery. Prevention of PONV is of major importance. If a throat pack is not used by the surgeon, the patient's stomach should be suctioned at the end of the case, and further gastric emptying may be facilitated by administration of metoclopramide (1–2 mg/kg up to 20 mg iv). Administration of 5-HT_3 blockers (e.g., ondansetron 0.1 mg/kg up to 4 mg iv), with or without steroids (e.g., dexamethasone 4–12 mg iv), will usually provide adequate antiemetic prophylaxis.
Emergence	Removal of a throat pack (if used by the surgeon) should be verified before extubation. Care must be exercised while suctioning the oropharynx to avoid bleeding. The use of the rubber-tipped vs. Yankauer tip suction catheter may be preferred. Extubation should be smooth and performed after the patient is

	able to follow commands because this usually signifies return of protective airway reflexes. If extubation is to be performed at deeper levels of anesthesia (e.g., in small children), the patient should be placed in the lateral decubitus, head-down position ("tonsillar position") to protect the airway from soiling 2° postop bleeding or aspiration of gastric contents. The patient should remain in this position until fully awake. This method of extubation is time and labor consuming, requires adequate depth of anesthesia to prevent postextubation laryngospasm, and does not prevent postextubation upper airway obstruction. Careful attention is required to protect patient's pressure points and to prevent the patient from rolling supine. Furthermore, with the head-down position, venous pressure in the surgical wound is increased with the possibility of provoking postop bleeding. This method of extubation cannot be advocated for routine use in adults. Discuss with surgeon local wound infiltration. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 18 ga × 1 (adult) 20 ga × 1 (child) BSS @ 2–4 mL/kg/h (adult)	Blood loss is typically minimal. Adequate hydration should continue in the immediate postop period. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes	See Anesthetic Considerations for Panendoscopy.
Complications	ETT obstruction dislodgement Bleeding	ETTs of different sizes should be readily available.

		Blood loss sometimes may be difficult to assess 2° drainage into stomach, especially if a throat pack is not used. Careful observation of suction canisters and close communication with the surgeon are essential.

POSTOPERATIVE

Complications	Retention of throat pack	Manifested by immediate symptoms of upper airway obstruction. Under direct laryngoscopy, remove pack with Magill forceps.
	Laryngospasm	A relatively common complication, particularly in the pediatric population. Rx: 100% O_2 via mask ventilation with jaw thrust and CPAP. Rapid-sequence induction (RSI) and direct laryngoscopy/intubation for persistent laryngospasm.
	Bleeding tonsil	Bleeding usually occurs at a slow pace; large volumes of blood may be swallowed, and hypovolemia may occur before any bleeding is detected. Frequent swallowing should alert to the possibility of ongoing

		hemorrhage. ET intubation (RSI) may prove difficult due to poor visualization secondary to bleeding (effective suction must always be available) and upper airway edema.
	Postobstructive (negative pressure) pulmonary edema (POPE)	POPE is a rare complication; however, it may occur in patients with preexisting symptoms of severe upper airway obstruction. Although most cases resolve spontaneously, some patients may require reintubation and postop ventilatory support.
Multimodal pain management	Adult tonsillectomy is a painful procedure	However, most patients are discharged home unless unable to sustain po intake. Fentanyl is the preferred PACU drug, but the addition of morphine or hydromorphone may be necessary in some patients. Ibuprofen works as well as acetaminophen/opiate combinations. Ice water or lidocaine-containing mouth rinse can provide temporary pain relief.
Tests	Hct	If blood loss is suspected.
ERAS	PONV protocol (see	Encourage early enteral

	Appendix B, p. B-1)	nutrition, Foley catheter removal, and mobilization.

Suggested Readings

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GLOSSECTOMY

SURGICAL CONSIDERATIONS

Description

Partial glossectomy is done for many tongue malignancies. During this procedure, nasal intubation may be helpful but is not mandatory. Complete muscle relaxation is necessary. Surgical exposure is improved with a bite block placed laterally and a lip retractor. The lesion is resected with electrocautery. Reconstruction is either advancing the tongue on itself or to the floor of the mouth, or a radial free flap may be indicated. Depending on the size and location of the tumor and whether a free flap is planned, a **tracheostomy** may be indicated; or nasal intubation alone may suffice for a few days. A short course of steroids may help reduce tongue edema. An NG tube is often used for postop feeding.

Variant procedure or approaches

Glossectomy can be done with a **neck dissection** (in which case the neck dissection may be in continuity or done via a separate sterile field**)** or as part of a composite resection (which includes a **partial marginal or segmental mandibulectomy** and may include an osteocutaneous free flap reconstruction and hence a tracheotomy). Rarely, a **total laryngectomy** is also done.

Usual preop diagnosis

Neoplastic disease of the tongue or adjacent structures (e.g., alveolus, floor of mouth) with involvement of the tongue

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Partial	If with composite resection
Position	Supine	⇐
Incision	Intraoral	⇐ + suprahyoid approach/neck approach
Special instrumentation	Mouth gags per surgeon	⇐
Unique considerations	Hypotensive anesthesia Nasal intubation Possible tracheostomy Steroids, if tracheostomy not performed	⇐ ⇐ ⇐ (required)
Antibiotics	Cefazolin 2 g iv with, metronidazole 500 mg	⇐
Surgical time	1–3 h	3–8 h
Closing considerations	Local or free flap. Nasal ETT 24–48 h possibly if minimal tongue edema	Flap repair required Tracheostomy postop
EBL	50–150 mL	100–300 mL

Postop care	Intubated 24–48 h	Tracheostomy care
Mortality	<1%	⇐
Morbidity	Bleeding Infection Aspiration	Aspiration Bleeding Infection
Pain score	1–2	2–4

PATIENT POPULATION CHARACTERISTICS

Age range	Adults
Male:Female	3:1
Incidence	Uncommon
Etiology	Neoplasia
Associated conditions	Nonspecific

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

See Preoperative Considerations for Neck Dissection.

Airway	Thorough airway assessment is mandatory. Nasal intubation may or may not be required, depending on location of tumor (side vs. base of tongue [BOT]) and surgeon's preference (inquire preop).
Premedication	Standard. Preop administration of antisialagogue (e.g., glycopyrrolate 0.2 mg iv) may improve operating conditions—check with the surgeon.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 500–1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: Complete muscle relaxation is an essential surgical requirement. For partial glossectomy, smooth extubation is desirable but not mandatory unless skin graft was used for closure (graft hematomas are the primary cause of skin graft failure). Intraop infiltration with a local anesthetic effectively supplements intraop and postop analgesia.

Induction	With a normal airway and submucosal location of tumor on the side of the tongue, standard induction is appropriate. With mobile, fungating BOT tumors, awake flexible scope intubation may be a safer approach. Similar to the considerations for laryngectomy (see Anesthetic Considerations for Laryngectomy), direct visualization of the passage of the ETT through the VC (DL or VL) is essential, to reduce the risk of tumor fragmentation with seeding of the lower airway or bleeding. Among the video laryngoscopes, the Pentax Airway Scope™ (AWS) is beneficial for use in BOT pathology, as the blade lodges under the epiglottis. Large immobile tumors may make ET intubation by conventional means extremely difficult or impossible. Awake nasal FOI may be the technique of choice in these cases. **Transoral robotic surgery (TORS)** is increasingly used for many BOT operations, as well as for procedures including supraglottic laryngectomy. See discussion below.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	During a partial glossectomy, closure is quick, and short-acting inhalational agents (desflurane, sevoflurane) may be favored; TIVA may also be employed. ↓ BP (see Introduction), although desirable, is not mandatory for partial glossectomy. If tracheostomy is performed as part of the planned procedure, the usual considerations apply (see

	Anesthetic Considerations for Laryngectomy, and Tracheostomy).	
Emergence	With prolonged procedures, especially involving BOT tumors, it is prudent to assess the degree of upper airway edema prior to extubation (it may be impossible to reintubate the patient if postextubation upper airway obstruction occurs). Rapid recovery with full return of protective airway reflexes is essential in patients after partial glossectomy. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Complications	Vagal reflexes: ↓ HR, ↓ BP, mediated by surgical manipulation at the base of the tongue	Rare. Rx: notify surgeon; deepen anesthetic; iv atropine (0.4 mg).

For further discussion, see Intraoperative Considerations for Neck Dissection.

POSTOPERATIVE

Complications	Postop airway obstruction	May occur 2° ↑ airway edema; emergent tracheostomy may be required. Prophylactic intraop steroids are beneficial.
Multimodal pain management	PCA Parenteral opiates	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with peripheral local anesthetics (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition, Foley catheter removal, and

	mobilization.

For further discussion, see Neck Dissection.

Suggested Readings

1. Feldman MA, Patel A: Anesthesia for eye, ear, nose, and throat surgery. In: Miller RD, ed. Miller's Anesthesia, 7th edition. Elsevier, Philadelphia: 2010, 2357–88.
2. Nekhendzy V, Biro P: Airway management in head and neck surgery. In: Hagberg C, ed. Hagberg's Benumof Airway Management, 4th edition. Elsevier Saunders, Philadelphia: 2018, 668–91.

ANESTHETIC CONSIDERATIONS FOR TRANSORAL ROBOTIC SURGERY

TORS is becoming the technique of choice for treating a wide range of primary oropharyngeal and laryngeal cancers and for performing multilevel surgery for OSA, including base of the tongue (BOT) reduction and uvulopalatopharyngoplasty (UPPP). With TORS, surgery proceeds from the inside out, starting with the mucosal surface and extending outward, eliminating the need for skin incisions or transmandibular access, and also decreasing the need for tracheostomy. A highly magnified view of the surgical pathology, increased depth perception, and elimination of surgical tremor lead to shorter hospital stays and better functional outcomes affecting long-term speech and swallowing.

The essential anesthetic requirements for precision TORS surgery include the ability to safely share the patient's airway with the surgeon; enhanced situational awareness; a clear, quiet surgical field; and the absence of patient movement to ensure optimal surgical conditions to allow preservation of function. As usual, the anesthetic technique should include a stable plane of anesthesia, nonstimulating emergence, rapid return of consciousness and protective airway reflexes, and adequate PONV prophylaxis.

PREOPERATIVE

For preop considerations, see Preoperative Considerations for Neck Dissection and Glossectomy.

Airway	Thorough airway assessment is mandatory (see Introduction) and should include assessment of the patency of the nasal passages for nasotracheal intubation.

Premedication	Standard. Preop administration of an antisialagogue (e.g., glycopyrrolate 0.2 mg iv) may improve operating conditions—check with the surgeon.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of superficial cervical plexus nerve blocks for postop pain management. Consider preop acetaminophen 500–1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: Complete muscle relaxation and clear surgical field are the essential surgical requirements.

Induction and airway management	IV induction is used in the majority of patients. If the airway is compromised, strategies for atraumatic tracheal intubation should be devised and discussed with the surgeon (see Introduction and Anesthetic Considerations for Laryngectomy). A nasal intubation with a small-diameter (6.0 mm ID) microlaryngeal tracheal (MLT) tube is preferred, to improve the view and accommodate surgical instrumentation. The MLT tube is sutured in place through the nasal septum by the surgeon, and a 120° curved metal ETT connector is used to direct the anesthesia circuit over the patient's head and provide unrestricted intraoral access for the surgeon. For TORS-assisted laser surgery, patients may be intubated orally or nasally with a laser ETT. With nasal intubation, the anesthesiologist must ensure sufficient depth of ETT placement to prevent the accidental withdrawal of the ETT into the larynx during surgical manipulations and/or extending

	patient's head intraop. A sudden air leak may immediately compromise the field during precision surgery and also create an airway fire hazard during the use of laser or electrocautery. The unrecognized ETT displacement out of the trachea and into the glottis may prompt the anesthesiologist to repeatedly add more air to ETT cuff, which overtime may lead to compression of the anterior branch of the recurrent laryngeal nerve and VC injury. Special attention should be directed to adequately protecting the patient's eyes with special safety goggles to prevent accidental injury due to heavy surgical instrumentation.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Increased situational awareness is required at all times, as TORS is performed with OR lights switched off. All the lines, anesthesia circuit, and patient's position on the OR table must be secured and checked. Any intraop adjustment of equipment or the OR table by the anesthesiologist should be closely coordinated with the surgeon. BIS-type–guided TIVA with propofol and opioid represents the author's anesthetic technique of choice. The full synergistic effect of propofol with remifentanil allows quick titration of the anesthetic to the desired clinical effect. Intermittent iv fentanyl or sufentanil boluses, as well as IV administration of acetaminophen, are warranted for supplementing propofol/remifentanil TIVA, as postop pain after TORS is usually moderate. Large doses of iv fentanyl/sufentanil are usually unnecessary.
Emergence	Rapid recovery with full return of protective airway reflexes is essential. The majority of patients are

	extubated routinely after adequate reversal of NMB. A staged extubation using an airway exchange catheter (AEC) is rarely required but may be necessary following prolonged procedures, especially involving BOT, posterior airway, or laryngeal work. If postop airway patency is deemed problematic, patient should be left intubated. Postop tracheostomy is rarely indicated. Discuss with surgeon local wound infiltration or nerve block (e.g., superficial cervical plexus block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Complications	Vagal reflexes: ↓ HR, ↓ BP, mediated by surgical manipulation at the base of the tongue	Rare. Rx: notify surgeon; deepen anesthetic; iv atropine (0.4 mg).
Blood and fluid requirements	IV: 18 ga × 1. BSS @ 3–4 cc/kg/h.	Blood loss minimal. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors. ± art line.	A-line monitoring may be indicated by patient's medical history.
Positioning	Head may be elevated 20–30° Table 180° ✓ and pad pressure points ✓ and protect the eyes with goggles	

POSTOPERATIVE

Complications	Postop airway obstruction	May occur 2° ↑ airway edema. Prophylactic intraop steroids are beneficial.
Multimodal pain	PCA/parenteral opiates	Emphasize multimodal

management	Multimodal analgesia	approach combining nonopioid and bolus/PCA opioid analgesics with peripheral local anesthetics (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

MAXILLECTOMY AND ORBIT EXENTERATION

SURGICAL CONSIDERATIONS

Description

Partial maxillectomy and/or **orbital exenteration** (OE) may be required for some malignancies. In an **OE**, the contents of the orbit are removed, including the eyeball and its attached extraocular muscles posterior toward the conus. This can be done via an incision that is made around the upper and lower eyelashes, occasionally with an extension that includes a limited incision for an external ethmoidectomy; a lateral rhinotomy incision is rarely needed. If the eyelid skin is not involved by tumor it is preserved other than the eyelashes and lid margins. Bradycardia may occur with dissection near the optic nerve.

A **maxillectomy** may be done with the orbit exenteration or independently. If the superior maxilla is removed as part of the OE, with palate preserved, the incision is the same as for just the OE as access to the superior maxilla is provided by the exenteration. If only a partial maxillectomy is to be done preserved, whether the hemipalate is to be preserved or not, the resection can often be done fully through an intraoral incision. For example, if the hard palate is to be preserved, the approach is similar to that of a Caldwell-Luc. If the hard palate is to be removed (as for a tumor involving the alveolar ridge and extending into the maxillary sinus), then the transoral resection of the alveolar ridge usually provides adequate access for the complete resection. Rarely, a transfacial partial Weber-Ferguson incision is needed, or endoscopic equipment may be used to supplement access. Osteotomies are generally made with power equipment, though osteotomes and rongeurs may at times be adequate.

Reconstruction of palate defects are generally done with an obturator with or without a split-thickness skin graft placed intraoperative on exposed soft tissue. A free flap is selectively an alternative, such as in a younger patient or when too little hard palate and too few teeth remain to stabilize a large obturator. There are a number of options to reconstruct orbit defects depending on whether skin is also resected. These options include the pericranial-galeal flap discussed for anterior cranial base surgery, a free myogenous flap such as an anterolateral thigh (ALT) flap or a radial free flap.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Maxillectomy	Orbital Resection
Position	Head raised 30°, back raised (reduces bleeding)	⇐
Incision	Intraoral	Eyelash incisions
Special instrumentation	Paranasal sinus set; headlight	⇐
Unique considerations	Nasal pledgets	⇐; see reconstruction
Antibiotics	Cefazolin 2 g iv with metronidazole 500 mg; or clindamycin 600 mg	Cefazolin 2 g
Surgical time	2–4 h	1.5–3 h
EBL	100–300 mL	25–100 mL
Postop care	Same as endoscopic surgery	Reconstruction dependent
Mortality	Rare	Very rare
Morbidity	Bleeding: 5% Transient diplopia: 5% Infection: 5%	⇐ ⇐

Pain score	2–3 if no oral entry; 4–6 if palate	2–4

PATIENT POPULATION CHARACTERISTICS		
Age range	50–70	40–80
Male:Female	3:1	2:1
Incidence	Common	⇐
Etiology	Malignant tumors, selected benign tumors	Malignancies, rare benign processes
Associated conditions	Tobacco, alcohol, rare others	⇐

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Typically, these patients are older males who may have concomitant cardiopulmonary disease. Their nutritional status is not usually affected.

Airway	For patients presenting for maxillectomy, careful inspection is warranted, although it is unlikely that the disease process will → airway compromise. With large tumors, space available for laryngoscope blade manipulation may be somewhat decreased. XRT typically is done postop.
Cardiovascular	Preop evaluation should focus on the patient's suitability for controlled ↓ BP: may be contraindicated in patients with advanced cerebrovascular or cardiovascular disease. **Tests:** ECG; other tests as indicated from H&P
Laboratory	Tests as indicated from H&P
Premedication	Standard premedication
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 500–1000 mg po with sip of water. Consider aprepitant 40–80 mg po with

	sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: Bifrontal craniotomy may be required if the disease process extends into the paranasal sinuses, dura, and anterior skull base. These procedures can be lengthy and very stimulating; the use of potent opioids (see Introduction) is beneficial. The essential surgical requirement is ↓ bleeding into the field. Intraop hemorrhage may occasionally be brisk and substantial (in excess of 500 cc) during maxillectomy. Maintaining adequate circulating volume is crucial. Promotion of rapid awakening with full return of protective airway reflexes presents additional challenges to the anesthesiologist.

Induction	An opioid-based technique, as outlined previously (see Introduction). Any iv induction agent can be safely used; ↓ dose in elderly and patients with significant cardiac disease. Oral tracheal intubation is performed with a small (6.0 mm ID) reinforced ETT to facilitate surgical manipulation inside patient's mouth. With large tumors, especially on the right side, care is necessary when performing DL to avoid bleeding. ETT should be secured over the chin. Placement of a small-diameter esophageal temperature probe will not interfere with the surgical field.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Controlled hypotension is often requested. A combination of opioid (e.g., remifentanil) or sufentanil infusion with a potent, quickly titratable inhalational agent (e.g., desflurane), supplemented with iv β-blockers, if required, is usually sufficient. After the specimen has been removed, surgical stimulation decreases, and the inhalational anesthetic should be significantly reduced to promote rapid awakening.

Emergence	The patients are routinely extubated, even after extended procedures. The stomach should be suctioned at the end of the case (throat pack is removed only by the surgeon to facilitate placement of a dental prosthesis). Stomach emptying should be facilitated by administration of iv metoclopramide (10–20 mg). Nasal passages may be packed → obligate mouth breathing; oropharynx must be suctioned thoroughly and carefully. No dressing is applied postop. Washing blood from the patient's face is frequently accompanied by vigorous movement of the patient's head and ETT. If a sufficient dose of opioids has been used, the patient will tolerate this well without coughing/gagging/straining while breathing spontaneously. Extubation must be smooth, with full return of protective airway reflexes. Hemoptysis may occur after extubation, and the patient's mouth should be promptly covered with an O_2 mask, to avoid contamination. Discuss with surgeon local wound infiltration. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 16 ga × 1 BSS @ 5–7 cc/kg/h	Blood loss minimal to severe. It can be sudden and substantial. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors ± arterial line	A-line monitoring is warranted for anterior cranial base surgery or in patients with significant cardiovascular disease.
Positioning	Head elevated 20–30° Table may be turned 90–180°	

	✓ and pad pressure points	
Complications	✓ eyes VAE	A risk of air embolism, with surgery on the paranasal sinuses, should be kept in mind.
	Dysrhythmias	Dysrhythmias may occur 2° significant surgical stimulation and breakthrough adrenergic responses.
	Hypotension ↓↓ HR	↓ BP may be sudden 2° brisk blood loss. Trigeminocardiac reflex may occur during intraoperative manipulation of the trigeminal nerve.
	Brain edema	Careful fluid management, not to promote/exacerbate brain edema associated with the bifrontal craniotomy.

POSTOPERATIVE

Complications	Occult postop bleeding	Postop bleeding may cause the patient to swallow large quantities of blood, which represents an aspiration risk and may manifest as ↓ BP.
	Pneumocephalus	Persistent pneumocephalus (if the paranasal sinuses were opened) with symptoms of increased ICP.

Multimodal pain management	PCA Parenteral opioids	Pain is moderate. Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with peripheral local anesthetics (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Reading

1. Codère-Maruyama T, Moore A: Anesthesia in the elderly patient undergoing otolaryngology head and neck surgery. Clin Geriatr Med 2018; 34(2):279–88.

COMPOSITE RESECTION WITH MARGINAL OR SEGMENTAL MANDIBULECTOMY (AND NECK DISSECTION)

SURGICAL CONSIDERATIONS

Description

A composite resection means that part of the mandibular alveolar ridge is resected, often along with the floor of mouth and a part of the tongue, generally for advanced squamous cell carcinoma, though occasionally for osteoradionecrosis following complications of prior irradiation or for other malignancies such as osteosarcoma. In a **marginal mandibulectomy**, bone inferior to the plane of the inferior alveolar nerve (which runs just below the teeth and provides dental innervation and cutaneous sensation to the lower lip and chin) is preserved. In a **segmental mandibulectomy**, a through-and-through segment of bone is removed such that there is a bone gap. A marginal mandibulectomy may at times be reconstructed with intraoral advancement flaps in an edentulous patient, or a radial free flap may be indicated. A segmental resection generally is best reconstructed with an osteocutaneous free flap, such as fibula free flap or for a short distance an osteocutaneous radial free flap. A composite resection generally requires a tracheostomy although an intraoral marginal mandibulectomy repaired without a free flap may not necessitate one.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Composite Resection (with MRND)	… and Free Flap
Position	Supine, head extended, and turned to opposite side	⇐ + preparation of 2nd sterile site, such as arm or leg; two surgical teams
Incision	Intraoral and neck	⇐ and donor site
Special	Headlights, suction,	⇐ donor site specific

instrumentation	cautery, lip retractor	
Unique considerations	Armored ETT converted to, or initial, tracheostomy	Dependent on 2nd site
Antibiotics	Common is ampicillin or cefazolin 2 g iv (± metronidazole 500 mg) or clindamycin 600 mg	⇐
Surgical time	3–6 h	⇐ add 3–4 h
EBL	150–400 mL; transfusions uncommon	⇐; little additional loss
Postop care	Drain management, monitor for wound breakdown	⇐ + monitored bed for flap surveillance
Mortality	<1%	⇐
Morbidity	Bleeding: <4% Infection ± fistula: <10% DVT/PE: <1% Medical: MI < 1% Pneumonia: <3%	⇐ Flap failure; return to OR < 5% Donor site morbidity
Pain score	4–8	⇐

PATIENT POPULATION CHARACTERISTICS		
Age range	40–70, occasionally older and younger	⇐
Male:Female	3:1	⇐
Incidence	Common	⇐
Etiology	SCC and other malignancy	⇐
Associated conditions	Smoking and alcohol, COPD, atherosclerotic heart disease	⇐

NECK DISSECTION

Description

The goal of a neck dissection is a lymphadenectomy either to remove known cervical metastases (an N_+ neck) or as a staging procedure in a patient apparently without clinically or radiologically involved nodes (an N_0 neck) but at significant risk nevertheless. The most common indication by far is in the management of squamous cell carcinoma (SCC) of the head and neck. For the purpose of discussing a neck dissection the neck is divided into five levels. Level 1 is the tissue that is inferior to the mandible, anterior to the posterior belly of the digastric muscle, and superior to the hyoid bone, including the submental triangle between the left and right anterior belly of the digastric muscles. The most prominent structure in level 1 is the submandibular gland. Level 2 through 4 includes the tissue beneath and anterior to the sternocleidomastoid muscle (SCM): level 2 is superior to the hyoid bone, level 3 is between the hyoid and cricoid bone, and level 4 is inferior to the cricoid. Level 5 contains the tissue between the posterior edge of the SCM and the anterior edge of the trapezius muscle.

There are several different kinds of neck dissection, depending on which levels are removed:

1. **Radical neck dissection (RND)** or **modified radical neck dissection** (**MRND**): this involves the removal of levels 1–5. Except in markedly advanced disease, seldom is an RND (which removes the internal jugular vein, SCM, and accessory [XI] nerve necessary. An MRND preserves one or more of those three structures, generally at least the XI nerve. An MRND (or RND) is generally done only when there is N_+ disease. Similar surgery may also be necessary to remove extensive tumors other than SCC. An extended neck dissection involves removal of additional tissue, such as muscles deep to the superficial layer of the deep cervical fascia. MRND is a common additional procedure done for an N_+ neck at the time of removal of a primary SCC of the head and neck.
2. **Selective neck dissection** (SND) removes less than all five levels, such as for N_0 disease when adjacent surgery is planned or in an effort to ascertain there is no histologically demonstrable disease, thereby avoiding postop irradiation to the primary site and neck. The two most common types of SND are as follows:
   a. **Supraomohyoid neck dissection** (**SOHND**): This removes levels 1–3, generally in a patient with an oral cavity SCC with a depth of >3.5–5 mm at risk for nodal involvement despite a clinically N_0 neck.
   b. **Lateral neck dissection:** Removes levels 2–4, generally in N_0 patient with glottic or supraglottic carcinoma in whom, again, it is hoped that postop RT may be avoided. This may also be done in selected oropharyngeal carcinomas as part of

resection of the primary, again to further stage the malignancy and tailor subsequent intervention.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	MRND (or RND)	SOHND
Position	Supine, head extended and turned to opposite side; table 90° or 180°	⇐
Incision	Common incisions include a reverse hockey (submandibular resting skin tension line [RSTL] toward mastoid tip then extended inferiorly along anterior border of trapezius muscle); utility/hockey; superior and inferior neck RSTL (McFee)	~7-cm RSTL incision ~3 cm inferior to the mandible, beginning anterior to the SCM extending parallel to the hyoid as anteriorly as needed
Special instrumentation	Major head and neck set; headlights	⇐
Unique considerations	Avoid paralysis until after marginal mandibular nerve and XI identified. If bilateral, laryngeal edema may occur; dissection near carotid body and vagus may produce transient bradycardia	⇐
Antibiotics	Cefazolin 2 g iv (with	⇐

	metronidazole 500 mg if oral or pharyngeal entry planned) or clindamycin 600 mg	
Surgical time	2–4 h	1.5 h
EBL	50–150 mL; transfusions rarely indicated	⇐
Postop care	Drain management	⇐
Mortality	<1%	⇐
Morbidity	Unanticipated neuropathy (e.g., XII, X, VII marginal branch, recurrent laryngeal nerve, and phrenic nerve) <1% Chyle leak <2% if level 4 dissected Hematoma <4% Infection <5% DVT/PE ~1% XI weakness expected Shoulder pain ~20%	⇐
Pain score	4–8	2–4

■ PATIENT POPULATION CHARACTERISTICS		
Age range	40–80, occasionally older and younger	⇐
Male:Female	3:1	⇐
Incidence	Common	⇐
Etiology	1° site SCC; smoking and alcohol	⇐
Associated conditions	COPD, atherosclerotic heart disease	⇐

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Many of these patients are older males with a prior of tobacco and ETOH use and have a high incidence of associated cardiopulmonary diseases. Nutritional status of the patients may be poor and weight loss should be stabilized before surgery. Neck dissections are rarely associated with significant blood loss.

Airway	Airway management may be difficult 2° limited head and neck mobility, ↓ mouth opening, distorted airway, ↓ pharyngeal space and fixation of tissues 2° tumor expansion, radiation fibrosis or previous surgeries. Backup plans for airway management are essential, and a review of preop findings on indirect laryngoscopy and/or CT scan with the surgeon may be helpful in planning a strategy for intubation. If a difficult intubation is foreseen, awake FOI may be the technique of choice (see Anesthetic Considerations for Laryngectomy). Emergent tracheostomy may technically be very difficult 2° advanced disease, neck edema, previous surgeries and distorted anatomy.
Respiratory	High incidence of chronic bronchitis and COPD. **Tests:** CXR; preop ABG in patients with advanced COPD, CO_2 retention, and O_2 dependence. Flow-volume loops may be helpful in patients with symptoms of partial airway obstruction.
Cardiovascular	Careful assessment of cardiac risk factors and functional status. Documenting asymptomatic neck bruits or existing carotid artery stenosis, as well as any Sx of compromised cerebral circulation, is important (see Emergence, below). HTN must be controlled preop especially in patients presenting for radical neck dissection and flap reconstruction. Uncontrolled HTN in these patients carries additional risk of exaggerated hemodynamic responses postop

	2° surgical denervation of the carotid sinus (discussed below). **Tests:** ECG. Consider carotid ultrasound, cardiac stress testing, and imaging studies if indicated from H&P.
Neurologic	See Preoperative Considerations for Laryngoscopy/Bronchoscopy/Esophagoscopy. **Tests:** As indicated from H&P
Hematologic	In cases of malignancy or chronic disease, anemia or coagulopathies may be present. **Tests:** CBC, coagulation studies
Laboratory	LFTs, electrolytes, albumin, BUN, and creatinine; other tests as indicated from H&P
Premedication	Standard premedication. Avoid premedication in patients with symptoms of partial airway obstruction.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 500–1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

The anesthetic considerations for **composite resection and neck dissection** are similar. The use of deep and superficial cervical plexus blocks, as well as cervical epidural anesthesia, either alone or in combination with light GETA, has been described in the literature, but used rarely. GETA is virtually universally employed. The specific surgical requirements for the anesthetic technique are outlined above (see Introduction). Straining or coughing/gagging on the ETT during emergence from anesthesia is particularly undesirable in neck surgery 2° easily provoked bleeding and swelling at the surgical site. Smooth emergence from anesthesia is essential. Use of a FLMA in major cancer neck surgery cannot be recommended.

Induction	Choice of induction will depend on the degree of the airway compromise and anatomical location of any

	obstructing lesion. The airway may need to be secured asleep, with the patient breathing spontaneously, awake (FOI), or a tracheostomy may need to be performed preinduction. In patients with uncompromised airways, potent opioids (see Introduction) can be safely used for induction. The induction dose of a hypnotic agent frequently must be reduced because of the patients' age, preexisting medical conditions, and hypoalbuminemia.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Maintaining moderate ↓ BP (see Introduction) and aggressive treatment of ↑ BP are necessary. In patients with flap reconstruction, ↑ BP may overcome vasospasm, dislodging a hemostatic blood clot or poorly tied ligature → formation of a flap hematoma. Muscle relaxation is usually avoided to facilitate identification of nerves. All inspired gases should be humidified to minimize ↓ T° and propensity for mucous plugging in this patient population. However, the use of low gas flows is preferred to use of an in-circuit humidifier. Venous air embolism (VAE) during radical neck surgery occurs very rarely; maintaining adequate intravascular volume and PPV will further ↓ the incidence of this complication. If a large collection of air bubbles is observed by the surgeon in the internal jugular vein, the anesthesiologist should be notified immediately; these bubbles can be safely aspirated with a fine needle by the surgeon. Vagal reflexes from the carotid sinus may cause ↓ HR and ↓ BP. Transient prolongation of the QT interval during right radical neck dissection has been described and may potentially progress to ventricular arrhythmias and even cardiac arrest. Tracheostomy can be performed as part of the radical neck dissection with implications for anesthesia management (see

	Anesthetic Considerations for Tracheostomy).	
Emergence	If airway compromise is present preop, but tracheostomy was **not** performed, consider staged extubation over an airway exchange catheter to facilitate possible reintubation. The majority of patients with microvascular flap reconstruction will have a tracheostomy placed and could be awakened or continued on overnight ventilatory support in the ICU. Awakening the patient in the OR may help to exclude possible intraop embolic stroke before their transfer to the PACU or ICU. Administration of iv labetalol before awakening may prevent rebound hypertension. Up to 10% of patients may develop a sustained hypertensive response postop, probably 2° denervation of the carotid sinus; Rx aggressively 2° ↑ risk of stroke. Discuss with surgeon local wound infiltration. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 16(18) ga × 1 BSS @ 5–7 mL/kg/h Fluid warmer ± humidifier	Blood loss is typically gradual. Sudden blood loss resulting from injury to the internal jugular vein or carotid artery can be surgically controlled. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Control of blood loss	Surgical hemostasis Deliberate ↓ BP	Continue aggressive Rx of ↑ BP in the PACU.
Monitoring	Standard monitors ± Arterial line	Art line may be indicated for patients with preexisting severe cardiac and pulmonary disease, chronic renal insufficiency (CRI), symptoms of

		cerebrovascular insufficiency, location of tumor near the carotid artery, or in patients presenting for lengthy procedures, including microvascular flap reconstruction.
	± CVP line Foley catheter	CVP monitoring may be warranted in severely malnourished patients, patients with severe COPD, patients with CRI, and patients presenting for microvascular flap reconstruction.
Positioning	Usually supine, head elevated 30° Table turned 180° ✓ and pad pressure points ✓ eyes	
Complications	Vagal reflexes: ↓ HR and ↓ BP	2° carotid sinus stimulation; Rx: stop surgery; lidocaine infiltration of the carotid sinus by the surgeon; iv atropine
	↑ QT interval (with right radical neck dissection)	Probably caused by interruption of cervical sympathetic outflow to heart
	Dysrhythmias	Due to either the carotid sinus stimulation or the ↑ QT interval
VAE	↓ $ETCO_2$ ↑ ETN_2 ↓ BP	With large veins open in the neck, VAE is possible and may account for

	↑ ST segment "Mill-wheel" murmur Dysrhythmias	unexplained ↓ BP and/or dysrhythmia. Rx: Notify surgeon (compress open neck veins); flood field with NS; left lateral decubitus/head-down position; aspirate CVP; FiO_2 = 1.0; circulatory support (fluid, pressors, as required).

POSTOPERATIVE

Complications	↑ BP and ↑ HR	2° carotid sinus denervation; Rx: aggressive pharmacologic intervention
	Nerve injury Diaphragmatic paralysis	Facial nerve injury → facial droop. Recurrent laryngeal nerve injury can result in VC dysfunction. Phrenic nerve injury → respiratory problems 2° diaphragmatic paralysis
	Pneumothorax	Pneumothorax may occur with low neck dissection. Dx and Rx: see Postop Complications after Laryngoscopy/Bronchoscopy/Esophagoscopy
	Agitation	Agitation → ↑ $PaCO_2$, ↓ PaO_2, ↑ HR. Rx: ✓ restrictive neck dressings; evacuate any hematoma; reestablish airway with ETT; FiO_2 = 1.0; ventilatory support, if required.
Multimodal pain management	PCA Parenteral opiates	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with peripheral local anesthetics (see Appendix K, p. K-6).
Tests	CXR	For position of tracheostomy tube, evidence of pneumothorax and CVP line placement
	ECG	For diagnosis of rhythm disturbances
ERAS	PONV protocol (see Appendix	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

B, p. B-1)

Suggested Readings

1. Bonner S, Taylor M: Airway obstruction in head and neck surgery. Anaesthesia 2000; 55:290–1.
2. Cavallone LF, Vannucci A: American Society of Anesthesiologists Task Force on Management of the Difficult Airway. Review article: extubation of the difficult airway and extubation failure. Anesth Analg 2013; 116(2):368–83.
3. Charters P, Ahmad I, Patel A, et al: Anaesthesia for head and neck surgery: United Kingdom National Multidisciplinary Guidelines.J Laryngol Otol 2016; 130(S2):S23–7.
4. Coyle MJ, Main B, Hughes C, et al. Enhanced recovery after surgery (ERAS) fo head and neck oncology patients. Clin Otolaryngol 2016; 41(2):118–26.
5. Mason RA, Fielder CP: The obstructed airway in head and neck surgery.Anaesthesia 1999; 54:625–8.
6. Nekhendzy V, Biro P: Airway management in head and neck surgery. In: Hagberg C, e d . Hagberg's Benumof Airway Management 4th edition. Elsevier Saunders, Philadelphia: 2018, 668–691.
7. Prasad KC, Shanmugam VU: Major neck surgeries under regional anesthesia.Am J Otol 1998; 19:163–9.
8. Rice M, Turner M, Carapiet D: The use of the laryngeal mask airway in maxillofacia surgery. Anaesthesia 2002; 57:826.

LYMPH NODE BIOPSY

SURGICAL CONSIDERATIONS

Description

An open cervical node biopsy is indicated when a fine needle aspiration biopsy (FNA) has proven inadequate or is felt likely to be inadequate (as in determining a type of lymphoma). This can be done under local anesthesia, with or without monitoring, or under general anesthesia. A node is chosen based on its likelihood to answer the clinical question and minimization of operative risk to adjacent structures, especially, for example, the accessory nerve that runs in level 5 (posterior triangle) from about the midportion of the posterior border of the SCM toward the posterior clavicle and may be quite superficial.

Operative and anesthesia considerations are similar to that of a SOHND, except that the

incision should be only a few cm, and its location is variable though still in a RSTI (resting skin tension line), pain should be low, a small drain or no drain is used, and the patient should be able to go home the day of surgery. Often, the surgeon will request a frozen section to be sure there is diagnostic tissue available.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine, head extended, and turned to opposite side
Incision	Small (often requiring only local anesthesia)
Antibiotics	Cefazolin 2 g iv
Surgical time	10 min
EBL	Minimal
Postop care	Drain management
Mortality	Very rare
Morbidity	Rare injury to adjacent structures (e.g., accessory nerve)
Pain score	1–3

PATIENT POPULATION CHARACTERISTICS	
Age range	Wide range
Male:Female	1:1
Incidence	Common
Etiology	In adults, 80% benign, pleomorphic adenoma (benign mixed tumor) 75% of these 20% malignant, low-grade mucoepidermoid carcinoma, adenoid cystic carcinoma, other Chronic sialadenitis/stone rare In children, a greater % malignancy; 60% benign, 35% malignant. Chronic sialadenitis/stone <5%

Associated conditions	None

Suggested Reading

1. Mandel JE: Laryngeal mask airways in ear, nose, and throat procedures. Anesthesiol Clin 2010; 28(3):469–83.

PAROTIDECTOMY: SUPERFICIAL, TOTAL, OR RADICAL

SURGICAL CONSIDERATIONS

Description

A **superficial parotidectomy** (more accurately a lateral or a **supraneural parotidectomy**) removes tissue of the parotid lateral to the facial nerve, dissecting and protecting facial nerve branches (Fig. 3.8). It usually is done for a tumor but rarely is needed for infectious disorders. The integrity of the facial nerve is preserved during a parotidectomy, other than branches involved by malignancy. The nerve may be identified antegrade by locating it proximal to the parotid plexus (pes anserinus) (Fig. 3.9) or in a retrograde fashion that first identifies a distal branch (commonly the marginal mandibular branch or a buccal branch) and following it posteriorly as needed to resect the tumor. A parotidectomy may be combined with a neck dissection or with a lateral temporal bone resection when the tumor extends into the ear canal or middle ear or invades the facial nerve at or proximal to the stylomastoid foramen.

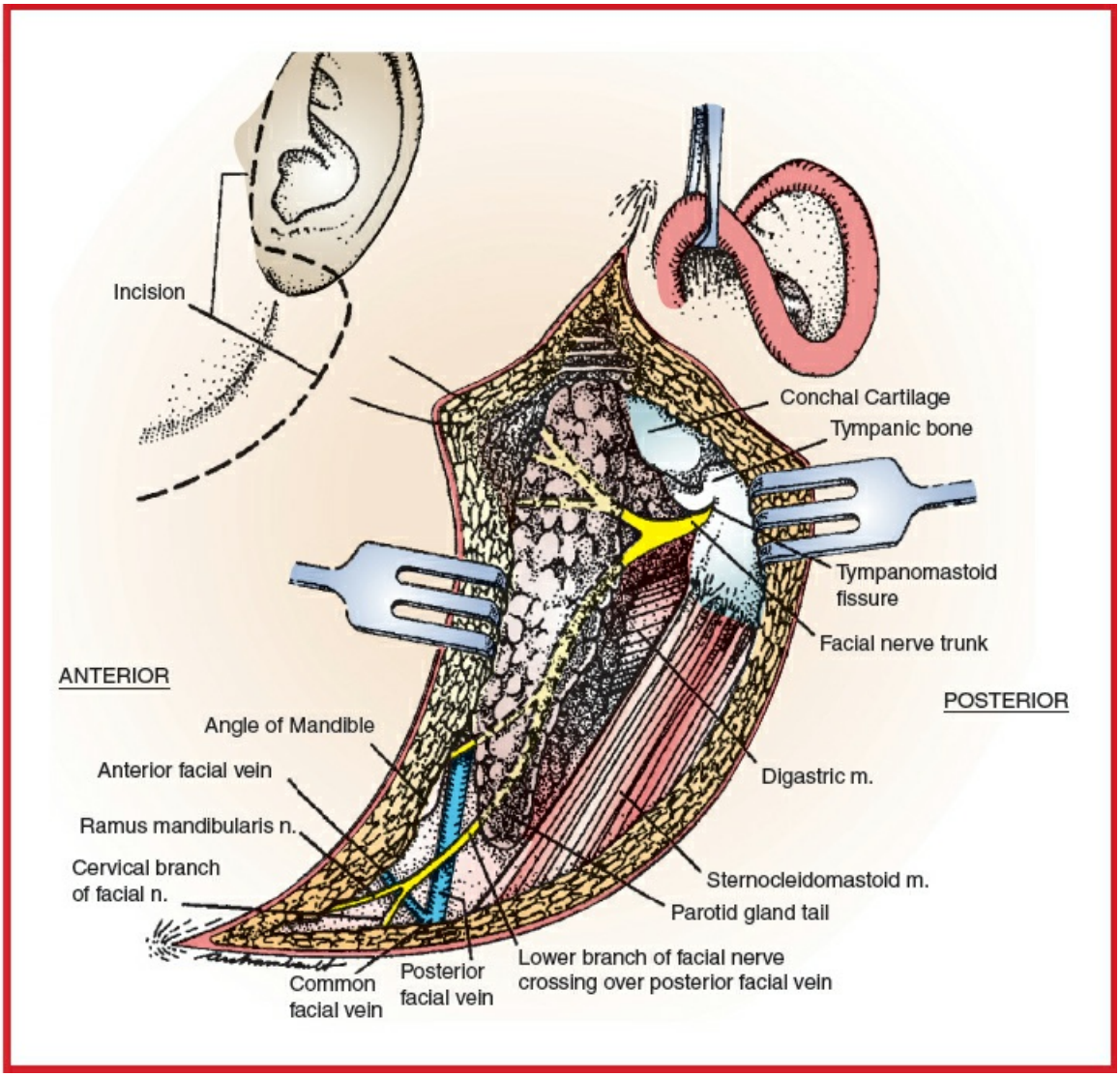

Figure 3.8 Inferior approach to facial nerve. The lower branch of the facial nerve is found immediately external to the posterior facial vein as it exits the lower pole of the parotid gland. The lower branch may divide into the ramus mandibularis and cervical branches before or after crossing the posterior facial vein. The lower branch of the facial nerve is dissected proximally to the facial nerve trunk. The posterior facial vein should not be confused with the external jugular vein, as the facial vein runs deep to the sternocleidomastoid muscle, whereas the external jugular vein lies superficial to this muscle. Elevation of the tail of the parotid gland greatly facilitates this dissection, which must be accomplished in a plane between the posterior facial vein and the parotid gland. (Reproduced with permission from Montgomery WW: Surgery of the Upper Respiratory System, 3rd edition. Williams & Wilkins, Baltimore: 1996.)

A **total parotidectomy** is simply a more extensive procedure and may be needed, for example, for a tumor that extends between branches of the facial nerve into deeper planes or for a tumor with facial nerve paralysis. If the facial nerve is resected (**radical parotidectomy**), a nerve cable graft is usually used in reconstruction. **Microsurgical techniques** are then used to graft the resected nerve. The donor nerve may be the greater auricular nerve, or if no suitable nerve is available in the neck, then the sural nerve. The mastoid may have to be drilled to get a healthy proximal end of the facial nerve.

Usual preop diagnosis

Benign or malignant tumor; occasionally infectious

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

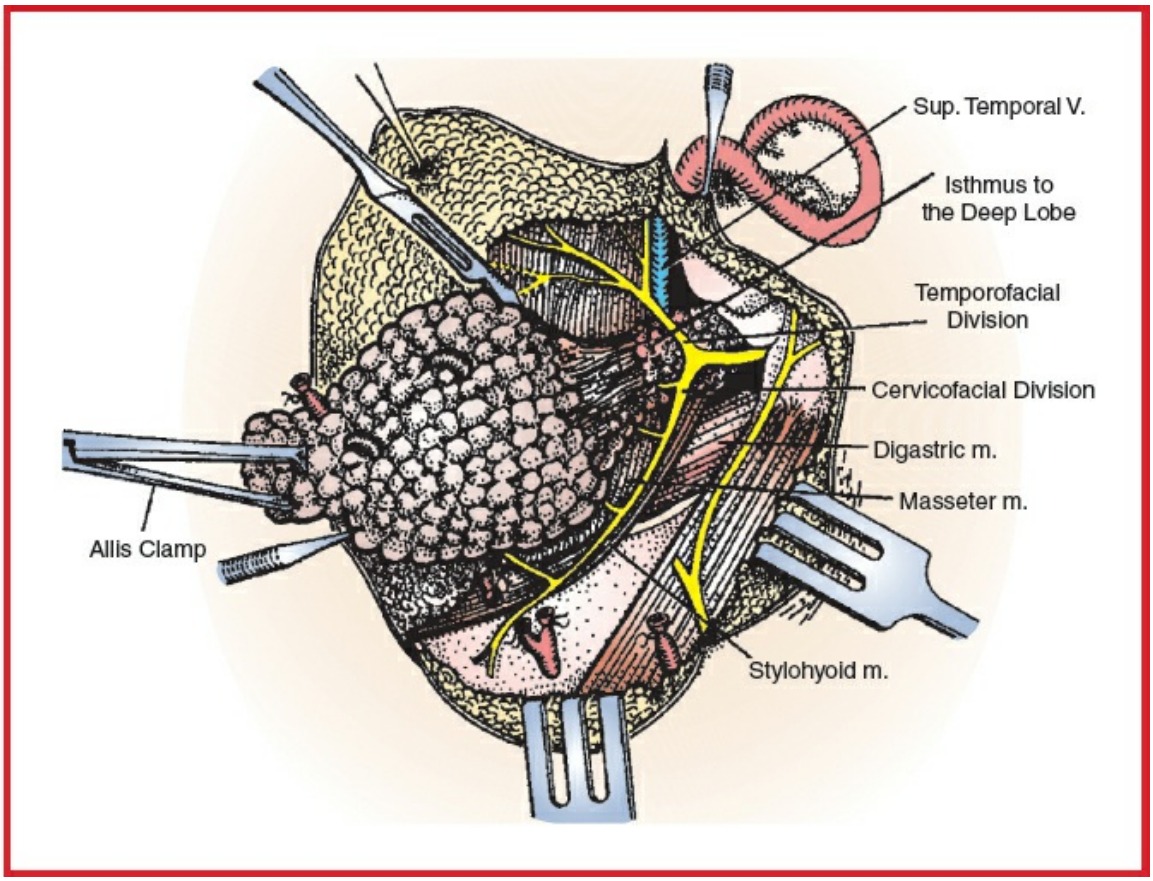

Figure 3.9 The parotid gland has been dissected from the trunk, divisions, and branches of the facial nerve. The anterior projection of the gland has been dissected free, and the parotid duct is being ligated. This dissection is conducted, for the most part, with a hemostat clamp. First, tunnels are created lateral to the branches; and the fascia between tunnels is incised as the gland is dissected forward. The facial nerve stimulator is a useful adjunct to this dissection. (Reproduced with permission from Montgomery WW: Surgery of the Upper Respiratory System, 3rd edition. Williams & Wilkins, Baltimore: 1996.)

SUMMARY OF PROCEDURES

	Superficial	Total/Radical
Position	Supine; head turned slightly to opposite side	⇐

Incision	Infra-auricular, extending into the neck, often with a preauricular component; many variations, such as a modified facelift incision	Postauricular incision extending inferiorly, with the extent dependent on whether a neck dissection is planned
Special instrumentation	Facial nerve stimulator, facial nerve monitor	⇐+ drill for mastoidectomy; microscope/microsurgical instruments and 9-0 Nylon for nerve reanastomosis
Unique considerations	Initial muscle relaxation is not indicated 2° facial nerve identification. Tape oral ETT to the opposite side of the mandible	⇐
Antibiotics	Cefazolin 2 g iv	⇐
Surgical time	1.5–4 h	4–8 h
EBL	25–200 mL	25–400 mL for total parotidectomy, neck dissection, and modified temporal bone resection. Sudden, large blood losses do not occur; transfusion, rare
Mortality	Very rare	⇐
Morbidity	Dysesthesia or anesthesia of the greater auricular nerve: 100% (almost all will recover within 1 yr)	Possible facial nerve loss: With graft, function returns slowly over 12–18 mo in about 60%. Gold (or platinum) weight may be done at same time
	Facial nerve weakness (temporary): 0–50%	⇐
	Frey syndrome: 100%, but <5% will have clinically	⇐

	noticeable gustatory sweating	
	Bleeding: 4%	⇐
	Infection: 4%	⇐
	Permanent facial nerve paralysis: <1%	⇐
Pain score	2–4	4–6

PATIENT POPULATION CHARACTERISTICS	
Age range	Wide range: infants to elderly
Male:Female	1:1
Incidence	Common
Etiology	In adults, 80% benign, pleomorphic adenoma (benign mixed tumor) 75% of these. 20% malignant, low-grade mucoepidermoid carcinoma and adenoid cystic carcinoma most common. Acinic cell carcinoma, high-grade mucoepidermoid carcinoma, adenocarcinoma, and salivary duct carcinoma less common Chronic sialadenitis/stone rare In children, a greater % malignancy; 60% benign, 35% malignant. Chronic sialadenitis/stone <5%
Associated conditions	None

SUBMANDIBULAR GLAND EXCISION

SURGICAL CONSIDERATIONS

Description

Removal of the submandibular gland is done for either chronic sialoadenitis due to ductal strictures and/or stones or benign or malignant tumors of the submandibular gland. (General anatomy of the area is shown in Fig. 3.10.) The patient is supine with

neck mildly extended and head turned slightly to opposite side. A skin crease incision is made below the mandible and skin flaps elevated. The marginal mandibular nerve, which lies just superficial to the facial vein, is identified (or may be avoided altogether) by identifying the facial vein and dissecting deep to its plane and elevating the ligated vein superiorly (displacing the nerve superiorly out of harm's way). Dissection of the submandibular gland continues, avoiding the lingual nerve and ligating the submandibular duct.

Variant procedure or approaches

A **neck dissection** may also be done if there are involved nodes and considered for selected high-grade malignancies such as salivary duct carcinoma and high-grade mucoepidermoid carcinoma even if N_0.

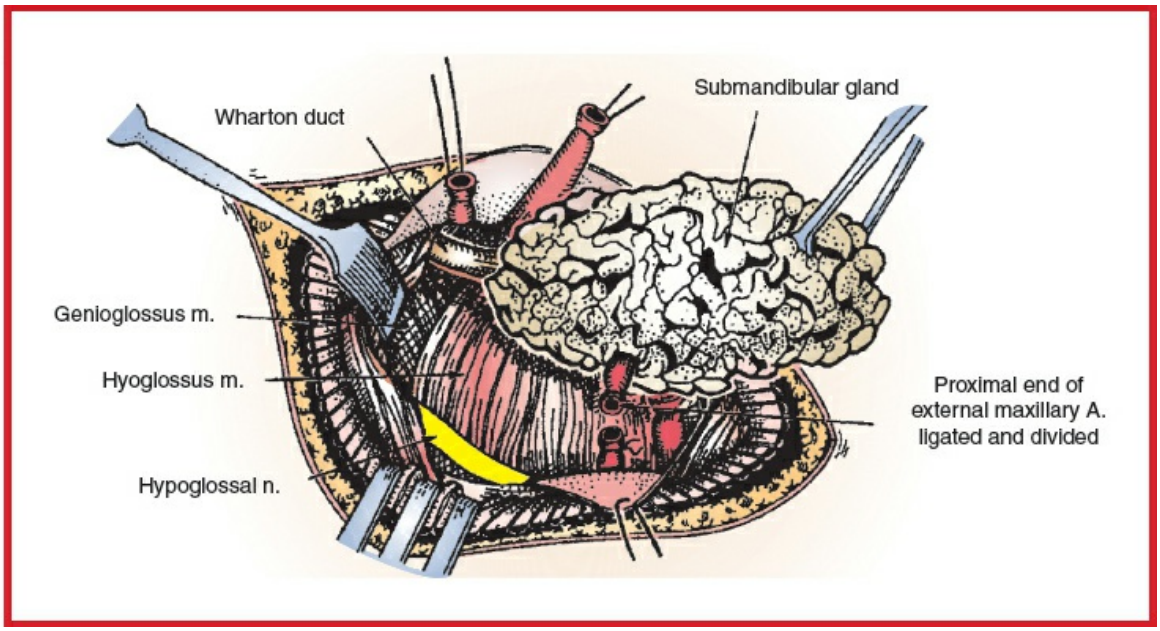

Figure 3.10 Exposure of the submandibular gland. (Reproduced with permission from Montgomery WW: Surgery of the Upper Respiratory System, 3rd edition. Williams & Wilkins, Baltimore: 1996.)

Usual preop diagnosis

Chronic sialoadenitis; stones; benign or malignant tumors

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE

Position	Supine
Incision	Upper neck skin crease
Special instrumentation	Occasionally, facial nerve stimulator
Unique considerations	If surgeon plans to use facial nerve stimulator, muscle relaxation is contraindicated
Antibiotics	Usually not indicated
Surgical time	1–2 h
EBL	25 mL
Postop care	PACU → room or home
Mortality	Minimal
Morbidity	Marginal mandibular nerve paresis or paralysis: 20% Bleeding: 4% Infection: 4% Lingual dysesthesia: 1% XIIth nerve paresis or paralysis: ≤1%
Pain score	2–4

PATIENT POPULATION CHARACTERISTICS

Age range	Unlimited
Male:Female	1:1
Incidence	Rare
Etiology	Chronic infection Neoplasia: ~60% of tumors are benign with the remaining being low- and high-grade malignancies
Associated conditions	Nonspecific

ANESTHETIC CONSIDERATIONS

(Procedures covered: parotidectomy and submandibular gland excision.)

PREOPERATIVE

The majority of these patients are >40 yr, and any coexisting medical conditions should be fully evaluated. Diseases of the parotid gland have been associated with ETOH abuse and with autoimmune disease (e.g., Mikulicz-Sjögren syndrome); therefore, Sx of these conditions should be sought.

Respiratory	Airway may be affected by impaired mouth opening or parotid gland enlargement. Patients with involvement of the masseter muscle may present with trismus. **Tests:** As indicated from H&P
Neurologic	Surgical approach to the parotid gland will place the facial nerve in jeopardy; any preop facial nerve deficits should be documented. Also, see Preoperative Considerations for Laryngoscopy/Bronchoscopy/Esophagoscopy. **Tests:** As indicated from H&P
Hematologic	Submandibular and parotid malignancies may be associated with chronic debilitation and anemia. **Tests:** CBC
Laboratory	Other tests as indicated from H&P; liver panel and coagulation studies in patients with Hx of ETOH abuse
Premedication	Standard premedication
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of superficial cervical plexus nerve blocks for postop pain management. Consider preop acetaminophen 500–1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA is most commonly used. Use of an FLMA also has been advocated, but does no represent the author's preference due to the possibility of distorted neck anatomy caused by the inflated FLMA cuff. The FLMA also may be displaced 2° surgical intrusion int the submandibular space and occasional intraoral surgical manipulation. These procedures involve meticulous surgical dissection and are characterized by alternating levels of stimulation: relatively long, stable levels of stimulation, with sudden adrenergic responses when surgery progresses into deeper fascial planes. (For essential surgical requirements, see Introduction.) Emergence should be rapid enough to allow immediate patient cooperation for assessment of facial nerve function by the surgeon. Muscle relaxation with nondepolarizing NMB may or may not be contraindicated depending on the surgeon's preference and type of surgery performed (inquire preop). Patients after **submandibular gland resection** may be discharged home the same day, while parotidectomy patients are admitted to the ward.

Induction	Opioid-based techniques (see Introduction) are beneficial. Standard iv induction with propofol (1–2 mg/kg) is typically employed. ETT should be carefully secured on the nonoperative side. Nasal intubation may be requested by the surgeon (inquire preop) for selected cases, to allow full manipulation of the patient's jaw.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Moderate ↓ BP (see Introduction) will greatly improve operating conditions and speed up the surgery. The use of a remifentanil infusion supplemented with sufentanil or fentanyl will promote ↓ BP. Anticipate ↑ anesthetic requirements in patients with Hx of ETOH abuse. NMB is typically avoided to allow for intraop monitoring of the facial nerve (parotidectomy) or marginal mandibular nerve (submandibular gland excision).
Emergence	Smooth emergence is extremely desirable, and absence of reaction to the ETT is obligatory if facial nerve repair has been performed. Discuss with

	surgeon local wound infiltration or nerve block (e.g., superficial cervical plexus block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	EBL typically ~200 mL IV: 18 ga × 1 BSS @ 3–5 mL/kg/h	3rd spacing is usually minimal. See Goal-Directed Fluid Strategy, Appendix K, p. K-4.
Monitoring	Standard monitors	
Positioning	Table usually is rotated 90–180° away from the anesthesiologist. ✓ pad pressure points ✓ eyes	

POSTOPERATIVE

Complications	Facial paralysis 2° surgical trauma	Notify surgeons.
Multimodal pain management	Parenteral opiates PCA	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with peripheral local anesthetics (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Reading

1. Mandel JE: Laryngeal mask airways in ear, nose, and throat procedures. Anesthesiol Clin 2010; 28(3):469–83.

ENDOSCOPIC SINUS SURGERY

SURGICAL CONSIDERATIONS

Peter H. Hwang and Sarmela T. Sunder

Description

Sinus surgery is performed most often for the management of chronic sinus disease, nasal polyps, or recurrent sinus infections or for neoplastic conditions that may cause obstruction of the sinus cavities. This surgery includes either external procedures, through the skin or oral cavity, or endoscopic approaches, through the nostrils. The endoscopic approach—the preferred technique for most surgeons—is called **endoscopic sinus surgery (ESS)** or **functional ESS (FESS).**Other surgical procedures —including septoplasty, turbinate reduction, and, occasionally, sleep apnea surgery involving the tonsils, palate, and oropharynx—may be combined with FESS.

Endoscopic sinus surgery

ESS or FESS is a minimally invasive technique that utilizes telescopes intranasally t visualize and access the paranasal sinuses and anterior skull base. The primary indication for ESS is chronic sinusitis that has failed to clear with aggressive medical therapy. The goal of ESS is to open the sinuses through a transnasal minimally invasive approach. Inflamed bone and tissue are cleared from the outflow tracts of the sinuses under direct endoscopic illumination and magnification. By surgically enhancing the drainage and ventilation of the sinuses, normal mucociliary clearance can be restored. Depending on the extent of disease, surgery may involve the maxillary, ethmoid, sphenoid, and/or frontal sinuses. If all four sinuses are being treated, a maxillary antrostomy is typically performed first, followed by an ethmoidectomy. A sphenoidotomy and frontal sinusotomy usually follow thereafter.

Providing openings (drainage, aeration) to the sinus cavities and obtaining tissue for pathologic evaluation are the main aims of ESS. Patients are orally intubated, and a throat pack can be placed in the pharynx to decrease the amount of blood swallowed. Oral gastric tubes are recommended if more than minimal bleeding is expected. Following induction of anesthesia, local medications are applied to the nasal cavity, including injection of 1% lidocaine with 1:100,000 epinephrine and/or topical application of 4% cocaine. It is important that these local medications be noted in the anesthesia record, as complications (HTN, dysrhythmias, seizures) from local application have been reported. Patients with a history of illicit cocaine use should be warned of potential drug interactions, and the intraop use of vasoactive drugs should be

limited to avoid unexpected cardiovascular events.

At the end of the procedure, packing may be placed. It is imperative that any pharyngeal or throat pack be removed before the end of the procedure to avoid airway destruction.

Sinus surgical procedures may use **image guidance or surgical navigation tools.** These computer-assisted techniques involve a preop CT or MRI scan to create a navigational map for the surgeon to localize disease, normal tissues, and the boundaries of the surgical dissection. Surrounding the sinuses are several vital structures, including the periorbital tissues (e.g., orbital muscles, lacrimal apparatus, and the optic nerve), the sphenopalatine artery, ethmoid arteries, the carotid artery, as well as the skull base.

Variant procedure or approaches

For **external approaches** to sinus surgery, see External Sinus Surgery.

Usual preop diagnosis

Nasal polyps; chronic sinusitis; recurrent acute sinus infections, benign and malignant tumors, inverted papilloma, and management of previous surgical complications (e.g., repair of cerebrospinal fluid [CSF] leak, lacrimal duct injury, and persistent or remnant ethmoid cells or scar tissue formation)

Preoperative management

Patients should receive a decongestant nasal spray, such as oxymetazoline, preop to reduce nasal edema. This is generally given 30 min. before the start of the case, with repeat administration every 10–15 min. Preop antibiotics or steroids will vary depending on surgeon preference. Typically, an antibiotic with gram-positive and some gram-negative coverage (such as cephalexin) and an intravenous steroid such as dexamethasone are administered.

Intraoperative management

ESS is usually performed under GA, using either endotracheal intubation or an LMA. The LMA offers the potential advantages of reducing the entry of blood into the stomach and causing less bucking or coughing during emergence (which may provoke unnecessary bleeding from the surgical site). The tube should be taped securely to the left side or midline of the patient's mouth. The OR table is routinely turned 90° or 180°, and the patient is positioned with the head slightly elevated. The surgeon sits or stands at the patient's right and operates from a video monitor positioned at the patient's head.

The eyes are taped but should remain visible in the surgical field throughout the procedure so that the status of the orbits may be noted by the surgeon. The

presence of ecchymosis or proptosis suggests a transgression of the thin bony orbital wall and requires immediate attention. Throughout the procedure, the surgeon may palpate the orbit externally while endoscopically evaluating for dehiscences of the orbital wall, which if present will reveal transmitted movement of orbital fat or periorbita.

In more complex FESS or endoscopic skull base surgery, the surgeon may use a stereotactic navigation system to map out the surgical field according to a preoperatively acquired CT or MRI scan. During preparation of the patient, a localizing headset is placed over the patient's forehead, and a computer workstation tower is positioned adjacent to the head of the patient. After a registration process, a navigating probe communicates with the workstation via electromagnetic or infrared technology to provide triplanar localization of the probe tip relative to critical anatomic structures in and adjacent to the sinuses.

Hemostasis is critical in ESS, where the small lens of the endoscope (4 mm) can be easily obscured by blood. When possible, a hypotensive anesthesia regimen can reduce bleeding and thereby optimize the surgeon's view of the operative field. It may be reasonable to maintain blood pressure at ~80% of the preop level.

To improve hemostasis, the surgeon may place pledgets soaked in a vasoconstrictive agent such as cocaine, oxymetazoline, or epinephrine in the nasal cavity before starting the case. A transoral or transnasal sphenopalatine ganglion block may be performed using 1% lidocaine with 1:100,000 epinephrine, which will provide vasoconstriction of the sphenopalatine artery. The lateral nasal wall and middle turbinate are also infiltrated with lidocaine/epinephrine. Additional vasoconstrictor-soaked pledgets may be placed in the operative field during the procedure to control oozing.

Complications of endoscopic sinus surgery

Along the boundaries of the paranasal sinuses are important structures that may be injured in the course of the procedure.

Maxillary Sinus: Just anterior to the maxillary sinus ostium is the nasolacrimal duct. Injury to this structure, manifesting as excessive tearing, will not usually be evident until postop.

Ethmoid Sinus: Two critical boundaries of the ethmoid sinus are the medial orbital wall laterally and the skull base superiorly. Transgression of the orbit may result in medial rectus injury, prolapse of orbital fat, or orbital hemorrhage. If orbital hemorrhage progresses to the point of marked proptosis, vision may be threatened,

and an emergent decompression of the orbit may be required via lateral canthotomy and cantholysis.

The superior extent of the ethmoid dissection is the cribriform plate and the anterior skull base. A breach through the ethmoid roof may result in a cerebrospinal fluid leak. CSF leaks require immediate repair using autogenous tissue grafts and require an inpatient recovery period. Vigorous bag-mask ventilation should be avoided in patients with known skull base defects because of the risk of creating a pneumocephalus.

Sphenoid Sinus: The sphenoid sinus, the posteriormost of the paranasal sinuses, lies adjacent to critical structures of the parasellar region. The carotid artery and optic nerve run along the superolateral wall of the sphenoid sinus. Any significant bleeding on entry into or while working in the sphenoid sinus is concerning for potential carotid injury. Carotid artery injury requires emergent tamponade, possible fluid resuscitation, and angiography with embolization.

Frontal Sinus: Endoscopic approaches to the frontal sinus are especially challenging because of the narrowness of the region. Violation of the cribriform plate medially or the orbital wall laterally may lead to complications of CSF leak or eye injury, respectively.

Postop Management: In the PACU, patients s/p ESS require continued monitoring for possible delayed manifestation of complications. Maintaining normotensive hemodynamics is extremely helpful in controlling postop bleeding. Changing nasal dressings for oozing every 20–30 min is expected, but brisker bleeding should be evaluated by the surgeon for possible arterial sources requiring intervention.

Orbital injury can also present in the postop period with significant pain, diminished visual acuity, diplopia, proptosis, or ecchymosis. Any complaints of eye pain or visual changes need to be addressed urgently. The surgeon must be alerted immediately, and an ophthalmology consult should be considered.

Altered mental status, focal neurologic exam, or severe headache may indicate a possible intracranial complication. Clear rhinorrhea, especially unilateral, should be closely evaluated for the possibility of CSF leak.

Other applications of endoscopes in sinonasal surgery

Although the most common indication for ESS is medically refractory chronic sinusitis endoscopic techniques can be applied to a wide range of sinonasal and skull base

pathology. OR setup and patient positioning are identical to that for ESS (except as noted).

Turbinate reduction

The inferior turbinate is the largest of the nasal turbinates (inferior, middle, superior) and when hypertrophied can cause nasal obstruction. Various methods exist for inferior turbinate reduction and include radiofrequency ablation, cauterization, submucosal resection, partial resection, and outfracture. Both turbinate cauterization and RF ablation involve inserting a probe into the soft tissue of the turbinate and producing a coagulative lesion, which ultimately contracts to reduce the turbinate soft tissue. Similarly, submucosal reduction involves making an incision through the mucosa and mechanically reducing the underlying soft tissue. Partial resection of the turbinate involves cutting through the bone, soft tissue, and mucosa of the anterior one-third of the turbinate. At the conclusion, the cut edges are cauterized. The main adverse event from the majority of procedures on the turbinate is bleeding, which is usually controlled with cautery or nasal packing.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine; table turned 90° or 180°
Incision	Mucosal, intranasal
Special instrumentation	4-mm nasal endoscopes, camera monitor, computer-guided navigation system
Premedication	Cefazolin 2 g iv, dexamethasone 8–12 mg iv
Surgical time	1–3 h
EBL	50–300 mL; transfusions rare
Postop care	PACU monitoring for surgical complications; discharge home from PACU
Mortality	Rare
Morbidity	1% major complication rate (see complications of ESS above)

Pain score	2–3

PATIENT POPULATION CHARACTERISTICS	
Age range	15–80
Male:Female	1:1.5
Incidence	Common
Etiology	Medically refractory chronic sinusitis
Associated conditions	Asthma, allergic rhinitis, migraine

Septoplasty

Septal deviation may arise congenitally or during periods of rapid craniofacial growth or from nasal trauma. Septoplasty is indicated when the septal deviation causes obstructed nasal breathing. Through an incision in the nasal vestibule, a mucoperichondrial septal flap is elevated to reveal deflections in the underlying septal cartilage and bone. Selective excision of bone and cartilage allows the septum to return to a midline position. Although the procedure may be performed using direct visualization with a headlight, nasal endoscopy provides superb visualization and allows for precise surgical maneuvering.

Control of epistaxis

Control of epistaxis can usually be performed in the clinic; however, the OR provides a controlled environment suitable for high-risk patients and patients with profuse bleeding. Under endoscopic visualization, bleeding sites can be readily identified and controlled with cautery or laser. A more definitive procedure to control posterior epistaxis is sphenopalatine artery ligation. The artery is identified at the posteriormost aspect of the middle turbinate through a mucoperiosteal incision. The artery is then cauterized or ligated with surgical clips.

Orbital decompression

Endoscopic orbital decompression is performed for Graves ophthalmopathy to preserve diminishing vision and to improve cosmesis associated with exophthalmos. An ethmoidectomy is performed first, followed by removal of the medial orbital wall. After adequate exposure is achieved, the orbital periosteum is incised, causing the orbital fat to prolapse into the ethmoid cavity, thereby decompressing the orbit contents. Decompression may be extended to the floor of the orbit if medial decompression alone

is insufficient.

Repair of CSF leak

Discontinuity of the anterior skull base, occurring traumatically or spontaneously, may result in CSF rhinorrhea. The defect may be a small crack in the skull base or a larger defect with prolapse of meninges or brain tissue through the defect. The majority of anterior skull base CSF leaks can be closed effectively with endoscopic approaches. Meningoencephaloceles that protrude through a bony skull base defect are reduced with bipolar cautery. After endoscopic visualization of the bony defect, a layered repair is performed using bone or cartilage, followed by a free mucosal graft.

A lumbar subarachnoid drain may be placed prior to starting the case. Fluorescein can be placed through the drain to aid in identifying the leak site during surgery. If fluorescein is used, it must be carefully measured and administered to avoid the neurotoxic effects of overdose (accepted dose is 0.1 cc of 10% fluorescein mixed in 10 cc of nonbacteriostatic saline, administered slowly over 5 min). Postop, patients remain at bedrest for 1–3 d, typically as an inpatient.

Pituitary surgery

The application of endoscopic technique to transnasal transsphenoidal approaches to the sella provides an excellent panoramic view unavailable with microscopic approaches. Pituitary adenomas, craniopharyngiomas, and other sellar masses are suitable for endoscopic resection. The operating team consists of a neurosurgeon and an otolaryngologist working in concert. The approach is performed by the otolaryngologist, while the tumor resection is performed by the neurosurgeon under endoscopic guidance by the otolaryngologist ("four hands technique"). After performing intraoral greater palatine blocks and topically decongesting the nasal mucosa, the surgeon performing the approach creates bilateral sphenoidotomies. The posterior portion of the septum is then resected, allowing for the subsequent removal of the remainder of the sphenoid rostrum. This provides wide exposure of the sella and parasellar anatomy. The sella is then entered, and tumor resection is performed endoscopically.

The dissection of the sella risks injury to the adjacent optic nerve, cavernous sinus, and carotid artery. The anesthesiologist should be prepared to hemodynamically resuscitate the patient in the rare event of a carotid injury. Additional monitoring such as an arterial line may be indicated at the discretion of the anesthesiologist.

A CSF leak may occur if the arachnoid is breached during the tumor resection. This is repaired easily with abdominal fat, fibrin glue, and an absorbable reconstruction plate. In the event of a CSF leak, a lumbar subarachnoid drain may be placed.

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

The majority of these procedures are performed on an outpatient basis. Patients with extensive polypoid disease may be at risk for substantial (>400 mL) blood loss. Many of these patients will have received a short preop course of steroid therapy to decrease tissue swelling and reduce bleeding intraop. Routine intraop administration of dexamethasone (8–12 mg iv) to minimize postop edema makes additional stress dose of glucocorticoids unnecessary.

Respiratory	Many patients with nasal polyposis have a high incidence of reactive airway disease (up to 26%) as well as a hypersensitivity to aspirin, which can precipitate bronchospasm (triad patients). In these patients, NSAIDs, including ketorolac, should be avoided. In general, ketorolac administration for postop pain relief is not recommended in these patients because it may promote microvascular bleeding. **Tests:** CXR, as indicated by H&P
Cardiovascular	See Anesthetic Considerations for Nasal Surgery.
Premedication	See Anesthetic Considerations for Nasal Surgery.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 500–1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

FESS can be performed under local anesthesia with sedation (MAC) or GA. The essential surgical requirements are similar to those for other types of nasal surgery (see Anesthetic Considerations for Nasal Surgery), although more meticulous control of intraop BP is crucial. Local anesthesia offers the advantage of reduced blood loss, but GA is performed more frequently and may be associated with ↓ incidence of surgical complications. Patients with extensive sinus disease, history of multiple previous nasal

and sinus surgeries, patients feeling uneasy about being awake, and those with reactive airway disease or labile HTN may not be candidates for MAC. Use of an FLMA instead of an ETT offers significant advantages (see Introduction), including decreasing airway reactivity and improving mucociliary clearance. For tracheal intubation, the use of wire-reinforced or oral RAE ETTs is preferred to facilitate surgical access.

Maintaining intraop controlled hypotension (see Introduction) is essential for improving surgical visibility and operating conditions. Although MAP may largely affect the arterial inflow, other factors including the condition of the vascular network, local mechanisms regulating functional nasal capillary density, and local venous pressure also play a significant role in regulating overall nasal capillary perfusion. As with other types of nasal surgery, these procedures are typically characterized by minimal immediate postop pain 2° submucosal infiltrative local anesthesia used by the surgeon.

Induction	See Anesthetic Considerations for Nasal Surgery. The patient's eyes should be protected in a manner that allows the surgeon to quickly diagnose proptosis in case of inadvertent orbital wall penetration and intraorbital hemorrhage.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	See Anesthetic Considerations for Nasal Surgery. TIVA, with or without nitrous oxide, promotes superior hemodynamic stability and minimizes direct peripheral vasodilation. When additional ↓ BP is required esmolol is preferred over SNP. Breakthrough adrenergic responses occur more frequently with FESS compared to other types of nasal surgery because many reflexogenic areas (e.g., skull base) cannot be blocked by infiltrative local anesthesia. These responses can be effectively controlled by vasoactive agents or additional boluses of remifentanil (0.5–1.0 mcg/kg iv). The anesthesiologist should frequently observe the video monitor for signs of possible complications—prolapse of periorbital fat (orbital injury) and "washout" of blood in the surgical field (CSF leak).

Emergence	See Anesthetic Considerations for Nasal Surgery. If a dural injury has occurred, a smooth extubation is mandatory. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 20 ga × 1 (unilateral FESS) 20–18 ga × 1 (bilateral FESS)	Blood loss is usually minimal but can be substantial in high-risk patients (as described above). See Goal-Directed Fluid Management, Appendix K, p. K-4.
	BSS @ 3 cc/kg/h Blood loss generally minimal	Meticulous surgical technique and the use of injectable vasoconstrictors are essential in reducing intraop bleeding. An iv is usually placed at the side where the surgeon is positioned (patient's right upper extremity).
Monitoring	Standard monitors BP cuff left arm	Prevent BP cuff from inflating against the surgeon's hands during delicate endoscopic manipulation.
Positioning	Table turned 90–180° Head elevated 15–30° ✓and pad pressure points ✓ eyes	Patient's arms usually tucked and carefully padded.
Complications	Dysrhythmias Tachycardia	Usually related to use of vasoconstrictor agents; and may present a problem in patients with

		CAD. Short-acting β-blocker (esmolol 0.5–1.0 mg/kg iv boluses) should be available to blunt these hemodynamic effects.

POSTOPERATIVE

Complications	Occult bleeding.	Occult postop bleeding may cause the patient to swallow large quantities of blood (↑ aspiration risk), and repacking the nostrils may be required.
Multimodal pain management	Fentanyl 25–50 mcg iv prn is usually sufficient in PACU.	Occasionally, pain after FESS may be significant. If external approaches to the sinuses were utilized, higher doses of opioids may be necessary. Emphasize multimodal approach combining nonopioid (e.g., ibuprofen) and bolus/PCA opioid analgesics (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-1).	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Amorocho MR, Sordillo A: Anesthesia for functional endoscopic sinus surgery: a review. Anesthesiol Clin 2010; 28(3):497–504.
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EXTERNAL SINUS SURGERY

SURGICAL CONSIDERATIONS

Description

Transoral or transfacial approaches to the paranasal sinuses (Fig. 3.11) include a transoral sublabial approach to the maxillary sinus and pterygomaxillary space (**Caldwell-Luc**), rarely done external ethmoidectomy (often with medial orbitotomy and/or medial maxillectomy), and osteoplastic approaches to the frontal sinus via a bicoronal incision just behind the hairline. The usual indication for such approaches is resection of malignant and occasionally benign locally extensive tumors such as angiofibroma, especially when for technical reasons (e.g., angle of access or extension into the orbit) it is felt that an endoscopic approach is not indicated. The continued

improvement in endoscopic equipment along with increasing surgical experience makes endoscopic resection increasingly more common and appropriate.

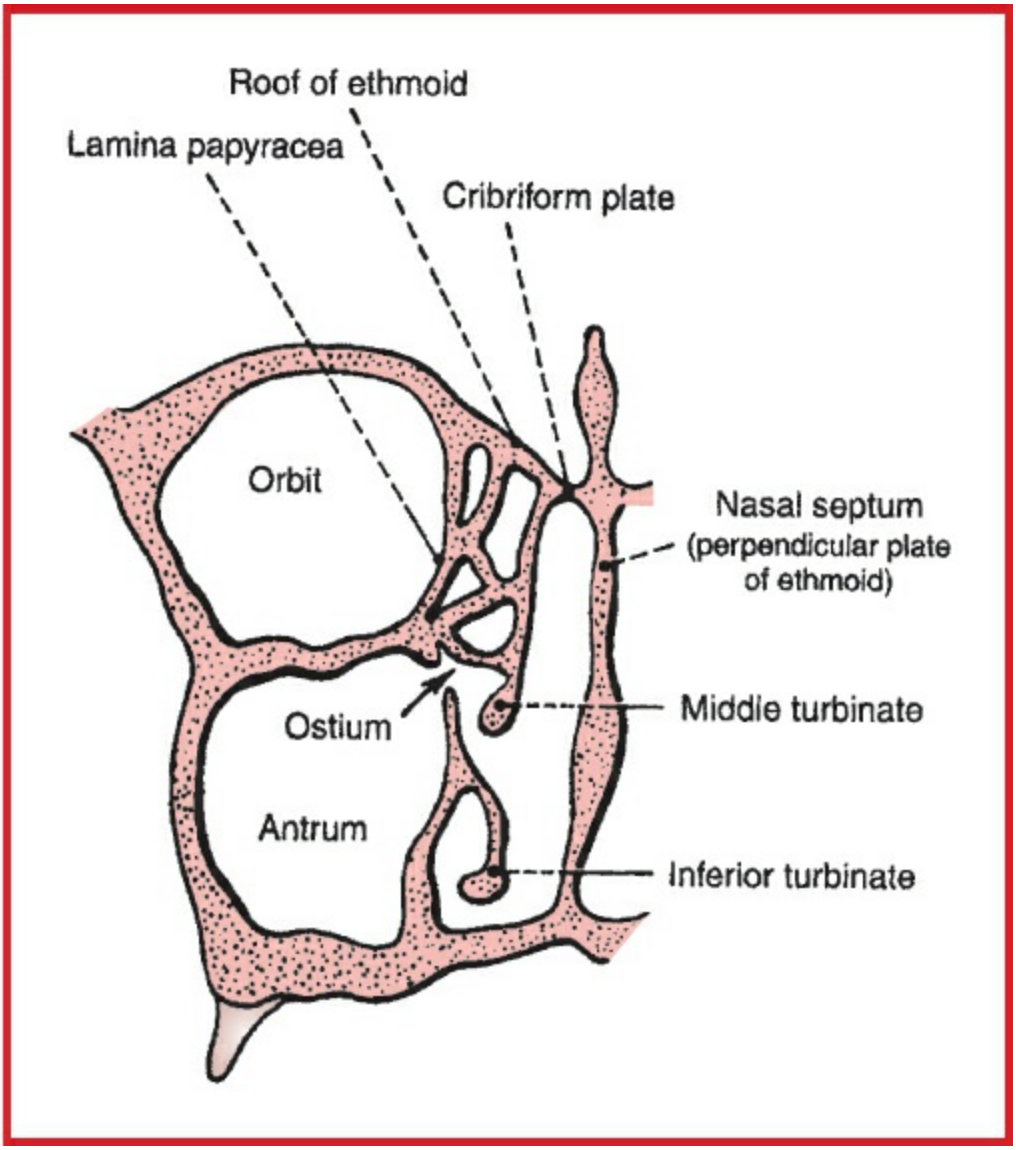

Figure 3.11 Diagrammatic representation of the relationships of the orbit, maxillary antrum, ethmoid labyrinth, and nasal cavity. Note that the medial wall of the ethmoid labyrinth is an upper extension of the attachment of the middle turbinate. The attachment of the upper extension separates the roof of the ethmoid and the cribriform plate. (Reproduced with permission from Montgomery WW:Surgery of the Upper Respiratory System, 3rd edition. Williams & Wilkins, Baltimore: 1996.)

Anterior cranial base surgery

When tumors transgress the anterior cranial base at the cribriform plate and ethmoid roof, an anterior cranial base resection is needed. If the extent of the anticipated dural resection is limited and the lateral extent amenable, then the resection can be accomplished endoscopically; otherwise, an open approach is done. A central facial incision today is almost never required as adequate exposure may be obtained via a

bicoronal incision and bifrontal craniotomy, with endoscopic assist if needed. The CSF leak is addressed by a combination of dural substitution (autologous tissue, such as temporalis fascia, bovine pericardium, or manufactured substitutes) and a pericranial-galeal flap. A lumbar subarachnoid drain is sometimes used in this setting.

Variant approaches

Approaches to the middle cranial base include an orbitozygomatic approach to the infratemporal fossa. The zygomatic arch and part of the zygomatic body is temporarily removed, the temporalis major muscle is transposed inferiorly. The lateral orbital bone with or without the orbital rim may be temporarily removed. A middle fossa craniotomy or craniectomy is usually done. This provides access to the foramen ovale, foramen rotundum, and carotid artery at the skull base, as well as the lateral orbit and superior infratemporal fossa and pterygomaxillary fossa to the pterygoid plates, and, as needed, lateral sphenoid sinus and maxillary sinus. Following tumor resection, part of the temporalis muscle may be used to assist in CSF leak management.

Usual preoperative diagnosis

Malignant and some benign tumors

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	External Sinus Surgery	Anterior Cranial Base Surgery
Position	Head up 30°, back raised (reduces bleeding)	⇐ also reduces intracranial pressure
Incision	Access to the ethmoid and maxilla is via a 3–4-cm incision midway between the medial canthal ligament and the midline, in the shadow of the nasal bone; a lateral rhinotomy incision is not needed	A bicoronal incision posterior to the hairline masks the scar. A supplemental facial incision is rarely needed

Special instrumentation	Paranasal sinus set; headlight	⇐ + craniotomy set
Unique considerations	Nasal packing	⇐ see frontal craniotomy
Antibiotics	Cefazolin 2 g iv	⇐
Surgical time	1.5–4 h	5–8 h
EBL	25–300 mL	150–750 mL
Postop care	Same as endoscopic surgery	Same as craniotomy
Mortality	Very rare	Rare
Morbidity	Bleeding: <5%	Anosmia if bifrontal craniotomy CSF leak: <2% CVA: <1% Bone flap loss: <1% Meningitis: <1% Infection: <1%
Pain score	4–6	4–6

PATIENT POPULATION CHARACTERISTICS

Age range	Children–seniors
Male:Female	1:1
Incidence	Common
Etiology	Malignant tumors, selected benign tumors, occasionally infectious
Associated conditions	Dependent on specific tumor; also, see Endoscopic Sinus Surgery

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Endoscopic Sinus Surgery.

NASAL SURGERY (RHINOPLASTY, SEPTOPLASTY, SEPTORHINOPLASTY)

SURGICAL CONSIDERATIONS

Sam P. Most

Description

Nasal surgery is performed for cosmetic and functional restoration of the airway. Functional restoration is usually performed for either congenital or posttraumatic deviations of the septum. The nasal cavity is first cocainized with 4% cocaine-soaked pledgets placed in each nostril for 5–10 min. **Septoplasty** (reconstruction of the nasal septum) usually can be carried out under sedation with local anesthesia, using 1% lidocaine with 1:100,000 epinephrine. **Rhinoplasty-septorhinoplasty** usually is carried out under local anesthesia, but if GA is used, a mouth pack is inserted. Local infiltration with 1% lidocaine with 1:100,000 epinephrine is used to ensure vasoconstriction and to minimize bleeding. Intranasal incisions are made and septal problems corrected. Generally, an anterior hemitransfixion incision is made down to the cartilage, and a submucoperichondrial flap is elevated the length of the septum. A similar flap may be elevated on the contralateral side. Bony deformities are resected with an osteotome, whereas cartilaginous deformities are either resected or weakened by morselizing, either in situ or after removal, and then replaced. The incision is closed with interrupted absorbable sutures. In **rhinoplasty**, tip remodeling, hump reduction, and bony osteotomies are performed to remodel the nasal contour. Surgery on the inferior turbinates in the form of intramural cautery, resection of turbinate bone, resection of turbinate mucosa, or, in some cases, complete turbinectomy may be required to produce a satisfactory airway. After the surgery is complete, both nasal cavities are packed and external splints may be used for rhinoplasty and septorhinoplasty cases. For the plastic surgeon's perspective, see Chapter 11.1.

Usual preop diagnosis

Nasal deformity or deviation; deviated septum

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Head up 30° to reduce bleeding. Table may be turned 90–180°
Incision	Intranasal, usually; extended only in open septorhinoplasty
Unique considerations	Nose initially cocainized; use of 1% lidocaine with 1:100,000 epinephrine to ↓ bleeding
Antibiotics	Cefazolin 2 g iv; routinely used as long as nasal packs are in place
Surgical time	1–2.5 h
Closing considerations	Nose often packed postop, necessitating oral airway after extubation
EBL	50–100 mL (excessive blood loss rare)
Postop care	PACU
Mortality	Minimal
Morbidity	Septal perforation: 5% Bleeding: 4% Infection: 4%
Pain score	4–6

PATIENT POPULATION CHARACTERISTICS	
Age range	Young teens–young adults
Male:Female	1:1
Incidence	Common
Etiology	Congenital/traumatic septal and/or nasal deviation

FACIAL PLASTIC SURGERY

Overview

Facial plastic surgery encompasses both reconstructive and aesthetic surgery of the face

and neck. Typically, these surgeons are trained in otolaryngology—head and neck surgery/facial plastic surgery, general plastic surgery (see Chapter 11.1), or both. The procedures to be covered in this section are rhinoplasty, rhytidectomy (facelift), and blepharoplasty (eyelid rejuvenation).

SURGICAL CONSIDERATIONS

RHINOPLASTY

Description

Rhinoplasty has traditionally been considered an aesthetic procedure. However, when combined with a septoplasty (rhinoseptoplasty, septorhinoplasty), it is both a functional and aesthetic operation. In some cases, a purely functional operation (functional rhinoplasty) is performed to improve the ability to breathe through the nose. The approach and anesthetic requirements for these can be considered together.

Technique

A septoplasty involves a unilateral intranasal incision along the anterior septum with minor variations in the placement of the incision in the anteroposterior plane. The approaches to rhinoplasty can be intranasal, extranasal, or both. Frequently, the external (or "open") approach to rhinoplasty is employed. The intranasal approach involves incisions along the septum anteriorly and some combination of incisions in the nasal vestibule. The external approach combines these approaches with a midcolumellar incision. In both functional and aesthetic rhinoplasty, the maneuvers include cartilage remodeling or resection and possibly osteotomies to manipulate the bony pyramid of the nose.

Usual preop diagnosis

For aesthetic patients, the typical preop diagnosis is nasal deformity. However, many patients also complain of nasal obstruction, and some rhinoplasty patients have purely functional concerns. Patients with significant nasal obstruction may have some component of sleep-disordered breathing or even OSA. Because of this, patients with nasal obstruction are routinely asked about snoring and daytime somnolence (if they have not already had a diagnostic sleep study).

Preop and intraop preparation

Preoperatively, patients receive a nasal decongestant spray (0.05% oxymetazoline spray, 3 doses 10 min apart) to reduce intraop bleeding. Preop corticosteroid (4–8 mg dexamethasone iv) and antibiotics (cefazolin, 2 g iv) are administered. Intraop, we prefer LMA for protection of the airway and esophageal inlet, as some bleeding in the

nasopharynx is expected. If an ETT is used, a throat pack can be placed to reduce blood entrance into the esophagus/stomach. The tube should be secured to the midline of the lower lip to avoid distortion of the nose/nasal base.

Postop care

At the end of the procedure, prior to extubation, the surgeon will place an external splint of some type on the nose. Any mask placed on the patient should be done in such a fashion as to not place pressure on the nose. We prefer the transport oxygen mask be cut off such that no contact occurs. Any Valsalva can result in epistaxis and/or bleeding under the septal or nasal skin flaps. Thus, any maneuvers to reduce bucking or coughing during extubation are in order.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Intranasal + columella (external rhinoplasty)
Special instrumentation	Headlight
Unique considerations	Nasal obstruction postop
Antibiotics	Often administered preop: cefazolin 2 g iv
Other preoperative meds	Nasal decongestant spray, dexamethasone 4–8 mg iv
Surgical time	1–3 h
EBL	25–50 mL
Mortality	Minimal
Morbidity	Epistaxis, septal perforation, unsatisfactory aesthetic result
Pain score	1–4, typically mild

PATIENT POPULATION CHARACTERISTICS	
Age range	15+ yr
Male:Female	1:1
Incidence	Common
Etiology	Nasal obstruction, desire for change in nasal form

RHYTIDECTOMY (FACELIFT)

Description

Rhytidectomy (facelift) is almost always an aesthetic procedure. In the common vernacular, "facelift" is often used to describe total surgical facial rejuvenation (including eyelids and forehead). Strictly speaking, rhytidectomy involves aesthetic improvement of the lower half of the face and upper neck. For this reason, some have called it a "neck lift" or "lower facelift" to avoid confusion. Perhaps the latter term is more appropriate, as a separate "neck lift" procedure does exist. In any event, the anesthetic requirements for these are similar.

Technique

Rhytidectomy incisions are bilateral, extending pre- and postauricularly with minor variations. In addition, the surgeon may place a small (0.5–2 cm) incision submentally for access to submental fat and/or platysma muscle. As dissection may be near branches of the facial nerve, **avoidance of muscle relaxants** is required.

Usual preop diagnosis

For aesthetic patients, the typical preop diagnosis is simply desire for reduction in nasolabial and labiomandibular lines, jowling, and neck skin laxity. Patients are typically over the age of 40 and usually in good health. Smoking is a contraindication due to the risk of poor wound healing and/or skin flap necrosis.

Preop and intraop preparation

Preop patients receive corticosteroid (4–8 mg dexamethasone iv) and antibiotics (cefazolin, 2 g iv). Intraop, we prefer LMA for protection of the airway and esophageal inlet, though an ETT can be used. The tube should be secured to the **midline of the lower lip** to avoid distortion of the lower face/neck. The tube is prepped into the field and may be manipulated side to side during the procedure as the submental incision is accessed. In addition, the head may be turned about 30–45° to the side opposite the surgeon. Typically, dissection near the branches of the facial nerve is undertaken, and

visual monitoring for any twitches is performed by the assistant; thus, **avoidance of muscle relaxants is imperative.**

Postop care

At the end of the procedure, prior to patient extubation, the surgeon will place a circumferential external pressure dressing of some kind on the face. Typically, cotton balls soaked in antibiotic ointment are placed in the ears. The patient may have difficulty hearing due to this dressing. Drains may have been placed on each side of the neck. Any Valsalva can result in bleeding under the skin flaps. Hematoma is one of the most common periop complications and requires evacuation. Thus, any maneuvers to reduce bucking or coughing during extubation are in order.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Pre- or postauricular and submental
Special instrumentation	Headlight
Unique considerations	Facial nerve is monitored (visually); avoid paralytics
Antibiotics	Often administered preop: cefazolin 2 g iv
Other preop meds	Dexamethasone: 4–8 mg iv
Surgical time	3 h
EBL	25–50 mL
Mortality	Minimal
Morbidity	Hematoma, facial paralysis, unsatisfactory aesthetic result
Pain score	1–4, typically mild

PATIENT POPULATION CHARACTERISTICS

Age range	40+
Male:Female	1:8
Incidence	Common
Etiology	Desire for change in facial aesthetics
Associated conditions	Other facial aesthetic considerations

BLEPHAROPLASTY

(For the plastic surgeon's perspective, see Chapter 11.1)

Description

Blepharoplasty (eyelid rejuvenation surgery) is, in the overwhelming majority of cases, an anesthetic procedure. In some cases, functional upper lid blepharoplasty may be performed to reduce visual field obstruction and is typically covered by insurance. These procedures are often performed under local anesthesia with sedation. However, as they are often combined with other procedures (brow lift, facelift), the patients are often under general anesthesia.

Technique

Upper blepharoplasty incisions are placed on curvilinear fashion along the upper eyelid creases with minor variations. The amount of skin to be excised is marked by the surgeon, and local anesthetic with epinephrine is administered. The evolution of upper eyelid blepharoplasty has led to a more conservative approach with less muscle and fat excision being performed. As the procedure becomes more skin only, many are being performed under local anesthesia as an isolated procedure.

Lower blepharoplasty is generally performed transcutaneously with a subciliary incision or transconjunctivally via the inner portion of the lower eyelid. In the former approach, a small amount of lower lid skin and muscle is typically excised. With both approaches, the surgeon removes or repositions a small amount of the intraorbital fat pockets for the desired aesthetic result.

Usual preop diagnosis

For aesthetic patients, the typical preop diagnosis is simply desire for reduction of upper lid skin excess, which may obstruct their vision (see above). In the lower lid, the most common complaint is "puffiness" of the lower eyelid, which is often due to

pseudoherniation of orbital fat and descent of the midface fat with age. Patients are typically over the age of 30 and usually in good health.

Preop and intraop preparation

Preop patients receive corticosteroid (4–8 mg dexamethasone iv) and antibiotics (cefazolin, 2 g iv). Intraop, we prefer LMA for protection of the airway and esophageal inlet. The tube should be secured to the midline of the lower lip to avoid distortion of the lower face/neck.

Postop care

At the end of the procedure, prior to patient extubation, the surgeon will confirm satisfaction with symmetry and aesthetic result. No dressings are used. Any Valsalva can result in bleeding under the skin flaps. More important, intraorbital pressure must be avoided as it may result in a serious complication, placing the patient's vision at risk. Thus, any maneuvers to reduce bucking or coughing during extubation are in order.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Upper lid crease, lower lid via transconjunctival or transcutaneous approaches
Special instrumentation	None
Unique considerations	None
Antibiotics	Often administered preop: cefazolin 2 g iv
Other preop meds	Dexamethasone: 4–8 mg iv
Surgical time	1.25 h (upper or lower only); 2 h (both upper and lower)
EBL	<5 mL

Mortality	Minimal
Morbidity	Asymmetry, dry eye, ectropion, corneal abrasion, blindness (rare)
Pain score	1–4, typically mild

PATIENT POPULATION CHARACTERISTICS	
Age range	30+
Male:Female	1:8
Incidence	Common
Etiology	Desire for change in facial aesthetics; in some cases, upper blepharoplasty is performed for functional reasons
Associated conditions	Other facial aesthetic considerations

ANESTHETIC CONSIDERATIONS FOR FACIAL COSMETIC SURGERY (NASAL SURGERY, RHYTIDECTOMY, AND BLEPHAROPLASTY)

PREOPERATIVE

These cases typically are performed on an outpatient basis. Most of the patients are young and otherwise healthy, but some patients presenting for rhinoplasty/septoplasty and turbinate reduction surgery may have OSA with the corresponding implications for intraop management. Older patients may present for major reconstructive nasal surgery following resections of a basal cell carcinoma of the nose. Patients presenting for closed reduction of nasal fractures may have suffered concomitant closed head trauma. If the nose injury is recent, blood may have been swallowed, and the patient should be considered "full stomach."

Patients with diabetes mellitus (DM) and those with rheumatologic diseases may be particularly prone to bruising, infection, and delayed healing. The use of nonsteroidal anti-inflammatory medications (NSAIDs),aspirin, and certain herbal supplements, such as ginkgo or echinacea, and certain vitamins (e.g., vitamin E) should be stopped at least 2 wk prior to surgery to avoid the risk of excessive microvascular bleeding.

Respiratory	Some patients may present with a Hx of reactive airway disease; their functional status should be checked and optimized preop. Increased airway reactivity may provoke excessive postop coughing and straining, increasing the risk of bleeding. **Tests:** As indicated from H&P
Cardiovascular	Special attention should be directed to the presence of HTN, which may predispose the patients to hematoma formation. HTN should be well controlled preop. In patients with preexisting cardiac disease, cocaine for topical anesthesia or control of bleeding may be contraindicated. **Tests:** ECG in older population; others as indicated from H&P
Neurologic	Psychologic disturbances are common in patients presenting for rhinologic surgery.
Premedication	Standard premedication. Sedation should be avoided or used with caution in patients with OSA.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 500–1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

The anesthetic plan should provide for patient immobility, smooth emergence from anesthesia, a rapid return of consciousness, prevention of PONV, and fast-tracking patients for discharge. A wide variety of office-based cosmetic procedures, including rhinoplasty, rhytidectomy, and blepharoplasty, can be performed under either local anesthesia with iv sedation or GA. The choice is frequently dictated by the patient's desires and the surgeon's level of comfort. MAC removes the triggers for malignant hyperthermia (MH) GA-induced emergence phenomena, reduces the incidence of PONV, and facilitates patient discharge; however, administration of a successful MAC without immediate access to the patient's airway is frequently more challenging than conducting GA. With MAC, FiO_2 must not exceed 0.3 to prevent intraop fire.

Induction	Standard induction with propofol (1–2 mg/kg) is an ideal induction agent because of its short duration and intrinsic antiemetic effect. For GETA, the use of an oral RAE or reinforced ETT will facilitate surgical access. Spontaneous or controlled ventilation can be used, and FLMA is strongly preferred over tracheal intubation (see Introduction). Both ETT and FLMA are usually taped midline.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	All GA techniques (balanced, inhalational, or TIVA) can be used safely, although TIVA is preferred. Propofol infusion (80–150 mcg/kg/min) may offer the advantage of ↓ BP without compensatory ↑ HR and ↓ PONV. Remifentanil infusion (0.1–0.25 mcg/kg/min) will improve hemodynamic stability and facilitate rapid and smooth emergence. Maintaining moderate degree of ↓ BP is essential.
Emergence	Aggressive prevention of PONV, usually with iv 5-HT_3 antagonist (e.g., ondansetron 4–8 mg) in combination with iv dexamethasone (8–10 mg) is highly effective and may lead to improved patient outcome. Dexamethasone is administered routinely during facial cosmetic surgery. Multimodal PONV prophylaxis is warranted in high-risk patients. Avoid ↑ BP, bucking, and coughing on emergence (FLMA is superior to ETT in this regard) to prevent microvascular bleeding and hematoma formation, especially after rhinoplasty and rhytidectomy. Emergence from anesthesia after nasal surgery presents significant challenges to the anesthesiologist. Nasal passages may be packed at the end of surgery, making the patients obligate mouth breathers; the oropharynx should be suctioned carefully. Avoid pressure on the patient's nose with the face mask. Full return of airway

	reflexes should occur before extubation. Discuss with surgeon local wound infiltration. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Blood loss usually minimal IV: 20 ga × 1 BSS @ 2–3 mL/kg/h	Blood loss is controlled with surgical hemostasis and topical applications of vasoconstrictor (epinephrine) but also may include cocaine. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	
Positioning	Head elevated 15–30° Table turned 90–180° ✓ and pad pressure points ✓ eyes	Patient's arms usually tucked in and should be carefully padded. The eyes are usually protected by the surgeon according to surgeon's preference.
Complications	Tachycardia, dysrhythmias	These are usually related to use of vasoconstrictor agents and may present a problem in patients with CAD. Short-acting β-blocker (esmolol, 0.5–1 mcg/kg in boluses) should be available to blunt these hemodynamic effects.
	Laryngospasm, negative pressure pulmonary edema	Treatment is supportive: reestablishment of airway patency, oxygen supplementation, ventilatory support (CPAP

		or tracheal intubation with positive pressure ventilation and PEEP), management of fluid shifts, and maintenance of normal intravascular volume.

POSTOPERATIVE

Complications	Occult bleeding	Occult postop bleeding may cause the patient to swallow large quantities of blood (↑ aspiration risk); and repacking the nostrils may be required. Adequate prophylaxis of hypertensive responses postop (iv bolus doses of labetalol, 0.1–0.2 $mg \cdot kg^{-1}$) and PONV are essential.
Multimodal pain management	Fentanyl 25–50 mcg iv prn is usually sufficient.	Emphasize multimodal approach using acetaminophen/NSAIDs (see Appendix K, p. K-5).
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

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15. See references for Introduction and for Anesthesia Considerations for Endoscopic Sinus Surgery.

OTHER ANESTHETIC CONSIDERATIONS FOR FACIAL COSMETIC SURGERY

See Anesthetic Considerations for Facial Cosmetic Surgery.

OTOLOGY AND NEUROTOLOGY

SURGICAL CONSIDERATIONS

Otologic Surgery

Otologic surgery is indicated for a spectrum of disorders, including traumatic, developmental, infectious, and neoplastic disease. Procedures involving the external auditory canal, middle ear, and inner ear will be considered in this section. Surgery confined to the pinna or that requiring craniotomy is considered elsewhere.

The temporal bone is as complex as any region of human anatomy (Figs. 3.12 and 3.13). Multiple vital neurovascular structures interrelate in a small confined space. These include the organs of hearing and balance, the facial nerve, the carotid artery, the jugular vein, and the delicate mechanisms of the middle ear. The density and complexity of the anatomy dictate the delicate nature of otologic procedures and hence many of its anesthetic requirements. Most procedures are performed via a transcanal approach (through the natural meatus of the external ear), a retroauricular incision, or a combination of the two.

Many otologic procedures are undertaken to control recurrent or chronic ear infections (otomastoiditis). The simplest of these is the **myringotomy**, in which the tympanic membrane (TM) is incised through the ear canal, and the middle ear contents are aspirated. In most cases, a myringotomy tube is also placed to maintain middle ear aeration and drainage. This procedure usually takes just a few minutes and is performed under mask GA. A myringoplasty involves the repair of a persistent TM perforation and usually involves placement of autologous tissues as a patch to enable healing. When combined with repair of chronic middle ear changes, the procedure is termed a tympanoplasty.

The mastoid is an area of bone and air spaces situated behind the middle ear and external auditory canal. The removal of this bone, through a **simple mastoidectomy**, enables the removal of loculated infection and diseased tissue and provides access to additional anatomy. This is often combined with tympanoplasty **(tympanomastoidectomy)** to address the changes from chronic infection. This is the standard surgical approach to resect a **cholesteatoma**, which is a keratin-containing epithelial cyst originating from the TM that has grown into the middle ear and mastoid cavity. When the posterior bony wall of the external auditory canal is left in place to keep the mastoid cavity anatomically distinct from the external auditory canal, the procedure is called a **canal wall-up tympanomastoidectomy**. In contrast, for more aggressive disease, the partition between the external canal and the mastoid cavity can be removed, thereby exteriorizing the mastoid cavity in what is termed a **canal wall-down tympanomastoidectomy**. During this procedure, the external auditory canal meatus should also be enlarged to accommodate the resulting mastoid bowl. The

complete removal of mastoid and middle ear contents is sometimes referred to as a **radical mastoidectomy**. Tympanomastoid surgery is usually performed under GA and may take several hours to complete.

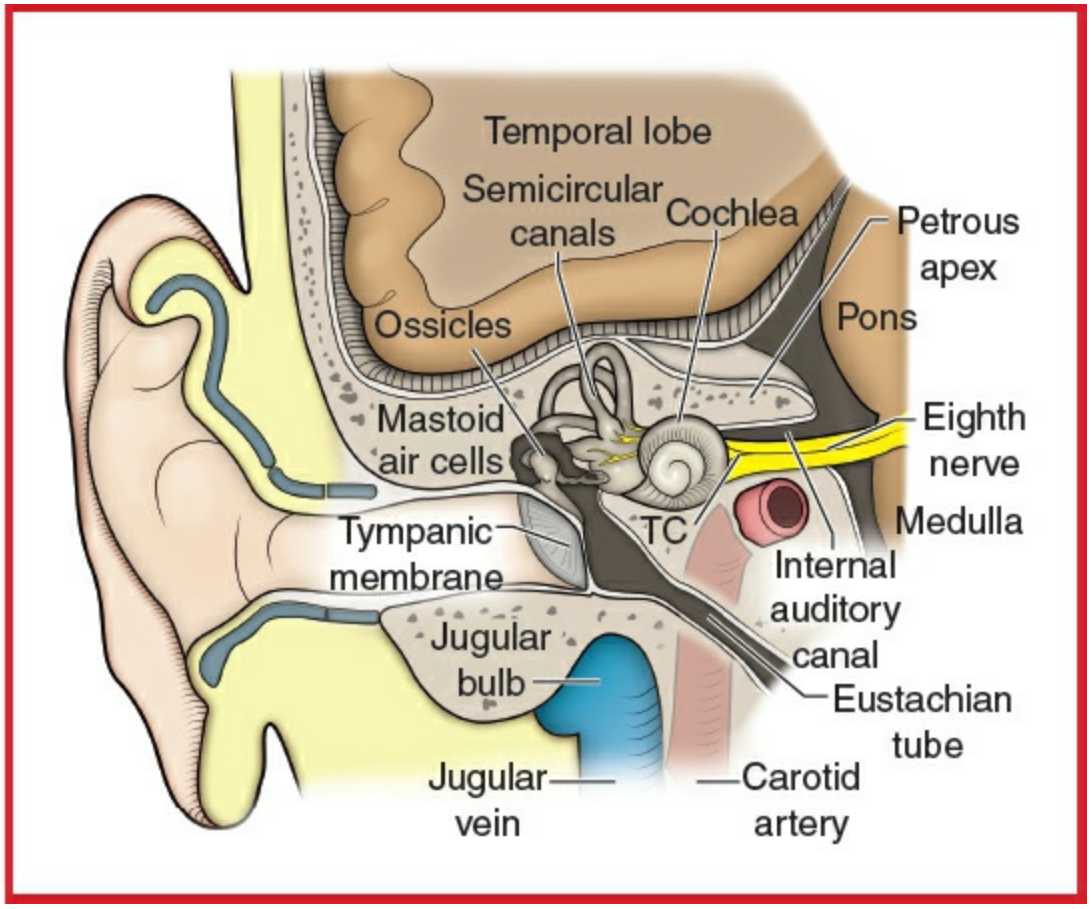

Figure 3.12 Coronal diagram of the right ear.

Surgery is often performed to improve the mechanical conduction of sound vibrations through the middle ear into the inner ear ("conductive hearing loss"). If the cause of the mechanical dysfunction is not clear, the surgeon may perform an **exploratory tympanotomy**, during which the TM is elevated and the middle ear structures are inspected and palpated to reveal deficits in their function. **Ossicular chain reconstruction** involves rebuilding or replacing the bones of hearing (malleus, incus, and stapes) with either the patient's own tissues or with alloplastic prostheses. Otosclerosis is a disorder characterized by the progressive fixation of the stapes to the surrounding bone, resulting in hearing loss. One option for affected patients is to perform a **stapedectomy** (or stapedotomy) in which the stapes is replaced by a prosthesis to restore more normal continuity of sound conduction. This procedure can be performed under either local or general anesthesia. It involves extreme accuracy for success and can be one of the most challenging cases for the otologic surgeon.

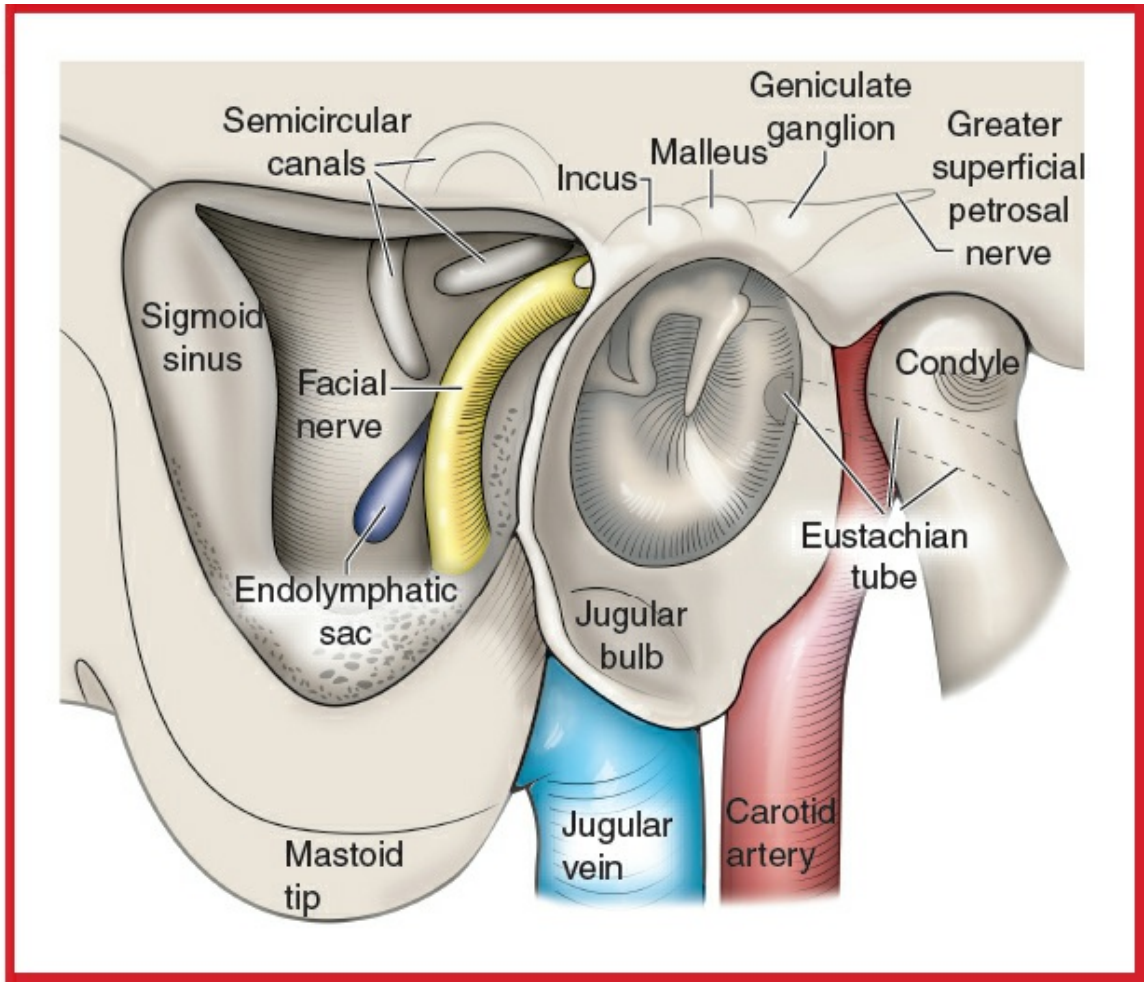

Figure 3.13 Lateral diagram of the right ear.

Cochlear implantation is an option to address severe or profound inner ear hearing loss ("sensorineural hearing loss"). During implantation, a retroauricular incision and mastoidectomy are performed to provide a pathway for device placement into the inner ear. A receiver-stimulator is placed under the skin behind the ear, and a flexible electrode array is threaded into the turns of the cochlea to later be used to stimulate the cochlear nerve directly and thereby bypass the dysfunctional inner ear. The devices are activated usually several weeks following placement, at which time hearing function is expected to increase.

A number of procedures address disorders specifically confined to the external auditory canal. Patients may develop extra bone growths (exostoses) in the ear canal that obstruct the canal. **Exostoses resection** can be performed through a retroauricular incision or via a transcanal approach if the disease is limited. Patients may lack an ear canal (canal atresia) as the result of a congenital disorder, from chronic inflammation, or posttraumatic scarring. In such patients, a **canalplasty**, involving removal obstructing skin, bone, and scar, can be performed. Similarly, patients may require the resection of

a number of neoplastic lesions of the ear canal, most commonly of cutaneous origin. Such resections may require additional resection of adjacent tissues affected by the neoplastic process. A skin graft may be used to reconstruct the external auditory canal. This may be harvested from the retroauricular region, the inner aspect of the arm, or from the hip or thigh.

The majority of otologic surgery requires the use of a surgical microscope. The presence of the microscope has a number of implications for anesthesia. Often, the OR table is turned 180°. Of critical importance is that the patient remains entirely motionless. Any adjustment of equipment or position can have profound consequences during microdissection. Therefore, the surgeon must be made aware of any plans that may result in patient motion—even those that would otherwise seem insignificant. During microsurgery, even small amounts of bleeding can have dramatic implications; thus, maintenance of a stable low blood pressure is useful.

One common theme to otologic procedures is the need to identify and preserve the **facial nerve**. The 7th cranial nerve winds its way through the temporal bone from its origin in the brainstem to the stylomastoid foramen. It passes through the middle ear and is at risk during almost all otologic procedures. The use of an EMG-based neural monitor is now commonplace to assess neural function. The monitor will not function if paralytic agents are in use, and their untimely use can prevent the surgeon from receiving critical warnings regarding nerve activity. As a standard rule, always check with the surgeon prior to the administration of any paralytic agents during otologic procedures.

Although the internal carotid artery and jugular bulb pass through the middle ear, significant vascular injury is quite rare. Most if not all bleeding can be readily controlled with packing in the surgical field. The use of absorbable gelatin sponges (e.g., Gelfoam™) is routine to hold reconstructive materials in place and also can help with hemostasis. Venous injury, such as laceration of the sigmoid sinus during mastoidectomy, can usually be controlled using bone wax or with other hemostatic materials (e.g., Surgicel™) held with pressure against the site of bleeding. In the case of a large venous injury, a **venous air embolism** can potentially result, and timely communication between the surgical and anesthesia teams can facilitate its identification and treatment. More severe arterial injury may require additional neuroradiologic or neurosurgical intervention. Even in these rare instances, hemodynamically significant blood loss can usually be avoided with prompt and secure packing.

The temporal bone abuts the dura of the middle fossa above and the posterior fossa behind. Rarely, transgression of the dura can result either as the result of pathology or

from dissection of adjacent tissues. When this occurs, the surgeon can usually close the leak using autologous tissues. The surgeon may request administration of a Valsalva maneuver to check the integrity of the repair.

Usual preop diagnoses

Acute or chronic otitis media, cholesteatoma, hearing loss (conductive or sensorineural), otosclerosis, aural atresia (acquired or congenital), tympanic membrane perforation, temporal bone fracture, temporal bone neoplasm

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Postauricular or transcanal
Special instrumentation	Binocular surgical microscope, otologic microinstruments, otologic drill, laser
Unique considerations	Complex microanatomy, no paralytics given, need for facial nerve monitoring, possible avoidance of nitrous oxide
Antibiotics	Often administered preop
Surgical time	<1 h to >4 h
EBL	Usually minimal
Mortality	Minimal
Morbidity	Infection, hearing loss, vertigo, facial nerve dysfunction, spinal fluid leak
Pain score	1–6, typically mild

PATIENT POPULATION CHARACTERISTICS	
Age range	All ages
Male:Female	1:1

Incidence	Common
Etiology	Infectious, traumatic, congenital, neoplastic
Associated conditions	Hearing loss, head trauma

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients presenting for ear surgery are generally young and healthy, and most procedures are performed on an outpatient basis. Communicating with these patients may be difficult 2° ↓ hearing ability. Myringotomy and pressure equalization (PE) tube insertion are very short procedures. In contrast, ossicular and tympanic membrane reconstruction with facial nerve preservation may last several hours. Patients presenting for external ear reconstructions may have associated congenital abnormalities, which should be considered preop.

Respiratory	Patients may present with Sx of concurrent URI including cough (see Anesthetic Considerations for Tonsillectomy). **Tests:** As indicated from H&P
Cardiovascular	No special considerations **Tests:** EKG in older population.
Neurologic	Document brief neuro exam (including facial nerve function) and extent of any hearing loss
Premedication	Standard premedication
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GA, often with moderate controlled hypotension

Induction	Standard iv induction with propofol is used most

	often. If GETA is planned, a single intubating dose of an intermediate-acting nondepolarizing NMB (e.g., rocuronium) is usually inconsequential with regard to intraop monitoring of the facial nerve. In the absence of contraindications, succinylcholine can also be safely administered for tracheal intubation. Coadministration of iv remifentanil bolus 3–4 mcg/kg (or alfentanil 40–60 mcg/kg) given over 90 sec, and propofol iv bolus 2–2.5 mg/kg, will provide excellent intubating conditions without the need for NMB in the majority of patients. PPV through the ETT or LMA are used most commonly, although spontaneous ventilation techniques can also be employed in selected patients.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Moderate ↓ BP (see Introduction) may be requested. If an inhalational agent is used, N_2O is best avoided. Inhalational anesthesia, balanced inhalational anesthesia, TIVA, and even combined propofol-inhalational anesthetics have all been successfully used for maintenance. Sevoflurane may be preferred for outpatient surgery: it improves the quality of postop patient recovery, shortens the discharge time, is associated with reduced incidence of coughing and postop agitation compared to desflurane, and produces less somnolence and PONV compared to isoflurane. The use of an LMA in children undergoing myringotomy and PE tube placement may be associated with ↓ incidence of intraop hypoxemia and better operating conditions as compared to the standard face mask technique. The second-generation LMA family of devices (LMA ProSeal™ or LMA Supreme) will offer the greatest advantages (see Introduction).

	As the patient's head is usually maintained in a fixed position (turned away from the surgeon), the position of these devices remains stable. A total intraoperative dose of fentanyl can be safely limited to 2–3 mcg/kg in the majority of patients, especially when remifentanil is used intraoperatively.	
Emergence	At the end of the procedure, the patient's head is moved during dressing application, which may provoke gagging or bucking. Smooth emergence from anesthesia is mandatory. The use of the LMA eliminates laryngeal stimulation and facilitates smooth emergence (see Introduction). If postextubation laryngospasm occurs, the use of CPAP or face mask ventilation may be contraindicated, as it may unseat the tympanic membrane graft or disrupt other repairs. Postoperative pain is usually mild to moderate but may be minimal (e.g., laser stapedectomy, tympanoplasty) or severe (e.g., radical mastoidectomy). Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 18–20 ga × 1 BSS @ 3–4 mL/kg/h	Blood loss is usually minimal. An IV is usually placed at the side where the surgeon is positioned, to eliminate the possibility of triggering sudden surgical tremor during cuff inflation. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Control of bleeding	Head-up position (10–15°), per surgeon's preference Injection of epinephrine-	These special considerations are applicable to surgical procedures carried out

	containing solutions by surgeon Deliberate moderate ↓ BP	under microscopic control, where even the smallest quantity of blood may interfere with visualization.
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes ✓ opposite ear	The LMA should be diligently secured midline. Surgical drapes can usually be arranged in a way that allows the anesthesiologist limited access to the patient's airway.

POSTOPERATIVE

Complications	PONV Facial nerve injury	Liberal prophylactic use of antiemetics is indicated.
Multimodal pain management	Fentanyl (outpatient) Hydromorphone (inpatient)	The use of a PCA may be appropriate in older children and adults. Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with peripheral local anesthetics (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

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comparison of desflurane, isoflurane and sevoflurane. Eur J Anaesthesiol 2004; 21:902–6.
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NEUROTOLOGIC SKULL BASE SURGERY

SURGICAL CONSIDERATIONS

The skull base refers to the floor of the cranial cavity and can be divided into anterior, middle, and posterior fossae. It is formed by the frontal, ethmoid, sphenoid, temporal, and occipital bones. Neuro-otologists primarily deal with lesions in the posterior fossa, which is bordered by the clivus (anterior), temporal bone (lateral), and occipital bone (posterior). An axial view of the skull identifying these structures is shown in Figure 3.14.

The term **skull base surgery** is a misnomer as the majority of lesions treated are located adjacent to the brainstem and not intrinsic to the skull base itself. Removal of the skull base bone allows exposure to these lesions while minimizing cerebral and cerebellar

retraction.

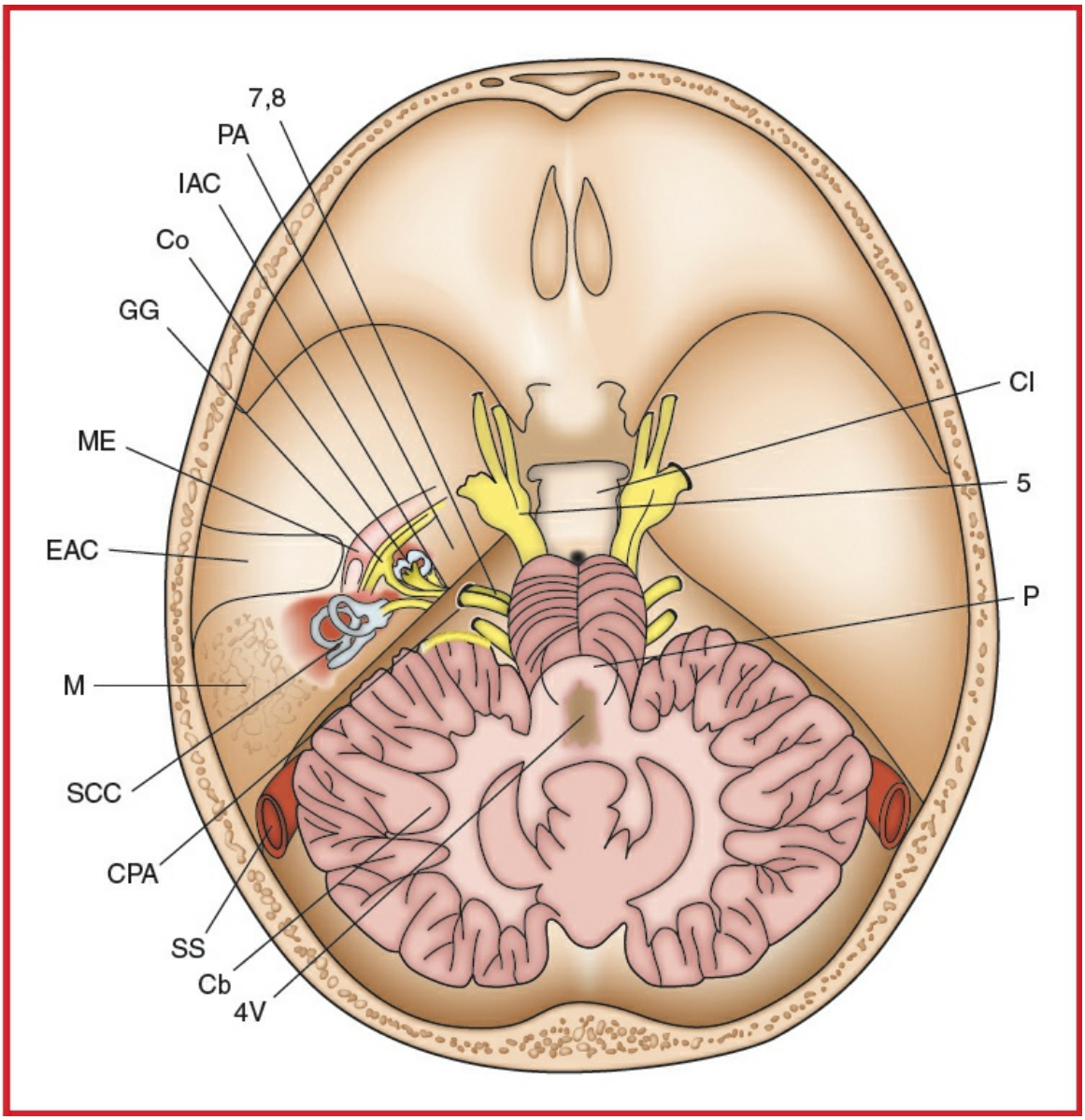

Figure 3.14 An axial view of the skull through the level of the internal auditory canal and cerebellopontine angle. 5, trigeminal nerve; 7, facial nerve; 8, audiovestibular nerve; PA, petrous apex; IAC, internal auditory canal; Co, cochlea; GG, geniculate ganglion of the facial nerve; ME, middle ear; EAC, external auditory canal; M, mastoid air cell system; SCC, semicircular canals; CPA, cerebellopontine angle; SS, sigmoid sinus; 4V, 4th ventricle; Cl, clivus; P, pons; Cb, cerebellum. (Republished with permission from Jackler RK: Atlas of Neurotology and Skull Base Surgery. Mosby, St. Louis: 1996. Copyright Dr. R. K. Jackler © 2007.)

The cerebellopontine angle (CPA) is a fluid-filled space containing the facial nerve (VII) and vestibulocochlear nerve (VIII) coursing laterally toward the internal auditory canal. A depiction of the CPA and associated cranial nerves is shown in Figure 3.15. This is one of the most commonly approached areas in skull base surgery, and lesions include vestibular schwannomas (91.3%), meningiomas (3.1%), epidermoids (2.4%),

nonvestibular schwannomas (1.4%), and arachnoid cysts (0.5%).

Vestibular schwannomas (also known as **acoustic neuromas**) are removed via three surgical approaches: translabyrinthine, retrosigmoid, and middle fossa. The translabyrinthine approach uses a postauricular incision to access the temporal bone (Fig. 3.16). Retraction of the temporal lobe and cerebellum is minimized as the entire mastoid and labyrinth are removed to create access. This approach results in complete sensorineural hearing loss and is most commonly used in patients with large tumors and/or nonserviceable hearing. Patients with serviceable hearing may elect for a hearing conservation approach for their tumors (retrosigmoid or middle fossa). The retrosigmoid approach uses a more posterior craniotomy between the sigmoid and transverse sinuses. The cerebellum is retracted posterior away from the petrous face of the temporal bone (Fig. 3.15). Disadvantages include the increased incidence of postop headache and the need for rigid skull fixation (e.g., Mayfield). The middle fossa approach places the craniotomy above the ear and requires retraction of the temporal lobe (Fig. 3.17). This approach has the highest rate of hearing conservation but can only be used in smaller tumors without increasing the risk of postop facial palsy.

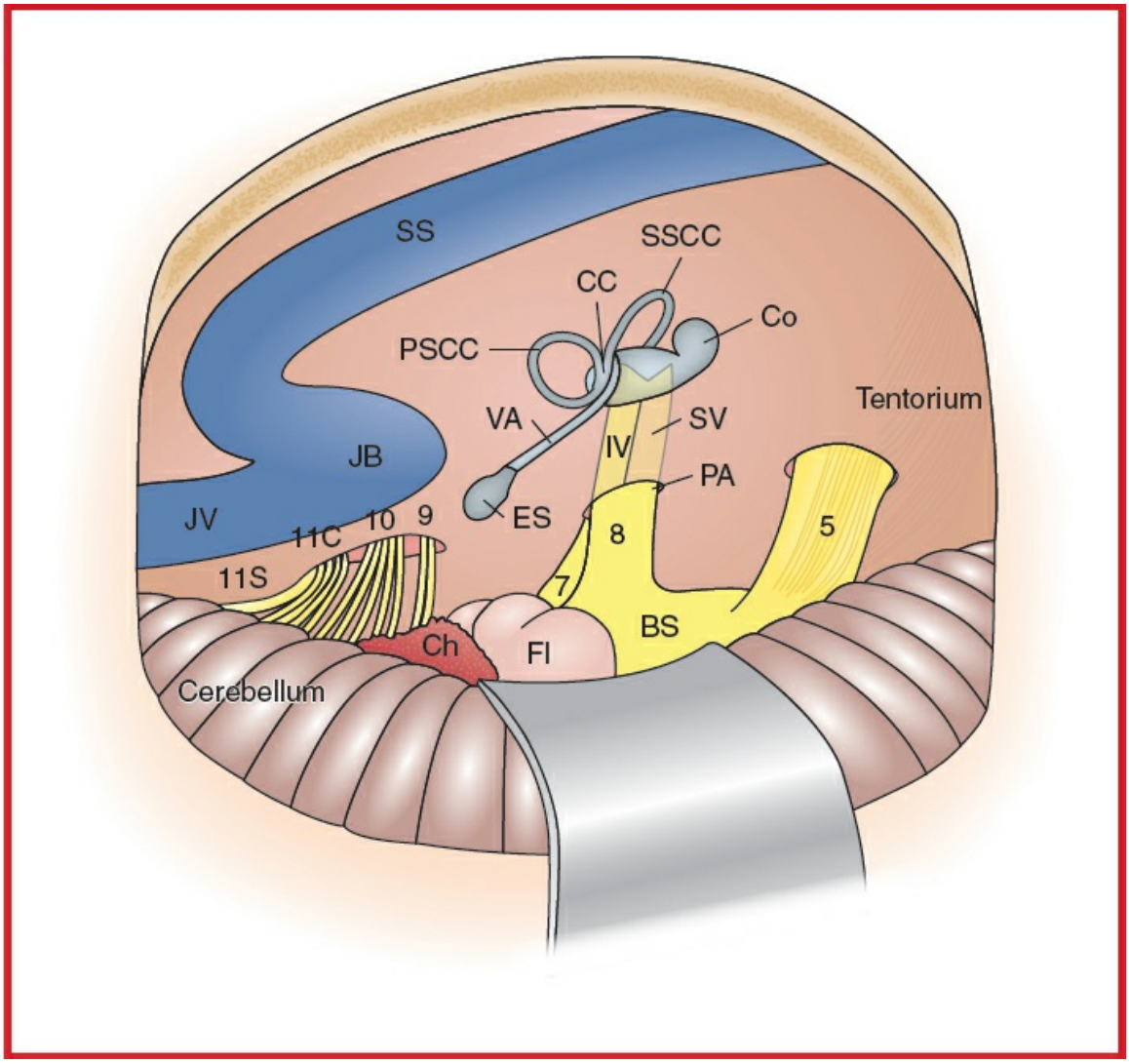

Figure 3.15 Anatomical relationships of the cerebellopontine angle shown through a retrosigmoid posterior fossa craniotomy. JV, jugular vein; JB, jugular bulb; SS, sigmoid sinus; 11s, spinal component of the accessory nerve; 11c, cranial component of the accessory nerve; 10, vagus nerve; 9, glossopharyngeal nerve; Ch, choroid plexus emanating from the lateral recess of the 4th ventricle; Fl, flocculus; BS, brainstem surface (pons); 5, trigeminal nerve; 7, facial nerve; 8, audiovestibular nerve; PA, porus acousticus; IV, inferior vestibular nerve; SV, superior vestibular nerve; ES, endolymphatic sac; VA, vestibular aqueduct; PSCC, posterior semicircular canal; CC, common crus; SSCC, superior semicircular canal; Co, cochlea. (Republished with permission from Jackler RK:Atlas of Neurotology and Skull Base Surgery. Mosby, St. Louis: 1996. Copyright Dr. R. K. Jackler © 2007.)

Another commonly approached area is the jugular foramen, which lies at the junction of the petrous apex and occipital bone. This foramen connects the intracranial compartment to the neck and contains the glossopharyngeal nerve (IX), vagus nerve (X), accessory nerve (XI), jugular bulb, and inferior petrosal sinus. The most common tumors in this area are paragangliomas. Paragangliomas are divided into two groups: (a) adrenal paragangliomas (also known as pheochromocytomas) and (b) extra-adrenal paragangliomas located in the abdomen, chest, and head and neck regions. In the jugular foramen, these tumors are often referred to as **glomus jugulare**. Less common

pathologies in this area include meningiomas and lower cranial nerve schwannomas.

Glomus jugulare tumors are highly vascular, and patients undergo preop embolization before surgery. Two to 4 U of autologous or cross-matched blood are kept available depending on the size and extent of the tumor. Large-bore ivs should be placed in case rapid transfusion is needed. In addition to a lateral craniotomy similar to the translabyrinthine approach, a limited neck dissection is performed to gain vascular control of the jugular vein and carotid artery. This transjugular craniotomy exposes the entire jugular fossa and involves resection of the involved sigmoid sinus and jugular vein (Fig. 3.18). New lower cranial nerve deficits occur in 25–50% of patients; therefore, appropriate airway and aspiration precautions must be taken. Rehabilitation often involves speech therapy and VC medialization. Tracheotomy and PEG tube placement are rarely necessary.

In all of the preceding craniotomies, the patient is turned 180° away from the anesthesiologist. This allows room for the operating microscope, scrub assistant, and surgeon to all be placed around the head of the patient (Figs. 3.19 and 3.20). The patient's head is turned to one side to allow exposure of the lateral cranium and neck. In the retrosigmoid craniotomy, a Mayfield is used for rigid skull fixation. As lateral table rotation is often used during these cases, three straps should be used to secure the patient, and the contralateral arm should be well padded in order to avoid ulnar neuropathy. Neurophysiologic monitoring (EMG, auditory brainstem responses, and SSEPs) is used throughout the case; therefore, muscle relaxants should be avoided.

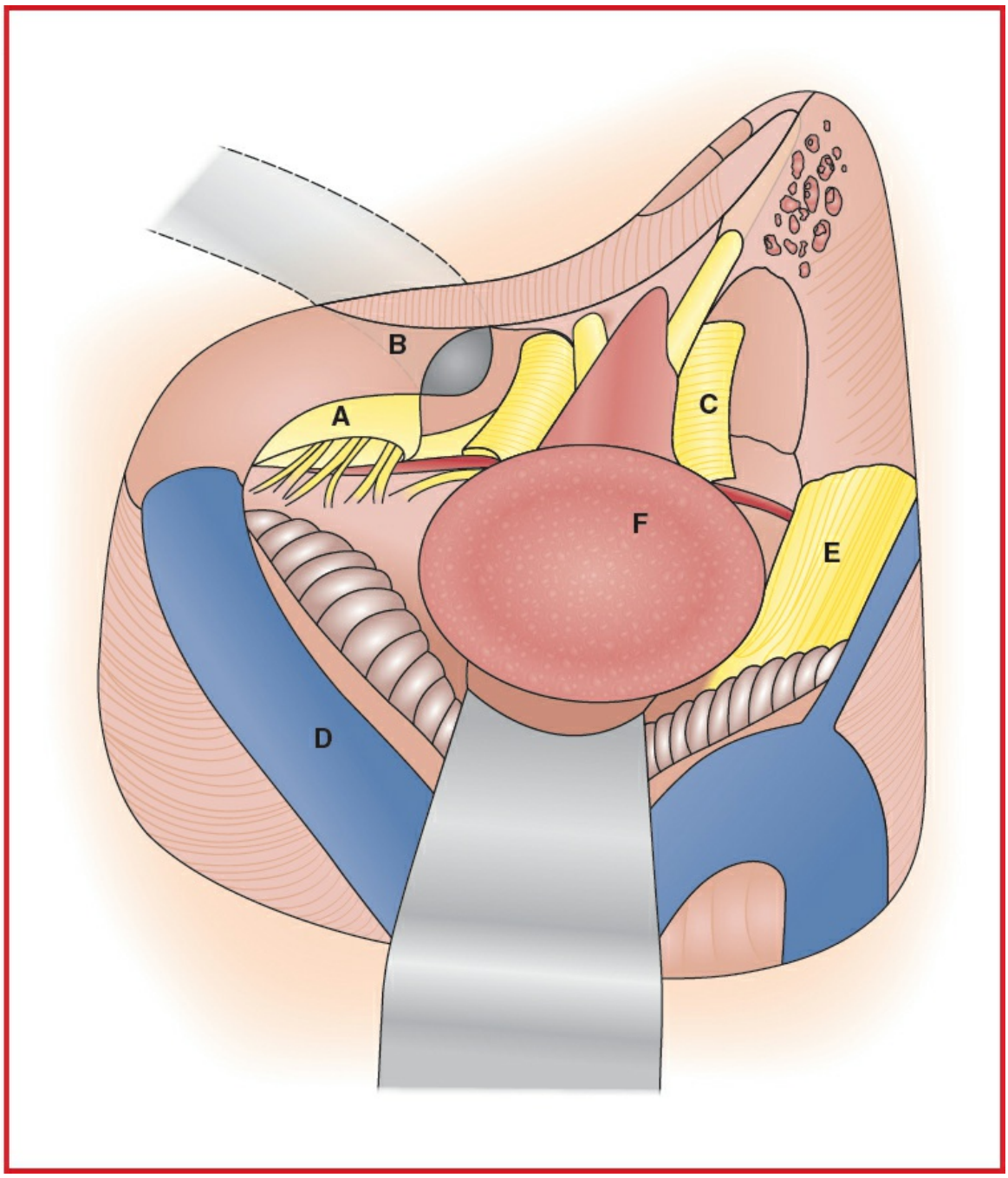

Figure 3.16 Typical left translabyrinthine posterior fossa craniotomy exposure of a medium-sized tumor. Inferiorly, the lower cranial nerves (A) are visible, and the jugular bulb (B) has been identified. Troughs have been drilled above and below the IAC, and the dura (C) has been reflected off the tumor surface. The sigmoid sinus (D) and cerebellum are gently retracted posteriorly. The trigeminal nerve (E) is located superiorly. The facial nerve (F) takes a variable and often serpentine course across the medial side of the tumor. (Republished with permission from Jackler RK:Atlas of Neurotology and Skull Base Surgery. Mosby, St. Louis: 1996. Copyright Dr. R. K. Jackler © 2007.)

Stimulation of the trigeminal or vagus nerves can cause bradycardia; therefore, the surgeon should be informed of any unexpected physiologic changes occurring with the patient. Stable low blood pressure is useful in controlling slow bleeding in the surgical field. Significant hemodynamic blood loss is rare and can usually be controlled with

secure packing. Large venous injuries may result in air embolism, and arterial injuries may require the assistance of interventional neuroradiology. Having 1 U of cross-matched blood available is prudent in most craniotomies, whereas 2–4 U may be required in glomus jugulare cases. CSF leaks are controlled using an abdominal fat graft.

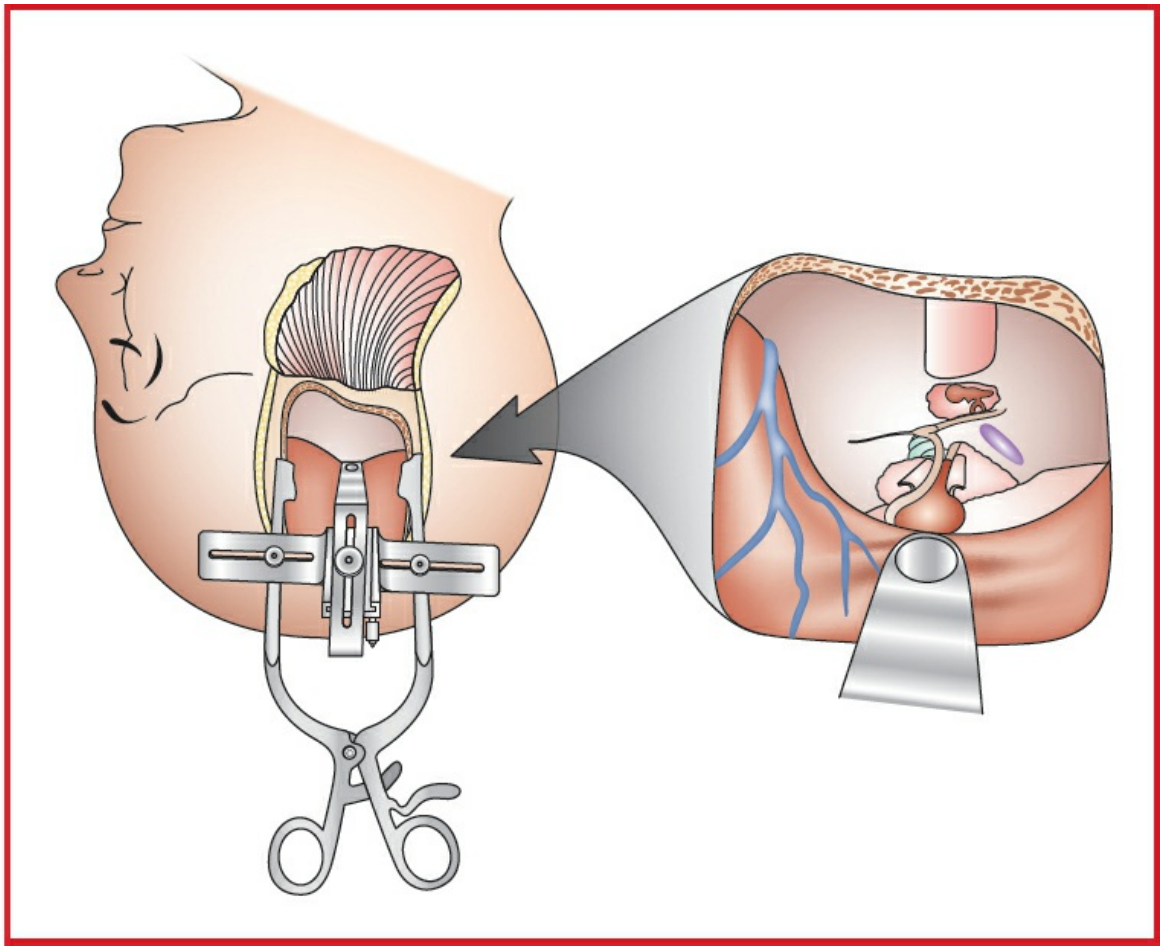

Figure 3.17 Middle fossa exposure of a small right-sided tumor. The retractor is engaged over the posterior lip of the petrous bone and retracts the temporal lobe. Bone has been removed around the IAC, and the dura has been opened to expose the tumor. The facial nerve typically courses across the superior aspect of the tumor surface. (Republished with permission from Jackler RK:Atlas of Neurotology and Skull Base Surgery. Mosby, St. Louis: 1996. Copyright Dr. R. K. Jackler © 2007.)

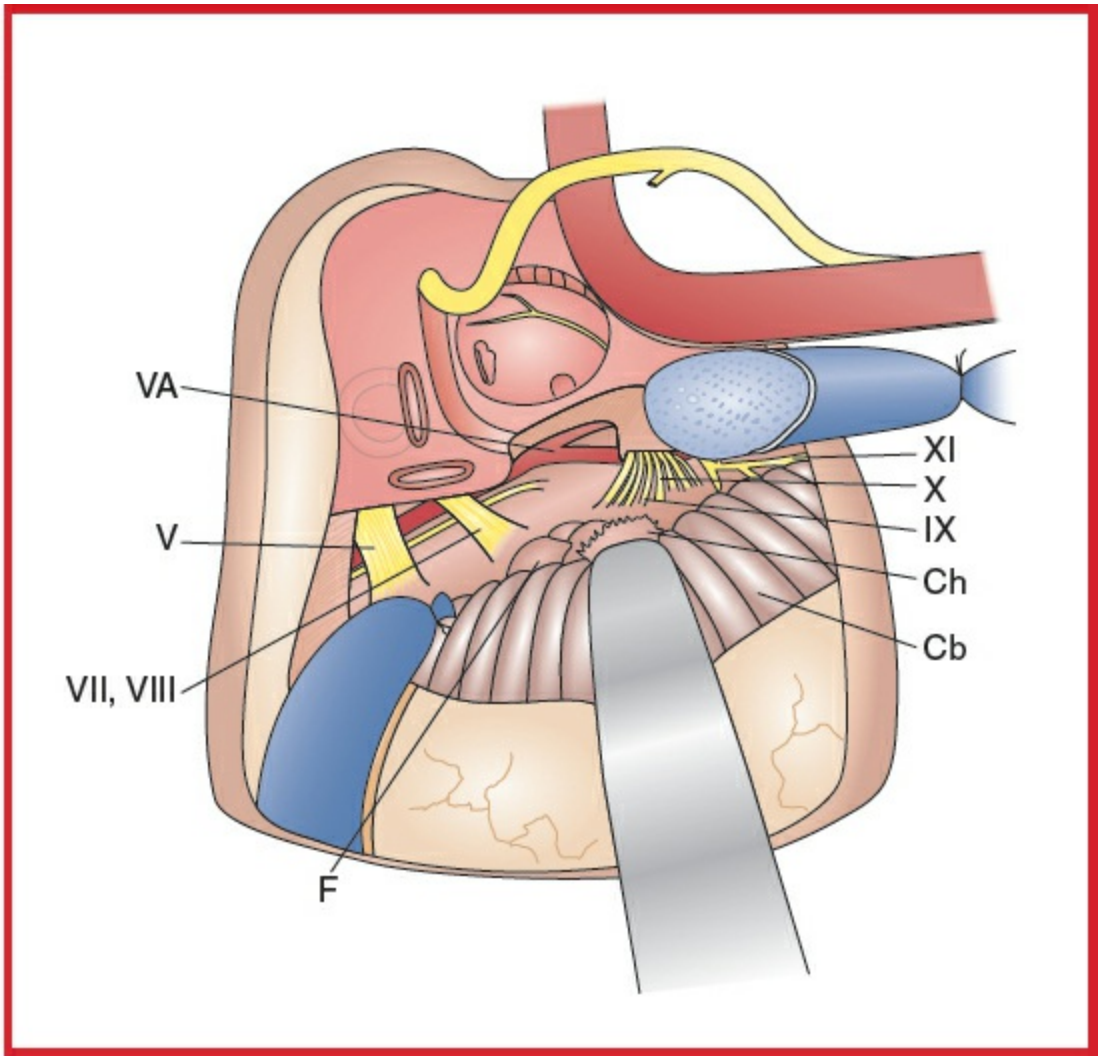

Figure 3.18 Transjugular craniotomy illustrating the degree of intracranial exposure obtained following resection of the sigmoid-jugular system and wide opening of the posterior fossa dura. Note the multiple small rootlets of the lower cranial nerves emanating from the lateral surface of the medulla. In contrast to extracranial procedures, the sigmoid sinus is ligated proximally rather than packed extraluminally. While this illustration depicts anterior rerouting of the facial nerve, this is not necessary in most intracranial jugular foramen tumors. The sigmoid sinus has been controlled with a suture ligature just distal to the transverse-sigmoid junction. VA, vertebral artery; F, flocculus; Ch, choroid; Cb, cerebellum; V, trigeminal nerve; VII, facial nerve; VIII, audiovestibular nerve; IX, glossopharyngeal nerve; X, vagus nerve; XI, accessory nerve. (Republished with permission from Jackler RK:Atlas of Neurotology and Skull Base Surgery. Mosby, St. Louis: 1996. Copyright Dr. R. K. Jackler © 2007.)

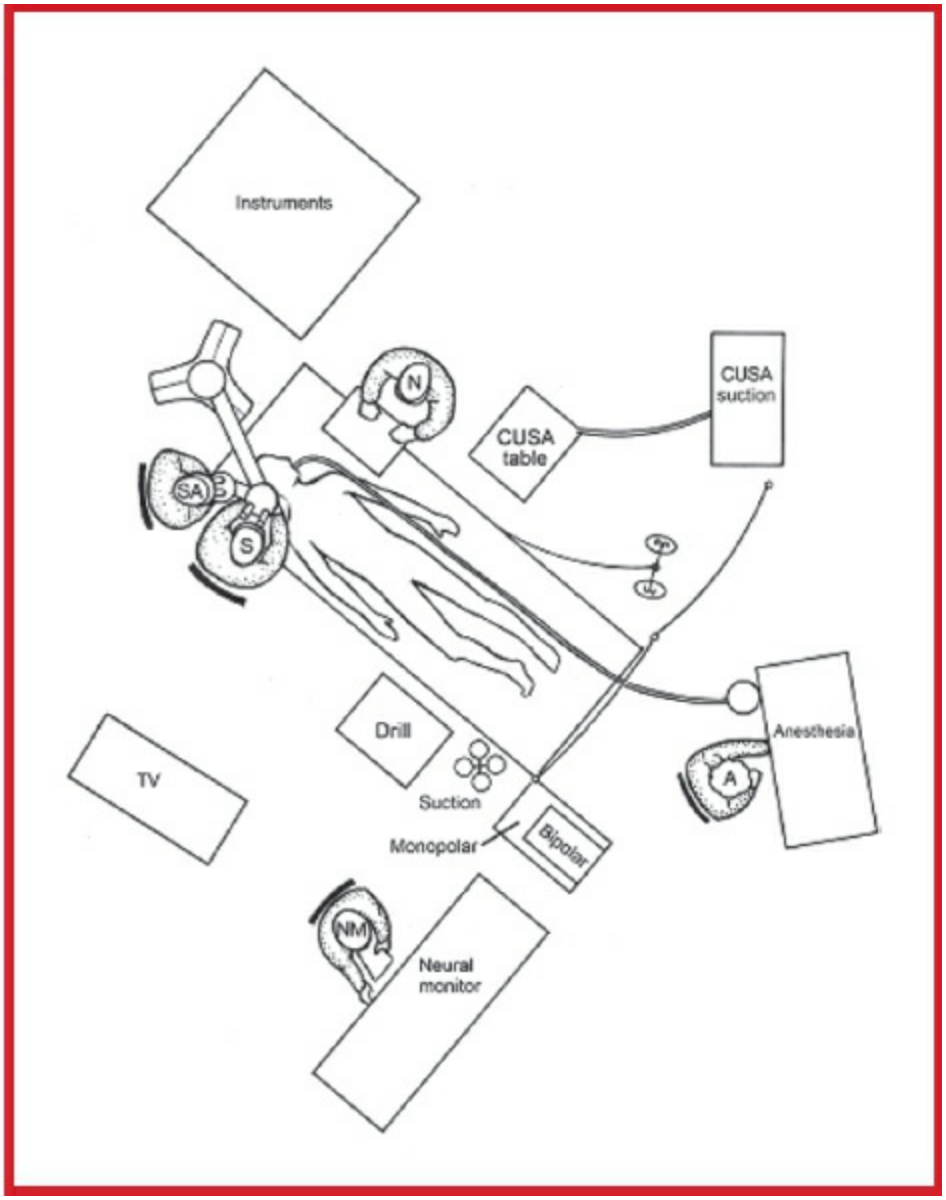

Figure 3.19 Operating room setup for posterior fossa craniotomy (translabyrinthine, retrosigmoid, and transjugular). (Republished with permission from Jackler RK:Atlas of Neurotology and Skull Base Surgery. Mosby, St. Louis: 1996. Copyright Dr. R. K. Jackler © 2007.)

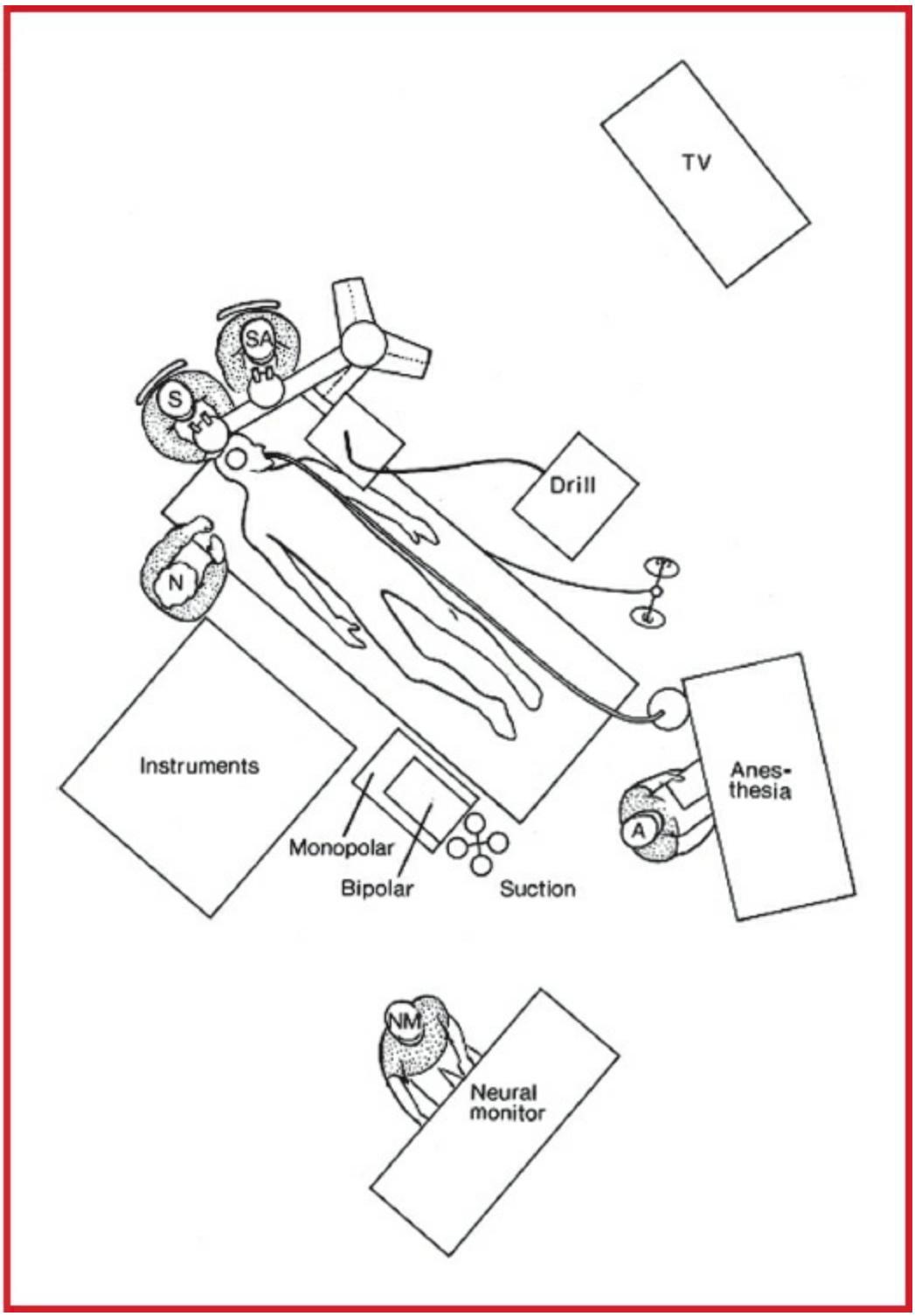

Figure 3.20 Operating room setup for middle fossa craniotomy. (Republished with permission from Jackler RK:Atlas of Neurotology and Skull Base Surgery Mosby, St. Louis: 1996. Copyright Dr. R. K. Jackler © 2007.)

Usual preop diagnoses

Vestibular schwannoma (acoustic neuroma); meningioma; paraganglioma (glomus jugulare); lower cranial nerve schwannoma; epidermoid cyst; arachnoid cyst;

cholesterol granuloma; chondrosarcoma; chordoma

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine, turned 180° from anesthesia (Figs. 3.19 and 3.20). Three straps to secure patient and arms well padded. Mayfield rigid fixation in retrosigmoid craniotomies
Incision	Postauricular or temporal with possible extension into neck depending on approach
Special instrumentation	Microscope, neurophysiologic monitoring team, ultrasonic aspirator, neck dissection and vascular instruments (transjugular), middle fossa retractor (middle fossa), otologic drill
Antibiotics	Ceftriaxone 2 g iv or vancomycin 1 g iv for CSF penetration
Procedure time	4–12 h
Closing considerations	Minimize coughing and ↑ ICP. Abdominal fat often harvested for CSF leak closure. Head dressing may be placed
EBL	100–1000 mL depending on approach and tumor. One unit of cross-matched or autologous blood for craniotomies (2–4 U for glomus jugulare tumors) should be available
Postop care	Extubation in majority of cases. Monitoring in the ICU for the first night. Minimal sedatives to allow neurologic monitoring. Airway and aspiration precautions in patients with possible lower cranial nerve palsies
Mortality	Rare

Morbidity	Hearing loss (approach dependent) Vertigo Facial nerve dysfunction Hoarseness Aspiration CSF leak Meningitis Stroke (rare)
Pain score	4–6

PATIENT POPULATION CHARACTERISTICS	
Age range	Fifth to sixth decades for most pathology Younger patients in tumors associated with neurofibromatosis (NF-2)
Male:Female	1:1 for vestibular schwannoma
Incidence	1/100,000
Etiology	Neoplastic
Associated conditions	Hearing loss (use assistive devices when possible), vertigo, lower cranial nerve dysfunction (aspiration precautions), neurofibromatosis

ANESTHETIC CONSIDERATIONS FOR NEUROTOLOGIC SURGERY

PREOPERATIVE

Large **vestibular schwannomas** (acoustic neuromas) can compress the brainstem, cause cranial nerve deficits, and occasionally produce symptoms of ↑ intracranial pressure (ICP). If ↑ ICP is present, anesthetic management should follow the same genera principles as for other intracranial mass lesions.

Highly **vascular tumors** are usually embolized during preop neuroangiography. If the tumor's blood supply is from the anterior and posterior ethmoidal arteries, these vessels cannot be safely embolized unless the patient has already lost vision. ICA balloon occlusion test is performed during angiography if the ICA is involved or encased.

Large **glomus tumors** (GT) are capable of secreting catecholamines and occasionally

serotonin, presenting with symptoms of pheochromocytoma (e.g., hypertension, sweating, cardiovascular instability) or carcinoid syndrome. Urine and plasma catecholamine levels should be routinely checked preop for all extensive GT, even if the patient is asymptomatic. The same preop pharmacologic stabilization used for patients with a pheochromocytoma may be required for these patients. Dehydration and/or electrolyte abnormalities must be corrected preop. Intraop, the release of histamine and bradykinin can cause bronchospasm, tachycardia, and both hypotension and hypertension. Large GT can cause cranial nerve IX, X, XI, and XII palsies, whic may predispose to airway compromise, by either obstruction or aspiration (the risk of gastroparesis is increased in these patients).

The **anterior skull base** is a common location for many intradural and extradural cranial and/or facial pathologies. The anterior cranial base surgery may involve combined transethmoidal incision and bifrontal craniotomy approaches. With that approach, the intraop surgical navigation set is frequently used, and a lumbar drain may be placed after induction of anesthesia.

Respiratory	GT patients may be at ↑ risk for aspiration (cranial nerve impairment) or airway obstruction depending on tumor location. GT may release histamine or bradykinin → bronchospasm. **Tests:** Imaging studies
Cardiovascular	~5% of GT secrete catecholamines → cardiovascular instability. **Tests:** ECG, UA catecholamine metabolites
Neurologic	Examine cranial nerves and document preop function. Check for Sx of ↑ ICP.
Laboratory	CBC; coagulation studies; other tests as indicated from H&P
Premedication	In the absence of airway compromise, standard premed is appropriate.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 500–1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: The essential anesthesia considerations for neurotologic surgery are largely similar to otologic surgical procedures. The anesthesiologist must be familiar with the principles of neuroanesthesia and understand both the pathologic process involved and the planned surgical approach.

Standard premedication with short-acting benzodiazepine (e.g., iv midazolam) is warranted in the majority of cases, but should be done with caution or avoided if symptoms of ↑ ICP are present. IV antibiotics with good CSF penetration (e.g., iv ceftriaxone 1–2 g) are uniformly used. Corticosteroids (e.g., iv dexamethasone 10–12 mg) may or may not be given, depending on the size of the tumor and presence of brain edema.

The most critical aspect of the skull base surgery is identification and preservation of the cranial nerves. Intraoperative neurophysiologic monitoring (IOM) is used widely, especially when the tumors are located at the cervicomedullary junction, jugular foramen (JF), the upper clivus, when the tumors are large, and during revision surgeries. Cranial nerves VII, IX, X, XI, and XII are most commonly monitored.

These surgeries can be extremely lengthy, and meticulous attention to proper patient positioning is paramount.

Induction	Preop airway compromise is rare. Standard GETA is used in the majority of cases. Patients with GT or other lesions extending into the JF, upper neck, or skull base may require intraop identification and monitoring of the vagus nerve. In these patients, placement of specialized ETT (e.g., Xomed ETT, Medtronic Xomed Inc., Jacksonville, FL) to monitor EMG activity in the vocal cords may be requested by the surgeon. The use of an intermediate-acting NMB (e.g., rocuronium) for tracheal intubation is inconsequential with regard to IOM. In patients with ↑ ICP, standard induction precautions should be observed. With large tumors, a lumbar drain will be placed after induction to remove CSF to reduce surgical brain retraction.

ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	The anesthetic technique should facilitate IOM. Intraop use of NMB is avoided. Remifentanil-based techniques, allowing a safe reduction of the concentration of inhalational agent to ≤0.5 minimal alveolar concentration (MAC) are widely used. Administration of iv mannitol (0.5–1 g/kg), started after the scalp incision, and the use of mild hyperventilation will facilitate brain relaxation for dural entry. Patients should be kept euvolemic, and electrolyte status should be monitored during the surgery. Stimulation of the trigeminal or vagus nerves during surgery can cause ↓↓ HR, ↓ BP or ↑ BP, and arrhythmias and even transient asystole, and the surgeon should be promptly informed of their occurrence.
Emergence	A smooth extubation is important because coughing and bucking on the ETT may provoke postop bleeding, increase cerebral edema, and cause tension pneumocephalus (TP). Tracheal extubation is carried out in the majority of cases. The exceptions are the patients who had undergone free flap reconstruction of the cranial base and possibly those where cranial nerve deficits existed preop. New paralysis of the lower cranial nerves with dysphasia remains the most serious complication of surgery, and delayed extubation and tracheotomy may be required in some patients. The patients are observed in the ICU overnight. Discuss with surgeon local wound infiltration. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.
Blood and fluid	IV: large-bore access With the exception of GT,

requirements	BSS @ 3–4 mL/kg/h	blood loss is usually gradual and rarely requires transfusion. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors Arterial line ± CVP	A-line is placed after induction of anesthesia. CVP should be guided by the patient's medical history; consider if significant blood loss is anticipated.
	Foley catheter	A Foley catheter is used routinely.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Massive blood loss Cranial nerve injury VAE Aspiration	Glomus tumors are highly vascular. Airway compromise may preclude extubation. Monitor for VAE (e.g., $ETCO_2$).

POSTOPERATIVE

Complications	Trigeminal and vagal reflexes Cranial nerve injury Tension pneumocephalus	IV atropine Extubation considerations (cranial nerve deficits)
Multimodal pain management	Fentanyl/hydromorphone	The use of a PCA may be appropriate in older children and adults. Emphasize multimodal with peripheral local anesthetics (see

		Appendix K, p. K-6)
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition, Foley catheter removal, and mobilization

Suggested Readings

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RECONSTRUCTIVE SURGERY FOR SLEEP-DISORDERED BREATHING

SURGICAL CONSIDERATIONS

Robert W. Riley, Nelson B. Powell, Donald M. Sesso, and Jerome E. Hester

Description

The surgical approaches to the upper airway attempt to relieve obstruction occurring most commonly at the level of the palate, base of the tongue, or pharynx. These fall into three categories: (a) classic procedures that directly enlarge the upper airway, (b) specialized procedures that directly enlarge the upper airway, and (c) tracheotomy to bypass the pharyngeal portion of the upper airway. The surgeon performs a preop evaluation, including complete head and neck exam, fiberoptic examination of the upper airway, and cephalometric radiographs. This, together with the results of the polysomnogram, will enable the surgeon to determine what levels of the airway need to be surgically modified. Individuals with severe obstruction may require a multistage approach to treatment.

Uvulopalatopharyngoplasty (UPPP)(Fig. 3.21) is a procedure that removes a rim of the soft palate, including the uvula. This shortens and tightens this tissue, thus preventing collapse during sleep. The tonsils, if present, are removed. The muscular crease of the palate is used as a landmark to prevent overly aggressive resection, which could → velopharyngeal insufficiency (VPI), an uncommon but serious complication. The wound is then closed, using interrupted absorbable sutures.

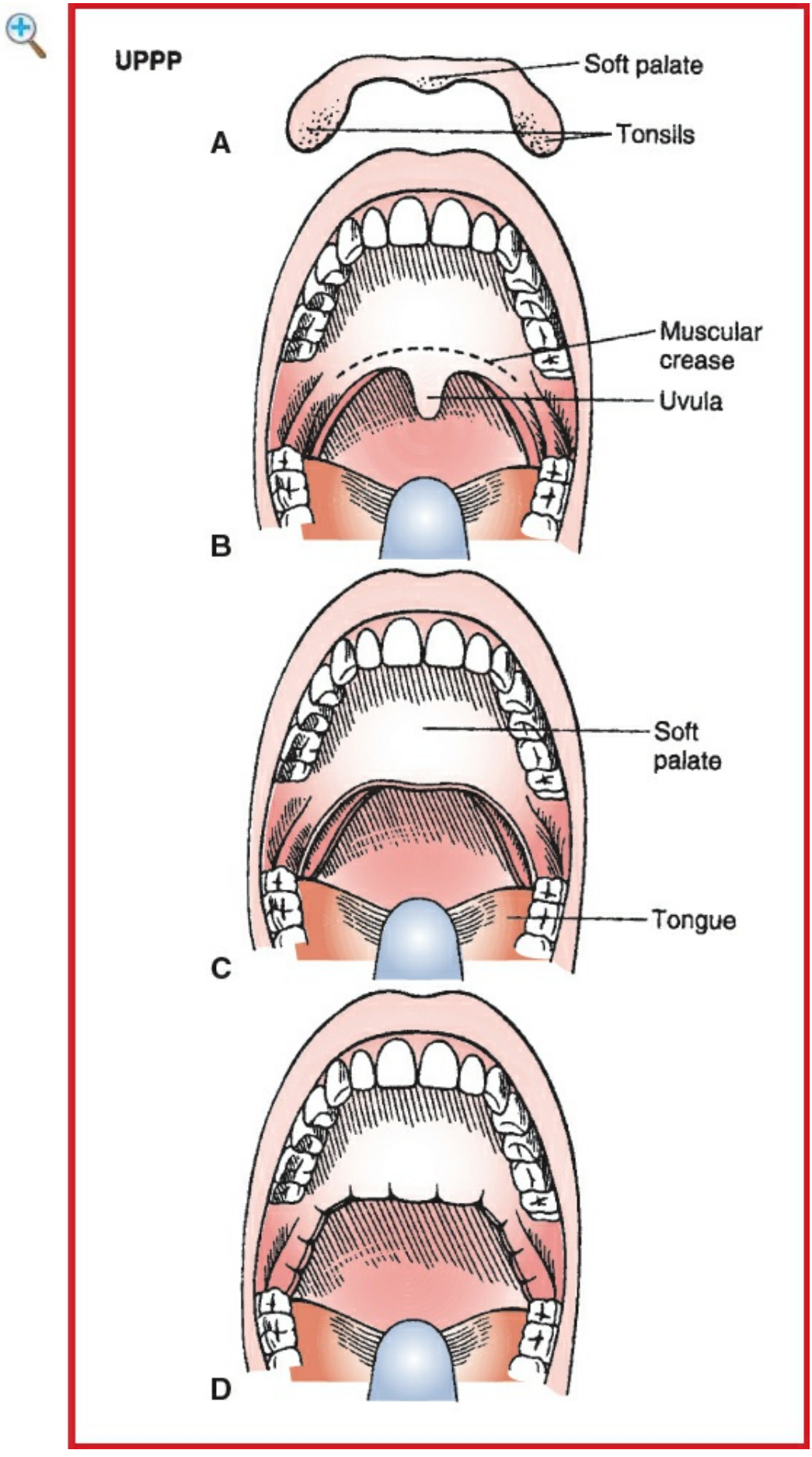
UPPP
Soft palate
Tonsils
A
Muscular crease
Uvula
B
Soft palate
Tongue
C
D

Figure 3.21 Uvulopalatopharyngoplasty (UPPP): **(A and B)** tonsils and redundant soft palate are excised; **(C)** mucosal flaps are prepared for closure; **(D)** the soft palate is closed to itself, and the anterior and posterior tonsillar pillars are sutured to each other.

Uvulopalatal flap (UPF) (Fig. 3.22) is a variation of UPPP, used for treating palatal obstruction. Rather than excising a rim of the soft palate, the mucosa of the anterior aspect of the uvula is removed, along with a corresponding area of the soft palate. The uvula is then reflected superiorly and sutured into place with absorbable suture. This procedure may be done in combination with a tonsillectomy. UPF is theoretically reversible if signs of VPI become evident. UPF also may be somewhat less painful than UPPP.

Uvulopalatopharyngoglossoplasty (UPPGP) is a rarely performed, intraoral procedure incorporating a modified UPPP with limited resection of the base of the tongue for both retropalatal collapse and retrolingual collapse.

Laser midline glossectomy (LMG) is used to enlarge the retrolingual airway by excision of ~2.5 × 5 cm of midline tongue tissue through an intraoral approach. This also may require lingual tonsillectomy, reduction of the aryepiglottic folds, and partial epiglottectomy (Fig. 3.23). LMG usually is combined with a tracheotomy for airway protection.

Lingualplasty (LP) is the same procedure as LMG, except that additional tongue tissue is extirpated posteriorly and laterally to that portion removed by LMG (Fig. 3.23). It is usually combined with a tracheotomy (see below) for airway protection.

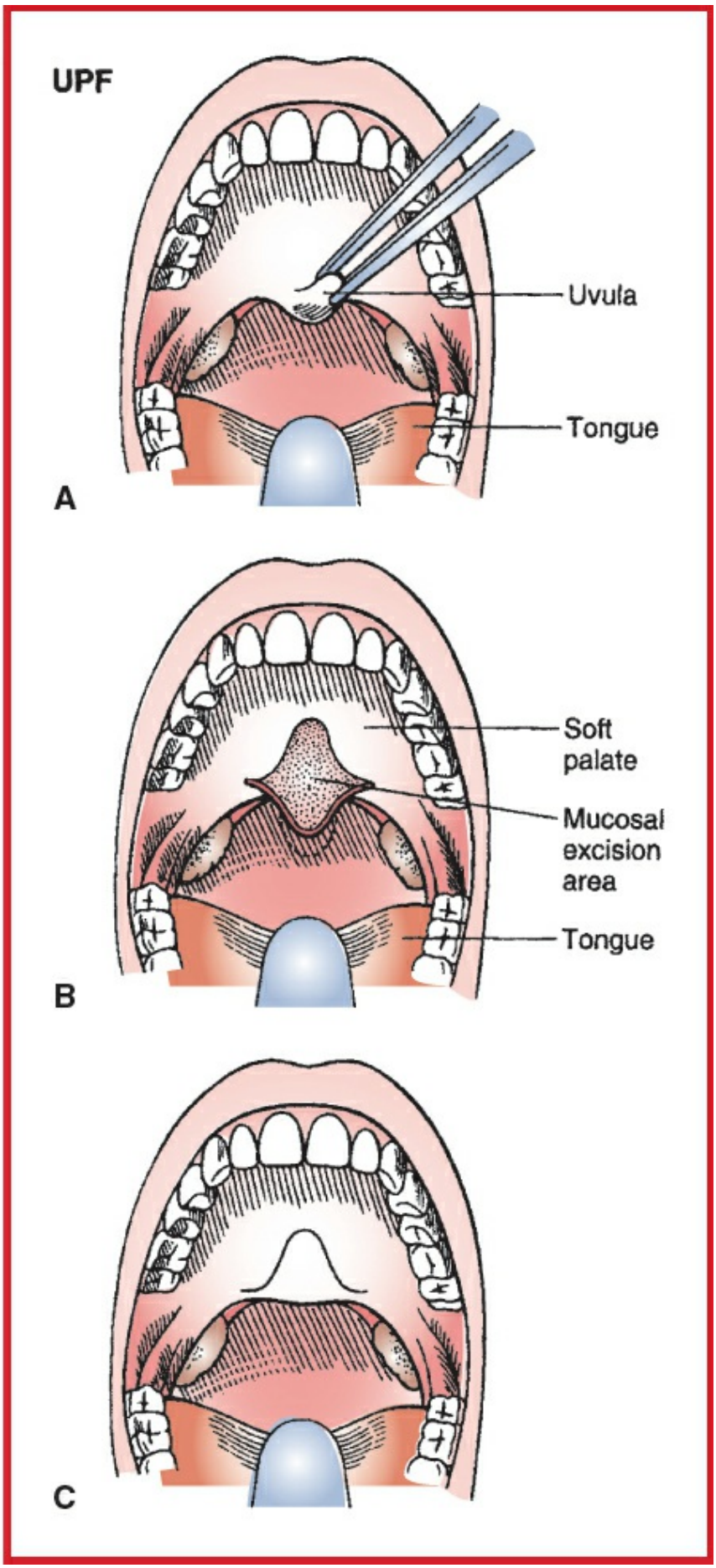
UPF
Uvula
Tongue
A
Soft palate
Mucosal excision area
Tongue
B
C

Figure 3.22 Uvulopalatal flap (UPF):**(A)** the uvula is reflected back to the hard palate to identify the muscular crease; **(B)** the mucosa on the oral side of the uvula and soft palate are removed, and part of the uvula is amputated; **(C)** mucosal incisions are closed with absorbable suture.

Inferior sagittal mandibular osteotomy and genioglossal advancement (MOGA) (Fig. 3.24) is an intraoral approach designed to enlarge the retrolingual area. This procedure relies on the firm attachment of the genioglossus muscle to the geniotubercle, a bony protuberance on the medial (lingual) aspect of the mandible. A mucosal incision is made intraorally, and soft tissue, including the mentalis muscle, is elevated off the mandible. Osteotomies, which include the geniotubercle on the inner cortex, are then performed. The segment is advanced and rotated to lock it in place. The outer cortex is removed, and the fragment is fixated to the inferior mandible with a titanium screw. The advancement is limited by the width of the mandible and laxity in the genioglossus muscle.

Hyoid myotomy and suspension (HM) is a retrolingual procedure that alleviates obstruction by redundant lateral pharyngeal tissue or a retrodisplaced epiglottis. A horizontal cervical incision above the hyoid bone is performed, and the dissection is carried down to the suprahyoid musculature. The midline hyoid bone is isolated and then advanced over the thyroid ala. It is then immobilized with two medial and two lateral permanent sutures (Fig. 3.25). The wound is closed, a drain placed, and a pressure dressing applied.

Maxillomandibular osteotomy and advancement (MMO) prevents retropalatal collapse through stenting of the superior pharyngeal muscles and widening of the nasopharyngeal inlet. It also minimizes retrolingual obstruction by placing the genioglossus muscle under tension, providing more room in the oral cavity for soft tissues, and stenting the lateral pharyngeal wall. An outer-table cranial bone graft usually is performed, along with arch bar placement (or orthodontic banding in an outpatient setting) prior to the osteotomies. A LeFort I maxillary osteotomy and bilateral sagittal-split mandibular osteotomy are performed. The skeletal arches are advanced forward ~10 mm and secured with the aid of a methylmethacrylate dental splint (Fig. 3.26). Immobilization with wires, plates, and screws follows, along with wound closure, intermaxillary fixation, and pressure dressing application. This procedure usually is performed if previous upper airway procedures have not completely relieved the sleep-related obstruction.

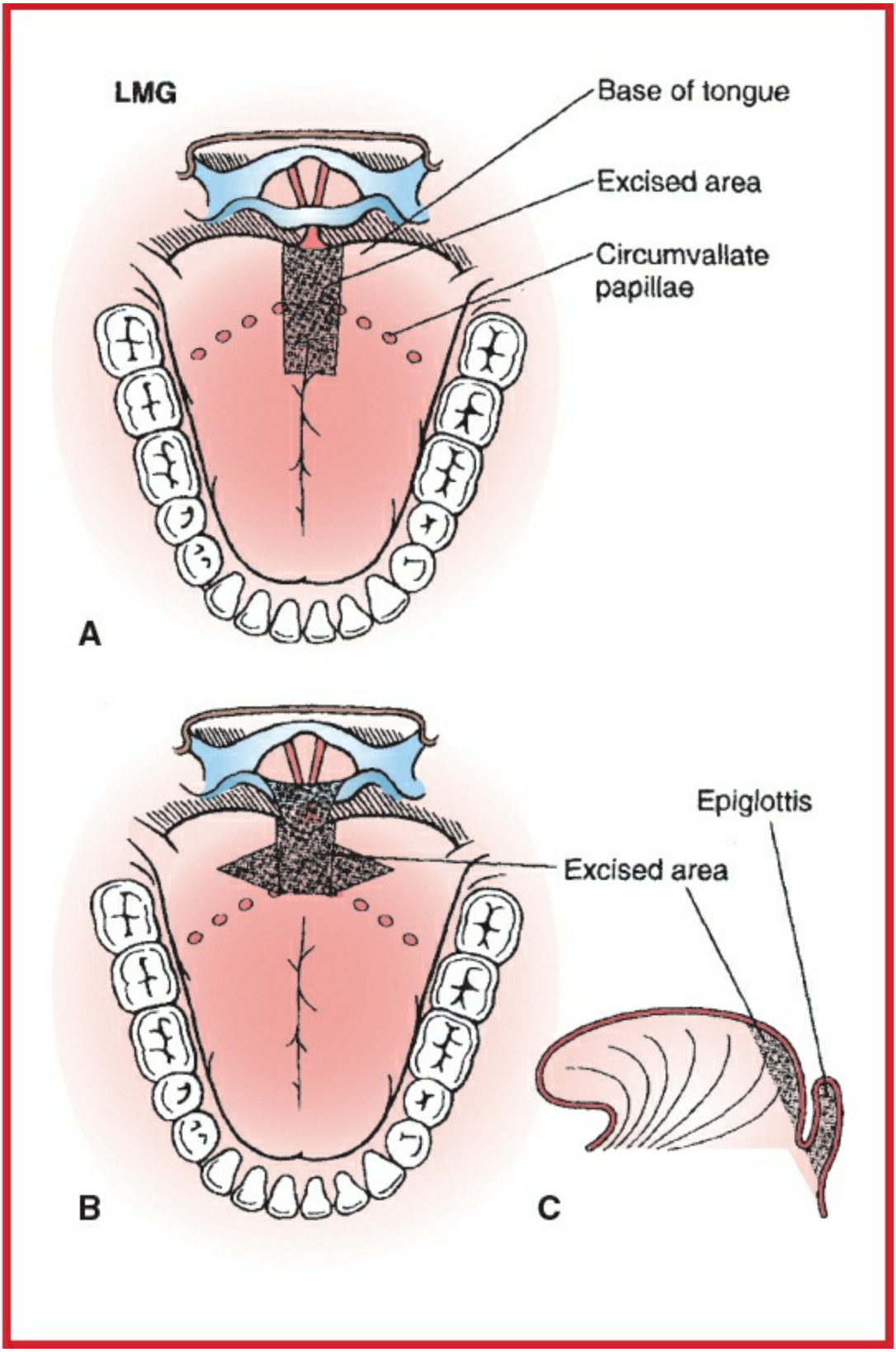

Figure 3.23 LMG/lingualplasty technique. **A:** Excision of a midline segment of the base of the tongue is performed with a laser or electrocautery; this excision occasionally is carried lateral. **B:** The remaining tongue muscle edges are reapproximated with absorbable suture. **C:** Lateral view of the tongue.

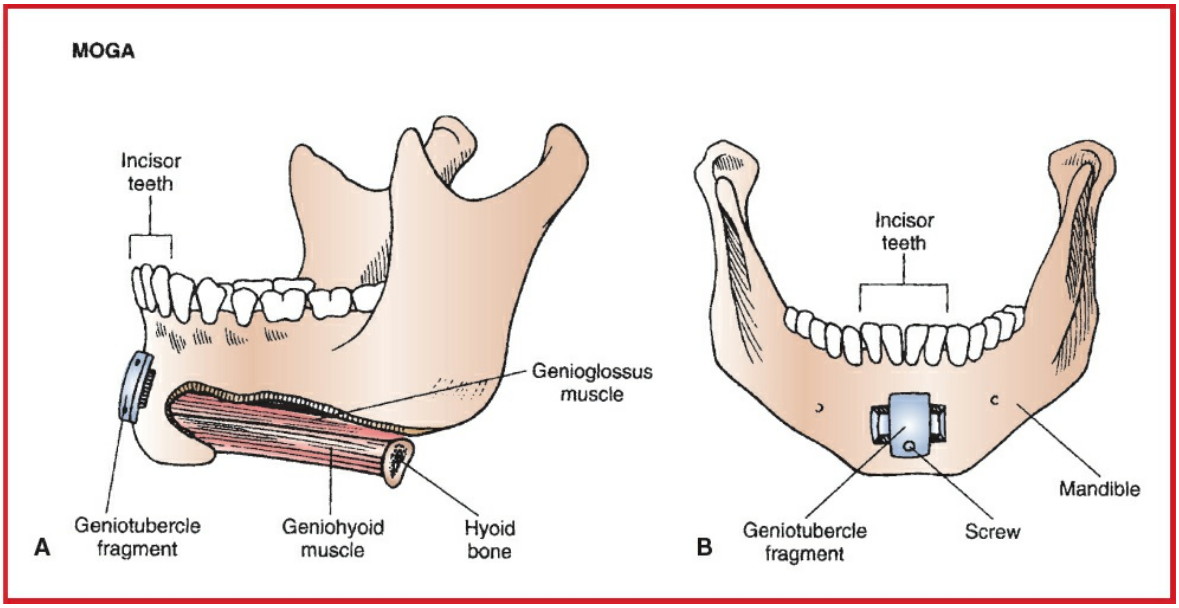

Figure 3.24 The mandibular osteotomy and genioglossus advancement (MOGA) technique.**A:** Lateral view. **B:** Anterior view. A rectangular anterior mandibular osteotomy below the incisor teeth is advanced, rotated, and immobilized.

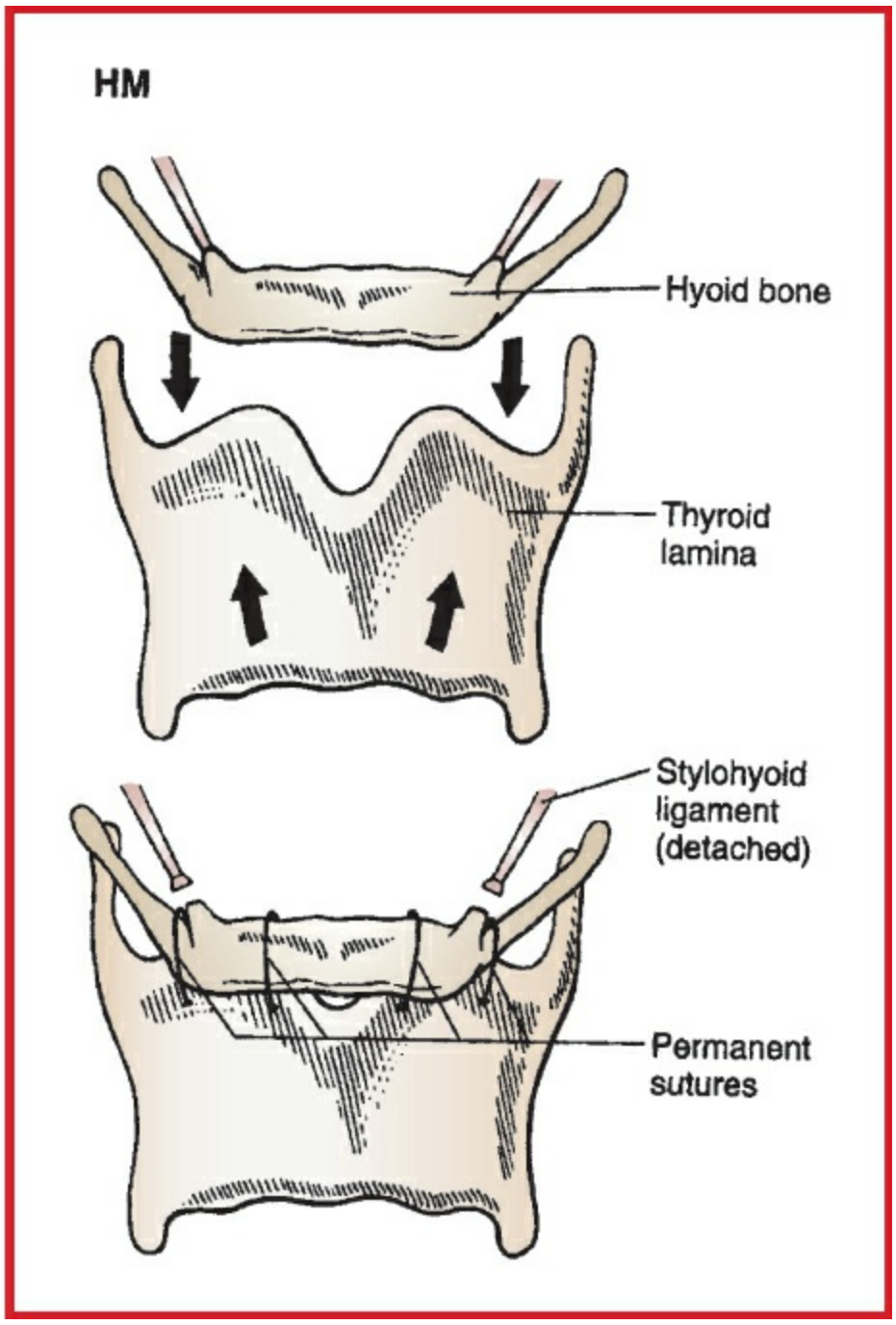

Figure 3.25 The hyoid myotomy (HM) and suspension technique. The hyoid is advanced over the thyroid lamina and immobilized.

Tracheotomy is a procedure performed to bypass pharyngeal obstruction. It is usually reserved for those individuals with severe OSA and may be used to secure the airway before other procedures. Preop evaluation, including fiberoptic examination, will help identify those individuals whose airways are so compromised that the tracheotomy should be done with the patient awake and under local infiltration anesthetic. A horizontal cervical incision is performed midway between the manubrium and the cricoid cartilage. Dissection is carried out in the midline down to the trachea, frequently

transecting the thyroid gland; then, an opening in the superior trachea allows placement of a tracheotomy tube.

Radiofrequency (RF) probes use heat to cause reduction and tightening of tissue. This may be used to enable the airway at the level of the nose (by reduction of the turbinates), the palate, or the base of the tongue. Whereas the nasal and palatal procedures are usually performed as outpatient under local anesthesia, the initial treatment of the base of the tongue commonly is performed in the OR, either alone or in conjunction with other airway procedures. The area of the tongue just anterior to the circumvallate papillae is infiltrated with local anesthetic. A needle-like RF probe is then used to heat the tissue. There is usually little or no immediate edema, although the surgeon may admit the patient overnight for airway observation.

Usual preop diagnosis

Sleep-disordered breathing, including upper airway resistance syndrome and OSA syndrome

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

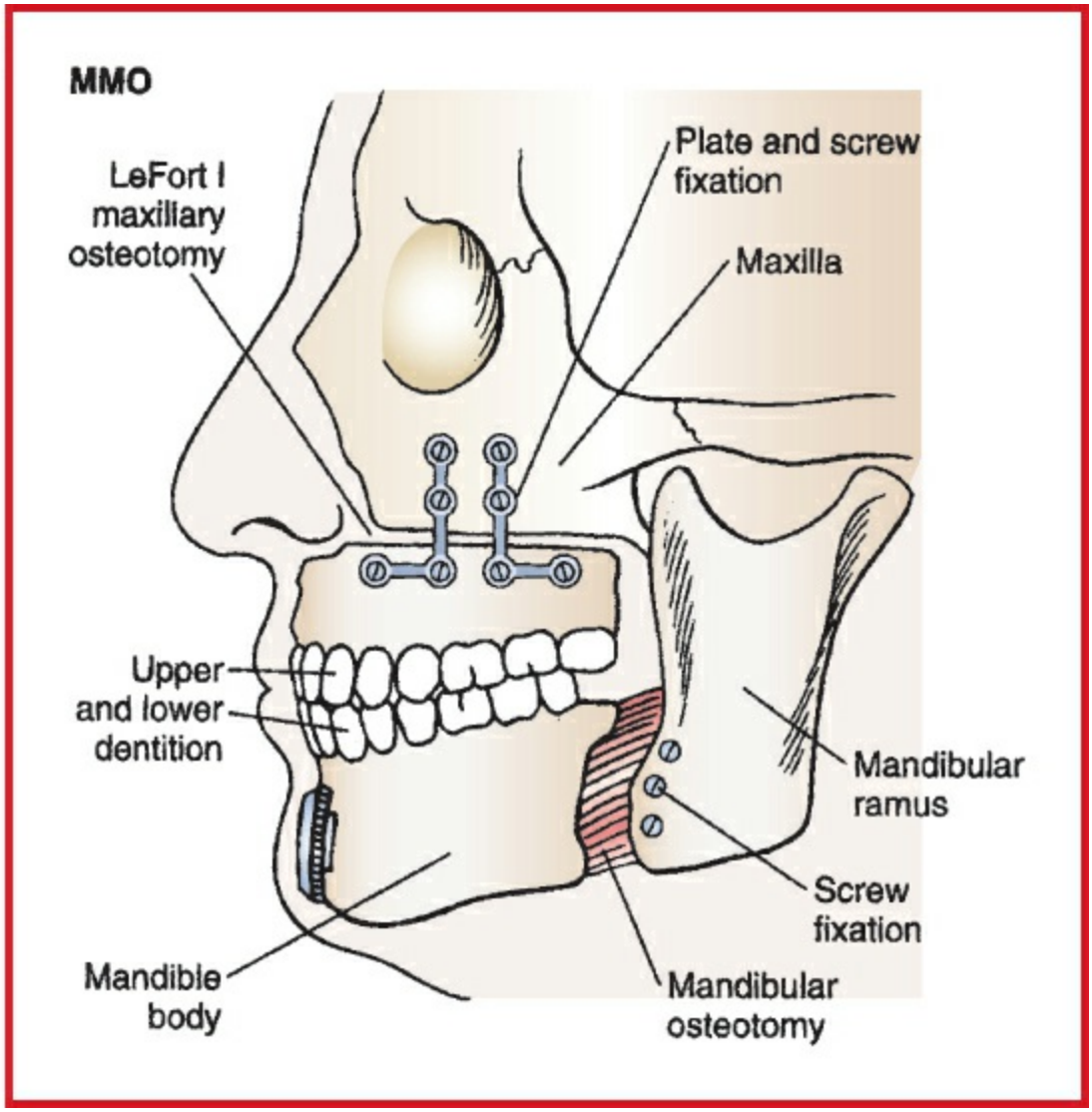

Figure 3.26 Maxillomandibular osteotomy (MMO) and advancement surgery technique.

SUMMARY OF PROCEDURE

Position	Supine
Incision	Intraoral (except HM–horizontal cervical above hyoid bone)
Special instrumentation	For osteotomy cases (MOGA, MMO), sagittal and reciprocating saws, drills
Unique considerations	When using a CO_2 laser (LMG, LP), a laser-safe ETT or, more commonly, a tracheotomy tube is required. MMO requires a nasal intubation. Tracheotomy may be performed with patient sitting with iv sedation and/or local infiltration. Dexamethasone 8 mg iv

Antibiotics	Cefazolin 2 g iv
Surgical time	UPPP, UPF: 20–60 min UPPGP, LMG, LP: 1–3 h MOGA, HM: 30–60 min MMO: 3–5 h
EBL	UPPP, UPF, MOGA, HM: 0–100 mL UPPGP, LMG, LP: 50–250 mL MMO: 100–500 mL
Postop care	UPPP, UPF: PACU → ward Multiple procedures, MMO, labile HTN: ICU → ward
Mortality	Rare
Morbidity	Paresthesias: 10% HTN: 5% Wound dehiscence: 5% Bleeding: 1–2% Infection: 1–2% Hematoma/seroma: 1–2% Upper airway obstruction: 1%
Pain score	UPPP, UPPGP, LMG, LP: 8–10 UPF, MOGA, HM, MMO: 6–8

PATIENT POPULATION CHARACTERISTICS

Age range	Children, adolescents, adults
Male:Female	3–10:1
Incidence	4–10% of adult males; 2–4% of adult females
Etiology	Upper airway collapse by frank obstruction or muscular relaxation
Associated conditions	Systemic and pulmonary HTN; CAD; cardiac arrhythmias; GERD; depression; obesity; polycythemia

ANESTHETIC CONSIDERATIONS

Vladimir Nekhendzy and Tiffany Cheng

PREOPERATIVE

Sleep-disordered breathing is extremely common, affecting nearly 20% of adult population, with 7–8% suffering from moderate-to-severe OSA. It is estimated that over 20% of adult surgical population suffer from OSA, where it remains undiagnosed in the majority (70%) of patients. OSA is characterized by periods of intermittent upper airway occlusion during sleep, leading to repeated episodes of hypoxemia/hypercapnia, sympathetic activation, and sleep fragmentation. OSA adversely affects a variety of organ systems, with widespread implications for the surgical patient. The presence and severity of OSA are strongly correlated with obesity and metabolic syndrome, systemic and pulmonary HTN, CHF, arrhythmias, heart attacks, and stroke. The mainstay of treatment is continuous positive airway pressure (CPAP), which acts to stent open collapsible airways, and the CPAP treatment must be continued in the perioperative setting, especially in patients with severe OSA.

When screening for the presence of OSA during preop office visit, a physician may wish to use the highly sensitive and validated STOP-BANG questionnaire (Table 3.4). The patients with either known or presumed OSA should undergo outpatient surgery only if their comorbidities are optimized, if postop pain is going to be mild and can be predominantly managed with nonopioid analgesics, and if (for CPAP users) the patients can continue to use CPAP postop. For practical purposes, patients with severe OSA (ASA physical status III) should not routinely undergo office-based surgery under GA or sedation. Postop, the ASA recommends extended monitoring of outpatients with OSA for an additional 3 h.

Other ENT pathology (e.g., septal deviation, laryngotracheomalacia, tonsil and adenoid hypertrophy) may be present in OSA patients. Intraop, the OSA patients demonstrate enhanced sensitivity to opioids and benzodiazepines, which may lead to rapidly developing respiratory depression, upper airway collapse, and airway obstruction. Conscious sedation of these patients should be performed with extreme caution. A multimodal approach that minimizes narcotic medications (e.g., NSAIDs, acetaminophen, cyclooxygenase-2–specific inhibitors) should be used perioperatively whenever feasible.

Table 3.4 The STOP-BANG Questionnaire for Screening for the Risk of Obstructive Sleep Apnea (OSA)

Snore loudly?	**B**MI > 35 kg/m^2?
Tired during the day?	**A**ge > 50 yr?

Observed cessation of breathing during sleep?	**N**eck circumference > 40 cm?
Pressure (high blood pressure)?	**G**ender male?

Answering "Yes" to three or more questions confers a high risk of OSA. The higher the cumulative risk score, the greater the possibility of severe OSA.

Respiratory	OSA patients may present with difficult airway problems, related to both mask ventilation and tracheal intubation. The awake versus asleep approach to tracheal intubation should be guided by careful airway evaluation with special attention to the presence of the predictors of difficult mask ventilation (DMV) and their association with difficult intubation (see Introduction, Anesthesiologist's Perspective, above). Awake intubation is rarely required but should be considered if the predictors of DMV coincide with factors predicting difficult intubation. Mask ventilation problems encountered in OSA patients are most commonly due to the pharyngeal airway obstructing at the level of soft palate and base of the tongue. This obstruction can usually be managed with supraglottic airway, which can also serve as a conduit for a subsequent tracheal intubation, either blind (e.g., intubating LMA) or fiberoptic guided. Discussion with the surgeon of the results of preop nasopharyngoscopy is useful. COPD/asthma often coexists and has a synergistic effect on worsening OSA. In advanced cases, chronic OSA → hypoxia/hypercarbia → pulmonary HTN → right heart failure. **Tests:** CXR, ABG, and PFT as indicated from H&P
Cardiovascular	Patients are at ↑ risk for systemic and pulmonary HTN (Sx: loud P_2, clubbing, ↑ JVD, cyanosis, RVH, right-axis deviation), CHF, cardiac arrhythmias (nonsustained VT, second-degree block, sinus arrest), MI, and stroke. Patients may have dyspnea on exertion and at rest, making routine assessment of cardiovascular function and reserve difficult.

	Tests: ECG; stress ECHO if abnormal ECG; others as indicated from H&P
Neurologic	A polysomnogram is typically performed preop, reporting the number of apneas (cessation or near cessation of airflow for 10 sec) and hypopneas (30% reduction in airflow over 10 sec with 3% hemoglobin desaturation). The apnea hypopnea index (AHI) is the number of apneas and hypopneas per hour of sleep. AHI of <5 is normal, 5–15 indicates mild OSA, 15–30 indicates moderate OSA, and >30 indicates severe OSA. OSA patients exhibit various degrees of daytime somnolence and may be chronically fatigued and irritable due to sleep fragmentation. Daytime sleepiness also may be associated with hypothyroidism or anemia, which should be ruled out. The impaired sleep/arousal cycle leads to autonomic hyperactivity; peripheral neuropathy and gastroparesis due to obesity may occur. An exaggerated response to sedative medications is frequently observed. **Tests:** As indicated by H&P
Hematologic	Chronic hypoxia → polycythemia (Sx: clubbing, cyanosis) →↑ risk of CVA. Hypercoagulability may be present due to chronic oxidative stress that leads to associated systemic inflammation and endothelial dysfunction. **Test:** Hct, coagulation studies as required
Gastrointestinal and Renal	This patient population has a higher incidence of GERD and hiatal hernia; thus, full-stomach precautions may be required. Renal function may be impaired, likely due to chronic sympathetic activation.
Laboratory	**Tests:** As indicated from H&P. Impaired glucose control is often present. Elevated plasma bicarb levels point to coexisting obstructive respiratory disease (asthma, COPD) and/or CO_2 retention.
Premedication	Typically, sedative medications should be kept to a

	minimum or avoided in this patient population. If sedative premedication is given, the anesthesiologist should remain with the patient and be prepared to manage the airway. Occasionally, OSA patients may have been prescribed stimulants (i.e., amphetamine) to combat daytime somnolence. These patients may not respond to indirect sympathomimetics (i.e., ephedrine) used to treat postinduction hypotension.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 500–1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique: GETA.

Induction	Asleep airway management is safe in the majority of OSA patients (see Preoperative Respiratory Considerations, above). Supraglottic airways with gastric access (e.g., LMA ProSeal/LMA Supreme™) should be readily available for rescue ventilation (see above). Topical anesthesia of the upper airway may impair airway reflexes and airway muscle tone, therefore provoking airway collapse and possibly worsening OSA postop. Orotracheal intubation is preferred, except in patients undergoing base of the tongue surgery (e.g., lingular tonsillectomy) or MMO, where nasotracheal intubation is required (see Anesthetic Considerations for TORS, p. 204). Preoxygenation with CPAP in 25° head-up position for 3–5 min will prolong safe apnea time. OSA patients with severe GERD should receive aspiration prophylaxis, and RSI should be performed, when indicated. Standard induction with propofol and an opioid (e.g., fentanyl) is safe, followed by administration of an

	intermediate-acting neuromuscular blocker (e.g., rocuronium) for tracheal intubation.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Maintenance using TIVA with propofol (80–180 mcg/kg/min) and remifentanil (0.05–0.3 mcg/kg/min), supplemented with iv boluses of fentanyl (usually not exceeding 2–4 mcg/kg total dose), with or without N_2O, is useful for OSA surgery. It facilitates maintenance of moderate controlled hypotension and improves hemodynamic stability during even most stimulating parts of surgery. Propofol administration causes profound depression of airway reflexes, thereby facilitating smooth emergence from anesthesia. A "sandwich anesthetic" technique utilizing a combination of TIVA and a low-dose inhalational agent (e.g., sevoflurane 0.4–0.6%) can also be used to achieve the above-stated objectives. Hypertensive responses should be treated aggressively, especially during craniofacial advancement with down fracture of the pterygoid plate in MMO. Maintaining low SBP (below 100 mm Hg) and low MAP (60–70 mm Hg) is critical during this part of the procedure. Administration of "ad lib" iv boluses of remifentanil 1–3 mcg/kg, supplemented with iv labetalol (5–10 mg increments) and hydralazine (5 mg increments), is usually effective. Esmolol and SNP infusions can be considered, but are usually not necessary. Administration of a dexmedetomidine infusion should be considered. A typical loading dose is 0.5–1.0 mcg/kg iv bolus over 10 min, followed by a continuous infusion of 0.2–1.0 mcg/kg/hr. Dexamethasone 0.1–0.15 mg/kg is recommended to decrease postop airway edema.
Emergence	The patient must remain intubated until sufficiently

	awake to respond to verbal commands. Neuromuscular blockade should be fully reversed, and the return of protective airway reflexes (e.g., swallowing) should be observed. The patient's stomach should be suctioned to remove swallowed blood. Premature extubation can cause complete loss of airway (2° glossopalatal obstruction) or laryngospasm. With extensive pharyngeal and base of the tongue work, significant upper airway edema must be anticipated, and extubation over a tube changer may be appropriate in selected cases. An insertion of a nasopharyngeal airway before emergence can be recommended in patients who had extensive surgery or had severe OSA preop. Anticipate pain and ↑ BP during emergence, which will continue into first postop day. Narcotic analgesics (e.g., morphine 0.1–0.15 mg/kg) should be administered before emergence. Antihypertensive agents usually required to prevent rebound hypertension and associated postop bleeding, particularly from osteotomy sites. Discuss with surgeon local wound infiltration. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 16–18 ga × 1 BSS @ 2–3 mL/kg/h	Minimal-to-little blood loss with all except MMO. EBL with MMO is 100–500 mL. Attempt to minimize fluids to reduce severity of postop airway edema (<1000 mL of NS/LR for all except MMO; <2000 mL for MMO). See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	Arterial line also

	Arterial line (MMO and ICU admits)	suggested for postop BP control in all patients with preexisting HTN and in any patient who displays labile BP intraop. Control of BP in the postop period is an extremely high priority.
Positioning	✓ and pad pressure points ✓ eyes	Occasional requests for minimal Trendelenburg or semisitting positioning
Complications	ETT damage Airway Hemorrhage	Airway problems and respiratory depression are the most common complications (hypercapnia, pulmonary edema, reintubation, bronchospasm, and laryngospasm). In addition, OSA patients are at increased risk for CHF, MI, arrhythmia, CVA, and delirium. ETT may become dislodged or kinked during surgical manipulations.
	Dysrhythmias	Vagally mediated severe bradycardia/asystole may occur with maxillary or mandibular advancement during MMO.

POSTOPERATIVE

Complications	Airway compromise Airway obstruction	Airway compromise 2° hematoma, edema, excessive sedation, or

		underlying disease. Consider observation in ICU for patients having multiple procedures, MMO, or labile HTN.
	HTN Aspiration	Postop HTN is extremely common and can contribute significantly to likelihood of postop airway obstruction 2° hematoma.
	Infections	The risk of wound infection is increased postop in OSA patients.
Multimodal pain management	Minimize iv narcotics	Avoid excessive postop sedation. UPPP patients, in particular, should be warned preop of anticipated significant postop discomfort. CPAP should be continued throughout the entire postop period. Consider BiPAP if noncompliant with CPAP.
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. American Society of Anesthesiologists Task Force on Perioperative Management o patients with obstructive sleep apnea: Practice guidelines for the perioperative management of patients with obstructive sleep apnea: an updated report by the American Society of Anesthesiologists Task Force on Perioperative Management o patients with obstructive sleep apnea. Anesthesiology 2014; 120(2):268–86.
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ANESTHESIA FOR DRUG-INDUCED SLEEP ENDOSCOPY

PREOPERATIVE

General

Patients with OSA may undergo drug-induced sleep endoscopy (DISE) to evaluate the upper airway collapsibility pattern in an attempt to stratify and personalize the required surgical intervention.

Preop considerations for DISE are typical for patients with OSA, with particular attention to upper airway exam and careful review of comorbidities to determine their ability tolerate periods of desaturations.

Airway	A thorough airway examination is essential, as no airway supporting maneuvers are usually made, until the patient desaturates significantly (SpO_2 < 85%).

	These patients should be carefully assessed preop for the predictors of difficult mask ventilation or difficult intubation (see Introduction). Rescue maneuvers to relieve upper airway obstruction during DISE must be performed gently and expeditiously.
Respiratory	These patients may have ↓ respiratory reserve due to ↓ FRC and ↑ O_2 consumption for patients with significant coexisting obesity. Evaluation for underlying pulmonary disease that may further compromise oxygen exchange should be undertaken.
Cardiovascular	Careful evaluation for underlying cardiac is essential given that the common comorbidities in patients with OSA (↑ age, male, HTN, obesity, smoking history, etc.) are also notable cardiac risk factors. **Tests:** ECG; other tests as indicated from H&P
Premedication	Sedative premedication and iv opioids should be avoided in patients undergoing DISE to optimize visualization of dynamic changes in the upper airway. An anticholinergic agent (e.g., glycopyrrolate 0.1–0.2 mg iv) should be considered preop for baseline HR < 50 bpm, if dexmedetomidine is used for DISE.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Most commonly, DISE using a flexible fiberoptic endoscope is performed under MAC allowing the surgeon to visualize and identify the sites of dynamic upper airway obstruction. The goal of anesthesia in DISE is to utilize sedative-hypnotics to produce loss of consciousness and any associated obstruction in patients with OSA while permitting spontaneous ventilation and avoiding prolonged periods of oxygen desaturation.

Currently, no consensus exists for the ideal sedative agent or agents to achieve adequate

sedation for DISE. The three agents studied for DISE include midazolam, propofol, an dexmedetomidine. The drawbacks of midazolam and propofol infusions include their respiratory depressant effects and dose-dependent increases in airway collapsibility (particularly with propofol), thereby increasing the possibility of a false-positive study. IV propofol has a propensity to cause anteroposterior upper airway collapse. As a result, we prefer iv dexmedetomidine as the primary DISE agent.

Induction	IV dexmedetomidine (1.5 mcg/kg iv bolus over 10 min) or propofol (in a ramp-up function) is used most often, with the goal of gradually inducing sleep and airway obstruction. Some patients may require additional boluses of 0.25 mcg/kg iv dexmedetomidine or propofol (10–20 mg iv) to achieve adequate sedation/obstruction.	
ERAS	Verify preincision antibiotics.	
Maintenance	Dexmedetomidine at 1.2–1.5 mcg/kg/hr iv infusion. Maintain good communication with otolaryngologist during procedure regarding intervention for low SpO_2 levels. Be prepared to intervene with jaw-thrust/chin-lift maneuvers, supplemental O_2, or advanced airway intervention (e.g., LMA or ETT) if SpO_2 falls below 85%. Judicious crystalloid loading intraop 10 cc/kg, to minimize incidence of postop orthostatic hypotension	
Emergence	Monitor spontaneous ventilation and evaluate degrees of upper airway obstruction following the endoscopy. Can apply supplementary O_2, reposition head and neck, perform jaw thrust/chin lift, and/or place oral/nasal airways to maintain SpO_2 > 95%.	
Fluid Requirements	IV: 20 ga × 1 BSS @ 2–3 mL/kg/h	10 mL/kg for the procedure is usual.
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes	The procedure is usually performed on the gurney. Patients should be positioned comfortably in

		a way that will allow for comfortable light sleep while supine. Checking padding of pressure points.
Complications	Upper airway obstruction	Apply jaw-thrust/chin-lift, supplemental O_2, or advanced airway maneuvers if SpO_2 falls below 85% or when procedure is completed.
	Orthostatic hypotension	Postop; particularly following the use of iv dexmedetomidine. PRN iv crystalloid bolus in PACU, as required. Assess for postop orthostatic hypotension prior to ambulation.

Suggested Readings

1. Atkins JH, Mandel JE: Drug-induced sleep endoscopy: from obscure technique t diagnostic tool for assessment of obstructive sleep apnea for surgical interventions. Curr Opin Anaesthesiol 2018; 31(1):120–6.
2. Atkins JH, Mandel JE, Rosanova G: Safety and efficacy of drug-induced slee endoscopy using a probability ramp propofol infusion system in patients with severe obstructive sleep apnea. Anesth Analg 2014; 119(4):805–10.
3. Capasso R, Rosa T, Tsou DY, et al: Variable findings for drug-induced sleep endoscopy in obstructive sleep apnea with propofol versus dexmedetomidine. Otolaryngol Head Neck Surg 2016; 154(4):765–70.
4. Kuk TS, So E, Karm M, et al: Anesthetic management for simultaneous drug-induce sleep endoscopy and maxillomandibular advancement in a patient with obstructive sleep apnea. J Dent Anesth Pain Med 2017; 17(1):71–6.
5. Shteamer JW, Dedhia RC: Sedative choice in drug-induced sleep endoscopy: a neuropharmacology-based review. Laryngoscope 2017; 127(1):273–9.

Suggested Viewing

Links are available online to the following videos:

Segmental Anatomy (www.bronchoscopy.nl): https://www.youtube.com/watch?v=ThYHLG50pH0

Principles of Laryngoscopy (Fibreoptic): https://www.youtube.com/watch?v=6MKKdu2bFDw

TMJ Anatomy "The Yoint" Video: https://www.youtube.com/watch?v=nH8KG3fIoBM

Clinical Complications of Tracheostomy: https://www.youtube.com/watch?v=UCYBGRj4Teo

Transoral Robotic Surgery: Supraglottic Laryngectomy – Johns Hopkins Hospital https://www.youtube.com/watch?v=6q9q4umrBAI

Endoscopic Septoplasty: https://www.youtube.com/watch?v=bpSVrVL77kc&list=PL3F3EEEA621

Tonsillectomy: https://www.youtube.com/watch?v=RTFUpoqhbHo

Thyroidectomy: https://www.youtube.com/watch?v=i1y1RVagkfs&t=5s

Modified Radical Neck Dissection: https://www.youtube.com/watch?v=ALcizhZln58

Modified Radical Neck Dissection, part 1: https://www.youtube.com/watch?v=2uilaptogdU

Modified Radical Neck Dissection, part 2: https://www.youtube.com/watch?v=pp6oqT2Pvr4

Modified Radical Neck Dissection, part 3: https://www.youtube.com/watch?v=HkdiXwN_yR8

Endoscopic View of Zenker Diverticulum Repair: https://www.youtube.com/watch?v=P79SsJxO2SA

Endoscopic Sinus Surgery: https://www.youtube.com/watch?v=NX9NjsvLJwE

SECTION **4.0**

DENTAL SURGERY

SURGEON
Stephen A. Schendel, MD, DDS, FACS

ANESTHESIOLOGIST
Richard A. Jaffe, MD, PhD

TEMPOROMANDIBULAR JOINT ARTHROSCOPY/ARTHROTOMY/ARTHROPLASTY

SURGICAL CONSIDERATIONS

Description

Temporomandibular joint (TMJ) surgical procedures include both open and closed surgical techniques.

TMJ arthrotomy involves a preauricular, postauricular, or endaural incision to gain access to the joint compartment. It usually is performed for severe fibrous adhesion removal in the TMJ, bony or fibrous ankylosis, tumor resection, chronic dislocation, painful nonreducing disc dislocation, and severe osteoarthritis. **Open TMJ** surgery may range from discoplasty, discectomy, arthroplasty, and/or eminoplasty (reshaping of articular eminentia) to optimize the fit of the disc, condyle, and fossa to total joint replacement utilizing costochondral grafts or total joint metal implants. For the open treatment of condylar fractures, extraoral approaches (e.g., preauricular, retromandibular, and submandibular) are used. All extraoral approaches to the TMJ have the risks of facial nerve damage and the creation of visible scars. Due to those possible complications, endoscopically assisted transoral approaches for open reduction and miniplate fixation of condylar mandible fractures are being used more often. In any of these procedures, facial nerve monitoring is indicated.

TMJ arthroscopy is a minimally invasive technique that has reduced the need for open surgery of the TMJ. Arthroscopic TMJ surgery is indicated for treatment of interna derangements and intracapsular disorders. The major advantage is that it results in less periarticular tissue disruption and better preservation of vascular supply and lymphatic drainage of the joint. The procedure involves insertion of a TMJ miniscope through a preauricular puncture on the canthus-tragus line and insertion of an outflow needle. The joint compartment is continually lavaged with LR. A second cannula may be inserted. Arthroscopic TMJ procedures include lysis of adhesions and lavage, partial synovectomy, and abrasion arthroplasty. Sometimes a holmium:YAG laser is used to make intra-articular incisions anterior to displaced discs and to treat inflamed synovial tissue. Usually, at the end of the procedure, 2-mg dexamethasone is injected into the joint space. Injection of 2 mL 0.5% bupivacaine mixed with 1 mL sterile saline solution has been shown to significantly reduce postop pain. Arrhythmia, reflex bradycardia, and pulmonary edema have been reported as general complications in TMJ arthroscopy.

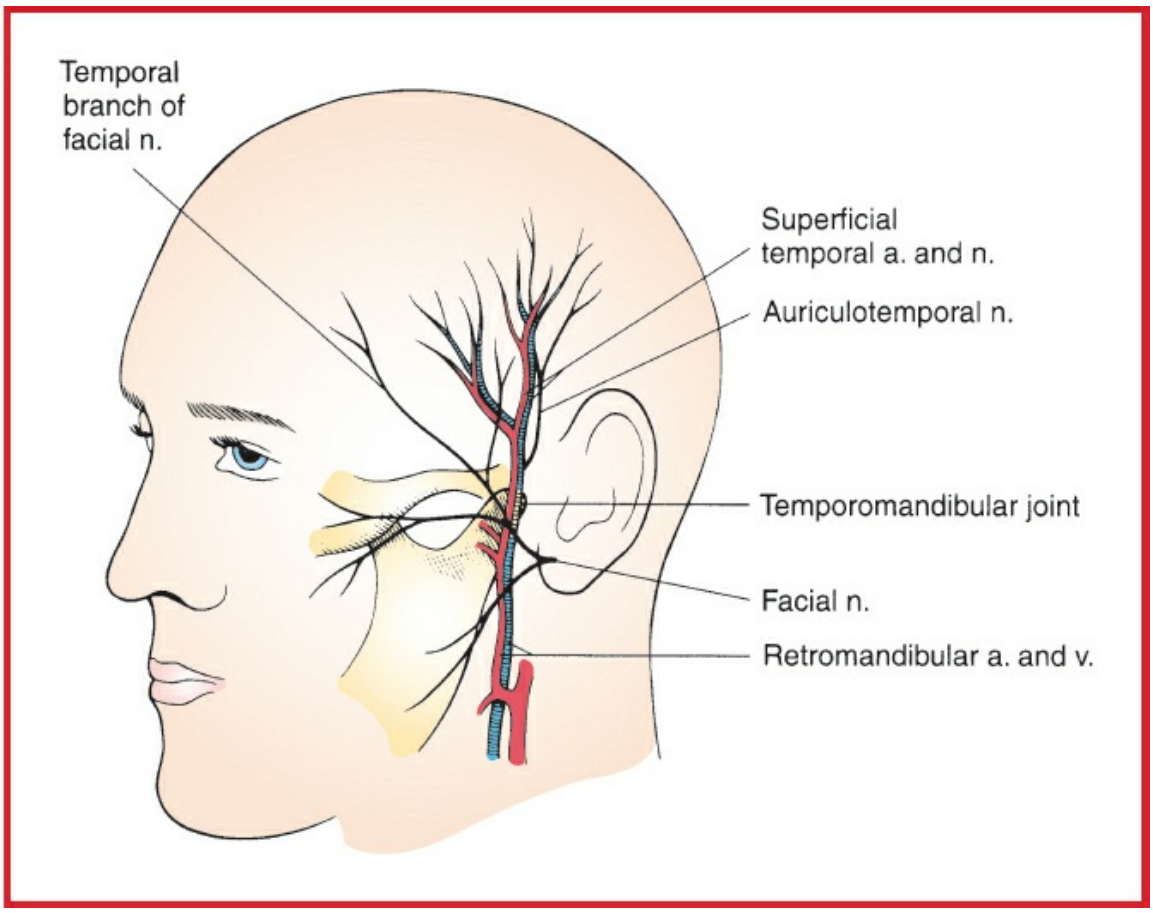

Figure 4.1 Anatomy for TMJ procedure.

Usual preop diagnosis

Internal derangement; subluxation; and ankylosis of TMJ

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, carb loading, and postop pain management options. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

SUMMARY OF PROCEDURES

	Arthroscopy	Arthrotomy/Arthroplasty
Position	Supine	⇐
Incision	Preauricular	⇐
Special instrumentation	Arthroscope; laser	Power tools, endoscope, implant plates
Antibiotics	Cefazolin 2 g	⇐

Surgical time	0.5 h	1.5–3.5 h/side
EBL	Minimal	Minimal-moderate
Postop care	Outpatient procedure	24-h stay
Mortality	Minimal	⇐
Morbidity	VII nerve damage V nerve damage Hemorrhage Partial hearing loss Ear fullness Vertigo	⇐ ⇐ ⇐
Pain score	5	5

PATIENT POPULATION CHARACTERISTICS	
Age range	20–40 yr
Male:Female	1:9
Incidence	20% of adult population suffers from TMJ dysfunction (TMJD)
Etiology	TMJD possibly 2° muscle spasm, bruxism, and osteoarthritis; idiopathic; trauma
Associated conditions	Psychiatric problems (typically depression); trismus; pain on opening the mouth; stress

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Dental/Oral Surgery.

Suggested Readings

1. Al-Ani Z, Gray R: TMD current concepts: 1. An update.Dent Update 2007; 34(5):278–80, 282–4, 287–8.
2. Furst IM, Kryshtalskyj B, Weinberg S: The use of intra-articular opioids and bupivacaine for analgesia following temporomandibular joint arthroscopy: a prospective, randomized trial. J Oral Maxillofac Surg 2001; 59(9):979–83.
3. Hoffman D, Puig L: Complications of TMJ surgery.Oral Maxillofac Surg Clin North Am 2015; 27(1):109–24.
4. Indresano AT: Surgical arthroscopy as the preferred treatment for internal

derangements of the temporomandibular joint. J Oral Maxillofac Surg 2001; 59(3):308–12.
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6. Lieblich S: Providing anesthesia in the Oral and Maxillofacial Surgery Office: a look back, where we are now and a look ahead. J Oral Maxillofac Surg2018; 76(5):917–25.
7. Rajapakse S, Ahmed N, Sidebottom AJ: Current thinking about the management o dysfunction of the temporomandibular joint: a review. Br J Oral Maxillofac Surg 2017; 55(4):351–6.
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9. Tsuyama M, Kondoh T, Seto K, et al: Complications of temporomandibular joint arthroscopy: a retrospective analysis of 301 lysis and lavage procedures performed using the triangulation technique. J Oral Maxillofac Surg 2000; 58(5):500–5.

ORAL SURGERY

SURGICAL CONSIDERATIONS

Description

The most common surgeries of the oral cavity are third-molar removal, surgical extractions, apicoectomies, orthodontic exposures of teeth, osseointegrated implants, bone grafting, treatment of oral pathologic conditions, and preprosthetic surgery. **Surgical extractions** of teeth involve intraoral exposure of the roots through a mucosal incision and removal of the overlying bone with a surgical drill. Risks associated with removal of teeth in the mandible are damage to the inferior alveolar nerve (anesthetic numb lip), lingual nerve (anesthetic numb tongue), and, rarely, mandibular fracture. In the posterior maxilla, oroantral fistulas can occur and are closed with a mucoperiosteal flap. **Exposure of teeth** for orthodontic therapy involves creation of a mucoperiosteal flap and attachment of a bracket with a small gold chain on which the orthodontist can pull to integrate the tooth into the dental arch. **Grafting** to the maxilla and mandible is done for augmentation of the atrophied alveolar ridge and the maxillary sinus and in cases of cleft lip and palate, and can consist of bone and/or other materials to induce bone formation. A second team usually harvests the bone at the same time. Possible extraoral harvesting sites include the anterior or posterior iliac crest, the tibia, and the skull. **Preprosthetic surgery** of the oral soft tissue in preparation for dentures has been replaced largely by insertion of **osseointegrated implants** for retention of individual

teeth and dentures. Surgical treatment of **oral pathology** can range from removal of dentigerous cysts, with and without bone graft, to laser or surgical removal of mucosal lesions.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Dental Surgery	Dental Implants	Oral Pathology	Grafting
Position	Supine	⇐	⇐	Supine or prone
Incision	Intraoral	⇐	⇐	Intraoral and donor site
Special instrumentation	Surgical drill	Implant drill and kit	Surgical drill, laser	Special graft materials
Antibiotics	None	Penicillin 1 g	Cefazolin 2 g iv	⇐
Unique considerations	Nasotracheal intubation ±Throat pack	⇐ ⇐	⇐ ⇐	⇐ ⇐
Surgical time	0.5 h/tooth	0.5 h/implant	1–3 h	2–3 h
EBL	Minimal	⇐	⇐	Moderate
Postop care	Outpatient	⇐	⇐ or 24-h stay	24-h stay
Mortality	Minimal	⇐	⇐	⇐
Morbidity	V nerve damage Aspiration of dental debris	⇐ ⇐	⇐	Hemorrhage
Pain score	3	2	3–5	5

PATIENT POPULATION CHARACTERISTICS

Age range	12–40 yr	>16 yr	All ages	>8 yr
Male:Female	1:1	⇐	⇐	⇐
Etiology	Idiopathic	Tooth loss	Various	⇐
Associated conditions	Craniofacial syndromes			

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Dental/Oral Surgery.

Suggested Readings

1. Bataineh AB: Sensory nerve impairment following mandibular third molar surgery. J Oral Maxillofac Surg 2001; 59(9):1012–7.
2. Zou L, He D, Ellis E: A comparison of clinical follow-up of different tota temporomandibular joint replacement prostheses: a systematic review and meta-analysis. J Oral Maxillofac Surg 2018; 76(2):294–303.

Suggested Viewing

Links are available online to the following video:
TMJ Anatomy "The Yoint" Video: https://www.youtube.com/watch?v=nH8KG3fIoBM

RESTORATIVE DENTISTRY

SURGICAL CONSIDERATIONS

Description

Multiple dental restorative procedures are performed under GA when there are rampant caries, and an extensive amount of dental work must be performed at one time. The second most common indication for GA is for procedures that need to be performed on mentally retarded patients who are not candidates for a local anesthetic. The actual amount of restorative dentistry is quite variable, depending on the individual case; thus, surgical time can be quite variable. Generally, blood loss is not a problem.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES	
Position	Supine
Incision	Intraoral
Special instrumentation	Dental armamentarium
Unique considerations	Nasal intubation; throat pack

Antibiotics	Penicillin × 5 d po
Surgical time	0.5–3 h
EBL	Minimal
Postop care	PACU → home
Mortality	Minimal
Morbidity	Pain Aspiration of dental debris Swelling
Pain score	1–3

PATIENT POPULATION CHARACTERISTICS	
Age range	2 yr to adult
Male:Female	1:1
Incidence	Unknown
Etiology	Idiopathic or congenital anomalies
Associated conditions	Mental retardation (majority), Down syndrome, seizures

ANESTHETIC CONSIDERATIONS FOR DENTAL/ORAL SURGERY

PREOPERATIVE

Most patients presenting for dental or oral surgery usually will require only local anesthesia provided by the dentist/oral surgeon. Deep sedation or GA may be required, however, for several unique patient groups: (a) young children (some with systemic diseases such as CHD and hemophilia), (b) the mentally disabled, (c) those with poorly controlled seizure disorders, (d) those presenting for TMJ procedures, and (e) those with an oral septic focus, who may be quite ill. If the patient does not fall into one of these readily identifiable categories, the reasons for GA should be ascertained. An LMA with a flexible wire-reinforced airway tube (LMA Flexible) has been used successfully for a variety of oral surgical procedures. The use of an LMA should be discussed with the surgeon in advance because its presence may interfere with the planned procedure.

Airway	Patients presenting for TMJ procedures may have problems with mouth opening (2° pain, trismus, and arthritis), making airway examination difficult. Mouth opening may not improve with GA and muscle relaxation. Nasotracheal intubation using FOL (done awake in patients with difficult airways) should be planned. Examine nares for patency; check for loose teeth.
Respiratory	Surgery should be postponed (at least 2 wk) in patients presenting with Sx of acute RTI (fever, coughing, purulent sputum, etc.). Sx of chronic respiratory disease should be sought and treated before surgery. LMA use has been reported to decrease respiratory complications in children with upper RTIs. **Tests:** As indicated from H&P
Cardiovascular	Patients with dysrhythmias may be sensitive to the epinephrine used in local anesthetic solutions administered intraop. As with other types of elective surgery, preexisting cardiovascular problems should be treated before surgery. Prophylactic antibiotics for endocarditis are not required in most patients; exceptions include patients with prosthetic valves, congenital heart disease, h/o infective endocarditis, or heart transplant. Endocarditis prophylaxis: amoxicillin 2 g po or cefazolin 2 g iv 30–60 min before procedure. **Tests:** As indicated from H&P
Neurologic	Patients with seizure disorders should be on optimal medical therapy before surgery. Discuss precipitating factors and prodromal Sx with the patient. **Tests:** ✓ therapeutic levels of anticonvulsant (e.g., levetiracetam = 12–46 mcg/mL; phenytoin = 10–20 mcg/mL,; carbamazepine = 3–12 mcg/mL; phenobarbital = 10–40 mcg/mL)
Musculoskeletal	In addition to TMJ problems, rheumatoid arthritis is

	associated with cricoarytenoid joint immobility and cervical spine immobility/instability that may complicate intubation. Patients with prosthetic joints do not require special antibiotic prophylaxis.
Laboratory	Other tests as indicated from H&P
Premedication	Standard premedication usually is appreciated, although, in patients with limited airway access, sedation may be inappropriate. If FOL is planned, pretreatment with an antisialagogue (e.g., glycopyrrolate 4 mcg/kg) is useful. Metoclopramide (e.g., 10–20 mg iv adult) will reduce the incidence of PONV 2° swallowed blood. Avoid long-lasting sedative medications.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen (adult: 1000 mg po; peds: 10–15 mg/kg iv or po as an elixir).

INTRAOPERATIVE

Anesthetic technique

GETA (although LMAs have been used successfully for many procedures). Typically a nasotracheal intubation is requested, using an ETT 0.5–1 mm smaller than for oral intubation. In patients with difficult airways, an awake nasal FOL is indicated. For conscious sedation, dexmedetomidine (e.g., 0.5 mcg/kg loading dose over 10 min + 0.5 mcg/kg/h infusion) in combination with midazolam (e.g., 0.03 mg/kg) ± propofol (e.g., 25 mcg/kg/min) has the advantage of minimal respiratory depression.

Induction	In patients with normal airways, a standard induction with nasal intubation is appropriate. Following loss of consciousness, topical intranasal cocaine may be applied (4% on pledgets, 4 mL maximum) to shrink the nasal mucosa and for vasoconstriction. Side effects are rare but may include ↑ BP, ↑ or ↓ HR, dysrhythmias, and Sz. Other topical vasoconstrictors (e.g., 0.05% oxymetazoline) may be used; however, they are also associated with cardiovascular side effects. The well-lubricated ETT is passed through

	the nose into the trachea, either blindly or assisted by Magill forceps under direct laryngoscopy. The ETT is often sewn to the nasal septum. The successful use of a flexible reinforced LMA in both adult and pediatric dental patients has been reported. Claimed advantages include no risk of epistaxis and no need for a throat pack, laryngoscopy, or muscle relaxation. Disadvantages include interference with the procedure, throat trauma (e.g., swelling of the epiglottis), and aspiration risk.
ERAS	Verify preincision antibiotics. Maintain normovolemia and normothermia.
Maintenance	Standard maintenance
Emergence	**NB: throat packs must be removed prior to extubation**. An LMA is typically removed after the patient is awake and able to follow commands.
Blood and fluid requirements	IV: 18 ga × 1 NS/LR @ 4–6 mL/kg/h See Zero Balance Fluid Management, Appendix K, p. K-2.
Monitoring	Standard monitors
Positioning	✓ pad pressure points ✓ eyes

POSTOPERATIVE

These patients may swallow blood, with consequent PONV. Rx: metoclopramide 10–20 mg iv ± ondansetron 4 mg iv.

Complications	Airway obstruction 2° retained throat pack PONV	Always check for retained throat pack in patients exhibiting symptoms of airway obstruction. Rx: ondansetron 4 mg iv
Multimodal pain management	Oral analgesics	Use nonopioid analgesics. Backup with po opioid

		analgesics
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition and mobilization.

Suggested Readings for Dental/Oral Surgery

1. Al-Jandan BA, Syed FA, Zeidan A, et al: Pharyngeal pack placement in minor ora surgery: a prospective, randomized, controlled study. Ear Nose Throat J 2018; 97(3):E18–21.
2. Atan S, Ashley P, Gilthrope MS, et al: Morbidity following dental treatment o children under intubation general anaesthesia in a day-stay unit. Int J Paediatr Den 2004; 14(1):9–16.
3. Cummings DR, Yamashita DD, McAndrews JP: Complications of local anesthesi used in oral and maxillofacial surgery. Oral Maxillofac Surg Clin North Am2011; 23(3):369–77.
4. Hanzawa A, Handa T, Kohkita Y, et al: A comparative study of oral analgesics for postoperative pain after minor oral surgery. Anesth Prog 2018; 65(1):24–9.
5. Lin S, McKenna SJ, Yao CF, et al: Effects of hypotensive anesthesia on reducing intraoperative blood loss, duration of operation, and quality of surgical field during orthognathic surgery: a systematic review and meta-analysis of randomized controlled trials. J Oral Maxillofac Surg 2017; 75(1):73–86.
6. Mayhew JF: Airway management for oral and maxillofacial surgery. Int Anesthesiol Clin 2003; 41(3):57–65.
7. Njuguna B, Delahaye F: Infective endocarditis prophylaxis: a review.Expert Rev Cardiovasc Ther 2017; 15(2):127–36.
8. Ogle OE, Mahjoubi G: Local anesthesia: agents, techniques, and complications.Dent Clin North Am 2012; 56(1):133–48.
9. Smith MH, Lung KE: Nerve injuries after dental injection: a review of the literature J Can Dent Assoc 2006; 72(6):559–64.
10. Todd DW: Anesthetic considerations for the obese and morbidly obese oral and maxillofacial surgery patient. J Oral Maxillofac Surg 2005; 63(9):1348–53.
11. Wakita R, Kohase H, Fukayama H: A comparison of dexmedetomidine sedation with and without midazolam for dental implant surgery. Anesth Prog 2012; 59(2):62–8.
12. Yasny JS: Perioperative dental considerations for the anesthesiologist. Anesth Analg 2009; 108(5):1564–73.
13. Yu SH, Beirne OR: Laryngeal mask airways have a lower risk of airway complications compared with endotracheal intubation: a systematic review. J Oral Maxillofac Surg 2010; 68(10):2359–76.

SECTION **5.0**

THORACIC SURGERY

Surgeon
Natalie Shaubie Lui, MD

Anesthesiologist
Vivek Kulkarni, MD, PhD

INTRODUCTION: SURGEON'S PERSPECTIVE

AIRWAY AND LUNG ACCESS CONFLICTS

Induction and maintenance of anesthesia for thoracic surgery require close cooperation between the surgeon and anesthesiologist. For example, during periods of one-lung ventilation (OLV), significant hypoxia and hypotension may occur, and surgery may need to be stopped temporarily while the hypoxia is corrected by reinflation of the unventilated lung. Hypotension in the absence of bleeding can sometimes be corrected by less vigorous retraction of the lung and heart by the surgeon. Quick and timely communication between the anesthesiologist and the surgeon can be lifesaving. Occasionally, during critical parts of the dissection, cessation of all respiration for short periods of time can make the surgeon's job much easier.

TUBES AND TUBE SIZES

The size of the endotracheal tube (ETT) is important for many thoracic surgical procedures. Fiberoptic bronchoscopy (FOB) through the ETT is a common event. The standard operating FOB just fits through an 8.0 single-lumen endotracheal tube (SLT). The fiberoptic laryngoscope (FOL) used for difficult intubations will fit smaller ETTs and double-lumen tubes (DLTs). Often the patient is intubated with a SLT initially so that bronchoscopy can be performed, and then either the SLT is switched to a DLT or a bronchial blocker is placed. The bronchoscope should be lubricated with a polyethylene glycol–based (e.g., Carbowax®) or silicone-based (e.g., EndoLube®) ointment rather than an aqueous jelly, which will dry out quickly making manipulation quite difficult. The FOL can be used for correct positioning of a DLT. If the bronchial portion of the DLT cannot be advanced into the left main bronchus, the FOL can be advanced through the bronchial side of the DLT into the left main bronchus. Then, the DLT can be advanced over the bronchoscope into the left bronchus. The depth of the tube can be determined by FOL observation of the right main bronchus through the tracheal side of the DLT.

PATIENT POSITIONING AND SURGICAL INCISIONS

The most common open incisions used by thoracic surgeons are the **posterolateral thoracotomy** (and its variations; Fig. 5.1A), the **median sternotomy** (Fig. 5.1B), and the anterior thoracotomy (often bilateral; Fig. 5.1C). The standard posterolateral thoracotomy involves division of the latissimus dorsi and sparing of the serratus anterior muscles. For procedures where exposure of both lungs is mandatory (e.g.,

bilateral lung transplantation), bilateral anterior thoracotomy with a transverse sternotomy, or the **clamshell incision** (Fig. 5.2), is useful. Generally, patients are in the **supine position** for anterior incisions (sternotomy, cervical incisions, anterior thoracotomy, and the clamshell incision) and in the **lateral position** for lateral and posterolateral thoracotomies. Minimally invasive techniques include **video-assisted thoracic surgery (VATS)** and **robot-assisted** approaches, which are quickly becoming the standard of care for many thoracic operations. They are performed using several (often three for VATS and five for robot-assisted) small incisions without spreading the ribs with a retractor. (NB: A preincision review of recent imaging in the OR will help ensure that the operation is performed on the correct side.)

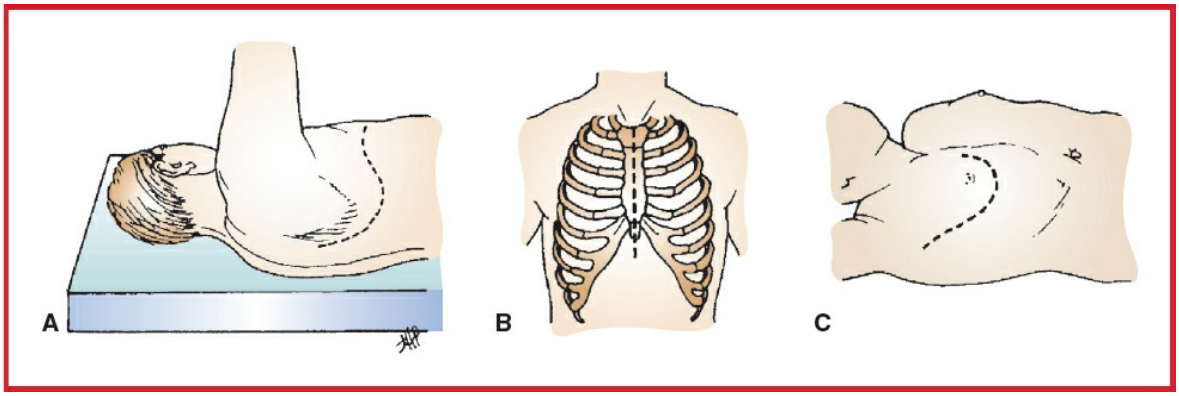

Figure 5.1 Primary incisions for thoracic surgery. **A:** Posterolateral thoracotomy, in lateral position. The incision curves in an S shape, passing under the tip of the scapula over in the fifth interspace anteriorly. **B:** Median sternotomy, in supine position, arms at side: the incision is made from the suprasternal notch to a point between the xiphoid process and the umbilicus. **C:** Anterior thoracotomy in supine position. (Reproduced with permission from Fry WA: Thoracic incisions. In: Shields TW, LoCicero J III, Ponn RB, eds. General Thoracic Surgery, 5th edition. Lippincott Williams & Wilkins, Philadelphia: 2000.)

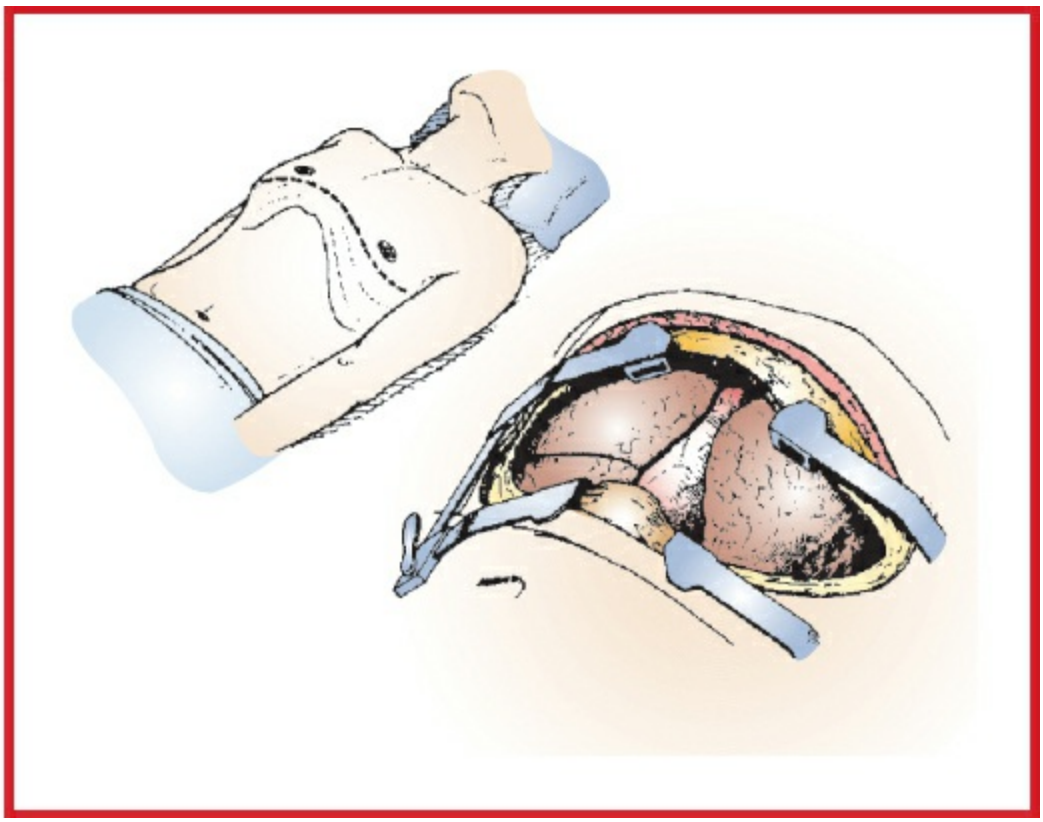

Figure 5.2 The "clamshell" incision, in classic supine position, affords excellent exposure, especially for bilateral lung procedures. (Reproduced with permission from Fry WA: Thoracic incisions. In: Shields TW, LoCicero J III, Ponn RB, eds. General Thoracic Surgery, 5th edition. Lippincott Williams & Wilkins, Philadelphia: 2000.)

Most thoracic operations are performed with the patient in the **lateral decubitus** position. A patient in the right lateral decubitus position has the left side up and vice versa. After general anesthesia is induced and the patient is intubated, the patient is positioned relative to the break in the bed, usually at the level of the xiphoid or umbilicus. The patient is then rotated onto their side, using either bolsters or a beanbag to stabilize them. An axillary roll may be used to prevent axillary compression. The lower leg is flexed, and the upper leg is extended and supported by pillows. Then the table is flexed to assist in spreading the ribs and sometimes placed in slight Trendelenburg or reverse Trendelenburg position to level out the chest. The head and neck require extra support to remain in a neutral position to avoid brachial plexus injuries. The lower arm can be either extended on an arm board or flexed and placed next to the patient's head (Fig. 5.3A). The upper arm is extended and held in position with either an airplane holder or an arm board with several pillows (Fig. 5.3B). Wide adhesive tape is placed across the hips to further secure the patient. A lower-body warming blanket (e.g., Bair Hugger™) should be used to avoid hypothermia. At the end of the operation, when the surgical incisions are being closed, the table can be returned to the level position. The neck and arms should be checked after the position is changed.

The anesthesiologist may be asked to exert posterior pressure on the patient's shoulder to align and diminish tension on the latissimus dorsi closure.

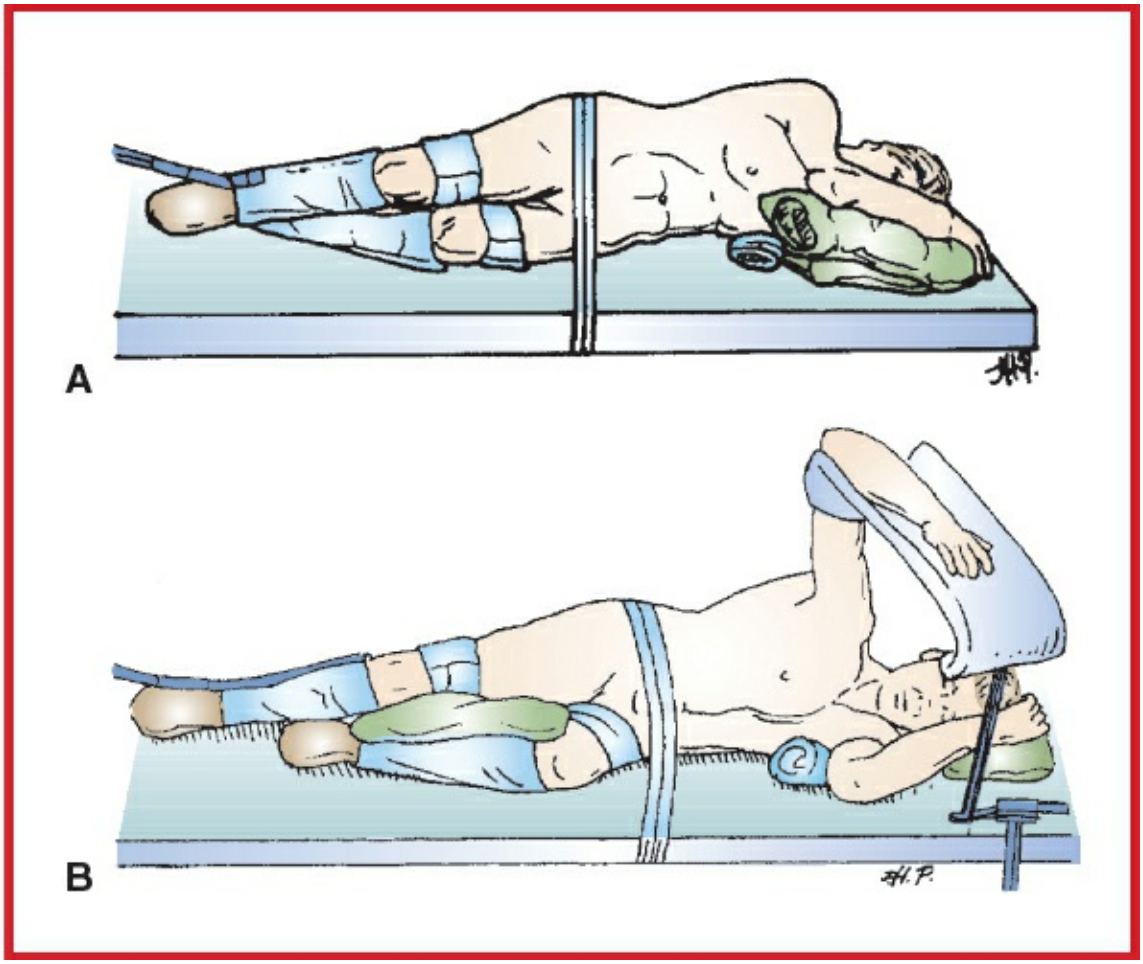

Figure 5.3 Lateral positioning for thoracic lateral and posterolateral procedures. **A:** Patient on his side, with kidney rest, axillary roll, pillows between knees, and padding under elbows. Wide adhesive tape secures the position. **B:** The upper arm abducted 90% on arm board. (Reproduced with permission from Fry WA: Thoracic incisions. In: Shields TW, LoCicero J III, Ponn RB, eds. General Thoracic Surgery, 5th edition. Lippincott Williams & Wilkins, Philadelphia: 2000.)

Thoracic operations using an anterior incision are performed with the patient in the **supine** position. A small roll is placed under the shoulder blades to extend the neck and facilitate access to the upper mediastinum. This is particularly important for mediastinoscopy and proximal tracheal operations. In general, the arms should be tucked at the patient's sides. Having an arm extended during a sternotomy can place undue stretch on the brachial plexus.

The probability of deep venous thrombosis (DVT) in general thoracic cases is controversial, whereas the risks of prophylaxis are minimal. Given that patients often have protracted periods of immobility, both during and after surgery, and often have a malignancy, the use of DVT prophylaxis is good practice. We use sequential

compression devices (SCD) for all patients, except those undergoing short video-assisted procedures, and reserve subcutaneous heparin for those at higher than normal risk.

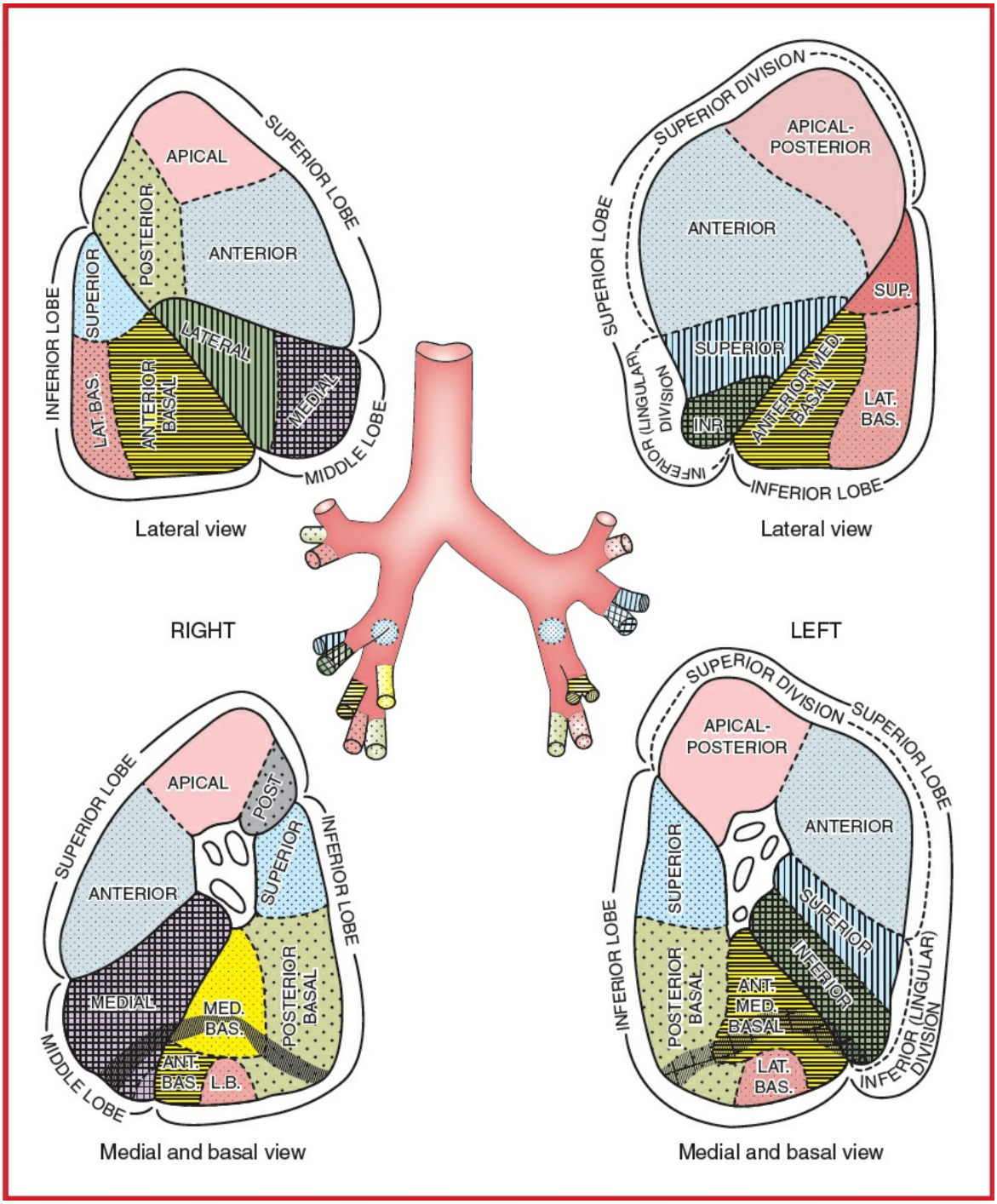

Figure 5.4 Segmental anatomy of the lungs. (Reproduced with permission from Clemente CD: Gray's Anatomy, 30th American edition. Lea & Febiger, Philadelphia: 1985.)

POSTOPERATIVE ISSUES

The most common postop issues relevant to anesthesiologists are:

- The need for postop mechanical ventilation
- Airway management
- Hemodynamic instability
- Pain control

The majority of patients can be extubated immediately after the case in the OR. This includes patients undergoing shorter or minimally invasive procedures and even those undergoing lung volume reduction surgery (LVRS). The most common exceptions are patients requiring preop mechanical ventilation, lung transplant patients, and those with difficult airways. Patients undergoing prolonged surgery may require postop mechanical ventilation. Because DLTs are larger than standard SLTs, there is greater potential for laryngeal trauma and airway edema and thus loss of airway following extubation. By exchanging the DLT for a SLT over a tube changer, this potentially catastrophic complication can be avoided.

Hemodynamic instability following surgery may be due to several causes, the most important being ongoing blood loss, inadequate intraop fluid replacement, and cardiac dysfunction. Epidural anesthesia may cause intraop and postop hypotension.

With the use of epidural anesthesia and systemic analgesics (e.g., acetaminophen and ketorolac), postop pain can be managed effectively. It is important for the anesthesiologist to communicate to the surgeon (and postop care team) which agents have been used, how the patient responded to them, and what types of hemodynamic, pulmonary, and neurologic effects can be expected in the postop period. Most patients will go to the ICU or a step-down unit with telemetry, depending on the institution policy and procedure.

Suggested Readings

1. D'Ercole F, Arora H, Kumar PA: Paravertebral block for thoracic surgery. J Cardiothorac Vasc Anesth 2018; 32(2):915–27.
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VIDEO-ASSISTED THORACIC SURGERY

SURGICAL CONSIDERATIONS (ALSO SEE SURGEON'S PERSPECTIVE ABOVE)

Description

Video-assisted thoracic surgery refers to endoscopically assisted direct, robotic, and other minimally invasive techniques for thoracic surgery. Although initially used for the assessment of pleural processes of unknown etiology (e.g., pleural effusion that has defied diagnosis), VATS has largely replaced traditional thoracotomy. VATS is now accepted for treatment of spontaneous pneumothorax due to apical blebs, biopsy of peripheral infiltrates or nodules, talc pleurodesis, drainage of pleural effusions and other fluid collections, decortication of early empyemas, evaluation and evacuation of traumatic hemothorax, and standard pulmonary resections including wedge resection and lobectomy. Although not appropriate for all non–small-cell lung cancers, small, peripheral tumors without significant hilar or mediastinal lymph node involvement are often appropriate for VATS lobectomy. VATS also has been used for **lung volume reduction surgery**, **esophageal (Heller) myotomy**, and **upper dorsal sympathectomy**. Less well-accepted procedures include **pneumonectomy** and **esophagectomy.**

In most VATS cases, the use of a DLT or other means (e.g., bronchial blocker) to provide collapse of the ipsilateral lung is necessary because satisfactory visualization of the pleural cavity is impossible without collapse of the lung. The patient is usually in the lateral position. Several small incisions are used—usually three, sometimes four, or more. The video thoracoscope is placed through the first incision, and the pleural cavity is inspected. Other small incisions are then made for insertion of instruments. The

position of the video thoracoscope and instruments may be interchanged, depending on the location of the problem.

More recently, **nonintubated VATS** (NIVATS) under local/regional anesthesia is being considered because of the perceived advantages of avoiding GA, reduced hospital costs, and faster discharge. Contraindications to NIVATS include BMI > 29, CAD, EF < 50, asthma, and sleep apnea. In the spontaneously breathing patient, the lung on the operative side will collapse with pleural opening, and spontaneous OLV will begin. Face mask oxygen is usually sufficient. Permissive hypercapnia may occur and is usually tolerated. Epidural anesthesia or nerve blocks should be considered. Dexmedetomidine is useful for procedural sedation. Conversion to GETA may become necessary.

Usual preop diagnosis

Pleural disease (e.g., effusions); recurrent empyema; recurrent pneumothorax; localized lung masses; achalasia; pulmonary infiltrates; hyperhidrosis; reflex sympathetic dystrophy (RSD)

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, need for a chest tube, and physiotherapy plan. See Appendix K: Enhanced Recovery After Surgery, p. K-1.

SUMMARY OF PROCEDURES	
Position	Lateral
Incision	Usually 3–5 small incisions (portals; Fig. 5.5)
Special instrumentation	Video thoracoscope with thoracoscopy instruments, DLT required
Antibiotics	Cefazolin 2 g iv
Surgical time	1–3 h
Closing considerations	Chest tube placed
EBL	Minimal, although there is a risk for major bleeding
Postop care	Chest tube

Mortality	Minimal
Morbidity	Major vascular injury: rare Conversion to open thoracotomy: 4% Pneumothorax/persistent air leak
Pain score	2–3

PATIENT POPULATION CHARACTERISTICS

Age range	All age groups
Male:Female	1:1
Associated conditions	Pleural effusions, lung mass, pneumothorax

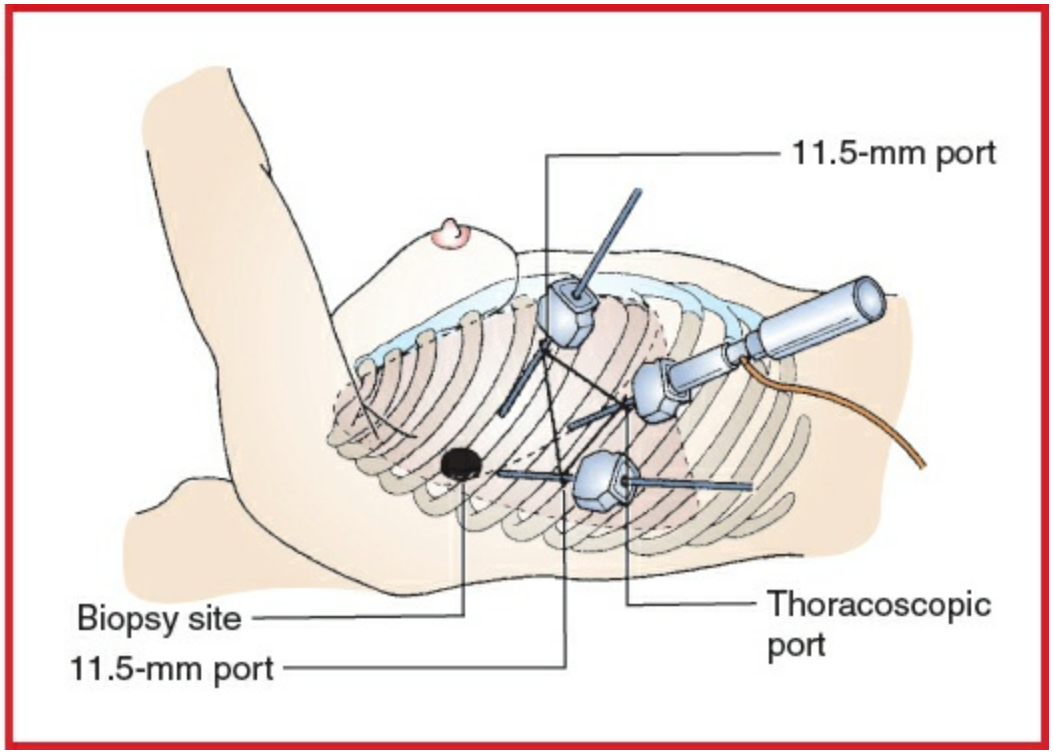

Figure 5.5 Example of thoracoscopic port placement. Positioning varies for individual need, but the principle of triangulation used for laparoscopic surgery is equally applicable in the thorax. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al., eds:Surgery: Scientific Principles and Practice, 2nd edition. Lippincott-Raven Publishers, Philadelphia: 1997, 741.)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

As VATS is used for both diagnostic and therapeutic purposes, this patient population is

quite diverse: patients may be of any age group and may present with an asymptomatic mass or be in respiratory distress due to undiagnosed interstitial disease. VATS is also used for nonthoracic procedures such as sympathectomy, pericardial window, and minimally invasive cardiac surgery. For robotic-assisted thoracic surgery (RATS), the requirements are similar to those for a VATS procedure except for (a) lateral decubitus position for prolonged periods of time with the table turned 90° and (b) limited access to the patient, requiring extensions to vascular lines and anesthetic circuit tubing, and increased difficulty ensuring OLV with a properly positioned DLT.

Respiratory	The preop evaluation should focus on the patient's ability to tolerate OLV, as well as the postop effects of the planned surgery. PFTs and ABG are useful prognostic tests. Question patient about dyspnea, productive cough, and cigarette smoking; examine for cyanosis, clubbing, RR, and pattern. Listen to the chest for wheezes, rhonchi, and rales. Preop lung function may be improved by treating respiratory tract infections, stopping smoking for several weeks, and treatment with bronchodilators and steroids, as indicated. **Tests:** PFT; CXR; if chest CT is available, look for airway anomalies that could interfere with DLT placement; ABG.
Cardiovascular	Directed at any underlying disease process
Laboratory	As indicated from H&P
Premedication	Standard premedication. Avoid heavy sedation that might impair postop respiratory function.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of epidural or paravertebral nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA, typically with OLV, using DLT or BB. OLV may be difficult to achieve in pediatric patients, so chest insufflation with CO_2 has been described but is fraught with risks. Thoracoscopy has also been described in the awake, sedated patient under local or regional anesthetic technique. Although tissue trauma is significantly less than with the open thoracotomy, pain scores are not insignificant, and chronic pain syndromes are common. Referred pain due to lung dissection, chest wall pain due to decortication, and intercostal nerve impingements secondary to trocar insertion may cause marked postop pain. Multimodal therapy with opioid and nonsteroid anti-inflammatory drug (NSAID) is sufficient in many, but patient-controlled analgesia (PCA) may on occasion be required. Regional techniques (epidural or paravertebral) should be considered in compromised patients, in procedures with high conversion risk, or in procedures with significant tissue trauma (e.g., decortication).

Regional anesthesia

The incision site is infiltrated with local anesthetics, and intercostal nerve blocks are performed at the level of incision and at several levels above and below incision. The same effect can be accomplished by multiple-level single-shot paravertebral nerve blocks, which can be performed awake or asleep in the lateral position. Alternatively, continuous paravertebral or epidural catheters can be placed.

General anesthesia

The patient is intubated with a DLT or BB to selectively collapse the operative lung. Lung collapse is slower than with thoracotomy because the chest cavity is not completely opened to atmospheric pressure. To accelerate lung collapse, (a) start OLV early, use an FiO_2 of 1.0, and apply gentle suction to the unventilated lung; (b) make sure trocars are opened to atmosphere for 30–60 sec following insertion; and (c) CO_2 insufflation can be used to accelerate lung collapse. CO_2 insufflation is often well tolerated if begun slowly. There is a risk of venous gas embolism. Sudden insufflation can result in cardiovascular collapse as a result of ↑ intrathoracic pressure → ↓ BP, ↓ HR, and hypoxemia. Insufflated gas will be absorbed and may → hypercarbia.

Induction	Standard induction. Placement of DLT is discussed on p. 320.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and

	normothermia. Consider preincision placement of nerve blocks.	
Maintenance	O_2 (60–100%) and isoflurane, desflurane, or sevoflurane (0.6–1 MAC). No N_2O. Short-acting muscle relaxant and opioids as required. Consider remifentanil infusion (0.1–0.2 mcg/kg/min).	
OLV		
Emergence	Extubation in OR. Discuss with surgeon local wound infiltration or nerve block (e.g., intercostal block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose is given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 16–18 ga × 1 BSS @ 2 mL/kg/h	See Restrictive Fluid Management, Appendix K, p. K-4
Monitoring	Standard monitors ± Arterial line	Arterial catheter generally not required, unless indicated by patient's medical condition
Positioning	✓ and pad pressure points ✓ eyes, ears, and genitals	See p. 306 for proper positioning
Complications	Air leak from the lung Hemorrhage Injury to intrathoracic structures Air embolism	Air leak observed on reexpansion of the lung Excessive blood drainage via chest tube, falling Hct Repair may require open thoracotomy

POSTOPERATIVE

Complications	Tension pneumothorax	In the absence of chest tube, air leak can → pneumothorax that can progress to tension

		pneumothorax if not treated. This may manifest as hyperresonance, ↓ chest wall movement, dyspnea, subcutaneous emphysema, tracheal shift, dysrhythmias, cardiovascular collapse, ↓ PO_2, and ↓ SaO_2. CXR diagnostic, but need to diagnose clinically if hemodynamically unstable. Requires immediate decompression of tension pneumothorax with 14-ga iv catheter through 2nd intercostal space at midclavicular line, followed by chest tube and continuous suction.
Multimodal pain management	IV opioids, ketorolac (30 mg)	Analgesic requirements less than for lateral thoracotomy, but moderate to severe pain may occur and chronic pain is not uncommon. Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with peripheral local anesthetics (see Appendix K, p. K-6).
	Intrapleural anesthesia	Intrapleural local anesthetics (0.25% bupivacaine + 1:200,000 epinephrine 0.5 mL/kg) via thoracostomy drainage tube after the lung is reinflated but before chest tube suction applied.

	Epidural or paravertebral	Indicated in patients with significant comorbidities and/or for procedures with significant tissue trauma (decortication, lobectomy).
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.
Tests	CXR postop	

Suggested Readings

1. Harris RJ, Benveniste G, Pfitzner J: Cardiovascular collapse caused by carbo dioxide insufflation during one-lung anaesthesia for thoracoscopic dorsal sympathectomy. Anaesth Intensive Care 2002; 30(1):86–9.
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LUNG RESECTIONS

SURGICAL CONSIDERATIONS (ALSO SEE SURGEON'S PERSPECTIVE ABOVE)

Description

The most common indication for lung resection is lung cancer. Patients with Stage I or II non–small-cell lung cancer (disease confined to the lung and intrapulmonary or hilar lymph nodes) are generally offered surgery, unless their pulmonary function is

prohibitively poor or their comorbidities pose an unacceptable risk. Patients with lymph node involvement often undergo adjuvant chemotherapy. Patients with Stage IIIA disease (including those with mediastinal lymph node involvement) often receive neoadjuvant chemotherapy and sometimes radiation, with restaging scans before surgery. Patients with Stage IIIB or IV disease are rarely offered an operation. Othe indications for lung resection include infection (particularly mycobacterial and fungal disease and bronchiectasis), congenital abnormalities such as pulmonary sequestrations, and trauma.

For lung cancer, the standard of care is lobectomy. Bilobectomy or pneumonectomy may be required for complete resection and segmentectomy, or wedge resection (nonanatomic lung resection) may be performed to spare lung parenchyma in patients with poor pulmonary function and patients with multiple indolent tumors. Patients without a preop diagnosis may undergo diagnostic wedge resection, followed by completion lobectomy if frozen section shows malignancy. Wedge resections are also performed for metastatic disease. In certain cases, sleeve lobectomy may be performed instead of pneumonectomy.

Lung resections can be performed through open or minimally invasive techniques. Minimally invasive techniques are becoming the standard of care for wedge resections and early-stage lung cancer without lymph node involvement. Large or central tumors or cases with lymph node involvement often require an open operation. Multiple wedge resections for metastases may be performed through open incisions in order to palpate the lung thoroughly.

Regardless of the underlying disease, the preop evaluation should include an assessment of pulmonary function. Spirometry with diffusing capacity is standard for any anatomic lung resection (Table 5.1). Predicted postop FEV_1 and D_LCO should be >40%. If the results are borderline, quantitative ventilation/perfusion scans or formal exercise testing may be necessary (Fig. 5.6). Preop smoking cessation is strongly encouraged.

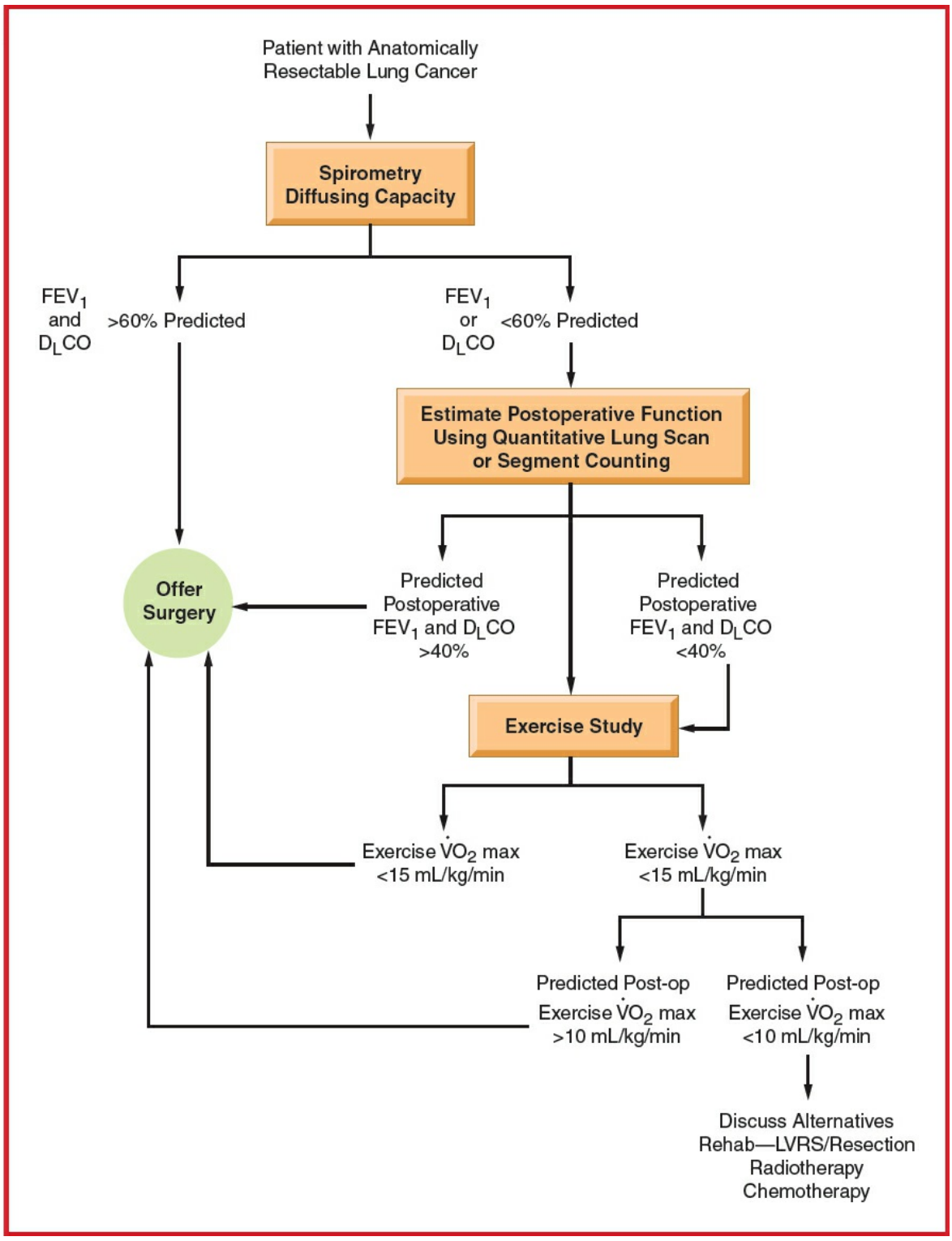

Figure 5.6 Physiologic assessment of patients with compromised lung function. (Reproduced with permission from Olson GN: Pulmonary physiologic assessment of operative risk. In: Shields TW, LoCicero J III, Ponn RB, edsGeneral Thoracic Surgery, 5th edition. Lippincott Williams & Wilkins, Philadelphia: 2000.)

Table 5.1 Spirometric Criteria for Pulmonary Resection

Spirometry	Operable	Further Study Suggested
Forced vital capacity (FVC)	>60% predicted	<60% predicted
Forced expired volume in 1 sec (FEV_1)	>60% predicted	<60% predicted
FEV_1 FVC ratio	>50%	<50%
Maximum voluntary ventilation	>50% predicted	<50% predicted
Gas exchange		
Diffusing capacity for carbon monoxide	>60% predicted	<60% predicted
Arterial carbon dioxide tension	<45 mm Hg	>45 mm Hg

Reproduced with permission from Olson GN: Pulmonary physiologic assessment of operative risk. In: Shields TW, LoCicero J III, Ponn RB, eds. General Thoracic Surgery, 5th edition. Lippincott Williams & Wilkins, Philadelphia: 2000.

Following induction of GA and intubation with a SLT, many surgeons perform a flexible bronchoscopy to confirm normal airway anatomy and check for secretions. In patients with tumors in the trachea or mainstem bronchi, bronchoscopy may be important in determining whether the patient should undergo a lobectomy, sleeve lobectomy, or pneumonectomy. After the bronchoscopy, the SLT is switched to a DLT, or a bronchial blocker is placed. The patient is then positioned in the lateral decubitus position (Fig. 5.3). The lung should be isolated at this time to make entry into the chest safer. Following entry into the chest, the lung on the operative side is allowed to deflate, and sometimes carbon dioxide insufflation is used. If the lung remains ventilated, a flexible bronchoscope should be used to verify correct positioning of the DLT or bronchial blocker (Fig. 5.7). After stable OLV has been obtained, the lung is mobilized and the bronchovascular structures are identified. Generally, the vascular structures are divided first and then the bronchus. Surgical staplers are used to divide vascular structures, the bronchus, and the lung parenchyma. Hypotension and arrhythmias may occur when the hilar structures or pericardium is retracted vigorously but generally resolve quickly on restoration of normal anatomic relationships. Inadvertent entry into the pulmonary artery or its branches during dissection can result in rapid blood loss. Because these vessels are usually under low pressure, bleeding generally can be temporarily controlled with direct pressure while the anesthesiologist resuscitates the patient. If the operation is

performed through VATS, conversion to thoracotomy may be necessary for the surgeon to obtain more definitive vascular control. Before division of the bronchus, the surgeon may ask the anesthesiologist to ventilate the lung while the bronchus leading to the lobe that will be removed is occluded. This will ensure that the remaining lobes inflate appropriately. Thorough suctioning immediately before the lobectomy eliminates secretions as a cause of continued atelectasis. After the lobe has been resected, the surgeon may ask the anesthesiologist to ventilate the lung again to check for an air leak from the bronchial stump. Large air leaks are best addressed at the time of surgery rather than waiting for them to resolve postop.

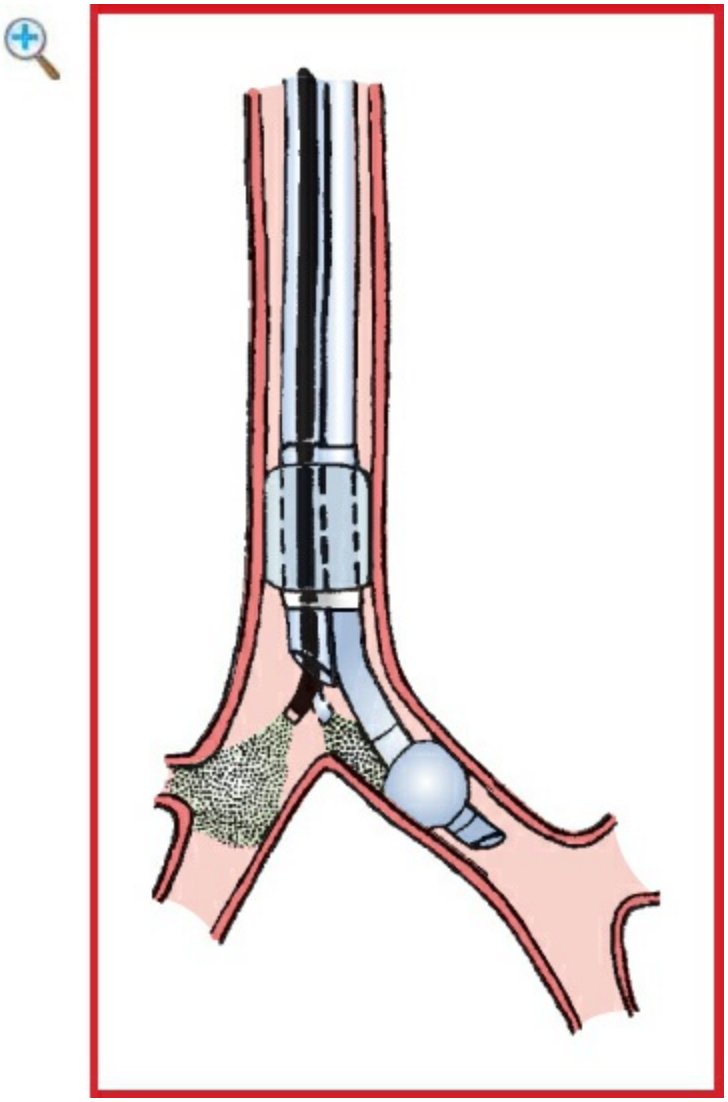

Figure 5.7 The use of a fiberoptic bronchoscope to ensure correct positioning of a left-side DLT. (Reproduced with permission from Fry WA: Thoracic incisions. In: Shields TW, LoCicero J III, Ponn RB, eds. General Thoracic Surgery, 5th edition. Lippincott Williams & Wilkins, Philadelphia: 2000.)

Chest drainage is standard following lung resection and involves placement of a chest tube (usually about 28 Fr in size) attached to water seal or suction. Following

pneumonectomy, chest drainage is not always performed; if a chest tube is placed, a balanced drainage system or water seal must be used. Otherwise, the mediastinum will shift to the operative side, creating adverse hemodynamic consequences. An alternative to drainage (after the patient is placed supine) is to aspirate air from the operative pleural space until a slight negative pressure is obtained.

Usual preop diagnosis

Carcinoma of the lung; infection; congenital abnormalities; trauma

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, need for a chest tube, and physiotherapy plan. See Appendix K, p. K-1.

Summary of Procedure	
	Lung resection—anatomic (segmentectomy, lobectomy, bilobectomy, pneumonectomy, sleeve resections) and nonanatomic (wedge resection)
Position	Lateral/supine
Incision	Posterolateral thoracotomy or VATS
Special instrumentation	DLT or bronchial blocker
Antibiotics	Cefazolin 2 g iv
Surgical time	2–4 h
EBL	<500 mL (more in redo or inflammatory cases)
Postop care	PACU or ICU; careful attention to pulmonary toilet; chest tube output; chest tubes should not be placed to suction after pneumonectomy
Mortality	±1%
Morbidity	Dysrhythmias: 10% after lobectomy, 30% after pneumonectomy DVT: 5% ARDS PE

	MI Bronchopleural fistula Chylothorax Subcutaneous emphysema Phrenic nerve injury Recurrent laryngeal nerve injury
Pain score	7–8

PATIENT POPULATION CHARACTERISTICS	
Age range	60–80 yr
Male:Female	15:1
Incidence	Common thoracic procedure, increasing in females
Etiology	Smoking
Associated conditions	Cardiopulmonary disease, PVD

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

The main indication for lung resection is neoplasm. Other indications include infection and congenital malformation. Many patients have a history of cigarette smoking with associated emphysema and/or chronic bronchitis. As most patients are older, other comorbidities are common (CAD, DM, HTN). Morbidity and mortality followin thoracotomy are increased with preexisting pulmonary, cardiovascular, and neurologic disease. Lung resections are commonly being performed via thoracoscopy, which decreases patient morbidity. Lung isolation (DLT or BB) and OLV are mandatory for surgical exposure.

Respiratory	Question patient about exercise tolerance, dyspnea, productive cough, and cigarette smoking. Examine patient for cyanosis, clubbing, RR, and pattern. Listen to the chest for wheezes, rhonchi, and rales. Timely cessation of smoking (>8 wk), adequate management of bronchospasm with bronchodilator treatment ± steroids, and prompt treatment of

	preexisting lung infections are important to reduce postop pulmonary complications. **Tests:** PFT (see below and Table 5.2); CXR; chest CT (if available), always examine chest imaging for ease of lung isolation; ABG (only if indicated from H&P).
Pulmonary function	Nonsmoker with normal lungs may not require any studies for simple lobectomy. Any preexisting respiratory disease (or possibility of pneumonectomy) should trigger lung function studies. Whole-lung tests (ABG, spirometry) are sufficient in most cases. Split-function lung tests (V/Q scan) should be considered if the patient has heterogeneous disease or a planned pneumonectomy or borderline lung resection is planned. Many variables have been shown to correlate with poor outcome. The most important are FEV_1, D_LCO, and VO_2 max, which focus on different aspects (mechanics, parenchymal function, and cardiopulmonary reserve, respectively). Postop predictive values of $FEV_1 < 40\%$, $D_LCO < 40\%$, or baseline VO_2 max < 15 mL/kg/min predict ↑ risk for postop complications following pulmonary resection. Preop hypercapnia and PHTN/RV dysfunction are relative contraindications to lung resection, except for specific circumstances (e.g., combined with LVRS in severe emphysema). Trial pneumonectomy with PA balloon occlusion is frequently discussed, but not used in clinical practice. Preop optimization of respiratory function with bronchodilator therapy should be routine.
Cardiovascular	RV dysfunction is a relative contraindication to lung resection (particularly pneumonectomy). Prophylactic digoxin or amiodarone to ↓ risk of postop atrial fibrillation has limited efficacy; however, drugs like diltiazem are often used in the postop period. **Tests:** ECG—look for evidence of RV hypertrophy,

	conduction problems, ischemia, and prior MI. Echo/stress echo to evaluate ventricular function, others as indicated from H&P.
Neurologic	✓ Hx of previous back surgery and peripheral neuropathy. Examine thoracolumbar area for skin lesions, infection, and deformities.
Musculoskeletal	Patients with lung cancer may have myasthenic (Eaton-Lambert) syndrome with resistance to depolarizing muscle relaxants and ↑ sensitivity to NDMRs. Monitor relaxation with peripheral nerve stimulator.
Hematologic	Adequate O_2-carrying capacity is important. Optimize Hb preop if possible (iron, EPO); consider transfusion with Hb < 7 g/dL (<10 g/dL with CAD), depending on vital signs. Although rare, bleeding can be profuse, so blood should be immediately available. Coagulopathy may preclude neuraxial anesthesia. **Tests:** Hct, PT, PTT (if epidural anesthesia is planned).
Laboratory	Other tests as indicated from H&P.
Premedication	Midazolam 0.5–2 mg iv if patient is anxious (unless respiratory compromise). When epidural opioids are planned, avoid additional systemic opioid or sedative premedication that can potentiate postop respiratory effects of neuraxial opioids.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of epidural or paravertebral nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

Table 5.2 Assessment of Risk of Postop Pulmonary Complications Following Thoracic and Abdominal Procedures

Category	Point
I. Expiratory Spirogram a. Normal (%FVC + %FEV_1/FVC > 150) b. %FVC + %FEV_1/FVC = 100–150 c. %FVC + %FEV_1/FVC < 100 d. Preop FVC < 20 mL/kg e. Postbronchodilator FEV_1/FVC < 50%	 0 1 2 3 3
II. Cardiovascular System a. Normal b. Controlled HTN, MI sequelae for more than 2 yr c. Dyspnea on exertion, orthopnea, paroxysmal nocturnal dyspnea, dependent edema. CHF, angina	 0 0 1
III. ABGs a. Acceptable b. $PaCO_2$ > 50 mm Hg or PaO_2 < 60 mm Hg on room air c. Metabolic pH abnormality >7.50 or <7.30	 0 1 1
IV. Nervous System a. Normal b. Confusion, obtundation, agitation, spasticity, discoordination, bulbar malfunction c. Significant muscular weakness	 0 1 1
V. Postop Ambulation a. Expected ambulation (minimum, sitting at bedside) within 36 h b. Expected complete bed confinement for at least 36 h	 0 1

0 points = low risk, 1–2 points = moderate risk, 3 points = high risk.

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INTRAOPERATIVE

Anesthetic technique

Combined GA with continuous regional technique (epidural or paravertebral). Anesthesia for lobectomy/pneumonectomy relies on OLV techniques to improve surgical exposure and minimize damage to the operative lung in the case of lobectomy or bilobectomy. The challenges to the anesthesiologist include maintaining adequate

oxygenation in patients with poor pulmonary reserve and ensuring that the patient is comfortable, warm, and awake at the end of surgery.

Preinduction	In patients undergoing open operations, placement of a regional analgesia catheter is important for postop pain control. Continuous epidural (lumbar or thoracic) and paravertebral blocks have been shown to be effective. Epidural catheters should be placed in the awake patient, whereas paravertebral catheters can be sited asleep or intraop under direct vision. The catheter tip should be as close as possible to the level of incision to minimize the sympathectomy. Intraop use of regional analgesia reduces the amount of systemic anesthetics/analgesics required and, therefore, facilitates rapid emergence. An adequate block can be established with lidocaine or bupivacaine; however, higher concentrations will be required for intraop anesthesia than postop analgesia. In patients undergoing minimally invasive operations, paravertebral blocks or intraop nerve blocks placed by the surgeon are often used.
Induction	Standard induction. If flexible bronchoscopy is planned prior to lung resection, intubate with an ETT (≥8 mm), which will be replaced with DLT after bronchoscopy (see below). Otherwise, proceed to intubation with an appropriate-sized DLT (check imaging, rough guideline: adult male, 39–41 Fr; adult female, 35–37 Fr) after induction.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks
Maintenance	Air/O_2 and isoflurane/desflurane/sevoflurane (around 0.5–0.7 MAC if neuraxial block is established). Avoid N_2O. Use high FiO_2 = 0.8–1.0 at onset of OLV; titrate to lowest possible after HPV is well established and

	operative lung collapsed. A local anesthetic (e.g., 2% lidocaine or 0.25–0.5% bupivacaine) can be infused or injected hourly into a thoracic (1–3 mL) or lumbar (5–10 mL) epidural catheter. Continuous infusion of local anesthetic (0.125% bupivacaine) generally provides better hemodynamic stability than hourly bolus injection. To enhance the effect of epidural analgesia, a loading dose of epidural opiate (e.g., hydromorphone 200–500 mcg [thoracic] or 1–1.5 mg [lumbar]) can be administered prior to incision. Epidural hydromorphone has a superior side-effect profile over morphine at equipotent doses. IV (compared to inhalational) anesthetics have a clinically insignificant benefit on OLV oxygenation (particularly if volatile agents are limited to <1 MAC); therefore, TIVA is not necessary in the majority of cases.	
Emergence	Before chest closure, lungs are inflated gradually to 20–30 cm H_2O pressure to reinflate atelectatic areas and to ✓ for significant air leaks. Surgeon inserts chest tubes to drain pleural cavity and aid lung reexpansion. Patient is extubated in OR. If postop ventilation is required (rare), DLT is exchanged for single-lumen ETT. Patient is transferred in head-elevated position to PACU or ICU, breathing mask O_2. If hemodynamically unstable, monitor ECG, pulse oximetry, and arterial pressure during transfer. Discuss with surgeon local wound infiltration or nerve block (e.g., intercostal block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose is given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 18 ga × 1 + 14 or 16 ga × 1 Maintain stable hypovolemia; limit BSS to 10–15 mL/kg if	Postop, PVR is increased in proportion to the amount of lung tissue removed. An overhydrated patient is at risk of RV failure and pulmonary

	possible Blood: available, but rarely required; use vasopressor (ephedrine 5–10 mg iv bolus or phenylephrine 50–100 mcg iv bolus) if hypotensive	edema. Replace blood loss with colloid (1:1) to minimize volume load. Third-space loss is negligible and need not be replaced. The use of epidural local anesthetics can cause ↓ BP in a volume-restricted patient; vasopressor may be needed. See Goal Directed Fluid Management, Appendix K, p. K-4
Monitoring	Standard monitors Arterial line Urinary catheter ± CVP line ± PA line or TEE (rare)	It is mandatory to follow oxygenation continuously during OLV. Typically, this can be done with pulse oximetry, although continuous intra-arterial PO_2 monitoring is now commercially available. CVP and/or PA line is optional for pneumonectomy and for patients with coexisting cardiac disease. CVP monitoring may be inaccurate intraop and is mostly placed for postop care. PA lines are rarely necessary and may interfere with PA stapling or endanger the PA stump. TEE may be of benefit in the borderline pneumonectomy to check for RV tolerance of PA cross-clamp.
Positioning	Axillary roll, "airplane" for the upper arm Avoid hyperextending arms	✓ radial pulses to ensure correct placement of axillary roll (if misplaced, it will compromise distal pulses).

	✓ and pad pressure points ✓ eyes, ears, and genitals	Placing the oximeter probe on the down arm may assist in monitoring arm perfusion.
Fiberoptic bronchoscopy	FOB performed immediately before thoracotomy to evaluate resectability of lesion. Patient intubated with large ETT (≥8 mm), replaced with DLT or BB following bronchoscopy (see Bronchoscopy)	Use the largest DLT that atraumatically passes through the glottis (typically, 39–41 Fr for men, 35–37 Fr for women). DLT can be placed accurately by careful auscultation ±confirmation by FOB. For a DLT, fiberoptic confirmation is done both through the tracheal lumen to confirm that the blue bronchial cuff is not herniating above the carina and through the bronchial lumen to confirm that the end of the tube is not abutting the secondary carina (L-DLT) or through the bronchial lumen to confirm that the end of the tube is in the bronchus intermedius and the opening in the blue bronchial cuff is facing the (R)UL orifice (R-DLT). For small children, the balloon of a Fogarty embolectomy catheter is used as a BB; for adults, either a BB or a Univent tube may be used if the proper size DLT cannot be placed. BB not ideal as FOB is always needed to confirm placement, lung collapse is slow, suction and CPAP application is more difficult, and repeated

		inflation and collapse may be difficult through the small lumen.
Lung isolation	Separate lung ventilation	Separate lungs to prevent contralateral contamination (infection, pus, blood, tumor), allow selective ventilation, and facilitate operation
OLV	Two-lung vent: Vt = 6–8 mL/kg Normocapnia PEEP 3–5 cm H_2O OLV: Vt = 4–6 mL/kg Permissive hypercapnia ($PaCO_2$ 50–60 mm Hg) except in PHTN PEEP 3–8 cm H_2O (unless BPF) FiO_2: 0.6–1.0 PIP <35 cm H_2O and plateau pressures <25 cm H_2O, consider PCV	Issues during OLV are oxygenation, ventilation, and lung injury. Oxygenation is rarely an issue if the DLT is adequately placed and derecruitment is avoided in the nonoperative lung. Ventilation is impaired by the smaller lumen of the DLT and the fact that only one lung is ventilated, resulting in higher ventilatory pressures. However, permissive hypoventilation allows for limiting the ventilatory stress. Acute lung injury may result in postpneumonectomy pulmonary edema, which may occur even after lesser resections. Limiting Vt, peak and plateau pressures, FiO_2, duration of OLV, and atelectasis formation help to minimize the risk.
Complications	Hypoxemia	Hypoxemia is now relatively infrequent (<5% of cases) due to better lung isolation techniques and anesthetic agents with less suppression

	of HPV. If hypoxemia occurs, tube position should immediately be confirmed and FiO_2 increased toward 1.0. Suctioning of secretions and lung recruitment maneuvers are often all that is required. If derecruitment has occurred, higher levels of PEEP should be employed; however, this may potentially worsen oxygenation. CPAP to the (recruited) operative lung is always helpful in open thoracotomy cases, as is clamping of the PA or one of its branches to reduce shunt flow. Return to two-lung ventilation (if possible) will always improve oxygenation (even if used intermittently only) and should be considered with refractory hypoxemia.
Hypercarbia	Mild hypercarbia is well tolerated except in the setting of severe PHTN. CO_2 levels above 70 mm Hg may be associated with tachycardia, dysrhythmias, and cardiac depression. Treat with higher minute ventilation.
Arrhythmia	✓ for mechanical compression of the heart or great vessels.
Hypotension	✓ volume status and cardiac function. Avoid fluid overload.

		Consider phenylephrine if ↓ BP is 2° epidural anesthetic.
	Airway rupture	✓ integrity of the intubated bronchus after reexpanding the lung
	DVT	Preventive measures: TED hose or SCD
	Airway trauma from intubation, tracheobronchial rupture	Force should NEVER be used during insertion of a DLT, as it may result in catastrophic airway disruptions. Do not overdistend bronchial balloon or DLT cuffs. DLT bronchial cuff usually requires <3 mL air for airtight seal, if an appropriate (large) DLT is used.

POSTOPERATIVE

Complications	Injuries related to lateral positioning	Pressure damage to ear, eye, nose, deltoid muscle, iliac crest, brachial plexus, and radial, ulnar, common peroneal, and sciatic nerves has all been reported.
	Structural injuries related to thoracotomy	Neurologic (phrenic and recurrent laryngeal nerves), and spinal cord injury; bronchopleural fistula; tracheobronchial and thoracic duct disruption
	Surgical complications	Cardiac herniation, tension pneumothorax, bleeding, torsion of the residual lobe, acute lung injury/ARDS

	Cardiopulmonary complications	Supraventricular dysrhythmias, SVT, acute RV failure, atelectasis, BPF, pneumonia, PE. For SVT, treat underlying cause and correct electrolyte abnormalities. Most postop SVTs are 2° atrial fibrillation or 2° catecholamine surge and may resolve spontaneously. Hemodynamically unstable patients will require cardioversion. Beta-blockers, amiodarone, Ca^{++} channel blockers, and overdrive cardiac pacing are effective in patients with unstable AF.
Multimodal pain management	Neuraxial opioids—epidural or intrathecal Parenteral opioids (iv, im, continuous iv, PCA) Intercostal blocks Interpleural analgesia Epidural local anesthetics Cryoanalgesia NSAID (ketorolac)	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with peripheral local anesthetics (see Appendix K, p. K-6). Effective analgesia via epidural or paravertebral route is essential for patient to cough, breathe deeply, and ambulate early. Epidural infusions consist of a local anesthetic + opioid mixture (smaller volume and higher concentration with thoracic placement). Paravertebral infusions are local anesthetic only, thereby avoiding opioid side effects. Paravertebral analgesia interferes less with postop lung function than

		epidural analgesia. ESP (erector spinae plane) block is a newer technique for pain management. Ketorolac (15–30 mg iv) is helpful as adjunct analgesic, particularly with referred shoulder pain.
Tests	Hct, CXR, ABG, and others as indicated	
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Alam N, Flores RM: Video-assisted thoracic surgery (VATS) lobectomy: the evidence base. JSLS 2007; 11(3):368–74.
2. Bernstein WK, Deshpande S: Preoperative evaluation for thoracic surgery.Semin Cardiothorac Vasc Anesth 2008; 12(2):109–21.
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9. Refai M, Andolfi M, Gentili P, et al: Enhanced recovery after thoracic surgery: patient information and care-plans. J Thorac Dis 2018; 10(Suppl 4):S512–6.
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CHEST WALL RESECTION

SURGICAL CONSIDERATIONS (ALSO SEE SURGEON'S PERSPECTIVE ABOVE)

Description

The two most common indications for chest wall resection are (a) lung cancer that has invaded the chest wall and (b) primary chest wall tumors (the notable exceptions being Ewing sarcoma and rhabdomyosarcoma). If the operation is performed for lung cancer, the chest wall resection is often performed en bloc with lung resection. This operation may be done open or VATS for the lung resection but requires a thoracotomy for the chest wall resection. If the operation is performed for sarcoma, some patients may have received Adriamycin, which is associated with cardiotoxicity at high doses. If the tumor involves the skin, an appropriate area of the skin—typically, 4 cm around the tumor—must be resected along with the specimen. Underlying subcutaneous tissue and muscle should always be resected en bloc; however, the tumor itself must not be exposed. Wide skin flaps are frequently necessary as well. Limited resection (<5-cm segments of one or two ribs) generally requires no specific reconstructive measures, but larger resections may require reconstruction using polytetrafluoroethylene (PTFE) mesh or myocutaneous flaps. Removal of anterolateral or anterior portions of the chest wall, particularly resections that include the sternum, is associated with greater postop instability than are resections of posterior portions of the chest wall, which are protected by the back muscles and scapula. Larger defects can be tolerated posteriorly without reconstruction, as the scapula provides chest wall stabilization and prevents lung herniation. If a prosthesis is required, it must be covered by viable muscle to avoid erosion through the skin. Extensive reconstruction of the chest wall is often carried out in conjunction with plastic surgeons.

Usual preop diagnosis

Lung cancer with chest wall invasion; primary tumor of the chest wall (bone, cartilage, or soft tissue); radiation necrosis

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, need for a chest tube, and physiotherapy plan. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

Position	Supine or lateral
Incision	Over mass to be resected, sometimes en bloc lung resection is performed VATS
Special instrumentation	Bone instruments, Marlex® (or other) mesh, methyl methacrylate
Antibiotics	Cefazolin 2 g iv
Surgical time	1–6 h
Closing considerations	May require help of plastic surgeon in extensive cases
EBL	<500 mL
Postop care	PACU or ICU; some patients require temporary ventilator support
Mortality	<5%
Morbidity	Paradoxical chest wall motion (less in posterior resections) Pneumothorax Wound complications
Pain score	3–8

PATIENT POPULATION CHARACTERISTICS

Age range	Adults of all ages; children, rarely
Male:Female	1:1
Incidence	Relatively rare
Etiology	Unknown
Associated conditions	Lung cancer, metastatic disease, smoking-related diseases, cardiovascular disease

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Repair of Pectus Excavatum or Carinatum.

Suggested Reading

1. Hazel K, Weyant MJ: Chest wall resection and reconstruction: management o
complications. Thorac Surg Clin 2015; 25(4):517–21.

REPAIR OF PECTUS EXCAVATUM OR CARINATUM

SURGICAL CONSIDERATIONS

Description

Standard bony and cartilaginous repair of a pectus excavatum (funnel chest) or carinatum (pigeon breast) deformities is usually elective surgery with the aim of improving contour and body image. Evidence that these repairs have any positive effect on cardiopulmonary function is controversial, although some surgeons feel that it can be more than a cosmetic procedure—particularly in patients with prominent deformities. Recent evidence suggests that, although resting cardiopulmonary function tests do not improve after pectus repairs, maximal exercise capacity may improve.

Pectus excavatum repair is performed with the Ravitch or Nuss procedures. The Ravitch procedure involves removing enough pairs of costal cartilages (usually four to six) to be able to mobilize and elevate the sternum. Depending on the severity of the defect and patient's age, fixation of the sternum in the corrected position may be necessary. The Nuss procedure is much less invasive and involves placing a metal bar across the chest wall under the sternum. VATS is often used for safe placement. **Pectus carinatum repair** is somewhat more complicated because the defects are more varied —often with a rotational component as well as anterior/posterior displacement. Removal of cartilages and correction of the position of the sternum are still the mainstays of treatment.

A midline incision provides the most satisfactory access to the cartilages and sternum. For cosmetic reasons, however, it may be important to use a curvilinear transverse incision, particularly in women. This incision requires extensive mobilization of subcutaneous and muscle flaps. The wound complication rate is somewhat greater after transverse incisions. The costal cartilages are moved by subperichondrial dissection. This may be tedious and time consuming, especially because several pairs of cartilages need to be removed. The elevation of the sternum is usually fairly straightforward and usually is accompanied by a transverse sternal osteotomy (Fig. 5.8). Intercostal muscle bundles may be left attached to the sternum or may be detached and reattached for better positioning of the sternum. Sternal support normally is not used in infants but may be used in older children. One common method of support is the use of a temporary

transverse metal strut resting on the ribs but beneath the sternum. The final position of the sternum is easier to predict following repair of the pectus carinatum than following repair of pectus excavatum. Because of the negative intrathoracic pressure, it is easier to hold the sternum down than up. Ideally, patients for repair of pectus excavatum are just under school age. Satisfactory repair, however, may be carried out at almost any time during childhood. As full growth is attained, results tend to be less favorable. Pectus carinatum generally has its onset during adolescence, and it is well to let the patient complete his or her growth spurt prior to undertaking repair. (Also see Repair of Pectus Excavatum/Carinatum in Pediatric General Surgery.)

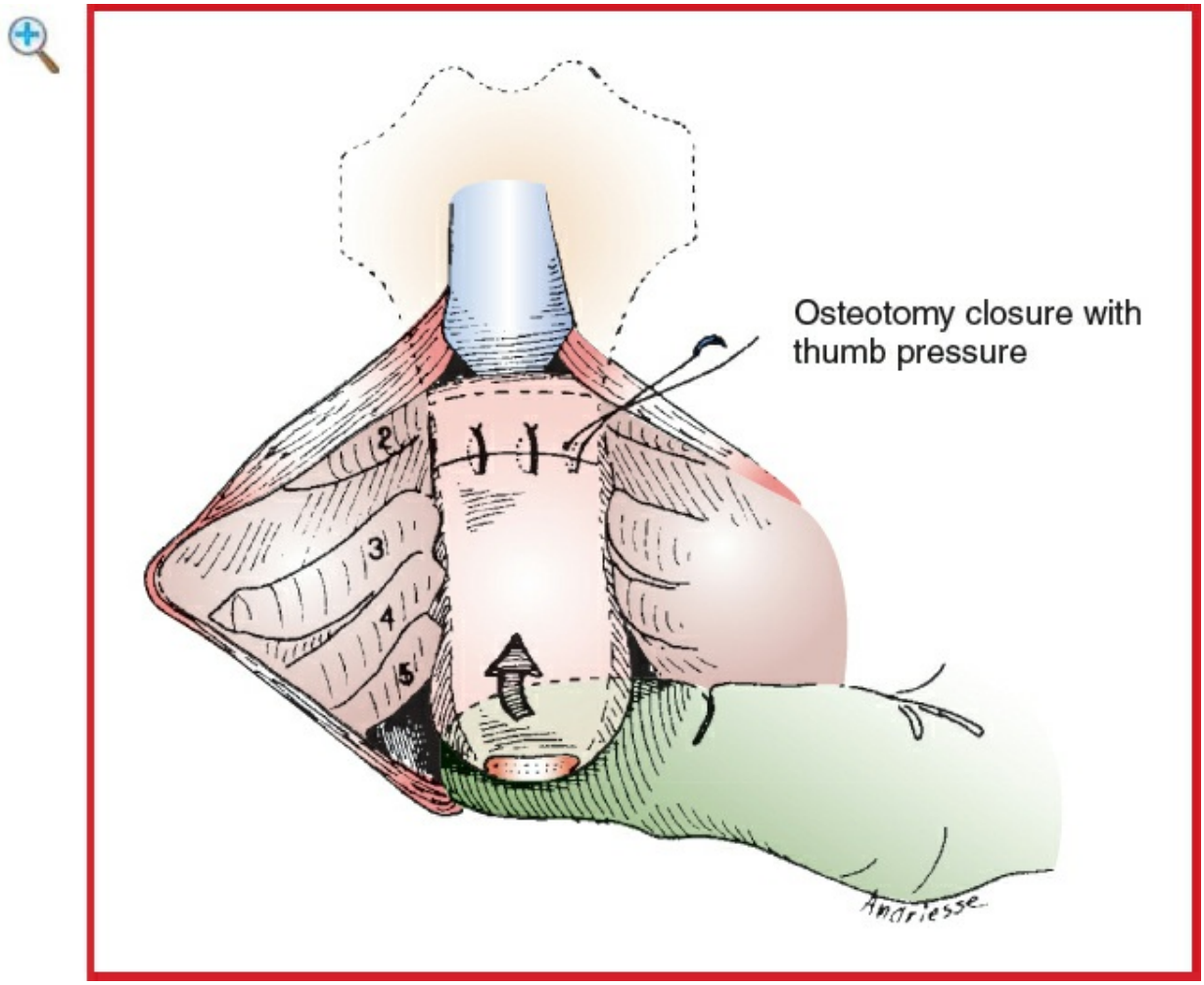

Figure 5.8 Correction of a pectus excavatum defect in a child. After subperichondrial resection of the involved costal cartilages, a wedge osteotomy permits anterior mobilization of the lower portion of the sternum. (Reproduced with permission from Shamberger RC: Chest wall deformities. In: Shields TW, LoCicero J III, Ponn RB, edsGeneral Thoracic Surgery, 5th edition. Lippincott Williams & Wilkins, Philadelphia: 2000.)

Variant procedure or approaches

In certain circumstances, particularly in teenage girls and patients who do not engage in

strenuous sports, subcutaneous, custom-made implants may be placed to improve body contour without necessitating major bony and cartilaginous repairs. These are usually carried out by plastic surgeons.

Usual preop diagnosis

Pectus excavatum or carinatum

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, need for a chest tube, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

Position	Supine
Incision	Transverse or vertical or VATS for Nuss procedure
Special instrumentation	Bone instruments, sometimes metal struts or wires for reconstruction
Antibiotics	Cefazolin 2 g iv
Surgical time	2–3 h
Closing considerations	Pleural and wound drainage common
EBL	100–500 mL
Postop care	ICU
Mortality	Minimal
Morbidity	Pneumothorax 5% Wound infection Sternum necrosis Immigration of strut Paradoxical chest wall motion → hypoventilation/atelectasis
Pain score	4–5

PATIENT POPULATION CHARACTERISTICS

Age range	Usually children, 5–10 yr; teenagers, sometimes; adults, rarely
Male:Female	1:1
Incidence	Unusual
Etiology	Unknown
Associated conditions	Marfan syndrome; MVP

ANESTHETIC CONSIDERATIONS

(Procedures covered: chest wall resection, repair of pectus excavatum/carinatum)

PREOPERATIVE

Patients for chest wall resection often have extensive cancer and may be weak and debilitated. A very large resection may create a "flail chest" situation, compromising postop ventilation.

Respiratory	Mild pectus seldom interferes with ventilation; no special studies are indicated. Severe pectus deformity can be associated with restrictive lung defects. **Tests:** CXR, PFT, ABG, if indicated from H&P
Cardiovascular	With severe pectus, the heart is displaced to the left and compressed; arrhythmias and RVOTO can occur 2° impaired filling, especially during exercise or in upright position. ECG may show right axis deviation, atrial and ventricular arrhythmias. A functional murmur may be detected. Echo may reveal ↓ SV with MVP. **Tests:** ECG, cardiac catheterization if indicated. Echocardiogram if symptoms or signs suggest MVP or RVOTO.
Hematologic	**Test:** Hct
Musculoskeletal	Chest wall resection is performed for invasive or metastatic cancer; patient may be markedly

	debilitated: pectus repair of chest wall deformity for cosmetic, orthopedic, or cardiopulmonary indications—pectus deformity usually asymptomatic.
Laboratory	Other tests as indicated from H&P
Premedication	Consider anxiolysis with short-acting benzodiazepine. When epidural opioids are planned, minimize systemic opioid or sedative premedication to avoid potentiating postop respiratory depression from central neuraxial opioids.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of epidural or paravertebral nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA +/– epidural anesthesia for minimal chest wall resection; however, epidural anesthesia is a recommended adjunct for extensive chest wall resections or repair of pectus deformities.

Induction	Standard induction. In the setting of RVOTO, avoid myocardial depressants, hypovolemia, and a short diastolic filling time (e.g., tachycardia). Lung isolation (DLT or BB) is usually required for chest wall resections. Sequential OLV can often be accomplished with a single-lumen ETT and an EZ-Blocker™.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.

Maintenance	Standard maintenance or high-dose opioid technique (fentanyl 10–25 mcg/kg) for patient with severe RVOTO. Patients with MVP will require prophylactic antibiotics for bacterial endocarditis. OLV, if necessary, as outlined for lobectomy/pneumonectomy.	
Emergence	Extubate in OR, or if high-dose opioid →ICU for later extubation. Discuss with surgeon local wound infiltration or nerve block (e.g., intercostal block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose is given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 18–16 ga × 1 BSS @ 1–2 mL/kg/h	Usually minimal blood loss. Fluid restriction is unnecessary as this is extrapulmonary operation. See Goal Directed Fluid Strategy, Appendix K, p. K-4
Monitoring	Standard monitors ± Arterial line	Close monitoring with arterial and central venous catheters may be required in patients with significant cardiopulmonary compromise.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Pneumothorax	Unintentional pleural tear can cause pneumothorax. Intraop deterioration characterized by ↑ peak inspiratory pressure, hypotension, and hypoxemia suggests pneumothorax. Increase FiO_2; d/c N_2O. Ensure pleural space is decompressed appropriately with needle or tube thoracostomy.

	Cardiac perforation	Rare, catastrophic event reported with aberrant bar placement during minimally invasive approach. Heralded by signs of hemorrhagic or obstructive shock. Supporting bar may interfere with external cardiac compressions.

POSTOPERATIVE

Complications	Hypoventilation Flail chest Atelectasis/pneumonia Pericarditis Bar displacement	Although most patients do not require postop ventilator support, with extensive chest wall resection, patient may hypoventilate. Respiratory stimulants, such as doxapram, should be avoided as they may → deep inspirations that can → severe sternal retractions. Paradoxical chest wall movement may occur during spontaneous ventilation with flail chest, postop atelectasis 2° splinting. Obtain postop CXR. Similar to postpericardiotomy syndrome, usually responsive to NSAIDs though occasionally corticosteroids or percutaneous drainage is required. Following minimally invasive repair (Nuss), the bar may become displaced and require

		repositioning. Inadequate analgesia and absence of a stabilizing bar are often cited as contributing factors.
Multimodal pain management	Depends on site and extent of chest wall resected Parenteral or epidural opioids with local anesthetic	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with peripheral local anesthetics (see Appendix K, p. K-6). Epidural opioids and local anesthetics are particularly useful if flail chest is present—which reduces need for ventilator support.
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Frantz FW: Indications and guidelines for pectus excavatum repair. Curr Opin Pediatr 2011; 23(4):486–91.
2. Frawley G, Frawley J, Crameri J: A review of anesthetic techniques and outcomes following minimally invasive repair of pectus excavatum (Nuss procedure). Paediatr Anaesth 2016; 26(11):1082–90.
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THORACOPLASTY

SURGICAL CONSIDERATIONS (ALSO SEE SURGEON'S PERSPECTIVE ABOVE)

Description

The objective of a **thoracoplasty** (removal of several ribs) is to permanently obliterate an existing pleural space, when the remaining lung cannot expand to fill it. Formerly, this operation was used in the treatment of tuberculosis (TB); however, because of better drug therapy, appropriate pulmonary resection, and the decrease in incidence of TB, thoracoplasty is now very rare. The procedure also was used for obliterating empyema spaces and helping to close bronchopleural fistulas (BPFs). The use of **pedicled muscle flaps** (serratus anterior, pectoralis major, and latissimus dorsi are the most common) or an **omental transposition** has largely replaced thoracoplasty for filling empyema spaces and encouraging closure of BPFs. These operations are less deforming and better tolerated physiologically because they do not result in paradoxical motion of the chest wall.

For patients whose lung will never expand to fill the space—such as those who have had a pneumonectomy or who have a permanently noncompliant lung—resection of multiple overlying ribs may be necessary (Fig. 5.9). Thoracoplasty is accomplished by removing several ribs in a subperiosteal fashion, allowing the underlying chest wall to collapse. This collapse is aided by the normally negative intrapleural pressure. Because the periosteum is left intact, the ribs will regenerate, resulting in a permanent, bony collapse of the chest wall. If the objective of the thoracoplasty is to obliterate a relatively small space (meaning that segments of only two to three ribs need be removed), the procedure may be done in a single stage, with little postop physiologic impairment of respiration. If extensive thoracoplasty is necessary, however, the procedure may be done in stages to minimize postop chest wall instability and resultant respiratory problems.

Usual preop diagnosis

Pulmonary TB; BPF; empyema

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, need for a chest tube, and physiotherapy plan. See Appendix K, p. K-1.

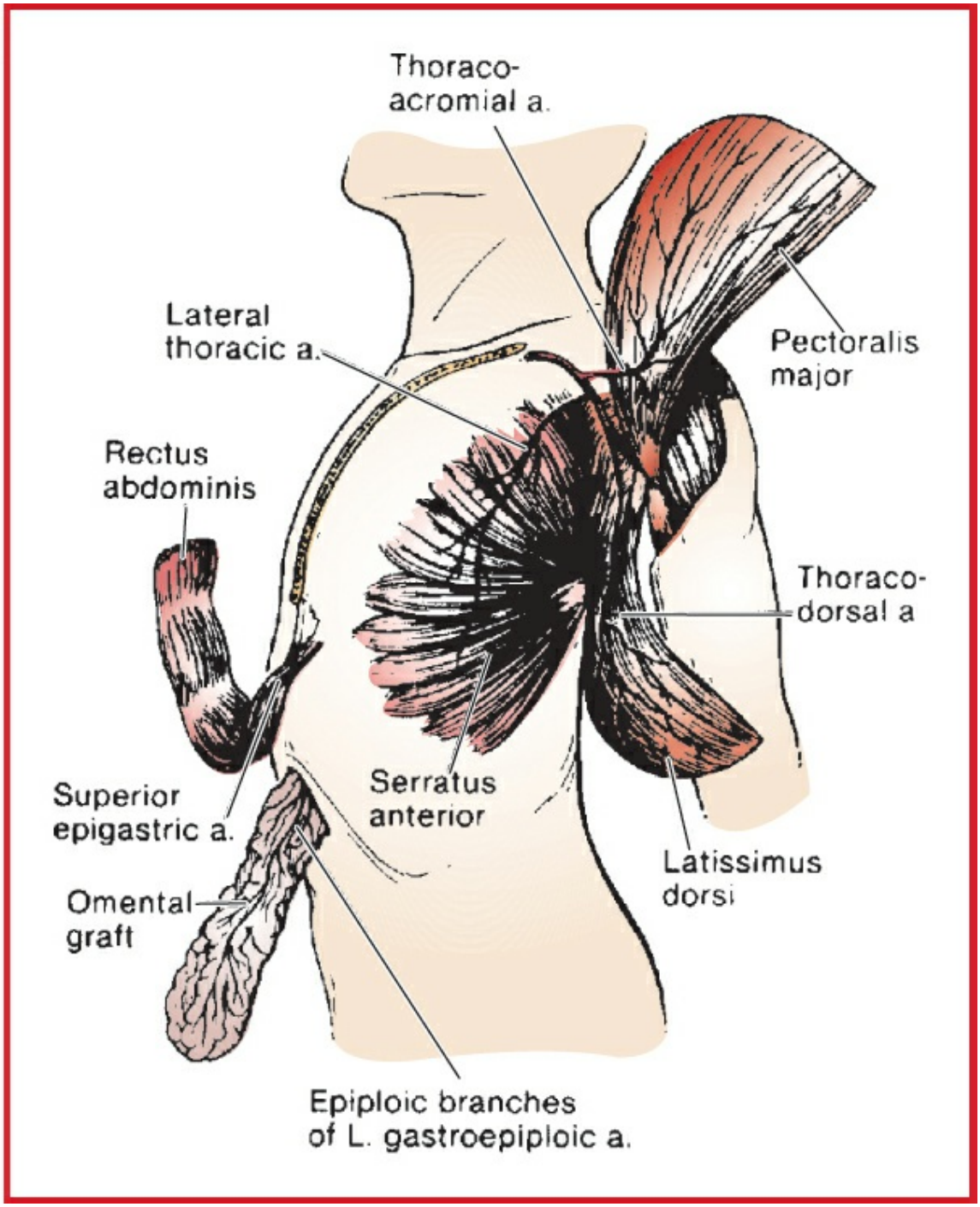

Figure 5.9 Extrathoracic muscle flaps that may be used to obliterate a postpneumonectomy empyema cavity. (Reproduced with permission from Miller JI Jr: Postsurgical empyema. In: Shields TW, LoCicero J III, Ponn RB, eds.General Thoracic Surgery, 5th edition. Lippincott Williams & Wilkins, Philadelphia: 2000.)

SUMMARY OF PROCEDURES

Position	Usually lateral
Incision	Along rib line

Special instrumentation	Bone instruments
Unique considerations	TB or fungal infection may be present
Antibiotics	As indicated by culture and sensitivity
Surgical time	2–3 h
EBL	500 mL or more
Postop care	ICU
Mortality	Minimal
Morbidity	Paradoxical chest wall motion → atelectasis → hypoxemia: 10% Pneumothorax: rare
Pain score	7–8

PATIENT POPULATION CHARACTERISTICS

Age range	Middle-aged or older adults
Male:Female	1:1
Incidence	Rare
Etiology	TB; pneumococcal infection; neoplasm; complication of pneumonectomy
Associated conditions	Immunosuppression

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Drainage of Empyema.

Suggested Reading

1. Seify H, Mansour K, Miller J, et al: Single-stage muscle flap reconstruction of the postpneumonectomy empyema space: the Emory experience. Plast Reconstr Surg 2007; 120(7):1886–91.

DRAINAGE OF EMPYEMA

SURGICAL CONSIDERATIONS

Description

Empyema is infection within the pleural space, and the primary treatment for it is drainage. Patients may be acutely ill or they may have a history of prolonged infirmity. The most common cause of empyema is extraparenchymal extension of a pneumonia, although other causes include trauma, BPF, and esophageal perforation. The three phases of an empyema are the exudative, fibrinopurulent, and organized phases. The early, or exudative, phase of an empyema is usually associated with fever, dyspnea, and a pleural effusion, with the diagnosis generally being made by thoracentesis. In more established infections, patients may complain of chronic symptoms, such as pain, dyspnea, and chest heaviness, and their medical history may include several previous courses of antibiotics.

Treatment of empyemas is based on the stage and the underlying cause of the infection. In the exudative phase, chest tube drainage alone may provide adequate therapy. Intrapleural tPA administration through the chest tube may assist in resolution. In the fibrinopurulent stage, thoracoscopic drainage with disruption of loculations and decortication (removal of the fine peel on the lung) is enough to drain the infected fluid and allow the underlying lung to expand. This procedure typically is done with the patient in the lateral position and involves three thoracoscopy ports. Blood loss is generally small, although large volumes of irrigation fluid may be necessary to thoroughly débride the thoracic cavity.

As the empyema becomes more established, the peel becomes thicker and more difficult to remove thoracoscopically. In such cases, an **open thoracotomy** is necessary. Due to the extensive intrapleural inflammation, blood and fluid losses may be substantial. To identify the correct plane between the lung and the thickened pleura, the lung may need to be reexpanded frequently throughout the procedure. Satisfactory drainage is accomplished when the infected fluid is removed and the lung expands freely. Because the peel often intimately adheres to the underlying lung, there may be a moderate postop air leak.

In patients too ill to undergo thoracotomy, **rib resection** with subsequent open drainage tube will permit the underlying lung to expand over a period of several weeks. Although this may be done under local anesthesia, a brief general anesthetic is often easier on the patient. In this operation, the patient is placed in the lateral position, and an incision is

made over the rib corresponding to the most dependent portion of the empyema cavity. A 6-cm length of the rib is excised and a large-diameter (≥50 Fr) tube is inserted into the empyema cavity. More permanent open drainage is obtained by fashioning an **Eloesser flap.** In this procedure, a U-shaped flap of the skin is rotated into the empyema cavity after rib resection. This creates a long-term, skin-lined tube that will last indefinitely. A variant of this procedure—the **Clagett procedure**—is carried out for empyema (with or without BPF) following pneumonectomy because closed drainage rarely suffices in that situation. The principle is the same: drainage is accomplished through an epithelial-lined permanent opening. The opening is made anterolaterally and dependently so that drainage is effective and the patient can handle dressing changes without assistance. Segments of 2–3 ribs are removed, and the skin is sutured to the parietal pleura, leaving a permanent opening for drainage and irrigation. Without an underlying lung and with a relatively fixed mediastinum, this procedure is well tolerated physiologically.

Usual preop diagnosis

Nontuberculosis empyema (typically pneumococcal)

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, need for a chest tube, and physiotherapy plan. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Eloesser or Clagett
Position	Usually lateral
Incision	Over empyema pocket for Eloesser
Special instrumentation	None
Unique considerations	Patient may have BPF
Antibiotics	As indicated by culture and sensitivity
Surgical time	2 h
Closing considerations	Wound left open

EBL	100 mL
Postop care	PACU → room
Mortality	Minimal
Morbidity	Fluid drainage Bleeding: rare
Pain score	3–4

PATIENT POPULATION CHARACTERISTICS

Age range	Usually adults
Male:Female	1:1
Incidence	Decreasing
Etiology	Pneumonia; esophageal or bronchial leak; lymphatic or hematogenous spread of infection; posttrauma or thoracic surgery
Associated conditions	Bronchopleural fistula (BPF); sepsis; malnutrition

ANESTHETIC CONSIDERATIONS

(Procedures covered: thoracoplasty, drainage of empyema)

PREOPERATIVE

The guiding principle in the anesthetic management of empyema is to protect the unaffected lung from soiling by the affected side. These patients are often chronically ill with sepsis and cachexia, and there is usually an underlying BPF (which may require awake intubation).

Respiratory	Patients usually have preexisting pulmonary disease. Preop pulmonary findings may include collapse of the ipsilateral lung, impaired hypoxic pulmonary vasoconstriction 2° infection, and mediastinal shift to the ipsilateral side. Procedure often is performed for empyema in the presence of BPF following lung resection (particularly pneumonectomy), penetrating

	injury to the chest, or rupture of a cyst or bulla. When possible, surgeon should drain empyema under local anesthesia before induction, with patient sitting upright. If empyema is loculated, complete drainage may not be possible. **Tests:** Consider PFTs; ABG; obtain CXR to determine efficacy of preop chest drainage; if chest CT is available, look for airway obstruction that could interfere with DLT placement.
Cardiovascular	There may be ECG changes because of mediastinal shift to the affected side. **Tests:** As indicated from H&P
Neurologic	✓ Hx of back surgery and peripheral neuropathy. Examine the lumbar area for skin lesions, infection, and deformities. Avoid placement of epidural catheter in patient with neurologic problems or if obviously bacteremic or septic.
Musculoskeletal	Patients with lung cancer may have myasthenic (Eaton-Lambert) syndrome with resistance to depolarizing muscle relaxant and ↑ sensitivity to NDMRs. Monitor relaxation with peripheral nerve stimulator.
Hematologic	Transfuse patients with preop Hct < 25% or Hct < 30% in patients with CAD. (Hb level necessary to maintain adequate O_2 content.) Obtain autologous blood during the month before surgery or consider preop erythropoietin therapy in anemic patients.
Laboratory	Other tests as indicated from H&P
Premedication	Midazolam 0.5–2 mg iv if patient is anxious. When epidural opioids are planned, avoid systemic opioid or sedative premedication, which can potentiate postop respiratory effects of central neuraxial opioids.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of epidural or

	paravertebral nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA; combined with epidural anesthesia/analgesia if thoracotomy is indicated and patient is not bacteremic or septic.

Induction	Consider inhalational induction (e.g., sevoflurane) if patient has significant BPF. Semi-Fowler position with a lateral tilt to make the infected side dependent, along with rapid control of the airway followed by isolation, makes contralateral contamination less likely. Rapid-sequence induction with cricoid pressure is an alternative. Intubate with DLT; isolate lungs to protect from aspiration and tension pneumothorax. Consider using DLT with the bronchial lumen to side opposite BPF. Contamination of the healthy lung from aspiration of pus is a major concern; thus, proper tube position should be verified by FOB, and adequate cuff inflation should be checked. Large DLT provides snug fit in the bronchus and limits aspiration. Pus may appear in the tracheal lumen (the lumen to the diseased lung); suction frequently to avoid soiling good lung.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	O_2 and isoflurane (1.0–1.5%); less required if epidural local anesthetics are used. No N_2O. Use FiO_2 = 0.5–1.0. A local anesthetic (e.g., 2% lidocaine with 1:200,000 epinephrine or 0.25% bupivacaine) can be infused or injected hourly into a thoracic (3–5 mL) or

	lumbar (5–10 mL) epidural catheter. Continuous infusion of local anesthetic generally provides better hemodynamic stability than hourly bolus injection. To enhance the effect of epidural analgesia, a loading dose of opiate (e.g., hydromorphone 0.4–1 mg [thoracic] or 1–1.5 mg [lumbar]) can be administered early in the surgery and at least 1 h before conclusion. Following intubation, isolate lung with DLT or BB. The chest tube is then removed, while the chest is prepped for the operation. Ventilate only the healthy lung. Because BPF is an abnormal communication between the bronchial tree and pleural cavity, if no chest tube is present, conventional intubation with IPPV can produce tension pneumothorax. Keep unclamped and do not remove a functioning chest tube until the lung is isolated and ventilation to the diseased lung is stopped. After the chest is opened, there is no chance of pneumothorax, but the large air leak through BPF may prevent satisfactory ventilation of that lung. High-frequency ventilation (HFV) is recommended by some, but studies show no benefit; in some patients, the BPF is actually increased with HFV.
Emergence	Before closing the chest, lungs are inflated gradually to 30 cm H_2O pressure to reinflate atelectatic areas and to check for significant air leaks. The surgeon will insert chest tubes to drain pleural cavity and aid lung reexpansion. Patient is extubated while still in OR. If postop ventilation is required (rare), the DLT is exchanged for an ETT. If BPF is still open, consider selective ventilation postop through DLT. It may be necessary to ventilate each lung separately; use smaller TVs to the lung with BPF. Alternatively, pressure-controlled ventilation may be used to avoid major air leaks through BPF. Discuss with surgeon local wound infiltration or nerve block (e.g., intercostal block) placement or reinforcement if

	initially placed >4 h ago. Consider iv acetaminophen if po dose is given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 16–18 ga × 1; BSS Avoid hypervolemia	An overhydrated patient is at increased risk of right heart failure and pulmonary edema. Replace blood loss with crystalloid (1:3) or colloid (1:1). Third-space losses are negligible and do not need to be replaced. See Restrictive Fluid Management, Appendix K, p. K-4.
	Use vasopressor (ephedrine 5–10 mg iv bolus or phenylephrine 50–100 mcg iv bolus) if hypotensive	The use of epidural local anesthetics can cause ↓ BP in a volume-restricted patient; vasopressor is often needed.
Monitoring	Standard monitors ± CVP and/or PA line ± Arterial line	
Positioning	Axillary roll, "airplane" for the upper arm Avoid hyperextending arms ✓ and pad pressure points ✓ eyes, ears, and genitals	Placing the oximeter probe on the downside may help detect inadequate perfusion from compression.

POSTOPERATIVE

Complications	Tension pneumothorax Aspiration pneumonia	Functioning chest tube necessary to prevent tension pneumothorax.

	("down" lung)	
Multimodal pain management	Analgesic requirements minimal Parenteral opioids (iv, im, PCA), epidural, NSAID	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with peripheral local anesthetics (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Alifano M, Gaucher S, Rabbat A, et al: Alternatives to resectional surgery for infectious disease of the lung: from embolization to thoracoplasty. Thorac Surg Clin 2012; 22(3):413–29.
2. Shiraishi Y: Surgical treatment of chronic empyema. Gen Thorac Cardiovasc Surg 2010; 58(7):311–6.

TRACHEAL RESECTION

SURGICAL CONSIDERATIONS

Description

The primary indications for **tracheal resection** are benign stricture and primary tracheal neoplasm. Benign strictures often are related to previous intubation or tracheostomy, whereas the most common malignant tumors include squamous cell carcinoma and adenoid cystic carcinoma. Proximal tracheal resections may also be required for trauma or idiopathic laryngotracheal stenosis. The preop assessment of patients with tracheal disease generally involves imaging with either CT or MRI, as well as bronchoscopy. Important considerations include the length and location of the lesion and the caliber of the airway. Although up to 50% of the trachea can be resected with a successful primary anastomosis, shorter segment resections are technically simpler and do not require special techniques to maximize tracheal mobility.

When operating on the upper trachea, a **cervical approach** is used. The patient is positioned supine with the neck extended. A transverse collar incision is used and subplatysmal planes are developed. The trachea is then extensively mobilized anteriorly

and posteriorly. To minimize the risk of devascularizing the trachea, only the region to be removed should be circumferentially dissected. During this portion of the operation, care is taken to avoid injury of the recurrent laryngeal nerves. The trachea is then opened, the oral ETT is withdrawn into the proximal trachea, and a sterile armored ETT is passed across the operative field for cross-table ventilation. Fine, interrupted, absorbable sutures are placed, but not tied. Once all sutures are in place, the armored tube is removed and the oral ETT is positioned across the anastomosis. The ends of the trachea are approximated with minimal tension and the sutures are tied (Fig. 5.10). The neck is flexed for this portion of the procedure. A guardian suture may be placed from the chin to the chest wall to maintain neck flexion for several days. At the end of the procedure, the patient should be extubated to minimize airway irritation and disruption of the anastomosis.

When operating on the lower trachea, a **right thoracotomy** is used. The patient is positioned in the left lateral decubitus position. To facilitate exposure of the distal trachea, OLV using either a DLT or a SLT advanced into the left main bronchus is helpful.

As is apparent from the preceding discussion, all tracheal procedures require frequent communication between the surgeon and anesthesiologist. Occasionally, special techniques, such as jet ventilation or cardiopulmonary bypass (CPB), may be necessary for tracheal surgery.

Usual preop diagnosis

Tracheal stenosis or tumor (adenoid cystic carcinoma or squamous cell carcinoma most common)

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, need for a chest tube, and physiotherapy plan. **See Appendix K, p. K-1.**

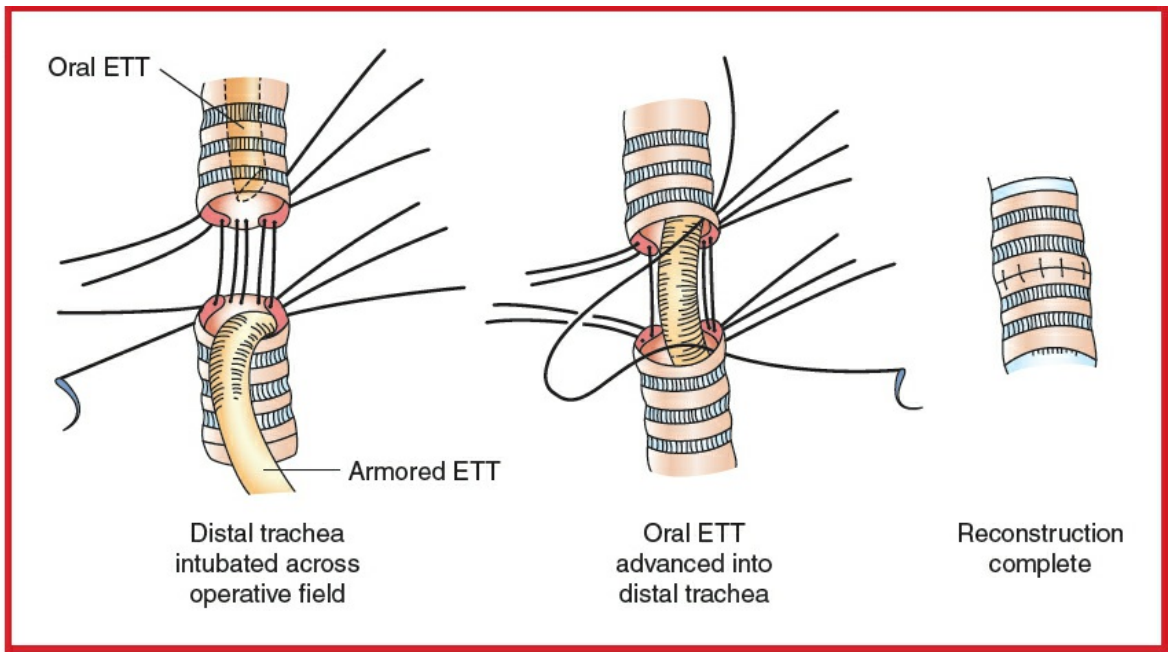

Figure 5.10 Stages of tracheal reconstruction. Note ETT in the distal trachea. (Reprinted from Grillo HC. Surgery of the trachea. Curr Probl Surg 1970; 7(7):3–59. Copyright © 1970 Elsevier. With permission.)

SUMMARY OF PROCEDURES

	Cervical Approach	Right Thoracotomy
Position	Supine	Left lateral decubitus
Incision	Transverse low cervical	Right thoracotomy
Antibiotics	Cefazolin 2 g iv	⇐
Surgical time	4 h	4 h
Closing considerations	Neck flexion (chin stitch)	⇐
EBL	<200 mL	<500 mL
Postop care	ICU	⇐
Mortality	<5%	⇐
Morbidity	Retained secretions Dehiscence Recurrent stenosis Recurrent/superior laryngeal nerve injury	⇐

	Granuloma	
Pain score	3–4	4–6

PATIENT POPULATION CHARACTERISTICS

Age range	Wide variation
Male:Female	1:1
Incidence	Rare
Etiology	Stenosis due to intubation or injury; tumor, either primary (e.g., smoking) or secondary (e.g., thyroid cancer)
Associated conditions	Carcinoid syndrome; cardiopulmonary disease; tracheoesophageal fistula (TEF)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Respiratory	Initial presentation may involve Sx of airway obstruction (stridor, cough, dyspnea), which may be misdiagnosed as asthma or pneumonitis. Patients presenting for tracheal resection almost exclusively have fixed obstruction but may have an associated dynamic component. A careful preop evaluation of the airway usually includes bronchoscopic delineation of lesion site and size. This, in combination with a review of CT images, will help to determine a plan including the type of induction, size of ETT, and location of ETT tip. **Tests:** PFT with flow/volume loops; bronchoscopy; CT scan to determine the extent of tracheal obstruction
Laboratory	Other tests as indicated from H&P
Premedication	Patients with stridor or critical airway lesions should not receive preop sedation. It is probably best to avoid sedation in all patients. Patients may be

	unable to lie flat 2° respiratory distress. Low-density helium-oxygen (heliox) mixtures have the clinical advantage of reducing airway resistance to flow past the obstruction, which may be beneficial in optimizing the patient prior to the procedure.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of epidural or paravertebral nerve blocks for postop pain management for thoracotomy approach. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA, combined with epidural or paravertebral catheter if sternotomy or thoracotomy approach is used. Surgery is divided into five phases: induction, dissection, open trachea, closure, and emergence. Induction, open trachea, and emergence are the critical and potentially dangerous stages. Close communication between surgeon and anesthesiologist is required.

Induction	Be prepared for airway emergency. Surgeon must be present and prepared for emergency rigid bronchoscopy and/or to perform tracheostomy below lesion. Induction depends on the site and degree of airway narrowing. Proximal or narrow lesions usually require inhalation induction or awake FOI, whereas distal or mild lesions may be approached with a rapid-sequence iv induction. Sevoflurane/O_2 is preferred for smooth inhalation induction with depression of cough reflex; avoid N_2O. High concentrations of sevoflurane may be necessary. Heliox (79% helium in oxygen) has been recommended to decrease resistance to flow past the obstruction; however, helium is not widely

	available and limits the FiO_2 that can be administered. Have a variety of laryngeal blades and uncut ETTs of various sizes, including small 5-mm tubes available. If ETT passes beyond lesion, IPPV can be started. If ETT cannot be passed, spontaneous ventilation with 100% O_2 and sevoflurane will be required if there is a dynamic obstruction, while patients with fixed lesions will tolerate PPV through a proximal tube. Careful and gradual dilation of the stenotic lesion may be required, using different sizes of ETTs or rigid bronchoscopy to facilitate placement of an adequate-size ETT for ventilation. For carinal resections, use a sterile ETT, which can be placed by surgeon directly into each bronchus during resection for cross-field ventilation. An armored tube is preferable because it avoids kinking during repeated manipulations by the surgeon. Another option is to place jet ventilation catheters into the mainstem bronchi and jet-ventilate the patient during the open trachea stage.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Inhalational anesthesia can be unreliable (and may pollute the OR environment) due to frequent tube changes and intermittent apnea. TIVA is preferable: use propofol (25–100 mcg/kg/min) and remifentanil (0.05–0.2 mcg/kg/min) infusions. After the airway is secured, muscle relaxation should be given to avoid movement or coughing during the procedure. Standard maintenance. FiO_2 = 1.0 if using apneic oxygenation; continuous monitoring with pulse oximetry is mandatory. Consider HFJV through a small-diameter catheter if ETT interferes with operation. HFJV will require iv anesthesia because inhalational agents cannot be delivered predictably; CPB can be used (rare). Analgesia requirements are

	highly dependent on surgical approach. Standard parenteral opioids are sufficient for the cervical approach, whereas epidural or paravertebral analgesia (similar to lobectomy) is used for open intrathoracic procedures.	
Emergence	Early extubation; presence of ETT and IPPV can disrupt fresh suture line. Remove ETT as soon as patient is awake enough to protect airway and breathing spontaneously but before bucking and coughing occur. The presence of a "guardian suture" (chest wall to chin) will make reintubation more difficult. Assess integrity of recurrent laryngeal nerve after high tracheal resections. Discuss with surgeon local wound infiltration or nerve block (e.g., intercostal block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose is given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 16–18 ga × 1 (left arm) BSS @ 3 mL/kg/h	✓ innominate artery compression, which will ↓ right-arm perfusion. See Goal Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors ± Arterial line	Left radial artery cannulation permits uninterrupted monitoring of BP during periods of innominate artery compression. Placement of iv in the left arm allows unimpeded infusion. Right-extremity pulse oximetry will help detect innominate artery occlusion (which otherwise could lead to stroke).
Positioning	✓ and pad pressure points	

	✓ eyes	
Airway management	ETT replaced with sterile ETT and circuit intraop	After the trachea is divided, the surgeon places a sterile ETT in the distal trachea. The original ETT is withdrawn above the surgical site. The surgeon attaches a sterile anesthesia circuit to distal ETT for ventilation. Then, the surgeon places a suture through the distal tip of the original ETT. Before reanastomosis of the trachea, the distal trachea is suctioned to remove accumulated blood and secretions. After a posterior suture line is completed, the original ETT is pulled through the trachea, and the distal tube (which is below the resection) is removed. Reattach and ventilate patient through original ETT.
Complications	Tracheal edema	Corticosteroids (dexamethasone 6–8 mg iv) to ↓ tracheal edema.
	Injury to the neck	Any structure in the neck can be damaged, including superior and recurrent laryngeal nerves, the trachea, and the thoracic duct.

POSTOPERATIVE

Complications	Tracheal disruption	Neck swelling, subcutaneous

	Recurrent laryngeal nerve injury	emphysema, and inability to ventilate indicate loss of airtight anastomosis. Immediate reexploration of the neck is essential. May be fatal. Bilateral (occasionally unilateral) laryngeal nerve damage may → airway obstruction, necessitating reintubation. Mask ventilation may be ineffective.
Position	Airway edema Keep the head flexed to reduce tension on tracheal suture line	Place patient in head-up, neck-flexed position. Treat with nebulized racemic epinephrine if airway compromise occurs. If reintubation is required, a small ETT should be placed under direct vision or fiberoptic guidance, to avoid disruption of the anastomosis.
Multimodal pain management	Acetaminophen, NSAIDs, opioids	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with peripheral local anesthetics (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Ashiku SK, Mathisen DJ: Idiopathic laryngotracheal stenosis.Chest Surg Clin North Am 2003; 13(2):257–69.
2. Auchincloss HG, Wright CD: Complications after tracheal resection and

reconstruction: prevention and treatment. J Thorac Dis 2016; 8(Suppl 2):S160–7.
3. Gaissert HA, Grillo HC, Shadmehr MB, et al: Long-term survival after resection c primary adenoid cystic and squamous cell carcinoma of the trachea and carina. Ann Thorac Surg 2004; 78(6):1889–96, discussion 1896–7.
4. Hobai IA, Chhangani SV, Alfille PH: Anesthesia for tracheal resection and reconstruction. Anesthesiol Clin 2012; 30(4):709–30.
5. McRae K: Anesthesia for airway surgery. Anesthesiol Clin North Am 2001; 19(3):497–541.

TRACHEOBRONCHOPLASTY

SURGICAL CONSIDERATIONS (ALSO SEE SURGEON'S PERSPECTIVE ABOVE)

Description

Posterior splinting tracheobronchoplasty is performed for tracheobronchomalacia, when the airway collapses on exhalation. Patients often present with shortness of breath, cough, and recurrent respiratory infections; many have undergone Y-stent trials to determine whether their symptoms improved with airway stabilization. The operation is performed through a **right posterolateral thoracotomy**. The posterior distal trachea, bilateral mainstem bronchi, and bronchus intermedius are exposed. A Y-shaped mesh is sewn onto the membranous wall using many rows of sutures, placating and stabilizing it. Left lung ventilation is used during the operation; often a wire-reinforced SLT in the left mainstem bronchus is used so that the trachea is not distorted. When the mesh is sewn onto the left mainstem bronchus, intermittent ETT cuff deflation and apnea are used, so the cuff is not punctured. Flexible bronchoscopy is performed at the end of the procedure, withdrawing the ETT into the proximal trachea.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, need for a chest tube, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES	
Position	Left lateral decubitus
Incision	Right posterolateral thoracotomy

Special instrumentation	Mesh
Antibiotics	Cefazolin 2 g iv
Surgical time	4–6 h
EBL	<500 mL
Postop care	ICU
Mortality	Minimal
Morbidity	Respiratory complications are common
Pain score	5–7

PATIENT POPULATION CHARACTERISTICS	
Age range	Older adults
Male:Female	3:1
Incidence	Not uncommon
Etiology	Unknown
Associated conditions	Smoking history, asthma, bronchitis, emphysema, GERD

ANESTHETIC CONSIDERATIONS

Tracheobronchoplasty is a procedure performed for tracheobronchomalacia (cartilaginous or membranous) that typically obstructs more than 80% of the lumen on dynamic CT. Prior to the procedure, a trial period with a Y-stent is often used to predict if the surgery may be beneficial. The procedure is done through a high right thoracotomy and is therefore similar to a tracheal resection although the airway is not usually entered. The inverted Y-shaped membranous tracheobronchial wall is plicated with a mesh or biologic membrane with sutures that do not pierce the entire thickness of the wall; however, the risk exists and puncture of the cuff is possible.

PREOPERATIVE

The preop considerations for tracheobronchoplasty are similar to those for tracheal resection.

Respiratory	H&P complemented by lab and imaging studies to focus on the underlying disease, evaluating for pulmonary problems. Constant coughing, inability to raise secretions, and recurrent respiratory infection are typical. Often there is a history of smoking, bronchitis, emphysema, asthma, and GERD. **Tests:** Consider PFTs, inspiratory-expiratory CT (dynamic CT), and awake functional bronchoscopy to assess the degree of luminal obstruction. When respiratory distress is present at rest or when exercise tolerance is poor, an ABG may be indicated to assess increased pulmonary risk (PaO_2 < 70 and PCO_2 > 45).
Cardiovascular	Many patients with tracheobronchomalacia may have concomitant cardiac disease, which may need cardiac consultation to optimize cardiovascular status. **Tests:** ECG and stress echo may be indicated.
Hematologic	Adequacy of oxygen-carrying capacity (Hb/Hct) is important to ascertain. A type and screen if the starting hematocrit is low. **Test:** Hct
Laboratory	Hb/Hct for oxygen-carrying capacity and BMP to ascertain that the K^+ and creatinine levels are in the normal range for safe use of muscle relaxants.
Premedication	Antisialagogue (e.g., glycopyrrolate 0.2 mg iv) to decrease secretions and mild sedation with midazolam (0.5–2 mg iv) along with a small dose of fentanyl (25–50 mcg) may be needed. Avoid respiratory depression and oversedation.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of epidural or paravertebral nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80

	mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA combined with thoracic epidural opioids (T5 or T6) since the procedure involves a high thoracotomy.

Induction	Following preoxygenation, a standard induction using propofol (1–2 mg/kg) or etomidate (0.3 mg/kg). A depolarizing relaxant (succinylcholine 1 mg/kg iv) or a short-acting nondepolarizing relaxant (e.g., rocuronium 0.3–0.6 mg/kg iv) can be used. A small dose of fentanyl (1–2 mcg/kg iv) or remifentanil (0.25–1 mcg/kg iv) can be used to facilitate intubation.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Intubation	Intubation is performed using either (a) a long wire-reinforced endobronchial tube (WRETT) placed over a fiberoptic scope so the end of the tube lies just above the secondary carina of the left main bronchus or (b) a left-sided 37F or 39F DLT, which has the tracheal component shaved off by the surgeon resulting in a long endobronchial tube, which is again placed with a FOB to lie just above the secondary carina.
Maintenance	Isoflurane or sevoflurane in oxygen (FiO_2 = 1); VT, 4–6 mL/kg; PEEP, 5–10 cm. Only the left lung is ventilated during the surgery. When the procedure involves the posterior wall of the trachea and right main bronchus, the cuff of the endobronchial tube is inflated. During surgery on the left main bronchus, the cuff is intermittently deflated (with intermittent

	left lung ventilation). At the end of the procedure, a FOB is used to assess the result of the surgery.	
Emergence	Muscle relaxant is reversed and extubation is accomplished with patient sitting up. To ICU for the first 24 h. Discuss with surgeon local wound infiltration or nerve block (e.g., intercostal block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose is given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 18 ga × 1 + 16 or 14 ga × 1 Limit BSS to and colloids	Blood should be available but is rarely needed. Vasopressors (e.g., phenylephrine, ephedrine) are used to maintain MAP. See Restrictive Fluid Management, Appendix K, p. K-4
Monitoring	Standard monitors + Arterial line Urinary catheter +/− CVP or PA line	Mandatory to follow oxygenation continuously during OLV, typically using pulse oximetry and intermittent ABGs
Positioning	Left lateral, axillary roll + airplane for the upper arm Avoid hyperextending the arm ✓ and pad pressure points ✓eyes, ears, and genitals	✓radial pulses to ensure correct placement of axillary roll. Placing the arterial line or the pulse oximeter on the down arm may assist in monitoring perfusion.
Complications	Hypoxia	Pulse oximetry monitored continuously. Interrupt the procedure to allow oxygenation to improve

		before proceeding if necessary.
	Hypercapnia	Ventilate to normalize the $ETCO_2$ before proceeding.
	Hemorrhage	Be prepared, but usually not a problem.

POSTOPERATIVE

Complications	Airway irritation	Airway irritation causing cough (Rx, lidocaine topical spray prior to or during the procedure) or bronchospasm (Rx, nebulized bronchodilators, e.g., racemic epinephrine or albuterol). Occasionally steroids may be necessary.
	Hypoxia	Humidified O_2 by mask.
	Hypoventilation	Avoided by adequate reversal of neuromuscular blockade and using minimal-dose short-acting opioids.
	Hemorrhage	Usually self-limiting.
Multimodal pain management	Epidural ± Opioids	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with peripheral local anesthetics (see Appendix K, p. K-6). Try limiting opioids to decrease respiratory depression and ineffective coughing.
Tests	CXR	A postop CXR is often performed to confirm the absence of pneumothorax or

ERAS	PONV protocol (see Appendix B, p. B-1)	mediastinal emphysema. Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Buitrago DH, Wilson JL, Parikh M, et al: Current concepts in severe adul tracheobronchomalacia: evaluation and treatment. J Thorac Dis 2017; 9(1):E57–66.
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EXCISION OF BLEBS OR BULLAE

SURGICAL CONSIDERATIONS (ALSO SEE SURGEON'S PERSPECTIVE ABOVE)

Description

Pulmonary blebs or bullae requiring surgical treatment may vary from small, apical blebs—most usually seen in young people with spontaneous pneumothorax—to expanding, giant bullae causing respiratory distress. Specific indications for bullectomy include large size (>30% of the lung), recurrent pneumothorax, dyspnea in conjunction with compressed adjacent parenchyma, and recurrent infection of the bullae. The small blebs can be excised through **VATS**, while giant bullae are generally removed by **thoracotomy**. In either case, the goal is to resect the nonfunctional bullae and allow the compressed yet relatively preserved lung tissue to reexpand and contribute to gas exchange. The surgical technique generally involves **stapling** across the base of the bulla with reinforcing strips being applied to the staple line to minimize air leak. Alternatively, a **clamp and suture** technique may be used. However, the most important point is that an airtight closure should be obtained as a prolonged air leak can be very debilitating. Patients undergoing operation for giant bullae frequently have limited pulmonary reserve and present formidable operative risks. Because the operation is

planned to improve their pulmonary function, however, these patients frequently do well following operation. **Pleural abrasion** or, rarely, **pleurectomy** may accompany the excision of blebs or bullae. The blebs in young patients with recurrent spontaneous pneumothorax usually are located at the apex of the upper lobe. Bullae in patients with emphysema are usually in the upper lobe but may be anywhere in the lung. Preop localization by CT scan is usually sufficient. The patient is usually in the lateral position.

Variant procedure or approaches

Patients with more generalized emphysema may be candidates for lung volume reduction surgery.

Usual preop diagnosis

Spontaneous pneumothorax 2° ruptured blebs; giant bullae causing respiratory distress

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, need for a chest tube, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

Position	Usually lateral
Incision	Thoracotomy or VATS
Special instrumentation	Staplers
Antibiotics	Cefazolin 2 g iv
Surgical time	1–3 h
EBL	<500 mL
Postop care	PACU → room; ICU or IIC for giant bullae
Mortality	Minimal
Morbidity	Air leak: 20% or more in giant bullae
Pain score	5–7

PATIENT POPULATION CHARACTERISTICS

Age range	Young adults (blebs/small bullae), elderly (large bullae)
Male:Female	3:1
Incidence	Not uncommon
Etiology	Emphysema (usually 2° smoking), congenital, infectious
Associated conditions	Spontaneous pneumothorax, emphysema, long smoking Hx, α-antitrypsin deficiency

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients with apical blebs tend to be young with normal lung function and otherwise healthy. Bleb resection in these patients tends to be a routine thoracoscopic wedge resection procedure. Patients with bullous emphysema, on the other hand, may have end-stage lung disease, often with pulmonary hypertension (HTN) and RV dysfunction. The risk of rupture of a bulla/bleb on the nonoperated side, with resultant tension pneumothorax, must be considered throughout the procedure. The majority of considerations and concerns therefore relate to the patient with bilateral disease. Most procedures are done thoracoscopically.

Respiratory	Cysts may be bronchogenic, postinfective, infantile, or emphysematous. With blebs, elicit Hx of repeat pneumothoraces. Bullae usually result from destruction of alveolar tissue; they represent end-stage emphysematous disease associated with severe COPD. Patients may have incapacitating dyspnea and limited pulmonary reserve. CO_2 retention ± hypoxia may be present. Obtain PFTs and ABG for baseline. **Tests:** CXR; presence of pneumothorax; if chest CT is available, look for bilateral bullous disease and rule out airway anomalies that could interfere with DLT placement; ABG, as indicated from H&P.
Cardiovascular	**Test:** ECG
Neurologic	✓ Hx for previous back surgery and peripheral

	neuropathy. Examine thoracolumbar area for skin lesions, infection, and deformities.
Hematologic	Transfuse patient with preop Hct < 25% (Hct < 30% if patient has CAD). Crossmatch 2 U of blood or obtain 1–2 U of autologous blood during the month before surgery, or consider erythropoietin therapy in patients who are anemic. **Test:** Hct
Laboratory	Other tests as indicated from H&P.
Premedication	Midazolam 1–2 mg iv if patient is anxious and not in respiratory distress. Minimize sedation if planning epidural placement, as the combination of parenteral sedation and epidural opioid, may result in significant respiratory depression.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of epidural or paravertebral nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA—combined with regional technique if open thoracotomy.

Induction	**Minor bleb:** standard induction **Major bullae (particularly bilateral):** main issue is risk of pulmonary tamponade/tension pneumothorax secondary to bulla expansion by PPV. Best to establish lung isolation prior to instituting PPV (DLT essential in bilateral disease, to allow for ventilation/exclusion of either side; BB sufficient for unilateral disease). Strategies include an awake intubation (difficult with DLT), a spontaneous

	ventilation induction (inhalational or iv), or, in patients with easy airway anatomy, a true rapid-sequence intubation. Lung isolation should immediately be confirmed with FOB prior to providing PPV. Rapid placement of a chest tube is essential should a bulla rupture.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.	
Maintenance	Patients with severe COPD may have significant auto-PEEP. To avoid worsening dynamic hyperinflation of the lung, treat bronchospasm aggressively and allow adequate expiratory time (↓ I/E ratio, low RR). Caution with applied PEEP: it may increase total PEEP (and therefore air trapping). Minimize risk of bulla rupture by reducing ventilatory pressures (low tidal volumes, permissive hypercapnia, and pressure-controlled ventilation @ <20 cm H_2O). Inhalational anesthesia supplemented with epidural and local anesthetics or iv opioids. Avoid N_2O at all times because bullae may be filled with air.	
Emergence	Reexpand the lung under direct vision to check for major air leaks. Extubate patient early. In postbullectomy, unlike other lung resections, patients have greater functional lung tissue than preop. Discuss with surgeon local wound infiltration or nerve block (e.g., intercostal block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose is given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 16 ga × 1 BSS @ 1–2 mL/kg/h Use vasopressors if hypotensive	Excess fluid predisposes to right heart failure. Epidural local anesthetics can ↓ BP in a volume-restricted patient;

		vasopressor is often needed (e.g., ephedrine 5–10 mg iv bolus or phenylephrine 50–100 mcg iv bolus). See Restrictive Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors Arterial line ± CVP, or PA line, ± TEE	For patients with coexisting severe cardiac disease
Positioning	✓ and pad pressure points ✓ eyes, ears, and genitals Axillary roll, "airplane" for the upper arm	See Positioning.
Ventilation	DLT or BB needed to separate the lungs	Allows PPV of the nonoperative lung. Use gentle PPV (pressure control) with low Vt and permissive hypercapnia ($PaCO_2$ 50–70 mm Hg). Inspiratory pressure should be as low as possible (~10 cm H_2O), to reduce likelihood of rupture of bullae in nonoperative lung. Treat intraop hypoxemia with CPAP to "up" lung. In extreme cases, consider CPB (rare).
Complications	Tension pneumothorax Bronchopleural cutaneous fistula Hypoxia Hypercarbia Dysrhythmias	Can occur on either side during induction, only on nonoperated side after the chest is open, and again on either side postop. Presents with ↑ ventilatory pressure, progressive tracheal

		deviation, wheezing, and cardiovascular collapse. CXR to r/o tension pneumothorax. Rx: insertion of chest tube. Placement of a chest tube can create a bronchopleural cutaneous fistula. Rx: low Vt, spontaneous ventilation; may require DLT for differential ventilation. ✓ position of DLT, suction DLT, and avoid hypoventilation.

POSTOPERATIVE

Complications	Hypoventilation Dental damage Airway trauma Pneumothorax Hemorrhage Risk of aspiration Airway obstruction (bronchospasm, bleeding, dislodged tumor, FB)	Ensure complete reversal of muscle relaxants and patient is wide awake with good respiratory effort prior to extubation. Obtain ABG if patient has difficulty breathing or is overly sedated. If nerve blocks are used to depress gag reflex for awake FOI, keep patient NPO for several hours postop.
Multimodal pain management	Regional analgesia Epidural opioids Parenteral opioids	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with peripheral local anesthetics (see Appendix K, p. K-6). Parenteral opioids + intrapleural local anesthetics (0.5% bupivacaine + 1:200,000 epinephrine, 0.5

		mL/kg) + single-shot paravertebral blocks are adequate for thoracoscopy.
Tests	CXR	ABG if indicated.
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

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LUNG VOLUME REDUCTION SURGERY

SURGICAL CONSIDERATIONS (ALSO SEE SURGEON'S PERSPECTIVE ABOVE)

Description

Lung volume reduction surgery was initially described by Brantigan in 1958 but reintroduced by Joel Cooper in 1995 for the treatment of severe emphysema. Typically, patients referred for LVRS are chronically ill, requiring steroids, bronchodilators, and supplemental oxygen. With appropriate preop selection and perioperative care, these patients survive surgery and demonstrate improved pulmonary function. Physiologically, reducing the volume of the lung by resecting diseased tissue improves elastic recoil and decreases airway resistance. The chest cavity also is reduced in size, thereby improving chest wall and diaphragmatic function.

The procedure can be carried out either through a median sternotomy or minimally

invasively. The **open approach** begins with a median sternotomy. OLV is initiated following opening of the pleurae. Often the diseased portions of the lung remain inflated, whereas healthy areas develop absorption atelectasis. These diseased portions are resected with the aid of a linear stapler. The visceral pleura is very thin; the stapling is done with bovine pericardium to bolster the staple line; and high inspiratory pressures (>20 cm H_2O) must be avoided. From 15% to 30% of the lung volume may be removed. Following careful examination for air leaks, the pleurae and chest wall are closed.

The **minimally invasive approach** is carried out using standard VATS techniques and instrumentation. Diseased tissue will have been identified preop using V/Q and CT scans. VATS forceps are used to guide this diseased tissue into the jaws of the stapler. Again, 15–30% of lung tissue may be removed by this means. At some centers, the anesthesiologist may be asked to measure inspiratory and expiratory volumes. Any difference between these volumes may represent an air leak requiring further exploration. Following this, access ports and the thoracotomy are closed, and chest tubes are placed. The patient is turned over to the opposite side, reprepped, and redraped, and the surgery is repeated. With either approach, patients should be extubated in the OR so that no unnecessary ventilatory pressures are put on the lungs. A functional epidural catheter and early extubation are important to the success of this procedure, especially in the very ill patient. Pleural drainage consists of one or two chest tubes per side; in contrast with lobectomy, they are left to water seal so as not to exert excessive negative pressure on the lung and disrupt the staple lines. A small pneumothorax is acceptable if the patient is not in respiratory distress. Ideally, patients are extubated at the conclusion of the operation. Their respiratory status is often tenuous, so close monitoring, vigorous pulmonary toilet, and good pain control are essential in the postop period.

Bronchoscopic LVRS often involves the endoscopic placement of one-way endobronchial valves that allow air to escape from selected lung segments. This will induce volume reduction through lobar atelectasis but only in areas devoid of collateral ventilation (assessed by CT imaging). Other bronchoscopic techniques include intrabronchial valves (conscious sedation for placement) or coil insertion (requiring GA). Coils appear to function by restoring the elastic recoil in small airways, thereby preventing early airway collapse during expiration (Table 5.3).

Usual preop diagnosis

COPD (emphysema)

ERAS: **Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, need for a chest tube, and physiotherapy plan.** **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Open LVRS	VATS LVRS
Position	Supine	Lateral decubitus
Incision	Median sternotomy	Three small incisions
Special instrumentation	Stapling devices, DLT	⇐+ Endoscopic instrumentation
Unique considerations	Bovine pericardium to bolster staple line	⇐
Antibiotics	Cefazolin 2 g iv	⇐
Surgical time	2 h	1 h per side
Closing considerations	Avoid high PIPs (>20 cm H_2O)	⇐
EBL	Minimal	⇐
Postop care	Extubated in OR; avoid chest tube suction	⇐
Mortality	≤5–10%	⇐
Morbidity	Pneumothorax Infection Tearing of suture line Wound healing problems	⇐ ⇐ ⇐ ⇐
Pain score	6–8	4–6

PATIENT POPULATION CHARACTERISTICS

Age range	>50 yr

Male:Female	Male > female
Incidence	Although the incidence of emphysema is high in the general population, only a fraction of these patients will be candidates for LVRS
Etiology	Smoking, genetic factors
Associated conditions	CAD; pulmonary HTN; PVD; cerebrovascular disease

Table 5.3 Suggested Selection Criteria for LVRS

Medical history	Severe COPD (emphysema rather than chronic bronchitis) Age < 75 yr No cigarette smoking for 6 mo Lowest effective prednisone dose No previous chest surgery
Pulmonary function	FEV_1 > 30–35% of predicted $PaCO_2$ < 50 mm Hg TLC > 100% of predicted (hyperinflation)
Cardiac function	Mean PAP < 35 mm Hg (if pulmonary HTN is suspected) No evidence of LV dysfunction on dobutamine stress testing (if Hx of angina or CHF is present)
Radiographic	Hyperinflation, flattened diaphragm (CXR) Decreased upper lobe perfusion (ventilation-perfusion scan) Emphysema, with upper lobe predominance (CT scan)
Relative exclusion criteria	Continued smoking Illness other than emphysema that may cause severe dyspnea (e.g., CAD, CHF, cancer, interstitial lung disease, bronchiectasis) Severe malnutrition Obliteration of pleural space (e.g., pleurodesis or pleurectomy) Previous thoracic surgery Morbid obesity Severe pulmonary HTN (mean PAP > 35) Chest wall deformity with restrictive lung disease (e.g.,

	kyphoscoliosis, severe pectus deformity, $PaCO_2$ > 55 mm Hg)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

LVRS involves either laser thermal contraction or surgical resection of emphysematous lung tissue. Patients have end-stage emphysema with associated pulmonary HTN anc RV dysfunction. These patients are a great challenge to the anesthesiologist because it may be difficult to maintain relatively normal physiologic parameters intraop and to have an awake, comfortable, and spontaneously breathing patient at the completion of surgery. Carefully selected patients may undergo endoscopic lung volume reduction with placement of valves (usually requiring only sedation) or coils (usually requiring GA).

Respiratory	These patients have advanced pulmonary emphysema. Examine patient for cyanosis, clubbing, RR, and pattern. Listen to the chest—breath sounds are often very distant or absent. Hx should include the use of O_2 supplementation, recent infection, severe bronchospasm, prior surgery on the chest, and other associated diseases, such as CAD or CHF. **Test:** PFT (± bronchodilators). Hyperinflation usually is indicated by TLC and RV value >120%; V/Q scan; CXR; chest CT scan; noninvasive exercise test (6-min walk); preop ABG—check for hypoxemia and hypercarbia.
Cardiovascular	These patients often have coexisting cardiac disease with pulmonary HTN. **Tests:** Right heart function can be determined by echocardiography or selective right heart catheterization, if indicated by H&P.
Premedication	Avoid premedication with sedative or opioids—cannot have respiratory depressants—patients have severe COPD and often are CO_2 retainers.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status.

	Discuss with surgeon the possibility of epidural or paravertebral nerve blocks for postop pain management in open surgery. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA (with DLT or BB) ± epidural anesthesia. Place and test epidural catheter before surgery. (See Lobectomy, Pneumonectomy.)

Induction	Standard induction. DLT or BB is absolutely necessary during surgery to selectively ventilate each lung. DLT preferable for patients with severe bilateral disease with increased risk of pneumothorax (see Lobectomy, Pneumonectomy).
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks for open surgery.
Maintenance	Inhalational agent and/or propofol. IV opioids and sedative agents should not be used (exception, remifentanil infusion intraop). Anesthesia may be supplemented by continuous or bolus administration of epidural anesthetics. Mechanical ventilation with O_2 and inhalation agent only. During TLV: Vt = 6–10 mL/kg, limit PIP to <25 cm H_2O (best to use PCV). Respiratory rate and inspiratory flow should be adjusted to minimize air trapping (low RR, long E-time). Beware of overinflation and "breath stacking," which can → pulmonary tamponade with severe ↓ BP and ↑ airway resistance. ABG to determine $ETCO_2$-$PaCO_2$ gradient. During OLV, use PCV for Vt = 4–8 mL/kg, long E-time, RR 6–10, and permissive hypercapnia ($PaCO_2$: 50–70 mm Hg); monitor lung

	compliance closely because the ventilated lung also has emphysema/bullous disease. Avoid overdistension with hyperinflation (→ pneumothorax) on ventilated, nonoperated lung. Patients with severe COPD may have significant auto-PEEP. To avoid dynamic hyperinflation of the lung, treat bronchospasm aggressively, allow adequate expiratory time (↓ I:E ratio), limit PIP to 15–20 cm H_2O, and cautiously use applied PEEP, as it may increase total PEEP (best managed with in-line spirometry). Moderate hypercapnia is well tolerated, but higher levels may result in significant pulmonary HTN, RV dysfunction, and tachydysrhythmias. CPAP to nonventilated lung may be necessary to maintain oxygenation. Maintenance of hemodynamic stability may require pressor support (e.g., ephedrine, phenylephrine, dopamine). Dynamic hyperinflation of the lung (pulmonary tamponade) during mechanical ventilation should be suspected if ↓ BP with ↑ PIP occurs.
Emergence	Emergence is a critical time for these patients. All physiologic parameters need to be optimized. Air leaks are common and may be worsened by prolonged mechanical ventilation, coughing, or straining on the ETT. Different options are available to achieve those goals, including deep extubation or deep conversion to spontaneous pressure support ventilation. Either way, ventilation has to be assisted until patients are wide awake, comfortable, warm, and maintaining adequate respiration with minimal support. These patients are critically dependent on good analgesia, upright/sitting position, and suctioning to ↓ mucous plugging (can be catastrophic). Recovery from GA occurs in the OR and may take 1–2 h. Ventilatory assistance via face mask with supplemental O_2 is usually necessary. ABG and CXR may be useful. When spontaneous ventilation and analgesia are satisfactory, the patient is

	transported to ICU. If postop mechanical ventilation is required, consider using pressure support ventilation with low levels of CPAP. The CPAP may help minimize the inspiratory work of breathing caused by lung hyperinflation. The pressure support mode of ventilation will permit control of airway pressure, while allowing patient control of $PaCO_2$. If postop intubation is anticipated, changing from DLT to ETT is required. Discuss with surgeon local wound infiltration or nerve block (e.g., intercostal block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose is given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 14–16 ga × 1 BSS @ 1–2 mL/kg/h Autologous PRBC	Fluid management to restore preop deficit and provide maintenance fluid but restrict fluids similar to lung resection surgery. Replace minor blood loss with colloid. Transfuse autologous blood for Hct < 30. See Restrictive Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors Arterial line Urinary catheter CVP and/or PA line	See Lobectomy, Pneumonectomy ✓ ABGs: baseline (preop) during sternotomy, 15 min after initiation of OLV, 15 min after initiation of OLV on the second lung, during closure of sternotomy, prior to extubation Useful for postop fluid management Depending on the level of PHTN, RV dysfunction, and

		comorbid CAD
Positioning	✓ and pad pressure points ✓ eyes, ears, and genitals	Axillary roll and support for upper airway are necessary for the lateral decubitus position (see Lobectomy, Pneumonectomy)

POSTOPERATIVE

Complications	Hypercarbia Hypoxemia Air leak/pneumothorax Hemorrhage	
Multimodal pain management	Lumbar or thoracic epidural opioids ± Local anesthetics	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with peripheral local anesthetics (see Appendix K, p. K-6). Essential that patient be comfortable. Begin infusion of epidural opioids and local anesthetics (see Lobectomy, Pneumonectomy). Breakthrough pain treatment options include iv hydromorphone (cautious boluses of 0.2–0.5 mg) and/or ketorolac (30 mg).
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

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BRONCHOPULMONARY LAVAGE

SURGICAL CONSIDERATIONS

Description

Whole-lung bronchopulmonary lavage is occasionally required for patients with pulmonary alveolar proteinosis—a condition characterized by excessive (or abnormal) surfactant production with resultant flooding of the lungs with proteinaceous fluid. Although the underlying cause of the condition is unclear, treatment consists of periodic whole-lung lavage and, more recently, GM-CSF administration. It is our practice to perform **unilateral lavage** only, although single-session, bilateral lavage has been reported. After induction of GA, a DLT is placed, and the correct position is confirmed bronchoscopically. The lung is then lavaged in aliquots of 500–1000 mL normal saline to dilute and wash out excess alveolar surfactant, pus, or mucus and to obtain material for cytologic and histochemical examination. Care should be taken not to overdistend the lung, and a running tally of fluid instilled and withdrawn should be performed to avoid overhydrating the patient. Frequently, 9–12 L of fluid is used, with the initial effluent being very cloudy and the final effluent being clear. Techniques that may improve the distribution of the lavage fluid include external chest percussion and tilting the operating table (laterally as well as in the craniocaudal directions).

Usual preop diagnosis

Pulmonary alveolar proteinosis; refractory asthma; cystic fibrosis; bronchiectasis; lipoid pneumonitis; silicosis; alveolar microlithiasis; inhalation of radioactive dust

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES	
Position	Supine or lateral decubitus
Special instrumentation	Bronchoscope, DLT, lavage fluids
Antibiotics	None
Surgical time	45 min/side
EBL	None
Postop care	PACU → home
Mortality	Rare
Morbidity	Aspiration of lavage fluid Pneumothorax/hydrothorax Atelectasis
Pain score	1–2

PATIENT POPULATION CHARACTERISTICS	
Age range	17–35 yr
Male:Female	1:1
Incidence	Uncommon
Etiology	Pulmonary alveolar proteinosis, cystic fibrosis, bronchiectasis, lipoid pneumonitis, silicosis
Associated conditions	Asthma and other abnormalities of lung function

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Although whole-lung lavage is primarily a treatment for pulmonary alveolar proteinosis, it is also used as a therapeutic modality for many other lung-related conditions (see Usual preop diagnosis, above). Respiratory dysfunction of variable symptomatology is expected in these patients. Indications for whole-lung lavage include dyspnea on exertion, resting room air PaO_2 < 60 mm Hg, and shunt fraction >10–12%. Because the

procedure requires GA with OLV, it is recommended that preop V/Q scans be obtained so that unilateral lung irrigation can be performed first on the more severely affected lung. If both lungs are equally diseased, lavage should be performed on the left lung initially to allow the larger right lung to be used for ventilation to provide better gas exchange. Patients then return in subsequent days or weeks for therapeutic lavage of the contralateral lung. A nonoperative treatment option for pulmonary alveolar proteinosis using granulocyte-macrophage colony-stimulating factor (GM-CSF) has shown promise for some patients with the acquired form of pulmonary alveolar proteinosis.

Respiratory	Patients with pulmonary alveolar proteinosis generally present with cough (nonproductive > productive), dyspnea, and fatigue. Physical findings consist of diffuse rales ± clubbing or cyanosis. CXR typically reveals diffuse bilateral patchy airspace consolidation. Pulmonary compliance is reduced 2° the restrictive disease pattern. PFTs show ↓ TLC, ↓ RV, ↓ VC, and ↓ D_LCO. Though nonspecific, baseline ABGs classically demonstrate respiratory alkalosis and hypoxemia, with a calculated elevation in A-a DO_2 gradient. Some patients may be O_2-dependent or have concomitant COPD 2° Hx of smoking. Secondary infections, especially in the respiratory tract, are well-recognized risks in these patients. Cessation of smoking (>6–8 wk) and prompt treatment of any underlying infections before whole-lung lavage may be prudent. **Tests:** CXR; PFT; ABG; V/Q scans; ± CT
Cardiovascular	Directed at any underlying disease process.
Laboratory	Abnormal elevation of serum LDH has been reported in some patients and has been shown to correlate with the severity of A-a DO_2. **Tests:** LDH; other tests as indicated from H&P
Premedication	Standard premedication. Avoid heavy sedation that might impair adequate gas exchange before induction. O_2 supplementation may be required after premedication.
ERAS	Check compliance with presurgical ERAS

	recommendations (see above) including NPO status.

INTRAOPERATIVE

Anesthetic technique

GETA is required with OLV using a DLT. In pediatric patients or small adults where appropriate-sized DLT is not available and in patients who cannot tolerate OLV, the use of partial venoarterial CPB, venovenous bypass, or even ECMO has been reported. In some cases, sequential lobar lavage with smaller volume of lavage fluid has been achieved under conscious sedation for those patients in whom OLV is not possible.

Induction	Standard induction with thorough preoxygenation (FeO_2 > 90%). The largest DLT should be used to facilitate infusion and drainage of the lavage fluid. (Placement of DLT is discussed on p. 320.) Due to the underlying impaired respiratory function in these patients, instituting OLV will further compromise gas exchange. It is imperative to avoid spillage of lavage fluid into the ventilated lung during the procedure. This is achieved by verifying the correct position of the DLT with FOB and confirming the competency of the cuff seal by testing it against pressures as high as 50 cm H_2O. Baseline individual lung compliance, airway pressures, and ABG should be ✓'d after DLT placement.
ERAS	Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	100% FiO_2 with inhalational agent (e.g., sevoflurane) or TIVA using propofol and remifentanil infusions. Muscle relaxation is necessary to avoid movement or coughing that can cause leakage of lavage fluid into the ventilated lung. Because chest physiotherapy, including vibration and percussion, is required after each cycle of lavage filling, any deleterious change from baseline lung compliance decrease or airway pressure increase of the ventilated lung should prompt the anesthesiologist to look for evidence of

	spillage. Filling the nonventilated lung with lavage fluid can → ↓ pulmonary shunting (→ improved O_2 sat) and ↑ PVR (→ ↓ CO). Draining the lavage fluid can → ↑ pulmonary shunting (→ ↓ O_2 sat) and ↓ PVR (→ ↑ CO). Accurate inflow and outflow volume of the lavage fluid should be recorded to ensure return volumes are 90%.	
Emergence	At the conclusion of surgery, the lavaged lung should be adequately suctioned to remove any residual fluid. Bilateral lung ventilation should be reinstituted. Because the compliance of the lavaged lung is greatly reduced, higher airway pressures are required to reexpand it, but at the risk of causing barotrauma to the nonlavaged lung. A brief period of OLV to the lavaged lung, using large TVs or ↑ airway pressure, may be necessary to recruit the collapsed alveoli (higher pressure, including PEEP, is needed to counter the increase in surface tension after the removal of significant amounts of surfactant). The patient's trachea should be extubated after adequate reversal of muscle relaxation; however, if prolonged postop ventilation is anticipated (e.g., in those who aspirated lavaged fluid to the ventilated lung), changing the DLT to single-lumen tube is indicated. DLT should be maintained for patients in whom differential lung ventilation is required postop.	
Blood and fluid requirements	IV: 18 ga × 1 BSS @ 1–2 mL/kg/h	See Restricted Fluid Management, Appendix K, p. K-4
Monitoring	Standard monitors Arterial line ± CVP line ± PA line	Although warmed lavage fluid is used, some patients may become hypothermic after several hours of lavage under GETA. CVP or PA line is only needed as indicated by comorbid

		conditions. Consider fluoroscopic or TEE-guided positioning of a PA catheter to the lavaged lung. In doing so, the therapeutic potential of the catheter may be realized. Selective occlusion of pulmonary arterial blood flow can improve matching of blood flow to ventilation.
Positioning	Supine ✓ and pad pressure points ✓ eyes	Some prefer the lavaged lung to be dependent to minimize the risk of contaminating the contralateral lung with lavage fluid. Others prefer the lavaged lung to be nondependent because, in this position, perfusion will more closely match ventilation in the dependent lung. As a compromise, we perform lavage with the patient supine. However, intermittent manipulation of the patient position may be required to facilitate the lavage and drainage of any retained fluid. Prevention of DLT displacement during repositioning is paramount.
Complications	Hypoxemia	Hypoxemia during OLV is most commonly 2° luminal obstruction (by blood or pulmonary secretions) of the DLT, worsening of shunting, or malposition of DLT. Rx: suction the DLT; use PEEP to ventilated lung (may ↑

		shunting); return to two-lung ventilation; and ✓ DLT position. In extreme cases, temporarily inflating the balloon of the PA catheter (if available) may be necessary to improve shunting and, thus, oxygenation. Inadequate positioning of the DLT demands stopping further instillation of fluid. Most authors recommend suspending the lavage fluid 30 cm above the midaxillary line. Instilling fluid from excessive height or under pressure may precipitate pulmonary edema.
	Hypercarbia	Ensure adequate TV and RR.
	Aspiration	✓ DLT position. Turn patient to lavaged side down and head down, suction the ventilated lung, and reinstitute bilateral lung ventilation with PEEP, after the lavaged lung is thoroughly drained and suctioned. Termination of procedure may be needed in severe cases. Patient may need to be kept intubated after the procedure.

POSTOPERATIVE

Complications	Pneumothorax Hydrothorax Atelectasis	Obtain CXR; conservative measures if small pneumothorax or

		hydrothorax. Otherwise, chest tube placement will be required. Decrease in surfactant after lavage will → airspace collapse. Most patients will experience moderate coughing, which will help reexpand the atelectatic lung units.
Multimodal pain management	Acetaminophen or NSAID (ketorolac 30 mg iv)	Some patients may experience chest pain due to vigorous intraop percussion. Emphasize multimodal approach combining nonopioid and bolus opioid analgesics (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Ben-Abraham R, Greenfeld A, Rozenman J, et al: Pulmonary alveolar proteinosis step-by-step perioperative care of the whole lung lavage procedure. Heart Lung 2002; 31(1):43–9.
2. Cohen E, Eisenkraft JB: Bronchopulmonary lavage: effects on oxygenation and hemodynamics. J Cardiothorac Anesth 1990; 4(5):609–15.
3. Tan Z, Tan KT, Poopalalingam R: Anesthetic management for whole lung lavage in patients with pulmonary alveolar proteinosis. A A Case Rep 2016; 6(8):234–7.

ENDOBRONCHIAL ULTRASOUND-GUIDED TRANSBRONCHIAL NEEDLE ASPIRATION

SURGICAL CONSIDERATIONS

Vivek Kulkarni, MD

Description

Endobronchial ultrasound-guided transbronchial needle aspiration (EBUS-TBNA) ha been introduced as a less-invasive alternative to mediastinoscopy for pathologically staging the mediastinal lymph nodes. The procedure is performed by both pulmonologists and thoracic surgeons. This technique has become widely adopted and will likely play an increasingly important role in cancer staging.

The EBUS bronchoscope (Olympus America Inc., Center Valley, PA) contains a curvilinear ultrasound probe, at the distal end of the bronchoscope, which provides a linear continuous B-mode ultrasound image and color Doppler capability to allow identification of vascular structures. There are a 30° fiberoptic lens and biopsy channel through which a 22-gauge biopsy needle (NA-202C Olympus) can be deployed. A latex balloon can be placed over the ultrasound probe and inflated with saline to provide a fluid interface between airway and probe that improves ultrasonic image transmitted. EBUS-TBNA can be performed under GA or monitored anesthesia care (MAC). The use of a laryngeal mask airway (LMA) or iGEL permits evaluation of the upper paratracheal lymph nodes that may not be accessible when a standard ETT is placed. The mediastinal lymph node stations (see Fig. 5.11) that are accessible by EBUS-TBNA include 2R, 2L, 4R, 4L, 7, 10R, 10L, 11R, and 11L. With standard cervical mediastinoscopy, the 11R and 11L lymph node stations cannot be assessed for biopsy, although it is highly unusual that involvement at these stations would impact treatment decisions.

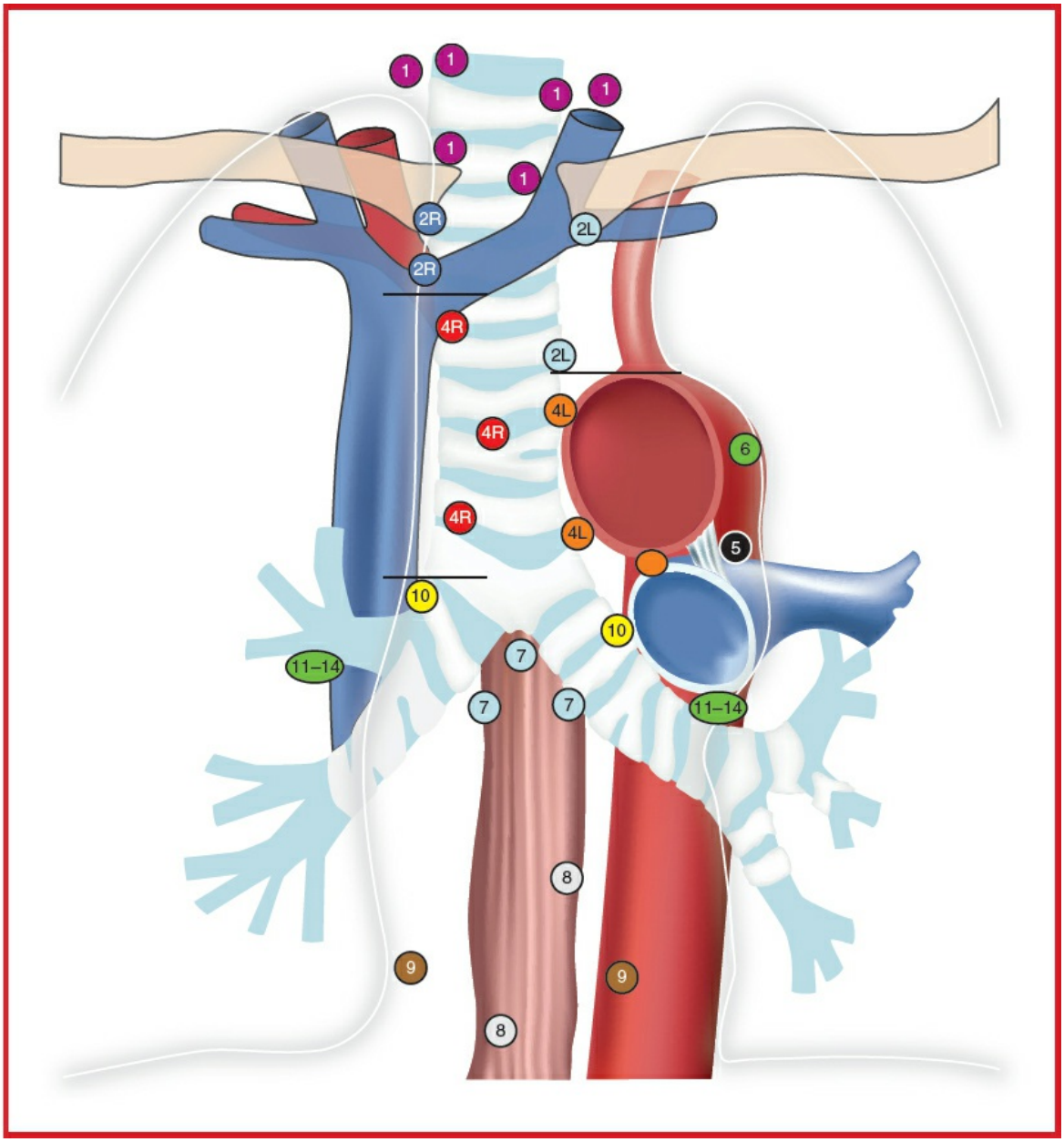

Figure 5.11 Regional lymph node stations for lung cancer staging.

At the beginning of the procedure, the EBUS bronchoscope is advanced into airway, and the ultrasound probe is used to scan the mediastinal lymph node stations of interest. Significant vascular structures, such as the pulmonary artery and aorta, appear hyperechoic and can be further identified with color Doppler. Once the lymph node is visualized, the 22-gauge biopsy needle is placed into the lymph node under direct ultrasound guidance. A suction syringe is applied to the biopsy needle, and the needle is passed into the lymph node for ~10 passes under ultrasound guidance. The aspirate is then placed on a slide with the assistance of a cytopathologist.

Rapid onsite examination by a cytopathologist in the OR is essential to confirm adequacy of diagnostic material, optimal specimen preparation, and preliminary

diagnosis. The observation of moderate to abundant numbers of lymphocytes or pigmented histiocytes may serve as an indicator of adequate sampling of lymph nodes that are free of metastatic carcinoma.

Usual preoperative diagnosis

Carcinoma of the lung; sarcoidosis; lymphoma

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES	
Position	Supine
Incision	None
Special instrumentation	Fiberoptic EBUS bronchoscope
Antibiotics	None
Surgical time	<1 h
EBL	Minimal
Postop care	PACU → home
Mortality	<0.1%
Morbidity	Pneumothorax: rare Airway bleeding: rare
Pain score	0–1

PATIENT POPULATION CHARACTERISTICS	
Age range	Adults
Male:Female	Male > female
Incidence	Frequently part of lung cancer evaluation
Etiology	Lung cancer, lymphoma, sarcoidosis
Associated conditions	Lymphadenopathy, mediastinal mass

Suggested Readings

1. Adams K, Shah L, Edmonds L, et al: Test performance of endobronchial ultrasound and transbronchial needle aspiration biopsy for mediastinal staging in patients with lung cancer: systematic review and meta-analysis. Thorax 2009; 64(9):757–62.
2. Alsharif M, Andrade RS, Groth SS, et al: Endobronchial ultrasound-guided transbronchial fine-needle aspiration. Am J Clin Pathol 2008; 130(3):434–43.
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5. Sarkiss M, Kennedy M, Riedel B, et al: Anesthesia technique for endobronchial ultrasound-guided fine needle aspiration of mediastinal lymph node. J Cardiothorac Vasc Anesth 2007; 21(6):892–6.
6. Vaidya PJ, Munavvar M, Leuppi JD, et al. Endobronchial ultrasound-guided transbronchial needle aspiration: safe as it sounds. Respirology 2017; 22(6):1093–101.

ANESTHETIC CONSIDERATIONS

EBUS-TBNA is a procedure performed for biopsy of mediastinal nodes or mass lesions. The procedure is therefore similar to a mediastinoscopy but is less invasive. Pulmonologists may perform the procedure under sedation and local anesthesia, whereas thoracic surgeons often perform the procedure under GA to ensure patient immobility, which may be safer when sampling nodes close to vascular structures. Occasionally the procedure may be unsuccessful requiring conversion to a mediastinoscopy.

PREOPERATIVE

The preop considerations for EBUS-TBNA are similar to those for bronchoscopy and mediastinoscopy. If the mediastinal mass to be biopsied is compressing the airway or a vascular structure, proceed with caution as described under excision of anterior mediastinal tumor.

Respiratory	H&P complemented by lab and radiologic studies to focus on the underlying disease, evaluating for pulmonary problems. Consider PFTs with flow-

	volume loops for lesions that may be compressing the airways. When respiratory distress is present at rest or when exercise tolerance is poor, an ABG may be indicated to assess increased pulmonary risk (PaO_2 < 70 and PCO_2 > 45).
Cardiovascular	Many patients with tumor may have concomitant cardiac disease, which may need cardiac consultation to optimize cardiovascular status. **Tests:** ECG and stress echo may be indicated.
Musculoskeletal	Patients with lung cancer may have myasthenic syndrome with sensitivity to nondepolarizing relaxants and resistance to depolarizing relaxants. Monitoring neuromuscular blockade during the procedure is essential.
Hematologic	Adequacy of oxygen-carrying capacity (Hb/Hct) is important to ascertain. A type and screen may be indicated when the node or mass to be biopsied is abutting a vascular structure (check with surgeon). **Test:** Hct
Laboratory	Hb/Hct for oxygen-carrying capacity and BMP to ascertain that the K^+ and creatinine levels are in the normal range for safe use of muscle relaxants.
Premedication	Antisialagogue (e.g., glycopyrrolate 0.2 mg iv) to decrease secretions and mild sedation with midazolam (0.5–2 mg iv) along with a small dose of fentanyl (25–50 mcg) may be needed. Avoid respiratory depression and oversedation.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status.

INTRAOPERATIVE

Anesthetic technique

IV sedation + topical anesthesia: if the procedure is to be done with sedation and topical anesthesia. Nerve blocks and topical anesthesia techniques are described under

bronchoscopy. General anesthesia is the common technique requested by thoracic surgeons. For higher nodes, an LMA or iGEL is preferred, while lower nodes can be accessed via an ETT.

Induction	Following preoxygenation, a standard induction using propofol (1–2 mg/kg) or etomidate (0.3 mg/kg). A depolarizing relaxant (succinylcholine 1 mg/kg iv) or a short-acting nondepolarizing relaxant (e.g., rocuronium 0.3–0.6 mg/kg iv) can be used. A small dose of fentanyl (1–2 mcg/kg iv) or remifentanil (0.25–1 mcg/kg iv) can be used to facilitate intubation. Antibiotic is often not needed because only needle punctures are made.
ERAS	Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Intubation	Higher nodes are often easier to access with an LMA or iGEL (size no. 3 or larger), whereas lower nodes can be adequately accessed through an endotracheal tube. The ETT needs to be large enough to enable manipulation of the bronchoscope without damaging the balloon that surrounds the ultrasound probe. An 8.5-mm ID for women and 9.0-mm ID for men facilitate the procedure. The LMA/iGEL or ETT is linked to the anesthesia circuit through an angled bronchoscopy adaptor. The seal on the adaptor is often slit to allow easier to-and-fro passage of the bronchoscope → significant leak.
Maintenance	Because of the significant leak at the adaptor, TIVA is a good choice for anesthetic maintenance. Because of the significant leak, ventilation is performed with higher fresh gas flows either manually to overcome the leak and changing compliance or in a pressure-controlled mode with a FiO_2 sufficient to maintain adequate oxygen saturation. The adequacy of ventilation can only be assessed intermittently using $ETCO_2$ and manually closing the leak between biopsy attempts. Local

	anesthetic is often applied topically either prior to intubation or during surgery to decrease postop tracheal irritation caused by the procedure.	
Emergence	Muscle relaxant is reversed and the patient is extubated sitting upright with remifentanil infusion (0.03–0.05 mcg/kg/min) for a smooth wake-up. Supplemental oxygen postop.	
Blood and fluid requirements	IV: 18 ga minimum BSS @ 2 mL/kg/h	See Restrictive Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors ± Arterial line Second pulse oximeter	Place the EKG electrodes away from the sternum in case an emergency sternotomy is necessary. Place a BP cuff or arterial line (when indicated) on the left side in the event of a possible mediastinoscopy (with intermittent pressure on the innominate artery). Place a pulse oximeter on both sides.
Positioning	Supine, arms tucked ✓ and pad pressure points	To facilitate surgery, the patient is usually turned 90° from the anesthesia provider with a jelly doughnut to stabilize the head.
Complications	Hypoxia	Pulse oximetry monitored continuously. Interrupt the procedure to allow oxygenation to improve before proceeding.
	Hypercapnia	$ETCO_2$ monitoring is inaccurate because of the leak at the adaptor. Intermittently pause the procedure and manually close

		the leak to confirm that $ETCO_2$ is not too high. Ventilate to normalize the $ETCO_2$ before proceeding.
	Hemorrhage	Often minor and local, which can be controlled with epinephrine solution irrigation. Rarely major, which may require an emergency sternotomy or thoracotomy.

POSTOPERATIVE

Complications	Airway irritation	Airway irritation causing coughing (decreased by lidocaine topical spray prior to or during the procedure) or bronchospasm, treated with nebulized bronchodilators, for example, racemic epinephrine or albuterol. Occasionally steroids may be necessary.
	Hypoxia	Humidified O_2 by mask.
	Hypoventilation	Avoided by adequate reversal of neuromuscular blockade and using minimal-dose short-acting opioids.
	Hemorrhage	Usually self-limiting.
Multimodal pain management	Usually minimal	
Tests	CXR	A postop CXR is often performed to confirm the absence of pneumothorax or mediastinal emphysema.
ERAS	PONV protocol (see	Encourage early enteral

Appendix B, p. B-1) nutrition and mobilization.

Suggested Readings

1. Lee HJ, Haas AR, Sterman DH, et al: Pilot randomized study comparing tw techniques of airway anaesthesia during curvilinear probe endobronchial ultrasound bronchoscopy (CP-EBUS). Respirology 2011; 16:102–6.
2. Sarkiss M, Kennedy M, Riedel, et al: Anesthesia technique for endobronchia ultrasound-guided fine needle aspiration of mediastinal lymph node. J Cardiothorac Vasc Anesth 2007; 21(6):892–6.

BRONCHOSCOPY—FLEXIBLE AND RIGID

SURGICAL CONSIDERATIONS

Description

Bronchoscopy can be performed using either rigid or flexible instrumentation. **Flexible fiberoptic bronchoscopy (FOB)** is used for the diagnosis and evaluation of a variety of pulmonary conditions and can be accomplished using topical anesthesia and sedation without an anesthesiologist. Transbronchial biopsies can be performed in sedated patients, although more extensive interventions—such as laser ablation of a tumor, stent placement, and balloon dilation—require general anesthesia. When performed under GA, the bronchoscope should be passed through a size 8 or larger ETT. FOB is ofte performed through a single-lumen tube before lung resections.

Rigid bronchoscopy is more appropriate for evaluating hemoptysis and for intrabronchial procedures such as mechanical dilation of tracheal or bronchial strictures, laser or mechanical tumor debridement, and removal of foreign bodies that cannot be extracted with basket forceps through a flexible bronchoscope. Rigid bronchoscopy is performed under general anesthesia. With the patient's head and neck extended, the eyes, teeth, and gums must be protected, and the bronchoscope is inserted into the posterior pharynx until the epiglottis is visualized. The epiglottis is lifted anteriorly, with care being taken not to use the patient's teeth as a fulcrum. The bronchoscope is then advanced into the trachea (Fig. 5.12), and the diagnostic or therapeutic procedure is carried out. Ventilation is through the side-arm of the bronchoscope, and, as there is no cuff to prevent escape of anesthetic gases, high ventilatory volumes may be required. Because interventions (e.g., biopsy or tumor debridement) require removal of the bronchoscope viewing lens, the anesthesiologist must time ventilation appropriately. A Venturi ventilator may be useful when the

viewing lens must be off for prolonged periods.

Laser bronchoscopy can be performed using either flexible or rigid bronchoscopes. The CO_2 laser is characterized by limited tissue penetration. As such, it is useful for superficial lesions of the upper airway. The Nd:YAG lasers use higher energies, can be directed by fiberoptic light guides, and can be used for tumor ablation. As both of these types of lasers rely on thermal damage to tissues, precautions—particularly $FiO_2 \leq 30\%$—must be taken to prevent the devastating complication of airway fire. **Photodynamic therapy** uses visible light to activate a photosensitive compound into a locally toxic drug. Because no thermal energy is involved, airway fires are not an issue.

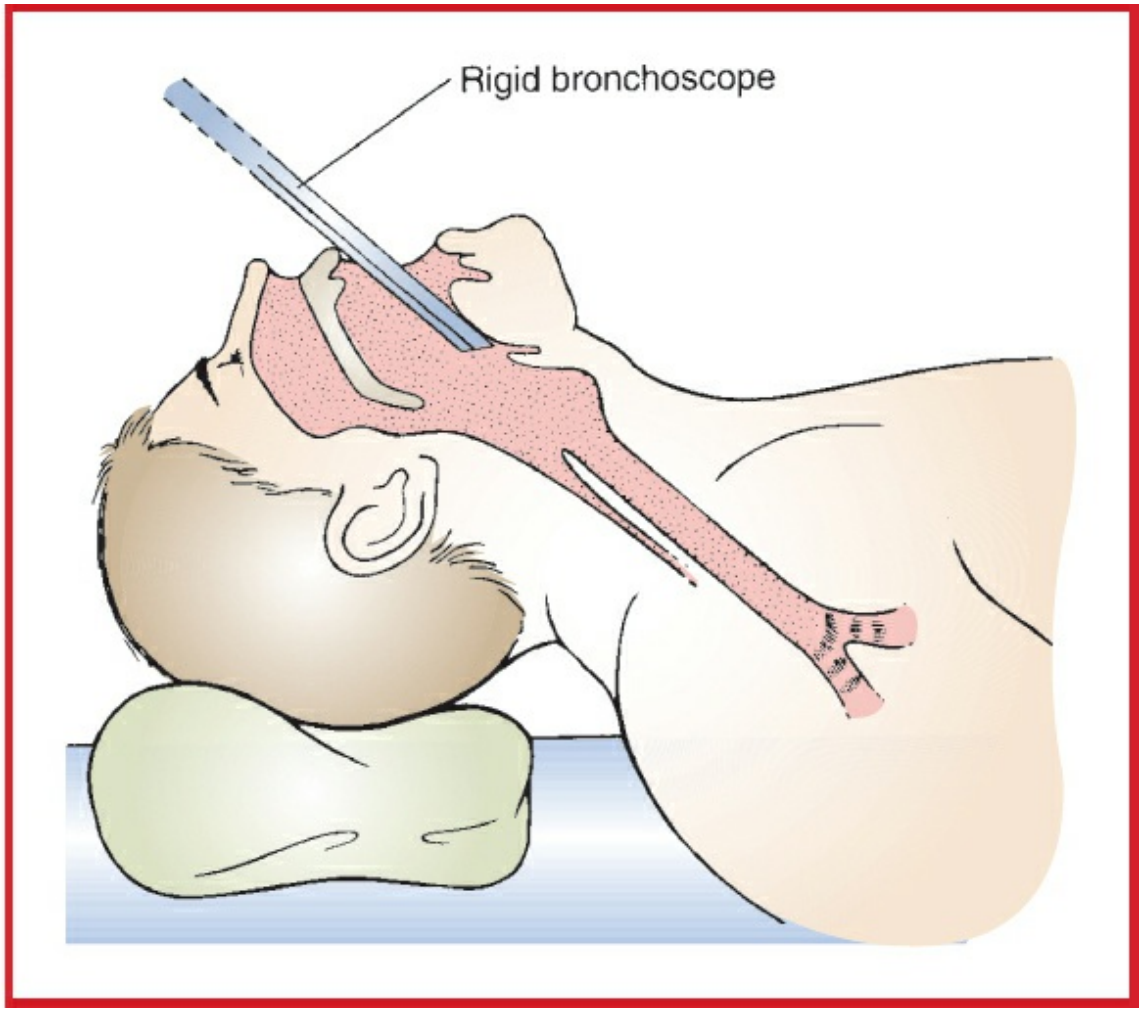

Figure 5.12 Patient positioning for rigid bronchoscopy.

Usual preop diagnosis

Carcinoma of the lung, primary or recurrent; hemoptysis; obstruction; foreign body; benign tumor; respiratory papillomatosis

ERAS: **Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, carb loading, and postop pain management options. See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Fiberoptic Bronchoscopy	Rigid Bronchoscopy	Laser Bronchoscopy
Position	Supine	⇐ (See Fig. 5.12)	⇐
Special instrumentation	FOB and instruments	Rigid bronchoscope and instruments	Nd:YAG laser and bronchoscope
Unique considerations	None	Shared airway	⇐ + Keep FiO_2 ≤0.4 during the use of laser
Antibiotics	Usually none	± Cefazolin 2g iv	⇐
Surgical time	<30 min	⇐	1 h
EBL	Minimal	⇐	⇐
Postop care	PACU then home	⇐	⇐
Mortality	Minimal	⇐	5%
Morbidity	Barotrauma Airway obstruction Pneumothorax	⇐ ⇐ ⇐ Tooth damage Tracheal laceration Pneumomediastinum Esophageal perforation	⇐ Airway fire Hemorrhage Perforation
Pain score	1	1	1

PATIENT POPULATION CHARACTERISTICS

Age range	Usually adults >50 yr
Male:Female	1:1

Incidence	Common
Etiology	Smoking, hemoptysis, aspiration of foreign body
Associated conditions	Lung cancer or metastatic spread to tracheobronchial tree, airway obstruction 2° tumor or FB, lung infiltrates

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients presenting for bronchoscopy range from asymptomatic to those in severe respiratory distress. FOB is performed most commonly as it is less invasive, is usually easily done under sedation, and allows for more distal airway examination. Rigid bronchoscopy is mostly reserved for specific interventional procedures such as hemorrhage control, foreign body removal, tumor debulking, and stent placement.

Respiratory	H&P to focus on underlying condition. Evaluate for acute and chronic pulmonary problems by H&P and lab and radiologic studies. **Tests:** Consider ABG in patient with respiratory distress, SOB at rest, or poor exercise tolerance. PaO_2 < 70 mm Hg and/or $PaCO_2$ > 45 mm Hg indicate significant respiratory impairment and predict increased risk; PFT with flow-volume loop (for airway lesions); CXR.
Cardiovascular	Many patients have Hx of cardiac disease. Cardiology consultation should be obtained for active/unstable cardiac issues or for patient with poorly controlled chronic disease. **Tests:** Consider ECG; others as indicated from H&P
Musculoskeletal	Patients with lung cancer may have myasthenic (Eaton-Lambert) syndrome with resistance to depolarizing muscle relaxants and ↑ sensitivity to NDMRs. Monitor relaxation with peripheral nerve stimulator.
Hematologic	Type and cross rarely required unless high risk of hemorrhage (✓ with surgeon). Adequate O_2 carrying capacity (Hct) is important. **Tests:** Hb/Hct
Laboratory	Other tests as indicated from H&P
Premedication	Antisialagogue (glycopyrrolate 0.2 mg iv, avoids central anticholinergic effects). Light sedation with midazolam 1–2 mg iv and/or fentanyl, 50–100 mcg

	iv. Avoid heavy sedation that might impair postop ventilation.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status.

INTRAOPERATIVE

Flexible bronchoscopy

Anesthetic technique for flexible FOB requires sedation or GA. Anxious patients and those with respiratory compromise may not tolerate sedation for awake FOB, and patients with Hx of gastric reflux or aspiration are not candidates for awake FOB. Local anesthetic toxicity is a distinct possibility; ensure availability of resuscitative equipment.

Sedation with topical anesthesia	Sedate patient as necessary to ensure comfort and cooperation (midazolam 1–2 mg iv and/or fentanyl 50–100 mcg iv). Bronchoscopy is often better tolerated if using nasal route. Airway anesthesia can be provided with direct nerve blocks or topical anesthesia. **Nerve blocks:** Transtracheal local anesthesia—pass needle through the cricothyroid membrane, aspirate air into syringe, and then inject lidocaine (2%) 2–4 mL. Remove needle quickly because injection causes cough (spreads the anesthetic). Perform superior laryngeal nerve blocks: insert needle anterior to superior cornu of the thyroid cartilage. After resistance is felt, aspirate gently; then inject lidocaine (2%) 2 mL; repeat on the other side. **Topical anesthesia:** Spray the palate, the pharynx, the larynx, vocal cords, and the trachea with lidocaine (4%), using nebulizer, or have patient gargle viscous lidocaine (4%). Hold the base of the tongue forward and, using Krause forceps, place pledgets soaked in local anesthetic in each pyriform fossa to block the internal branch of the superior laryngeal nerve. Laryngeal structures are well topicalized with having the patient gargle 4%

	lidocaine. The trachea can be topicalized by administering 1% lidocaine through the working channel of the fiberoptic scope. Patient can hold a suction catheter in the mouth to remove oral secretions. A special face mask (Patil-Syracuse) incorporates a diaphragm through which the FOB can pass while patient breathes 100% O_2. Use a special oral airway (Ovassapian) to guide FOB over the back of the tongue into the trachea to prevent damage to FOB by teeth. Limit amount of suctioning by surgeon because suctioning through FOB decreases FiO_2 and FRC, → ↓ PaO_2.

General anesthesia

Almost any anesthetic technique is acceptable, including the use of an LMA. A large ETT has less resistance to air flow; minimum size is 8 mm (ID) for adult FOB. If patient requires ETT < 8 mm, use a pediatric FOB. Placing an LMA allows for examination of the proximal airway, and a size 2.5 or larger ProSeal LMA has an airway caliber equivalent to or larger than a size 8.0 ETT. The presence of a FOB in the ETT or LMA increases airway resistance and may result in intrinsic PEEP and dynamic hyperinflation/pulmonary tamponade (hypotension).

Rigid bronchoscopy

This requires relatively deep GA, and usually paralysis for scope insertion.

Induction	Preoxygenate well. Standard induction. Consider short-acting paralytics (e.g., succinylcholine 1 mg/kg or rocuronium 0.3–0.6 mg/kg). Use only small amount of iv opioids because postop analgesic requirements are minimal; consider remifentanil (1 mcg/kg) to avoid postop respiratory depression.
ERAS	Verify preprocedure antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Commonly inhalation anesthesia with isoflurane or sevoflurane and 100% O_2. The adequacy of inhaled agent delivery may be hampered by ongoing

	suctioning. TIVA is an alternative: propofol (50–150 mcg/kg/min) and remifentanil (0.1–0.3 mcg/kg/min). Paralysis is usually used for ETT placement and is required during rigid bronchoscopy. May be provided with short-acting, nondepolarizing agents (atracurium, vecuronium, or rocuronium) or alternatively a succinylcholine drip (1 g/250 mL NS, titrated to effect; be aware of onset of phase II block at doses >5–6 mg/kg). Manual IPPV through side-arm of rigid bronchoscope. High flow (up to 20 L/min) to compensate for leak. Hyperventilate patient in preparation for periods of apnea. Ventilation must be interrupted whenever surgeon removes eyepiece to suction or biopsy. Manually ventilate to compensate for compliance changes that occur when bronchoscope is in the trachea (ventilating both lungs) and when it is in the bronchus (ventilating one lung). O_2 flush is used to compensate for leak and bypasses anesthetic vaporizer. Frequent flushing lowers anesthetic concentration. Sanders jet ventilator using Venturi effect and the Monsoon III high-frequency ventilator (Acutronic Medical Systems AG) are alternatives that allow for uninterrupted ventilation and may shorten the length of the procedure. They require TIVA. Entrainment of air results in variable FiO_2. Adequacy of ventilation is hard to determine as no $ETCO_2$ monitoring is available; prolonged procedures may require intermittent blood gas analysis or transcutaneous CO_2 monitoring.
Emergence	Place ETT, LMA, or iGEL at conclusion of rigid bronchoscopy. Patient must be fully awake before extubation with no residual neuromuscular blockade. Emergence can be "stormy." Patient may cough violently to clear secretions and blood. Wake-up from remifentanil infusion tends to be smoother. Other considerations include early suctioning of the airway and lidocaine (1 mg/kg iv) to decrease airway

	reactivity. Provide postop O_2 supplementation (preferably humidified).	
Blood and fluid requirements	Blood usually not required IV: 18 ga × 1 BSS @ 2 mL/kg/h	Transfusion unnecessary unless complicated by massive hemorrhage; may require emergency thoracotomy. Usually restrict iv fluids to avoid fluid overload. See Restrictive Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	**NB:** $ETCO_2$ not accurate during rigid bronchoscopy because of dilution effect at sample port.
Positioning	✓ and pad pressure points ✓ eyes Shoulder roll for rigid bronchoscopy	
Complications	Hypoxemia	Monitor pulse oximetry continuously. If patient is hypoxemic, surgeon must withdraw bronchoscope into the trachea. If problem persists, remove bronchoscope and ventilate by mask or ETT.
	Hypercapnia	Common, due to hypoventilation. Mild hypercarbia is well tolerated except for the setting of severe pulmonary HTN. CO_2 levels above 70 mm Hg may be associated with

		tachycardia, dysrhythmias, and cardiac depression. Easily treated with higher minute ventilation/hyperventilation. IV lidocaine for dysrhythmias.
	Bleeding Tracheobronchial injury Aspiration of debris	Requires frequent suctioning. For major hemorrhage, place uncut ETT down the healthy bronchus and ventilate the good lung. Consider DLT. May require thoracotomy using DLT or BB to isolate and/or tamponade bleeding site.
	Hypoxemia	Rx: supplemental O_2. Nebulized racemic epinephrine and steroids may ↓ airway edema. Humidified O_2 may ↓ airway irritation.
	Hypoventilation Dental damage Airway trauma Pneumothorax	Incomplete reversal of muscle relaxants or opioid overdosage can cause hypoventilation. Obtain ABG if patient has difficulty breathing or is oversedated. Be prepared to reintubate.

POSTOPERATIVE

Complications	Hemorrhage Risk of aspiration Airway obstruction Bronchospasm, bleeding, dislodged tumor, FB	If nerve blocks are used to depress gag reflex, no eating or drinking for several hours postbronchoscopy.
Multimodal pain management	Minimal pain	Emphasize multimodal approach combining nonopioid and occasionally po

		opioid analgesics (see Appendix K, p. K-6).
Tests	CXR	Obtain CXR in the recovery room to ✓ for atelectasis, pneumothorax, and mediastinal emphysema.
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition and mobilization.

Suggested Readings

1. Bolliger CT, Sutedja TG, Strausz J, et al: Therapeutic bronchoscopy with immediat effect: laser, electrocautery, argon plasma coagulation and stents. Eur Respir J 2006; 27(6):1258–71.
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AIRWAY LASER SURGERY

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients usually present with complications related to an airway mass (endobronchial, carinal, or tracheal). Resection tends to be a misnomer, as the laser is most commonly used for debulking of an unresectable lesion. Central airway obstruction is a primary concern when providing anesthesia.

Respiratory	It is imperative to define the exact location and magnitude of any central airway obstruction. This helps to estimate an appropriate ETT size and quantify the potential for obstruction during induction. CXR and CT scan must be studied. PFTs and flow-volume loops may also characterize the lesion. **Tests:** PFTs; ABGs; CXR; CT scan (to delineate airway anatomy, including site and severity of airway lesion)
Musculoskeletal	Although there may be no clinically detectable muscle weakness, some of these patients will have Eaton-Lambert syndrome → ↓ sensitivity to NDMRs and ↑ resistance to depolarizing muscle relaxants.
Hematologic	Transfuse patients with preop Hct <25% (or <30%, if CAD is present). **Test:** Hct
Laboratory	Other tests as indicated from H&P
Premedication	Minimal; avoid respiratory depressants; consider antisialagogue (e.g., glycopyrrolate).
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status.

INTRAOPERATIVE

Anesthetic technique

Usually GA. Unexpected patient movement may be disastrous, which is why sedation and local anesthesia are rarely practical. Nd:YAG laser can be transmitted through a flexible quartz monofilament passed through either a rigid bronchoscope or FOB. Rigid bronchoscope provides improved visibility and better debris retrieval. It also maintains the airway with less chance of fire, although it can reflect the laser beam, causing tissue damage. Manual ventilation through the side-arm may be difficult. FOB is used with local anesthesia or through ETT under GA. Laser-safe ETTs (required for surgery in the proximal trachea) include regular ETTs wrapped in metallic tape or commercially available "laser" tubes (usually some combination of aluminum, stainless steel, Teflon, and/or silicon). Fill cuff with saline (+ methylene blue to facilitate leak detection) and

avoid any petroleum-based lubricants on ETT. Steps also must be taken to protect the OR staff from laser injury. These include safety glasses to avoid ocular damage and specially designed and properly fitted filter face masks to protect from inhalation of vaporized viral particles. Photodynamic therapy is simpler in its considerations and risks: routine GETA with large ETT, immobile patient, and no risk of fire.

Induction	**Without or with distal airway obstruction** (past carina) Standard induction. **With proximal airway obstruction:** Awake bronchoscopy may help to determine the feasibility of tracheal intubation. Awake fiberoptic intubation is the safest route. In patients with less severe obstruction, an inhalation induction with spontaneous ventilation may be appropriate. Avoid muscle relaxants until the airway has been secured. Several special laser ETTs are available though none guarantee against airway fire. The risk is minimized with Nd:YAG lasering of central airway lesions as the beam is directed distal to the tip of the ETT. **With rigid bronchoscopy:** GA with standard or rapid-sequence induction.
ERAS	Verify preprocedure antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Use isoflurane/desflurane/sevoflurane, air-O_2 mixture. Keep FiO_2 < 0.4. Avoid N_2O, which supports combustion. TIVA with propofol (50–150 mcg/kg/min) and remifentanil (0.1–0.3 mcg/kg/min) infusion is preferable during rigid bronchoscopy as it ensures anesthetic delivery to the patient and avoids anesthetic contamination of the OR. Frequent suctioning during bronchoscopic examination may make inhalation techniques unreliable. Short-acting, nondepolarizing relaxant or succinylcholine infusion should be used to provide an immobile patient during laser use. If the patient becomes hypoxemic, ventilate the lungs with higher FiO_2 and ask the surgeon to stop.
Emergence	Following rigid bronchoscopy, the patient's airway usually is maintained with an LMA/iGEL or ETT until awake and breathing well and protective airway reflexes have returned.

	Emergence can be "stormy," with bleeding and secretion clearance a problem. Patient should be recovered in the sitting position. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 14–16 ga × 1–2 BSS @ 1–2 mL/kg/h	There is a potential for massive blood loss following inadvertent perforation of a major blood vessel See Restrictive Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	Continuous pulse oximetry essential; monitor $ETCO_2$ to assess adequacy of ventilation ($ETCO_2$ value may be inaccurate; consider ABG during long cases). Keep alveolar PO_2 <40%.
Positioning	✓ and pad pressure points ✓ eyes and laser shields	
Complications	Airway obstruction	From tumor, blood, tissue debris, etc. May be catastrophic secondary to pneumothorax/pneumomediastinur and cardiac tamponade; lung isolation may be lifesaving.
	Hypoxemia/hypercarbia	From inadequate ventilation.
	Bleeding	Keep a BB handy to protect the healthy lung.
	Perforation of tracheobronchial tree	Can be massive from perforation of the blood vessel by laser. Apply topical epinephrine following laser photocoagulation to control bleeding.
	Airway fire	Rx: stop ventilation, remove O_2 source, and extubate trachea to decrease inhalation of toxic

		products. Douse fire with saline. Suction all debris from airway. Ventilate patient by mask and then reintubate. Prior to subsequent extubation, perform bronchoscopy to reevaluate airway damage and suction debris. Consider steroids.
	Venous air embolism	Rx: inform surgeon, d/c laser, and prevent further entrainment. If access is present, attempt to aspirate air. Immediately volume load and support circulation with vasopressors.

POSTOPERATIVE

Complications	Airway edema	Edema formation is difficult to appreciate simply based on epithelial changes during bronchoscopy. May progress dramatically after the procedure resulting in airway obstruction and need for CPAP or emergency reintubation. Steroids are routinely given to minimize edema formation (dexamethasone 6–8 mg iv). Nebulized racemic epinephrine is helpful. Complications such as hemorrhage or obstruction can be delayed up to 48 h.
Multimodal pain management	Minimal pain	Rarely requires analgesic.
Tests	Continuous pulse oximetry	

ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition and mobilization.

Suggested Readings

1. McRae K: Anesthesia for airway surgery. Anesthesiol Clin North Am 2001; 19(3):497–541.
2. Ochroch EA: Laser endobronchial treatment does not need to occur in the operating room. J Cardiothorac Vasc Anesth 2005; 19(1):118–20.
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THYMECTOMY

SURGICAL CONSIDERATIONS (ALSO SEE SURGEON'S PERSPECTIVE ABOVE)

Description

The two most common indications for thymectomy are **myasthenia gravis** and **thymoma.** The severity of myasthenia gravis can be classified using the Osserman scheme, which assigns Stage I to patients with ocular symptoms only, with Stages II–IV for progressive degrees of bulbar and systemic symptoms. Indications for surgery versus medical management remain controversial, with some neurologists referring nearly all patients with myasthenia gravis for surgery, whereas others refer only those with refractory symptoms. Patients referred for surgery often take a combination of pyridostigmine and immunosuppressants (steroids and azathioprine). In cases of severe myasthenia gravis, preop plasmapheresis may be helpful in minimizing periop muscle weakness. Patients with thymoma may be asymptomatic, although ~10–20% of them have a Hx of myasthenic symptoms.

Thymectomy can be performed through a complete median sternotomy, an upper sternal split (manubrium only), a cervical approach, or a minimally invasive approach (VATS or robot-assisted). The value of a complete **median sternotomy** is that it allows for removal of all anterior mediastinal tissue that may harbor small thymic rests. This is the

most invasive approach, however, and the one associated with the greatest degree of intraop tissue injury. An **upper sternal split** is performed with the neck extended and a roll placed under the shoulder blades. Either a short vertical incision or a transverse incision at the level of the sternal angle may be used. Division of only the manubrium provides adequate exposure for identification, dissection, and removal of the thymus. Mobilization of the thymus can be accomplished without entering the pleural space. Care must be taken to avoid injuring the phrenic nerves. In contrast with the removal of anterior mediastinal tumors, thymectomy usually does not require OLV.

Transcervical thymectomy is performed through a collar incision similar to that used for thyroidectomy (Fig. 7.11-3). The cervical extensions of the thymus are identified and the dissection is advanced progressively into the neck. Attachments of the gland are cauterized, and a clip is placed on the thymic vein (which drains directly into the innominate vein). Exposure is aided by a special retractor that elevates the sternum anteriorly and exposes the anterior mediastinum. **Minimally invasive** thymectomy is performed through three or four small incisions with the patient in the supine position with a bump under the side of operation and arm abducted.

At the conclusion of the operation—whether it is done through the chest or the neck—the thymic bed is drained with a small suction drain. Preop medications should be resumed as soon as possible.

Usual preop diagnosis

Myasthenia gravis; thymoma

ERAS: Preop counseling by the surgeon/anesthesiologist should include medication management, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Sternotomy	Cervical Approach
Position	Supine	⇐
Incision	Median sternotomy or minimally invasive	Suprasternal
Special instrumentation	None	Special sternal retractor

Antibiotics	Cefazolin 2 g iv	⇐
Surgical time	1–2 h	⇐
EBL	<500 mL	⇐
Postop care	ICU—special attention to muscle strength, related to respiratory function	⇐
Mortality	<5%	⇐
Morbidity	Phrenic nerve injury Infection Pneumothorax Hemothorax	⇐
Pain score	5–7	2

PATIENT POPULATION CHARACTERISTICS

Age range	Usually young adults
Male:Female	Females > males
Incidence	Infrequent
Etiology	Unknown
Associated conditions	Myasthenia gravis, benign or malignant thymoma, other autoimmune diseases (e.g., rheumatoid arthritis)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients presenting for thymectomy may have myasthenia gravis, an autoimmune disease of the neuromuscular junction characterized by muscle weakness and easy fatigability. Thymomas (benign or malignant) also may be associated with myasthenia gravis. The anesthesiologist needs to be aware of the possible compression effects of the tumor (see Excision of Other Mediastinal Tumors), the potential for respiratory failure, and anticipate complications of various treatment modalities.

Respiratory	Patient may have marked reduction in VC 2° muscle weakness; establish baseline spirometry values.

	Classic (Leventhal) criteria predicting the need for postop ventilation include duration of disease >6 yr, chronic comorbid pulmonary disease, pyridostigmine dose >750 mg/d, and VC < 2.9 L. Others include preop use of steroids and previous episode of respiratory failure. These predictors have not been widely validated. Inform the patient of the potential requirement for prolonged ventilation. **Tests:** PFTs, others as indicated from H&P
Cardiovascular	There is a rare association between myasthenia gravis and cardiomyopathy. Consider ECG and cardiac consult if indicated from H&P.
Neurologic	Review neurologic assessment. Patients often exhibit diplopia, ptosis, and easy fatigability of muscles. Difficulties with swallowing and speech are common. Review tests (EMGs, Tensilon® test) done by neurologist to evaluate the adequacy of drug therapy (steroids, anticholinesterases, azathioprine, and cyclosporin A). Azathioprine (Imuran) may actually antagonize neuromuscular blockade by inhibiting phosphodiesterase. Cyclosporin A is reserved for severe disease because of the side effects of renal insufficiency and HTN. It may prolong neuromuscular blockade. Up to 50% of the patients with thymomas will have myasthenia gravis, and >85% of myasthenics will have thymus abnormalities.
Musculoskeletal	Determine adequacy of anticholinesterase medication. Evaluate hand strength, inspiratory efforts, and PFTs. Note that an excess of anticholinesterase agents can cause weakness and respiratory failure (cholinergic crisis). A deleterious response (weakness) to Tensilon®, administration (10 mg), and the presence of cholinergic side effects (e.g., pupil constriction) characterize cholinergic crises. Plasmapheresis may offer temporary (days to weeks) improvement in symptoms. Typically, patients with worsening symptoms receive 4–8

	treatments prior to surgery. There should be a 24-h delay between the last plasmapheresis and surgery to restore clotting factors and immunoglobulins. Plasmapheresis also may transiently decrease plasma cholinesterase, which could prolong the effects of succinylcholine, mivacurium, and ester-type local anesthetics.
Endocrine	Other autoimmune phenomena occur in 10–15% of myasthenic patients. Check for symptoms of thyroid or adrenal disease. **Tests:** TSH; evaluate screening test if indicated from H&P
Laboratory	Other tests as indicated from H&P
Premedication	Avoid premedication; for the anxious patient, give a small dose of midazolam (0.5–1 mg); avoid opioids or any other sedatives that may depress ventilation. Current recommendations for anticholinesterases suggest that, in mild disease without physiologic dependence, the morning dose can be held or halved. Patients with severe disease or with marked anticholinesterase dependence should receive their regular morning dose. For patients on steroids—depending on dosage and duration of steroid therapy—hydrocortisone (up to 100 mg iv bolus) before induction, then 100 mg q8h × 24 h, may be helpful. Note that acute steroid exposure in naïve patients may paradoxically exacerbate neuromuscular weakness. Consider aspiration prophylaxis.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of epidural or paravertebral nerve blocks for postop thoracotomy pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o

	severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA, combined with thoracic epidural opioids if transsternal approach will be used. Lung isolation may be requested by surgeon and can be accomplished with an EZ-Blocker™ or a DLT.

Induction	Inhalational induction with sevoflurane to avoid muscle relaxants entirely; however, patients with profound muscle weakness are at risk for aspiration 2° inadequate airway protective mechanism. Alternatively, iv propofol induction with remifentanil 1–2 mcg/kg (without muscle relaxants). If absolutely necessary, succinylcholine may be used to facilitate intubation, although myasthenic patients are considered resistant and require a dose of 1.5–2.0 mg/kg to obtain adequate conditions, which then will result in prolonged muscle weakness. Anticholinesterase therapy may prolong the duration of action of succinylcholine.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Standard maintenance. Patients with myasthenia gravis have ↑ sensitivity to nondepolarizing NMBs, which are rarely ever needed, as maintenance with inhalational agents provides adequate neuromuscular relaxation when combined with the existing baseline weakness. If relaxants are needed, titrate small amounts (1/10 ED_{95}) of drug, using a peripheral nerve stimulator to maintain a single twitch. Cisatracurium (20–30 mcg/kg q15–20min or infusion 1–3 mcg/kg/min) is useful because it is rapidly eliminated. With the advent of sugammadex, the judicious use of rocuronium is often possible.

	Alternatively, potent inhalation agents may provide adequate muscle relaxation and avoid the need for any muscle relaxant. Avoid drugs with neuromuscular blocking effects (e.g., antidysrhythmics, calcium channel blockers, diuretics, aminoglycosides, Mg^{2+}, iodinated contrast agents). Extremes of temperature, hypokalemia, and hypophosphatemia may also aggravate neuromuscular weakness and should be prevented. If the patient has normal ventilatory function, then spontaneous ventilation during cervical thymectomy may be appropriate. Patients undergoing sternotomy, and any patient with ↓ pulmonary reserve, require mechanical ventilation.	
Emergence	Criteria for extubation include head lift (5 sec), MIF > −25 cm H_2O, TV > 5 mL/kg, and full reversal evidenced by twitch monitor. Extubate when fully awake; usually immediate postop ventilation is not necessary. However, because of the variable response to muscle relaxation and delayed benefits of the surgery, some patients may require postop ventilation. Whether intubated or not, monitor patient for pulmonary function by measuring MIF and spirometry (Vt). Avoid residual pharmacologic neuromuscular blockade, which will → hypoventilation and ↑ risk of gastric aspiration if protective airway reflexes are inadequate. Discuss with surgeon local wound infiltration or nerve block (e.g., intercostal block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose is given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 18 ga × 1 BSS @ 1–2 mL/kg/h	Consider lower extremity iv access when hemorrhage is anticipated. See Goal Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	Avoid muscle relaxants if

		possible; use nerve stimulator.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Hemorrhage Dysrhythmia Compression of mediastinal structures Pneumothorax	

POSTOPERATIVE

Complications	Pneumothorax Respiratory failure Phrenic nerve damage Myasthenic or cholinergic crises	Pleura can be entered—usually at the right side—if so, chest tube is needed (for Dx and Rx, see VATS).
Multimodal pain management	Acetaminophen NSAIDs Parenteral opioids Epidural opioids	Emphasize multimodal approach combining nonopioid analgesics with peripheral local anesthetics and limited opioid analgesics (see Appendix K, p. K-6). Avoid respiratory depression; for breakthrough pain, consider parenteral opioids (cervical incision) and epidural opioids for median sternotomy. Of note, anticholinesterases are reported to potentiate the effect of morphine.
Drug management	Usually ↓ anticholinesterase requirement in the immediate postop period	Reduce daily anticholinesterase by 20%. Beware of "cholinergic" crisis. Sx include ↑ salivation, sweating, lacrimation, abdominal cramps, urinary

		frequency, fasciculations, and weakness 2° anticholinesterase overdose. Rx: anticholinergic agent (e.g., atropine) ± intubation and mechanical ventilation.
Tests	Tensilon® (edrophonium) Muscle strength Pupil exam	Tensilon® test may differentiate between myasthenic (↑ strength) and cholinergic (↓ strength) crises. Determine muscle strength postop (grip strength and sustained head lift). Pupil dilation (myasthenic crisis), pupil constriction (cholinergic crisis).
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Blichfeldt-Lauridsen L, Hansen BD: Anesthesia and myasthenia gravis.Acta Anaesthesiol Scand 2012; 56(1):17–22.
2. Dillon F: Anesthesia issues in the perioperative management of myasthenia gravis. Sem Neurol 2004; 24(1):83–94.
3. Limmer KK, Kernstine KH: Minimally invasive and robotic-assisted thymu resection. Thorac Surg Clin 2011; 21(1):69–83, vii.
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EXCISION OF OTHER MEDIASTINAL TUMORS

SURGICAL CONSIDERATIONS (ALSO SEE SURGEON'S PERSPECTIVE ABOVE)

Description

Mediastinal tumors are characterized by their location (anterior, middle, and posterior) and their size. Common anterior mediastinal tumors include thymic tumors (thymoma and thymic carcinoma), germ cell tumors, lymphoma, and substernal goiters. Typically, thymic and germ cell tumors are resected, whereas lymphomas are biopsied. Substernal goiters usually can be resected through the neck. Tumors in the anterior mediastinum usually are removed through a median sternotomy, a VATS, or a robot-assisted approach, whereas tumors in the middle and posterior mediastinum usually are removed through a lateral thoracotomy, a VATS, or a robot-assisted approach. Although middle and posterior mediastinal tumors usually do not present airway management problems, the issue of functioning neuroendocrine tissue must be considered. Mediastinal pheochromocytomas are uncommon middle mediastinal tumors. However, as with pheochromocytomas arising in other locations, appropriate preop adrenergic management is necessary.

Mediastinal tumors that are well encapsulated generally are removed in a straightforward fashion. If anterior mediastinal tumors are not well encapsulated and are attached to the pericardium or lung on either side, appropriate portions of these attached structures may be removed en bloc. If there is attachment to phrenic nerves on either side, one nerve may be sacrificed, if necessary, to remove the tumor completely. In patients with anterior mediastinal tumors, invasion of the major vascular structures, particularly the aorta and great vessels, presents an even greater problem.

Germ cell tumors of the anterior mediastinum are treated with chemotherapy initially. For nonseminomatous tumors, surgical resection is performed only if there is residual tumor. A common regimen for these patients consists of cisplatin, etoposide, and bleomycin, and because bleomycin is associated with pulmonary toxicity—particularly in conjunction with high concentrations of inhaled oxygen—care must be taken to keep the $FiO_2 < 40\%$ when conducting these operations.

Another common issue with patients with large anterior mediastinal masses is that of intrathoracic airway obstruction at the time of anesthetic induction. Although most mediastinal masses do not cause obstruction of the trachea or tracheobronchial tree, large mediastinal masses in the anterior mediastinum, in conjunction with muscle relaxation, can lead to complete obstruction of the airway with inability to ventilate the patient. Although rigid bronchoscopy may permit ventilation through the obstruction, it

cannot be counted on to relieve the obstruction; therefore, only short-acting or no muscle relaxants (spontaneous ventilation) should be used in these patients.

Usual preop diagnosis

Thymoma; germ cell tumor; ganglioneuroma; lymphoma; schwannoma; substernal goiter; congenital bronchogenic or pericardial cysts

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, need for a chest tube, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES	
Position	Supine or lateral
Incision	Median sternotomy, lateral thoracotomy, or minimally invasive
Special instrumentation	Sternal or rib retractors
Antibiotics	Cefazolin 2 g iv
Surgical time	2 h
EBL	<500 mL
Postop care	Frequently ICU
Mortality	Minimal
Morbidity	Bleeding
Pain score	5–8

PATIENT POPULATION CHARACTERISTICS	
Age range	All ages
Male:Female	1:1
Etiology	**Anterior mediastinum:** thymoma, teratoma, pericardial cyst, lymphoma, parasternal (Morgagni) hernia, lipoma **Superior mediastinum:** goiter, aneurysm,

	parathyroid tumor, esophageal tumor, angiomatous tumor **Middle mediastinum:** lymphoma, lymph node inflammation, bronchogenic tumor, bronchogenic cyst **Posterior mediastinum:** neurogenic tumor, aneurysm (enteric cyst), esophageal tumor, bronchogenic tumor
Associated conditions	SVC syndrome, myasthenia gravis, recurrent laryngeal nerve damage, airway obstruction, dyspnea, Horner syndrome

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Mediastinoscopy.

Suggested Readings

1. Carter BW, Marom EM, Detterbeck FC: Approaching the patient with an anterio mediastinal mass: a guide for clinicians. J Thorac Oncol 2014; 9(9 Suppl 2):S102–9.
2. Marshall MB, DeMarchi L, Emerson DA, et al: Video-assisted thoracoscopic surgery for complex mediastinal mass resections. Ann Cardiothorac Surg 2015; 4(6):509–18.
3. Narang S, Harte HB, Body SC: Anesthesia for patients with a mediastinal mass Anesthesiol Clin North Am 2001; 19(3):559–79.
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MEDIASTINOSCOPY

SURGICAL CONSIDERATIONS

Description

Mediastinoscopy is used for biopsy of mediastinal lymph nodes. The most common indication for this procedure is bronchogenic carcinoma, although lymphadenopathy associated with lymphoma, sarcoidosis, and infectious granulomatous diseases is also indication for mediastinoscopy. **Cervical mediastinoscopy** provides access to the pretracheal, paratracheal, and anterior subcarinal nodes (Fig. 5.13), whereas **transthoracic mediastinoscopy** (also known as **anterior mediastinotomy** or **Chamberlain procedure**) provides access to the aortopulmonary lymph nodes. Previous mediastinoscopy and radiation are relative contraindications to this procedure. If a thoracic aneurysm is present or SVC is obstructed, mediastinoscopy is

contraindicated because the anatomy is distorted and vessels can be punctured inadvertently by the mediastinoscope.

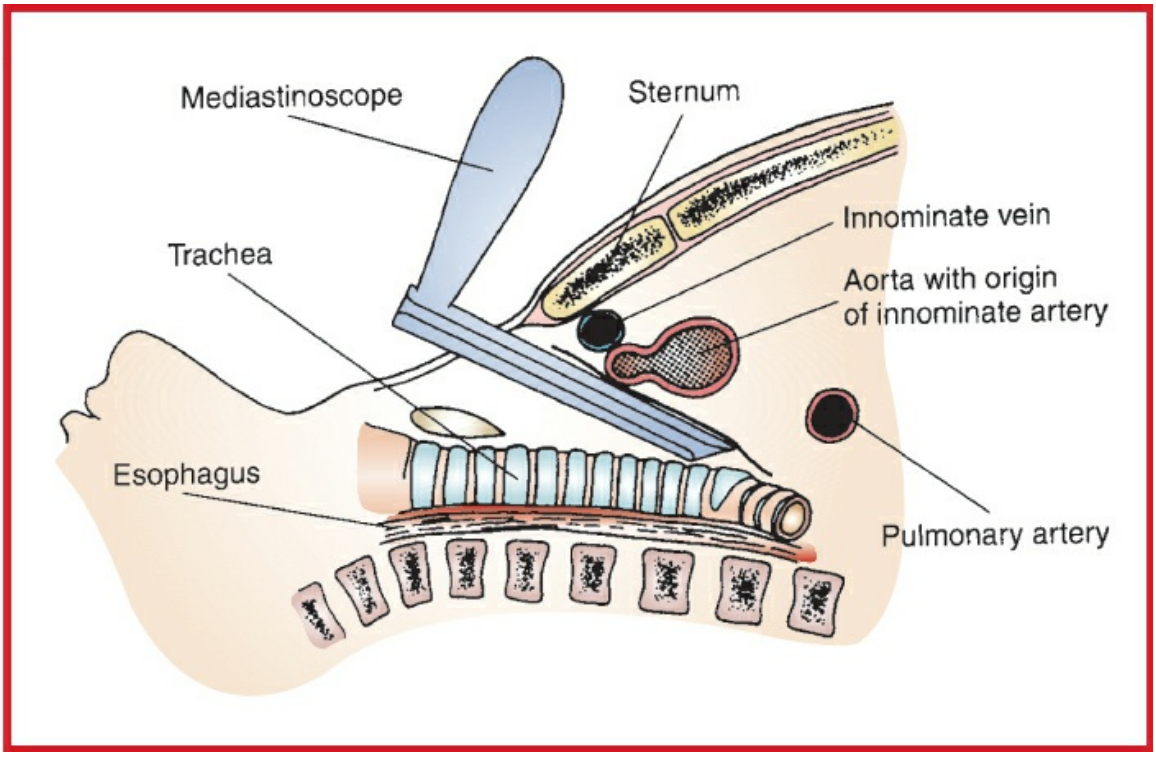

Figure 5.13 Mediastinoscope is inserted through a small cervical incision into the middle mediastinum, along the pretracheal plane. (Reproduced with permission from Baker RJ, Fischer JE, eds.Mastery of Surgery, 4th edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Variant procedure or approaches

For nodes on the left side of the mediastinum, **transthoracic mediastinoscopy** is performed through a limited anterior thoracotomy. In the classic **Chamberlain procedure,** the 3rd costal cartilage is resected, and the mediastinum is explored without entering the pleural space. As with cervical mediastinoscopy, visualization is often limited and lymph nodes should be aspirated before biopsy. If the pleural space is entered during the course of the procedure, either a chest tube can be placed postop or the pleural space can be aspirated immediately before wound closure. Patients should be extubated at the end of the operation. Cervical mediastinoscopy is usually an outpatient procedure, whereas patients undergoing transthoracic mediastinoscopy are usually hospitalized overnight.

Usual preop diagnosis

Carcinoma of the lung with enlarged mediastinal nodes; mediastinal node enlargement 2° lymphoma, thymoma, or others

ERAS: **Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, carb loading, and postop pain management options. See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

Position	Supine
Incision	For mediastinoscopy, low cervical; for anterior mediastinotomy, left or right parasternal in the 2nd interspace
Special instrumentation	Mediastinoscope
Antibiotics	Cefazolin 2 g iv
Surgical time	1 h
EBL	Minimal (but risk of significant blood loss if major vascular injury occurs)
Postop care	PACU and then same-day discharge
Mortality	<0.1%
Morbidity	Bleeding Pneumothorax: rare Vocal cord paralysis: rare Esophageal perforation: rare Pleural tear: rare Tracheal laceration: rare
Pain score	2 (mediastinoscopy), 2–3 (anterior mediastinotomy)

PATIENT POPULATION CHARACTERISTICS

Age range	Adults, usually >50 yr
Male:Female	Male > female
Incidence	Frequently part of evaluation for patients with lung cancer
Etiology	Lung cancer, lymphoma, thymoma, retrosternal goiter

Associated conditions	Airway obstruction

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

(Procedures covered: excision of mediastinal tumor, mediastinoscopy)

Typically, these patients can be divided into two populations, depending on the presence or absence of a significant mediastinal mass (with the potential for catastrophic airway obstruction or cardiovascular collapse on induction of anesthesia). The preop assessment must focus on the differentiation of these two populations. Close consultation with the surgeon is essential in formulating the anesthetic plan. On occasion, patients with critical airway or cardiac compression may require a tissue biopsy for diagnostic purposes only. If general anesthesia poses a significant physiologic threat to the patient, search for an alternative, less-invasive biopsy site.

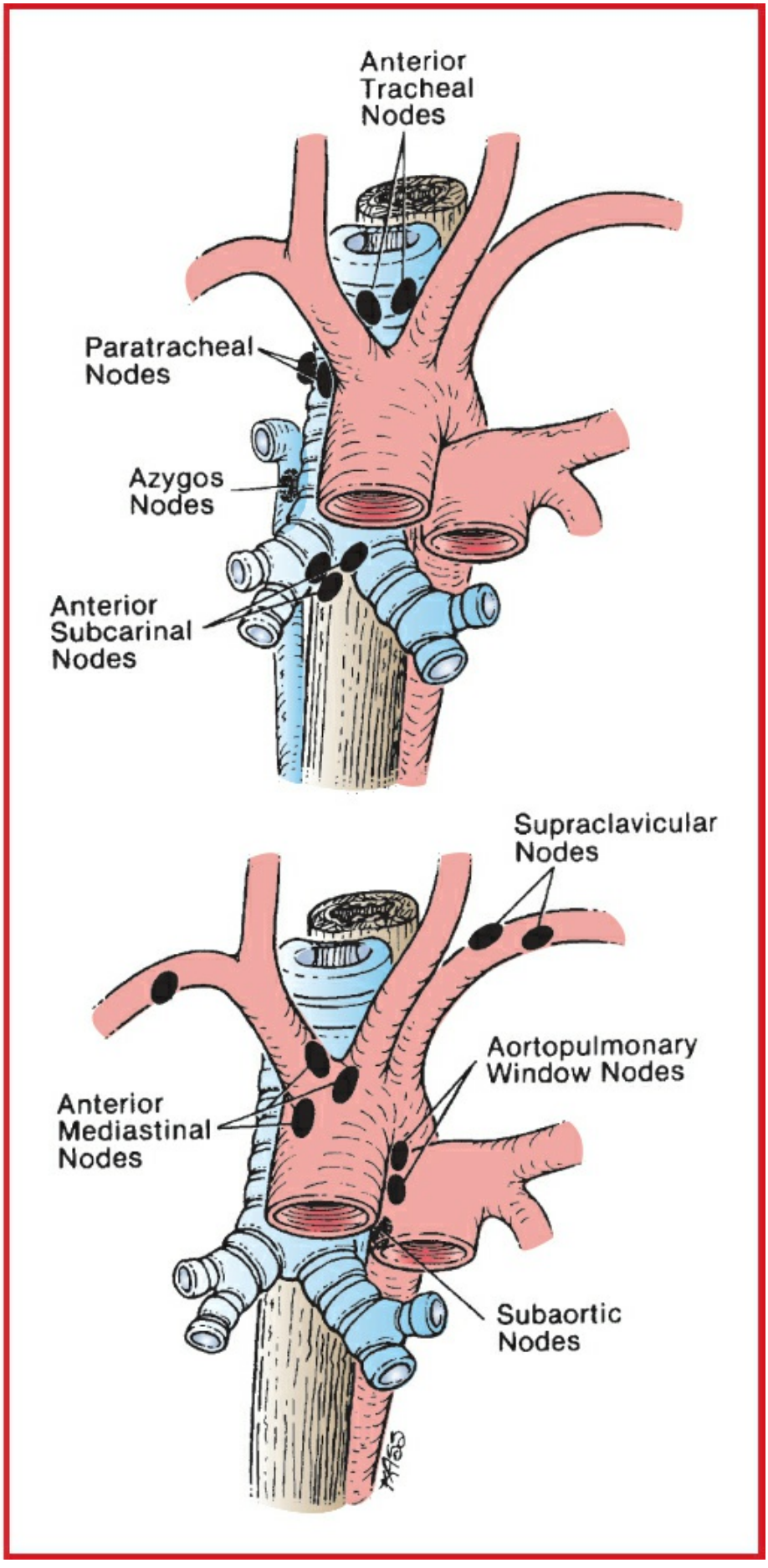
Anterior
Tracheal
Nodes
Paratracheal
Nodes
Azygos
Nodes
Anterior
Subcarinal
Nodes
Supraclavicular
Nodes
Aortopulmonary
Window Nodes
Anterior
Mediastinal
Nodes
Subaortic
Nodes

Figure 5.14 Lymph node sites accessible to mediastinoscope biopsy. Many of these can be reached by standard cervical mediastinoscopy. Anterior and aortopulmonary window nodes, however, require extended or anterior mediastinoscopy, VATS, or needle biopsy. (Reproduced with permission from Bocage J-P, Mackenzie JW, Nosher JL: Invasive diagnostic procedures. In: Shields TW, LoCicero J III, Ponn RB, eds. General Thoracic Surgery, 5th edition. Lippincott Williams & Wilkins, Philadelphia: 2000.)

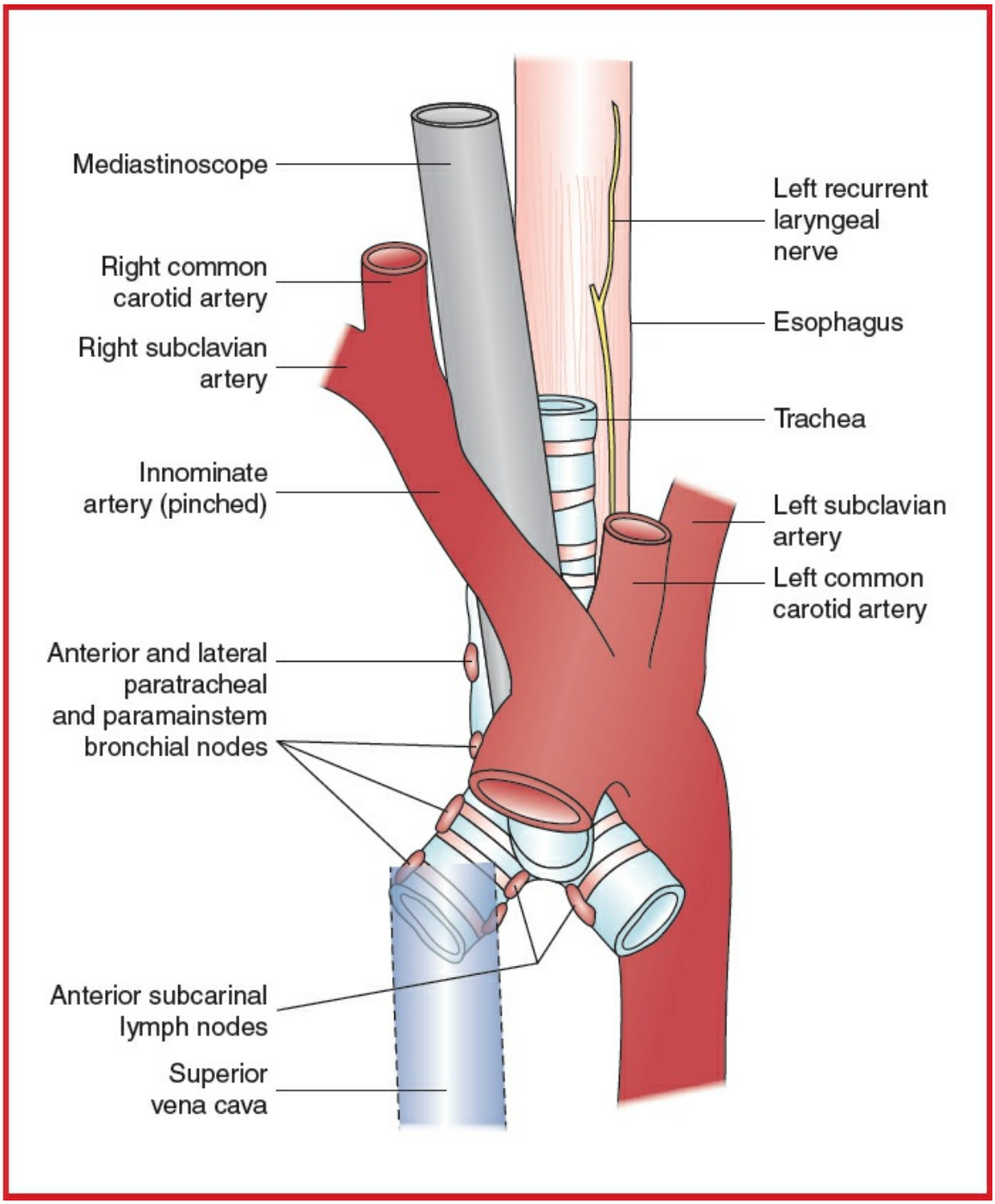

Figure 5.15 Relationship of mediastinoscope to the trachea and great vessels. (Reproduced with permission from Petty C: Right radial artery pressure during mediastinoscopy. Anesth Analg 1979; 58:428. Modified in Rogers MC:Principles & Practices of Anesthesiology. Mosby-Year Book, St. Louis: 1993.)

Respiratory	Question patient with anterior mediastinal mass about ability to lie supine and the presence of cough or dyspnea. Determine what position they prefer ("safe position"). Change in position may cause superior vena caval obstruction or cardiac and airway compression by mediastinal mass (which may be apparent only following induction or on emergence from anesthesia). On PE, ✓ for the presence of cyanosis, wheezing, or stridor in the upright and supine positions. If significant airway compression or SVC obstruction is present, the surgeon may delay surgery for radiation or chemotherapy. Patients with SVC syndrome (edema; venous engorgement of the head, neck, and upper body; supine dyspnea; ± headache; mental status change) may have significant airway edema. **Tests:** Classic teaching has recommended PFTs with flow-volume loops in upright and supine positions (Fig. 5.16 shows flow-volume loop) in patients with suspected central airway obstruction. These investigations demonstrate airflow obstruction during inspiration in patients with an extrathoracic mass and during expiration in patients with an intrathoracic mass. CT scans obtained with the patient supine delineate the location and extent of both airway and cardiac ± vascular compression. These images may predict patients at higher risk (>50% tracheal compression).
Cardiovascular	Intrathoracic vascular structures (e.g., right heart, PA, SVC) may be compressed → ↓ BP, hypoxia, and SVC syndrome. Involvement of the pericardium may → tamponade. **Tests:** Echo, CT/MRI if indicated by H&P
Musculoskeletal	Patients with lung cancer may have myasthenic (Eaton-Lambert) syndrome with resistance to depolarizing agents and ↑ sensitivity to NDMRs. Monitor relaxation with peripheral nerve stimulator.

Neurologic	Patient may have ↑ ICP if SVC is obstructed. Consider neurology consultation. Patients with preexisting carotid disease are at risk for stroke if there is significant compression of the innominate artery during the procedure.
Endocrine	Due to the diverse causes of an anterior mediastinal mass, consider comorbid thyroid disease and paraneoplastic syndromes.
Laboratory	Other tests as indicated from H&P
Premedication	Avoid sedation in patients with the potential for airway obstruction; otherwise, midazolam 1–2 mg iv may be appropriate. Antisialagogue may facilitate awake intubation. In patients with critical airway obstruction, heliox may prove useful.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

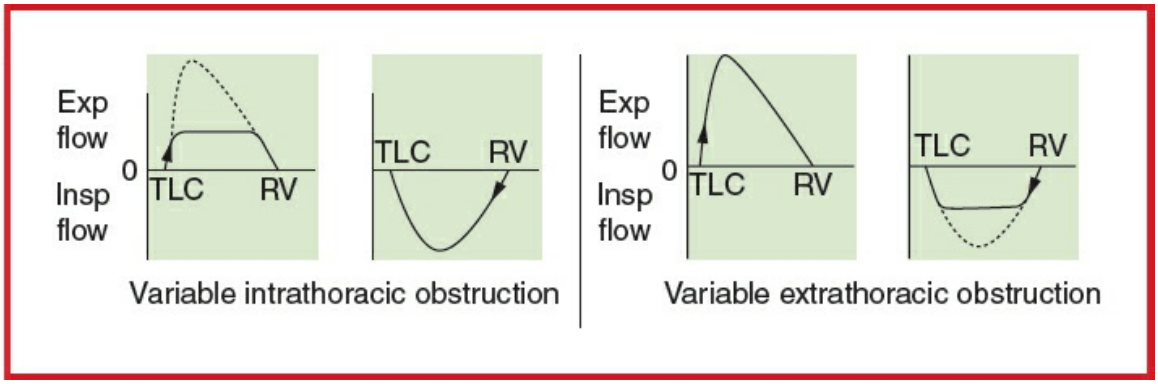

Figure 5.16 Flow-volume loop: with variable extrathoracic lesion, the alteration in the flow-volume loop is seen by flow limitation and a plateau on inspiration. The reverse occurs with variable intrathoracic lesions. (Reprinted from Acres J, Kryger MH: Clinical significance of pulmonary function tests.Chest 1981; 80:207–11. Copyright © 1981 The American College of Chest Physicians. With permission.)

INTRAOPERATIVE

Anesthetic technique

GETA, combined with epidural anesthesia if thoracotomy is planned.

Induction	Consider awake FOI (e.g., if symptomatic in supine

	position). Alternatively, a mask induction with sevoflurane/O_2 in a spontaneously breathing patient may be adequate in "the safe position." The use of neuromuscular blockers in high-risk patients may precipitate airway obstruction and CV collapse. Select a reinforced endotracheal tube when intubating patients with airway compression. Complete or partial airway obstruction by anterior mediastinal mass can also be due to changes in lung and chest wall mechanics associated with changes in the patient's position (sitting to supine during procedure) or to muscle relaxation. Consider placing the patient in the lateral or prone position in the event of central airway compression. A surgeon familiar with rigid bronchoscopy must be in the OR ready to bypass any obstruction. In rare instances, percutaneous cardiopulmonary bypass (CPB) may be necessary to complete the procedure safely. If this is indicated, it must be employed electively, not as a rescue measure. Salvage or emergent use of CPB in these patients is rarely successful.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	O_2 (100%) and isoflurane (1–1.5%) or sevoflurane (1.5–2.5%). Avoid N_2O, especially during OLV. Short-acting muscle relaxant and opioid as indicated.	
Emergence	Extubation in OR	
Blood and fluid requirements	IV: 14–16 ga × 1 BSS @ 1–2 mL/kg/h Blood in OR	Have blood for transfusion available in OR prior to surgery. Patients with SVC syndrome may have impaired venous return from upper-limb veins. In these patients, a large-bore iv cannula should be placed in lower limb for fluid and blood

		transfusions. See Restrictive Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors ± Arterial line ± CVP/PA	Invasive monitors are appropriate in patients with large mediastinal masses. In the presence of SVC syndrome, CVP/PA catheters should be placed, using the femoral vein. BP cuff on the left arm, radial artery line (if used) and pulse oximeter on the right. Mass or mediastinoscope can compress the innominate artery, causing reduction in right radial pulse and right-arm BP. If only right-arm BP is measured, patients may be treated inappropriately for "hypotension" or cardiac arrest. Suspect great vessel compression if right-arm pressure is lower than left or if right-arm BP disappears in the presence of a normal ECG. Arterial compression can compromise cerebrovascular perfusion → cerebral ischemia → stroke. Place pulse oximeters on both hands so the right side can monitor compression of the innominate and warn the surgeon if prolonged.
Positioning	Head-up position ✓ and pad pressure	In patients with an anterior mediastinal mass, the head-

	points ✓ eyes	up position reduces mass compression effect on airway and vascular structures but may subject the patient to ↑ risk of VAE if venous bleeding occurs during the procedure. Patients with SVC obstruction, if placed in head-down position with IPPV (further impedes venous return of thoracic cavity), are at ↑ risk of airway edema and airway obstruction following extubation.
Complications	Bleeding	Surgical tamponade through mediastinoscope may be indicated. For major hemorrhage, emergency thoracotomy or median sternotomy may be required to stop bleeding. Can occur from laceration of mediastinal vein.
	Air embolism	Head elevation increases risk of embolism, particularly if patient breathes spontaneously. Monitor $ETCO_2$ and ETN_2.
	Airway rupture or obstruction	Requires immediate thoracotomy.
	Tracheal collapse	Acute obstruction may require rigid bronchoscope to reopen airway.
	Recurrent laryngeal nerve injury	If recurrent laryngeal nerve injury is suspected, the vocal cords should be examined during spontaneous breathing

		at the time of extubation.

POSTOPERATIVE

Complications	Pneumothorax Phrenic/recurrent laryngeal nerve damage Tracheomalacia Bleeding	Bilateral laryngeal nerve damage may result in airway obstruction, necessitating reintubation. Mask ventilation may be ineffective. May occur in patients with long-standing mediastinal mass (e.g., retrosternal goiter).
Multimodal pain management	Acetaminophen Parenteral opioids ± Epidural	Emphasize multimodal approach combining nonopioid and bolus opioid analgesics (see Appendix K, p. K-6).
Tests	CXR on all patients to r/o pneumothorax	
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Barash PG, Tsai B, Kitahata LM: Acute tracheal collapse following mediastinoscopy. Anesthesiology 1976; 44(1):67–8.
2. Bechard P, Letourneau L, Lacasse Y, et al: Perioperative cardiorespiratory complications in adults with mediastinal mass. Anesthesiology 2004; 100(4):826–34.
3. Blank RS, de Souza DG: Anesthetic management of patients with an anterior mediastinal mass: continuing professional development. Can J Anesth 2011; 58:853–67.
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5. Cata JP, Lasala J, Mena GE, et al: Anesthetic considerations for mediastinal staging procedures for lung cancer. J Cardiothorac Vasc Anesth 2018; 32(2):893–900.
6. Hnatiuk OW, Corcoran PC, Sierra A: Spirometry in surgery for mediastinal masses. Chest 2001; 120(4):1152–6.

7. Marshall MB, DeMarchi L, Emerson DA, et al: Video-assisted thoracoscopic surgery for complex mediastinal mass resections. Ann Cardiothorac Surg 2015; 4(6):509–18.
8. Petty C: Right radial artery pressure during mediastinoscopy. Anesth Analg 1979; 58(5):428–30.
9. Slinger P, Karsli C: Management of the patient with a large mediastinal mass: recurring myths. Curr Opin Anaesthesiol 2007; 20(1):1–3.

LUNG TRANSPLANT (ALSO SEE SURGERY FOR LUNG TRANSPLANTATION IN CHAPTER 6.4)

SURGICAL CONSIDERATIONS

Description

The most common indications for lung transplantation include emphysema, pulmonary fibrosis, cystic fibrosis, and pulmonary HTN. Patients with the first three of these diagnoses have marked abnormalities in mechanical pulmonary function, whereas patients with pulmonary HTN often have normal lung mechanics but very abnormal cardiac function. Patients with emphysema and pulmonary fibrosis often receive single-lung transplants, and those with cystic fibrosis require double-lung transplants. The best operation for patients with pulmonary HTN continues to be debated, with options including single-lung, double-lung, and heart-lung transplantation. Although candidates for lung transplantation, by definition, have end-stage lung disease, their overall state of health and functional abilities varies considerably. Furthermore, although these patients all have poor pulmonary function, many with multisystem disease are eliminated during the preop screening process. Thus, the remaining patients are generally well motivated and free of significant cardiac, renal, and vascular disease.

Single-lung transplants generally are carried out through a thoracotomy incision. Patients with emphysema as the underlying disease rarely require CPB, whereas those with pulmonary fibrosis (decreased pulmonary reserve and increased incidence of pulmonary HTN) more commonly require bypass. Although the need for bypass can be assessed at the outset of the operation by instituting OLV, a CPB circuit and perfusionist should always be available. The route for vascular access for bypass (transthoracic or through the groin vessels) must be considered by the surgeon at the start of the case.

Double-lung transplants generally are done through bilateral anterior thoracotomies or a clamshell incision (Fig. 5.2). Mobilization of the lung is facilitated by the use of a DLT. If the patient does not tolerate OLV, CPB can be established using aortic and atrial cannulation. Some surgeons routinely use a single-lumen ETT, with a defined plan for using CPB.

The procedure for both single- and double-lung transplantation is the same for each side. The native lung is mobilized, and the bronchovascular structures are divided. Mediastinal adenopathy and extensive pleural adhesions are the rule, rather than the exception, for patients with cystic fibrosis. Such pneumonectomies take significantly longer than those for emphysema. Once the native lung is removed, the donor lung is

brought into the surgical field. The bronchial anastomosis is created first, and the lung is allowed to fall into the posterior costovertebral gutter. The venous anastomosis (atrial cuff anastomosis) is fashioned next. The final sutures are placed but left untied for later deairing. The arterial anastomosis is created last. Upon removal of the arterial clamp, the lung is perfused and deaired. The venous sutures are then tied and the atrial clamp is removed. After ensuring that the vascular anastomoses are hemostatic and that there is no air leak at the bronchial site, the incision is closed, or, in the case of double-lung transplant, attention is directed to the other side.

The anesthesiologist should be aware that hypotension is not uncommon on reperfusion of the donor lung but that it usually resolves spontaneously. Specific immunosuppression protocols vary from institution to institution, but intravenous administration of steroids immediately before lung reperfusion is a common practice. Lung transplant patients typically remain intubated following surgery; however, changing from a DLT to a single-lumen tube at the conclusion of the operation facilitates postop ET suctioning.

Usual preop diagnosis

COPD; pulmonary fibrosis; cystic fibrosis; pulmonary HTN; Eisenmenger syndrome

For Summary of Procedure and Anesthetic Management, see Surgery for Lung and Heart/Lung Transplantation, and Anesthetic Considerations for Lung Transplantation, p. 528.

Suggested Viewing

Links are available online to the following videos:

Part 1 of 3 VATS Thoracoscopic Lobectomy: https://www.youtube.com/watch?v=LPwsnQY3HkQ

Thoracotomy (On-Q catheter insertion for post-thoracotomy pain management): https://www.youtube.com/watch?v=XX_e4wTQ-90

Chest tube insertion: https://www.youtube.com/watch?v=EcIDkJHRq8c

Decompressing a Tension Pneumothorax: https://www.youtube.com/watch?v=0W-OmFBu93w

Thoracoscopic: Right Lower Lobectomy: https://www.youtube.com/watch?v=RgI4EcL0fDE

Sleeve Pneumonectomy for Lung Cancer: https://www.youtube.com/watch?v=GitI8FAU_vo

SECTION 6.0

CARDIOVASCULAR SURGERY

CHAPTER 6.1

Cardiac Surgery

SURGEON
R. Scott Mitchell, MD

ANESTHESIOLOGISTS
Linda E. Foppiano, MD
Daryl Oakes, MD
Albert Tsai, MD

CARDIOPULMONARY BYPASS

SURGICAL CONSIDERATIONS

The development of cardiopulmonary bypass (CPB) technology has allowed the repair of many congenital and acquired lesions of the heart and great vessels. Designed to replace cardiac and pulmonary functions, full CPB requires a blood pump and oxygenator. The pump may be of the roller-head or centrifugal variety with the latter producing less trauma to formed blood elements. The oxygenator allows O_2 and CO_2 to diffuse through a thin membrane into the surrounding blood (membrane oxygenator), though older forms of oxygenators may bubble gases through a blood-filled reservoir (bubble oxygenator). Utilization of any blood pump requires at least partial heparinization (ACT > 180 sec), and introduction of an oxygenator mandates full heparinization (ACT > 400 sec). Heparin-coated components, which partially eliminate the necessity for heparin, are available.

Full CPB typically drains systemic venous return via the right atrium into a venous reservoir, from which the blood is pumped through an oxygenator and then returned to the ascending aorta, subclavian artery, innominate artery, or femoral artery, completely bypassing the heart and lungs (Figs. 6.1-1 and 6.1-2). **Partial CPB** usually supports

only a portion of the body—typically the infradiaphragmatic portion—and requires maintenance of native cardiac output and ventilation in addition to an oxygenator-equipped CPB circuit in order to supply oxygenated blood to both the supradiaphragmatic and infradiaphragmatic portions of the body. **Left heart bypass** relies solely on the patient's lungs as the oxygenator and diverts a portion of oxygenated blood from the left atrium to the infradiaphragmatic portion of the body, while supradiaphragmatic perfusion is supplied by native cardiac output. Full CPB is utilized during a sternotomy for work on the heart, ascending aorta, and transverse arch, while partial CPB is normally used for work on the descending or thoracoabdominal aorta.

After exposure of the relevant organs (heart or descending thoracic aorta), and after heparinization, venous and arterial cannulae must be placed intraluminally. **Cannulation of the heart** usually involves venous drainage from the right atrium, with either two cannulae inserted through the atrium into the SVC and IVC (bicaval) or via a larger dual-stage cannula draining the right atria and IVC. Bicaval cannulation reduces venous return (and rewarming) to the heart and allows caval snares to be placed so that the right atrium can be opened without introducing air into the venous return. Occasionally, atrial manipulation for cannulation can depress cardiac output with resultant hypotension. This usually can be reversed with volume replacement. Aortic cannulation usually is not associated with any physiologic perturbation, although hypertension must be avoided to minimize aortic complications. After the cannulae are in place and connections are made to the bypass circuit, CPB may be instituted electively. Depending on surgical procedure and surgeon preference, cardiac operations may be conducted under mild (32–35°C), moderate (28–32°C), or deep (<28°C) hypothermia. Deep hypothermia is utilized to facilitate aortic arch repair in the setting of profound hypothermic circulatory arrest (PHCA). However, recent advancements in cerebral protective strategies, such as selective antegrade cerebral perfusion (SACP) and retrograde cerebral perfusion (RCP), have allowed for aortic arch repair to be performed under more moderate hypothermia. For operations on the descending thoracic aorta, normothermia is maintained unless surgical access of the aortic arch is necessary, in which case PHCA may be utilized.

With initiation of CPB, many physiologic variables are now controlled by the anesthesiologist, perfusionist, and surgeon, including systemic flow rate and perfusion pressure, arterial O_2 and CO_2, temperature, and hematocrit. Other physiologic parameters follow either directly or indirectly. Thus, physiologic monitoring for the anesthesiologist and perfusionist includes, at a minimum, arterial pressure, central venous pressure, arterial blood gas determination (preferably online during CPB), cardiac output, urine output, and cardiac electrical activity. Constant communication

among surgeon, perfusionist, and anesthesiologist is essential for a smooth operation. TEE is used to verify cannula positioning, characterize primary pathology and identify previously undiagnosed pathology, evaluate effectiveness of surgical repair, and provide information about overall cardiac function and volume status. As such, the use of TEE has become standard practice for cardiac surgery.

The **physiologic response to CPB** is complex and is associated with a massive catecholamine release that resolves after bypass. Subsequent changes include abnormal bleeding, increased capillary permeability, leukocytosis, renal dysfunction, and impairment of the immune response. Hemodilution, nonpulsatile flow, hypothermia, exposure of formed elements to nonendothelial surfaces, complement activation, protein denaturation, cascading effects within the coagulation and fibrinolytic system, and activation of the kallikrein-bradykinin cascade all contribute to this physiologic derangement and account for much of the morbidity and mortality after CPB.

For periods of **cardiac arrest**, during which the heart is deprived of its arterial blood supply, the metabolic demands of the myocardium must be minimized. This usually is accomplished by achieving electrical and mechanical arrest with a hyperkalemic cardioplegic solution, by lowering myocardial temperature to <15°C and by ensuring the ventricles are adequately decompressed to minimize myocardial wall tension. Frequent reinfusions of cardioplegia maintain hypothermia and electrical silence, prevent lactic acid accumulation, and deliver some minimally available dissolved O_2.

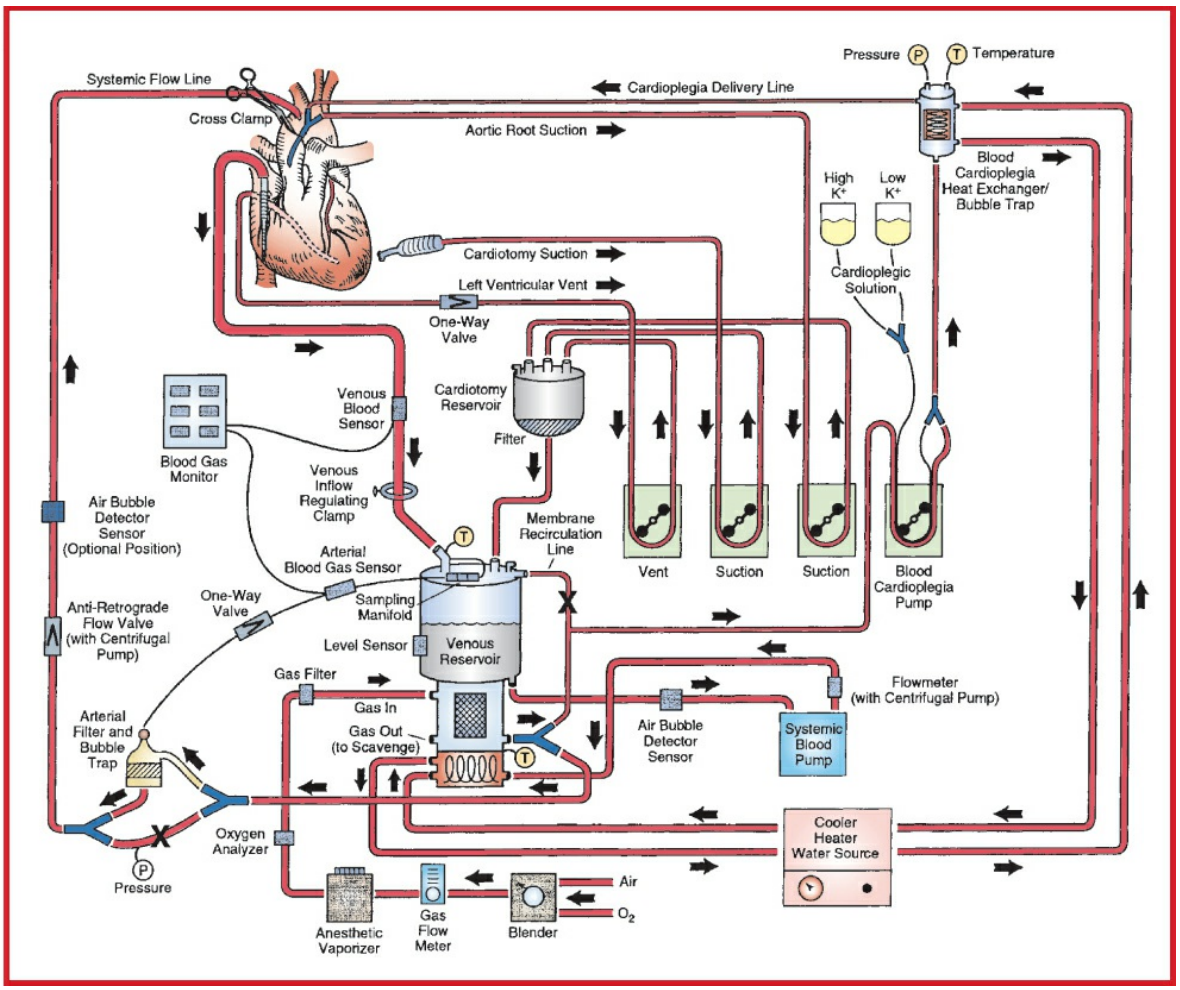

Figure 6.1-1 Detailed schematic diagram of the arrangement of a typical cardiopulmonary bypass circuit using a membrane oxygenator with integral hard-shell venous reservoir (lower center) and external cardiotomy reservoir. Venous cannulation is by a cavoatrial cannula, and arterial cannulation is in the ascending aorta. Some circuits do not incorporate a membrane recirculation line; in these cases, the cardioplegia blood source is a separate outlet connector built into the oxygenator near the arterial outlet. The systemic blood pump may be either a roller or centrifugal type. The cardioplegia delivery system (right) is a one-pass combination blood/crystalloid type. The cooler-heater water source may be operated to supply water to both the oxygenator heat exchanger and cardioplegia delivery system. The air bubble detector sensor may be placed on the line between the venous reservoir and systemic pump, between the pump and membrane oxygenator inlet, or between the oxygenator outlet and arterial filter (neither shown) or on the line after the arterial filter (optional position on drawing). One-way valves prevent retrograde flow (some circuits with a centrifugal pump also incorporate a one-way valve after the pump and within the systemic flow line). Other safety devices include an oxygen analyzer placed between the anesthetic vaporizer (if used) and the oxygenator gas inlet and a reservoir level sensor attached to the housing of the hard-shell venous reservoir (on the left center). Arrows, directions of flow; X, placement of tubing clamps; P and T (within circles), pressure and temperature sensors. Hemoconcentrator (described in text) not shown.

Cessation of CPB is accomplished by gradually decreasing pump flows, allowing for right heart filling, and gradually replenishing the circulating blood volume. Pulmonary and coronary vasodilators may be required during this phase, as there may be heightened vasoreactivity after periods of ischemia and hypothermia.

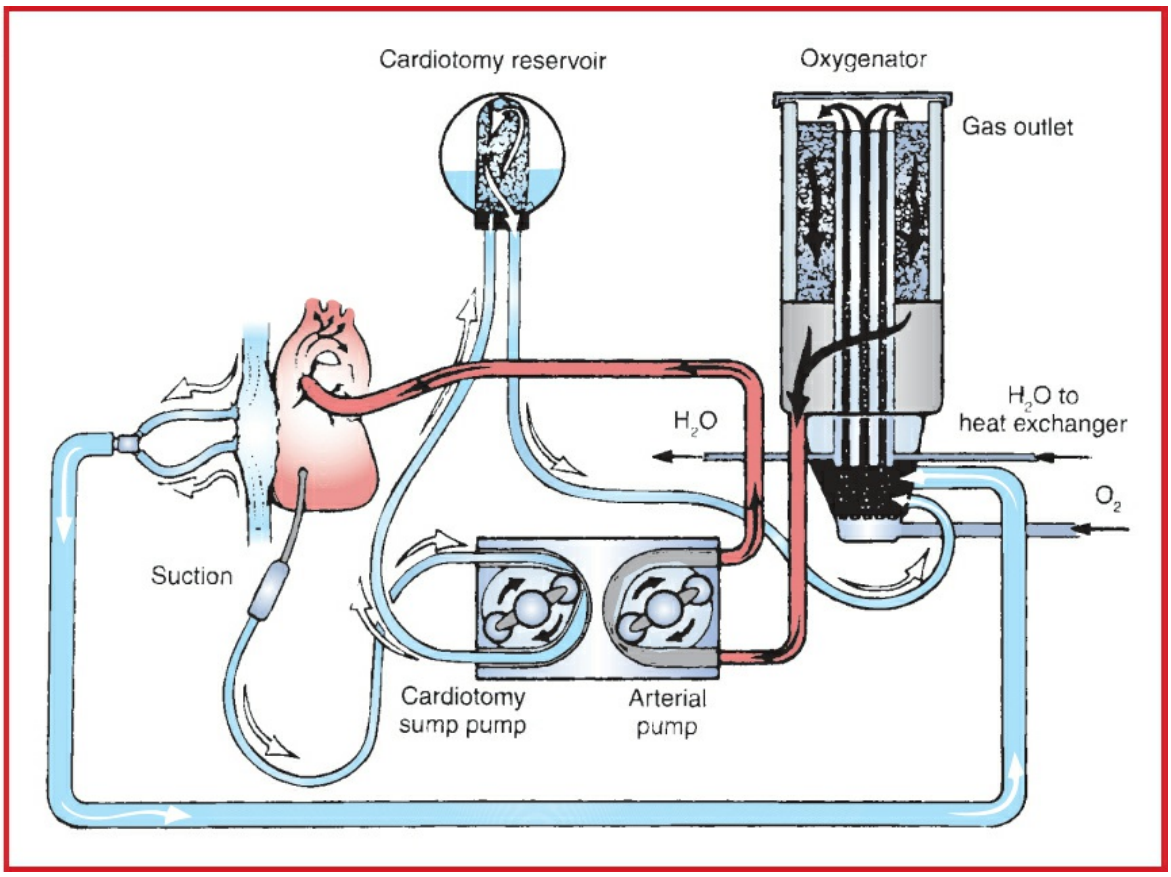

Figure 6.1-2 Schematic representation of the CPB circuit. (Reproduced with permission from Hardy JD: Hardy's Textbook of Surgery, 2nd edition. JB Lippincott, Philadelphia: 1988.)

Secondary effects of CPB demand special considerations during the final stages of the procedure and chest closure. Adverse effects on coagulation have already been mentioned, and vigorous attention to maintenance and replacement of coagulation factors is essential. The capillary leak phenomenon results in interstitial myocardial and pulmonary edema. Decreased myocardial performance and compliance mandate an increase in preload and inotropic support, especially during the physical act of chest closure, where a transient rise in intramediastinal pressure may depress systemic venous return. Similarly, decreased pulmonary compliance and gas exchange mandate control of inspiratory pressures and lung volumes during chest closure because mediastinal volume is physically decreased.

ANESTHETIC CONSIDERATIONS FOR CARDIOPULMONARY BYPASS

This segment is not meant to be a definitive text on CPB, but rather a guide to the anesthetic management of bypass. Communication among surgeons, anesthesiologists, and pump technicians is of vital importance in carrying out this procedure.

PREPARATION FOR BYPASS

Prebypass/anticoagulation	✓ baseline ACT (normal = 90–130 sec). Heparin (3 mg [~300 U]/kg) is administered via a central vein (✓ back-bleeding to verify intravascular position) or by the surgeon directly into the atrium (preferred). ✓ ACT 3 min after heparin. It is essential to ensure adequate anticoagulation (ACT = 400–500 sec, depending on whether CPB circuit is heparin-coated).
Aortic cannulation	Control MAP to ~70 mm Hg or SBP < 100 mm Hg for cannulation to ensure that the aortotomy does not extend. If needed, vasodilators may be used. The arterial line should be inspected for air bubbles.
Venous cannulation	Venous cannulation may be associated with atrial dysrhythmias. Blood loss can be excessive. Be prepared to infuse volume boluses, if necessary.
Pupils	Assess pupil symmetry for later comparison.

TRANSITION ONTO CPB

Stop ventilation	Commencing bypass is a dangerous period for the patient as a result of the many hemodynamic changes that occur. D/C ventilation once there is no pulmonary blood flow (as determined by nonpulsatile arterial line or pulmonary arterial catheter tracing).
Withdraw PA catheter	Withdraw PA catheter 4–5 cm to minimize pulmonary artery injury.
Stop infusions	Stop unnecessary iv infusions (typically inotropic agents) and reduce iv fluid infusions to KVO.
Anticoagulation	ACT should be rechecked after 5 min on CPB to ensure anticoagulation (ACT > 400 sec); this is typically performed by the perfusionist.

Oxygenation	Verify oxygenation by checking arterial inflow color and inline sensors and by ABG within 5 min of beginning CPB.
Flow	✓ for adequate venous drainage (CVP falls to a low level). Ensure adequate arterial inflow. Initial pressures may be very low due to acute hemodilution and release of inflammatory mediators, but usually will increase. View the descending thoracic aorta on TEE to verify flow (no aortic dissection).
Anesthesia	Anesthetics (e.g., fentanyl and midazolam) may be needed. A repeat dose (e.g., 50 mg of rocuronium) should be given to prevent movement or shivering (increases O_2 requirements).
Pupils	Assess pupils. Unilateral dilation may indicate arterial inflow into the innominate artery (unilateral carotid perfusion).

■ BYPASS PERIOD	
Anticoagulation	ACT levels should be checked regularly (q20–30min) and kept at >400. Add heparin (5000–10,000 U), if needed. This is typically performed by the perfusionist.
Pressure/flow	There is controversy about safe flows and pressures. Generally, flows of 1.2–3 L/m^2/min are used, with pressures of 30–80 mm Hg. A MAP of 50–60 mm Hg is generally accepted for adequate cerebral perfusion while preventing excessive noncoronary blood flow.
Acid-base status	α-stat (ABG measured and interpreted at 37°, regardless of actual patient temperature) regulation of acid-base status is preferred because of maintenance of normal cerebral flow and autoregulation on CPB (see Table 6.1-1).
Hct/electrolytes	Hematocrit generally decreases with CPB initiation and maintenance and is typically acceptable in most patients unless Hct < 25. Hyperkalemia is common and should be corrected prior to weaning off CPB. A

	K^+ ~4.5 mEq/L is desirable. Blood glucose levels should be monitored q1h. Treat blood glucose >160 mg/dL with iv regular insulin (see Table 6.1-2).
UO	Keep UO > 1 mL/kg/h. If needed, mannitol and/or furosemide should be given (assuming pump flow is adequate).
Temperature	During bypass, temperature is usually maintained between 28 and 34°C per surgeon preference and surgical procedure, unless PCHA is employed.

Table 6.1-1 Difference Between α-Stat and pH-Stat Management During CPB

α-Stat (Temperature-Uncorrected)	pH Stat (Temperature-Corrected)
Plasma pH maintained at 7.4 (when measured at 37°C)	Plasma pH maintained at 7.4 at actual patient temperature
Arterial PCO_2 maintained at 40 mm Hg (when measured at 37°C)	Arterial PCO_2 maintained at 40 mm Hg at actual patient temperature. Requires addition of CO_2 to inspired gases
Relative respiratory alkalosis during hypothermia	Relative normocapnia during hypothermia
Cerebral autoregulation preserved—CBF maintained	Results in loss of cerebral autoregulation

Table 6.1-2 Continuous Insulin Infusion in Intraoperative Adult Cardiac Surgery Patients

1. Bolus and start infusion pump as follows:

Blood Glucose	Insulin Bolus (U)	Insulin Drip (U/h)
<150	0	0

150–200	3	2
200–250	5	4
>250	BG/50	5
2. Frequency of blood glucose determination: every 60 min intraoperatively		
3. Insulin titration as follows:		
Blood Glucose	**Action**	
<120	Stop insulin; recheck blood glucose in 30 min. When blood glucose >150, restart with rate 50% of previous rate. If blood glucose <70 mg/dL, give D50W 25 g and recheck in 30 min	
120–150	No action	
150–175	Bolus dose 2 U, infusion 2 U/h	
175–200	Bolus dose 3 U, infusion 3 U/h	
200–225	Bolus dose 4 U, infusion 4 U/h	
225–250	Bolus dose 5 U, infusion 5 U/h	
>250	Bolus dose (BG/50), infusion 6 U/h	

TERMINATION OF BYPASS

Rewarming	Prior to discontinuing CPB, the patient should have a core temperature of at least 36°C.
Anesthesia/relaxation	Patient awareness may be a problem during rewarming. Volatile agents ± benzodiazepine (e.g., midazolam 3–5 mg) ± a narcotic to prevent awareness. In addition, a muscle relaxant also should be given.
Acid-base/electrolytes/Hct	✓ electrolytes, acid-base status, and Hct. Correct acidosis. K^+: 4.5–5.5, normal ionized Ca^{++}, and Hct ≥ 24 should be ensured.
Air maneuvers	Air maneuvers (to remove intracardiac and intra-aortic air) are carried out when the heart is opened.

	Ventilation is commenced after there is pulmonary blood flow and will aid in the evacuation of air. Pleural fluid should be removed.

WEANING FROM BYPASS

Prior to weaning	Prior to weaning from CPB, the aortic cross-clamp should have been off to allow rewarming and reperfusion of the heart. Reperfusion duration is typically determined by baseline cardiac function, surgical procedure, and duration of cross-clamp time. Defibrillation is often needed, and epicardial pacing may be required. NSR or AV pacing is preferred. Vasoactive drugs should be available. After normothermia, adequate ventilation, stable cardiac rhythm and function, and reperfusion are established, bypass may be terminated. The heart is gradually volume-loaded (transfused from oxygenator) to adequate filling pressures and bypass flow slowly decreased over 15–45 sec until it is off. Return to bypass may be needed in the event of progressive cardiac distension or dysfunction. Assess CO and BP and adjust vascular resistance as necessary. Inotropic agents often are required at this stage.
Reversal of anticoagulation	After the patient is off CPB, anticoagulation must be reversed with protamine (1–1.3 mg/100 U heparin), first given as a 10-mg test dose and then administered slowly over 10–20 min because rapid administration can be associated with ↓ BP (treat with volume, calcium, α-agonists as necessary). Other less common reactions include pulmonary HTN and true allergic reactions. ✓ ACT to ensure that it has returned to control (90–130 sec).
BP management	Vasoactive support often is needed in the postbypass period; the need varies with surgical procedure, disease process, and underlying cardiac function. In general, SBP should be limited to 120 mm Hg to avoid stress on the aortotomy site and to minimize surgical

	bleeding.
COAGULATION AND CPB	
General	Bleeding is common post-CPB and may be considerable. Both preop and intraop factors contribute to this. Knowledge of these factors and the tests involved will aid with the management of these patients (Table 6.1-3).
Preop factors	History of previous bleeding during surgery is important. Many drugs may contribute to bleeding: aspirin/NSAIDs/clopidogrel, anticoagulants (heparin, Coumadin), and fibrinolytic agents. These should be stopped preop, if possible, or their action reversed. Other pathologic processes (e.g., liver failure/congestion, renal failure, or hemophilia) also play a role. Preop testing is important and should include PT, PTT, platelet count, and bleeding time, as a minimum.
Intraop factors	CPB is associated with ↓ platelet count and function. Circulating clotting factors are decreased, and fibrinolysis occurs. Many surgical teams routinely use either aminocaproic acid (Amicar, 5- to10-g loading dose; 1 g/h, maintenance) or tranexamic acid (TXA, 10–30 mg/kg loading dose; 1–10 mg/kg/h maintenance) prophylactically during cardiac surgery to inhibit the fibrinolytic process.
Post-CPB bleeding	The common causes of post-CPB bleeding are surgical causes, inadequate heparin reversal, decreased platelet count and function, ↓ clotting factors, fibrinolysis, DIC, excessive blood pressure, and hypothermia. Surgical causes and inadequate heparin reversal (✓ ACT) should be ruled out. If no surgical cause is found and ACT is normal, platelets (1–2 plateletpheresis units) should be infused. PT, PTT, Plt count, and fibrinogen should be checked. TEG may prove very useful. (See Fig. 7.12-9 and Table 7.12-3 in liver/kidney transplantation.)

Table 6.1-3 A Treatment Plan for Excessive Bleeding After Cardiac Surgery

Action	Dosage	Indication
Rule out surgical cause	—	Oozing at puncture sites and incision
More protamine	0.5–1 mg/kg	ACT > 150 sec or aPTT > 1.5 times control
Warm the patient	—	"Core" temperature <35°C
Apply positive end-expiratory pressure (PEEP)* Desmopressin	5–10 cm H_2O 0.3 mcg/kg iv	Prolonged bleeding time
Aminocaproic acid	50 mg/kg, then 25 mg/kg/h	Elevated D-dimer or teardrop-shaped TEG tracing
Tranexamic acid	10 mg/kg, then 1 mg/kg/h	Elevated D-dimer or teardrop-shaped TEG tracing
Platelet transfusion	1 U/10 kg	Platelet count <100,000/mm^3
Fresh frozen plasma	15 mL/kg	PT or aPTT > 1.5 times control
Cryoprecipitate	1 U/4 kg	Fibrinogen <1 g/L or 100 mg/dL

*PEEP is contraindicated in hypovolemia.

Suggested Readings

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oxygenation and postoperative cognitive dysfunction among patients undergoing coronary artery bypass grafting randomised to surgery with or without cardiopulmonary bypass. Anaesthesia 2014; 69(6):613–22.
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7. Shaefi S, Mittel A, Klick J, et al: Vasoplegia after cardiovascular procedures-pathophysiology and targeted therapy. J Cardiothorac Vasc Anesth 2018; 32(2):1013–22.

CORONARY ARTERY BYPASS GRAFT SURGERY

SURGICAL CONSIDERATIONS

Description

Coronary artery bypass grafting (CABG) is the most frequently performed cardiac operation. Since the discovery that coronary thrombosis is the causative event for MI, many schemes have been devised to augment the restricted coronary blood flow, including collateral pericardial blood flow to epicardial arteries and implantation of the internal mammary artery (IMA) with unligated side branches into the LV muscle. With the discovery by Favalaro that saphenous veins can be anastomosed to the epicardial coronary arteries, a new era of myocardial revascularization began. Basically, the technique involves bypass to a narrowed or occluded epicardial coronary >1 mm in diameter with a small-diameter conduit (usually reversed saphenous vein or IMA) distal to the narrowed segment, with the proximal arterial inflow source being the ascending aorta. The IMA may be mobilized from the chest wall, leaving its proximal origin with the subclavian artery intact (pedicled graft), or the IMA may be transected and its proximal end anastomosed to the aorta or saphenous vein as a "free mammary graft." An "**all-arterial revascularization,**" using the left and right IMA and nondominant radial artery, is being utilized with increasing frequency, while other arterial conduits including the left gastroepiploic artery and superficial epigastric artery are being studied.

The heart is approached through a median sternotomy, with the patient typically supported on full **CPB** (see separate section on CPB). Although other operative strategies may be used—including full CPB support without cardiac arrest (on-pump beating heart) and no CPB support (off pump)—the most common regimen is for all distal (epicardial) anastomoses to be performed during a single period of aortic cross-

clamping and cardiac arrest. During that period of induced asystole, myocardial protection is achieved by hypothermia and occasional reperfusion via antegrade or retrograde cardioplegia. Cardiac standstill and a bloodless field are necessary when small-diameter anastomoses are to be constructed, with no obstruction to flow, in a minimal amount of time. The cross-clamp is then removed and the heart allowed to resume beating. A partially occluding aortic cross-clamp can then be applied to allow construction of the proximal aortic anastomoses. After a sufficient period of resuscitation, the patient is weaned from CPB, and decannulation, heparin reversal, and chest closure are allowed to proceed as previously noted.

The choice of conduit depends on availability and durability. Historically, the saphenous vein was the first small vessel conduit with acceptable patency, but with prolonged experience it appears that 50% of vein grafts will be significantly diseased or occluded at 10 yr. The IMA appears to have superior long-term performance with ~90% 10-yr patency rates. Other arterial conduits, such as the left gastroepiploic artery, superficial epigastric artery, and the radial artery, are being studied for long- and short-term durability. Typical target arteries include the distal right coronary and its major terminal branch and the posterior descending artery. From the left circulation, the left anterior descending (LAD), with its diagonal and septal branches, is the most important, having been estimated to supply blood to 60% of the left ventricle.

The left circumflex coronary artery courses in the posterior atrioventricular groove and is not easily accessible for bypass, which is usually performed to its obtuse marginal or posterolateral branches.

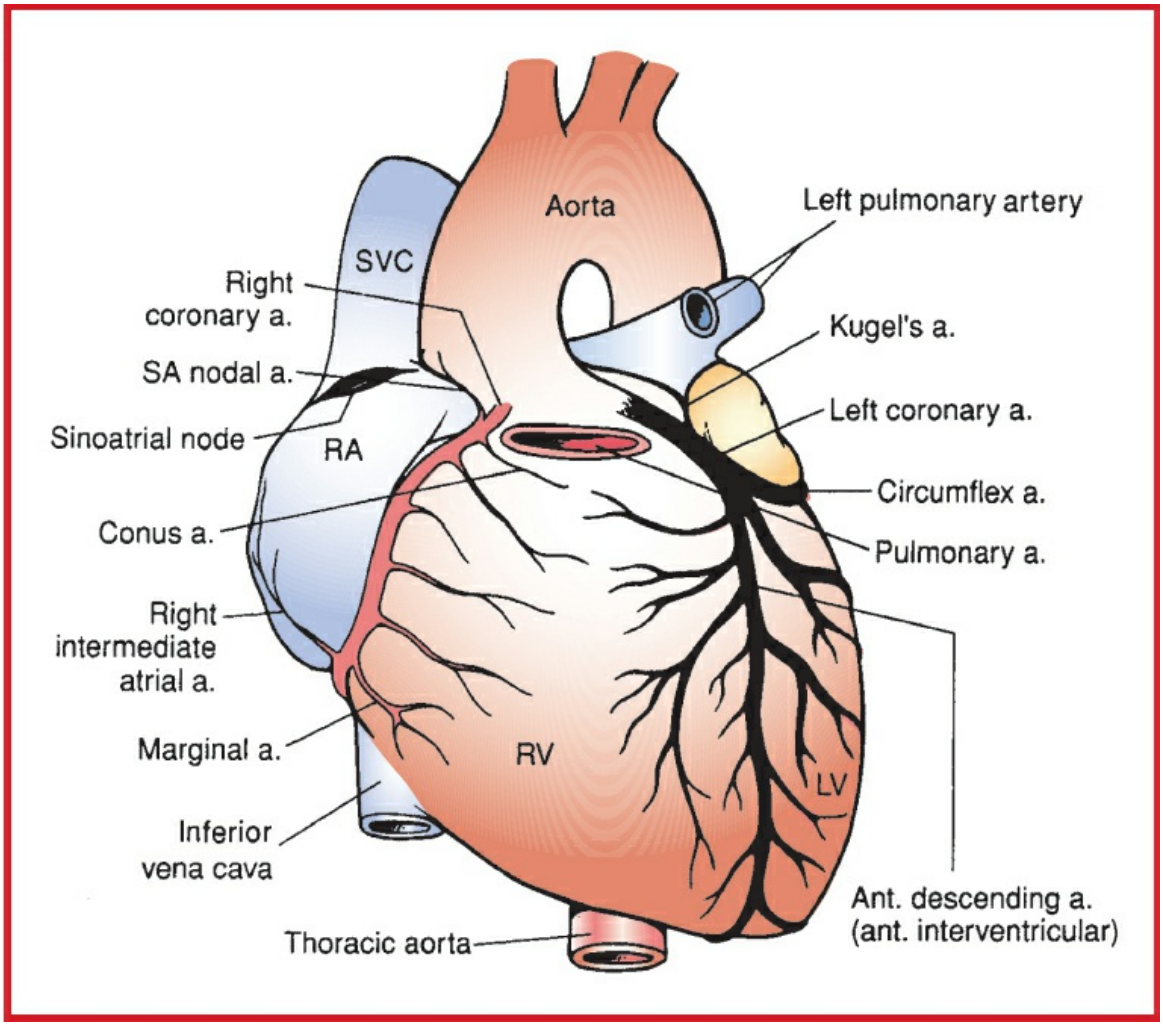

Figure 6.1-3 Coronary artery circulation—anterior view. (Reproduced with permission from Edwards EA, Malone PD, Collins JJ Jr: Operative Anatomy of the Thorax. Lea & Febiger, Philadelphia: 1972.)

In a randomized study on coronary artery surgery (CASS), coronary bypass was noted to be superior to medical management for relief of angina and to prolong life in patients with left main CAD and in those with three-vessel disease and impaired LV function. Other patients may receive bypass for intractable angina refractory to medical management.

Variant procedure or approaches

Port-access coronary artery revascularization; **off-pump,** on-pump without cardiac arrest; **and minimally invasive coronary artery bypass**

Usual preop diagnosis

CAD with class 3 or 4 angina (angina with minimal exertion or at rest)

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist

should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, possible need for a chest tube and postop mechanical ventilation, and physiotherapy plan. See Appendix K: Enhanced Recovery After Surgery, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Median sternotomy with legs prepped for saphenous vein harvest
Special instrumentation	Complete hemodynamic monitoring; TEE
Unique considerations	CPB
Antibiotics	Cefazolin 2 g iv prior to incision and then 2 g q4h (3 g if BW >120 kg)
Surgical time	3.5–4.5 h
Closing considerations	Prevention of coagulopathy; maintenance of preload
EBL	500–600 mL
Postop care	ICU: 1–3 d, intubated 6–24 h
Mortality	2–4%
Morbidity	Cognitive decline in patients >60 yr, 26%; MI, 3–6%; pneumonia, 5%; CVA/stroke, 2–4% ↓ renal function
Pain score	7–8

PATIENT POPULATION CHARACTERISTICS	
Age range	60–80 yr (mean = 74 yr)
Male:Female	2:1
Incidence	Common
Etiology	Coronary atherosclerosis
Associated	LV/RV failure; pulmonary HTN; ischemic mitral

conditions	regurgitation; diabetes mellitus; obstructive pulmonary disease

ANESTHETIC CONSIDERATIONS

(Procedures covered: CABG; LV aneurysmectomy)

PREOPERATIVE

H&P and tests will divide these patients broadly into two groups: (a) high-risk, characterized by poor LV function (cardiac failure; EF < 40%; LVEDP > 18 mm Hg; C < 2.0 L/min/m^2; ventricular dyskinesia; three-vessel disease; occlusion of left main or left main equivalent; valvular disease; recent MI; ventricular aneurysm; VSD; MI i progress; and old age), and (b) low-risk, characterized by good LV function. The type of monitoring chosen will depend on the patient's group.

Respiratory	Hx of smoking or COPD—patient should be encouraged to stop smoking at least 2 wk before surgery. Treat COPD and optimize therapy before surgery. **Tests:** CXR; PFTs; as indicated by H&P
Cardiovascular	In the preop assessment, the following factors will affect patient management and surgical outcome: • Hx of angina (stable, unstable at rest, and precipitating factors) • Patient's exercise tolerance will provide a clue to LV function and surgical outcome. • The presence of CHF (Sx: SOB, PND, orthopnea, DOE, pulmonary edema, JVD, third-heart sound). • Recent (<6 mo) MI, dysrhythmias, HTN, and vascular disease (particularly carotid stenosis, aortic disease) • Valvular disease (particularly MR or AS) or the presence of a VSD or LV aneurysm may imply increased risk of periop complications. **Tests:** 12-lead ECG: ✓ ischemia (area involved), LVH, previous MI, dysrhythmias. Exercise stress testing: ✓ exercise tolerance, area of ischemia, maximal HR and BP before ischemia occurs,

	dysrhythmias. Thallium scan: ✓ component of reversible ischemia. ECHO (may be combined with stress ECHO): ✓ LV function, wall motion abnormalities, valvular disease, VSD. Cardiac catheterization: ✓ extent and location of disease, LV function, valvular pathology, VSD, LVEDP, LV aneurysm
Postinfarction VSD	The development of a postinfarction VSD is associated with high operative morbidity and mortality because of the difficulty in repairing the lesion due to friable tissue, difficulty in obtaining hemostasis, emergent nature of the condition, and possible pulmonary edema. These patients effectively have poor LV function and should be considered as high-risk patients. They often require support, including IABP, during induction, prebypass, and postbypass.
LV aneurysm	LV aneurysm is usually a late complication of infarction; however, it can occur early, when it usually is associated with cardiac rupture (and high mortality). These patients usually have poor myocardial function and should be anesthetized with full monitoring, including PA catheterization. Postbypass, the LV cavity is reduced in size and compliance. To ensure an adequate CO, maintain adequate preload, a higher than normal HR (A-V pacing if needed), and sinus rhythm, and consider the use of inotropes. LV aneurysms are often associated with dysrhythmias and may require cardiac mapping. Hemostasis is often difficult to obtain, and adequate iv access is a necessity. Treatment usually entails the use of blood products.
Emergency revascularization	Emergency revascularization occurs in the setting of acute MI, often with acute LV failure or after failed PTCA, where the patient may be stable, suffering from acute ischemia and hemodynamically unstable, or even in full cardiac arrest. Factors to consider in

	these cases are full stomach (and the need for rapid-sequence induction in the face of ischemia), prior use of fibrinolytic agents (with increased risk of hemorrhage), need for inotropes, antianginals, IABP, and dysrhythmias. These patients have a higher morbidity and mortality. In patients who have received fibrinolytic agents, consider postbypass use of antifibrinolytic agents (e.g., aminocaproic acid and tranexamic acid).
Neurologic	Previous stroke or Hx/Sx of carotid artery disease should be documented and evaluated.
Endocrine	Diabetes is common and periop control of blood glucose is important. **Tests:** Blood glucose
Renal	✓ baseline renal function, as CPB places these patients at risk for renal failure. **Tests:** Cr; BUN; electrolytes (particularly K^+)
Hematologic	Patients are often on aspirin or other antiplatelet therapy, which may lead to increased intraop hemorrhage. These agents should be stopped 7–10 d before surgery, if possible. Some patients may be on anticoagulants (usually heparin in the immediate preop period). Heparin should be stopped 6–8 h preop; however, in some patients, heparin infusion is continued into the OR. Other patients may have received thrombolytic agents that put them at increased risk for intraop hemorrhage. **Tests:** Consider Plt count, Plt function mapping, and PTT, if indicated.
Laboratory	Hb/Hct; other tests as indicated from H&P. T&C 2–4 U PRBCs
Premedication	Patients should be instructed to continue all medications (e.g., nitrates, β-blockers; Ca^{++} antagonists, antidysrhythmics, and antihypertensives with the exception of ACEi, ARBs, and diuretics on the day of surgery. Allaying anxiety may decrease

	the incidence of periop ischemia and help with the preinduction placement of lines. If necessary, preop sedation may include diazepam (10 mg po) or lorazepam (1–2 mg po) the night before and again 1–2 h before arrival in the OR with the addition of morphine (0.1 mg/kg im) and scopolamine (0.3 mg im). Most often, midazolam (1–5 mg iv) immediately prior to OR is used. Severely compromised patients will require less premedication.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of thoracic epidural, continuous paravertebral, or chest wall nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: An arterial line should be inserted, using liberal amounts of local anesthetic, before induction. The presence of real-time BP monitoring can be critical in the care of these patients, especially during induction. Although it is helpful to have a CVP line before induction for preload monitoring and drug infusion, it is not essential. This line usually is inserted after the patient is intubated. If infused drugs are necessary before the CVP catheter is in place, they can be administered through a separate peripheral iv.

Induction	Generally, a moderate- to high-dose narcotic technique (e.g., fentanyl 100–500 mcg or sufentanil 10–50 mcg), supplemented by propofol (0.5–1.5 mg/kg), etomidate (0.1–0.3 mg/kg), or midazolam (50–350 mcg/kg), is appropriate. As with all cardiac cases, the speed of induction and total drug dose depend on the patient's cardiac function and pathology. Muscle relaxation may be obtained using

	rocuronium (0.6–1 mg/kg) or vecuronium (possibility of bradycardia, especially if the patient is β-blocked). It is important to avoid the sympathetic response to laryngoscopy. The use of high-dose narcotics (see above), esmolol (100–500 mcg/kg over 1 min, followed by 40–100 mcg/kg/min infusion), SNP (0.5–3 mcg/kg/min), lidocaine (1–2 mg/kg), or a combination of these agents may decrease or ablate this response. NTG (0.5–2 mcg/kg/min) also may be used during induction if evidence of ischemia occurs.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider placement of parasternal or chest wall nerve blocks if preop blocks have not been placed. Ketamine (0.5 mg/kg iv) at induction may improve pain management and reduce delirium after CPB.	
Maintenance	Usually, narcotic (total: fentanyl 10–20 mcg/kg or sufentanil 2–5 mcg/kg) with midazolam (2–5 mg) for amnesia. Patients with good LV function may benefit from the decreased myocardial O_2 demand associated with the use of volatile agents (2° ↓ contractility). N_2O is generally avoided. Propofol infusion may be used while rewarming and postbypass. Recommend the use of antifibrinolytics for all cases requiring CPB.	
Emergence	Transported to ICU, sedated, intubated, and ventilated. Extubate when able—often <6 h if lower-dose narcotic technique used (fast-track). Discuss with surgeon local wound infiltration or chest wall nerve block (e.g., via prefascial plane catheter) placement. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 14 ga × 1–2 BSS at 6–8 mL/kg/h	See Goal-Directed Fluid Management, Appendix

	UO 0.5–1 mL/kg/h Warm all fluids. Humidify gases.	K, p. K-4.
Monitoring	Standard monitors	Standard monitors and an A-line are placed before induction.
	Arterial line	✓ BP in both arms. Ensure placement in contralateral arm if radial artery harvest to be performed for grafting.
	CVP or PA catheter	CVP (and/or PA line, if indicated) usually is placed after intubation. In the low-risk/good LV function group, CVP is adequate; in high-risk/poor LV function, a PA catheter is useful for hemodynamic monitoring, weaning from bypass, and vasoactive therapy. Some groups use routine PA catheterization for all patients undergoing CABG surgery.
	ECG	Five-lead monitoring using leads II and V_5 (or area most at risk for ischemia)
	TEE	Will reflect regional wall motion abnormalities, papillary muscle dysfunction, and MR
Myocardial O_2 balance	Supply—coronary blood flow: Perfusion pressure	The balance of myocardial O_2 supply vs. demand is important in

	(DBP-LVEDP) Diastolic filling time (HR) blood viscosity (optimal Hct = 30) Coronary vasoconstriction: Spasm $PaCO_2$ (hypocapnia →constriction) α-sympathetic activity Supply—O_2 delivery: O_2 sat Hct Oxyhemoglobin dissociation curve Demand—O_2 consumption: BP (afterload) Ventricular volume (preload) Wall thickness (↓ subendocardial perfusion) HR Contractility	the management of these patients. The goal of anesthesia is to ensure that this balance remains in equilibrium and that no ischemia occurs, or, if it does, that it is treated promptly. Those patients with poor LV function or complicated disease will benefit from maintenance of contractility (avoid volatile agents) and a high FiO_2, whereas those with good LV function may benefit from mild cardiac depression (↓ demand associated with the addition of low-dose volatile agents). Certain events are associated with **increased risk of intraop ischemia:** intubation, incision, sternotomy, cannulation, tachycardia, ↑ BP or ↓ BP, ventricular fibrillation or distension, inadequate cardioplegia, emboli, spasm, or inadequate revascularization. Care should be taken to avoid these complications and to ablate responses to stimuli.
Detection of ischemia	ECG	ST segment depression or elevation or a new T-wave alteration may

		suggest ischemia. Monitoring two leads—one lateral (e.g., V_5) and one inferior (e.g., II)—gives the best detection rate.
	PA catheter	Elevations of PCWP may be indicative of ischemia. A new V-wave on the PCWP trace is a better sign of possible ischemia (papillary muscle dysfunction).
	TEE	The appearance of a new regional wall motion abnormality is the most sensitive indicator of ischemia, but it requires constant monitoring. The transgastric LV midpapillary short-axis view allows for monitoring of walls supplied by all coronary arteries.
Treatment of ischemia	Caused by tachycardia: Esmolol (100–500 mcg/kg) ↑ anesthesia Verapamil (2.5–10 mg iv) Caused by ↑ BP: NTG (0.5–4 mcg/kg/min); ↑ anesthesia Caused by ↓ BP: Phenylephrine (0.2–	Although avoidance of ischemia is the goal, when it does occur, it should be treated aggressively. Treatment may include inotropic support (e.g., dopamine 1–5 mcg/kg/min, epinephrine 25–150 ng/kg/min, or milrinone 0.375–0.75 mcg/kg/min). If LV failure persists

	0.75 mcg/kg/min) ↑ preload Caused by ↓ ↓ HR: A-V pacing	despite other therapy, an IABP or VAD may be inserted. ECMO initiation may also be considered.
Positioning	✓ and pad pressure points ✓ eyes	

POSTOPERATIVE

Complications	Infarction Ischemia Tamponade Dysrhythmias Cardiac failure Coagulopathy Hemorrhage	Postop control of ischemia is important because hemodynamic instability may be associated with inadequate pain relief, awakening, and ventilation.
Multimodal pain management	Limit opioids	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	If postop sedation is required, dexmedetomidine may be preferable to propofol. Encourage fast track extubation, early enteral nutrition, Foley catheter removal, and mobilization.
Tests	ECG CPK CXR	

Electrolytes
ABG
Coag profiles

Suggested Readings

1. Barry AE, Chaney MA, London MJ. Anesthetic management during cardiopulmonar bypass: a systematic review. Anesth Analg. 2015 Apr;120(4):749–69.
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8. Wong WT, Lai VK, Chee YE, et al: Fast-track cardiac care for adult cardiac surgica patients. Cochrane Database Syst Rev 2016; 9:CD003587.

LEFT VENTRICULAR ANEURYSMECTOMY

SURGICAL CONSIDERATIONS

Description

Extensive MI may → large areas of myocardial necrosis, with subsequent aneurysm formation. LV failure may ensue as a result of continuous LV dilation or mitral insufficiency 2° annular dilation or involvement of papillary muscles. Indications for this surgery include worsening CHF and increased dysrhythmias.

Typically, apical dilation with maintenance of basilar myocardial contractility allows for aneurysm resection and preservation of both myocardial contractility and chamber size to produce an adequate CO. Operation is commenced in the usual manner—by

establishing CPB, cross-clamping the aorta, establishing myocardial protection, and then assessing the left ventricle. A thinned, dilated ventricular segment with full-thickness scar formation can be resected and ventricular continuity restored with improvement of ventricular geometry and myocardial energy demands. Coronary bypass can be performed during this same period. Then, air is removed from the left side of the heart, the cross-clamp is removed, and coronary perfusion is reestablished. After a sufficient period of resuscitation and return of vigorous contractility, bypass is D/C'd, not infrequently with the assistance of intra-aortic balloon pump (IABP) to augmen forward output. Decannulation, protamine administration, and closure proceed as described in CPB.

Usual preop diagnosis

LV aneurysm with CHF

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, possible need for a chest tube and postop mechanical ventilation, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Median sternotomy, ± leg incision for saphenous vein harvest if coronary bypass is planned
Unique considerations	Preparations (ECG leads) should be made for pre- or postop IABP or LV assist device (LVAD).
Antibiotics	Cefazolin 2 g iv prior to incision and then 2 g q4h (3 g if BW > 120 kg)
Surgical time	Aortic cross-clamp: 40–100 min CPB: 70–130 min Total: 3–4 h
EBL	300–400 mL
Postop care	ICU × 1–3 d, intubated 6–24 h; usually requires inotropic support ± mechanical support (LVAD, IABP)

Mortality	5–7%
Morbidity	Overall: 8–10% Requirement for IABP: 10% Respiratory insufficiency: 5% CVA: 2–3%
Pain score	7–10

PATIENT POPULATION CHARACTERISTICS	
Age range	50–70 yr
Male:Female	3:1
Incidence	Uncommon
Etiology	Usually the end result of MI 2° CAD
Associated conditions	Mitral insufficiency; pulmonary HTN; CAD

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations Following Coronary Artery Bypass Graft Surgery.

Suggested Reading

1. Ruzza A, Czer LSC, Arabia F, et al: Left ventricular reconstruction for postinfarctio left ventricular aneurysm: review of surgical techniques. Tex Heart Inst J 2017; 44(5):326–35.

AORTIC VALVE REPLACEMENT

SURGICAL CONSIDERATIONS

Description

Disease of the aortic valve may present as valvular stenosis, insufficiency, or a combination of the two. Valvular disease may occur as a result of rheumatic disease, but also may occur 2° to calcific degeneration (aortic sclerosis) in the elderly. Congenitally bicuspid valves and endocarditis account for most of the remainder. Repair of the aortic valve is occasionally possible, but most conditions require valve replacement. The

three most commonly used **prostheses** are porcine bioprosthesis, especially in the older patient; mechanical prostheses with the necessity for lifelong anticoagulation; and cryopreserved homografts, which, unfortunately, are expensive and in short supply. The operation, on full CPB, usually is performed through a median sternotomy. After routine venous and aortic cannulation, the patient is taken onto full CPB. Left heart drainage may be accomplished via a vent placed in the pulmonary artery, left atrium, or left ventricle. Because LV hypertrophy is a common sequela of aortic stenosis, myocardial protection is of utmost importance. Most centers favor hyperkalemic, hypothermic cardioplegic arrest, augmented by topical cooling, using either a continuous infusion of cold saline into the pericardial well or a cooling jacket. Cardioplegic administration can be achieved either antegrade into the coronary ostia or retrograde via the coronary sinus. Myocardial temperature is monitored continuously.

After the heart is arrested, the aorta is opened to expose the aortic valve. Continuous insufflation of the operative field with CO_2 reduces the amount of dislodged or trapped air. The rheumatic, stenotic valve, including aortic annulus, is frequently heavily calcified, and all Ca^{++} must be debrided to allow the prosthetic valve to be securely seated. This is frequently a tedious and time-consuming procedure, but one that then allows the remainder of the procedure to proceed in a timely fashion. After excision of the valve leaflets and debridement of the annulus, ensuring that no particulate debris embolizes into the ventricle or coronary arteries, the annulus is measured to ensure a proper match between prosthetic valve and annulus, and an appropriate valve prosthesis is selected. Interrupted sutures are placed through the annulus for its entire circumference and then passed through the sewing ring of the prosthesis. The prosthesis is lowered into the annulus and securely tied in place. Proper sizing and positioning are mandatory to prevent paravalvular leaks or impingement on the coronary ostia. Systemic rewarming is initiated during the final stages of the valve implantation, and the LV is allowed to fill during aortic closure. With the patient in the head-down position, all remaining air is vented from the left heart and aorta, and the cross-clamp is removed to allow resumption of myocardial perfusion. The heart is allowed to recover from this period of ischemia, and after sufficient resuscitation, with continuous venting of air from the aorta, the patient is weaned from CPB. Vasodilators are frequently utilized, as there may be excessive vasospasm present in both the coronary and pulmonary circulations after hypothermia. Decannulation and heparin reversal with protamine are then accomplished in the routine manner.

Alternative procedures: Percutaneous, transcatheter procedures for aortic valve repair/replacement are discussed below and on p. 403.

Usual preop diagnosis

Severe AS with syncope, chest pain, or CHF; aortic insufficiency with CHF

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, possible need for a chest tube and postop mechanical ventilation, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Valve Replacement with Prosthesis	Homograft Valve Replacement
Position	Supine	⇐
Incision	Median sternotomy	⇐
Special instrumentation	TEE; hemodynamic monitoring; CPB	TEE or surface ECHO
Unique considerations	ECHO assessment of valve function and regional wall motion intraop	ECHO assessment of annular size and intraop evaluation of valve function after implantation
Antibiotics	Cefazolin 2 g iv prior to incision and 2 g q4h	⇐
Surgical time	Aortic cross-clamp: 45 min CPB: 90 min Total: 3 h	60 min 105 min ⇐
EBL	300–400 mL	⇐
Postop care	ICU: 1–3 d, intubated 6–24 h; hypertrophied, noncompliant LV requiring high preload	⇐
Mortality	5–8%	⇐
Morbidity	Pneumonia: 5–10% Neurologic sequela:	⇐

	Transient: 3–7% CVA: 1–2% Permanent: 1–2% Infection: 1%	⇐
Pain score	7–10	7–10

PATIENT POPULATION CHARACTERISTICS

Age range	Bicuspid valves, 50–60 yr; rheumatic, 55–80 yr (mean = 58 ± 13 yr)
Male:Female	3:1
Incidence	70–100 cases/yr in tertiary care center
Etiology	Postrheumatic (majority of patients worldwide); aortic sclerosis (most common in the United States); progressive stenosis of a bicuspid aortic valve; endocarditis
Associated conditions	Poststenotic dilation of the ascending aorta (may require separate surgical attention); rheumatic mitral valvular involvement; CAD; CHF

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Respiratory	Respiratory compromise may occur 2° pulmonary congestion (LV failure) and pleural effusion. An effusion, if significant, should be drained prior to surgery, as it may impair oxygenation and, with IPPV, may impair venous return →↓ CO + ↓ myocardial perfusion. **Test:** CXR
Cardiovascular	**Aortic stenosis (AS):** Sx are those of angina pectoris (if at rest may indicate concurrent CAD), syncope, and CHF (indicates severe disease with 2-yr life expectancy). The ejection murmur of AS is best heard at the 2nd right interspace. ECG shows LVH. Important points in the preop investigations include:

- Aortic orifice size: severe AS = 0.7–0.9 cm^2; critical AS ≤ 0.5 cm^2 (normal = 2.6–3.5 cm^2)
- Peak aortic valvular gradient: severe ≥ 70 mm Hg
- Ejection fraction (EF): ↓ EF indicates evidence of LV failure (normal ≥ 0.6).
- Coronary angiography: associated CAD often demonstrated. AS → ↑ LV work (↑ pressure load) → LV concentric hypertrophy → ↑ LV diastolic dysfunction + ↑ risk for ischemia (MVO_2 + O_2 supply).
- Reliance on atrial "kick:" important to maintain NSR. • Sensitivity to changes in SVR: ↓ SVR → ↓↓ BP → ↓ myocardial perfusion + ↓ CO → ↓↓↓ BP.
- Sensitivity to volume changes: hypovolemia → ↓ preload → ↓ ↓ CO.
- Sensitivity to rate changes: tachycardia → ↓ ejection time → ↓ myocardial perfusion.
- LV wall tension + ↑ duration of systole → ↑ MVO_2.
- ↑ LVEDP + ↑ wall thickness and tension + ↓ diastolic aortic pressure → ↓ O_2 supply.

Aortic regurgitation (AR): Sx include DOE, orthopnea, PND, palpitations, and (less frequently) angina. Exercise tolerance may remain reasonably good, even with severe chronic AR. Acute AR is very poorly tolerated. The pandiastolic murmur of AR is loudest over the sternum and left lower sternal border. AR → chronic LV volume overload → LV eccentric hypertrophy → massive cardiomegaly → LV failure (CHF) → ↑ LVEDP → ↑ PA pressure, and pulmonary congestion.

- Possibility of ischemia: ↑ MVO_2 and ↓ supply (↓ diastolic pressure, ↑ HR).
- Sensitivity to rate changes: ↓ HR → ↑ AR + ↓ CO.
- Sensitivity to changes in SVR: ↑ SVR → ↑ regurgitation + ↓ CO.

Tests: ECG: ✓ hypertrophy, LV strain, ischemia, rhythm. ECHO: ✓ LV function, valve area, regurgitant fraction. Angiography: ✓ LV function, right heart pressure, CAD, valve area, regurgitant

	fraction
Hepatic	CHF may result in passive liver congestion with ↓ liver function and possible coagulopathy. **Tests:** LFTs; PT; PTT
Neurologic	Syncopal episodes may have resulted in neurologic deficits. These should be well documented.
Renal	Prerenal failure often is associated with AR 2° ↓ CO. **Tests:** BUN; Cr, creatinine clearance, if indicated; electrolytes
Hematologic	**Tests:** Hb/Hct; clotting profile to investigate abnormalities. T&C for 4 U PRBCs
Laboratory	✓ digitalis level and electrolytes; other tests as indicated from H&P
Premedication	Beware of oversedation in patients with AS where ↓ BP could be detrimental. Light premedication with an anxiolytic is usually sufficient. Digitalis and diuretics should be continued.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of thoracic epidural, continuous paravertebral, or chest wall nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: A preinduction arterial line should be inserted, using liberal amounts of local anesthetic. The presence of real-time BP monitoring can be critical in the care of these patients, especially during induction. Although it is helpful to have a CVP line before induction for preload monitoring and drug infusion, it is not essential. This line usually is inserted after the patient is intubated. If infused drugs are necessary before the CVP catheter is in place, they can be administered through a separate peripheral iv.

Induction	**AS:** Typically, O_2 with moderate- to high-dose narcotic (e.g., fentanyl 5–10 mcg/kg). Avoid sufentanil in AS because of ↓ BP. Etomidate (0.1–0.3 mg/kg) and midazolam (50–350 mcg/kg) may be used to supplement the above. Paralysis with vecuronium or rocuronium. Induction is a critical period. CPB and surgeons should be available and ready to proceed. Danger is hypotension with a cycle of ischemia, further hypotension, and more ischemia. Hypotension should be treated aggressively with fluid and α-adrenergic agonists (phenylephrine 50–100 mcg iv bolus, infusion 0.1–0.75 mcg/kg/min). Critical AS patients may benefit from the use of phenylephrine as an infusion during induction and prebypass. The avoidance of hypotension is even more critical in the presence of CAD. Drugs causing tachycardia should be avoided. Atrial fibrillation (AF) or SVT should be treated with cardioversion. β-Blockers and other negative inotropes are generally contraindicated. Ventricular irritability should be treated early as ventricular fibrillation may be refractory to defibrillation. Beware of vasodilators, including NTG. **AR:** Again, O_2 with moderate- to high-dose narcotic (e.g., fentanyl 5–10 mcg/kg or sufentanil 2.5–10 mcg/kg). Etomidate (0.1–0.3 mg/kg) or benzodiazepines (e.g., midazolam 50–350 mcg/kg) may be used to supplement the opiates. Muscle relaxation with rocuronium (0.6 mg/kg) or vecuronium (0.1 mg/kg). These patients benefit from fluid augmentation, high normal HR (90 bpm) with afterload reduction (e.g., SNP 0.25–2 mcg/kg/min) to improve forward flow.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider placement of parasternal or chest wall nerve blocks if preop blocks have not been placed. Ketamine (0.5 mg/kg iv) at induction may improve pain management and reduce delirium after CPB.
Maintenance	Narcotic (e.g., total fentanyl 10–20 mcg/kg). Low-dose

	volatile agent/air/O_2. Relaxant. (See Anesthetic Considerations for CPB.) Recommend use of antifibrinolytics for all cases requiring CPB. The following table summarizes the goals of intraop management:

Parameter	AS	AR
LV preload	↑	Normal-to-↑
HR	Normal-to-slow ↓	Modest ↑
Rhythm	NSR	NSR
Contractility	Maintain	Maintain
SVR	Modest ↑	↓
PVR	Maintain	Maintain

Postbypass	**AS:** Postbypass, patients may be hyperdynamic and require vasodilators for HTN, although inotropes also may be needed. Because of the hypertrophied, noncompliant ventricle, filling pressure may be higher than normally required. **AR:** In the immediate postbypass period, patients with AR may require inotropic support (e.g., dopamine 3–10 mcg/kg/min, dobutamine 5–10 mcg/kg/min, epinephrine 25–100 ng/kg/min). Maintain LV filling. Other supportive measures (e.g., IABP) may be necessary.
Emergence	Transport to ICU sedated, intubated (6–24 h), and ventilated. Early extubation may be possible if a lower-dose narcotic technique is used (fast-track). Discuss with surgeon local wound infiltration or chest wall nerve block (e.g., via prefascial plane catheter) placement. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.
Blood and fluid requirements	IV: 14 ga × 1–2 BSS at 6–8 mL/kg/h UO 0.5–1 mL/kg/h Warm all fluids. Humidify gases. T&C 2–4 U blood See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors Standard monitors and arterial line

	Arterial line CVP line PA catheter ECG TEE Urinary catheter	should be placed before induction. CVP (and/or PA line, if indicated) usually is placed after intubation. CVP may underestimate left-side pressures. In acute AR, PCWP may underestimate true LVEDP. V_5 lead should be monitored for ischemia. TEE may be useful to estimate LV filling and regional wall motion abnormalities.
Positioning	✓ and pad pressure points ✓ eyes	

POSTOPERATIVE

Complications	Hemorrhage Tamponade Cardiac failure Dysrhythmias Ischemia	Inotropic and vasodilator therapy usually is continued into the postop period and then weaned.
Multimodal pain management	Limit opioids	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	If postop sedation is required, dexmedetomidine may be preferable to propofol. Encourage fast-track extubation, early enteral nutrition, Foley catheter removal, and mobilization.

Tests	ECG CXR Electrolytes Coag profile Hct

MINIMALLY INVASIVE AORTIC VALVE PROCEDURES (ALSO SEE P. 440)

SURGICAL CONSIDERATIONS

Description

Perhaps, the most significant advance in valve replacement surgery was the development of transcatheter aortic valve replacement/transcatheter aortic valve implantation (TAVR/TAVI), in which a biologic valve is attached to a metallic stent. The replacement valve can then be delivered transarterially into the aortic root, where the stenotic aortic valve can be balloon dilated, and the TAVR valve positioned carefully within the aortic annulus. The stent is then expanded, deploying the valve in proper position within the stenotic native valve. Initially utilized for the elderly, frail, and high surgical risk patients, TAVR/TAVI is being widely adopted for lower-risk patients, as the avoidance of a median sternotomy is attractive to both cardiologists and patients.

These procedures are often performed in hybrid surgical suites suitable for performing an open surgical aortic valve replacement (SAVR), which may become necessary for the TAVR/TAVI gone awry. Initially, TAVR procedures were performed under GETA, with full cardiac monitoring including arterial line, PA catheter and TEE monitoring. Presently, many groups perform TAVR/TAVI procedures under conscious sedation, with percutaneous femoral access. Arterial access is usually achieved via a femoral cutdown, although other access sites have included iliac, subclavian, and carotid arteries, as well as the ascending aorta and the left ventricular apex. Adequate vascular access is ascertained by CT angiography.

For procedural and anesthetic considerations, see p. 444.

Suggested Readings

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MITRAL VALVE REPAIR OR REPLACEMENT

SURGICAL CONSIDERATIONS

Description

Mitral valve repair or replacement is utilized typically for the correction of postrheumatic mitral valvular stenosis or insufficiency, as well as mitral valve prolapse, degenerative mitral insufficiency, or repair after endocarditis. For mitral regurgitation (MR) 2° posterior leaflet abnormalities (myxomatous degeneration, torn chordae) or pure annular dilation, most valves can be repaired. For severe rheumatic calcific mitral stenosis (MS), mitral valve replacement with preservation of subannular structures may be necessary.

The technique of mitral valve repair or replacement is similar regardless of the mitral valve pathology. After aortic and bicaval venous cannulation, CPB is established, and the left heart is vented through the PA. After cross-clamping of the aorta, diastolic arrest is accomplished with cardioplegia administered via the aortic root, augmented with topical cooling with either continuous pericardial saline infusion or a cooling jacket. Exposure is accomplished via a vertical incision in the left atrium just posterior to atrial septum. If the left atrium is not large enough, access may be gained via an incision in the right atrium and then incising the atrial septum, with caval snares in place to prevent air entry into the venous cannulae.

After suitable exposure, the atrium, atrial appendage, and mitral valve are carefully inspected, and a decision is made to repair or replace the valve. Repair of regurgitant valves caused primarily by posterior leaflet problems is usually possible. Similarly, annular dilation 2° LV enlargement is also usually possible by means of a ring annuloplasty. Regurgitation 2° anterior leaflet abnormalities is more problematic, requiring significant expertise, and may be less durable. Preop and postop evaluations are greatly facilitated by the use of TEE. Valve replacement can be performed after excising the valve leaflets, or the leaflets may be preserved in an attempt to maintain the benefits of the subvalvular apparatus to global ventricular performance. After appropriate excision and debridement, the annulus is rimmed with interrupted sutures passed through the sewing ring of the valve prosthesis. The prosthesis is carefully positioned, and the sutures are tied. After filling both the LV and atrium with blood, the atrium is closed, air is evacuated from the left heart, and the cross-clamp is removed to allow coronary perfusion. After a satisfactory period of resuscitation, and after all air has been evacuated from the circulation, CPB may be D/C'd, usually with the assistance of vasodilator agents. TEE may be utilized at this stage to assess adequacy of mitral valve repair.

Variant procedure or approaches

Mitral valve repair may also be accomplished via a right anterior thoracotomy approach, with the patient positioned right side up in slight lateral decubitus position. Peripheral (femoral artery-femoral vein +/− internal jugular vein) or central (femoral vein-aorta) bypass is used, and operation may be performed during ventricular fibrillation or without aortic clamping and cardioplegia. Single lung anesthesia is necessary, either with a double-lumen endotracheal tube or with a right-sided bronchial blocker. Cannulation of the coronary sinus may be requested, and the operative field will be flooded with CO_2. TEE is extensively used for preop diagnosis, and for postop monitoring of the surgical result. **Mitral commissurotomy** may be done as an endovascular procedure (e.g., during pregnancy).

Percutaneous repair of the regurgitant mitral valve (MitraClip™) has been approved as an alternative to open surgery (see p. 403).

Usual preop diagnosis

Class 3 or 4 CHF 2° mitral insufficiency or mitral stenosis

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of

nutritional status, discussion of carb loading, postop pain management options, possible need for a chest tube and postop mechanical ventilation, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Mitral Valve Replacement/Repair	Closed Commissurotomy
Position	Supine	Right lateral decubitus
Incision	Median sternotomy	Left lateral thoracotomy
Special instrumentation	TEE and epicardial ECHO to assess valve function and regional wall motion; CPB	Performed without CPB
Unique considerations	Special loading conditions may be used to estimate the amount of MR, which is frequently afterload-dependent.	⇐
Antibiotics	Cefazolin 2 g iv prior to incision and then 2 g q4h	⇐
Surgical time	Aortic cross-clamp: 45–150 min CPB: 90–200 min	Total: 2 h Total: 3–4 h
EBL	300–400 mL	200–400 mL
Postop care	ICU × 1–3 d, intubated 6–24 h; vasodilator therapy for reversal of pulmonary HTN and afterload reduction	⇐
Mortality	5–8%	<5%
Morbidity	Pneumonia: 10–15% CNS complications: Transient neurologic dysfunction: 5–10%	⇐ ⇐ ⇐

	CVA: 1–2% Infection: <1%	⇐
Pain score	7–10	7–10

PATIENT POPULATION CHARACTERISTICS		
Age range	40–75 yr	20–40 yr
Male:Female	1:1	Almost exclusively pregnant females
Etiology	Postrheumatic: majority of cases; increased aging; myxomatous degeneration; ischemic etiologies (increasing)	⇐
Associated conditions	Aortic valvular involvement with rheumatic disease, CAD, pulmonary HTN, and tricuspid regurgitation	⇐

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Respiratory	Pulmonary congestion, edema, and pleural effusions may be present, with an overall restrictive lung pattern. Pleural effusions should be drained before surgery if significant (↓ oxygenation, ↓ venous return with IPPV). ↑ LA volume may compress the left recurrent laryngeal nerve → left vocal cord paralysis (Ortner syndrome). **Tests:** CXR; PFTs, if indicated
Cardiovascular	**Mitral stenosis (MS):** Sx include exertional dyspnea and fatigue, progressing to pulmonary edema, atrial fibrillation (AF), and hemoptysis. Embolic events occur in 15% of patients. The opening snap and diastolic murmur of MS are best heard between the apex and left sternal border. The

ECG may show AF or wide-notched P-waves. It is important to grade the severity of MS by symptomatology and valve area: mild, 1.5–2 cm^2; moderate, 1–1.5 cm^2; and severe, <1.0 cm^2 (nl = 4–6 cm^2). AF is often the factor precipitating deterioration in these patients. Because of the decreased LV filling, these patients are sensitive to:

- Loss of atrial "kick:" maintain NSR.
- Volume changes: keep full.
- Rate changes: avoid ↑ HR → ↓diastolic filling time → ↓ CO.

Pathophysiology:

- MS → ↓ LVH filling → ↓ CO.
- MS → ↑ LA pressure →pulmonary edema + ↑ PA pressure → ↑ PVR → RV failure + TR + left shift of iv septum → ↓ CO → ↑ LA pressure → ↑ LA volume → AF and thrombi.

Mitral regurgitation (MR): May be acute (MI/endocarditis) or chronic (often associated with MS). Chronic Sx include palpitations, DOE, PND, fatigue, and orthopnea. Acute MR may → sudden ↓↓ CO and pulmonary edema. MR can be classified as mild (<30% RF), moderate (30–60% RF), or severe (>60% RF). The pansystolic murmur is loudest at the apex. The ECG may show LA and LV overload. MR patients are sensitive to:

- Changes in SVR: ↑ SVR → ↑ RF → ↓ CO + ↓ BP.
  ↓ SVR → ↓ RF → ↑ CO + ↑ BP.
- Change in HR: ↓ HR →acute LA volume overload.
  Mild ↑ HR→ ↑ CO.

Pathophysiology:

- Acute MR → ↑ ↑ LA pressure → ↓ CO + ↓ BP → ↑ HR → ↑ contractility → ↑ O_2 demand.
  → ↑ LV diastolic volume → ↑ LVEDP →↑ O_2 demand. → Pulmonary edema.
- Chronic MR → ↑ LA volume + AF → pulmonary edema → RV failure.

	→ LV volume overload → LVH → ↓ CO + LV failure. **Tests:** ECG: ✓ LVH, left and right atrial enlargement, rhythm. ECHO: ✓ RF, valve pressure gradients, LV function, valve pressure gradient and area.
Neurologic	The large left atrium and AF may result in thrombus formation, with the possibility of embolism. Neurologic deficits should be documented.
Gastrointestinal	Hepatic congestion may → decreased function, which may be reflected in coagulation problems. **Tests:** Consider LFTs; PT; PTT.
Renal	↓ CO may lead to renal failure. **Tests:** BUN; Cr; electrolytes
Hematologic	Because of the potential for thromboembolism, these patients may be on anticoagulants, which may be given up to the day before surgery. In the case of Coumadin, anticoagulant effects can be reversed by the use of FFP and vitamin K. **Tests:** Consider PT; PTT.
Laboratory	T&C for 2–4 U PRBCs. Hb/Hct; coagulation profile; other tests as indicated from H&P
Premedication	Premedication with an anxiolytic (e.g., lorazepam 1–2 mg po, midazolam 0.05–0.2 mg/kg im) or an analgesic (e.g., morphine 0.1–0.2 mg/kg) or a combination of these agents may be used, depending on patient status.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of thoracic epidural, continuous paravertebral, or chest wall nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: An arterial line should be inserted, using liberal amounts of local anesthetic, before induction. The presence of real-time BP monitoring can be critical in the care of these patients, especially during induction. Although it is helpful to have a CVP line before induction for preload monitoring and drug infusion, it is not essential. This line usually is inserted after the patient is intubated. If infused drugs are necessary before the CVP catheter is in place, they can be administered through a separate peripheral iv.

Induction	Typically, moderate- to high-dose narcotic (fentanyl 5–10 mcg/kg or sufentanil 2.5–20 mcg/kg), supplemental midazolam (50–350 mcg/kg), or etomidate (0.1–0.3 mg/kg). Use rocuronium or vecuronium **MS:** ↓ BP should be treated with fluid, but beware of precipitating pulmonary edema. Occasionally, phenylephrine may be needed to maintain SVR. Tachycardia should be avoided; if it occurs, it should be treated (↑ anesthesia, esmolol if ventricular function is preserved). Sinus rhythm should be maintained. New-onset atrial flutter/AF should be treated with defibrillation, ideally after LA thrombus is ruled out by TEE. Avoid factors that may increase PVR (N_2O, acidosis, hypoxia, hypercarbia). **MR:** Maintain or augment preload, depending on response to fluid load. Inotropic agents may be useful to maintain contractility. Afterload reduction will improve forward flow. Generally, SNP (0.5–4 mcg/kg/min) is used, but NTG (0.5–4 mcg/kg/min) may be more appropriate in patients with ischemia-induced regurgitation. Avoid ↑ PVR caused by N_2O, acidosis, hypoxia, or hypercarbia. IABP may be useful periop in patients with acute MR 2° MI (↓ afterload, ↑ coronary perfusion pressure).
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider placement of parasternal or chest wall nerve blocks if preop blocks have not been placed. Ketamine

	(0.5 mg/kg iv) at induction may improve pain management and reduce delirium after CPB.
Maintenance	Narcotic (total = fentanyl 10–20 mcg/kg, or sufentanil 5–20 mcg/kg) with benzodiazepine (e.g., midazolam 50–350 mcg/kg) for amnesia; low-dose isoflurane; O_2/air. Recommend use of antifibrinolytics for all cases requiring CPB. The following table summarizes the goals of intraop management:

Parameter	MS	MR
LV preload	Normal-to-↑	Normal-to-↑
HR	↓	↑
Rhythm	NSR	NSR
Contractility	Maintain	Maintain
SVR	Normal	↓
PVR	Avoid ↑	Avoid ↑

Postbypass	Although patients with MS generally do well after valve replacement, inotropes (e.g., dopamine, dobutamine) occasionally are necessary. This is especially true late in the disease when cardiomyopathy may be present.	
Emergence	Transport to ICU, intubated and ventilated 6–24 h. Early extubation is possible if lower-dose narcotic technique is used (fast-track). Discuss with surgeon local wound infiltration or chest wall nerve block (e.g., via prefascial plane catheter) placement. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 14 ga × 1–2 BSS at 6–8 mL/kg/h Maintain UO 0.5–1 mL/kg/h. Warm all fluids. Humidify gases.	See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors Arterial line	Standard monitors and an A-line are placed before induction. CVP (and/or

	CVP line PA catheter Urinary catheter	PA line, if indicated) usually is placed after intubation. Care should be exercised with PA catheter insertion because the dilated PA may be susceptible to rupture with the catheter. In MS, PCWP may overestimate the LV filling pressure due to stenosis.
	TEE	TEE may help in volume management, regional wall motion abnormalities (postacute MI), and assessing the success of mitral valve repair. Occasionally, the use of a valve ring during repair may cause systolic anterior motion of the valve leaflet with resultant regurgitation, which may be seen on TEE.
Positioning	✓ and pad pressure points ✓ eyes	

POSTOPERATIVE

Complications	Hemorrhage Tamponade Cardiac failure Dysrhythmias Conduction defects Atrioventricular disruption	Inotropic support or vasodilator therapy may be needed. IABP for mitral incompetence, especially in the presence of acute MR 2° infarction. Systolic anterior motion (SAM) of the mitral valve after MV repair should be excluded by TEE prior to completion of the case.
Multimodal pain management	Limit opioids	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with

		regional anesthetics whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	If postop sedation is required, dexmedetomidine may be preferable to propofol. Encourage fast-track extubation, early enteral nutrition, Foley catheter removal, and mobilization.
Tests	ECG CXR ABG Coag profile Electrolytes	

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TRICUSPID VALVE REPAIR

SURGICAL CONSIDERATIONS

Description

Insufficiency of the tricuspid valve is almost always 2° left-sided valvular disease, with tricuspid annular dilation and resultant valvular insufficiency usually 2° pulmonary HTN. Some congenital conditions (e.g., Ebstein deformity) may persist into early adulthood, when replacement is usually necessary. Tricuspid repair is normally possible in the absence of primary involvement of tricuspid leaflets. The procedure is usually accomplished on CPB, either with the heart fibrillating or during a brief period of aortic cross-clamping and diastolic arrest. After instituting CPB and snaring the venous cannulae to prevent air entry into the pump circuit, the tricuspid valve is exposed through an incision in the right atrium. In the absence of leaflet involvement by the rheumatic process, repair usually can be accomplished by a simple **annuloplasty.** After atrial closure, evacuation of air, and myocardial resuscitation, the patient is weaned from CPB with vasodilator agents. Temporary pacing wires usually are inserted and passed to the anesthesiologist in case inadvertent injury to the AV node or His bundle causes complete heart block. Maintenance of RV systolic function after repair of tricuspid regurgitation is of utmost importance, as the RV may be exposed to increased afterload with the elimination of a regurgitant tricuspid valve (loss of "pop-off valve"). This is frequently accomplished by the initiation of pulmonary vasodilators (i.e., epoprostenol) and inotropic support.

Variant procedure or approaches

Transcatheter tricuspid valve repair/replacement. Transcatheter procedures have a high success rate with an average 6% device migration, 2% conversion to open surgery, and 5% 30-d mortality in early trials. Residual TR occurs more frequently following

transcatheter interventions compared to open surgery, and further studies will be necessary for the postop implications (see p. 412).

Tricuspid Valve Replacement

Usual preop diagnosis

Tricuspid regurgitation; 2° annular dilation 2° pulmonary HTN and left-side failure

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, possible need for a chest tube and postop mechanical ventilation, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Median sternotomy
Special instrumentation	Intraop ECHO; hemodynamic monitoring; CPB
Antibiotics	Cefazolin 2 g iv prior to incision and then 2 g q4h
Surgical time	Aortic cross-clamp: 30–40 min CPB: 70–80 min Total: 3–4 h
EBL	400–800 mL (Long-standing tricuspid regurgitation may → impaired hepatic production of coagulation factors.)
Postop care	ICU × 1–3 d, intubated 6–24 h; vasodilator therapy for pulmonary HTN
Mortality	2–3%
Morbidity	Third-degree heart block: 10% RV failure: 2–3%
Pain score	7–10

PATIENT POPULATION CHARACTERISTICS

Age range	50–75 yr
Male:Female	1:1
Incidence	Rare
Etiology	Rheumatic; congenital (Ebstein anomaly)
Associated conditions	Rheumatic involvement of left-side valves with pulmonary HTN

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Cardiovascular	**Tricuspid regurgitation (TR)** usually is well tolerated, and Sx (↓ CO) may go unnoticed, masked by Sx associated with left-side valvular disease and pulmonary HTN. Occasionally, TR is 2° endocarditis and raises the suspicion of iv drug abuse. TR may be caused by pulmonary HTN → ↑ RV afterload → RV dilation, ↑ RV wall tension → dilation of tricuspid valve annulus, and TR. TR may also occur in heart transplant patients due to endomyocardial biopsies and in patients with PM and ICDs, particularly after lead removal. Pathophysiology: 1. TR → ↓ CO 2° ↑ RV size → shift of the intraventricular septum to the left → ↓ LV size, ↓ LV compliance → LV underloading due to ↓ LV size and ↓ RV stroke volume. 2. TR → atrial fibrillation (AF) 2° ↑ right atrial size. In isolated insufficiency, the ↑ in right atrial pressure may result in shunting across a patent foramen ovale (PFO), leading to paradoxical embolization with potentially disastrous consequences. **Tests:** ECG: ✓ AF. ECHO: ✓ relative chamber size, contractility, PFO, valve lesions. Cardiac catheterization: ✓ contractility, CO, pulmonary pressures and their response to vasodilators, other valvular pathology.

Respiratory	Pulmonary HTN (>25 mm Hg mean pressure), pulmonary edema, and effusions may be present. **Tests:** CXR: ✓ pulmonary edema, pleural effusion
Renal	Chronic venous congestion may → prerenal failure. **Tests:** BUN; Cr; electrolytes
Hepatic	Hepatic congestion may → impaired synthetic function, particularly coag factors. **Tests:** Consider PT; PTT
Hematologic	**Tests:** Hb/Hct; other tests as indicated from H&P and Sx. Consider viral testing (HIV, hepatitis in isolated tricuspid endocarditis or in iv drug abusers). T&C 2–4 U PRBCs
Laboratory	Other tests as indicated from H&P
Premedication	Standard premedication is usually appropriate.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of thoracic epidural, continuous paravertebral, or chest wall nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: An arterial line should be inserted, using liberal amounts of local anesthetic, before induction. The presence of real-time BP monitoring can be critical in the care of these patients, especially during induction. Although it is helpful to have a CVP line before induction for preload monitoring and drug infusion, it is not essential. This line usually is inserted after the patient is intubated. If infused drugs are necessary before the CVP catheter is in place, they can be administered through a separate peripheral iv.

Induction	Typically, O_2 and premedicate with midazolam (2–5 mg). Induce with moderate- to high-dose narcotic (fentanyl 5–10 mcg/kg or sufentanil 2.5–20 mcg/kg) with etomidate (0.1–0.3 mg/kg) or propofol (0.5–1

	mg/kg). Muscle relaxation is obtained with a nondepolarizing agent (e.g., rocuronium 0.6–1.0 mg/kg, vecuronium 0.1 mg/kg).
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider placement of parasternal or chest wall nerve blocks if preop blocks have not been placed. Ketamine (0.5 mg/kg iv) at induction may improve pain management and reduce delirium after CPB.
Maintenance	The choice of narcotic/benzodiazepine/O_2 or volatile agent and O_2 will be determined by the underlying lesion and ventricular function. Avoid N_2O (pulmonary HTN). Low-dose isoflurane may be used. Benzodiazepines (e.g., midazolam 50–200 mcg/kg) may be used for amnesia. Exact choice of agents for maintenance depends on underlying lesion, ventricular function, and coexisting disease. Management goals of TR are often those of coexisting valvular problems. The general principles, however, are (a) adequate preload (↓ preload →↓ RV stroke volume); (b) HR, normal-to-increased; (c) contractility, normal (may require inotropic support for ↑ PVR, anesthetic myocardial depression, or IPPV); (d) PVR, normal or decreased (high PVR →↓ RV stroke volume); and (e) SVR, little effect unless it affects left-side pathology. Recommend use of antifibrinolytics for all cases requiring CPB.
Emergence	To ICU intubated and ventilated × 6–24 h. Early extubation may be possible if a lower-dose narcotic technique is used (fast-track). Discuss with surgeon local wound infiltration or chest wall nerve block (e.g., via prefascial plane catheter) placement. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.

Blood and fluid requirements	IV: 14 ga × 1–2 BSS at 6–8 mL/kg/h UO 0.5–1 mL/kg/h Warm all fluids. Humidify gases. T&C 2–4 U PRBC	Because of the possibility of PFO and R→L shunt, ensure that all venous lines are clear of air. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors Arterial line CVP or PA catheter Urinary catheter	Standard monitors and an A-line are placed before induction. CVP (and/or PA line, if indicated) usually is placed after intubation. CVP may be a poor indicator of RV or LV filling. The PA catheter may be helpful in the management of fluid balance, CO, and pulmonary HTN but may be difficult to place and may require removal while valve or annular ring is placed.
	TEE	Because RV distension may affect LV filling and stroke volume, TEE may be useful in judging filling and relative LV size.
Pulmonary HTN	↑ PVR can result from: ↓ PaO_2 ↑ $PaCO_2$ ↓ pH N_2O α-Agonists Inadequate anesthesia	In TR, control of PVR is important because ↑ PVR may result in ↓ CO. Hypoxia, hypercarbia, acidosis, N_2O, or α-agonists may ↑ PVR. PVR may be reduced with hypocarbia, inotropic

		support with dopamine (5–10 mcg/kg/min), epinephrine (25–100 ng/kg/min), or milrinone (0.375–0.75 mg/kg/min), and by using pulmonary vasodilators—NTG (1–4 mcg/kg/min), SNP (0.5–2 mcg/kg/min), prostaglandin E_1 (0.05–0.4 mcg/kg/min), or inhaled NO (10–100 ppm).
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Coagulopathy Hemorrhage RV failure	Coagulopathy 2° prolonged bypass time for multiple valve replacements. RV failure 2° ↑ PVR (previously, RV decompressed by tricuspid incompetence). Rx includes inotropes, dopamine (5–10 mcg/kg/min), milrinone (infusion 0.3–0.75 mcg/kg/min), and epinephrine (25–100 ng/kg/min), avoidance of factors causing ↑ PVR, and the use of pulmonary vasodilators.

POSTOPERATIVE

Complications	Hemorrhage	Inotropic support and

	Coagulopathy Dysrhythmias RV failure Infection Renal impairment Methemoglobinemia	pulmonary vasodilators will need to be continued. Avoid those factors that ↑ PVR. Measure metHb levels during NO therapy.
Multimodal pain management	Limit opioids	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	If postop sedation is required, dexmedetomidine may be preferable to propofol. Encourage fast-track extubation, early enteral nutrition, Foley catheter removal, and mobilization.
Tests	ECG Coag profile Renal panel: BUN, Cr ABG Electrolytes	

Suggested Readings

1. Asmarats L, Puri R, Latib A, et al: Transcatheter tricuspid valve interventions landscape, challenges, and future directions. J Am Coll Cardiol 2018; 71(25):2935–56.
2. Cevasco M, Shekar PS: Surgical management of tricuspid stenosis.Ann Cardiothorac Surg 2017; 6(3):275–82.

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4. Fender EA, Zack CJ, Nishimura RA: Isolated tricuspid regurgitation: outcomes an therapeutic interventions. Heart 2018; 104(10):798–806.
5. Isomura T, Fukada Y, Miyazaki T, et al: Tricuspid surgery for tricuspid regurgitation: review. Gen Thorac Cardiovasc Surg 2016; 64(10):577–83.
6. Noss C, Prusinkiewicz C, Nelson G, et al: Enhanced recovery for cardiac surgery.J Cardiothorac Vasc Anesth 2018; 32(6):2760–70.

SEPTAL MYECTOMY/MYOTOMY

SURGICAL CONSIDERATIONS

Description

Patients with asymmetric septal hypertrophy usually present with symptoms 2° LV outflow tract obstruction (LVOTO), increased diastolic dysfunction and stiffness, or a combination of the two, manifested as syncope, CHF, or severe chest pain. The systolic hemodynamic abnormality is caused by the anterior leaflet of the mitral valve being drawn into the LV outflow tract (LVOT) and abutting the asymmetrically hypertrophied intraventricular septum, narrowing the LVOT, and producing a large dynamic intracavitary gradient. In addition, severe mitral insufficiency may result. The most common surgical procedure for asymmetric septal hypertrophy is **septal myectomy/myotomy.** After institution of CPB, aortic cross-clamping, and cardioplegic arrest, the aorta is opened, and visualization of the subvalvar ventricular septum is attained. Manual palpation, as well as TEE visualization, can localize the asymmetric hypertrophy. Using the right coronary orifice as a landmark, the ventricular septum is longitudinally incised with two parallel incisions ~1 cm apart, with care being taken to avoid injury of the papillary muscle or mitral valve chordae. A trough of the hypertrophied septum is then excised, alleviating the LVOTO. Removal of a portion of the asymmetrically hypertrophied myopathic septum also usually reduces the systolic anterior motion (SAM) of the anterior mitral leaflet and reduces the intracavitary gradient and MR. Infrequently, mitral valve replacement may be necessary for persistent MR.

Usual preop diagnosis

Asymmetric septal hypertrophy with CHF; chest pain; and/or syncope

ERAS: **For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, possible need for a chest tube and postop mechanical ventilation, and physiotherapy plan. See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Median sternotomy
Special instrumentation	TEE; hemodynamic monitoring; CPB
Unique considerations	Because of LV hypertrophy, maintenance of adequate preload is essential. Afterload also must be maintained to prevent LVOTO. Temporary pacing wires usually are placed at the start of the procedure.
Antibiotics	Cefazolin 2 g iv prior to incision and then 2 g q4h
Surgical time	2.5 h
EBL	150 mL
Postop care	ICU, intubated on ventilator 6–24 h
Mortality	3–4%
Morbidity	Complete heart block: 5% Persistent MR: 5% New aortic insufficiency: 2–5% CVA: <1% VSD: <1%
Pain score	6–10

PATIENT POPULATION CHARACTERISTICS	
Age range	20–80 yr (mean = 45 yr)
Male:Female	1:1
Incidence	30/yr at Stanford University Medical Center

Etiology	Asymmetric septal hypertrophy

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Respiratory	Affected only 2° to cardiac failure.
Cardiovascular	Patients with idiopathic hypertrophic obstructive cardiomyopathy (HOCM) often present with Sx of syncope, angina pectoris (CAD), CHF, and palpitations. The main feature of HOCM is dynamic LVOTO 2° to septal hypertrophy and a possible Venturi effect that draws the anterior mitral valve leaflet into the outflow tract. LVOTO →↑ LV hypertrophy.
	→ ↓ compliance and ↓ diastolic function → ↑ LVEDP, making diastolic filling dependent on preload and atrial contraction. Obstruction is worsened by decreased preload or afterload, increased contractility, or HR. HOCM also results in ↑ MVO_2 and ↓ coronary perfusion, especially to the septum and subendocardium, which increases the risk of ischemia. Hypertrophy occurs throughout the whole myocardium and may lead to further dysfunction. MR is often present and is exacerbated by the same conditions that increase LVOTO. Patients are often on β-blockers or Ca^{++} antagonists. These should be continued to the day of surgery. **Tests:** ECG: ✓ Q-waves (indicative of septal hypertrophy); short PR interval with slurred QRS complex; supraventricular tachycardia; LV hypertrophy. ECHO: ✓ septal hypertrophy; MR; LV hypertrophy, myocardial dysfunction. Cardiac catheterization: ✓ LVOT pressure gradient, which may increase with provocation (e.g., Valsalva maneuver); obliteration of the LV cavity; MR; CAD.

Neurologic	Document syncope and any neurologic deficits.
Laboratory	Hb/Hct, electrolytes, other tests as indicated from H&P.
Premedication	Avoid activation of the sympathetic nervous system because this will cause ↑ HR and ↓ inotropy →↓ CO + ↓ BP. Thus, adequate anxiolysis is essential and can be obtained by premedication with a benzodiazepine (e.g., midazolam 0.05–0.2 mg/kg im, lorazepam 1–2 mg po, or diazepam 5–10 mg po). Avoid ↓ SVR, and maintain β-blockade and Ca^{++} channel blocker therapy.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of thoracic epidural, continuous paravertebral, or chest wall nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: An arterial line should be inserted, using liberal amounts of local anesthetic, before induction. The presence of real-time BP monitoring is critical in the care of these patients, especially during induction. Although it is helpful to have a CVP line before induction for preload monitoring and drug infusion, it is not essential. This line usually is inserted after the patient is intubated. If infused drugs are necessary before the CVP catheter is in place, they can be administered through a separate peripheral iv.

Induction	Typically, moderate-dose narcotic (fentanyl 5–10 mcg/kg; avoid sufentanil due to vasodilation). Supplement with etomidate (0.1–0.3 mg/kg), midazolam (50–350 mcg/kg), or propofol (0.5–1 mg/kg). Ketamine should be avoided due to the activation of the sympathetic nervous system. Introduction of a volatile agent prior to intubation may be helpful. Vecuronium (0.1 mg/kg) or

	rocuronium (0.6–1.0 mg/kg) is used for muscle relaxation. Avoid inotropic agents.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider placement of parasternal or chest wall nerve blocks if preop blocks have not been placed. Ketamine (0.5 mg/kg iv) at induction may improve pain management and reduce delirium after CPB.	
Maintenance	O_2 and narcotic (total fentanyl 10–20 mcg/kg) + volatile agent. Midazolam (50–350 mcg/kg) can be used for amnesia. The cornerstone of anesthesia for HOCM is to avoid factors that will increase LVOTO: (a) ↓ preload, (b) ↓ afterload, (c) ↑ contractility, (d) loss of NSR, and (e) ↑ HR. Recommend use of antifibrinolytics for all cases requiring CPB.	
Emergence	To ICU intubated and ventilated × 6–24 h. Early extubation is possible if a lower-dose narcotic technique is used (fast-track). Discuss with surgeon local wound infiltration or chest wall nerve block (e.g., via prefascial plane catheter) placement. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 14 ga × 1–2 BSS at 6–8 mL/kg/h Maintain UO. 0.5–1 mL/h Warm fluids. Humidify gases.	See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors Arterial line PA catheter Urinary catheter	Standard monitors and an A-line are placed before induction. CVP (and/or PA line, if indicated) usually is placed after intubation. A PA catheter is useful for assessment of LV filling

		(keep high normal PCWP) and for monitoring SVR (normal-to-high). A pacing or pace port PA catheter may be useful for conduction problems occurring postop.
	TEE	TEE is useful to judge LV filling, LV contractility, LVOTO, MR, and VSD (post myectomy).
Intraoperative problems	↓ Preload ↓ Afterload ↑ Contractility ↑ HR Loss of NSR Complete heart block	Rx: volume, phenylephrine Rx: phenylephrine Rx: esmolol Rx: esmolol Rx: cardioversion, verapamil. Should have reliable means of pacing available, including temporary ventricular leads
	VSD	Septum may be damaged, → VSD (diagnosed by TEE). If present, it should be repaired.
Position	✓ and pad pressure points ✓ eyes	

POSTOPERATIVE

Complications	Hemorrhage	Dx: from chest tube drainage. Rx with blood and factors as needed.

		✓ coag status. May require reexploration
	Complete heart block	Pacing should be available. Occasionally, inotropes of vasodilators are required. β-Blockers and Ca^{++} antagonists are usually D/C'd.
	Late VSD	Late VSD, indicated by development of a murmur, will require repair.
	Tamponade	Dx: by raising filling pressure, equalization of CVP, and PADP, ↓ CO, ↓ UO, and by ECHO. Rx: re-exploration and drainage
Multimodal pain management	Limit opioids	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	If postop sedation is required, dexmedetomidine may be preferable to propofol. Encourage fast-track extubation, early enteral nutrition, Foley catheter removal, and mobilization.
Tests	ECG: ✓ conduction problems ABG ECHO: ✓ LVOTO; VSD	

Coag profile
Electrolytes

Suggested Readings

1. Crumley S, Schraag S: The role of local anaesthetic techniques in ERAS protocol for thoracic surgery. J Thorac Dis 2018; 10(3):1998–2004.
2. Geske JB, Ommen SR, Gersh BJ: Hypertrophic cardiomyopathy: clinical update JACC Heart Fail 2018; 6(5):364–75.
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5. Noss C, Prusinkiewicz C, Nelson G, et al: Enhanced recovery for cardiac surgery.J Cardiothorac Vasc Anesth 2018; 32(6):2760–70.
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7. Vives M, Roscoe A: Hypertrophic cardiomyopathy: implications for anesthesia. Minerva Anestesiol 2014; 80(12):1310–9.

PACEMAKER INSERTION

SURGICAL CONSIDERATIONS

Description

Pacemaker insertion may be required for relief of abnormalities of the conduction system. A transvenous pacemaker lead may be placed via the subclavian vein, through the tricuspid valve into the RV (single-chamber pacing), or two leads may be placed, one into the right atrium and the other into the RV (dual-chamber pacing). Typically, second- or third-degree heart block is the diagnostic indication, although sick sinus syndrome (SSS) and other abnormalities also may be found. Access to the subclavian veins usually is attained percutaneously, although a cutdown may be used to expose the cephalic vein in the deltopectoral groove. Passage of a guide wire into the RV may cause frequent premature ventricular beats, which usually subside spontaneously with repositioning of the guide wire or lead. After ventricular and/or atrial lead placement, the pacing lead will have to be tested for sensing threshold, pacing threshold, depolarization amplitude, and lead resistance. After satisfactory placement of the pacing leads, the actual pacemaker generator unit is connected and then placed in a subcutaneous pocket at the site of percutaneous lead placement.

Pacemakers are frequently placed in the cath lab (see p. 418).

Usual preop diagnosis

Abnormalities of S-A nodal function (SSS) or A-V nodal function (heart block)

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, possible need for a chest tube and postop mechanical ventilation, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Left subclavicular; mostly percutaneous
Special instrumentation	Fluoroscopy with fluoro-table
Unique considerations	Patient usually awake with mild sedation
Antibiotics	Cefazolin 2 g iv prior to incision
Surgical time	1 h
EBL	Minimal
Postop care	PACU → CCU; ECG monitoring × 2–4 h; chest radiograph to document lead configuration
Mortality	0–1%
Morbidity	Lead displacement, 1–2%; pneumothorax, 1–2%
Pain score	2

PATIENT POPULATION CHARACTERISTICS	
Age range	50–80 yr
Male:Female	2:1
Incidence	Infrequent
Etiology	CAD; cardiac valve repair/replacement

Associated conditions	Complete heart block with syncope; SSS; paroxysmal tachycardia; SVT

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

The indications for permanent pacemaker insertion are usually bradydysrhythmias (e.g., third-degree heart block, sinus node dysfunction) or, less commonly, tachycardia (e.g., atrial flutter not responsive to medical therapy). There are many different types of pacemakers, which are classified according to the chamber paced, chamber sensed, response to sensing, programmability, and antitachyarrhythmia functions. The anesthesiologist should be aware of the type of pacemaker to be implanted and the means for external control (Table 6.1-4).

Table 6.1-4 Five-Position Pacemaker Code (ICHD)

I	II	III	IV	V
Chamber(s) Paced	**Chamber(s) Sensed**	**Response(s) to Sensing**	**Programmability, Rate Modulation**	**Special Tachyarrhythm Functions**
V—Ventricle	V—Ventricle	T—Triggered	P—Simple programmable (rate and/or output)	B—Bursts
A—Atrium	A—Atrium	I—Inhibited	M—Multiprogrammable	N—Normal rate competition
D—Dual	D—Dual	D—Dual (T + I)	C—Communicating	S—Scanning
O—None	O—None	O—None	R—Rate modulation	
			O—None	E—External

Cardiovascular	Evaluate patient for associated disease, including CAD (~50%), HTN (~20%), cardiomyopathy, CHF, and valvular defect, and for any symptoms or recent

	changes related to the conduction problems (syncope, CHF). It is important to know the reason for pacemaker implantation and the patient's escape rhythm. These patients are often on antidysrhythmics, diuretics, cardiac glycosides, and a variety of other cardiovascular agents, which should be continued up to the day of surgery. **Tests:** Exercise tolerance by Hx. ECG: ✓ rate, ischemic changes, rhythm. Other tests as indicated by H&P. ✓ serum digoxin and other antidysrhythmic levels.
Pacemaker	If a permanent pacemaker is already in place, its type and present functional state should be assessed. (Sx of problems include chest pain, palpitations, syncope, and weakness.) If no permanent pacemaker, a temporary transvenous pacemaker should be placed before surgery, except in unusual circumstances. **Tests:** ECG: ✓ Valsalva maneuver or carotid sinus massage—may slow the heart sufficiently to allow the permanent pacemaker to fire and allow assessment of function. A rate lower than the set rate may indicate battery failure. CXR: ✓ lead continuity.
Hematologic	Hct or Hb
Laboratory	✓ K^+ level, which can affect pacing threshold, → loss of pacemaker capture, if low, or ventricular tachycardia, if high. Other tests as indicated from H&P.
Premedication	Standard premedication
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of thoracic epidural, continuous paravertebral, or chest wall nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water

	for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Permanent pacemakers commonly are placed via the transvenous route, requiring only local anesthesia and MAC with sedation. For epicardial pacemaker placement, GETA is required. These patients should be monitored during transport to OR. Care is taken to avoid dislodging temporary pacing electrodes. The function of the temporary pacemaker should be checked prior to induction.

General anesthesia

Induction	Usually, anesthesia can be induced with propofol (1–2 mg/kg) or etomidate (0.2–0.3 mg/kg) in combination with an opiate (e.g., fentanyl 1–2 mcg/kg) to attenuate the response to intubation. Vecuronium (0.1 mg/kg) or rocuronium (1 mg/kg) will provide adequate muscle relaxation.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider placement of parasternal or chest wall nerve blocks if preop blocks have not been placed. Ketamine (0.5 mg/kg iv) at induction may improve pain management and reduce delirium after CPB.
Maintenance	Standard maintenance. Avoid excessive hyperventilation ($\rightarrow\downarrow K^+$), and use volatile agents with caution because they may increase A-V conduction time. Recommend use of antifibrinolytics for all cases requiring CPB.
Emergence	Generally, patient is extubated at the end of the case. Discuss with surgeon local wound infiltration or chest wall nerve block (e.g., via prefascial plane catheter) placement. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.

Blood and fluid requirements	Minimal fluid requirements IV: 18–16 ga × 1 BSS at 4–6 mL/kg/h	See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors Urinary catheter	Rarely, arterial line if patient disease indicates.
Electrocautery interference	Minimize by: 1. Using bipolar cautery, if possible 2. Grounding pad on the leg 3. Limiting cautery output 4. Limiting cautery use	The use of electrocautery may interfere with pacemaker function and → dysrhythmias or failure of the pacemaker. Monitor ECG and pulse (because electrical activity does not mean CO) for interference. Have a magnet available to convert the pacemaker to asynchronous mode (check that this is possible and will not change the programming of the pacemaker).
Complications	Dysrhythmias Air embolism Cardiac tamponade Hemo/pneumothorax Hemorrhage	Availability of temporary pacing is important because complete heart block or dislodgement of leads may occur. In addition, pharmacologic agents (atropine, 0.5–2 mg; isoproterenol 10–100 ng/kg/min) to increase HR should be available.

POSTOPERATIVE

Complications	Dislodging of electrodes

	Dysrhythmias Pneumothorax Tamponade	
Multimodal pain management	Limit opioids	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	If postop sedation is required, dexmedetomidine may be preferable to propofol. Encourage fast-track extubation, early enteral nutrition, Foley catheter removal, and mobilization.
Tests	ECG CXR Electrolytes	

Suggested Readings

1. Arora L, Inampudi C: Perioperative management of cardiac rhythm assist devices in ambulatory surgery and nonoperating room anesthesia. Curr Opin Anaesthesiol 2017; 30(6):676–81.
2. Baranchuk A, Refaat MM, Patton KK, et al: Cybersecurity for cardiac implantable electronic devices: what should you know? J Am Coll Cardiol 2018; 71(11):1284–8.
3. Crumley S, Schraag S: The role of local anaesthetic techniques in ERAS protocol for thoracic surgery. J Thorac Dis 2018; 10(3):1998–2004.
4. Ellison K, Sharma PS, Trohman R: Advances in cardiac pacing and defibrillation Expert Rev Cardiovasc Ther 2017; 15(6):429–40.
5. Noss C, Prusinkiewicz C, Nelson G, et al: Enhanced recovery for cardiac surgery.J Cardiothorac Vasc Anesth 2018; 32(6):2760–70.
6. Reynolds DW, Murray CM: New concepts in physiologic cardiac pacing.Curr Cardiol Rep 2007; 9(5):351–7.
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PERICARDIECTOMY

SURGICAL CONSIDERATIONS

Description

Constrictive pericarditis, either acute or chronic, interferes with ventricular filling, reducing stroke volume and depressing the cardiac index (CI). Although there are many possible etiologies (infectious, nephrogenic, postradiation), the cause remains unknown for a majority of patients. Typically, patients present with a progressive Hx of breathlessness, fatigability, or peripheral or abdominal swelling, often months to years after the inciting event. The Dx may be confirmed by cardiac catheterization, with equalization of end diastolic pressures, although volume loading may be necessary to demonstrate this in the patient under medical management. The differentiation between constrictive pericardial disease and restrictive myocardial disease may be difficult, if not impossible, and may coexist in a single patient. After this Dx has been confirmed, surgical **pericardiectomy** should be undertaken because the outlook without surgical relief is one of gradual but persistent deterioration. Although surgical mortality remains in the 10–15% range, long-term relief for survivors is good. Because these patients are usually significantly compromised hemodynamically, intensive monitoring is indicated. Approach may be through a **median sternotomy** or left **anterolateral thoracotomy.** Removal of both visceral and parietal pericardia is essential for relief, but dense adhesions of these layers to underlying muscle may make this dissection very difficult, tedious, and bloody, especially if the visceral pericardium and epicardium are involved in the constrictive process. CPB may be utilized for hemodynamic instability, but it obviously increases bleeding complications. Complete excision from both ventricular surfaces is mandatory. Most periop difficulties evolve from cardiac failure.

Variant procedure or approaches

A limited **pericardial window,** draining fluid into the left hemithorax, may relieve tamponade, but will be of no benefit for a true constrictive process.

Usual preop diagnosis

Constrictive pericarditis

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist

should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, possible need for a chest tube and postop mechanical ventilation, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Median Sternotomy	Anterolateral Thoracotomy
Position	Supine	Supine, with elevation of left hemithorax
Incision	Midline	5th interspace
Special instrumentation	TEE; full hemodynamic monitoring; CPB standby	⇐
Antibiotics	Cefazolin 2 g iv prior to incision and then 2 g q4h	⇐
Surgical time	2–5 h, depending on tenacity of visceral peel	⇐
Closing considerations	Avoid volume overload and cardiac distension. Chronically depressed hearts may require inotropic or mechanical support (i.e., IABP) postop	⇐
EBL	100–500 mL	⇐
Postop care	ICU; intubated ×4–6 h. Hemodynamic monitoring. Low CO state may persist postop	⇐
Mortality	5–15%, predominantly from cardiac failure	⇐
Morbidity	Persistent CHF: 5%	⇐

	Transient phrenic nerve dysfunction: <1%	
Pain score	7–10	7–10

PATIENT POPULATION CHARACTERISTICS	
Age range	10–80 yr (median = 45 yr)
Male:Female	2:1
Incidence	3–4 patients/yr at tertiary referral center
Etiology	Majority unknown. Infectious, radiation, prior cardiac operation, rheumatic pericarditis, and amyloid deposition
Associated conditions	Restrictive myocardial diseases

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Pericardiectomy is performed most commonly for patients with constrictive pericarditis, whereas pericardial window procedures are used for patients with cardiac tamponade.

Respiratory	Restrictive disease may be present 2° fibrosis (e.g., post-TB) or pleural effusions. This may impair oxygenation and, if the effusions are significant, may ↓ venous return on institution of IPPV → rapid decompensation (↓ CO). Drain prior to surgery. **Tests:** CXR: ✓ active disease, fibrosis, effusions, pericardial calcification. Consider ABG, PFT, as indicated by CXR and Sx, and if time permits.
Cardiovascular	Of importance is the presence or absence of a pericardial effusion. A large effusion that develops slowly (chronic pericarditis) may cause minimal Sx. Conversely, a small and rapidly forming effusion may → cardiac tamponade. Although the cardiovascular signs for both tamponade and constriction are similar

	(pulsus paradoxus, venous HTN, exaggerated venous pulsations, ↓ BP, tachycardia), it is important to differentiate between them because it may affect intraop management. Constrictive pericarditis can be differentiated from cardiac tamponade by ECHO, by pulsus paradoxus (frequent, with tamponade; rare, with constrictive pericarditis). Kussmaul sign (distension of the jugular veins on inspiration) is rare with tamponade and common with constrictive pericarditis. Electrical alternans is present with tamponade and absent in constrictive pericarditis. Examination of the RV pressure wave form is unchanged in tamponade, but shows a dip and prominent Y descent in constrictive pericarditis. Anesthetic management is influenced by the planned procedure, the underlying process (constriction or tamponade), and its severity. Clues to severity are the physical symptoms and the degree of tachycardia, ↓ BP, and the filling pressure. (Although it is not possible to give exact figures, a HR of >100 bpm, a systolic BP < 100 mm Hg, and a filling pressure >15 mm Hg are probably significant.) In addition, it is important to assess concurrent cardiac problems: cardiomyopathy, CAD, or valvular disease (especially in constrictive disease associated with TB and radiation therapy or in rheumatoid diseases, such as lupus). **Tests:** ECG: ✓ low-voltage complexes and electrical alternans. ECHO: ✓ pericardial effusion, calcification of pericardium, valvular lesions, myocardial function.
Gastrointestinal	Chronic hepatic congestion may → ↓ synthetic function (↓ procoagulants). Development of ascites may → ↑ intra-abdominal pressure. Because of this and the fact that these are sometimes emergency procedures, consider possible full stomach. **Tests:** Consider LFTs; PT; PTT.
Renal	Renal failure may cause pericarditis, and conversely, pericarditis may cause renal failure (2° prerenal

	factors: ↑ venous pressure, ↓ perfusion pressure). This may affect the choice of drugs used for anesthesia that depend on renal clearance (particularly muscle relaxants). **Tests:** BUN; Cr; consider creatinine clearance; electrolytes.
Hematologic	Some renal or hepatic conditions may be associated with coagulation disorders. These include both procoagulant and Plt problems. If possible, any coagulopathy should be corrected before surgery with FFP, Plt, or both. Consult with a hematologist, if necessary. **Tests:** Hb/Hct; PT; PTT; Plt count
Laboratory	Other tests as indicated from H&P
Premedication	Little or no premedication may be indicated; otherwise, a benzodiazepine (e.g., midazolam 0.05–0.2 mg/kg im) may be used. Consider full-stomach precautions: H_2 antagonists (e.g., ranitidine 50 mg iv), metoclopramide (10 mg iv), and antacids (e.g., Na citrate 0.3 M 30 mL po).
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of thoracic epidural, continuous paravertebral, or chest wall nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: An arterial line should be inserted, using liberal amounts of local anesthetic, before induction. The presence of real-time BP monitoring can be critical in the care of these patients, especially during induction. Although it is helpful to have a CVP line before induction for preload monitoring and drug infusion, it is not essential. This line

usually is inserted after the patient is intubated. If infused drugs are necessary before the CVP catheter is in place, they can be administered through a separate peripheral iv. Consider pericardiocentesis or pericardial window under local anesthesia prior to induction, as drainage of even a small amount of fluid may improve the patient's status dramatically. The considerable manipulation of the heart, extensive dissection, blood loss, dysrhythmias, and unrelieved tamponade make pericardiectomy cases a challenge.

Induction	Typically, ketamine (1–2 mg/kg) or etomidate (0.2–0.3 mg/kg) ± narcotic (fentanyl 5–10 mcg/kg), depending on patient status. Consider maintaining spontaneous ventilation in tamponade patients until drained, as institution of IPPV may result in rapid decompensation and cardiac arrest due to ↓ ↓ venous return. Otherwise, succinylcholine (1 mg/kg) with cricoid pressure (full stomach) or vecuronium (0.1 mg/kg) for muscle relaxation. For unstable patients, may prep and drape and have surgeons standing by before induction of anesthesia.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider placement of parasternal or chest wall nerve blocks if preop blocks have not been placed. Ketamine (0.5 mg/kg iv) at induction may improve pain management and reduce delirium after CPB.
Maintenance	Narcotic (total fentanyl 10–20 mcg/kg), low-dose volatile agent, midazolam (50–350 mcg/kg), or a combination of these agents in 100% O_2. CO is dependent on maintaining a high preload to ensure adequate cardiac filling, avoiding and treating bradycardia, and preserving myocardial contractility. The use of inotropes (dopamine, isoproterenol, or epinephrine) may be necessary; α-agonists should be avoided but, on occasion, may be needed to increase coronary perfusion. These anesthetic considerations apply to both tamponade and constrictive disease. In patients with acute tamponade, dramatic increases in BP may occur when the pericardium is opened.

	Aggressive use of vasodilators and additional anesthetic agents may be necessary. Recommend use of antifibrinolytics for all cases requiring CPB.	
Emergence	In general, plan for extubation in the OR in the case of pericardial window and transport to ICU for postop ventilation 4–24 h following pericardiectomy. Discuss with surgeon local wound infiltration or chest wall nerve block (e.g., via prefascial plane catheter) placement. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 14 ga (or 7 Fr) × 1–2; BSS UO: 0.5–1 mL/kg/h Warm fluids and humidify gases. T&C 2–4 U for pericardiectomy	During pericardiectomy, anticipate rapid blood loss (a major cause of mortality). For this reason, CPB should be available on standby for all pericardiectomy procedures. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors Arterial line CVP line PA catheter TEE Urinary catheter	Standard monitors and an A-line are placed before induction. CVP (and/or PA line, if indicated) usually is placed after intubation. PA catheters aid the management of filling pressures, CO, and afterload. TEE may be useful to gauge filling volume and degree of relief of pericardial constriction.
Complications	Cardiac tamponade	Intrathoracic pressure

	Dysrhythmias	associated with IPPV may produce a ↓ ↓ CO in these patients (because of ↓ venous return). Spontaneous ventilation, therefore, is preferred until the tamponade is drained.
	Hemorrhage Heart failure	Hemorrhage is not usually a problem unless penetrating trauma is the cause of the tamponade. Once constriction is relieved, myocardial function does not return to normal quickly. Inotropes are often needed.
	Coagulopathy	Due to extensive dissection and hemorrhage, coagulopathies may develop and should be treated aggressively.
Positioning	✓ and pad pressure points ✓ eyes	

POSTOPERATIVE

Complications	Hemorrhage Coagulopathy Ventricular hypofunction Dysrhythmias Ischemia	Following pericardial window surgery, patients improve with the relief of the tamponade. Postpericardiotomy patients, however, may have a continuation of intraop dysrhythmias and myocardial depression.

		Inotropes (e.g., dopamine 5–10 mcg/kg/min) may be needed for 24–48 h. Normal cardiac function can take 4–6 wk to return.
Multimodal pain management	Limit opioids	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	If postop sedation is required, dexmedetomidine may be preferable to propofol. Encourage fast-track extubation, early enteral nutrition, Foley catheter removal, and mobilization.
Tests	ECG CXR ABG Coag profile Electrolytes	

Suggested Readings

1. Crumley S, Schraag S: The role of local anaesthetic techniques in ERAS protocol for thoracic surgery. J Thorac Dis 2018; 10(3):1998–2004.
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5. Noss C, Prusinkiewicz C, Nelson G, et al: Enhanced recovery for cardiac surgery.J Cardiothorac Vasc Anesth 2018; 32(6):2760–70.
5. Tuck BC, Townsley MM. Clinical update in pericardial diseases.J Cardiothorac Vasc Anesth 2019; 33(1):184–99.

Suggested Viewing

Links are available online to the following videos:

Bypass Surgery on a Beating Heart. Arie Blitz, MD, FACC: https://www.youtube.com/watch?v=MGzyhuCs43o

Heart Transplantation: Surgical Technique. Arie Blitz, MD: https://www.youtube.com/watch?v=lB_2Xvmqxjo

Surgical Repair of a Ruptured Type A Aortic Dissection: Arie Blitz, MD.https://www.youtube.com/watch?v=O398CeblR3U

Mitral Valve Replacement for Rheumatic Heart Disease: https://www.youtube.com/watch?v=W2FBtSysaPU

Repair of Ascending Aortic Aneurysm: Arie Blitz, MD: https://www.youtube.com/watch?v=h_u6SfPhHyc

Minimally Invasive Mitral Valve Surgery—Right Thoracotomy Approach: https://www.youtube.com/watch?v=EnJQh_W3r3A

NEJM Procedure: Deployment of an Endovascular Graft in an Abdominal Aortic Aneurysm https://www.youtube.com/watch?v=qUpXJBoAoWI

CHAPTER 6.2

Minimally Invasive Cardiac Surgery

SURGEON
James I. Fann, MD

ANESTHESIOLOGISTS
Albert Tsai, MD
Daryl Oakes, MD

OFF-PUMP AND MINIMALLY INVASIVE CORONARY ARTERY BYPASS GRAFTING

SURGICAL CONSIDERATIONS

Description

Although coronary artery bypass grafting (CABG) without cardiopulmonary bypass (CPB) was originally proposed more than six decades ago, development and advances in CPB resulted in the abandonment of off-pump cardiac surgery by most cardiac centers until the 1990s. The re-emergence of off-pump coronary revascularization was due in part to reported adverse effects of CPB (e.g., cerebral and systemic inflammatory response), increased comorbidities in an aging population, medical economics, and the development of reliable mechanical stabilization devices (Fig. 6.2-1). More recently, some of the advantages of off-pump CABG have been questioned. Off-pump surgery is technically more challenging and has been associated with a higher risk of incomplete revascularization. Results from a 5-yr randomized outcome study comparing off-pump versus on-pump CABG demonstrated the inferiority of off-pump surgery. Other studies have suggested that off-pump surgery may be beneficial in select patient populations (e.g., octogenarians and patients with chronic kidney disease).

From the standpoint of terminology, off-pump coronary artery bypass (OPCAB) grafting applies to all cases of coronary revascularization not using the CPB circuit, and although it does not refer directly to the surgical approach, most are via conventional median sternotomy. Minimally invasive direct coronary artery bypass (MIDCAB/MICAB) grafting refers to off-pump coronary revascularization via a small anterolateral thoracotomy incision, while totally endoscopic coronary artery bypass grafting (TECAB) refers to robotic off-pump coronary revascularization accomplished entirely endoscopically without thoracotomy.

Challenges of off-pump coronary revascularization include accurate vascular anastomosis while minimizing hemodynamic perturbations during the procedure. Interrupting flow to the target artery can → regional ischemia, arrhythmias, and hemodynamic instability; displacing the heart to expose lateral or posterior arteries may → ventricular compression and profound hemodynamic compromise. Pharmacologic interventions to decrease HR and ischemic preconditioning may facilitate the anastomosis. Although not fully defined, ischemic preconditioning results from exposure to transient myocardial ischemia and is an endogenous adaptation that may mitigate the effects of subsequent prolonged myocardial ischemia. Thus, mechanically occluding the coronary artery for a brief period may confer some protection from ischemic injury associated with coronary occlusion during the anastomosis. Important preop considerations include the number and suitability of distal-target coronary arteries, cardiac function and pulmonary status, and other medical comorbidities. The presence of cardiomegaly may limit the degree of intraop cardiac manipulation. The perfusionist is present during the procedure so that rapid conversion to conventional on-pump CABG can be achieved if there are hemodynamic compromise, unsuitable distal target inability to expose lateral or posterior target vessels, or regional myocardial ischemia. Occasionally, placement of intra-aortic balloon pump intraop may facilitate the off-pump approach in a patient with ischemic cardiomyopathy.

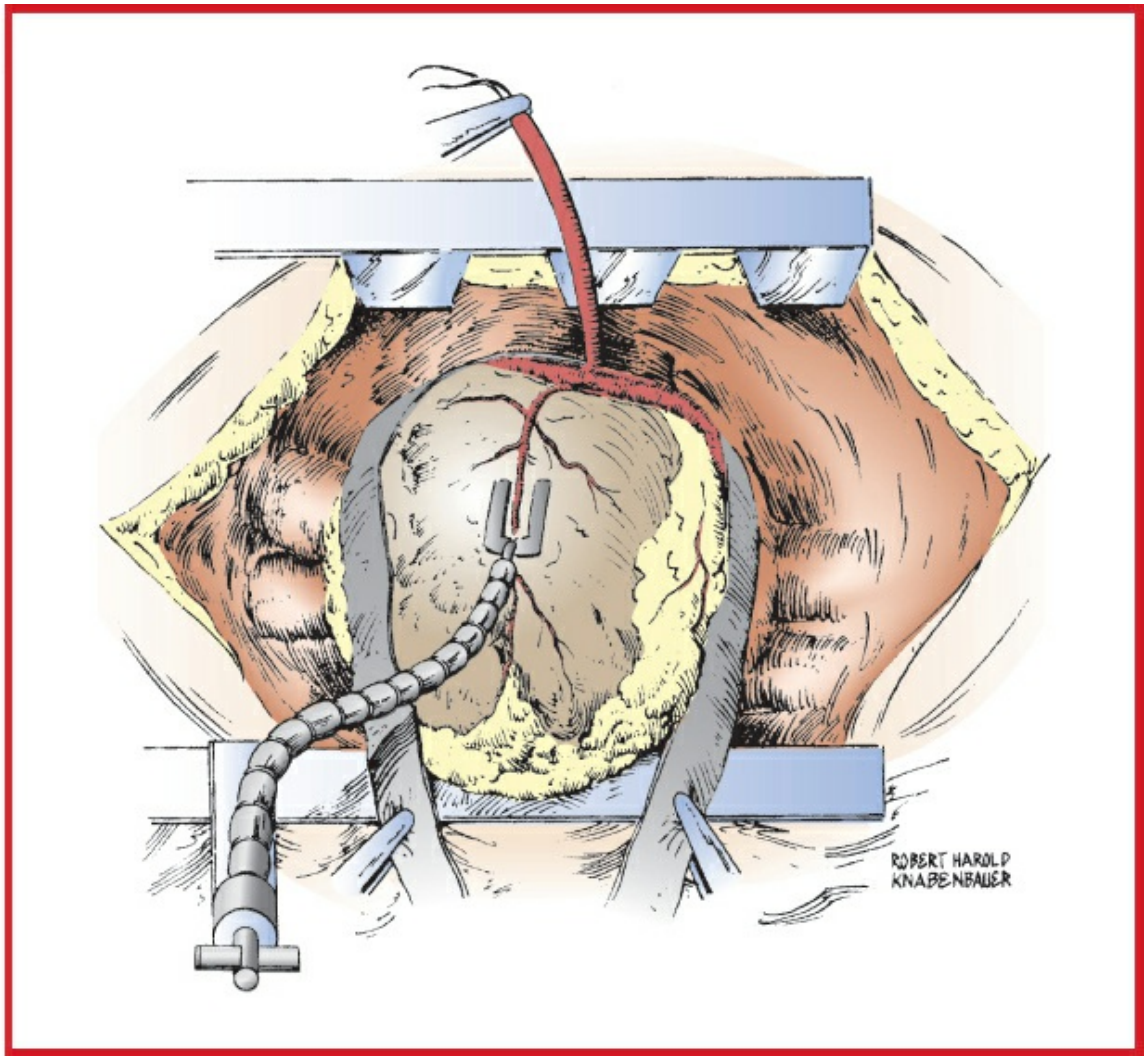

Figure 6.2-1 Manipulation of the heart and placement of a pressure-plate mechanical stabilizer is performed in preparation for OPCAB. (Reproduced with permission from Estafanous FG, Barash PG, Reves JG:Cardiac Anesthesia: Principles and Clinical Practice, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

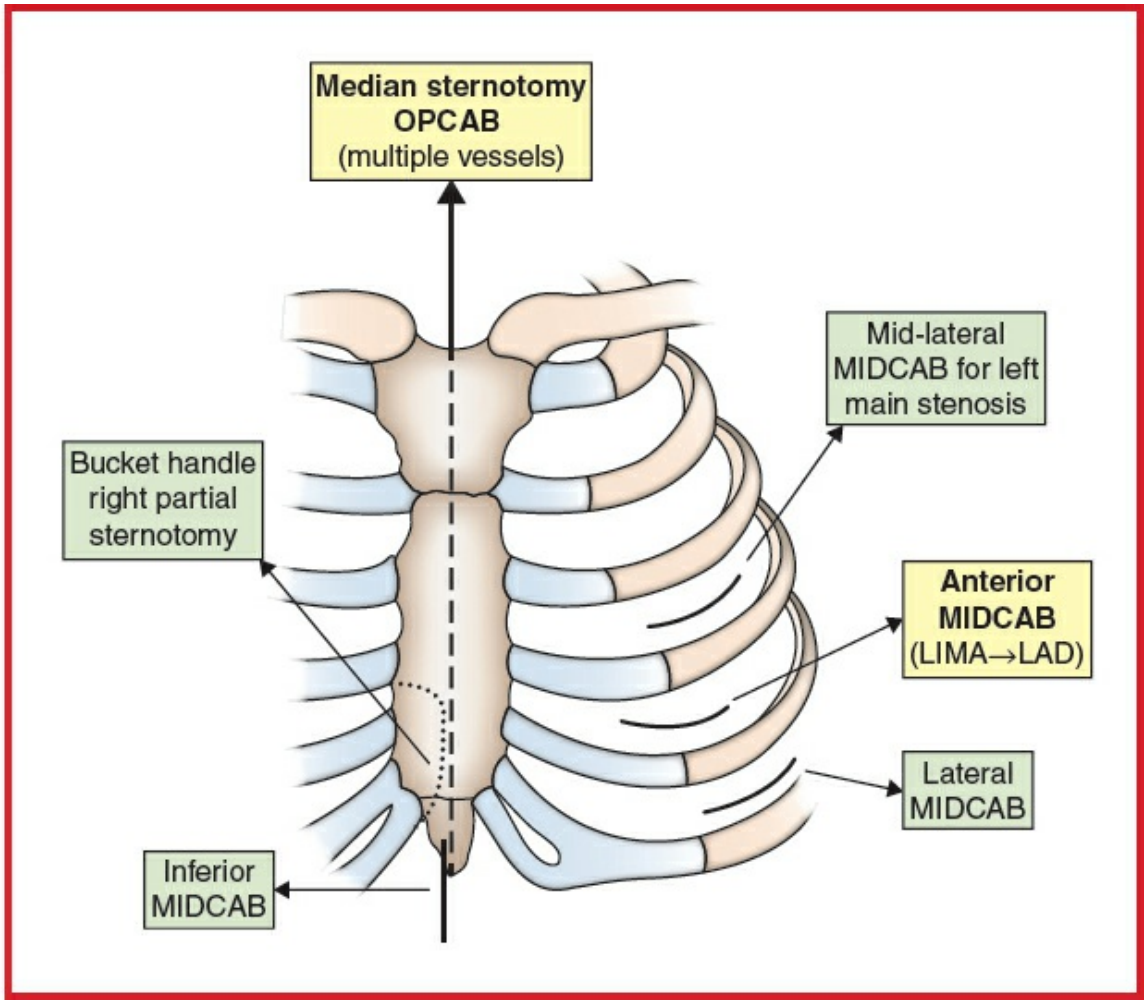

Figure 6.2-2 Incision sites for access to various target coronary arteries in MICAB. (Reproduced with permission from Estafanous FG, Barash PG, Reves JGCardiac Anesthesia: Principles and Clinical Practice, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

For conventional OPCAB, a standard median sternotomy is made (Fig. 6.2-2). If the internal mammary artery (IMA) is to be used as a graft, it is harvested in the usual fashion. The patient is partially heparinized, and an intravenous bolus of lidocaine is given. A sternal retractor with attachments for coronary stabilization is placed (Fig. 6.2-1). If vein grafts are used, the proximal anastomoses may be performed at this point or later, after the completion of the distal anastomoses, using a partial side-biting aortic cross-clamp or automated anastomotic device. During the period of partial aortic clamping, BP typically is lowered to reduce potential complications associated with the use of the clamp. The goal of the operation is to establish adequate perfusion of the most critical vascular bed first. Provided it is a target vessel, the left anterior descending (LAD) artery is often approached first because an IMA graft (or vein graft) can provide immediate perfusion to the anterior, septal, and anterolateral LV walls and requires minimal cardiac manipulation to construct the anastomosis. Mechanical coronary artery stabilizers, based on local myocardial compression (Fig. 6.2-1) or vacuum suction (Fig.

6.2-3) and attached to the retractor, provide stable local epicardial motion restraint, thereby facilitating the anastomosis. After stabilization, the artery is occluded (following a period of ischemic preconditioning), and an arteriotomy is made. Equipment that minimizes blood in the operative site includes standard suction attachments, temporary intracoronary shunts, vessel occluders, and "blower-misters" that displace blood by delivering a combination of gas (CO_2) and heparinized saline. The distal anastomosis is then performed. The patient is monitored closely at this point for any signs of myocardial ischemia and/or hemodynamic instability. To expose the lateral and posterior target vessels (most often branches of the circumflex and right coronary arteries), manipulation of the heart is necessary and may not be well tolerated. During lateral and posterior pericardial suture placement, the surgeon displaces and compresses the heart, resulting in temporary hemodynamic compromise due to decreased preload and ventricular distortion. Ventilation may need to be decreased temporarily to facilitate this maneuver. Additional exposure techniques include the use of an apical suction device to facilitate cardiac manipulation with potentially less hemodynamic compromise, Trendelenburg position and tilting the operating table to the right, release of right pericardial stay sutures, opening of the right pleura and incising the right pericardium, and placement of laparotomy sponges. The target vessel is stabilized again, ischemic preconditioning is carried out, and the artery is opened. After construction of the distal anastomosis, the graft is relieved of any residual air before securing the sutures and the proximal anastomosis performed if not already done so as noted earlier. Graft flow is assessed using a Doppler flow probe.

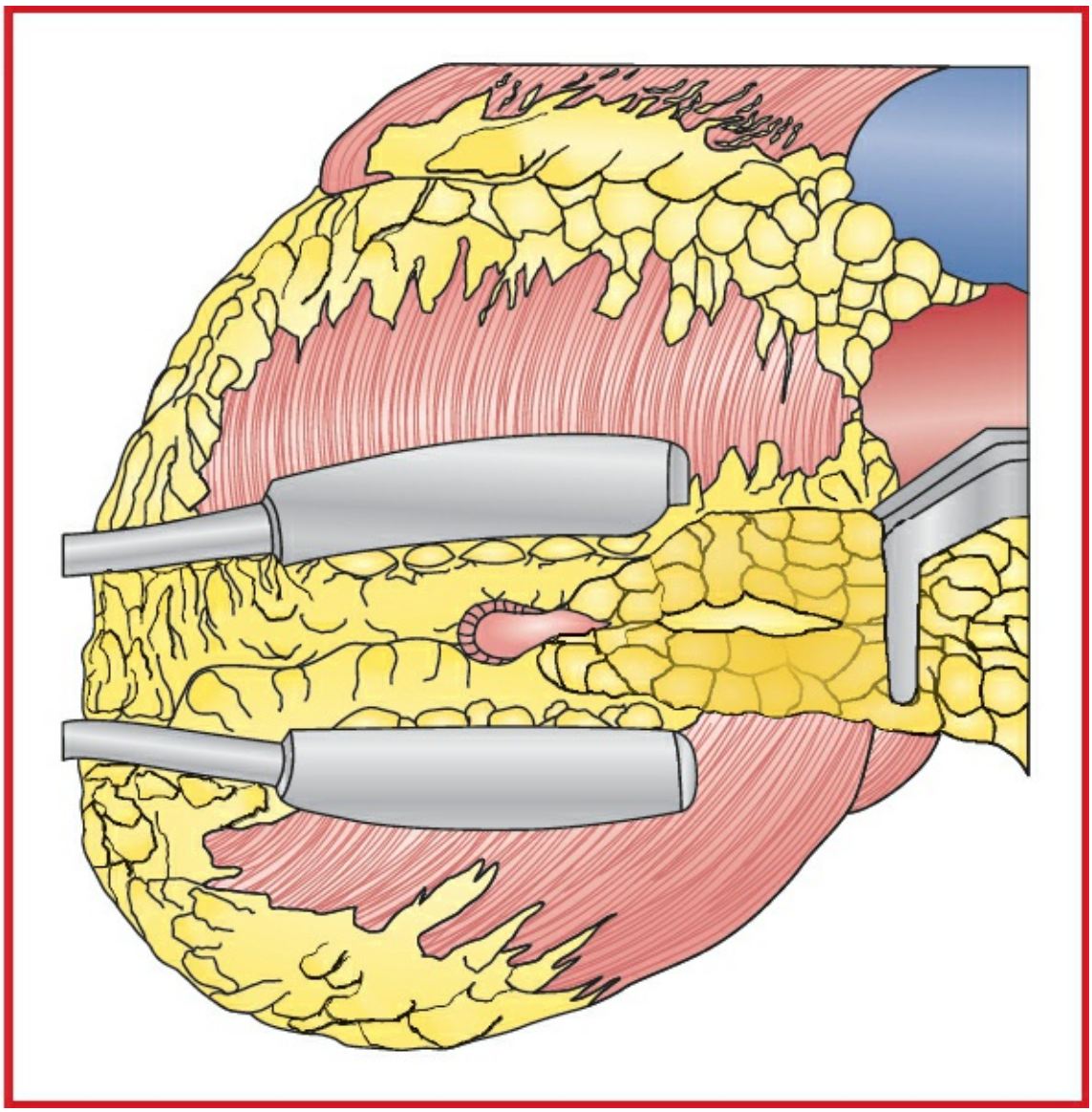

Figure 6.2-3 The Octopus stabilizer (Medtronic, Minneapolis, MN) uses a series of suction cups on two fixed arms that adhere to the epicardial surface and reduce myocardial motion at the anastomotic site during OPCAB. (Reproduced with permission from Estafanous FG, Barash PG, Reves JG. Cardiac Anesthesia: Principles and Clinical Practice, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, possible need for a chest tube and postop mechanical ventilation, and physiotherapy plan. See Appendix K: Enhanced Recovery After Surgery, p. K-1.

SUMMARY OF PROCEDURE

Position	Supine

Incision	Median sternotomy (OPCAB); alternatively, limited left anterolateral thoracotomy (MIDCAB; Fig. 6.2-2)
Antibiotics	Cefazolin 2 g iv
Surgical time	3–4 h
Closing considerations	No special considerations. Patients often can be extubated in OR
EBL	200–400 mL (consider using Cell-Saver)
Postop care	ICU for cardiac monitoring ± ventilator management, less volume required than with conventional CABG
Mortality	0–5% (higher with increasing age)
Morbidity	AF: 10–30% Pulmonary insufficiency: 3–5% Reoperation for bleeding: 1–4% Cardiac (e.g., myocardial infarction): 0–4% Mediastinal infection: 1–2% Neurologic (cerebrovascular accident): 1–2% Renal dysfunction: 1–2% IABP use: 0–2%
Pain score	4–6

PATIENT POPULATION CHARACTERISTICS

Age range	40 to >90 yr
Male:Female	3:2
Incidence	150,000/yr in the United States
Etiology	Multifactorial for atherosclerosis
Associated conditions	HTN, diabetes, PVD, COPD, cigarette smoking

ANESTHETIC CONSIDERATIONS FOR TECAB/MICAB/OPCAB

PREOPERATIVE

Preop assessment is similar to that used for standard CABG patients. Relative contraindications for MICAB include low EF, morbid obesity, previous cardiac surgery, AF, and COPD or other pulmonary pathology precluding the use of one-lung ventilation (OLV). It is important to know the coronary artery anatomy and the planned surgical procedure and sequence. For example, proximal surgical occlusion of a coronary artery with high-grade distal disease may be poorly tolerated as compared with severe proximal disease with collateralization.

Premedication	Adequate control of preop anxiety using midazolam (titrated to effect) may reduce periop tachycardia.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of thoracic epidural, continuous paravertebral, or chest wall nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: For MICAB/MIDCAB, selective lung ventilation with DLT, Univent ETT, c bronchial blocker. Unlike CABG on CPB, the anesthetic demands for OPCABG ar somewhat different, as CPB will not be providing hemodynamic support. Positioning of the heart for access to the target vessel and mechanical stabilization of the heart to immobilize the vessel for accurate anastomosis tend to produce hemodynamic compromise. In particular, elevation of the LV apex to allow access to lateral and posterior wall vessels can limit LV filling and obstruct RV outflow tract. In addition, ↓ TV may be necessary to prevent obstruction of visualization. Snares may be placed around the coronary target vessel to create a dry operative field; however, this may provoke regional ischemia. Many of these changes are assessed by intraop TEE, and they may require resuscitative measures with volume loading, vasoconstriction, and inotropic support (e.g., dopamine). Interventions on the RCA are particularly prone to arrhythmias, and appropriate antiarrhythmics and pacing should be available. For further discussion, see Intraoperative considerations for CABG.

Induction	As for CABG surgery. For MICAB, these patients will undergo a small anterior thoracotomy, and the aim is to extubate them at the end of the procedure or shortly thereafter. Thus, the dose of narcotic should be moderate (e.g., fentanyl 5–15 mcg/kg). Long-acting muscle relaxants should be avoided for the same reason. Consider regional anesthetic techniques (e.g., paravertebral or intercostal blocks) and local anesthetic infiltration.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider placement of parasternal or chest wall nerve blocks if preop blocks have not been placed. Ketamine (0.5 mg/kg iv) at induction may improve pain management and reduce delirium after CPB.	
Maintenance	Because early extubation is planned, volatile agents or propofol should be used and the overall dose of narcotic reduced. Remifentanil infusion may also be useful. Recommend the use of antifibrinolytics for all cases requiring CPB.	
Emergence	For further discussion, see Postoperative Considerations for CABG. If the patient is not suitable for extubation in the OR, a DLT may be exchanged for a conventional ETT (over a tube changer) before transport to ICU. Discuss with surgeon local wound infiltration or chest wall nerve block (e.g., via prefascial plane catheter) placement. Consider iv acetaminophen if po dose is given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	See CABG surgery	Without the use of CPB, hemodilution from the pump prime is avoided. See Goal-Directed Fluid Management, Appendix K, p. K-4.

Monitoring	See CABG surgery	Central venous access. PA catheters are useful for detecting ischemia in patients with poor LV function. If a continuous CO thermodilution catheter is used, consideration must be given to the delays in data display. ST segment analysis.
	TEE	Useful for detecting ischemia, LV dysfunction, and load assessment. Views may be limited by surgical positioning of the heart within the chest.
Special considerations	Anticoagulation	Heparin should be administered before surgical coronary artery occlusion.
	Ischemic preconditioning temporary occlusion → ischemia	Prior to occlusion, ischemic preconditioning may be accomplished with surgical manipulation and by pharmacologic means (e.g., isoflurane, sevoflurane). This is a great opportunity to consider how well transient ischemia is tolerated. During grafting, the vessel is temporarily occluded to avoid flooding the field with blood. The myocardium distal to this may become ischemic.

	✓ ECG, TEE	TEE imaging will be affected by surgical mechanical manipulation of the heart, and ECG voltage may be decreased.
	Cardiac positioning →↓ CO	Cardiac output may be markedly reduced by the combination of heart positioning and coronary artery occlusion. Vasoconstriction may be required to maintain adequate blood pressure. Patients poorly responsive to vasoconstrictors may have extremely depressed cardiac output and severe acidosis. Inotropic support or intra-aortic balloon pumping may be necessary.
	Coronary artery shunt	Surgical placement of a coronary artery shunt may be necessary. Treatment of rhythm disorders with pharmacologic agents, pacing, or defibrillation may be required. The capability to institute CPB rapidly should exist. A rest period with the heart returned to the normal position within the chest should be considered following each

		anastomosis to restore cardiac output and permit resolution of acidosis.
Positioning	✓ pad pressure points ✓ eyes	

POSTOPERATIVE

Complications	See CABG surgery Premature extubation	
Multimodal pain management	Same as CABG surgery	Preop placement of paravertebral catheters and postop intercostal blocks will decrease opioid use and aid in early extubation. Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-1)	If postop sedation is required, dexmedetomidine may be preferable to propofol. Encourage fast-track extubation, early enteral nutrition, Foley catheter removal, and mobilization.
Tests	See CABG surgery	

Suggested Readings

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outcomes in patients undergoing off-pump coronary artery bypass surgery: a prospective, randomized, controlled trial. Anesthesiology 2011; 114(2):380–90.
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PORT-ACCESS AND TECAB CORONARY REVASCULARIZATION

SURGICAL CONSIDERATIONS

Description

Advances in videoscopic technology have led to less-invasive approaches in the treatment of many general and thoracic surgical disorders. The development of less-

invasive surgery has resulted in alternative and novel approaches to cardiac surgery (Fig. 6.2-4), including port-access cardiac surgery and off-pump coronary revascularization. The port-access approach was developed in the mid-1990s and is now infrequently used because of its complexity. With the development of robotic (or total endoscopic) techniques, the port-access technology is being employed as a means to achieve CPB and cardioplegic arrest. Using a port-access approach, the surgeon can perform cardiac operations (e.g., CABG) and valve surgery in a motionless, bloodless field through smaller chest incisions. This approach typically relies on peripheral CPB (femoral artery and femoral vein cannulation, Fig. 6.2-5). The femoral artery is cannulated with a 19- to 23-Fr Y-shaped cannula, which permits arterial inflow and insertion of the endoaortic clamp. Venous drainage is provided by the 22- to 25-Fr cannula, introduced through a femoral vein. Drainage may be augmented by 20–40%, using vacuum-assisted venous drainage or a centrifugal venous drainage pump placed between the venous cannula and the reservoir. The port-access system includes a 10.5-Fr endoaortic "clamp" (EAC), a triple-lumen catheter with an inflatable balloon at its distal end. This clamp is positioned in the ascending aorta using fluoroscopy and TEE guidance. The lumen used for balloon inflation is connected to a manometer to monitor balloon pressure. Cardioplegic solution is delivered through a central lumen, which also acts as an aortic root vent after cardioplegia delivery. A third lumen serves as an aortic root pressure monitor. In addition, a percutaneous PA-venting catheter, placed via the jugular approach, helps in ventricular decompression. The left IMA is harvested under direct vision (Fig. 6.2-6), with video-assisted thoracoscopy (VAT; Fig. 6.2-7) or robotic assistance. After peripheral CPB is achieved, the EAC provides aortic occlusion and cardioplegic arrest. Exposure of the lateral and posterior aspects of the heart is easily accomplished in the arrested heart, thereby permitting two- and three-vessel coronary revascularization. Notably, if the ascending aorta is accessible, a dual-armed, Y-shaped cannula can be placed directly into the ascending aorta with one arm of the cannula connected to the arterial inflow of the CPB circuit and the other arm as a conduit for introducing the EAC.

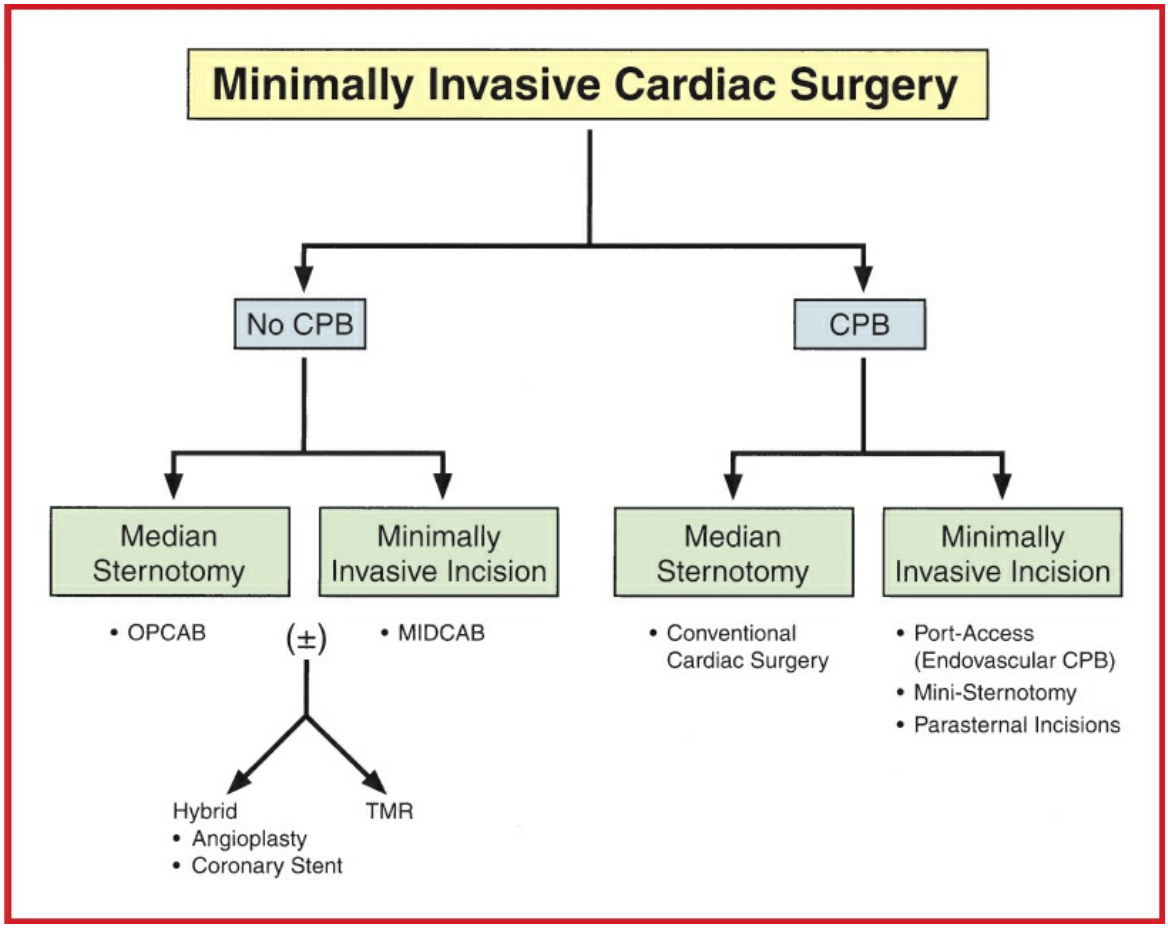

Figure 6.2-4 Variations in coronary artery bypass and valvular heart surgery, with minimally invasive techniques. CPB, cardiopulmonary bypass; OPCAB, off-pump coronary artery bypass; MIDCAB, minimally invasive direct coronary artery bypass; TMR, transmyocardial revascularization. (Redrawn with permission from Estafanous FG, Barash PG, Reves JGCardiac Anesthesia: Principles and Clinical Practice, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

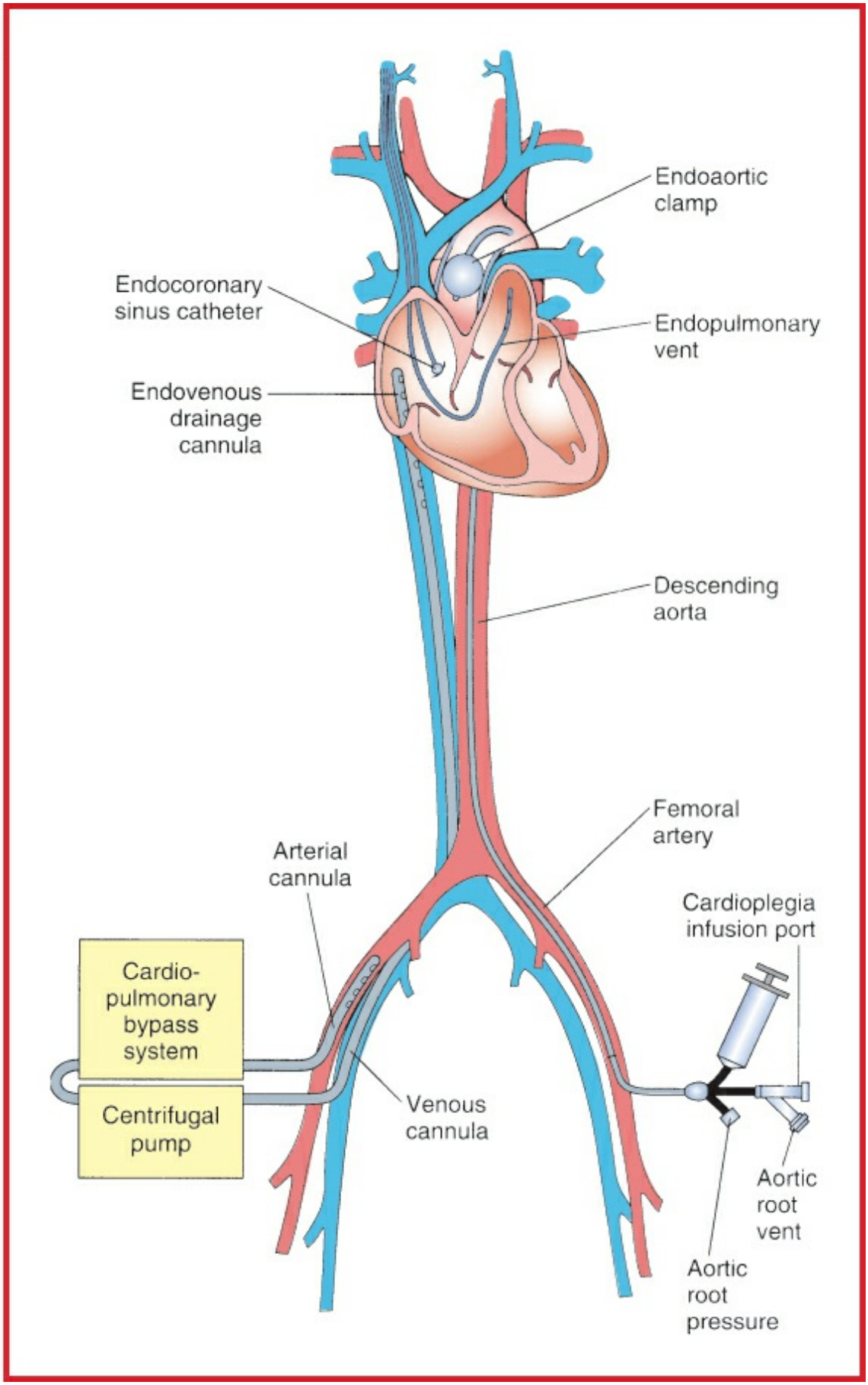

Figure 6.2-5 The port-access cardiopulmonary bypass (CPB) system. Femorofemoral (fem-fem) CPB

is utilized, and a centrifugal pump augments venous drainage. The endoaortic balloon occlusion catheter is inflated in the ascending aorta, and antegrade cardioplegia is delivered through the central lumen. The endopulmonary vent assists in ventricular decompression. (Redrawn from Fann JI, Pompili MF, Stevens JH, et al: Port-access cardiac surgery with cardioplegic arrest. Ann Thorac Surg 1997; 63:S35–9. Copyright © 1997 Elsevier. With permission.)

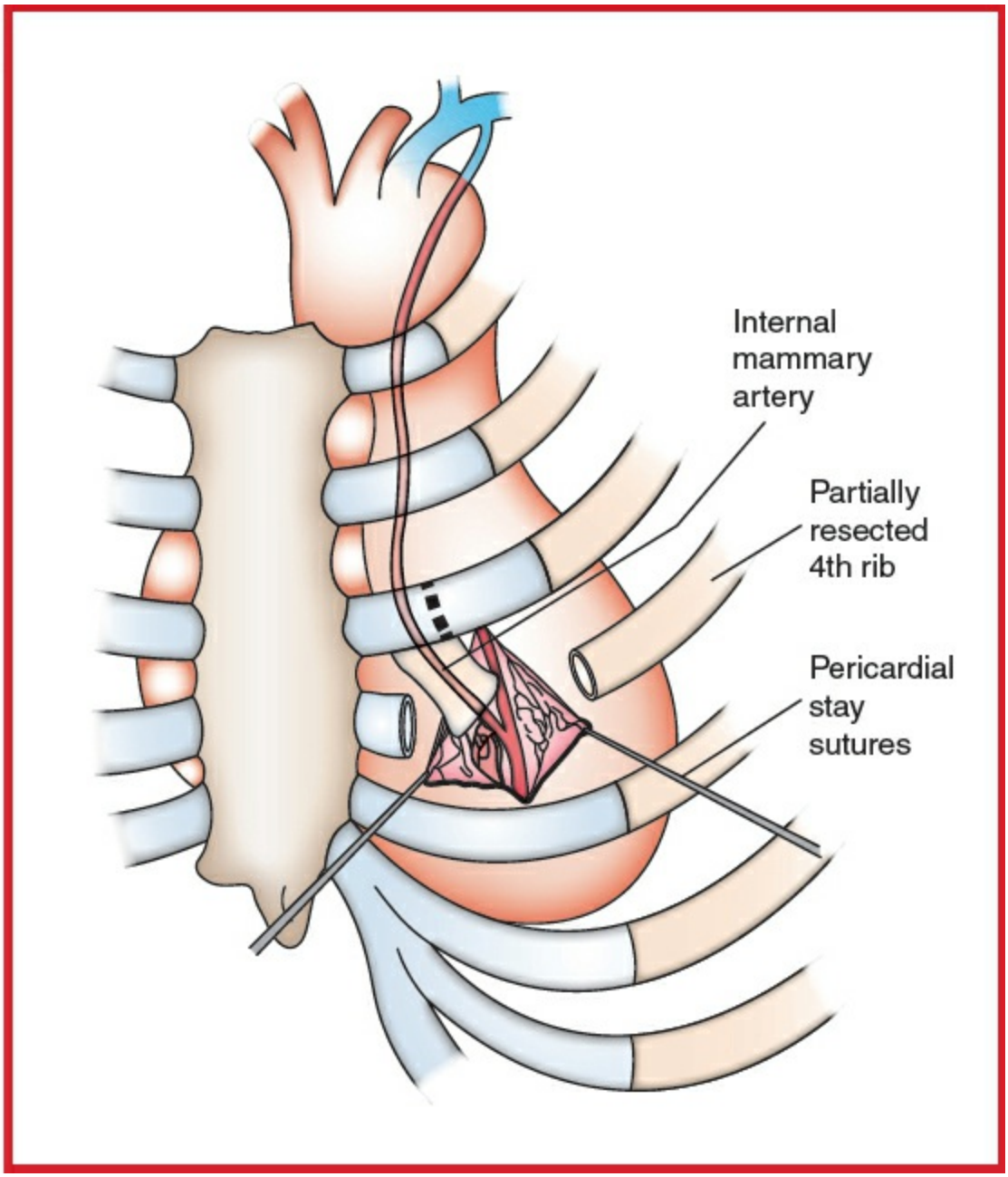

Figure 6.2-6 The left IMA-to-left anterior descending artery anastomosis is performed under direct vision. Stay sutures suspend the pericardium and bring the heart into view. (Redrawn from Acuff TE, Landreneau RJ, Griffith BP, et al: Minimally invasive coronary artery bypass grafting. Ann Thorac Surg 1996; 61(1):135–7. Copyright © 1996 Elsevier. With permission.)

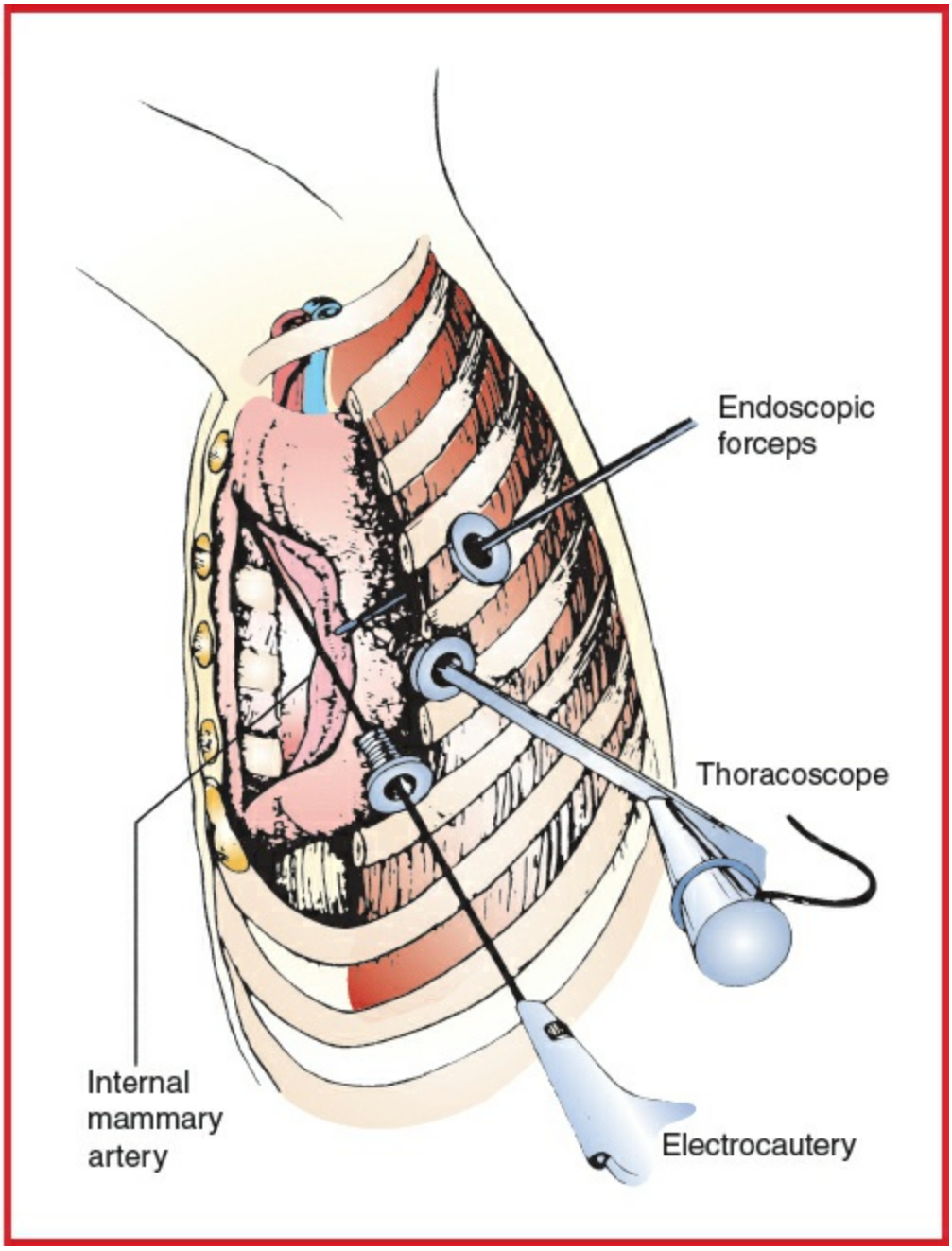

Figure 6.2-7 Dissection and harvesting of the left IMA using a thoracoscopic approach. (Redrawn from Acuff TE, Landreneau RJ, Griffith BP, et al: Minimally invasive coronary artery bypass grafting. Ann Thorac Surg 1996; 61(1):135–7. Copyright © 1996 Elsevier. With permission.)

Usual preop diagnosis

Coronary artery disease (CAD)

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, possible need for a chest tube and postop mechanical ventilation, and

physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	4th interspace, left anterior thoracotomy for CABG; may need to resect the 4th rib; may need thoracoscopy for IMA harvest
Special instrumentation	TEE and fluoroscopy
Unique considerations	CPB used with peripheral femoral cannulation, percutaneous insertion of PA vent and retrograde cardioplegic catheter
Antibiotics	Cefazolin 2 g iv at induction
Surgical time	3–5 h
Closing considerations	Assess chest wall for hemorrhage, chest tube insertion. Bupivacaine for field block
EBL	250–500 mL
Postop care	ICU monitoring, early extubation, may require inotropic support
Mortality	1–3%, depending on comorbidities
Morbidity	Arrhythmias (including atrial fibrillation): 10% Conversion to sternotomy: 4% MI: 0–4% Reoperation for bleeding: 3% Stroke: 2% Thrombosis of graft (graft failure): rare Fem-fem bypass complications (e.g., arterial dissection): rare
Pain score	1–4

PATIENT POPULATION CHARACTERISTICS	
Age range	40–80 yr

Male:Female	3:2
Incidence	<50,000/yr in the United States
Etiology	Multifactorial for atherosclerosis
Associated conditions	LV dysfunction, COPD, PVD, HTN, diabetes mellitus, cigarette smoking

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Port-Access Procedures.

Suggested Readings

1. Dogan S, Graubitz K, Aybek T, et al: How safe is the port access technique in minimally invasive coronary artery bypass grafting? Ann Thorac Surg 2002; 74:1537–43.
2. Ishikawa N, Watanabe G: Robot-assisted cardiac surgery. Ann Thorac Cardiovasc Surg 2015; 21(4):322–8.
3. Kofler M, Schachner T, Reinstadler SJ, et al: Comparative analysis of perioperative and mid-term results of TECAB and MIDCAB for revascularization of anterior wal Innovations (Phila) 2017; 12(3):207–13.
4. Langer NB, Argenziano M: Minimally invasive cardiovascular surgery: incisions and approaches. Methodist Debakey Cardiovasc J 2016; 12(1):4–9.
5. Maselli D, Pizio R, Borelli G, et al: Endovascular balloon versus transthoracic aortic clamping for minimally invasive mitral valve surgery: impact on cerebral microemboli. Interact Cardiovasc Thorac Surg 2006; 5:183–6.
6. See Suggested Readings for Port-Access Procedures.

LIMITED THORACOTOMY AND PORT-ACCESS APPROACHES TO VALVE SURGERY

SURGICAL CONSIDERATIONS

Description

Although the field of mitral valve surgery has seen marked advances in biomaterials and innovative repair techniques since the early 1960s, the **conventional median sternotomy approach** to access and expose the mitral valve has not changed substantially. Because of the progress in video-assisted surgery, a less-invasive approach to cardiac surgery has been developed, and various techniques of mitral valve

surgery through **limited thoracotomy** or **upper sternotomy** incisions and a **port-access technique** to achieve cardioplegic arrest are now used in the clinical setting. The transcatheter approach to valve surgery (see p. 440) may eventually supplant open surgical valve repair/replacement techniques.

Limited thoracotomy

The right thoracotomy incision is a less-invasive approach (compared to median sternotomy) for mitral valve procedures (Fig. 6.2-8). Utilizing hypothermic fibrillatory or cardioplegic arrest, the mitral valve, annulus, and subvalvular apparatus can be visualized directly and the valve procedure carried out. The addition of VAT to mitral valve surgery or using robotic technology has resulted in even smaller incisions for these procedures.

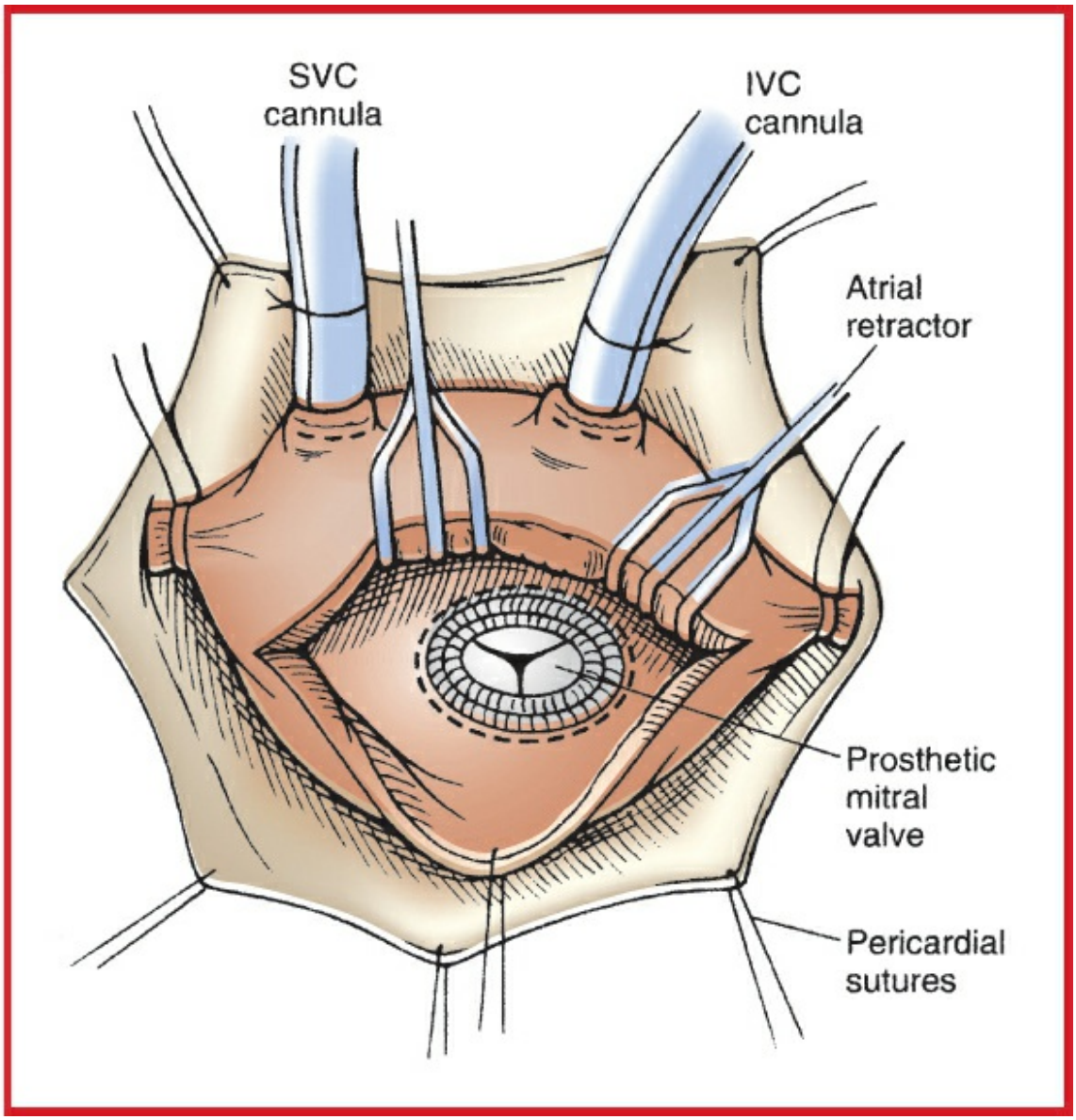

Figure 6.2-8 The right thoracotomy approach with left atriotomy and exposure of the mitral valve area

with prosthetic valve in place. (Reprinted from Tribble CG, Killinger WA Jr, Harman PK, et al: Anterolateral thoracotomy as an alternative to repeat median sternotomy for replacement of the mitral valve. Ann Thorac Surg 1987; 43:380–2. Copyright © 1987 The Society of Thoracic Surgeons. With permission.)

A "micromitral" approach to mitral valve replacement has been described, using VAT through a limited thoracotomy. Peripheral CPB (fem-fem) is used, and a catheter is placed in the coronary sinus for retrograde cardioplegia delivery. An external aortic cross-clamp is introduced through a separate incision in the chest. After achieving cardioplegic arrest, the mitral valve is replaced with thoracoscopic assistance. Proposed advantages of the micromitral approach include the avoidance of a sternotomy, with decreased chest wall trauma and patient discomfort.

An alternative **partial sternotomy approach** to mitral and aortic valve surgery has been described. The 7-cm partial sternotomy permits aortic and right atrial cannulation for CPB. The external aortic cross-clamp is positioned, and a left ventricular vent is placed through the right superior pulmonary vein. Mitral valve exposure is achieved through the dome of the left atrium.

Port-access mitral valve surgery

The port-access system has been used successfully in mitral valve surgery via limited thoracotomy incision using special instrumentation or even less-invasive robotic technology. To facilitate dissection and to provide adequate exposure of the left atrium, DLT intubation for OLV is used. Under fluoroscopic and TEE guidance, a retrograde cardioplegia catheter is directed into the coronary sinus via an introducer placed in the jugular vein; a PA-venting catheter is inserted through another jugular vein introducer. A limited right thoracotomy is made, with or without dividing the 4th rib, followed by the placement of a soft tissue retractor. A separate port is placed in the 6th interspace for introduction of a thoracoscope, if necessary. The pericardium is opened anterior to the phrenic nerve. After systemic heparinization, the femoral artery and vein are cannulated. The endoaortic clamp is introduced through the side limb of the femoral arterial cannula and its tip positioned in the ascending aorta. CPB is initiated and systemic hypothermia achieved. The balloon of the endoaortic clamp is inflated, achieving effective aortic occlusion. Cold blood cardioplegia is delivered using the distal port of the endoaortic clamp; retrograde cardioplegia is administered via the coronary sinus catheter. A left atriotomy is made, and an atrial retractor is placed through a separate port. Valve repair or replacement is carried out using specially designed instruments. Before completion of atriotomy closure, deairing maneuvers are accomplished. These include temporarily discontinuing pulmonary and aortic root venting, inflating the lungs to displace residual air, and increasing the patient's blood volume from the venous reservoir. Also, the

patient is placed in a Trendelenburg and left lateral decubitus position for further deairing. The balloon of the endoaortic catheter is deflated, and the catheter is left in place for further deairing through the aortic vent lumen. Temporary ventricular pacing wires are placed. After being weaned from CPB, the patient is decannulated and the anticoagulation reversed.

Usual preop diagnosis

Mitral valve disease

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, possible need for a chest tube and postop mechanical ventilation, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE

	Port-Access/Limited Thoracotomy
Position	Supine, with right side slightly elevated
Incision	4th interspace limited right thoracotomy, ports for possible thoracoscopy, port for atrial retractor
Special instrumentation	Specially designed retractors; TEE and fluoroscopy for guiding placement of endopulmonary vent, retrograde cardioplegia catheter, and endoaortic clamp
Unique considerations	CPB is achieved with peripheral femoral cannulation, placement of endopulmonary vent, placement of retrograde cardioplegia catheter, may require conversion to open procedure
Antibiotics	Cefazolin 1–2 g iv at induction
Surgical time	3–5 h
Closing considerations	Assess chest wall for hemorrhage
EBL	250–500 mL
Postop care	ICU monitoring, early extubation, may require inotropic

	support
Mortality	1–6%, depending on comorbidities (lower for mitral valve repairs)
Morbidity	AF:10–40% Chest wall hemorrhage: 2–9% Stroke: 1–3% Conversion to sternotomy: 2% Vascular injury: rare Pneumonia Renal failure
Pain score	1–4

PATIENT POPULATION CHARACTERISTICS	
Age range	40–70 yr
Male:Female	1:1
Incidence	<20,000/yr in the United States
Etiology	Myxomatous mitral valve (most common in developed countries), rheumatic valve disease (most common in developing countries), endocarditis, ischemic (papillary muscle dysfunction), mitral annular calcification
Associated conditions	Pulmonary HTN, atrial arrhythmias, CAD, aortic valve disease, tricuspid regurgitation

TRANSCATHETER VALVE REPLACEMENT PROCEDURES

SURGICAL CONSIDERATIONS

Description

Minimally invasive approaches to aortic valve replacement include transvenous (antegrade), transarterial (retrograde), and transapical (transthoracic). These minimally invasive valve replacement procedures are usually performed in the cath lab, may only require sedation (transvenous and transarterial approach), and can be accomplished without CPB. Transcatheter aortic valve replacement (TAVR) is becoming the

preferred treatment for patients with severe aortic stenosis (AS) who are otherwise at high risk for conventional sternotomy; however, trials are underway to evaluate its use in lower-risk populations. An alternative treatment, percutaneous balloon aortic valvuloplasty (BAV), has a high rate of restenosis and is now infrequently performed except to provide temporary relief while patients await more definitive treatment and during TAVR in preparation for valve placement.

Transcatheter approaches to mitral valve replacement have been slower to develop, in part because of the irregular shape of the valve orifice and the absence of heavy calcification to help anchor the prosthetic valve.

Transvenous aortic or mitral valve replacement: Under sedation, a guide wire is inserted through a femoral vein sheath into the right atrium. The atrial septum is punctured allowing the guide wire to enter the left atrium to cross the mitral valve and aortic valve, where it is snared by a device in the aorta introduced via the femoral artery (Fig. 6.2-9). The atrial septal puncture and the diseased valve are dilated, and then the compressed prosthetic valve is positioned and deployed during rapid ventricular pacing (RVP), which is used to ↓ LV stroke volume and the risk of unwanted device movement. This approach has largely been replaced by transarterial and transapical approaches for aortic valve replacement.

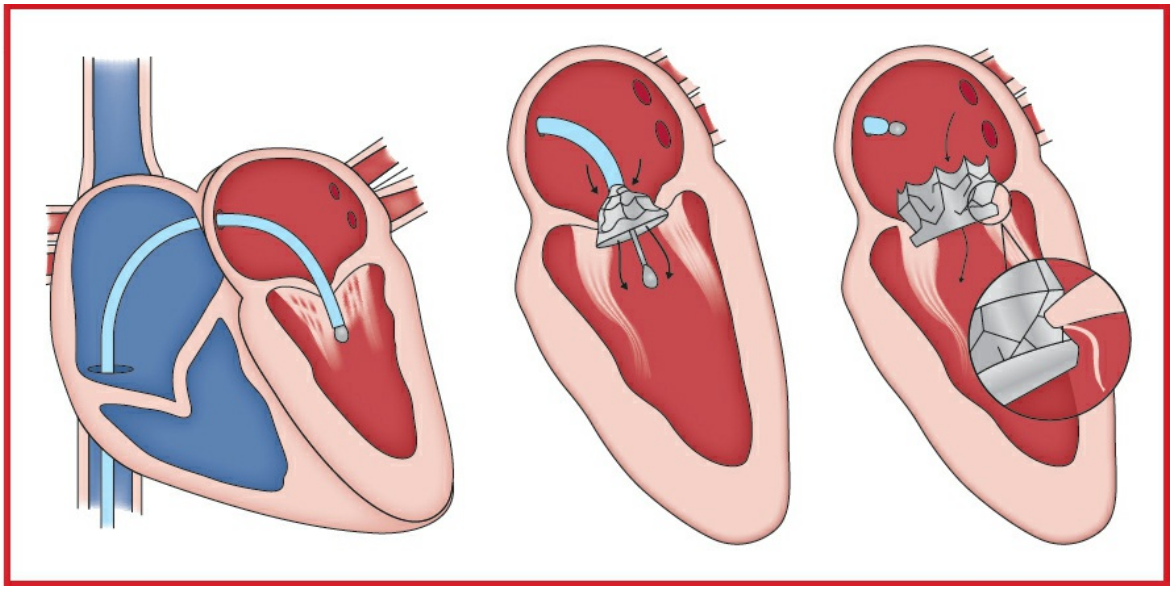

Figure 6.2-9 Transseptal (transvenous) approach to mitral valve (and aortic valve).

Transarterial aortic valve replacement: Under MAC or GETA, a guide wire is inserted from a femoral artery through the aorta (or directly into the aorta through the chest wall) and across the aortic valve. As in the transvenous approach, the diseased valve is dilated, and then, the compressed prosthetic valve is positioned and deployed (Fig. 6.2-

10) during RVP to ↓ LV stroke volume and the risk of unwanted device movement. A self-expanding aortic valve, which is deployed without the need for RVP, is available, although the incidence of postop heart block is high and necessitates placement of a temporary transvenous pacemaker. Although the direct arterial approach to the valve has some advantages, patients with small, tortuous, or diseased iliac and femoral arteries may not be suitable candidates for distal arterial access, and more proximal access to the aorta may be obtained through a minithoracotomy.

Transapical aortic valve replacement: Under GETA, a cardiothoracic surgeon exposes the LV apex through an anterolateral intercostal incision. Purse-string sutures are preplaced around the guide wire entry site at the apex, and the beating heart is punctured with insertion of a guide wire across the aortic valve. A sheath is placed, the diseased valve is dilated, and then, the compressed prosthetic valve is positioned and deployed (Fig. 6.2-11) during rapid epicardial pacing to ↓ LV stroke volume and the risk of unwanted device movement. The sheath is removed and the myocardium closed using the preplaced sutures.

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, possible need for a chest tube and postop mechanical ventilation, and physiotherapy plan. See Appendix K, p. K-1.

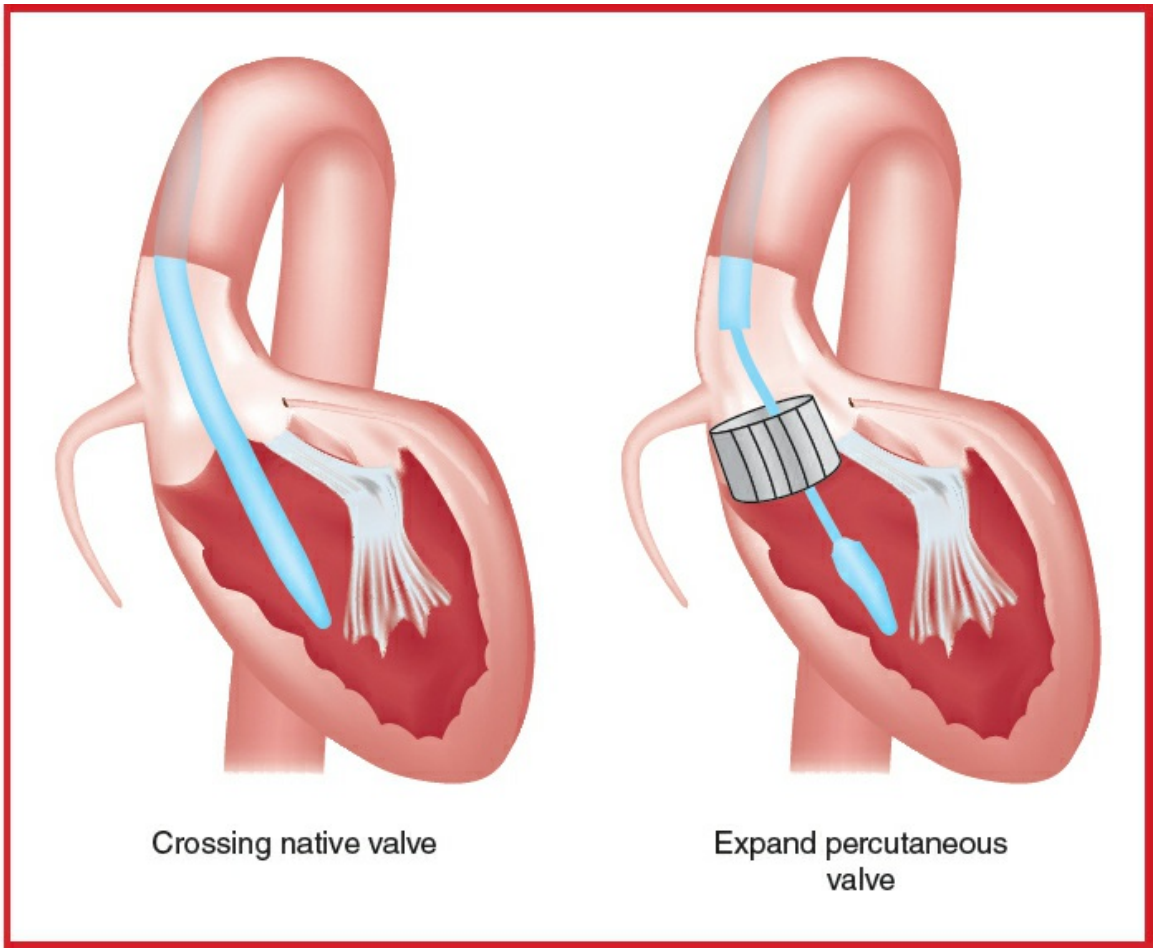

Figure 6.2-10 TAVR—Transcatheter aortic valve implantation: retrograde approach.

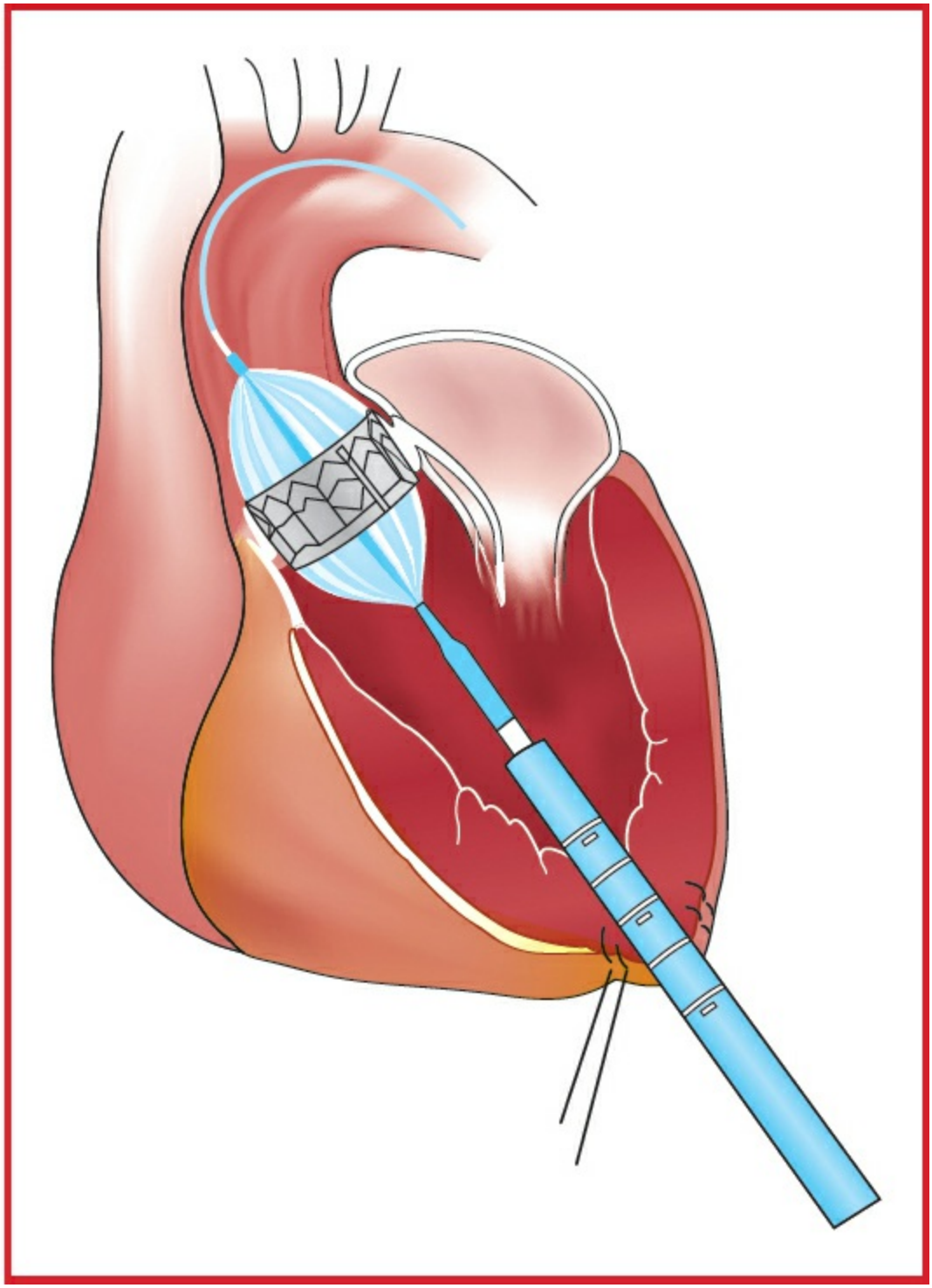

Figure 6.2-11 Transapical approach to aortic valve.

SUMMARY OF PROCEDURES

	Transvascular	Transapical
Position	Supine	⇐
Incision	Vascular sheaths	⇐ + Left

		minithoracotomy
Unique considerations	Anticoagulation (100 U heparin/kg) CPB standby (additional heparin will be necessary for CPB). Inotropic/vasopressor support may be necessary. TEE may be useful for valve sizing determination, positioning verification, and hemodynamic monitoring	⇐
Key procedural steps [with typical complications]	Retrograde placement of pigtail catheter in the noncoronary sinus (serves as landmark to depict the level of the aortic annulus) [intraventricular position with provocation of arrhythmias]	⇐
	—	Anterolateral minithoracotomy Pericardiotomy [pneumothorax, lung injury, pleural bleeding]
	Placement of temporary transvenous (transjugular or transfemoral) pacemaker in the right ventricle, testing of capture [ventricular perforation by pacemaker, pacer-induced hemodynamic deterioration]	Placement of epicardial pacemaker electrodes, testing of capture [bleeding, pacer-induced hemodynamic deterioration]
Key procedural steps [with typical complications] (cont'd)	—	Placement of purse-string sutures at the anterolateral left ventricular wall, myocardial puncture, placement of delivery

		sheath [bleeding, tamponade, air embolism, MV damage]
	Retrograde placement of a guide wire across the aortic valve [dysrhythmias]	Antegrade placement of a guide wire across the aortic valve [dysrhythmias]
	Start of rapid ventricular pacing (160–220 bpm) to ensure a stable balloon position during BAV [hemodynamic deterioration, shock, myocardial ischemia,↑ MR, VF]	⇐
	BAV [calcific embolism with myocardial or cerebral infarction, AR, rupture of aortic annulus/LVOT, aortic dissection, AV block]	⇐
	Recovery	Recovery
	Retrograde placement of transcatheter aortic delivery catheter [dysrhythmias]	Antegrade placement of transcatheter aortic delivery catheter [dysrhythmias]
	Start of rapid ventricular pacing (160–220 bpm) to ensure a stable device position during valve deployment [hemodynamic deterioration, shock, myocardial ischemia,↑ MR, VF]	⇐
	Valve positioning and deployment [calcific embolism with myocardial or cerebral infarction, coronary flow obstruction, valve	⇐

	embolization/malposition/failure, paravalvular or transvalvular regurgitation, MV damage, rupture of aortic annulus/LVOT, aortic dissection, AV block]	
	Recovery and assessment of regular valve position and function	⇐
	Removal of delivery sheath using a vascular closure device or surgical closure, crossover iliofemoral angiogram to assess hemostasis and patency [bleeding, dissection, ischemia, atrioventricular fistula, pseudoaneurysm]	Retrieval of delivery sheath, closure of apical puncture site and pericardium, closure of surgical incision [bleeding, dysrhythmias]
Antibiotics	Cefazolin 2 g iv	⇐
Surgical time	1–3 h	2–4 h
Closing considerations	Assess entry sites for hemorrhage	⇐
EBL	Usually <200 mL	⇐
Postop care	May be monitored on cardiac floor, ICU stay routinely not necessary	Short ICU stay and may remain intubated
Mortality	30 d, 5–11%; 1 yr, 18–27%	⇐
Morbidity	MI (<72 h): 0.2–2% Stroke (<30 d): 4–9% Renal injury: 16–26% Bleeding: 12–21% Vascular complications: 14–24% Moderate-severe AR: 5–10%	⇐
Pain score	2–3 (6–8 if transaortic	6–8

	approach)
PATIENT POPULATION CHARACTERISTICS	
Age range	65–90
Male:Female	3:2
Incidence	1.3–4% of the population >65 yo
Etiology	Degenerative calcification most common in this age group
Associated conditions	CAD (50%); HTN (40%); CHF, AF. Aortic regurgitation, mitral valve disease, and von Willebrand disease with impaired platelet function are common with severe AS

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients presenting for transcatheter aortic valve replacement (TAVR) are typically too frail to successfully undergo open surgical valve replacement. In addition to the problems associated with critical AS, these patients often have severe comorbidities including pulmonary hypertension, decreased cardiac function, significant mitral regurgitation (MR) or tricuspid regurgitation (TR), COPD, and renal disease that may challenge anesthetic management. TAVR is not currently recommended in patients with active endocarditis, thrombi in the left ventricle or ascending aorta, high risk of intraprocedure coronary ostium occlusion, or a valve annulus outside the range of 18–29 mm. For a complete preop discussion of AS, see Anesthetic Considerations for Aortic Valve Replacement.

INTRAOPERATIVE

Anesthetic technique

GETA is used for a transapical approach and is often used for transvascular approaches, although sedation may be appropriate for some patients (↓ hemodynamic compromise, faster recovery). Although these cases were primarily managed by GETA when this procedure was first being developed, with improvements and familiarity with the procedure, more and more centers are performing this procedure under MAC/sedation. Considerations for MAC versus GA include patient preference

cooperation, cardiopulmonary function, and need for intraop TEE guidance. CPB is no used in these patients; however, depending on the type of valve to be placed, there may be brief periods of RVP at 160–220 bpm that will produce a functional asystole (facilitates balloon and valve placement). For a complete discussion of intraop management in AS, see Anesthetic Considerations for Aortic Valve Replacement. A radial art line, external defibrillation pads, and standard monitors should be placed before induction. If TEE is utilized, it should be inserted postinduction. Maintain hemodynamic stability and coronary perfusion by guided volume repletion, avoiding hypotension or tachycardia, and preserving a sequential A-V rhythm. Before the start of RVP, ensure that MAP is >75 mm Hg (systolic BP > 120 mm Hg) using vasopressors as necessary. Hypertension after valve deployment increases the risks of ventricular rupture.

POSTOPERATIVE

After GETA, most patients can be extubated in the procedure room. For most patients hemodynamics are improved immediately following valve replacement and may require vasodilators to avoid HTN. However, diastolic dysfunction often persists and may worsen in the postop period, requiring continued hemodynamic support. Hypertension should be avoided to decrease the risk of ventricular rupture. In patients requiring a minithoracotomy, intercostal nerve blocks placed through the incision by the surgeons will provide good pain relief. Alternatively, paravertebral catheters can be used to infuse local anesthetic for continuous analgesia.

Suggested Reading

1. Gregory SH, Zoller JK, Shahanavaz S, et al: Anesthetic considerations fo transcatheter pulmonary valve replacement. J Cardiothorac Vasc Anesth 2018; 32(1):402–11.
2. Kanwar A, Thaden JJ, Nkomo VT: Management of patients with aortic valv stenosis. Mayo Clin Proc 2018; 93(4):488–508.
3. Mader T, Ngai J: "Transcatheter Valve Procedures and the Anesthesiologist", Int Anesthesiol Clin 2018 Fall;56(4):74–97.
4. Neuburger PJ, Saric M, Huang C, et al: A practical approach to managing transcatheter aortic valve replacement with sedation. Semin Cardiothorac Vasc Anesth 2016; 20(2):147–57.
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ANESTHETIC CONSIDERATIONS FOR PERCUTANEOUS AND PORT-ACCESS PROCEDURES

PREOPERATIVE

As with all anesthetic procedures, the use of the port-access system should not be attempted without appropriate training. Catheter placement and monitoring relies on TEE and/or fluoroscopy. The evaluation of the patient for port-access cardiac surgery should parallel that of patients having conventional cardiac surgery (for mitral valve surgery and for CABG surgery). There are, however, a number of specific conditions that preclude the use of the port-access system:

1. Aortic regurgitation (AR): Although mild-to-moderate AR is not a contraindication, it may make the delivery of antegrade cardioplegia via the endoaortic clamp catheter (EAC) problematic; therefore, insertion of the endocoronary sinus catheter (ESC) is very important. Severe AR is a contraindication.
2. Atherosclerotic disease of the aorta: Perfusion may be associated with embolization of atheromatous plaques (particularly pedunculated lesions).
3. PVD: Femoral bypass may be associated with retrograde arterial dissection. PVD and tortuous femoral and iliac vessels are contraindications to the use of femoral arterial cannulation.
4. Thoracic aortic aneurysm/Marfan syndrome: Port-access procedures require passage of the EAC into the thoracic aorta and inflation of the EAC balloon; therefore aneurysms or a weakened aortic wall is contraindication.
5. Scarring of the pleural cavity (e.g., chest trauma, previous thoracotomy) may make surgical access difficult although the surgical approach may be desirable in the patient with previous median sternotomy.
6. Inability to obtain TEE or fluoroscope imaging because placement of catheters relies on imaging.

Preop evaluation should focus on the underlying pathophysiology (valvular disease vs. CAD). In addition, the following aspects should be considered.

Respiratory	OLV is used to facilitate surgical exposure; thus, evaluation of patients with severe lung disease may include CXR, ABG, and PFTs (see Thoracic Surgery).

Cardiovascular	The vascular system should be evaluated with respect to insertion of the catheters and cannulae for endovascular CPB. Severity of arterial occlusive or atherosclerotic disease should be evaluated (embolization/dissection risk). The possible presence of a persistent left SVC should be considered. **Tests:** CXR; aortography; iliofemoral arteriography; vascular MRI/MRA; vascular ultrasound; TEE
Premedication	As for the underlying condition. Usually, a mild anxiolytic (e.g., midazolam 1–3 mg iv) is sufficient.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of thoracic epidural, continuous paravertebral or chest wall nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

Table 6.2-1 Common Abbreviations Used in Minimally Invasive Cardiac Surgery

Abbreviation	Definition
MICS	Minimally invasive cardiac surgery
MICAB	Minimally invasive coronary artery bypass (includes OPCAB, MIDCAB, port-access, and ministernotomy techniques)
OPCAB	Off-pump coronary artery bypass (“beating heart surgery”: median sternotomy)
MIDCAB	Minimally invasive direct coronary artery bypass (direct vision, no sternotomy, CPB, or cardioplegia)
MIDCABG	Minimally invasive direct coronary artery bypass graft (same as MIDCAB)
MITACAB	Minimally invasive thoracoscopically assisted coronary artery bypass

~~VADCAB~~ LAST	~~Video-assisted direct coronary artery bypass~~ Left anterior small thoracotomy
PACAB	Port-access coronary artery bypass (also called Port-CAB, Port-CABG)
TECAB	Totally endoscopic coronary artery bypass grafting

INTRAOPERATIVE

Anesthetic technique

GETA (DLT or BB): Anesthetic technique depends on the underlying pathophysiology (e.g., valvular disease vs. CAD). Early extubation and postop pain relief can be facilitated by using intrathecal narcotics (e.g., Duramorph 10 mcg/kg intrathecal) injected before induction or paravertebral catheters placed preop.

Induction	Typically, induction can be accomplished with etomidate (0.1–0.3 mg/kg) or propofol (0.5–2 mg/kg), with fentanyl (5–20 mcg/kg) and rocuronium (0.6–1 mg/kg) or vecuronium (0.1 mg/kg). The overall length of port-access procedures is similar to or slightly longer than conventional approaches, so that a long-acting muscle relaxant can be used. Intubation is accomplished with a DLT, and its placement is checked by auscultation and/or bronchoscopy. A bronchial blocker or Univent tube may also be used to provide selective lung ventilation.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider placement of parasternal or chest wall nerve blocks if preop blocks have not been placed. Ketamine (0.5 mg/kg iv) at induction may improve pain management and reduce delirium after CPB.
Maintenance	With the goal of early extubation, it is important to avoid oversedation. The use of volatile agents or a propofol infusion (25–100 mcg/kg/min)

	before, during, and after CPB will facilitate early extubation. During dissection of the IMA or exposure of the left atrium, OLV is needed. Recommend the use of antifibrinolytics for all cases requiring CPB.
Emergence	At the end of the procedure, intercostal blocks with ropivacaine or bupivacaine may be placed, and infiltration of the skin incision also is helpful. Extubation in the OR may be appropriate for stable patients. Alternatively, the patient is transported to ICU and ventilated. The DLT may be exchanged for a single-lumen tube when postop mechanical ventilation is required. Discuss with surgeon local wound infiltration or chest wall nerve block (e.g., via prefascial plane catheter) placement. Consider iv acetaminophen if po dose is given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.
Special considerations: placement/monitoring of endocardiopulmonary system	The port-access system consists of CPB with venous drainage via an endovenous drain (EVD) and an aortic or femoral arterial return cannula, which is Y-ed to accept the EAC. These are placed by the surgeon with the aid of fluoroscopy and/or TEE. Additional drainage of the right side of the heart is accomplished via an endopulmonary vent (EPV) placed by the anesthesiologist. Immediately after intubation and before CVP insertion, a TEE exam should be performed to exclude any contraindication to endo-CPB (e.g., severe AR, aortic atheromatous disease, aortic aneurysm); the size of the ascending aorta should be measured (aids the surgeon in inflation of the aortic balloon); and the coronary sinus should be identified to aid placement of the ESC (coronary sinus catheter). The right IJ vein is then cannulated with two sheaths (9 Fr for EPV and 11 Fr for the ESC). Cardioplegia is delivered in an anterograde fashion via the EAC or retrograde via

an ESC, also placed by the anesthesiologist.

Placement of ESC	The ESC can be placed with fluoroscopy and/or TEE. The coronary sinus is identified on TEE (transverse view of the right atrium or longitudinal bicaval view). Prior to placement, the patient should be partially anticoagulated with 70 U/kg of heparin. The ESC is placed through the 11-Fr sheath. After the tip of the catheter engages the coronary sinus, the catheter is advanced either directly or over a guiding wire until the occlusion balloon is 2–4 cm inside the sinus. Position is confirmed by inflating the balloon and obtaining ventricularization of the pressure tracing. Careful note should be taken of the volume of fluid required to occlude the coronary sinus (1–2 mL) so that overinflation and possible coronary sinus trauma do not occur. Contrast injection will define the correct positioning of the ESC in the coronary sinus. Care should be taken to avoid injecting contrast too quickly, thus pushing the ESC out of the coronary sinus. A time limit (20–30 min) should be set to pass this catheter, as repeated attempts increase the risk of cardiac injury (e.g., cardiac perforation).
Placement of EPV	The EPV (pulmonary vent) is positioned by advancing the catheter, using balloon flotation with pressure monitoring (as with a Swan-Ganz catheter). Fluoroscopy and/or TEE also may be used.
Placement of EVD	The EVD (venous drain) cannula is placed via the femoral vein into the right atrium over a guide wire. Fluoroscopy or TEE is used to ensure that the wire enters the SVC before advancing the EVD into position. The tip of the EVD should be at the SVC/RA junction or just inside the SVC.
Placement of arterial cannula	The aorta may be cannulated with a "Y" cannula with an incising introducer. For femoral arterial

	cannulation, a guide wire is advanced under fluoroscopy, and no resistance to its passage should be felt. The guide wire is advanced into the descending aorta and its intraluminal position confirmed on TEE prior to advancing the aortic return cannulation into its final position. The perfusionist should confirm normal line pressures with a test bolus of fluid and ✓ that normal arterial pulsation is present. These precautions will decrease the likelihood of arterial dissection.
Placement of EAC	The EAC (endoaortic clamp) may be advanced via the "Y" arterial cannula. For a femoral arterial cannula, the EAC is advanced over a guide wire with imaging into the ascending aorta so that the tip of the catheter is just proximal to the sinotubular ridge (2–3 cm above the aortic valve). Position is confirmed by contrast injection and/or TEE. It is also useful to identify the takeoff of the innominate artery in relation to the balloon. Migration of the balloon proximally or distally can occur, and thus, its position needs to be monitored. Monitoring of the pressure in the aortic root via this catheter should show that the mean aortic root pressure is the same as mean radial artery pressure prior to the initiation of bypass.
Sequence of events during endo-CPB	After initiation of bypass, the anesthesiologist should observe the descending aorta to exclude aortic dissection and open the EPV to allow venting. EPV pressures during bypass should be negative (positive pressures may indicate inadequate decompression of the heart or kinking of the EPV). Once adequate CPB is established and the heart is drained, the EAC balloon can be inflated (balloon pressure = 250–350 mm Hg). Occlusion of the aorta is confirmed by a differential between the radial and aortic root pressures and by an aortic root contrast injection. Antegrade cardioplegia is delivered via the EAC

	with careful monitoring to ensure that the balloon is not displaced distally, thus occluding the innominate artery (see Monitoring of endo-CPB: regional perfusion, below). After cardioplegic arrest, retrograde cardioplegia may be delivered via the ESC, and the left side of the heart may be vented via the EAC. Avoid overventing, high systemic pressures, or high CPB flow, which could displace the EAC toward the aortic valve. Initiation of retrograde cardioplegia should begin with a low flow to avoid displacing the ESC, followed by inflation of the ESC balloon until the pressure in the coronary sinus just starts to rise, indicating coronary sinus occlusion. No further inflation of the balloon should take place. Normal coronary sinus perfusion pressure is <40 mm Hg. After retrograde cardioplegia is delivered, the ESC balloon is deflated. Once the surgery is completed, the EAC balloon is deflated (after deairing procedures, as needed); the heart is reperfused; and the EAC is removed. Prior to weaning from CPB, mobility of the ESC and EPV should be assessed in mitral procedures to ensure that they have not been incorporated in the atrial suture line. Weaning from bypass is routine. The ESC should be removed prior to heparin reversal, and the EPV can be replaced with a pulmonary artery catheter, if needed.	
Blood and fluid requirements	As for underlying condition: For mitral valve surgery For CABG	See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	As for underlying condition: For mitral valve surgery For CABG	Special monitoring considerations for port-access are discussed below. External defibrillator pads should be placed on all

		patients.
Positioning	Supine Roll under the left chest for CABG and under the right chest for mitral valve	
Monitoring of endo-CPB	Regional perfusion	Distal migration of the EAC (innominate artery occlusion → ↓ cerebral blood flow) is possible, especially while cardioplegia is being delivered when pressure in the aortic root exceeds that in the systemic arterial system. Monitoring for regional perfusion includes: 1. Right-sided arterial pressure—radial, brachial, or axillary. The pump-induced artifact may be of use if roller heads are being used. 2. Bilateral arterial lines—right-sided, plus a second line in the left radial or in the femoral vessels to allow comparison 3. TEE—EAC visible in the ascending aorta proximal to the innominate artery. 4. Transcranial or carotid artery Doppler 5. Fluoroscopy
	Proximal EAC balloon	Most likely to occur

	migration	during aortic root venting when the systemic pressure exceeds aortic root pressure. Monitored by TEE
	Cardiac decompression	TEE can be useful in monitoring for adequate decompression of the heart.
Monitoring of endo-CPB (cont'd)	EAC balloon pressure	This is usually monitored by the perfusionist and ranges from 250 to 550 mm Hg. Decreases in pressure may be 2° proximal migration of the balloon into a wider area of the ascending aorta, rupture of the balloon, or prolapse into the left ventricle. Loss of balloon occlusion is indicated by blood in the surgical field, return of cardiac activity, cardiac distension, increased root venting, and TEE evidence.
	Aortic root pressure	<80 mm Hg while giving cardioplegia, 0–10 mm Hg during venting. Overventing should be avoided, as should venting when the left side of the heart is open, to avoid drawing air into the aortic root.

	Intracardiac air	TEE is very useful for determining that adequate deairing of the heart has occurred.
Complications of endo-CPB	Retrograde aortic dissection Coronary sinus damage EAC balloon migration	
	EAC balloon rupture	Especially 2° sutures placed in the mitral valve annulus
	Retained EPV in atrial suture line Chest wall hemorrhage	It is important that the surgeon ✓ the chest wall before closure.
	Limb ischemia	May follow femoral cannulation

POSTOPERATIVE

Complications	As for the primary procedure Low CO Chest wall hemorrhage Problems associated with peripheral cannulation (e.g., dissection, embolization) Perivalvular leak Heart block	See mitral valve surgery or CABG.
Multimodal pain management	Parenteral narcotics NSAIDs	Pain control is important to facilitate early extubation. Intrathecal narcotics and/or intercostal blocks with wound infiltration may be useful. Emphasize multimodal approach combining nonopioid and

		bolus/PCA opioid analgesics with regional anesthetics whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-1)	If postop sedation is required, dexmedetomidine may be preferable to propofol. Encourage fast-track extubation, early enteral nutrition, Foley catheter removal, and mobilization.
Tests	ECG Electrolytes ABG	

Suggested Reading

1. Crumley S, Schraag S: The role of local anaesthetic techniques in ERAS protocol for thoracic surgery. J Thorac Dis 2018;10(3):1998–2004.
2. Noss C, Prusinkiewicz C, Nelson G, et al: Enhanced recovery for cardiac surgery.J Cardiothorac Vasc Anesth 2018;32(6):2760–70.

CHAPTER 6.3

Vascular Surgery

SURGEONS

James I. Fann, MD
R. Scott Mitchell, MD
Clayton A. Kaiser, MD
Michael D. Dake, MD (Endovascular stent-grafting)

ANESTHESIOLOGISTS

Jessica L. Brodt, MD
Albert Tsai, MD
Daryl Oakes, MD

CAROTID ENDARTERECTOMY (VASCULAR)

SURGICAL CONSIDERATIONS

Description

Carotid endarterectomy (CEA) continues to be commonly performed open vascular surgery procedures in the United States, even as carotid stenting is being employed as an alternative approach. Because of presumed microemboli from stenotic/ulcerated plaques at the carotid bifurcation, CEA is an effective procedure to reduce the risk of subsequent stroke. Nearly 30 yr ago, the NASCET Collaborators determined, in a prospective, randomized, blinded trial, that CEA is more effective than medical therapy for symptomatic patients with internal carotid artery narrowing between 60% and 90%. Symptoms are usually hemispheric (contralateral, upper or lower extremity paresis or numbness) or retinal (unilateral monocular blindness). Symptoms may be transient (transient ischemic attach [TIA] or reversible ischemic neurologic deficit [RIND]) or permanent (CVA). The Asymptomatic Carotid Atherosclerosis Study (ACAS) has shown benefit from prophylactic CEA in asymptomatic patients with >60% stenosis of

the internal carotid artery. The Asymptomatic Carotid Surgery Trial 1 (ACST-1) is a randomized study of patients assigned to immediate CEA or deferral of any carotid artery procedure. Recruiting patients from 1993 to 2003 and following until 2006–2008, this study showed that successful CEA for asymptomatic patients younger than 75 yr of age reduces 10-yr stroke risks, particularly for disabling or fatal strokes. The ACST-2 is currently studying the outcome differences between CEA versus carotid stenting in asymptomatic individuals. Additionally, a recent Cochrane report found moderate-quality evidence for "some" benefit of CEA in patients with 50–69% symptomatic stenosis and "high" benefit in patients with 70–99% stenosis. The report also found high-quality evidence to suggest lack of benefit of CEA in patients with carotid near-occlusion.

Although some surgeons routinely prefer local anesthesia, most prefer general anesthesia (GA) with careful hemodynamic monitoring because of the frequent concomitant coronary artery disease (CAD). The carotid artery is approached through an oblique neck incision along the anterior border of the sternocleidomastoid muscle. After division of the common facial vein, the carotid sheath is opened and the carotid artery is exposed, avoiding injury to the phrenic, vagus, ansa hypoglossi, and hypoglossal nerves (Fig. 6.3-1). After controlling the internal, external, and common carotid arteries, heparin is administered, and the internal, external, and common carotid arteries are clamped sequentially. To maintain carotid perfusion, an indwelling shunt may be utilized (Fig. 6.3-2B), at the discretion of the surgeon. During clamping, mean arterial blood pressure is maintained at ~100 mm Hg with phenylephrine infusion or boluses. An endarterectomy plane is established proximally (Fig. 6.3-2C) and developed distally into both the external and internal branches, with establishment of a fine tapered end point. After removal of all thrombus, loose smooth muscle fibers and endothelium, the arteriotomy is closed, with or without a patch, the artery flushed, and flow restored. The incision is closed after meticulous hemostasis has been ensured.

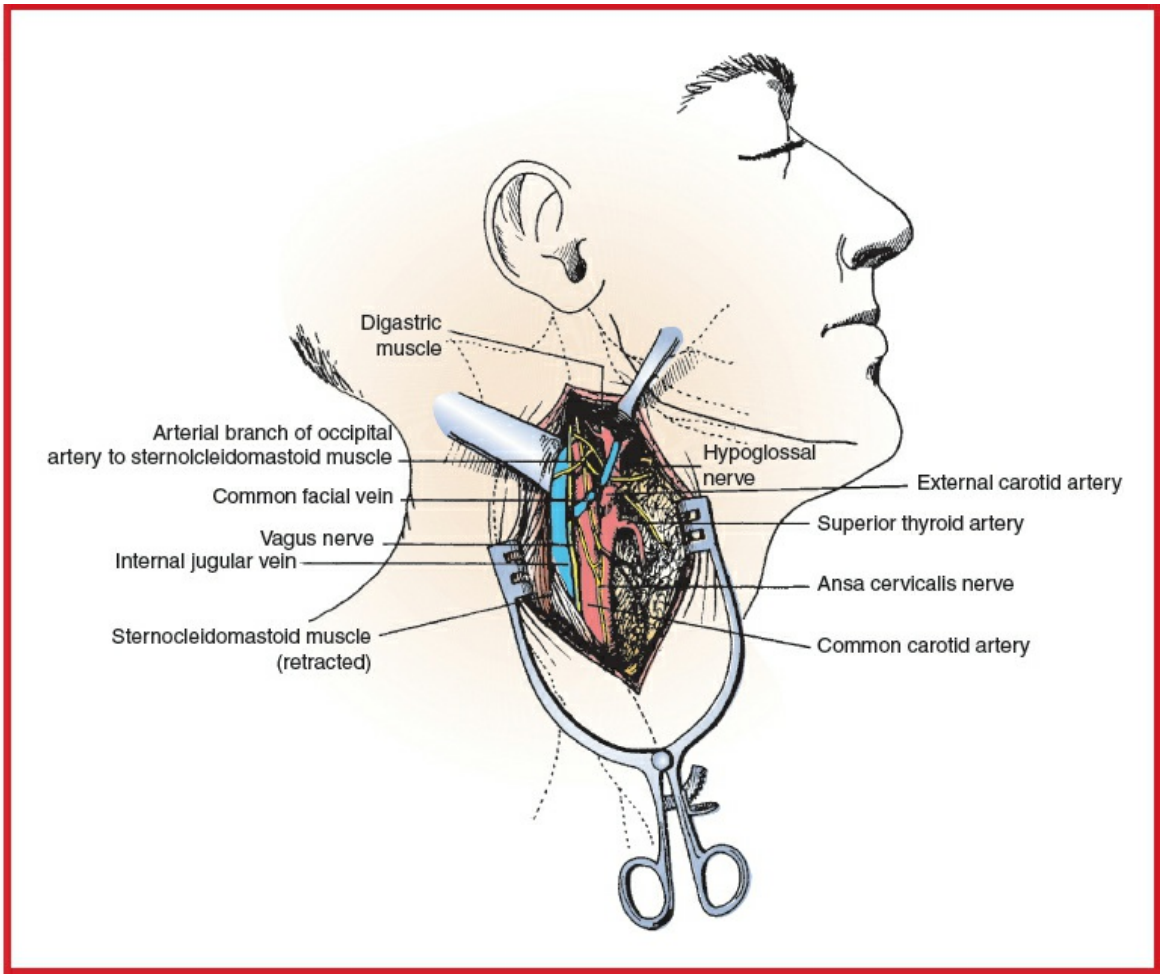

Figure 6.3-1 Exposure of the carotid bifurcation. (Reproduced with permission from Scott-Conner CEH, Dawson DL: Operative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

Usual preop diagnosis

Carotid artery disease

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. See Appendix K: Enhanced Recovery After Surgery, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine with neck extended and turned away from the side of the lesion
Incision	Anterior to the sternocleidomastoid from the earlobe to base of the neck or curvilinear in a skin crease over the carotid bifurcation

Special instrumentation	EEG monitor; ± shunt
Unique considerations	Capability to measure stump pressure may be needed. This can be accomplished by a high-pressure arterial line passed off the field to a pressure transducer. Avoid ↓ BP during carotid cross-clamping. An indwelling shunt may be utilized to restore carotid perfusion. Heparin 5000–10,000 U 5 min prior to cross-clamping, and protamine may be given after restoration of flow.
Antibiotics	Cefazolin 2 g iv (3 g if >120 kg) after induction of anesthesia
Surgical time	Carotid cross-clamp: 30 min Total operating time: 90 min
Closing considerations	To assess the patient's neurologic status, it is best to be able to awaken and extubate the patient at the conclusion of the procedure. Avoidance of HTN is also critical during this period because the endarterectomy tissues are thin and friable.
EBL	100–200 mL
Postop care	ICU × 12–24 h; BP control; cardiac monitoring
Mortality	1%
Morbidity	MI: Major cause of postop mortality Cranial nerve injury (recurrent and superior laryngeal nerves): 39% Restenosis Asymptomatic: 9–12% Symptomatic: <3% Neurologic complications: <2% Hemorrhage: 1% False aneurysm: <0.5%
Pain score	3–5

PATIENT POPULATION CHARACTERISTICS

Age range	55–80 yr
Male:Female	3:1
Incidence	Second most common vascular surgical procedure (after AAA repair)
Etiology	Arteriosclerosis; fibromuscular dysplasia
Associated conditions	Significant CAD coexists with carotid artery disease in at least 30% of patients, necessitating careful cardiac and hemodynamic monitoring.

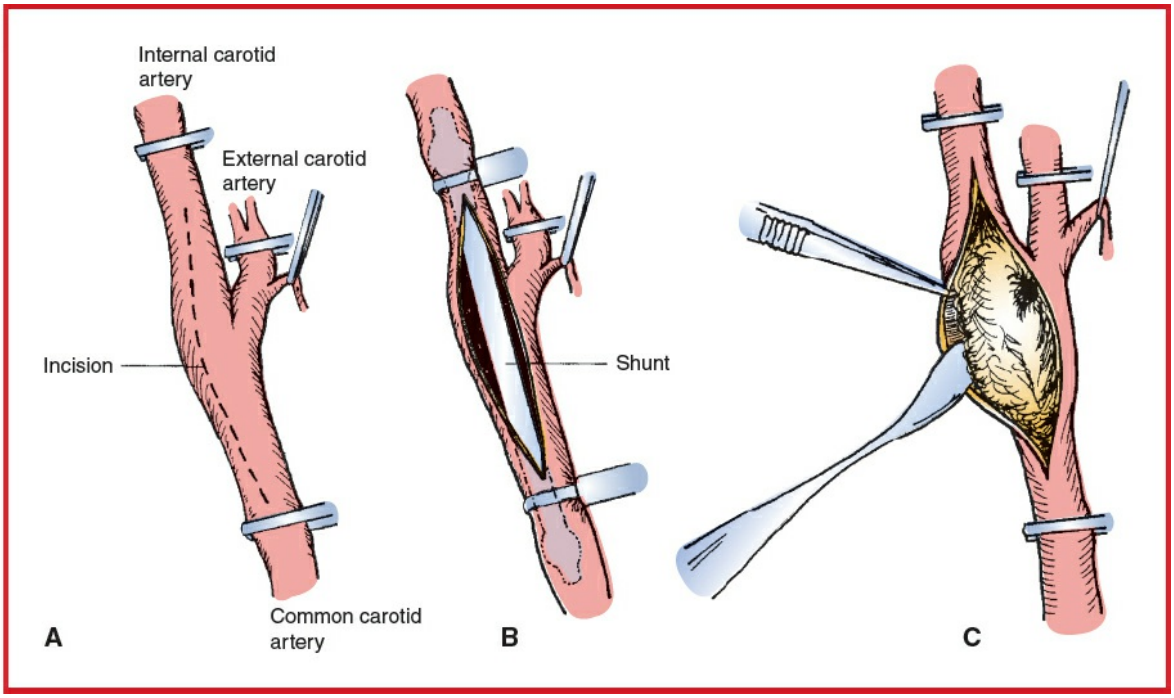

Figure 6.3-2 Carotid endarterectomy. **A:** Following occlusion of the superior thyroid and internal, external, and common carotid arteries, an arteriotomy is performed opposite the external carotid take off. **B:** A shunt may be placed to restore internal carotid flow. **C:** Plaque is separated from the artery wall. (Reproduced with permission from Scott-Conner CEH, Dawson DLOperative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Carotid Endarterectomy (Neurosurgical) in Extracranial Procedures.

Suggested Readings

1. Brott TG, Halperin JL, Abbara S, et al

ASA/ACCF/AHA/AANN/AANS/ACR/ASNR/CNS/SAIP/SCAI/SIR/SNIS/SVM/SVS guideline on the management of patients with extracranial carotid and vertebral artery disease: a report of the American College of Cardiology Foundation/American Hear Association Task Force. Circulation 2011; 124(4):e54–130.
2. Bulbulia R, Halliday A: The Asymptomatic Carotid Surgery Trial-2 (ACST-2): a ongoing randomised controlled trial comparing carotid endarterectomy with carotid artery stenting to prevent stroke. Health Technol Assess 2017; 21(57):1–40.
3. Doig D, Brown M: Carotid stenting versus endarterectomy. Annu Rev Med 2012; 63:259–76.
4. Halliday A, Harrison M, Hayter E, et al.; Asymptomatic Carotid Surgery Tria (ACST) Collaborative Group: 10-Year stroke prevention after successful carotic endarterectomy for asymptomatic stenosis (ACST-1): a multicentre randomized trial. Lancet 2010; 376:1074–84.
5. Howell SJ: Carotid endarterectomy. Br J Anaesth 2007; 99:119–31.
6. Lewis SC, Warlow CP, Bodenham AR, et al: General anaesthesia versus loca anaesthesia for carotid surgery (GALA): a multicentre, randomised controlled trial Lancet 2008; 372(9656):2132–42.
7. Mantese VA, Timaran CH, Chiu D, et al: Carotid Revascularization Endarterectomy versus Stenting Trial (CREST): stenting versus carotid endarterectomy for carotic disease. Stroke 2010; 41:S31–4.
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REPAIR OF THORACIC AORTIC ANEURYSMS

SURGICAL CONSIDERATIONS

Description

Repairs of aneurysms of the ascending, transverse arch, and descending thoracic aorta are performed to repair expanding or leaking aneurysms or prophylactically to prevent rupture. Patients with Sx of rapid expansion or aneurysm leaking may require urgent

repair. Each surgical type—ascending, arch, and descending—is considered separately, as follows. Aneurysms of the **ascending aorta** may arise 2° the degenerative changes of atherosclerosis (exacerbated by old age, hypertension [HTN], tobacco use), from inborn errors of metabolism (Marfan syndrome), or from poststenotic dilation and continued expansion of a chronic dissection. Diseases of the entire ascending aorta, including the sinuses of Valsalva, as in Marfan syndrome and annuloaortic ectasia, require replacement of the ascending aorta and aortic root with a composite valved conduit or a valve-sparing aortic root replacement (VSARR), whereas acquired diseases limited to the ascending aorta usually allow replacement of the aorta distal to the sinotubular ridge, avoiding the need to replace the aortic root and aortic valve. Repair of the ascending aorta is usually accomplished on full cardiopulmonary bypass (CPB) with an aortic cross-clamp placed just proximal to the innominate artery and arterial inflow through the femoral artery, distal to the aortic clamp on the ascending aorta, or via cannulation of the innominate or axillary arteries. The aneurysmal ascending aorta is replaced with a Dacron tube graft from the sinotubular ridge to the innominate artery or proximally if anatomically feasible (if nonaneurysmal tissue is present proximal to the innominate artery). Dilation of the sinuses of Valsalva mandates replacement with a composite valved conduit sewn proximally to the aortic annulus and distally to a normal-caliber ascending aorta, with coronary ostia reimplanted in the side of the tube graft, although in some cases with a normal-appearing aortic valve VSARR may be performed.

Aneurysms of the **aortic arch** are the least common of thoracic aortic aneurysms. Because of the need for concomitant replacement of the arch vessels, however, they are the most complex to repair. Total CPB is utilized, and cerebral protection is accomplished either by CPB perfusion of one or both carotid arteries, by retrograde cerebral perfusion (RCP), or by profound hypothermic circulatory arrest In the past profound hypothermia (cooling to 15–18°C) was required for the safe implementation of circulatory arrest and aortic arch repair. Now strategies including selective antegrade and RCP are employed to provide ongoing perfusion and cooling of the brain during circulatory arrest. As a result, most surgeons are cooling to more moderate levels of hypothermia (i.e., 24–28°). Repair can originate from the aortic annulus and extend distally to the middescending thoracic aorta at the level of the carina. Routine caval cannulation is accomplished via a median sternotomy, and arterial access is gained via the femoral artery or axillary artery. If circulatory arrest is to be used, the patient is cooled to 15–18°C; the heart is arrested; and, with no distal cross-clamp, distal anastomosis is accomplished, followed by implantation of the cerebral vessels attached to an island of aorta. If cerebral perfusion is augmented via RCP, air and debris may be eliminated from the cerebral circulation. However, RCP carries the risk of cerebral

edema if venous pressure becomes elevated (goal central venous pressure [CVP] typically <20 mm Hg). Some surgeons, however, prefer antegrade cerebral perfusion during circulatory arrest. This can be achieved by directly cannulating the innominate and carotid arteries via a Y from the arterial CPB limb. This technique requires multiple cannulas in the surgical field and is a bit cumbersome. To avoid this some surgeons instead utilize unilateral or selective antegrade cerebral perfusion (SACP). This involves cannulating only the innominate artery or alternatively cannulating the axillary artery (which connects to the innominate but is accessed in a right chest incision remote from the surgical field). This unilateral perfusion technique of SACP allows for antegrade arterial flow to be delivered into the right carotid via retrograde flow in the axillary artery and antegrade flow in the innominate artery. SACP avoids the concerns of elevated cerebral venous pressures associated with RCP but requires good collateral connections to the left carotid system via the circle of Willis to ensure flow to the left cerebral hemisphere. Close monitoring of the left cerebral blood flow is generally utilized either using cerebral oximetry (artifact prone) or EEG monitoring. Evidence of inadequate flow to the L cerebral circulation requires the placement of a direct left carotid perfusion cannula. Perfusion is then reinstituted via full CPB, the graft clamped proximal to the innominate artery, and the proximal anastomosis performed while the patient is being rewarmed. Alternatively, if one elects to perfuse the cerebral vessels, the innominate and left carotid arteries can be individually cannulated and perfused via a "Y" connection from the femoral arterial perfusion line. If axillary cannulation is used alone, antegrade cerebral perfusion can be achieved by control of the proximal innominate artery. This is termed "unilateral cerebral perfusion" and requires close monitoring with cerebral oximetry to estimate the adequacy of contralateral (e.g., left-sided) perfusion. If a unilateral drop in cerebral oximetry occurs, the surgeon may convert to bilateral perfusion by placing a catheter into the left carotid artery from inside the arch. The necessity for profound hypothermic circulatory arrest is thus avoided. After completion of the distal aortic arch, vessel island, and proximal aortic anastomoses, weaning from CPB and subsequent steps proceed in a routine fashion.

Open repair of aneurysms of the **descending thoracic aorta** is usually performed for symptomatic and leaking aneurysms, enlarging aneurysms, and aneurysms of sufficient size to warrant prophylactic repair. Due to increased morbidity and mortality associated with open descending thoracic aortic repair, endovascular approaches are generally favored and considered prior to committing the patient to open repair. **Aneurysm repair** is accomplished through a left posterolateral thoracotomy on full or partial CPB. After entry into the left thorax, venous drainage for CPB may be obtained from the left atrium (partial bypass) or the femoral vein (partial or full bypass), and arterial return is via the femoral artery. Maintenance of ventilation is necessary for partial bypass. If partial

bypass without an oxygenator is elected, thus minimizing the amount of heparin necessary, venous access can be gained via the pulmonary veins or left atrium and arterial return via the femoral artery or distal thoracic aorta. After institution of bypass, the aorta is cross-clamped above and below the aneurysm, the aorta is divided, a tube graft is interposed, and clamps are removed. The patient is weaned from bypass, and the operation is terminated in the routine fashion.

Usual preop diagnosis

Enlarging or symptomatic aortic aneurysm

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, possible need for a chest tube and postop mechanical ventilation, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Ascending Aorta	Transverse Arch	Descending Aorta
Position	Supine	⇐	Lateral decubitus with left side up
Incision	Median sternotomy	⇐	Left posterolateral thoracotomy with access to the femoral artery and vein
Special instrumentation	CPB, if used	Complete hemodynamic monitors; CPB	⇐ + DLT or BB; lower extremity BP monitor; epidural catheter; spinal catheter; ICP monitoring; full neuromonitoring (EEG, SSEP, MEP)
Unique	Routine CPB	If profound	OLV; partial CPB

considerations	hemodynamic monitoring	hypothermic arrest is utilized, neuroprotective adjuncts, including local hypothermia, barbiturates, and steroids, should be used.	
Antibiotics	Cefazolin 2 g iv (3 g if >120 kg)	⇐	⇐
Surgical time	Aortic cross-clamp: 40–120 min CPB: 70–150 min Total: 2.5–5 h	Aortic cross-clamp: 75–120 min Circulatory arrest: 30–45 min CPB: 3–4.5 h Total: 4–6 h	Aortic cross-clamp: 25–45 min CPB: 30–60 min Total: 2.5–4.5 h
Closing considerations	Aggressive management of coagulopathy, if a long pump run is necessary	Aggressive management of coagulopathy	Replacement of DLT with single-lumen tube
EBL	300–400 mL	400–700 mL	200–300 mL
Postop care	ICU, intubated 5–20 h, depending on preop condition	ICU, intubated 6–24 h	ICU, intubated 5–24 h
Mortality	5–10%	10–15%	⇐
Morbidity	Renal failure: 5–10% CVA: 4–6% Respiratory failure: 3–5% MI: 2–5%	— 2–5% 10% ⇐	10–15% 2–4% 10–15% 2–4%
Pain score	7–10	7–10	9–10

PATIENT POPULATION CHARACTERISTICS			
Age range	23–80 yr (mean = 55 yr)	50–75 yr	34–79 yr (mean = 65 yr)
Male:Female	3:1	2:1	2.5:1
Incidence	10–30/yr at tertiary center	5–10/yr at tertiary center	10–30/yr at tertiary center
Etiology	Degenerative disease Atherosclerotic disease	⇐ ⇐ Chronic dissections	⇐ ⇐ ⇐
Associated conditions	CHF (50%); angina (30%); HTN (30%); COPD (15%)	Aortic valve disease (30%); COPD (20%); CAD (15%)	HTN (65%); CAD (50%); COPD (30%); CHF (10%)

ANESTHETIC CONSIDERATIONS

ERAS: Enhanced Recovery after Cardiac Surgery (ERACS) protocols are increasingl advocated within the relevant societies (Society of Cardiac Anesthesiologists, American Association of Thoracic Surgeons, et al.). Principles of ERACS are based o evidence-based care pathways targeting specific aspects of perioperative cardiac surgical patient care. These principles are broadly applicable to all patients coming for major cardiac and vascular procedures.

Early mobilization	**Prehabilitation** for patients with significant deconditioning prior to surgery **Fast-track extubation** as soon as extubation criteria, hemodynamics, and bleeding are satisfactory **Sitting up in chair** from postop day 1 onward
Analgesic management	**Opioid-minimizing strategies** including multimodal approach with NSAIDs, gabapentin or pregabalin, acetaminophen, and regional techniques where feasible **Scheduled antiemetics** (e.g., ondansetron) for the first 24–48 h

Goal-directed therapy (GDT)	**Fluid and vasoactive management** using GDT to reduce postop complications **Targeted euglycemia** with insulin infusion
Hemostasis	**Antifibrinolytics** for all cases requiring cardiopulmonary bypass **Active management of chest tube patency** to avoid retention of mediastinal blood
Delirium management	**Delirium screening** at regular intervals, for example, every nursing shift **ICU liberation strategies** including sedation vacations **Preop screening** for excessive alcohol use
Temperature management	**Avoidance of postop hypothermia (<35°C) and hyperthermia (>38°C)**

PREOPERATIVE

Typically, patients with thoracic aortic aneurysms have atherosclerosis and HTN. A subset of patients will have a connective tissue disorder (e.g., Marfan or Loeys-Dietz syndrome). In contrast with thoracic aortic dissections, thoracic aortic aneurysms may be of a more chronic and asymptomatic nature. A ruptured or leaking aneurysm, however, may have a more precipitous presentation.

Cardiovascular	**Arch and ascending aneurysms** (60–70% of aneurysms): commonly associated with HTN, cystic medial necrosis, connective tissue disorder (e.g., Marfan syndrome), atherosclerosis, or syphilis. CHF may occur 2° to dilation of the aortic valve annulus and aortic regurgitation (AR). Aneurysmal compression or intrinsic disease of the coronary arteries may result in myocardial ischemia. **Descending thoracic aneurysms (30%):** usually associated with HTN, cystic medial necrosis, Marfan syndrome, and atherosclerosis **Tests:** ECG: ✓ for LVH, ischemia. ECHO: ✓ for valvular disease, size and extent of aneurysm, LV function. Angiography: ✓ exact extent of aneurysm (allows planning of procedure and sites for arterial

	monitoring), coronary artery anatomy, and degree of occlusion
Respiratory	Recurrent laryngeal nerve palsy may → hoarseness (ascending/arch aneurysms). Tracheal deviation ± stridor or dyspnea may be present 2° to tracheal or bronchial compression (✓ CT scan). Hemoptysis or a hemothorax suggests aneurysmal leakage or rupture warranting immediate surgical consultation. The implications include the difficult intubation with DLT, risk of hypoxemia, massive hemorrhage on thoracotomy, decreased thoracic compliance, and consequent decreased venous return (especially when IPPV is instituted). **Tests:** CXR: ✓ for widened mediastinum, distortion of the trachea and left main bronchus (because it may affect the placement of DLT); MRI/CT with contrast: ✓ anatomic relation of aneurysm to surrounding structures (especially the trachea/bronchi for intubation considerations and the esophagus for TEE precautions); others as indicated from H&P
Neurologic	Full neurologic exam including strength in lower extremities particularly hip flexion. Any deficit should be well documented as neurologic sequelae (e.g., paraplegia/paraparesis) may occur after surgery secondary to spinal cord ischemia.
Renal	Renal problems may occur 2° to AR (↓CO) and heart failure, HTN, or involvement of renal arteries in the aneurysm. **Tests:** BUN; Cr; consider Cr clearance; electrolytes
Gastrointestinal	Descending aneurysms that involve the celiac or superior mesenteric arteries may → bowel ischemia. **Tests:** Consider ABG: ✓ persistent metabolic acidosis (2% bowel ischemia). If indicated by H&P, consider abdominal CT/x-ray: ✓ ileus
Hematologic	If time permits, consider autologous blood donation;

	preexisting coagulopathy increases risk of the procedure.
Musculoskeletal	**Tests:** PT; PTT; Hct/Hb ✓ Marfanoid appearance; others as indicated from H&P
Laboratory	Lactic acid if concerned for organ hypoperfusion Others as indicated from H&P
Premedication	Pain and anxiety may significantly contribute to HTN and should be treated (e.g., morphine 0.1 mg/kg iv ± midazolam 0.025–0.1 mg/kg iv); but avoid obtundation. If patients present emergently with dissection or rupture, consider full-stomach precautions with rapid-sequence induction.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of thoracic epidural, continuous paravertebral, or chest wall nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

The anesthetic management of patients with aortic dissections and aortic aneurysms are similar in many respects. For intraop and postop management of these conditions, see Anesthetic Considerations for Repair of Acute Aortic Dissections and Dissecting Aneurysms.

Suggested Readings

1. Bisschoff MS, Di Luozzo G, Griepp EB, et al: Spinal cord preservation i thoracoabdominal aneurysm repair. Perspect Vasc Surg Endovasc Ther 2011; 23:214–22.
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ENDOVASCULAR STENT GRAFTING OF AORTIC ANEURYSMS

SURGICAL CONSIDERATIONS

Description

The standard treatment for descending **thoracic aortic aneurysm** is surgical resection of the aneurysm and replacement with a segment of prosthetic graft material. Although resection of aneurysms often can be performed without the need for extracorporeal circulation, the procedure has a reported mortality rate of up to 50% in emergency cases

and 12–15% in elective cases. Transluminal endovascular stent grafting (TEVAR) offers an alternative treatment that is less invasive, less hazardous, and potentially less expensive than standard operative repair.

In the initial workup, all patients have contrast-enhanced spiral CT scans of the thorax and thoracic aortography to assess the dimensions of the aneurysms. The most important features to consider in evaluating an aortic aneurysm for endovascular stent graft treatment is the presence of an adequate proximal and distal neck. A minimum neck length of at least 1.5 cm is required to allow secure anchoring of most stent grafts. The distance from the origins of the left subclavian artery and celiac axis to the aneurysm should be at least 1.5–3 cm to ensure that the stent graft does not inadvertently block these arteries. In an effort to reduce the incidence of paraplegia and to limit exclusion of intercostal arteries, the overall length of the stent graft is kept to a minimum. Stent graft technology has made significant advancements in recent years. Debranching grafts (which cover important branch vessels) are now sometimes placed in patients with unfavorable anatomy and lack of traditional landing zones. In these cases, snorkel grafts are placed into branch vessels and run parallel (usually outside the graft) and allow for important branch vessel flow to be maintained.

Another important anatomic consideration is the size of the proposed conduit vessel (e.g., iliac) to ensure that it is adequate for accommodation of the stent introducer system, which usually requires at least an 8-mm diameter vessel. Where the pelvic vessels are <8 mm, either a retroperitoneal iliac or retroperitoneal aortic approach is utilized. The stent is the metallic framework to which the graft material is applied. Various balloon-expandable or self-expanding stents are available. For application in the thoracic aorta, stents of 30–40 mm in diameter (mean 35 mm) are required.

Typically, thoracic aortic aneurysm stent graft procedures are performed in the cath lab (although some may be performed in the OR, depending on equipment availability and local politics), with the patient intubated and under GA. The cath lab is prepared for aortic surgery, with the patient placed on the table in a shallow right decubitus position. For an approach via the common femoral artery, the groin area is prepped for a femoral artery cutdown. In appropriately selected cases, percutaneous suture-mediated closure devices may be deployed in a preclose fashion at the beginning of the procedure. This approach obviates the need for surgical cutdown. When the iliac arteries are of insufficient size, the left lower abdomen is prepped for a retroperitoneal approach to either the aorta or the common iliac artery. High-quality fluoroscopic equipment is essential to ensure accurate placement of the device, and today, most procedures are performed using fixed angiographic units and fusion imaging guidance to take advantage

of preprocedure CT imaging for accurate guidance. When the iliac vessels are of sufficient size, a cutdown is performed on a femoral artery, the artery is punctured, and a guide wire is advanced into the thoracic aorta. A pigtail catheter is placed, and an aortogram is performed. The patient is then anticoagulated with iv heparin (100 IU/kg). A long, stiff guide wire is placed, and the endograft delivery system is introduced and advanced to the appropriate location under fluoroscopic guidance.

To reduce the likelihood of inadvertent downstream deployment of the stent graft caused by the force of blood flow during initial delivery, the arterial BP may be lowered to a mean of 50–60 mm Hg using SNP or clevidipine. This is especially valuable the more proximal the intended placement and is standard practice with targets involving the proximal aortic arch and/or ascending aorta. In cases involving the ascending aorta, rapid ventricular pacing with a temporary transvenous pacemaker is commonly performed to decrease the blood pressure at the time of deployment. Once the endograft is in the desired position, it is unsheathed to allow expansion (Fig. 6.3-3). Immediately following deployment, the vasodilator or rapid pacing is discontinued, allowing the BP to normalize. Relative HTN may be implemented to increase spinal perfusion if there is concern for stent graft–related spinal hypoperfusion. Repeat aortogram is performed, and any early leakage of contrast into the aneurysm is treated either with balloon angioplasty of the stent graft or further stent graft placement. Occasionally, a faint, persistent leak of contrast is caused by leakage through the graft material. This typically ceases when the patient's coagulation status returns to normal. Following removal of the delivery sheath, heparin is reversed with protamine sulfate, and the arteriotomy is repaired surgically or closed by the previously placed percutaneous closure systems. For stent placement through the retroperitoneal aorta, the procedure has a more extensive surgical component; however, the technique is similar.

The basic concept of **abdominal aortic aneurysm** (AAA) repair via an endovascular route (EVAR) is similar to the preceding section on thoracic aneurysm repair, with some notable exceptions. AAAs commonly arise inferior to the renal arteries, and 80–90% of cases involve either one or both iliac arteries. For this reason, stent grafts that can accommodate this more complicated anatomy are required (Fig. 6.3-4). The superior aneurysm neck needs to be of sufficient length (1.5–2 cm) inferior to the most inferior renal artery to provide for stable anchoring. Inferiorly, the stent graft must accommodate either or both iliac arteries. The procedure is performed in a two-stage fashion. Initially, an aorta-to-single-iliac-artery device is placed from the infrarenal aortic neck into one of the iliac vessels. A contralateral femoral artery puncture is then performed, and a catheter and guide wire are used to access an open stump of the stent graft from the contralateral limb. At this stage, a modular section of stent graft is placed

from the aortic component into the contralateral limb; in this way, an aorta-to-bi-iliac graft is placed.

Usual preop diagnosis

Aortic aneurysm

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

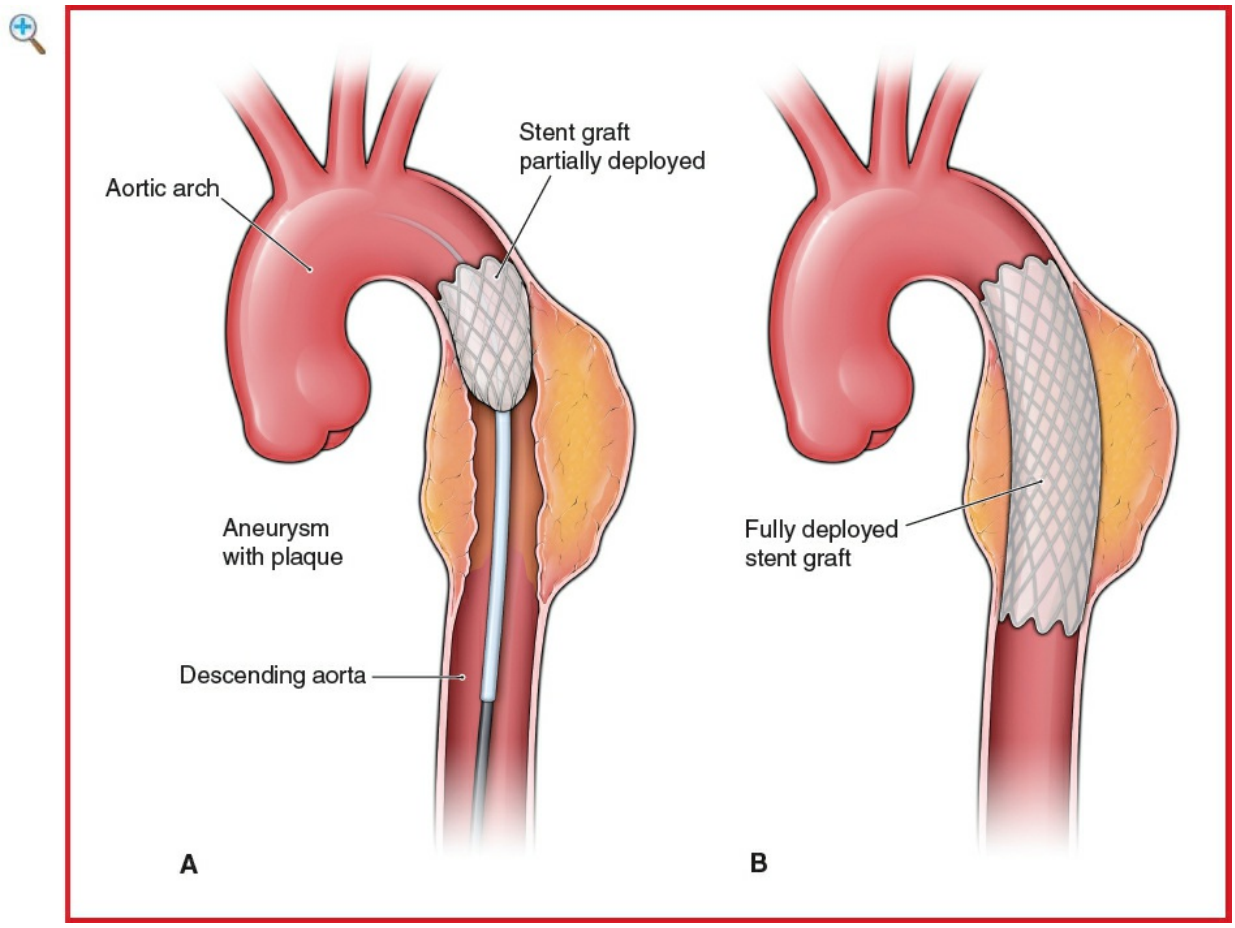

Figure 6.3-3 Deployment of endovascular stent graft in descending aorta.

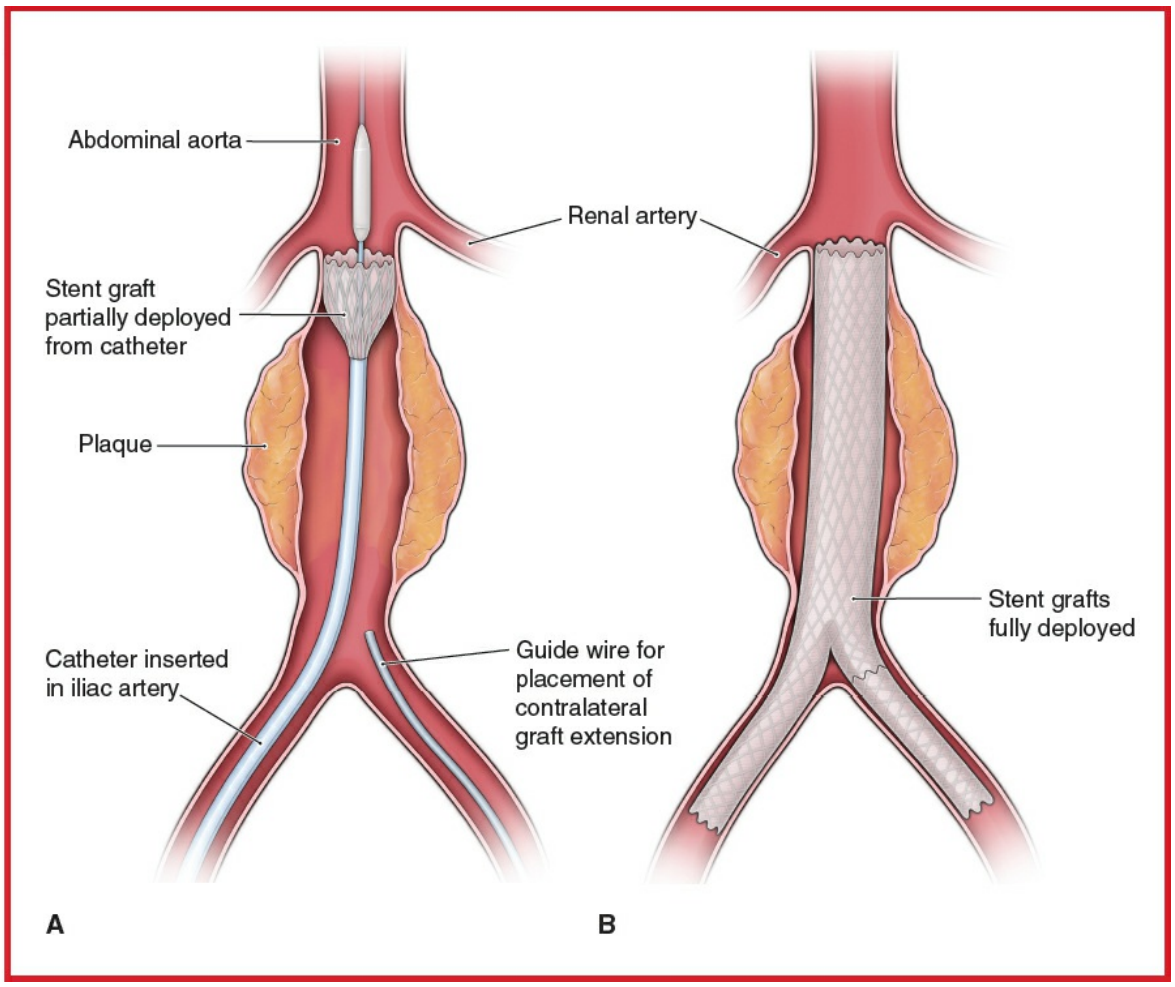

Figure 6.3-4 Deployment of endovascular stent grafts in the infrarenal aorta and iliac arteries.

SUMMARY OF PROCEDURES

	Thoracic Aortic Aneurysms	Abdominal Aortic Aneurysms
Position	Supine/slight right decubitus	Supine
Incision	Femoral artery cutdown	Bilateral femoral artery cutdowns
Special instrumentation	Catheters, guide wires, sheaths, dilators, and stent grafts	⇐
Unique considerations	May require adjunctive procedure (e.g., brachial artery catheterization,	⇐

	balloon angioplasty, possible left subclavian-to-common carotid artery bypass procedure); iv heparin 100–300 IU/kg; preop and intraop hydration may be required given the risk of contrast-induced nephropathy.	
Antibiotics	Cefazolin 2 g iv (3 g if >120 kg)	⇐
Surgical time	1–3 h	⇐
Closing considerations	None	⇐
EBL	Usually minimal; however, can be up to 2–3 U	⇐
Postop care	Routine floor monitoring or ICU × 1 d	⇐
Mortality	3–5%	2–3%
Morbidity	Paraplegia: 2–3% Infection: 1% Surgical conversion: <1%	Acute rupture: <1% ⇐ ⇐
Pain score	3–4	3–4

■ PATIENT POPULATION CHARACTERISTICS		
Age range	30–90 yr	40–90 yr
Incidence	1/10,000 of the population in the United States	1/1,000 of the population in the United States
Etiology	Atherosclerosis; HTN; trauma; aortic dissection; infection	Atherosclerosis; infection
Associated conditions	CAD; aneurysmal disease elsewhere	⇐

ANESTHETIC CONSIDERATIONS

The anesthetic considerations for thoracic and abdominal stent grafting are similar because the surgical techniques, patient comorbid disease, and stent graft deployment techniques are similar. Patients may be asymptomatic; most will have coexisting CAD, peripheral vascular disease (PVD), and/or cerebrovascular disease. A complication notably more likely with thoracic stent grafting is spinal cord ischemia or infarct requiring special consideration.

ERAS

Although not commonly referred to as ERAS, fast-track pathways are used in some centers to facilitate rapid recovery and early discharge after abdominal aortic stent grafting. The risk of spinal cord ischemia in patients coming for stent grafting of thoracic lesions generally precludes fast-track implementation.

At Stanford University, specific criteria for "fast-track EVAR" include:

- Preop: functional independence in all ADLs, social support with a responsible adult to assist patient for first 24 h, absence of significant comorbidities, normal kidney function, and favorable aortic anatomy (e.g., no significant thrombus, no angulated portions)
- Periop: uncomplicated periop course with surgical duration <2 h, uneventful 4 h postop observation period, adequate analgesia with PO analgesics, and tolerating regular diet

For patients meeting these criteria, discharge can be considered within 8–12 h of procedure.

For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

PREOPERATIVE

Preop considerations for these patients are the same as for any patient undergoing repair of a descending thoracic aneurysm, AAA, or aortobifemoral aneurysm. Many of these patients, however, are not suitable for conventional repair via a thoracotomy because of respiratory disease (e.g., FEV_1 < 1 L, severe chronic obstructive pulmonary (COPD) $PaCO_2$ > 60 mm Hg), CAD, renal failure, CHF, or other significant comorbid diseases

As such, they generally are at very high risk for periop morbidity and mortality. Before surgery, the anesthesiologist should consult with the surgical and radiologic teams to decide what will be done should a complication such as penetration or rupture of the aneurysm occur during surgery. Temporary control may be feasible with an occlusive endoaortic balloon; otherwise, an emergency thoracotomy or laparotomy may be necessary in the cath lab.

INTRAOPERATIVE

Anesthetic technique

Usually GETA (OLV may be required for emergency thoracotomy 2° ruptured thoracic aneurysm). Abdominal stent grafts may be placed under neuraxial anesthesia. Rarely, stent grafting may be carried out with local anesthesia or MAC in patients amenable to percutaneous approaches who are otherwise unable to tolerate GA or neuraxial techniques.

Induction	Patients are typically extubated prior to leaving the OR, so the dose of fentanyl (5–10 mcg/kg) is limited to that which will suppress the hypertensive response to intubation while still allowing for early extubation. The same considerations apply to the use of muscle relaxants (e.g., rocuronium [1–1.5 mg/kg]). If a thoracotomy is discussed as the primary plan for unexpected rupture, a DLT should be used or a bronchial blocker (e.g., Uniblocker™) should be available; otherwise, a SLT can be used.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Usually a balanced anesthetic technique of O_2/air/isoflurane or sevoflurane, supplemented with fentanyl (or remifentanil infusion) as needed. Hemodynamic control of BP (esmolol, SNP, NTG, clevidipine) and heart rate to avoid myocardial ischemia is important. **Anesthetic management during stent graft deployment:** During stent graft deployment, the aorta is momentarily occluded.

	Formerly, this resulted in a rapid ↑ BP → stent graft being moved from its intended position. The newer generations of stent grafts, using thermal or mechanical means for rapid deployment, cause minimal hemodynamic change, eliminating the need for aggressive BP control.	
Emergence	Extubation is desirable, although iatrogenic hypothermia (<34°C) may prevent this. If unable to extubate in the cath lab, reversal of NMB and emergence should be expedited to allow for rapid assessment of hip flexion if the spinal cord is at risk for ischemia. Recovery is usually in the ICU for thoracic stent grafts but may be on the floor for abdominal stent grafts. Consider iv acetaminophen if po dose not given. PONV prophylaxis should include ondansetron.	
Blood and fluid requirements	IV: 14–16 ga × 2 BSS < 1 L/case PRBC available	Although usually minimal, blood loss can be considerable. See Zero Balance Fluid Management, p. K-2 and p. K-4.
Monitoring	Standard monitors Arterial line ± CVP catheter	Arterial line placement should be on the right as the radiologists may require access to the left brachial artery. Central access for vasoactive drugs may be needed.
	Urinary catheter TEE	TEE is used to aid in the identification of the thoracic aneurysm necks, to monitor deployment of the stent graft, and to identify any continued flow of blood into the

		aneurysmal sac after deployment (endoleak) or aortic dissection.
	CSF pressure/drainage	Lumbar CSF drain → ✓ spinal cord perfusion pressure and ↓ CSF pressure to mitigate risk of spinal cord ischemia (anterior spinal artery syndrome).
Positioning	✓ and pad pressure points ✓ eyes	Supine ± slight right lateral decubitus Underbody Bair Hugger or warming blanket
Complications	Hemorrhage	Hemorrhage at the groin site can be considerable and may be concealed.
	Vessel damage	Damage to the vessels (femoral, iliac, or abdominal aorta) during passage of the insertion system can occur with attendant massive hemorrhage.
	Rupture of the aorta	Rupture or penetration of the thoracic aneurysm also can occur, necessitating rapid conversion to open thoracotomy.
	Deployment failure/incorrect position	The stent graft may deploy in an incorrect position or fail to fully deploy. This may require positioning of further stent grafts, balloon expansion of the stent

		graft, or conversion to thoracotomy.
	Hypothermia	Hypothermia can be a problem as a circulating-water warming blanket cannot be used on the operating table (use of fluoroscopy). Overbody Bair Hugger problematic for surgical prep. Underbody Bair Hugger compatible with fluoroscopy but beware of overzealous heating of back (spinal cord hyperthermia).

POSTOPERATIVE

Complications	Aortic perforation/rupture Migration of grafts Femoral artery dehiscence Distal embolization Paraplegia	Requires rescue with endoaortic occlusive balloon +/− emergency surgery. → loss of distal pulses, mesenteric ischemia, and acute renal insufficiency Requires prompt return to OR ✓ pulses; angiography/surgical intervention ✓ strength of hip flexion. Increase spinal cord perfusion pressure by deliberate hypertension (goal MAP 90–100 mm Hg after stent graft deployment + working

		lumbar CSF drain in patients at risk).
Multimodal pain management	Minimal analgesic requirements	
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.
Tests	As indicated by patient condition.	CT scan, angiogram prior to discharge and at regular intervals following discharge.

Suggested Readings

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REPAIR OF ACUTE AORTIC DISSECTIONS

SURGICAL CONSIDERATIONS

Description

Repair of **acute aortic dissection** is performed to prevent life-threatening complications such as hemorrhage, tamponade, and heart failure 2° acute aortic valve insufficiency and to redirect flow into the true lumen. Emergent repair of acute ascending dissections is generally accepted therapy to prevent rupture of the aortic root with exsanguination or pericardial tamponade. Mortality for acute ascending dissection is estimated at 1% per hour for the first 48 h. The management of descending thoracic aortic dissections remains controversial, but surgical intervention probably should be recommended only for younger patients, patients with uncontrolled pain or evidence for continued expansion or extravasation, and those with branch vessel compromise.

Ascending aortic dissections typically produce sharp, tearing retrosternal pain that penetrates straight through to the subscapular area. The presentation, however, is so frequently variable that any patient in extremis, especially with migratory pain or vacillating findings, and even asymptomatic patients with aortic valve regurgitation (AR), should be considered for the diagnosis. With a suggestive Hx, a new murmur, or a pulse deficit, an enlarged mediastinal shadow on chest radiography should prompt further diagnostic efforts. CT scanning, MRI, and aortography may all be diagnostic, bu no diagnostic modality has 100% sensitivity. TEE appears to be highly sensitive in detecting a mobile intimal flap in the ascending or descending aorta. In addition, TEE can provide useful information regarding AR, periaortic hematoma, and flow within a false channel. It is usually available at the bedside or in the emergency ward and does not subject the patient to a contrast load.

After patients are diagnosed, they are transported immediately to the OR. Through a median sternotomy, venous access is gained via the right atrium, and arterial inflow is supplied through the ascending aorta (challenging in cases of aortic dissection as it requires identification of the true lumen and is associated with a significant risk of aortic rupture), a femoral artery or axillary artery. Some surgeons opt for axillary cannulation to avoid direct manipulation of the aorta and to maintain antegrade flow in the aorta. This mode of cannulation may not be possible if the dissection flap involves the innominate artery or if urgent need to initiate CPB is necessary (e.g., tamponade, rupture, or myocardial ischemia causing hemodynamic compromise). Axillary cannulation requires sewing a temporary graft to the right axillary artery and takes time to complete. Femoral cannulation, though occasionally used, has significant risks of dissection (including further propagating the aortic dissection, causing flaps to occlude visceral branches causing organ malperfusion, and embolization of thrombus or debris

into the cerebral vasculature). CPB is established, the patient cooled (degree of cooling dependent on need for arch repair and utilization of cerebral perfusion strategies). If arch repair is necessary, circulatory support is discontinued with or without antegrade or RCP. The repair is carried distally into the arch, if the entire dissection can be resected, and the distal aortic layers are reapproximated with a Teflon felt strip supporting the medial and adventitial layers. The distal graft anastomosis is then completed, the graft clamped, the bypass pump restarted, and systemic warming commenced. Proximally, the aortic root may require reconstruction, again using Teflon felt to support the medial and adventitial layers and to resuspend the aortic valve, which can be salvaged in ~85% of cases. The heart is then cleared of air and the cross-clamp removed to allow reperfusion of the coronary circulation. After a sufficient period of resuscitation, the patient is weaned from CPB. Aggressive management of an acquired coagulopathy is not unusual prior to chest closure.

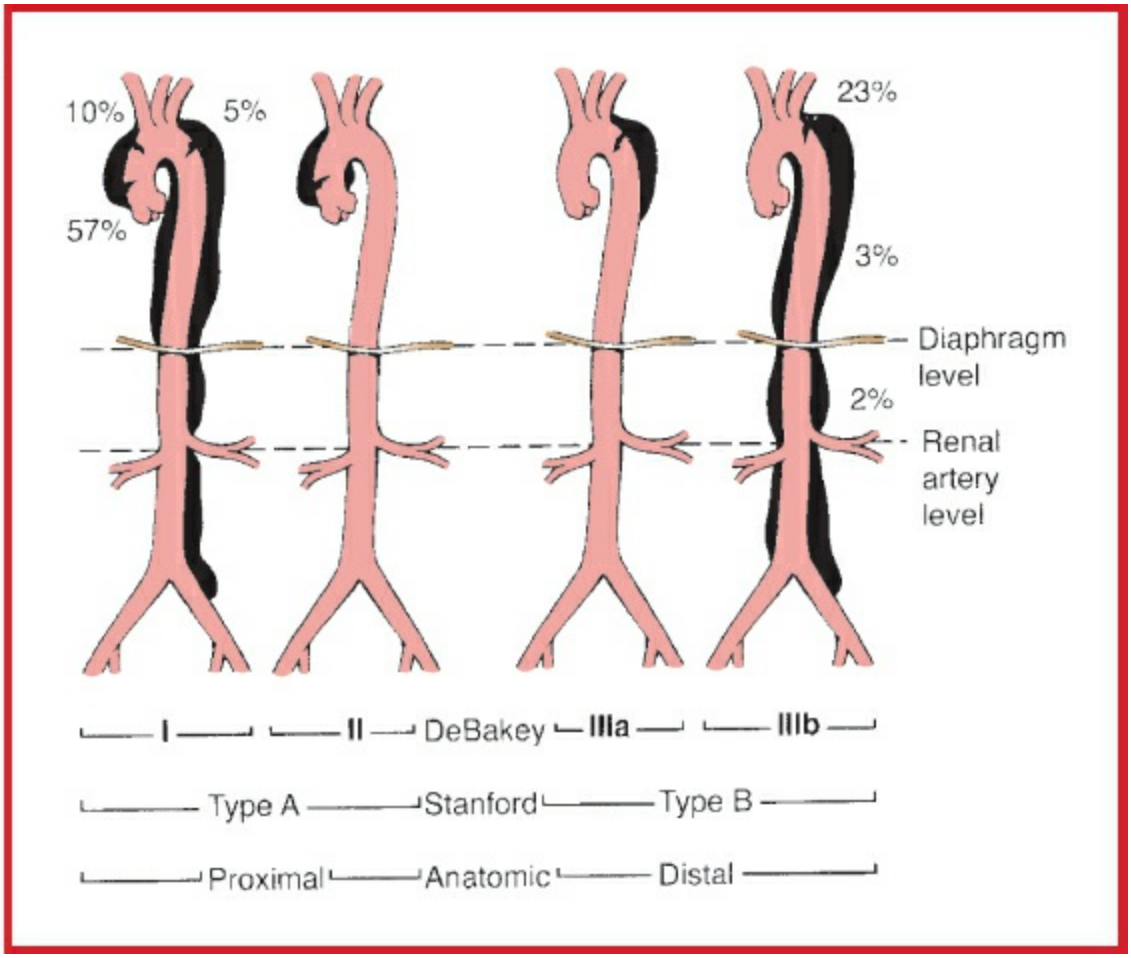

Figure 6.3-5 The three classification systems of aortic dissection and the distribution of the intimal tear.

Open repair of **dissections** involving the **descending thoracic aorta** is accomplished through a left thoracotomy utilizing partial CPB. Venous drainage is usually via the

femoral vein, although the pulmonary vein may be used for partial or "left heart" CPB. Arterial access is via the femoral artery. After institution of CPB, the dissected aorta above and below the most damaged area is cross-clamped and the aorta transected. After oversewing patent intercostal arteries, the medial and adventitial layers are buttressed with Teflon felt, and an interposition Dacron graft is sewn into place. After evacuation of air, clamps are removed, and the patient weaned from CPB. Heparin reversal, decannulation, and closure are accomplished in the usual manner.

Usual preop diagnosis

Acute dissection of the aorta (see Fig. 6.3-5 for types of dissection)

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, possible need for a chest tube and postop mechanical ventilation, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Ascending Aorta	Descending Aorta
Position	Supine	Lateral decubitus, left side up
Incision	Median sternotomy	Left lateral thoracotomy
Unique considerations	Full hemodynamic monitoring, with provisions for circulatory arrest, profound hypothermia, barbiturates, and steroids; TEE	DLT; CPB; TEE; lumbar drain
Antibiotics	Cefazolin 2 g iv (3 g if >120 kg)	⇐
Surgical time	Cross-clamp: 30–50 min Circulatory arrest: 20–30 min CPB: 60–100 min Total: 3–5 h	30–60 min — 35–60 min ⇐

Closing considerations	Aggressively treat coagulopathy (frequently 2° ↓ Plt)	Replace DLT with single-lumen ETT
EBL	400–800 mL	600–800 mL
Postop care	ICU: 1–2 d, intubated	⇐
Mortality	10–25%	⇐
Morbidity	Bleeding: 3–8% Respiratory insufficiency: 2–5% CVA: 2–4%	Paraplegia: 5% CVA: 1–2% MI: 1–2%
Pain score	7–10	9–10

PATIENT POPULATION CHARACTERISTICS	
Age range	40–70 yr
Male:Female	3:2
Incidence	10/100,000
Etiology	Degenerative aortic disease
Associated conditions	HTN; secondary AR; bicuspid aortic valve; Marfan syndrome

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Sx are usually of sudden onset and depend on the site of dissection and specific organ involvement. Aortic dissections are divided into 2 types, depending on the site of intimal tear: Stanford **type A**, ascending and aortic arch, and Stanford **type B**, descending aorta (Fig. 6.3-5). Initial treatment involves the use of antihypertensive medications (e.g., SNP, clevidipine, nicardipine) to control BP and β-blockers (e.g., esmolol) to ↓ contractility. Type A dissections usually require emergent surgery. Patients presenting electively for thoracotomy (descending aorta) may have a thoracic epidural catheter and lumbar CSF drain placed the night before surgery.

Respiratory	✓ for recurrent laryngeal nerve palsy associated with chronic aneurysmal dilation. Tracheal and left main

	bronchus compression → difficult intubation, atelectasis, hemoptysis 2° rupture into lung, hemothorax → compromised oxygenation, and ↑ intrathoracic pressure → ↓ venous return, especially with IPPV **Tests:** CXR: ✓ for widened mediastinum, tracheal or left main bronchus compression and distortion (affects DLT placement), risk of aortic rupture or injury during esophageal manipulation with TEE, atelectasis, and pleural effusion (or hemothorax 2° rupture)
Cardiovascular	Aortic dissections may be associated with chronic HTN, cystic medial necrosis, or other connective tissue disorder (e.g., Marfan syndrome) and trauma. Dissection may result in cardiac tamponade, acute aortic regurgitation, cardiogenic shock, angina, MI, or rupture of the aorta. Dissection of major arteries may result in ↓ or absent peripheral pulses, which may affect the placement sites for intra-arterial monitoring and peripheral cannulation options for CPB. Pain and anxiety may result in HTN, while rupture or leakage may result in ↓ BP and shock. **Tests:** ECG: ✓ for Sx of LVH, ischemia or infarction, or low voltage (tamponade). ECHO: ✓ for dissection confirmation, identification of true/false lumens, thrombus formation (most commonly false lumen), fenestrations, valvular incompetence, LV function, pericardial effusion, or tamponade. CT scan: ✓ site and extent of dissection. Angiography (not warranted in unstable patients): ✓ for site of dissection (type A or B), valvular function, involvement of coronary and other major arteries, sites of rupture, and LV function
Neurologic	Deficits are not uncommon, especially with dissections involving the arch vessels and type B dissections where the blood supply to the spinal cord may be jeopardized. Document preop exam carefully. Neurologic deficits secondary to carotid hypoperfusion in type A dissections infer immense

	surgical risk.
Renal	Renal failure 2° renal artery involvement in dissection, shock, or cardiac failure. UO should be monitored closely during initial medical therapy. **Tests:** UO; BUN; Cr; electrolytes
Gastrointestinal	Compromised blood supply to the bowel or liver may result in ischemia → metabolic acidosis and ↓ liver function. **Tests:** Consider ABG; ✓ persistent metabolic acidosis; LFTs, if indicated by H&P
Hematologic	Coagulopathy may be present 2° massive hemorrhage or liver involvement and can increase risk of the surgery. **Tests:** PT; PTT; Hct/Hb/Plt
Laboratory	Lactic acid if concerned for organ hypoperfusion Other tests as indicated from H&P
Premedication	Because many of these patients present emergently, consider full-stomach precautions with rapid-sequence induction. Cautious use of vasodilators in symptomatic patients prior to induction. Alleviate anxiety and pain (midazolam 0.025–0.05 mg/kg iv), which may worsen HTN, but avoid obtundation.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of thoracic epidural, continuous paravertebral, or chest wall nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: Preinduction control of BP and contractility (NTG or SNP to SBP = 105–11 and esmolol to HR = 60–80) is important in preventing extension of the dissection or

rupture of the aneurysm. Fluid resuscitation may be necessary prior to induction. Extreme caution and preemptive hemodynamic support are essential during induction of patients with hemopericardium to avoid hemodynamic collapse due to tamponade.

Induction	Control of hypertensive response to laryngoscopy and intubation is important and may be accomplished with moderate-dose narcotic (fentanyl 10–15 mcg/kg or sufentanil 1–2 mcg/kg) and etomidate (0.1–0.3 mg/kg), esmolol (5–10 mg iv bolus), or SNP (25–50 mcg bolus). Pretreatment with lidocaine (1.5 mg/kg) also may be required to further control the hypertensive response to laryngoscopy. Muscle relaxation may be obtained using vecuronium (0.1 mg/kg) or rocuronium (1–2 mg/kg). Remember the possibility of a full stomach in this patient population. Hence, a modified rapid-sequence induction (cricoid pressure with manual ventilation and NMR) may achieve the two goals of relatively rapid induction and intubation and tight control of BP. Patients with ascending and arch lesions undergoing median sternotomy do not need lung isolation. In patients with descending lesions, lung isolation is necessary to improve surgical access; however, it may be difficult to place a left DLT due to aneurysmal compression of the trachea and left mainstem bronchus, and it is associated with a small risk of aneurysmal rupture. For these reasons, a bronchial blocker or a right DLT may be preferred. FOB is mandatory to verify ET placement.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider placement of parasternal or chest wall nerve blocks if preop blocks have not been placed. Ketamine (0.5 mg/kg iv) at induction may improve pain management and reduce delirium after CPB.
Maintenance	O_2/narcotic/benzodiazepine: low-dose volatile agent

	(isoflurane [0.3–0.5%] or sevoflurane [0.5–1%]) may be used to control BP (MAP = 60–80), although infusion of vasopressors, vasodilators, or inotropes may be necessary. Control HR (<80; anesthesia, esmolol) and contractility (β-blockade or inotropes, depending on circumstances). Benzodiazepines may be used for amnesia (midazolam 100 mcg/kg). If thoracic epidural catheter is in place, fentanyl (20–30 mcg/kg) or sufentanil (4–6 mcg/kg) may be used. Most type A dissections and aneurysms involving the distal ascending or aortic arch require hypothermic CPB (see Anesthetic Considerations for Cardiopulmonary Bypass, p. 386). Intraop anesthetic considerations are governed primarily by the site of the aortic pathology. These considerations are discussed below. Recommend use of antifibrinolytics for all cases requiring CPB.	
Emergence	Transported to ICU, sedated, intubated, and ventilated × 6–48 h. Following repairs of the descending aorta (thoracotomy incision), weaning from ventilator may be aided by epidural narcotics after documentation of normal spinal cord function and coagulation. Discuss with surgeon local wound infiltration or chest wall nerve block (e.g., via prefascial plane catheter) placement. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Anticipate large blood loss. IV: 14 ga—7 Fr × 2 BSS @ 6–8 mL/kg/h Warm all fluids. Humidify gases. Cross-match 6–8 U of blood. UO 0.5–1 mL/kg/h	If innominate or axillary artery cannulation is planned, arterial line should be placed in the left arm due to inaccuracies of the right radial arterial line during CPB. Mannitol (0.25–0.5 g/kg iv) should be given if renal perfusion is

		compromised by dissection or before cross-clamping. Consider normovolemic hemodilution if the patient is stable and the Hct > 35. After unclamping: furosemide (1 mg/kg), if hemodynamically stable. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors Arterial line CVP, PA catheter (optional) Urinary catheter	Arterial line site is dependent on type of surgery, cannulation strategy, and location of the lesion. Because the right subclavian artery may be compromised in patients with ascending lesions, left upper extremity or femoral arteries may need to be used. Aortic arch lesions may involve the vascular supply to both upper extremities; hence, femoral artery catheterization may be necessary. In select cases, up to three arterial lines may be required, bilateral upper extremity arterial lines to permit estimation of flow with different cerebral perfusion strategies, as well as femoral arterial

		line to demonstrate distal (below clamp) perfusion pressure. Consult with surgeon to plan ideal site.
	TEE	TEE is used to confirm cannula placement and assess ventricular function, regional wall motion abnormalities, valve pathology, and integrity of aortic valve repair/replacement (if required as part of a type A repair). Probe passage may increase compression of the trachea, impeding ventilation. Caution should be used in the presence of aneurysmal compression of the esophagus.
	Temperature	Monitor both core (esophageal/bladder) and either nasopharyngeal (closest to brain T) or bilateral tympanic membranes T (for symmetric cooling)—important in hypothermic circulatory arrest.
	EEG/EP (arch/ascending lesions)	EEG/EP may help in assessing effectiveness of cerebral protection or adequacy of cerebral perfusion.
	SSEPs/MEPs (descending	SSEPs may detect

	lesions)	posterior spinal perfusion problems, while MEPs may detect anterior cord dysfunction. Both EEG and EPs may require expert help to set up, monitor, and interpret.
	Cerebral oximetry	Cerebral oximetry may be helpful in detecting changes in scalp + cerebral blood flow after cannulation of the innominate artery or gross malperfusion issues. Be aware of false-positive and false-negative readings.
Complications	Hemorrhage Coagulopathy	Both are common. Hemorrhage should be treated with crystalloid, colloid, or blood products, as indicated.
Ascending lesions	CPB AR Coronary arteries	Common CPB arterial cannulation sites include the axillary artery, innominate artery, ascending aorta, or femoral artery. Aortic valve replacement may be necessary if at least moderate AR is present. Patients may have myocardial ischemia 2° coronary artery occlusion or dissection; may require CABG or reimplantation of vessels.
	Hypothermic circulatory	Cerebral protective

	arrest (HCA)	measures and selective perfusion of cerebral vessels may be required (see below).
Arch lesions	CPB Hypothermic circulatory arrest	Usual site of cannulation for CPB is femoral or axillary artery. Cerebral protection relies on hypothermia (20–22°C) and drugs (hydrocortisone 100 mg iv or dexamethasone 8 mg iv) to reduce $CMRO_2$ and neuronal injury. The head is surface cooled (protect eyes and ears from cold injury). EEG may be monitored to ensure absence of brain electrical activity. Monitor tympanic membrane T as an indication of brain T. Avoid hyperglycemia and maintain normal pH and $PaCO_2$ when measured at 37°C (alpha stat). Maintain muscle relaxation.
Descending lesions	Pre–cross-clamping	Mannitol (0.5 g/kg) and furosemide (20–40 mg iv) should be given before clamp application to provide renal protection, even if a shunt is placed. Systemic hypothermia may be used to protect the spinal cord.

	Shunt	A heparin-bonded shunt may be used from the aortic arch to the femoral artery to provide distal perfusion.
	Partial bypass	Partial CPB may be used to provide distal perfusion. In this arrangement, the heart perfuses the head and upper extremities, while CPB is used to perfuse and oxygenate the lower body. Venous drainage is from the femoral vein, PA, or left atrium (specifically known as left heart bypass) and returned via the femoral artery. Distal and proximal pressures are altered by controlling cardiac filling, pump flow, and vasodilators. Arterial pressure monitoring pre- and postclamp is essential.
	Cross-clamping	Application of clamp may → acute HTN with ischemia and LV failure. This should be controlled with potent vasodilators (SNP 0.5–2 mcg/kg/min, NTG 0.5–2 mcg/kg/min). Partial CPB or shunting may attenuate hemodynamic response. During cross-clamping,

		monitor UO and ✓ metabolic acidosis (renal or bowel ischemia) with serial ABGs. Cross-clamp time should be <30 min to reduce incidence of paraplegia. A lumbar CSF drain should be inserted to ↓ CSF pressure (to ↓ spinal venous pressure) and, thus, improve spinal cord blood flow.
Descending lesions (cont'd)	Unclamping	Unclamping may result in severe ↓ BP and myocardial depression. Hypovolemia, acidosis, vasoactive factors, and reactive hyperemia have been implicated as the cause. Prior to unclamping, ensure adequate volume status (CVP and/or PCWP 2–5 mm Hg above patient's normal); treat acidosis; have vasopressors available; and the clamp should be released slowly over 1–2 min. Use of partial bypass or a shunt to ensure distal perfusion will mitigate unclamping shock. When hemodynamically stable, give furosemide (1 mg/kg iv). Inotropes (dopamine) may be needed to support circulation.

Positioning	✓eyes ✓ and pad pressure points Arch and ascending: supine, shoulder roll Descending: right lateral decubitus, beanbag, axillary roll, pillow between knees

POSTOPERATIVE

Complications	Myocardial ischemia, CHF Dysrhythmias Hemorrhage Coagulopathy Renal failure Bowel ischemia Respiratory failure	A DLT may be required in lesions of the descending aorta, if hemorrhage continues from the left lung; otherwise, the tube should be exchanged at the end of procedure to a single-lumen ETT. BP should be controlled to MAP 60–80 and HR < 100 to decrease the likelihood of bleeding or graft dehiscence.
	Paraplegia	Anterior spinal artery syndrome
Multimodal pain management	PCA Epidural	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics whenever possible (see Appendix K, p. K-6). Thoracic epidural catheter may be used in patients following thoracotomy if coagulation status is normal.
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	If postop sedation is required, dexmedetomidine may be

	preferable to propofol. Encourage fast-track extubation, early enteral nutrition, Foley catheter removal, and mobilization.
Tests	ECG: ischemia, infarction, dysrhythmias CXR: line and ETT placement; ALI/pulmonary contusion Coagulation profile BUN, Cr: AKI ABG: metabolic acidosis, mesenteric ischemia CT scan: CNS or spinal neurologic deficits Electrolytes, lactic acid: resuscitation goals, malperfusion

Suggested Readings

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REPAIR OF ANEURYSMS OF THE THORACOABDOMINAL AORTA

SURGICAL CONSIDERATIONS

Description

Aneurysms of the thoracoabdominal aorta (TAAA) may occur because of degenerative aortic disease (atherosclerosis), as a consequence of hereditary disorders of metabolism (Marfan syndrome), or as a sequela of chronic aortic dissections. These aneurysms are classified into four types (Fig. 6.3-6) that occur with equal frequency. Type I consists of aneurysms that involve most of the descending thoracic and upper abdominal aortas. Type II involves most of the descending thoracic aortas and most or all of the abdominal aortas. Type III involves the distal thoracic and varying segments of the abdominal aorta. Type IV involves most or all of the abdominal aortas, including the origins of the visceral vessels.

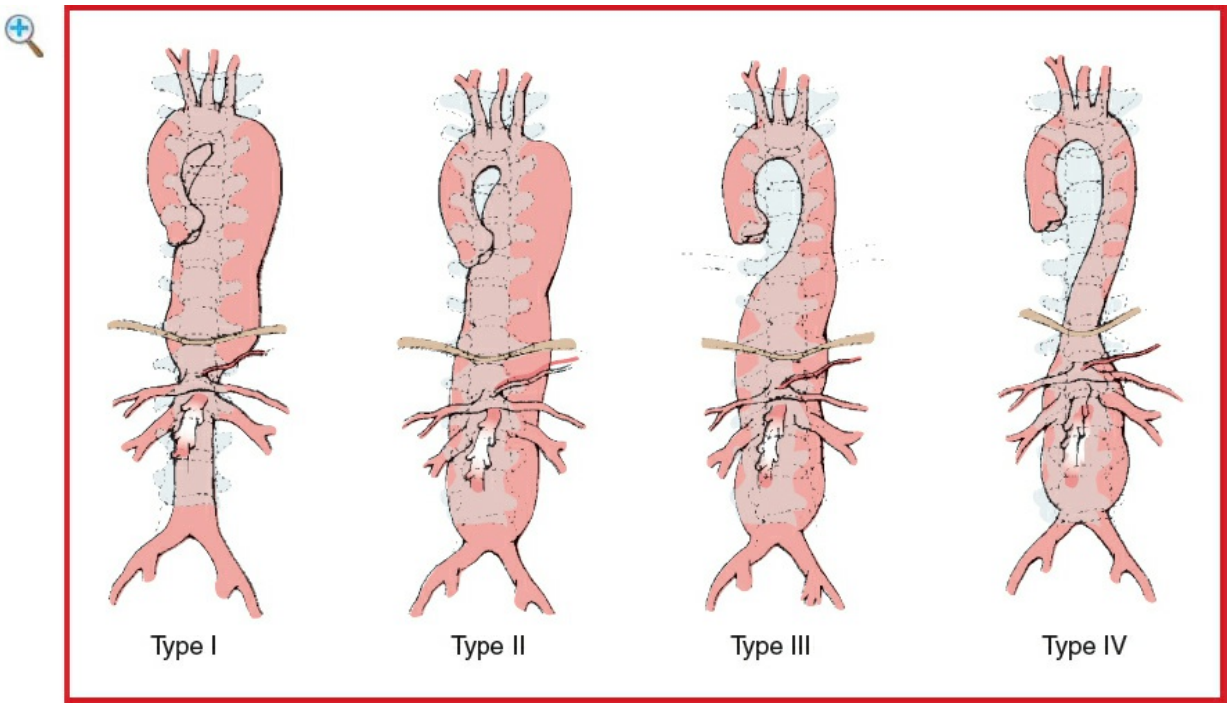

Figure 6.3-6 Crawford classification of thoracoabdominal aortic aneurysms (TAAA). (Reproduced with permission from Baker RJ, Fischer JE, edsMastery of Surgery, Vol. 2, 4th edition. Lippincott

Williams & Wilkins, Philadelphia: 2001.)

Repair of these aneurysms is an extensive, difficult, and demanding procedure, as blood flow to the entire body below the neck is interrupted, with resultant renal and visceral ischemia. In addition, the blood supply to the spinal cord may arise from lumbar and/or intercostal vessels in the affected aortic segment, producing critical cord ischemia during cross-clamping and postop paraplegia.

Almost all thoracoabdominal aneurysm repairs are performed through a thoracoabdominal incision (Fig. 6.3-7) using the **inclusion technique** (Fig. 6.3-8) as advocated by **Crawford** et al. After opening the chest, the incision is extended across the costal cartilage onto the abdomen. The diaphragm is radially incised to the aortic hiatus, and the retroperitoneal dissection plane established anterior to the psoas musculature. All intra-abdominal contents, as well as the left kidney, are reflected anteriorly (Fig. 6.3-8). Only proximal aortic control is established. After partial heparinization, OLV is established to allow collapse of the left lung, the proximal aorta at the aneurysm neck is cross-clamped, and the aneurysm is incised. Back-bleeding from patent intercostal, mesenteric, and renal vessels can be controlled by balloon catheters, and aggressive blood salvage with autotransfusion devices is mandatory. The repair entails suturing a tube graft proximally to the divided aorta and then sewing islands of aortic tissue containing intercostal visceral vessels onto appropriate-sized holes in the side of the tube graft. This allows reperfusion of important intercostal, celiac axis, superior mesenteric, renal arteries, and finally, the distal aorta or iliac arteries. Because there is obligate visceral ischemia during the period of cross-clamping (which must be limited to <60–75 min), the operation must proceed expeditiously.

Alternatively, in an effort to afford both spinal cord and visceral protection through hypothermia, the operation may be performed on full CPB during a period of profound hypothermic circulatory arrest, which may exacerbate hemorrhagic complications.

After aortic cross-clamping, the aneurysm is opened and the repair performed from within the aneurysm, sewing onlay patches of the intercostal, mesenteric, and renal vessels to openings created in the tube graft. This no-clamp technique allows reasonable management of these very extensive aneurysms but results in an obligatory and ongoing blood loss through back-bleeding of visceral vessels until the anastomoses are complete.

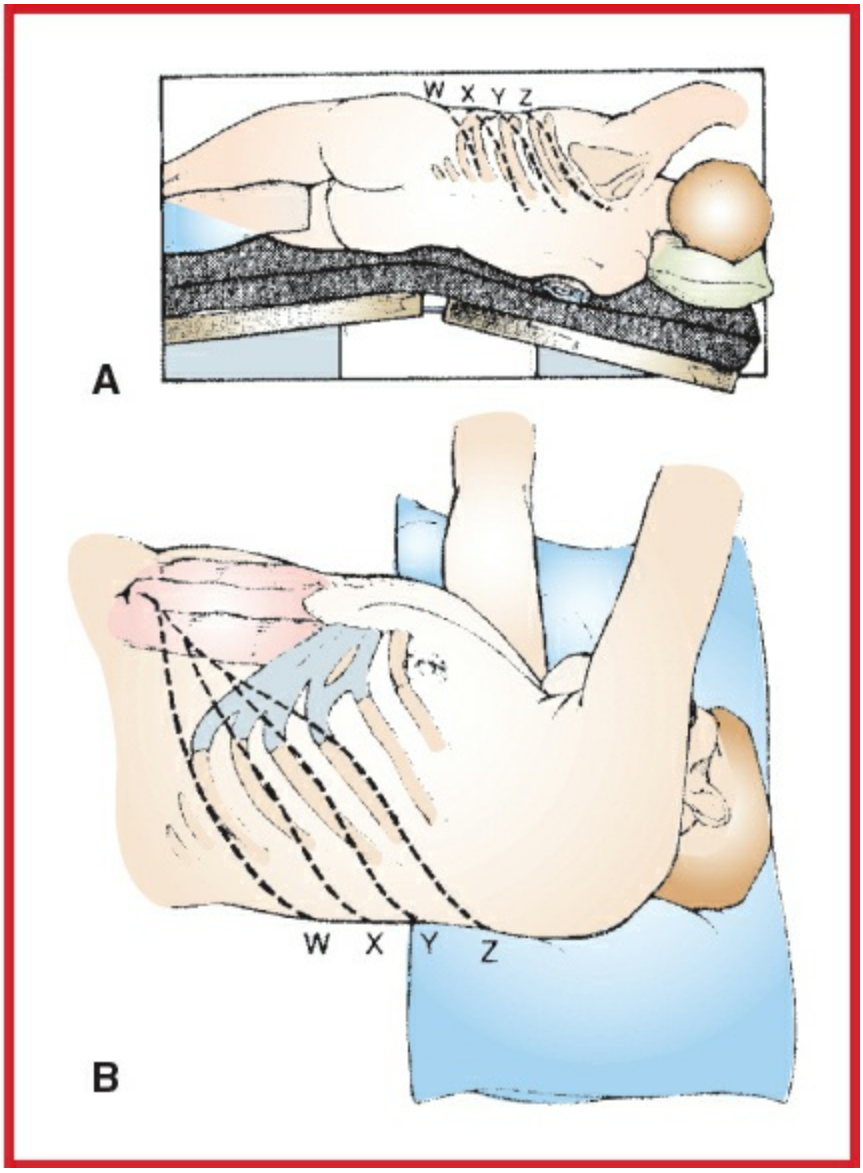

Figure 6.3-7 Lateral **(A)** and frontal **(B)** views of the thoracoabdominal incisions used for repair of type IV (W, X), type III (Y, Z), and types I and II (Z) TAAAs. (Reproduced with permission from Baker RJ, Fischer JE, eds: Mastery of Surgery, Vol. 2, 4th edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

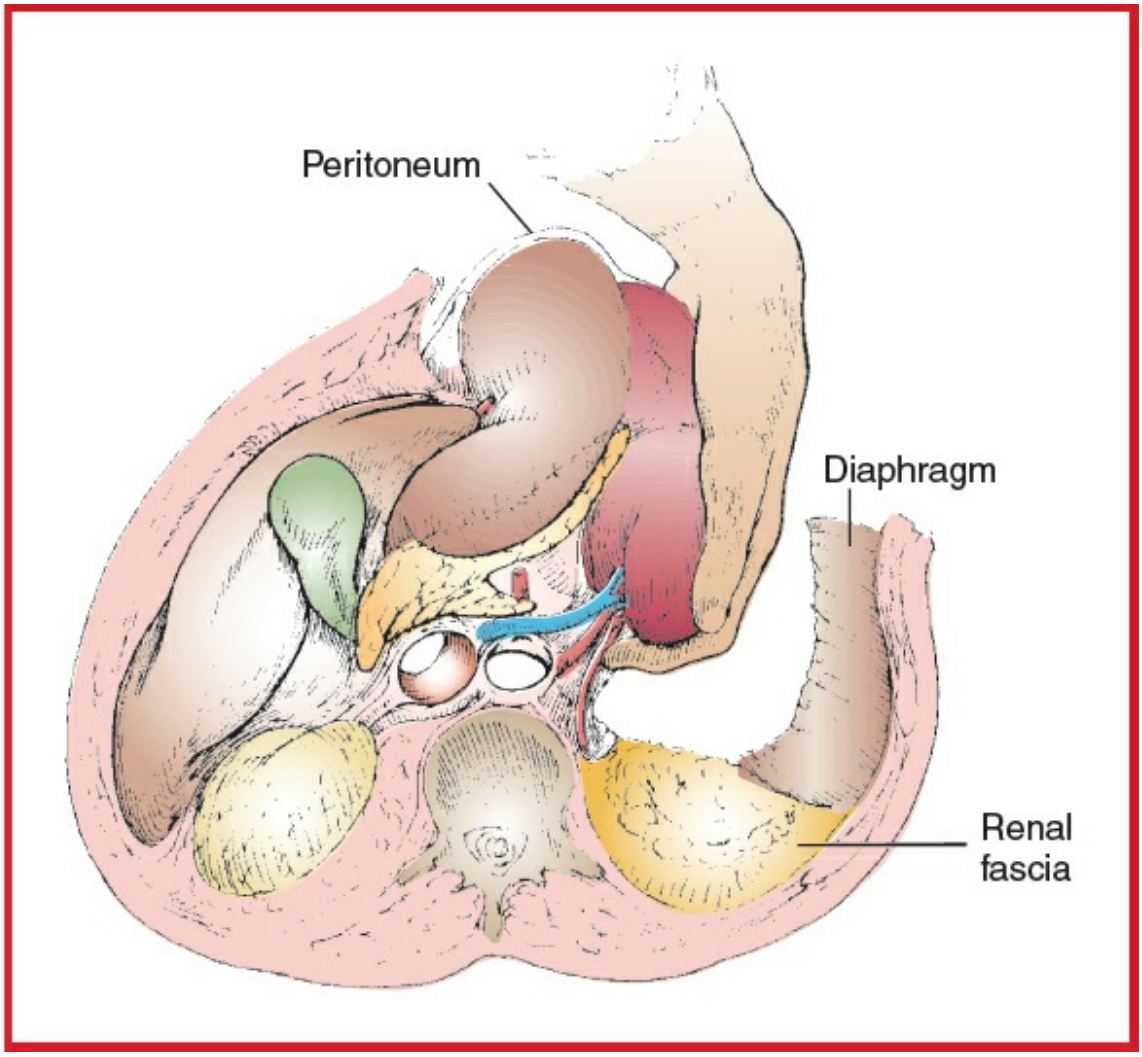

Figure 6.3-8 During the inclusion technique, the anterior renal fascia is opened and the kidney is mobilized, along with the upper abdominal organs (on the left). (Reproduced with permission from Wind GG, Valentine RJ: Anatomic Exposures in Vascular Surgery. Williams & Wilkins, Baltimore: 1991.)

Usual preop diagnosis

Expanding, painful, or large thoracoabdominal aneurysm

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, possible need for a chest tube and postop mechanical ventilation, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE

Position	Right lateral decubitus; hips rotated posteriorly to 45° and left arm draped forward over an airplane sling. Axillary roll placed. (See Fig. 6.3-7A.)
Incision	Posterolateral thoracotomy incision, in the appropriate interspace, extended across the costal margin to the midline and then extended inferiorly as a midline abdominal incision (Fig. 6.3-7). The incision is one of the largest incisions in surgery, necessitated by the absolute need for exposure in this difficult area, and is, unfortunately, associated with significant postop pain.
Special instrumentation	DLT; CPB; NG tube; cell saver; rapid infusion device; TEE; lumbar drain
Unique considerations	OLV with collapse of the left lung necessary for most cases. Cold LR may be injected into renal or visceral arteries for organ preservation. Alternatively, operation can be performed under profound hypothermic circulatory arrest for spinal cord protection in patients with chronic dissections. Frequently, operation is performed with only proximal cross-clamping; so there may be an obligate ongoing blood loss.
Antibiotics	Cefazolin 2 g iv (3 g if >120 kg)
Surgical time	6 h. Proximal aortic cross-clamping until completion of visceral revascularization may extend to 60 min. Longer cross-clamp times may be anticipated in patients with aneurysmal dilation from chronic aortic dissection for which profound hypothermic circulatory arrest may be utilized.
Closing considerations	OR → ICU, intubated × 24–72 h
EBL	Ongoing back-bleeding from visceral and iliac vessels results in substantial volume loss during cross-clamping. Most red cell volume is salvaged via cardiotomy suckers and returned through cardiopulmonary bypass circuit or via an RBC salvage system (e.g., cell saver).
Postop care	ICU, intubated and ventilated × 24–72 h. Rewarming, hemodynamic monitoring, neuromonitoring, and volume resuscitation are often required in ICU.

	Aneurysm Group:	**Type I**	**Type II**	**Type III**	**Type IV**
Mortality	Overall: 9%	—	10–25%	—	5%
Morbidity	Paraplegia/spinal cord ischemia	6%	15%	3%	2%
	Other neurologic complications	6%	12%	2%	1%
	Renal insufficiency	—	2–5%	—	—
	Respiratory failure	—	10%	—	—
	Hemorrhage	Common	⇐	⇐	⇐
	Graft infection	—	1–6%	—	—
	MI	Rare	⇐	⇐	⇐
	Graft failure	—	Rare	—	—
	False aneurysm	Rare	⇐	⇐	⇐
	Embolization	Rare	⇐	⇐	⇐
	Bowel ischemia	—	2–10%	—	—
	Impotence	Rare	⇐	⇐	⇐
	Ureteral injury	Rare	⇐	⇐	⇐
Pain score	6–10				

PATIENT POPULATION CHARACTERISTICS

Age range	Non-Marfan, 55–75 yr; Marfan, 35–55 yr
Male:Female	3:1
Incidence	<5 cases/yr in most hospitals, except major referral centers
Etiology	Predominantly atherosclerotic. Patients with Marfan syndrome may present with a progressive dilation of a chronic dissection.
Associated conditions	HTN (75%); CAD (30%); COPD (30%); renal insufficiency (15%)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Sx are usually of sudden onset and depend on the site of dissection and specific organ involvement. Initial treatment involves the use of antihypertensive medications (e.g., SNP) to control BP and β-blockers (e.g., esmolol) to ↓ contractility. Patients presenting electively for thoracotomy (descending aorta) should have a thoracic epidural catheter and a lumbar cerebrospinal fluid (CSF) drain prior to surgical repair, which may be placed the day before or the morning of surgery.

Respiratory	Due to the need for prolonged intraop OLV, chronic pulmonary disease is associated with postop morbidity. Preop preparation with bronchodilators, cessation of smoking, incentive spirometry, and chest physiotherapy may decrease the risk of postop problems. **Tests:** CXR: ✓ for distortion of the left mainstem bronchus, which may affect placement of the DLT. May need PFTs and ABG to determine severity of pulmonary disease.
Cardiovascular	CAD is the most frequent cause of periop and late death in elective thoracoabdominal aortic aneurysm repair. It is commonly associated with HTN. **Tests:** ECG: ✓ for LVH and ischemia
Neurologic	Increased risk of spinal cord ischemia with cross-clamping of the aorta; therefore, any preop

	neurologic deficits should be well documented. The use of CSF drainage and/or systemic hypothermia is protective during thoracic aneurysm repair. Intraop neuromonitoring is frequently employed.
Renal	Preop renal dysfunction increases the potential for postop renal problems. Aneurysmal involvement of the renal arteries also may occur. **Tests:** BUN; Cr. Consider creatinine clearance.
Gastrointestinal	Aneurysmal involvement of the inferior mesenteric and superior mesenteric arteries may cause visceral ischemia. **Tests:** Consider abdominal x-ray (ileus) and ABG (metabolic acidosis).
Hematologic	Preexisting coagulopathy increases risk. Many patients have been on aspirin preop. Rarely, a DIC process may occur within the lumen of the aneurysm. **Tests:** PT; PTT; Plt count; Hct
Laboratory	Electrolytes; radiologic assessment of aneurysm (ultrasonography, CT, and arteriography)
Premedication	Anxiety and pain may contribute to HTN and risk of aneurysmal rupture. Rx: morphine 0.1 mg/kg iv and midazolam 1–5 mg iv. Full-stomach precautions for emergent procedures (e.g., RSI +/− metoclopramide 10 mg iv, famotidine 20 mg iv).
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of thoracic epidural, continuous paravertebral, or chest wall nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: The goals of anesthesia for this procedure are (a) preserve myocardial, renal, pulmonary, CNS, and visceral organ function; (b) maintain adequate intravascular volume so that CO is not impaired; (c) control BP so that the transmural pressure across the aneurysm does not increase, which would increase the risk of rupture; and (d) provide good perfusion of other organs. CPB is used to accomplish deep hypothermic circulatory arrest. The rationale for this use is controversial. Deep hypothermic cardiac arrest (DHCA) may confer spinal cord protection and is usually reserved for patients with extensive aneurysms or complex chronic dissections. Drainage of CSF has been proposed as another means of protecting the spinal cord against ischemic injury. CPB may be used for distal perfusion of organs and afterload protection of the left ventricle. Partial CPB usually is reserved for suprarenal or supraceliac aneurysms to perfuse bowel and kidneys. (See Anesthetic Considerations for Cardiopulmonary Bypass and Repair of Acute Aortic Dissections, for more discussion on CPB and DHCA.)

Induction	Prevent hypertensive response to laryngoscopy and intubation with moderate-dose narcotic technique (fentanyl 5–10 mcg/kg or sufentanil 0.5–2 mcg/kg) in combination with etomidate (0.2–0.3 mg/kg) or propofol (1–2 mg/kg). Esmolol 100–500 mcg/kg over 1 min, NTG 0.5–3 mcg/kg, or lidocaine administered either by intratracheal spray or an iv dose of 1.5 mg/kg also will decrease the cardiovascular response to intubation. Muscle relaxation for intubation may be achieved with vecuronium (beware of ↓ HR) or rocuronium (1 mg/kg). A modified rapid-sequence induction may be necessary in emergent cases. A DLT is mandatory for this procedure; however, it may be difficult to position due to distorted anatomy. FOB is mandatory to verify position of DLT.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider placement of parasternal or chest wall nerve blocks if preop blocks have not been placed. Ketamine (0.5 mg/kg iv) at induction may improve pain management and reduce delirium after CPB.
Maintenance	O_2/air/narcotic ± low-dose volatile agent.

	Benzodiazepines may be used for amnesia (e.g., midazolam 100 mcg/kg). When epidural catheter is in place, sufentanil (loading dose 25–50 mcg, followed by 4–6 mcg/h) may provide adequate additional analgesia. In hemodynamically unstable patients, scopolamine (400 mcg) provides amnesia. Maintain CO and control of BP at preop levels. These patients may have increased hemodynamic variability on cross-clamping aorta, 2° bleeding, and coexisting disease. Keeping the patient warm may be difficult due to large incision and visceral exposure. Recommend use of antifibrinolytics for all cases requiring CPB.	
Emergence	Deferred to ICU. Postop ventilation 6–72 h. DLT may need to be maintained postop 2° to facial, oral, and airway edema. Discuss with surgeon local wound infiltration or chest wall nerve block (e.g., via prefascial plane catheter) placement. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Anticipate large blood loss. IV: 14 ga or 7 Fr × 2; BSS Rapid infuser Cell saver T&C 8–10 U PRBCs Warm fluids and humidify gases. Maintain UO @ 0.5–1 mL/kg/h.	Large incision and visceral exposure may require administration of large volumes of fluid. Consider use of mannitol or furosemide if concerned about renal function and UO. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors Arterial lines CVP catheter ± PA catheter ± ST-segment analysis	Consult with surgeon regarding planned location of cross-clamp and cannulas for CPB to ensure ideal arterial line site.

	UO TEE Core temperature ± EEG, SSEP, MEP ± Cerebral oximetry	Consider care when securing central venous lines in the right neck to ensure patency when in RLD position; consider LIJ lines if neck anatomy not favorable. ✓ for ↑ PA pressures and PCWP and ↓ in SvO_2 or CO TEE is a good monitor for ventricular filling, myocardial ischemia and changes in SV. Monitor core (esophageal/bladder) and either nasopharyngeal (closest to brain T) or bilateral tympanic membranes T (for symmetric cooling)—important in hypothermic circulatory arrest. EEG and EPs may be useful in assessment of cerebral protection (SSEP) and spinal cord perfusion problems (MEP ± SSEP). In case of the need of DHCA, cerebral oximetry may be helpful.
Cross-clamping	Clamping	Application of cross-clamp at supraceliac level produces the greatest hemodynamic stress experienced by surgical patients. Application of

	Unclamping	the clamp → HTN and ischemia. Preload, afterload, and HR can be controlled with SNP (0.25–5, mcg/kg/min) and esmolol (100–500 mcg/kg/min) infusions. Bolus dose NTG (100 mcg) may be useful to terminate an acute hypertensive episode. Ensure adequate volume; replace blood loss. Clamp should be removed gradually or stepwise. Just before removal of the cross-clamp, filling volumes are allowed to rise gradually, avoiding the occurrence of myocardial ischemia. Dilators are D/C'd. ↓ BP may occur with removal of cross-clamp 2° hypovolemia, reactive hyperemia, acidosis, ↑ K^+, or myocardial dysfunction. BE > −5 should be corrected before unclamping. If necessary, surgeon can reclamp or occlude the aorta.
Positioning	Right axillary roll ✓ and pad pressure points ✓ eyes	Right lateral decubitus with hips rotated posteriorly. Left arm placed in airplane sling or supported by pillows.

		Ensure neck and spine are aligned, and down ear and eye are free of pressure.
Complications	Myocardial ischemia HTN	
	Coagulopathy Hemorrhage Hemostasis	Coagulopathy due to dilutional and consumptive processes
	Hypothermia Other organ ischemia	Hypothermia may exacerbate coagulopathy, cause dysrhythmias, and depress cardiac contractility.

POSTOPERATIVE

Complications	Myocardial ischemia Neurologic deficits 2° cerebral or spinal cord ischemia Renal failure Respiratory failure	BP should be closely controlled postop to decrease bleeding from graft site and raw surfaces.
Multimodal pain management	Epidural narcotics	In selected patients, a thoracic epidural catheter may be placed the night before surgery; otherwise, an epidural catheter is placed only after normal neurologic and coagulation status is determined. Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics whenever

		possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	If postop sedation is required, dexmedetomidine may be preferable to propofol. Encourage fast-track extubation, early enteral nutrition, Foley catheter removal, and mobilization.
Tests	Neuro exam: ASAP at end of surgery, hip flexion bilaterally, should be done even while intubated CXR: line and ETT placement; ALI/pulmonary contusion Coagulation profile BUN, Cr: AKI ABG: metabolic acidosis, mesenteric ischemia CT scan: CNS or spinal neurologic deficits Electrolytes, lactic acid: resuscitation goals, malperfusion	

Suggested Readings

1. Anton JM, Herald KJ: Anesthetic management of open thoracoabdominal aortic aneurysm repair. Int Anesthesiol Clin 2016; 54(2):76–101.
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SURGERY OF THE ABDOMINAL AORTA

SURGICAL CONSIDERATIONS

Description

Operations on the abdominal aorta are generally performed for aneurysmal or occlusive diseases. Although **aortic aneurysms** may involve the suprarenal aorta, the majority is infrarenal in origin and may extend into the iliac arteries (Fig. 6.3-9). Most (>95%) are asymptomatic and are discovered incidentally during investigation of another medical problem. Because of the associated increased risk for rupture as the aneurysm increases in size, most vascular surgeons recommend prophylactic repair for aneurysms >5 cm in cross-sectional dimension. Repair also is indicated for painful aneurysms, those that have been associated with atheroembolism, and when there is documented recent increase in size or evidence of leak or rupture. CAD coexists in 30–40% of these patients and should be assessed preop.

Endovascular stent grafting of AAA has emerged as an alternative therapeutic approach. The open surgical repair may be either **transperitoneal** or **retroperitoneal** (Fig. 6.3-10). After exposure of the abdominal aorta from the level of the renal vein distally to the iliac arteries, the aorta is cross-clamped, distally at first to prevent atheroembolism and then proximally. Graft origin is usually from the infrarenal aorta but may arise from the intramesenteric aorta or even the supraceliac aorta. Graft termination may be to the

distal aorta above the bifurcation (tube graft), to the common or external iliac arteries (Y graft), or to the femoral arteries. Immediately prior to cross-clamping, vasodilators are increased to reduce afterload, which is significantly increased with application of the aortic cross-clamp. The aorta is then incised, lumbar vessels oversewn, and the aorta transected to allow an interposition graft to be sewn into place. The retroperitoneal approach has many advocates, as it may require less volume intraop, may be associated with less temperature loss, and may result in a shorter period of postop adynamic ileus. In a randomized, prospective study, however, no significant differences could be detected between these two approaches for blood loss or postop recovery time.

Aortoiliac occlusive disease can be a significant cause of lower extremity arterial insufficiency. Although the operative approach may be similar to that for aneurysmal disease, there exists a significant intraop difference in that there are not such profound changes associated with aortic clamping because there is already some element of increased afterload 2° the occlusive disease. Nevertheless, hemodynamic monitoring is mandatory to allow for rapid volume shifts and to ensure adequate preload and sufficient afterload reduction, especially during the period of aortic cross-clamping.

Variant procedure or approaches

In the rare patient with COPD severe enough to preclude weaning from the ventilato postop, extra-anatomic grafts (e.g., axillofemoral, iliofemoral, and femoral-femoral bypass) can be constructed under local anesthesia.

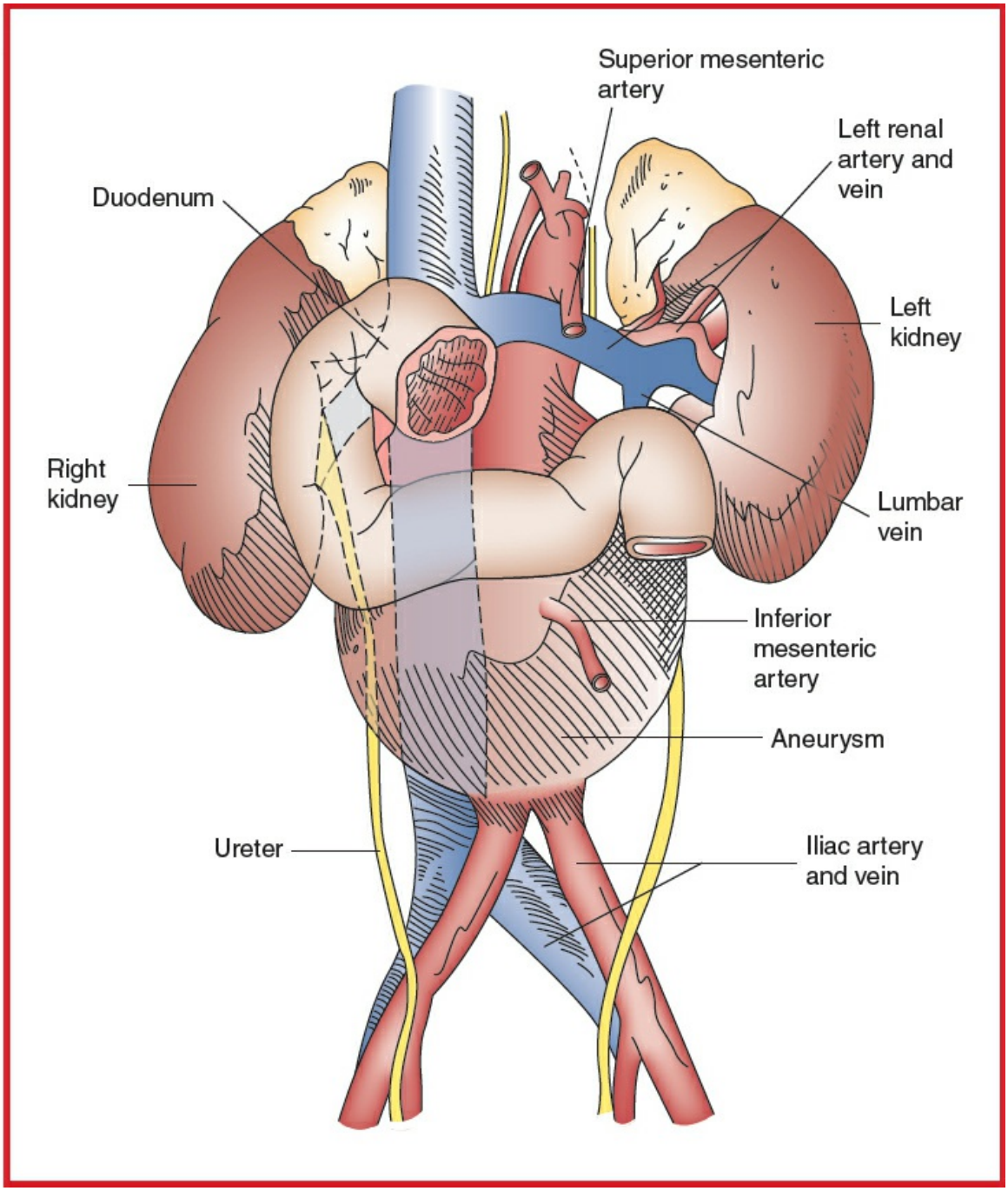

Figure 6.3-9 Aneurysm of the abdominal aorta.

Usual preop diagnosis

Abdominal aortic aneurysm; severe aortoiliac stenosis sufficient to cause debilitating buttock, thigh, or calf claudication; isolated inflow (aortoiliac) disease (rarely the sole cause for ischemic symptoms at rest or for tissue loss, except as a result of embolic complications)

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of

nutritional status, discussion of carb loading, postop pain management options, possible need for a chest tube and postop mechanical ventilation, and physiotherapy plan. See Appendix K, p. K-1.

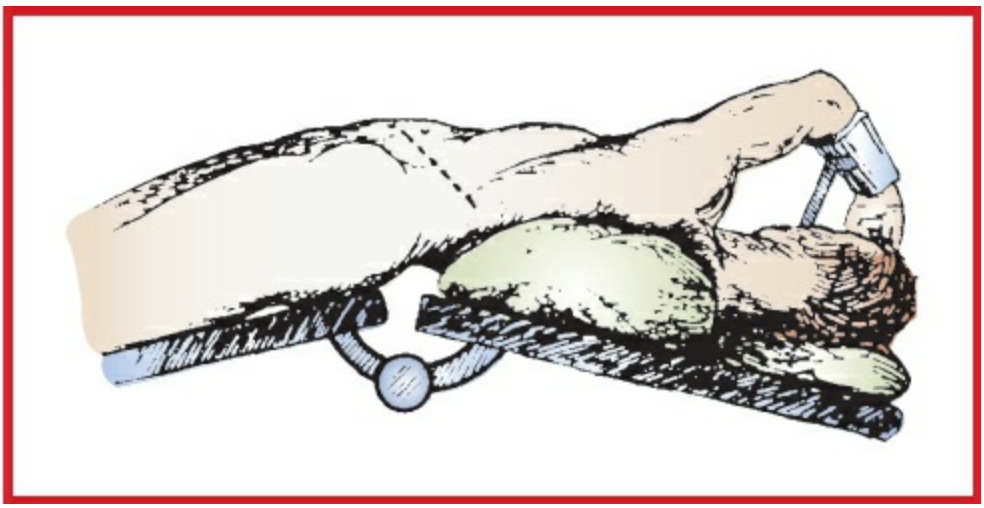

Figure 6.3-10 Retroperitoneal approach to the aorta: the incision is extended from the tip of the 11th rib or 10th intercostal space laterally toward the midhypogastrium. (Reproduced with permission from Scott-Conner CEH, Dawson DLOperative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

SUMMARY OF PROCEDURES

	Transperitoneal Approach	Retroperitoneal Approach
Position	Supine	Supine with mild elevation of left flank
Incision	Midline abdominal	Left subcostal, left oblique, along 10th rib toward umbilicus (See Fig. 6.3-10.)
Special instrumentation	Self-retaining retractor; TEE; if suprarenal change, SMA + renal artery perfusion catheters	⇐
Unique considerations	Will need pharmacologic manipulation to ↓ afterload or ↑ preload coincident with clamping or	⇐ (The retroperitoneal approach is not used for emergency cases.)

	unclamping of aorta	
Antibiotics	Cefazolin 2 g iv (3 g if >120 kg)	⇐
Surgical time	3–5 h	⇐
EBL	500 mL	⇐
Postop care	ICU 8–16 h, often extubated. Requires aggressive volume administration to allow for third-space loss in the first 12 h postop. Patient comfort and respiratory management markedly improved by epidural catheter for postop analgesia. Careful cardiac monitoring	⇐
Mortality	Elective: 2–5%; emergent: 50%	⇐
Morbidity	MI: 10–15% (3% fatal) Respiratory insufficiency/pneumonia: 5–10% Lower extremity ischemia: 2–5% Renal insufficiency: 2–5% Bowel complications: 3–4% Hemorrhage: 2–4% CVA: <1% Infection: <1% Paraplegia: <0.4%	⇐
Pain score	8–10	7–10

PATIENT POPULATION CHARACTERISTICS

Age range	55 yr +
Male:Female	4:1
Incidence	3% of males >55 yr; >5% of patients >50 yr in a general cardiology clinic; 30–66/1000
Etiology	Atherosclerosis; Marfan syndrome; Ehlers-Danlos syndrome; dissection; infection, including syphilis
Associated conditions	HTN; CAD; COPD; cerebrovascular disease; renal insufficiency

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients presenting for open AAA repair are typically older males with multiple coexisting diseases (e.g., CAD, HTN, PVD, COPD). Most commonly, these patients ar asymptomatic, and the Dx is made as an incidental finding during routine exams or other medical procedures; however, some patients may present with severe ↓ BP following aneurysm rupture. These patients require prompt resuscitation (SBP goal: 90–100 mm Hg) and emergent open or endovascular control (aortic cross-clamp vs. endovascular balloon occlusion). For anesthetic considerations, see Endovascular Stent Grafting of Aortic Aneurysms and Abdominal Trauma: Vascular Injuries.

Respiratory	Many patients have COPD and a long Hx of smoking. Preop preparation—including bronchodilators, cessation of smoking, incentive spirometry, and chest physiotherapy—will ↓ risk of postop complications. **Tests:** CXR. May need PFTs and ABG to determine severity of pulmonary disease.
Cardiovascular	CAD is present in up to 70% of these patients and is the most common cause of morbidity and mortality in this patient population. HTN increases risk of aneurysmal rupture; hence, tight control of BP is essential. ✓ BP in both arms to determine placement of arterial line intraop (arterial line should be placed in the arm with higher BP).

	Tests: Radiologic assessment of aneurysm using ultrasonography, CT, arteriography, and MRI. ECG: ✓ for evidence of ischemia, infarction, and LVH. Stress testing, coronary angiography in case of suspicion of coronary disease
Renal	Chronic renal insufficiency occurs frequently in this patient population 2° HTN, diabetes mellitus (DM), and atherosclerotic renovascular disease. Hypovolemia 2° radiographic dye studies and bowel prep → renal failure. **Tests:** BUN, Cr; consider creatinine clearance; electrolytes
Hematologic	Preop coagulation disorders should be corrected. ASA should be continued whenever feasible in patients with known CAD, but DAPT and other anticoagulants should be stopped or bridged with shorter half-life agents to reduce excess perioperative bleeding. Alcohol abuse can be associated with anemia, thrombocytopenia, and ↓ vitamin K–dependent factors. **Tests:** PT; PTT; Hct; Plt
Laboratory	Other tests as indicated from H&P
Premedication	Anxiety and pain may cause HTN and ↑ risk of aneurysmal rupture. Sedatives and analgesics should be used as indicated. Full-stomach precautions for emergent procedures.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of thoracic epidural, continuous paravertebral, or chest wall nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA or combination of epidural and general anesthesia. The goals of anesthesia are to (a) preserve myocardial, renal, pulmonary, and CNS perfusion; (b) maintain adequate intravascular volume and CO; (c) anticipate the surgical maneuvers that will affect BP and blood volume; and (d) control BP to minimize risk of rupture while ensuring perfusion of other organs.

Induction	If it is planned to extubate the patient postop, anesthesia should be induced using fentanyl (4–6 mcg/kg) in conjunction with propofol (1–2 mg/kg) or etomidate (0.2–0.4 mg/kg). If an epidural will be used for postop pain management, decrease intraop iv opioid dose. Patients with an epidural typically receive either morphine (2–4 mg), hydromorphone (0.2–0.8 mg), fentanyl (150–200 mcg), or sufentanil (50 mcg) in 10 mL into the epidural catheter. Local anesthetics may cause hemodynamic instability after unclamping 2° sympathectomy. Muscle relaxants are chosen to minimize tachycardia or ↓ BP (e.g., vecuronium 0.1 mg/kg or rocuronium 1 mg/kg). Anesthesia is deepened before intubation by mask ventilation with 1% sevoflurane. If there is a hemodynamic response to oral airway insertion, tracheal lidocaine or further anesthetic is given before gentle laryngoscopy and intubation. Etomidate is useful for induction in hemodynamically unstable patients. Full-stomach precautions may be necessary.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider placement of parasternal or chest wall nerve blocks if preop blocks have not been placed. Ketamine (0.5 mg/kg iv) at induction may improve pain management and reduce delirium after CPB.
Maintenance	O_2/air/narcotic and volatile agent. N_2O can be used, but it may cause bowel distention. Combining

	epidural and general anesthesia offers good abdominal relaxation. Patients receiving epidural local anesthesia may require phenylephrine to treat ↓ BP 2° sympathetic blockade. Epidural catheter placement before systemic anticoagulation is a safe technique. Narcotic epidural analgesia should be given within 1 h of skin incision if morphine 3–8 mg is used. If hydromorphone (0.5–0.8 mg) is given epidurally, it is given within 1 h of abdominal closure. Patient may become hypothermic 2° large incision with visceral exposure and prolonged operation. Recommend use of antifibrinolytics for all cases requiring CPB.	
Emergence	Normothermic (>35.5°C) patients who have had uneventful surgery, especially utilizing a retroperitoneal approach, are frequently extubated in the OR or shortly after arrival in the ICU. Patients with significant cardiac or pulmonary disease generally are left intubated and weaned from the ventilator in the ICU. Prevention of HTN and tachycardia during emergence may require titration of β-adrenergic–blocking drugs (e.g., esmolol 50–300 mcg/kg/min) and/or vasodilators (e.g., SNP 0.25–2.0 mcg/kg/min) or NTG (0.25–2.0 mcg/kg/min). Epidural morphine (2–4 mg) or hydromorphone (0.5–0.8 mg) is given ~60 min before the end of surgery. It is important to ensure full reversal from neuromuscular blockade. Discuss with surgeon local wound infiltration or chest wall nerve block (e.g., via prefascial plane catheter) placement. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Major blood loss IV: 14 ga (or 7 Fr) × 2; BSS 4 U PRBC UO 0.5–1 mL/kg/h	Use of rapid infusion and blood-salvaging devices is helpful. Consider acute normovolemic hemodilution.

	Warm all fluids. Humidify all gases.	Hemorrhage should be treated with crystalloid, colloid, or blood products as appropriate. Upperbody or underbody Bair Hugger or equivalent. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	Monitor for cardiac ischemia. Automated ST-segment analysis is useful.
	CVP line	The measurement of CVP may be sufficient in patients with good ventricular function and exercise tolerance.
	PA catheter	In patients with recent MI, Hx of CHF, Hx of unstable angina, or multisystem disease, or in those presenting emergently (without the benefit of a complete workup), a PA catheter is appropriate.
	TEE	TEE is invaluable for assessing cardiovascular changes 2° cross-clamping and unclamping the aorta.
	Arterial line Urinary catheter	The arterial line is generally placed in the radial artery of the arm having the higher BP (if difference exists).

Cross-clamping	↑↑ afterload ↑ preload ↑ filling pressures ↓ CO ± ↓ spinal cord perfusion ± ↓ renal perfusion ↓ perfusion to viscera below the clamp ✓ ABG/lytes and UO regularly	Application of aortic cross-clamp causes sudden increase in SVR, LVEDV, wall tension, and preload with a decrease in cardiac output. In a healthy heart, this should be well tolerated, with minimal increase in filling pressure. In case of poor left ventricular function, filling pressures generally rise. Control of preload, afterload, and HR can be accomplished with vasodilators and β-blockers. Negative inotropic agents (e.g., β-blockers, inhalational anesthetics) are used cautiously. Ensure adequate intravascular volume and CO and consider mannitol (0.25–0.5 g/kg) and furosemide (20–80 mg iv) before clamping to maintain UO.
Aortic unclamping	↓↓ afterload ↓↓ preload Lactate washout ± phenylephrine	Immediately before unclamping, D/C dilators and negative inotropic agents. Gradually increase filling pressures (volume loading) to avoid myocardial ischemia, start vasoconstrictors (phenylephrine or norepinephrine) to target

		MAP ~20% above baseline, and consider inotropic support if there is preexisting ventricular dysfunction. ↓↓ BP may occur with removal of cross-clamp 2° to hypovolemia, reperfusion syndrome, or myocardial dysfunction. Reperfusion of lower limbs and washout of lactate do not usually require use of HCO_3. If ↓↓ BP persists, ask surgeon to reclamp or partially clamp the aorta. If hemodynamically stable with ↓ UO, consider furosemide 20–80 mg.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Myocardial ischemia HTN Hemorrhage Coagulopathy Hypothermia Organ ischemia	Hypothermia may cause dysrhythmias, depress contractility, and exacerbate coagulopathy.

POSTOPERATIVE

Complications	Myocardial ischemia Renal failure Respiratory failure	
Multimodal pain	Epidural narcotics	Emphasize multimodal

management		approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	If postop sedation is required, dexmedetomidine may be preferable to propofol. Encourage fast-track extubation, early enteral nutrition, Foley catheter removal, and mobilization.
Tests	CXR to ✓ line and ETT placement ABG, lactic acid Coagulation profile BUN; Cr	BP should be closely controlled postop to decrease bleeding from graft site and raw surfaces.

Suggested Readings

1. Boccara G, Jaber S, Eliet J, et al: Monitoring of end-tidal carbon dioxide partia pressure changes during infrarenal aortic cross-clamping: a non-invasive method to predict unclamping hypotension. Acta Anesthesiol Scand 2001; 45:188–93.
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Pract Res Clin Anaesthesiol 2000; 14(1):143–60.
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INFRAINGUINAL ARTERIAL BYPASS

SURGICAL CONSIDERATIONS

Description

Due to the limited durability of distal bypass procedures, surgical bypass to the infrainguinal arteries is indicated only for salvage of the severely ischemic lower extremity, as manifest by gangrene, ischemic ulceration, or ischemic rest pain. Less frequently, it is used to alleviate functional ischemia of claudication, or leg discomfort with exercise. Its use is predicated on the existence of adequate inflow to the level of the groin or femoral artery. Other necessary components include an adequate target vessel, preferably in continuity with runoff into the plantar arch of the foot, and an adequate conduit, preferably autologous saphenous vein. Long-term patency rates of nonautologous conduits to the below-knee arteries are distinctly inferior to that of saphenous vein and should be avoided whenever possible. This population, almost by definition, includes patients with diabetes mellitus (DM), CAD, and cerebrovascular disease, all of which must be assessed preop.

The operative repair usually involves incisions at the groin and distal bypass sites to expose the donor and recipient arteries and to harvest leg or arm venous conduit. The operative approaches are rather similar. An unobstructed inflow source—usually the common femoral, superficial femoral, or deep femoral artery—is exposed in the groin. The target distal artery, usually at the level of the knee or below, can be approached through a medial incision. More distally, the peroneal and anterior tibial arteries can be approached laterally at the midtibial level. At the level of the malleolus, both the dorsalis pedis and posterior tibial arteries can be revascularized. After control of donor and recipient vessels, an anatomic tunnel is created, and the bypass conduit (saphenous vein, prosthetic graft) is passed through its length. After administration of 10,000 U of heparin, the distal anastomosis is constructed first, followed by the proximal

anastomosis. A completion arteriogram confirms unobstructed flow. Heparin is then partially reversed and meticulous hemostasis obtained, and the wounds are closed.

Although conventional wisdom has held that the anesthetic and operative risks for patients undergoing distal reconstructions are low, there may be little difference in postop morbidity and mortality when compared with patients undergoing a major inflow procedure within the abdomen.

Usual preop diagnosis

Severe PVD; CAD; DM; HTN; obstructive PA disease (These are almost ubiquitou comorbidities.)

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Groin, medial knee, ± distal leg incisions, + incision to harvest venous conduit
Antibiotics	Cefazolin 2 g iv (3 g if >120 kg) after induction of anesthesia
Surgical time	2–5 h
Closing considerations	Optimization of coagulation status
EBL	200–300 mL
Postop care	Possible ICU × 24 h; patients are at risk for myocardial ischemia
Mortality	2–4%
Morbidity	MI: 5–12% Respiratory insufficiency: 5% Infection: 2–5% Amputation: 2–4% CVA: <1%

Pain score	4–6

PATIENT POPULATION CHARACTERISTICS

Age range	>55 yr (mean age ≥ 70 yr)
Male:Female	4:1
Incidence	Claudication fairly common in elderly; however, 75% will remain untreated, but stable, over 2–5 yr, with <5% requiring amputation.
Etiology	Arteriosclerosis (primarily); chronic embolic disease (rare); vasculitis; popliteal artery entrapment; cystic adventitial disease of popliteal artery
Associated conditions	CAD; cerebrovascular disease; DM; HTN; COPD

ANESTHETIC CONSIDERATIONS

(Procedures covered: infrainguinal arterial bypass; arterial embolectomy; lumbar sympathectomy; venous thrombectomy or vein excision)

PREOPERATIVE

Patients presenting for peripheral vascular surgery may suffer from major systemic diseases, including CAD, HTN, and DM. Three types of occlusive vascular diseas have been described. Type 1, isolated to the aortic and iliac bifurcations, is not associated with CAD. Type 2, diffuse pattern involving coronary and cerebral circulations, is associated with a higher incidence of DM and HTN. Type 3, involving small vessels, especially of the lower limbs, is associated with higher postop morbidity and mortality.

Respiratory	Vascular patients frequently have Hx of smoking and COPD. Preop evaluation of pulmonary function helps to determine whether regional anesthesia vs. GA is appropriate while providing baseline values for postop comparison. **Tests:** CXR; consider PFTs; ABG
Cardiovascular	Vascular surgery of the lower extremities is often

	associated with ↑ morbidity and mortality 2° ↑ incidence of CAD and HTN in this patient population. **Tests:** ECG: ✓ for LVH and ischemia; other tests as indicated from H&P
Neurologic	↑ incidence of cerebrovascular disease. Careful neurologic assessment is necessary to document existing deficits.
Endocrine	↑ incidence of DM, which may be associated with peripheral and autonomic neuropathies (silent MI, labile BP) and delayed gastric emptying. Insulin requirements for most diabetic patients can be managed by administering one-half the usual a.m. dose of insulin, once a dextrose-containing iv (e.g., D5LR) has been established. Frequent blood glucose measurements should be made periop.
Renal	There is a higher incidence of renal artery disease and renal insufficiency in this patient population. **Tests:** BUN; Cr; consider creatinine clearance; electrolytes; UA
Hematologic	Many patients presenting for this surgery are taking anticoagulant/anti-Plt medications. Inquire as to bleeding or bruising tendency. **Tests:** Hct; Plt; consider PT, PTT
Laboratory	As indicated from H&P
Premedication	Continue usual medications up to time of surgery. Anxiety can contribute to HTN and tachycardia. Premedicate conservatively (midazolam 0.5–2 mg iv) for geriatric patients. If ischemic pain is present, a narcotic such as fentanyl (25–50 mcg iv) can be given. Avoid im administration in patients on anticoagulant therapy.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Either regional anesthesia or GETA may be used. For **infrainguinal arterial bypass,** there is evidence that regional anesthesia is superior for promoting graft survival. To date, no study has shown a difference in patient mortality between these anesthetic techniques. **Lumbar sympathectomy** may be accomplished with regional or general anesthesia. For **thrombectomy,** GETA with IPPV may reduce the risk of pulmonary emboli.

General anesthesia

Induction	Hemodynamic stability is important; therefore, a slow, gradual induction is carried out. Preoxygenation is followed by smooth iv induction, using small, incremental doses of fentanyl (1–3 mcg/kg); then propofol is given in divided doses until the patient is asleep. Alternatively, if the LV function is poor, etomidate (0.2 mg/kg iv) in combination with fentanyl (100–200 mcg) is appropriate. A full dose of muscle relaxant (vecuronium or rocuronium) is given, and ventilation is controlled. Muscle relaxation is not necessary during the procedure, but muscle relaxant is given to facilitate intubation. The muscle relaxant is chosen to avoid undesirable effects on HR.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance with fentanyl (1–2 mcg/kg/h) and inhaled anesthetic. Continued muscle relaxation is usually unnecessary. These surgical procedures are associated with minimal hemodynamic instability.
Emergence	Tracheal extubation should be based on standard criteria, such as adequacy of ventilation, return of airway reflexes, and reversal of muscle relaxation. Control of BP is accomplished with vasodilators (e.g., NTG 0.1–4.0 mcg/kg/min or SNP 0.25–5.0

	mcg/kg/min). Esmolol can be given in incremental doses of 10 mg or by infusion (50–200 mcg/kg/min). Consider iv acetaminophen if po dose not given. PONV prophylaxis should include ondansetron.

Regional anesthesia

Patients presenting for regional anesthesia must have a normal coagulation profile; also, they cannot be on heparin (including low molecular weight), urokinase, or streptokinase. The important goals in regional anesthesia are to achieve hemodynamic stability while establishing an adequate block. An epidural or spinal catheter (multi orifice) is frequently used to infuse local anesthetic for a gradual onset and to prevent an excessively high block. Hemodynamic stability can be improved by infusing 500–1000 mL of crystalloid before performing the block. The patient may be placed in the lateral decubitus position (with operative side down), which may provide a denser and more prolonged block on that side. Achieving a T8-T10 level is optimal. Overzealous hydration may → CHF in this patient population, when the vasodilation 2° regional sympathectomy dissipates. The American Society of Regional Anesthesia provides guidelines on perioperative management of neuraxial catheters and anticoagulation; generally, heparin dosing should be delayed until 1 h after manipulation of neuraxial space, and coags should be checked and corrected prior to catheter removal. If blood is aspirated after placement of an epidural, we remove the catheter and then replace it at a different interspace. Patients on minidose heparin should have a normal partial thromboplastin time (PTT) before use of regional anesthesia.

Spinal	**One-shot spinal:** 1% hyperbaric tetracaine (6–10 mg) or 0.75% bupivacaine (10–15 mg). Add epinephrine 0.2 mg (generally increases duration of block about 50%) or phenylephrine 5 mg (generally increases duration of block about 100%). Do not add vasoconstrictor if patient is diabetic. Large doses of hyperbaric local anesthetic should be avoided as they may cause postop cauda equina syndrome. **Continuous spinal:** A 20-ga catheter is placed via an 18-ga Tuohy needle. 0.5% hyperbaric tetracaine or 0.75% bupivacaine is titrated to desired anesthetic level (T8-T10). Catheters should be redosed every 60–80 min or as soon as BP trends upward. The risk of spinal headache is very low with

	continuous spinals.	
Epidural	Lidocaine 2% with 1:200,000 epinephrine or 0.5% bupivacaine is used. Titrate to desired anesthetic level (T8-T10).	
Blood and fluid requirements	IV: 14 or 16 ga × 1 BSS @ 3–5 mL/kg/h Warm fluids. Humidify gases. Maintain UO 0.5–1 mL/kg/h.	Minimal-to-moderate blood loss. Use forced-air warmer (e.g., Bair Hugger). See Zero Balance Fluid Management, p. K-2 and p. K-4.
Monitoring	Standard monitors	
	Arterial line ST-segment analysis	An arterial line is most often used in patients with severe cardiopulmonary disease or brittle diabetes. Blood sampling for ABGs, electrolytes, glucose, and Hct is facilitated by the use of an arterial line.
	± CVP/PA catheters ± TEE	CVP and PA catheters are not used routinely because large changes in intravascular volumes are uncommon. Patients with poor LV function, recent MI, or severe valvular disease may need PA and/or TEE monitoring.
Positioning	✓ and pad pressure points ✓ eyes	Diabetic patients may be at risk of skin ischemia due to poor positioning or inadequate padding of limbs.
Complications	HTN	

	Ischemic reperfusion syndrome (postembolectomy) Hypothermia Hemorrhage	Reperfusion of an ischemic limb → ↓ pH, ↑ K^+, and release of myoglobin from injured muscle → ATN.

POSTOPERATIVE

Complications	CHF	Infrainguinal bypass: avoid overhydration; when epidural sympathectomy fades, these patients are at increased risk for CHF. Maintain normovolemia so that peripheral vasoconstriction (which may limit outflow to the graft) does not occur.
	Hypothermia Graft occlusion	Hypothermia causes vasoconstriction and also may limit outflow to the graft.
Multimodal pain management	Epidural/spinal opiates PCA	Epidural (or spinal) catheter may be used for postop analgesia. Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Tests	CXR if central line placed Hct

Suggested Readings

1. Clair D, Shah S, Weber J: Current state of diagnosis and management of critical limb ischemia. Curr Cardiol Rep 2012; 14:160–70.
2. Conte MA: Critical appraisal of surgical revascularization for critical limb ischemia J Vasc Surg 2013; 57:8s–13s.
3. Hull DJ, Kizilgul M, Aung W, et al: Frequency of coronary artery disease in patients undergoing peripheral artery disease surgery. Am J Cardiol 2012; 110:736–40.
4. Noss C, Prusinkiewicz C, Nelson G, et al: Enhanced recovery for cardiac surgery.J Cardiothorac Vasc Anesth 2018; 32:2760–70. pii: S1053-0770(18)30049-1.
5. Singh N, Sidawy AN, Dezee K, et al: The effects of the type of anesthesia in outcomes of lower extremity infrainguinal bypass. J Vasc Surg 2006; 44:964–8.

ARTERIAL EMBOLECTOMY

SURGICAL CONSIDERATIONS

Description

The etiology of acute arterial insufficiency is often the result of thromboembolism, which is usually of cardiac origin. Patients at high risk for embolization are those with MI, mitral stenosis, or atrial fibrillation (AF), all of which increase the risk of intracardiac thrombus formation. Noncardiac causes include thoracic and abdominal aortic pathology, such as aneurysms, severe atherosclerotic disease, and paradoxical embolus via a patent foramen ovale (PFO). The emboli usually become lodged at tapering regions and branch sites and most commonly involve the extremities; the cerebrovascular and mesenteric vasculature also may be involved. In the lower extremities, emboli frequently lodge at the iliac, femoral, or popliteal arteries; the common femoral artery is involved in up to 50% of all embolic events. Emboli to the upper extremities typically affect the brachial artery. Because the collateral circulation may not be well developed in patients without underlying PVD, muscle necrosis can appear within 4–6 h after onset, although this time frame is highly variable. Patients are heparinized at time of diagnosis. Therapy directed at the specific etiology is critical to achieve a successful outcome. Revascularization after 8–12 h of ischemia usually is less effective. If the underlying source of the emboli is not adequately treated, recurrence is likely and is associated with poor prognosis. The surgical approach to femoral

embolectomy is a groin incision and isolation of the common, superficial, and deep femoral arteries. Both the superficial and deep femoral systems are explored, and small embolectomy catheters are passed into the distal lower extremity. In addition to passage of embolectomy catheters, angioscopy may be helpful. Residual thrombus on intraop arteriogram requires distal surgical exposure and exploration.

Usual preop diagnosis

Peripheral artery embolism

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Limited groin, medial knee, possible distal leg incisions
Antibiotics	Cefazolin 2 g iv (3 g if >120 kg)
Surgical time	Variable, 1–4 h
Closing considerations	Ischemia-reperfusion syndrome with acidosis and hyperkalemia, renal tubular necrosis from myoglobinuria
EBL	100–300 mL
Postop care	May need ICU for cardiac monitoring; monitor metabolic disturbances, neurovascular status, and for compartment syndrome
Mortality	10–40% (~80% cardiac); older age; acute onset →↑ risk
Morbidity	Arterial reocclusion or thrombosis: 20% Wound hematoma: 10–20% Recurrent emboli: 6–45% (less with anticoagulation) Amputation: 5–10% Metabolic complications: Frequent Compartment syndrome: Occasional

Pain score	4–6

PATIENT POPULATION CHARACTERISTICS	
Age range	30–90 yr
Male:Female	3:2
Incidence	50/100,000 admissions
Etiology	Cardiac origin (AF accounts for 50–75% of patients; less frequent, LV thrombus from MI) or noncardiac origin (mural thrombus from thoracic or abdominal aortic pathology)
Associated conditions	Rheumatic heart disease and mitral stenosis, mitral or aortic valve prosthesis, CAD and MI, CHF, endocarditis, peripheral vascular and cerebrovascular disease

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Infrainguinal Arterial Bypass.

Suggested Readings

1. Bandyk DF, Johnson BL, Kirkpatrick AF, et al: Surgical sympathectomy for reflex sympathetic dystrophic syndromes. J Vasc Surg 2002; 35:269–77.
2. Davis FM, Albright J, Gallagher KA, et al: Early outcomes following endovascular, open surgical, and hybrid revascularization for lower extremity acute limb ischemia. Ann Vasc Surg 2018; 51:106–12.
3. Jaffery Z, Thornton SN, White CJ: Acute limb ischemia.Am J Med Sci 2011; 342:226–34.
4. Setacci C, de Donato G, Setacci F, et al: Hybrid procedures for acute limb ischemia J Cardiovasc Surg 2012; 53:133–43.

LUMBAR SYMPATHECTOMY

SURGICAL CONSIDERATIONS

Description

The role of open surgical or endoscopic **lumbar sympathectomy** is not well defined.

The procedure is used selectively in patients with causalgia, inoperable lower limb ischemia with rest pain or toe gangrene, symptomatic vasospastic disorders (e.g., Raynaud phenomenon, frostbite), and sometimes as an adjunct to distal revascularization procedures. Causalgia responds well to lumbar sympathectomy, especially if performed early in the clinical course. There may be some benefit of the procedure in 50–60% of patients with rest pain or ischemic ulceration. Sympathectomy may increase collateral blood flow and local skin blood flow. Scleroderma with impending "minor" amputation may benefit from sympathectomy with improved wound healing. Sympathetic denervation involves the division of preganglionic fibers along their segmental origins and resection of corresponding relay ganglia. For most clinical indications, L2 and L3 **ganglionectomy** sufficiently sympathectomizes the lower extremity (Fig. 6.3-11).

The **anterolateral retroperitoneal approach** is the most commonly performed open surgical technique because of the adequate exposure and a relatively well-tolerated incision. For this approach, an oblique incision is made through the abdominal musculature, extending from the lateral border of the rectus abdominis to the anterior axillary line. Cephalad and caudad blunt dissection is performed between the transversalis fascia and peritoneum. The dissection is continued in a retroperitoneal fashion. The psoas muscle is identified, with care being taken to leave the ureter and gonadal vessels attached to overlying peritoneum. The sympathetic chain is identified between the psoas muscle and the vertebra (medial to psoas and overlying the transverse process of lumbar vertebra). On the left side, the sympathetic chain is lateral to the abdominal aorta; on the right, the sympathetic chain is beneath the inferior vena cava (IVC). The sympathetic chain is dissected free from surrounding tissue, clipped proximally and distally, and resected. Hemostasis is achieved, and the abdominal wall is closed in layers.

A **posterior approach** is used less often because of significant postop paraspinous muscle spasms. In this approach, a transverse lumbar incision is made, and the paraspinous muscles are partially divided and retracted to expose the vertebra. The sympathetic chain is identified and resected as described. The **anterior/transperitoneal approach** is performed in conjunction with an abdominal aortic or intraperitoneal procedure. Dissection is carried to the psoas muscle; the retroperitoneum is entered, and the sympathetic chain is isolated in the groove between the psoas and the vertebra. The sympathetic chain is clipped proximally and distally and resected.

Usual preop diagnosis

Causalgia; inoperable arterial occlusive disease with limb-threatening ischemia causing

rest pain, ulceration, or superficial digital gangrene; symptomatic vasospastic disorders (e.g., Raynaud phenomenon or frostbite)

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

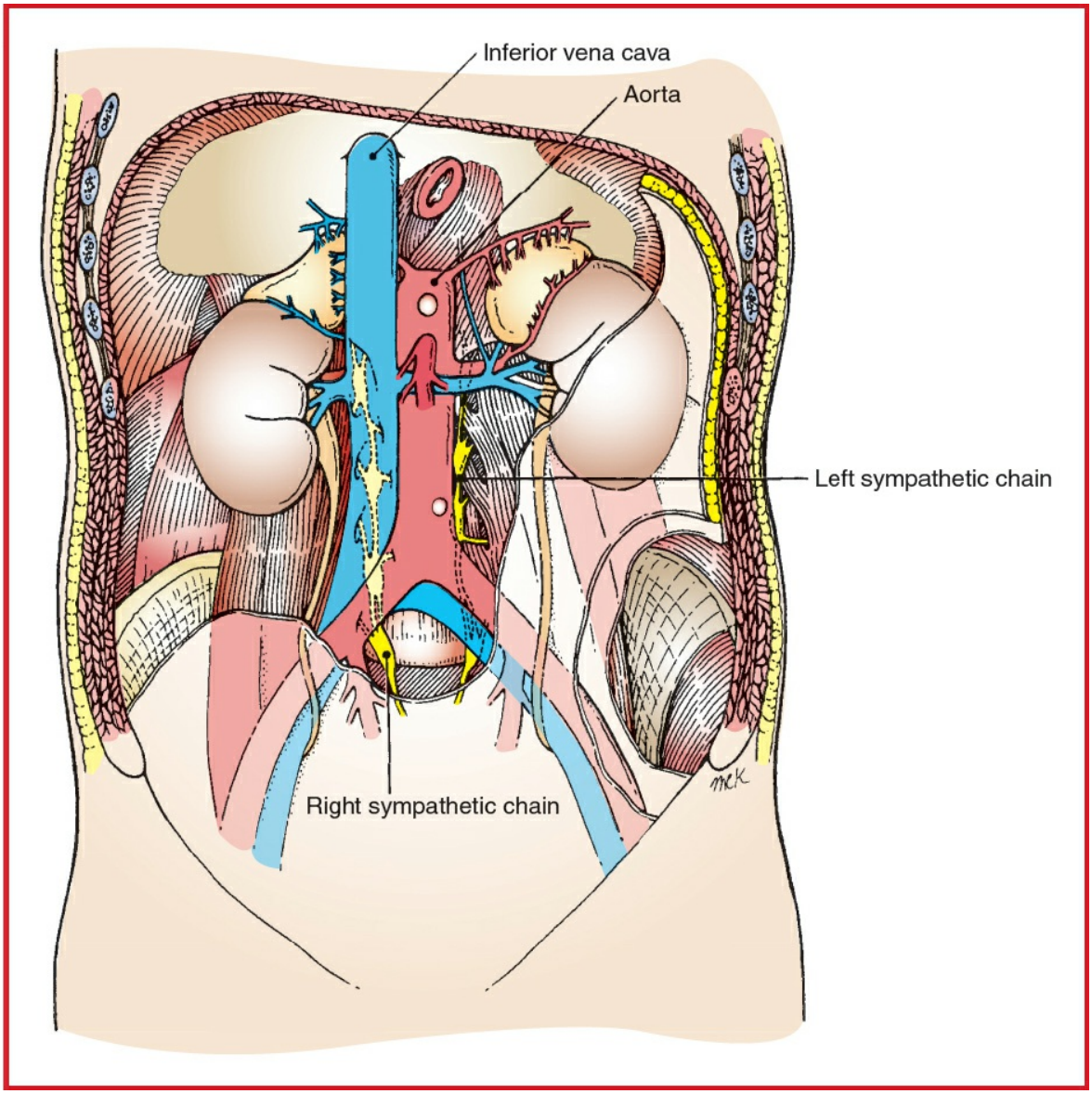

Figure 6.3-11 Surgical anatomy for lumbar sympathectomy. (Reproduced with permission from Scott-Conner CEH, Dawson DLOperative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

SUMMARY OF PROCEDURES

	Anterolateral	Posterior	Anterior

	(Flowthow)	(Royle)	(Adson)
Position	Supine (flank slightly raised); widen distance between costal margin and iliac crest	Prone	Supine
Incision	Oblique (lateral edge of rectus to ribs at anterior axillary line)	Posterior transverse over midlumbar region	Transverse or midline abdominal
Special instrumentation	Self-retaining retractor	⇐	⇐
Unique considerations	May use frozen section to confirm specimen	⇐	⇐
Antibiotics	Cefazolin 2 g iv (3 g if >120 kg)	⇐	⇐
Surgical time	2–3 h	3 h	4 h
Closing considerations	Flex table to facilitate abdominal wall closure; occasionally drain is placed	⇐	⇐
EBL	50–100 mL (unless complicated)	50–100 mL	⇐
Postop care	PACU → ward (may require cardiac and hemodynamic monitoring in high-risk patients, or if combined with distal revascularization)	⇐	⇐
Mortality	Minimal	⇐	⇐

Morbidity	Postsympathectomy neuralgia: 50% Sexual derangement—retrograde ejaculation (usually bilateral L1 sympathectomy): 25–50% Wound hematoma: 10% Wound infection: 1–3%	~50% ~25–50% ~10% ~1–3% Paraspinous muscle spasms	⇐ ⇐ ⇐ ⇐
Pain score	5	5	5 (related to primary procedure)

PATIENT POPULATION CHARACTERISTICS

Age range	38–91 yr; younger patients with vasospastic disease; older patients with PVD
Male:Female	2:1
Incidence	Unknown. ~30 cases/yr at Stanford University Medical Center, mainly for inoperable lower extremity ischemia or as an adjunct to revascularization procedures
Etiology	PVD (rest pain and tissue loss); vasospastic disorders; causalgia
Associated conditions	PVD (rare); vasospastic disorders (rare)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Infrainguinal Arterial Bypass.

Suggested Readings

1. Nemes R, Surlin V, Chiutu L, et al: Retroperitoneoscopic lumbar sympathectomy

prospective study upon a series of 50 consecutive patients. Surg Endosc 2011; 25(9):3066–70.
2. Sen I, Agarwal S, Tharyan P, et al: Lumbar sympathectomy versus prostanoids for critical limb ischaemia due to non-reconstructable peripheral arterial disease. Cochrane Database Syst Rev 2018; 4:CD009366.
3. Setaccia C, de Donatoa G, Teraa M, et al: Chapter IV: treatment of critical limb ischemia. Eur J Vasc Endovasc Surg 2011; 42(S2):S43–59.

VENOUS SURGERY—THROMBECTOMY OR VEIN EXCISION

SURGICAL CONSIDERATIONS

Description

Standard therapy for acute deep venous thrombosis (DVT) consists of anticoagulation bed rest, and elevation of the extremity. Endovascular or catheter-directed thrombolysis and thrombectomy systems have been shown to extract large venous thrombus burden. Open surgical thrombectomy for acute iliofemoral DVT remains controversial. **Venous thrombectomy** is recommended for patients with threatened limb loss or venous gangrene caused by massive DVT associated with high compartment pressures and arterial insufficiency (phlegmasia cerulea dolens). Surgical venous thrombectomy requires exposure of the femoral vein via a groin cutdown. The common femoral vein is isolated (located medial or posteromedial to the femoral artery) and controlled proximally and distally. The patient is given iv heparin at this stage, if not already heparinized. A transverse venotomy is followed by extraction of the thrombus, using forceps and Fogarty embolectomy catheters (Fig. 6.3-12). Distal thrombi are expressed through the same incision with the aid of an Esmarch bandage placed on the extremity. After complete removal of the thrombus, the venotomy is closed with nonabsorbable sutures, and flow through the femoral vein is reestablished. The femoral incision is closed in layers. A plastic/Silastic drain may or may not be used. The best results of thrombectomy are obtained in young patients with the first episode of proximal (iliofemoral) thrombosis.

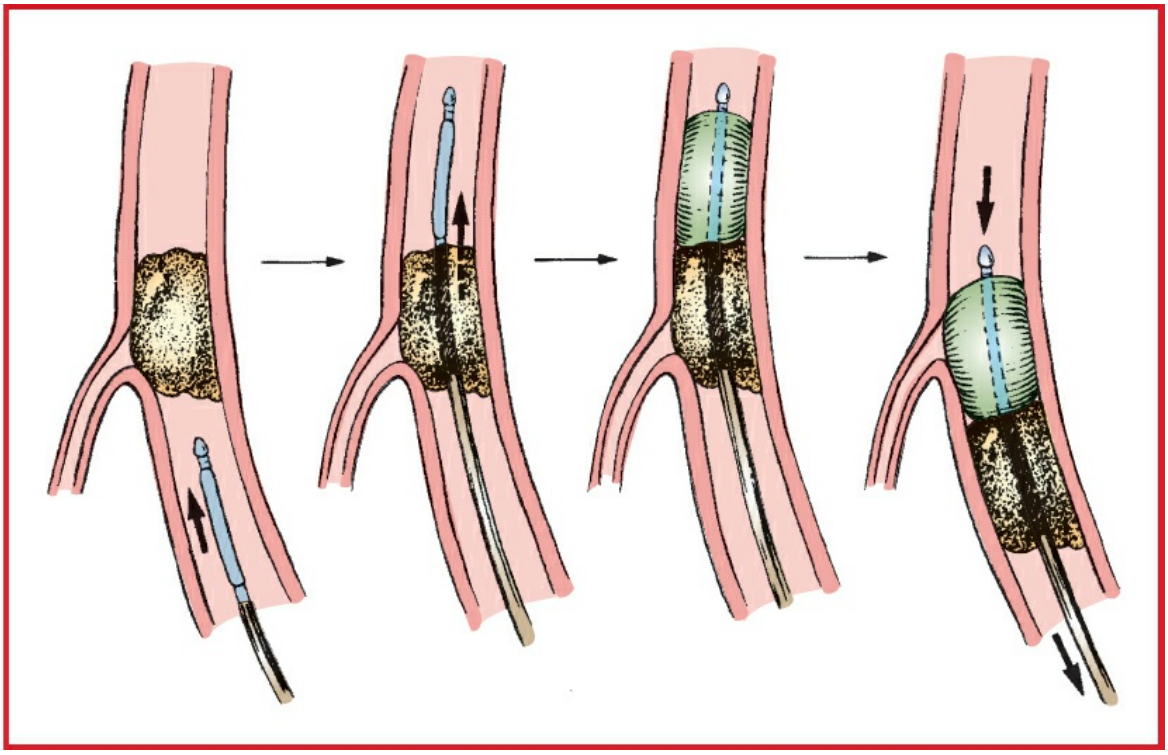

Figure 6.3-12 Fogarty catheter embolectomy with catheter insertion in the distal vessel. (Reproduced with permission from Baker RJ, Fischer JEMastery of Surgery, Vol. 2, 4th edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Nonsuppurative thrombophlebitis of the superficial veins may develop due to local trauma, prolonged inactivity, fungal infection, or the use of oral contraceptives. Suppurative thrombophlebitis may occur as a complication of iv line placement or iv drug abuse. Underlying varicose veins may predispose to thrombophlebitis. Migratory superficial thrombophlebitis may be associated with chronic ischemia of the extremities in Buerger disease, or it may develop in patients with a malignancy. Conservative management with hot compresses, nonsteroidal anti-inflammatory medications, and elevation of the extremity is effective in most cases. Rarely, **excision** of the acutely thrombosed greater saphenous vein is indicated to prevent progression of thrombosis to the saphenofemoral junction and into the deep venous system. Vein excision is simply approached by a longitudinal incision directly over the affected vein. The phlebitic vein is dissected from the surrounding tissue, ligated proximally and distally, and removed. The surrounding fibrotic tissue is debrided gently. The wound is irrigated and packed open with moist gauze. Suppurative phlebitis is treated with iv antibiotics and complete excision of the involved vein segment through multiple small incisions.

Usual preop diagnosis

Lower limb venous thrombosis threatening viability; femoral thrombosis <10 d; iliac thrombosis <3 wk; floating thrombi at hip level; acute deep or superficial venous

thrombosis; suppurative thrombophlebitis

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Thrombectomy	Vein Excision
Position	Supine	⇐
Incision	Ipsilateral longitudinal or oblique groin incision	Multiple small incisions along the course of vein to be excised
Special instrumentation	Fogarty embolectomy catheters; RBC salvage system	None
Unique considerations	IPPV during thrombectomy may decrease chance of PE 2° ↓ venous return → more complete extraction of the thrombus.	None
Antibiotics	Cefazolin 2 g iv (3 g if >120 kg). If the patient has septic thrombus, antibiotic is dependent on blood culture.	Dependent on culture of aspirate. Usually, a septic patient is on broad-spectrum antibiotics (guided by culture).
Surgical time	2–3 h	1–3 h
Closing considerations	None	Wound packed open for drainage
EBL	50–250 mL	⇐
Postop care	PACU → ward; ICU in high-risk patients; heparin administered before and	PACU → ward; support stockings

	after procedure, followed by Coumadin for 1–6 mo	
Mortality	Minimal (depending on underlying illness)	Minimal
Morbidity	Postthrombotic syndrome: <10–44% Venous stasis Nonpitting edema Brawny induration Aching pain	Minimal
Pain score	3	2

PATIENT POPULATION CHARACTERISTICS

Age range	Young adult—elderly
Male:Female	1:2
Incidence	6–7 million in the United States have adverse effects from chronic venous stasis; 500,000 have complications of leg ulceration.
Etiology	Chronic primary varicose veins; defective venous valves; impaired pumping action of muscles in the leg; previous iliofemoral thrombophlebitis; obstruction of venous return
Associated conditions	Multifactorial: varicose veins; underlying malignancy; altered coagulation status (hypercoagulability, acquired or congenital); Hx of DVT/thrombophlebitis

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Infrainguinal Arterial Bypass.

Suggested Readings

1. Comerota AJ: The current role of operative venous thrombectomy in deep veir thrombosis. Semin Vasc Surg 2012; 25:2–12.
2. Davenport DL, Xenos ES: Early outcomes and risk factors in venous thrombectomy an analysis of the American College of Surgeons NSQIP dataset.Vasc Endovascular Surg 2011; 45:325–8.

3. Kim HS, Patra A, Paxton BE, et al: Catheter-directed thrombolysis with percutaneou rheolytic thrombectomy versus thrombolysis along an upper and lower extremity deep vein thrombosis. Cardiovasc Intervent Radiol 2006; 29:1003–7.
4. Wissgott C, Kamusella P, Andresen R: Percutaneous mechanical thrombectomy: advantages and limitations. J Cardiovasc Surg 2011; 52(4):477–84.

SURGERY FOR PORTAL HYPERTENSION

SURGICAL CONSIDERATIONS

Description

Alcoholic liver disease is the major cause of portal HTN, and end-stage liver disease (ESLD) with cirrhosis is the 10th leading cause of death in the United States (exceeding 23,000/yr). Of patients with portal HTN, 15–20% have variceal hemorrhage during the 1st yr of diagnosis (additional 5–10% incidence of bleeding per yr); and the initial episode of variceal hemorrhage is associated with 50% mortality. Portal HTN (>15 mm Hg) develops when splanchnic venous flow to the right heart becomes impeded. Medical and surgical therapeutic interventions are directed not at portal HTN per se but at its complications—notably bleeding esophageal varices. Intractable ascites and hypersplenism are less common indications for operative therapy. Presinusoidal portal HTN, unlike sinusoidal or postsinusoidal obstruction, is not associated with severe hepatocellular disease; thus, the prognosis for patients with presinusoidal block is better than for those with sinusoidal or postsinusoidal disease. Surgical approaches can be divided into shunt and nonshunt procedures. **Shunt procedures** can be classified as either **total** (decompression of the portal venous system) or **selective** (decompression of only the varix-bearing area). It should be noted, however, that surgery for portal HTN has been replaced largely by the TIPS procedure.

Shunt procedures

There are two general types of total shunt (**portosystemic shunt**) procedures. The **end-to-side portacaval shunt** (Fig. 6.3-13A) is technically simpler and may be more appropriate in emergency situations. It is associated with immediate control of hemorrhage in the majority of cases. The portacaval shunt, however, does eliminate portal perfusion of the liver and does not decompress the hepatic sinusoids. Alternatively, the **functional side-to-side shunt** (Fig. 6.3-13B) allows decompression of hepatic sinusoids and may preserve some degree of portal perfusion of the liver. Also, it is more effective in controlling ascites. Variations of the side-to-side shunt include **portacaval, splenorenal, mesocaval** (**Clatworthy**), and **portarenal** (rarely

used).

For the **end-to-side** and **side-to-side portacaval shunts,** the approach is via an extended right subcostal incision. **Cholecystectomy** usually is not performed because of the likelihood of profuse bleeding from the liver bed. The hepatoduodenal ligament is identified, and the portal vein is exposed from the hilum of the liver to the pancreas. The gastroduodenal and right gastric branches may be divided to provide additional exposure of the portal vein. The IVC is exposed by incising the peritoneum just beneath the hepatic triad. Proximal and distal control of the portal vein is achieved, and a side-biting clamp is placed on the IVC. To perform an end-to-side portacaval shunt, the portal vein is divided and oversewn proximally; the end-to-side anastomosis is performed from the portal vein to the IVC. The alternative is to perform a side-to-side anastomosis of the portal vein to the IVC without division of the portal vein.

The **proximal splenorenal shunt** is approached through a left thoracoabdominal or transabdominal incision. The spleen is isolated and removed, and the distal splenic vein is mobilized from the distal pancreatic bed. The left renal vein is exposed and controlled. The distal splenic vein is then anastomosed in an end-to-side fashion to the midrenal vein. The **mesocaval shunt** (Fig. 6.3-13C) is indicated in cases of ascites, periportal fibrosis, portal vein thrombosis, and Budd-Chiari syndrome. The mesocaval shunt is approached through a vertical midline incision. The colon is retracted cephalad, and the superior mesenteric vein (SMV) is identified at the root of the mesentery. A length of the SMV is isolated and encircled. A **Kocher maneuver** (mobilization of the duodenum) is performed, and the IVC is exposed anteriorly and laterally. A side-biting clamp partially occludes the IVC, and a 14- to 20-mm Dacron graft is anastomosed in an end-to-side fashion to the IVC. The graft is clamped and the side-biting clamp removed from the IVC, thereby restoring flow via the IVC. The SMV is clamped, and an end-to-side anastomosis is created from the graft to the SMV. Flow is, thus, reestablished from the SMV through the graft to the IVC.

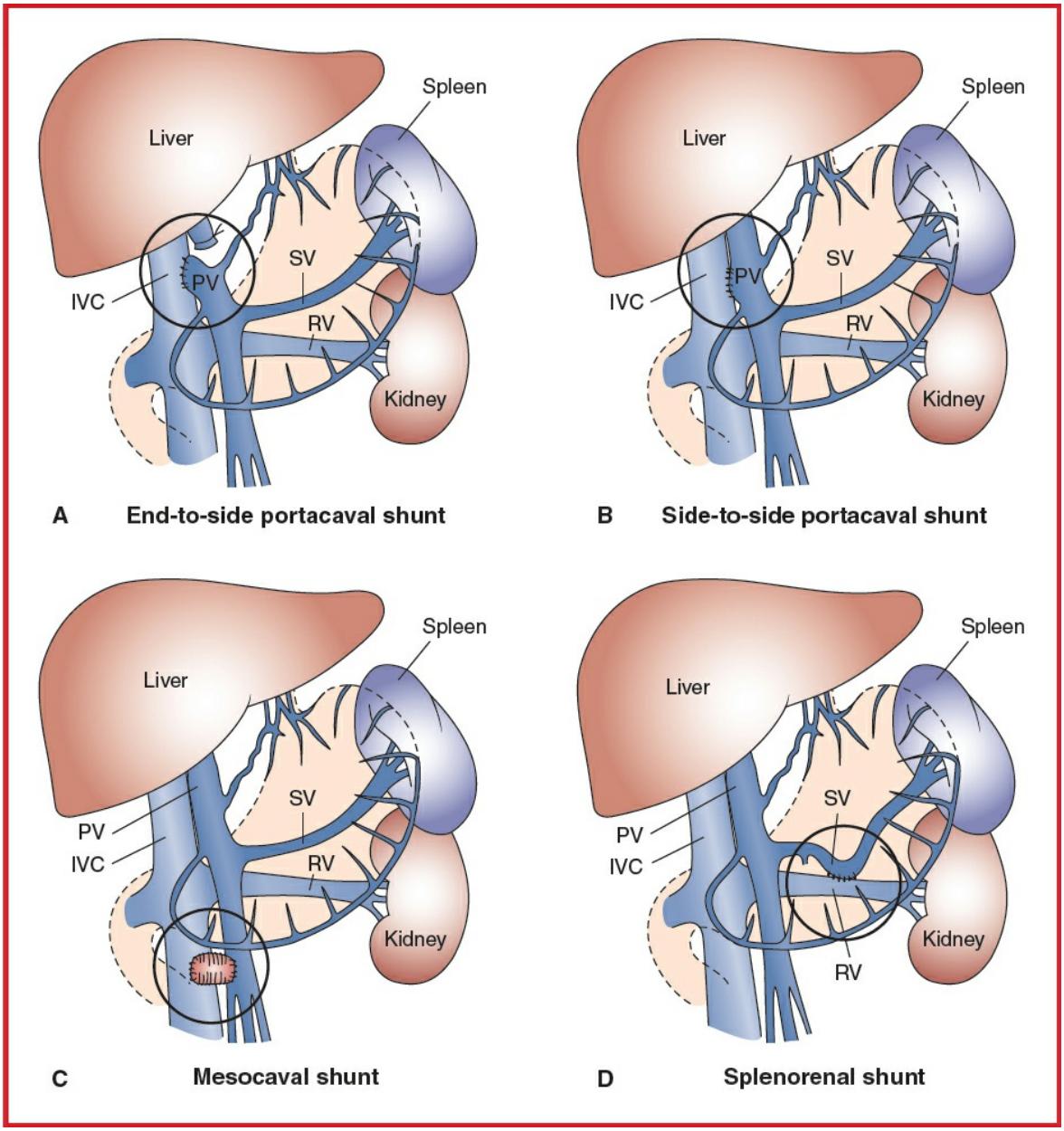

Figure 6.3-13 Types of shunts. **A:** End-to-side portacaval. **B:** Side-to-side portacaval. **C:** Mesocaval shunt. **D:** Distal splenorenal. (Reproduced with permission from Hardy JD:Hardy's Textbook of Surgery, 2nd edition. JB Lippincott, Philadelphia: 1988.)

Selective shunts are designed to decompress esophageal varices, while some portal perfusion of the liver is maintained. The hallmark example of this approach is the **distal splenorenal shunt** (**Warren**; Fig. 6.3-13D), which is seldom used in emergency situations. The principal feature of this shunt is disconnection of the splenic and superior mesenteric venous drainage systems. The distal splenorenal shunt is approached through a left chevron or extended left subcostal incision. The lesser sac is entered after division of the gastroepiploic vessels and mobilization of the splenic flexure of the colon. The stomach is retracted cephalad, and the peritoneum overlying the inferior aspect of the pancreas is incised. The splenic vein is identified and

controlled proximally and distally. The inferior mesenteric vein is divided. The splenic vein is divided proximally, and the proximal stump is oversewn. Then the splenic vein is mobilized from the pancreatic bed. The left renal vein is identified, and 5–7 cm of the vein is isolated. The splenic vein is anastomosed in an end-to-side fashion to the renal vein. The coronary vein is ligated close to its origin. The distal splenorenal shunt decompresses the stomach, distal esophagus, and spleen and controls variceal hemorrhage in 85% of patients.

Variant procedure or approaches

Total shunt (e.g., portacaval, proximal splenorenal, mesocaval); **selective shunt** (e.g., **Warren**); **nonshunt procedures** (e.g., **Sugiura, Hassab,** and **esophageal transection with stapling**)

Usual preop diagnosis

Bleeding esophageal varices (as a result of portal HTN); ascites; hypersplenism

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES (TOTAL AND SELECTIVE SHUNTS)

	Portacaval	Proximal Splenorenal	Mesocaval (Clatworthy)	Distal Splenorenal (Warren)
Position	Supine	Supine ± left flank elevated	Supine	Supine, left side elevated slightly
Incision	Extended right subcostal—may be lengthened or converted to left thoracoabdominal	Left thoracoabdominal or left subcostal or vertical midline	Vertical midline abdominal	Left chevron or left subcostal with midline extension
Special instrumentation	Self-retaining retractor	⇐	⇐	⇐
Unique considerations	May need FFP; consider cell saver	⇐	⇐	⇐
Antibiotics	Cefazolin 2 g iv (3 g if >120 kg)	⇐	⇐	⇐
Surgical time	4–6 h	⇐	⇐	⇐
Closing considerations	None	⇐	⇐	⇐
EBL	1000–2000 mL	⇐	⇐	⇐
Postop care	Patient → ICU; careful fluid management; consider Na^+ restriction; may require PA catheter	⇐	⇐	⇐

Mortality	Emergency: 38% Elective: 3% Child's A: 0–15% Child's B: 1–43% Child's C: 6–58%	5–10%	⇐	1–16%
Morbidity	Late liver failure: 50% Encephalopathy: 32% Child's A: 8% Child's B: 20% Child's C: 30% Early rebleeding: 0–19%	~50% ~32% ~0–19%	⇐ ⇐ ⇐	— 5–47% (overall) 5% at 2 yr 12% at 3–6 yr 27% at 10 yr —
	Shunt thrombosis: 1–10%	20%	9–30% Duodenal obstruction; erosion through bowel wall	— Loss of selectivity: 60% (@ 2 yr) Recurrent variceal hemorrhage (shunt occlusion): 3–19% Portal vein thrombosis: 4–10%
Pain score	6	6	6	6

Note: In addition to the shunt procedure itself, other factors that determine postop morbidity and mortality include severity of hepatocellular disease, degree of hepatic reserve, and urgency of the procedure. Although the specific numbers may vary, several comparative series have shown no difference in operative mortality rate or long-term survival rate among the various open shunt procedures.

Nonshunt procedures

Nonshunt procedures are designed to devascularize the esophagogastric region, thus eliminating acute variceal hemorrhage. Procedures of this type include **portoazygos disconnection**, **splenectomy**, **coronary vein ligation**, and **transesophageal** or **transgastric varix ligation**.

The **Sugiura operation,** approached via abdominal and thoracic incisions, includes esophageal transection and devascularization, splenectomy, and pyloromyotomy. This procedure is usually performed in two operative stages, sometimes with a delayed second stage. The **Hassab procedure** involves devascularization of the upper half of the stomach and splenectomy, thus effectively disconnecting the esophageal varices. (This operation has been reserved in some centers for the failures of sclerotherapy.) Finally, **esophageal transection,** using a stapling device, disconnects the varices in the lower esophagus. This is accomplished by placing a row of staples at the esophagus just above the esophagogastric junction. Because portal perfusion of the liver is maintained after the nonshunt procedures, hepatic function is preserved.

SUMMARY OF NONSHUNT PROCEDURES

	Sugiura (Two Stages)	Hassab	Esophageal Transection
Position	Supine, left side elevated	Supine	⇐
Incision	Abdominal stage: midline; thoracic stage: left thoracotomy	Vertical midline	⇐
Special instrumentation	Self-retaining retractor	⇐	⇐
Antibiotics	Cefazolin 2 g iv (3 g if >120 kg)	⇐	⇐
Surgical time	4–6 h for both stages	4 h	⇐
EBL	1000–2000 mL	⇐	⇐
Postop care	ICU; careful hemodynamic monitoring; PA catheterization	⇐	⇐
Mortality	Overall: 5–14% Emergent: 14% (≤60%) Elective: 3%	12–38% 10%	10–83%
Morbidity	Recurrent hemorrhage: 2–50% Esophagopleural leak: 6% Encephalopathy: 3% Ascites: 2% Wound infection: 2%	7% — 1–25% 4% —	0–50% 3% 33% 11% 11%

Pain score	6	5	5

■ PATIENT POPULATION CHARACTERISTICS FOR SHUNT A NONSHUNT PROCEDURES	
Age range	11–72 yr (mean age = 48 yr); depending on etiology: pediatric (e.g., congenital hepatic fibrosis) to adult (e.g., alcoholic liver disease)
Male:Female	2–8:1
Incidence	Rare
Etiology	Alcoholic liver disease (alcoholic hepatitis, chronic alcoholism, cirrhosis); postnecrotic cirrhosis; portal vein thrombosis; splenic vein occlusion; hematologic diseases; hepatic vein occlusion; schistosomiasis; congenital hepatic fibrosis; sarcoidosis; sinusoidal occlusion (vitamin A toxicity, Gaucher disease); veno-occlusive disease
Associated conditions	Alcohol dependency; cirrhosis/liver failure; poor nutritional status; coagulopathy; encephalopathy

ANESTHETIC CONSIDERATIONS

(Procedures covered: shunt and nonshunt procedures for portal HTN surgery)

PREOPERATIVE

Respiratory	Hypoxemia may be present 2° ascites, V/Q mismatch, ↑ R→L pulmonary shunting, atelectasis, pulmonary infections, and ↓ pulmonary diffusing capacity. Note whether patient most comfortable sitting, semirecumbent, or supine, and maintain that position prior to intubation and periextubation to optimize respiratory mechanics. **Tests:** Consider ABG; PFTs, as indicated; CXR
Cardiovascular	Patients presenting with portal HTN often have a

	hyperdynamic circulatory state with ↑ plasma volume, ↑ CO, and ↓ SVR, with a decreased ability to ↑ SVR or ↑ HR in response to stimuli. Ventricular performance may be abnormal (CHF), especially in patients with alcoholic liver disease. Ascites →↑ intrathoracic pressure, ↓ FRC, ↓ venous return, and ↓ CO. Older patients in this population usually have CAD. **Tests:** ECG. If LV function in question, ECHO or angiography
Hepatic	The physical manifestations of hepatic disease include palmar erythema, caput medusae, spider angiomas, and gynecomastia. Albumin and other products of liver synthesis (e.g., coagulation factors) may be decreased. Encephalopathy may be present 2° impaired ammonia metabolism. **Tests:** Bilirubin; albumin; PT; SGOT; SGPT; ammonia; alkaline phosphatase
Gastrointestinal	Portal HTN eventually → esophageal and gastric varices. Patients may present emergently with profuse GI bleeding. Ascites occurs in ~80% of patients with portal HTN, and splenomegaly is invariably present. As a result of elevated intra-abdominal pressure from ascites and slow gastric emptying, a rapid-sequence induction with full-stomach precautions will be necessary.
Renal	Portal HTN →↓ GFR and ↓ renal blood flow → renal failure (hepatorenal syndrome). **Tests:** Consider UA; creatinine clearance as indicated from H&P
Hematologic	These patients are often anemic as a result of poor nutrition, malabsorption, and intestinal tract blood loss. Hypersplenism may be present (Plt count < 50,000 and WBC < 2000). Synthesis of all coagulation factors is decreased except factor VIII and fibrinogen. A low-grade DIC may be present. T&C for 8–10 U PRBC. **Tests:** CBC; Plt count; PT; PTT; consider DIC screen

Pharmacologic	The liver is the major site of drug biotransformation; however, the effects of hepatic dysfunction on drug elimination and disposition are inconsistent.
Laboratory	These patients may have significant electrolyte disturbances (e.g., ↓↓ Na^+, ↓ K^+↓ albumin). **Tests:** Electrolytes and others as indicated from H&P
Premedication	If premedication is appropriate, small doses of anxiolytic, such as midazolam (0.5–1 mg iv), are preferable. Avoid im medications in patients with possible coagulopathy. Full-stomach precautions are necessary. Metoclopramide (10 mg iv) and famotidine (20 mg iv) may be given 60 min before surgery.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: Preservation of intravascular volume and myocardial stability can be a challenge in these patients.

Induction	In stable patients rapid-sequence induction with propofol (1–2 mg/kg) and succinylcholine (1–2 mg/kg) should be used. Replace blood loss and ensure normovolemia before induction (if possible). Etomidate (0.2 mg/kg) or ketamine (1 mg/kg) may be preferable for induction in hemodynamically unstable patients.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Combination of narcotics (fentanyl) and inhalation agents (isoflurane/sevoflurane) titrated to

	hemodynamic condition. Midazolam (0.1–0.2 mg/kg) may be given in conjunction with the narcotic to ensure amnesia during times of hemodynamic instability when volatiles cannot be tolerated but beware hepatic elimination. N_2O is avoided to prevent bowel distention. Muscle relaxation is needed, titrate using a nerve stimulator. **NB:** After drainage of ascitic fluid, there may be a precipitous drop in BP requiring rapid volume replacement ± vasopressor.	
Emergence	Generally deferred to ICU due to large fluid shifts and transfusion requirements. Patients who have undergone uneventful and nonemergent surgery may be candidates for extubation. PONV prophylaxis should include ondansetron.	
Blood and fluid requirements	Anticipate large blood loss. IV: 14 ga × 2 or 7 Fr × 2; BSS Rapid infuser RBC salvage device 8–10 U PRBC Warm all fluids. Humidify all gases. Warming blanket	FFP, Plt, and cryoprecipitate should be available to treat coagulopathy. See Zero Balance Fluid Management, Appendix K, p. K-2 and p. K-4. e. g., Bair-Hugger warmer
Monitoring	Standard monitors Arterial line CVP or PA catheter TEE	Arterial and central pressure monitoring are essential. A PA catheter is useful in this setting because most patients are cirrhotic and may have excessive blood loss and large fluid shifts. TEE is reserved for patients with severe cardiopulmonary disease

		or instability intraop due to risk of variceal bleeding.
	UO	UO is measured and is helpful as a monitor of renal perfusion. Mannitol (0.25–1 g/kg iv) may be needed to maintain UO.
	Temperature	In these procedures, prevention of hypothermia is important. In patients with large varices, avoid esophageal placement of T probes or stethoscopes.
	ABGs	Serial ABGs to determine adequacy of ventilation and normal acid-base status should be done.
	Hct, coags, Ca^{++}	Hct, coagulation, and Ca^{++} should be measured following replacement of large blood volumes.
	Electrolytes	Electrolytes and glucose also should be monitored.
	Blood glucose	Glucose metabolism in liver disease may be impaired → ↓ glucose.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Coagulopathy Hemorrhage Hypothermia	

POSTOPERATIVE

Complications	Coagulopathy Hypothermia Encephalopathy Renal failure	
Multimodal pain management	PCA Parenteral opiates	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.
Tests	CXR: line placement Hct Electrolytes Glucose	DIC screen, if continued bleeding

Suggested Readings

1. Costa G, Cruz RJ Jr, Abu-Elmagd KM: Surgical shunt versus TIPS for treatment o variceal hemorrhage in the current era of liver and multivisceral transplantation. Surg Clin N Am 2010; 90:891–905.
2. Henderson JM: The distal splenoral shunt. Surg Clin North Am 1990; 70(2):405–23.
3. Henderson JM: Surgery versus transjugular intrahepatic portal systemic shunt in the treatment of severe variceal bleeding. Clin Liver Dis 2006; 10:599–612.
4. Jenkins RL, Gedaly R, Pomposelli JJ, et al: Distal splenorenal shunt: role indications, and utility in the era of liver transplantation. Arch Surg 1999; 134:416–20.
5. Liu Y, Li Y, Ma J, et al: A modified Hassab's operation for portal hypertension: experience with 562 cases. J Surg Res 2013; 185:e1–e6.
6. Noss C, Prusinkiewicz C, Nelson G, et al: Enhanced recovery for cardiac surgery.J Cardiothorac Vasc Anesth 2018; 32:2760–70. pii: S1053-0770(18)30049-1.
7. Voros D, Polydorou A, Polymeneas G, et al: Long-term results with the modified Sugiura procedure or the management of variceal bleeding: standing the test of time in the treatment of bleeding esophageal varices. World J Surg 2012; 36:659–66.

ARTERIOVENOUS ACCESS FOR HEMODIALYSIS

SURGICAL CONSIDERATIONS

Description

Peripheral subcutaneous arteriovenous (AV) fistula, or **prosthetic graft,** is the current procedure of choice for patients requiring permanent hemodialysis access. The blood flow in the autogenous AV fistula increases with time, and the resulting vein wall thickening prevents venous tears and infiltration during dialysis.

The standard AV fistula is usually constructed by anastomosing the cephalic vein to the radial artery at the wrist level (**Brescia-Cimino fistula**; Fig. 6.3-14). Other locations include the "snuff box," or antebrachium. Vascular access using vascular substitutes or prosthetic grafts is performed when there is a lack of suitable veins in patients who have had failed-access procedures, peripheral vein sclerosis, or severe arterial disease involving the upper extremity. Forearm grafts are constructed as a direct communication between the radial or ulnar artery and the antecubital or brachial vein or as a "loop" between the brachial artery and these veins (Fig. 6.3-15). Similarly, an access can be constructed in the upper arm as a communication between the brachial artery above the elbow and the basilic or axillary vein in a straight fashion. The polytetrafluoroethylene (Teflon) graft has become the mainstay for hemodialysis access in patients who are not candidates for Brescia-Cimino fistula placement. These grafts are associated with a primary patency rate of 50–60% at 2–3 yr.

Variant procedure or approaches

Loop or straight graft, using vascular substitute in the forearm; **upper arm straight graft**

Usual preop diagnosis

End-stage renal failure requiring graft hemodialysis

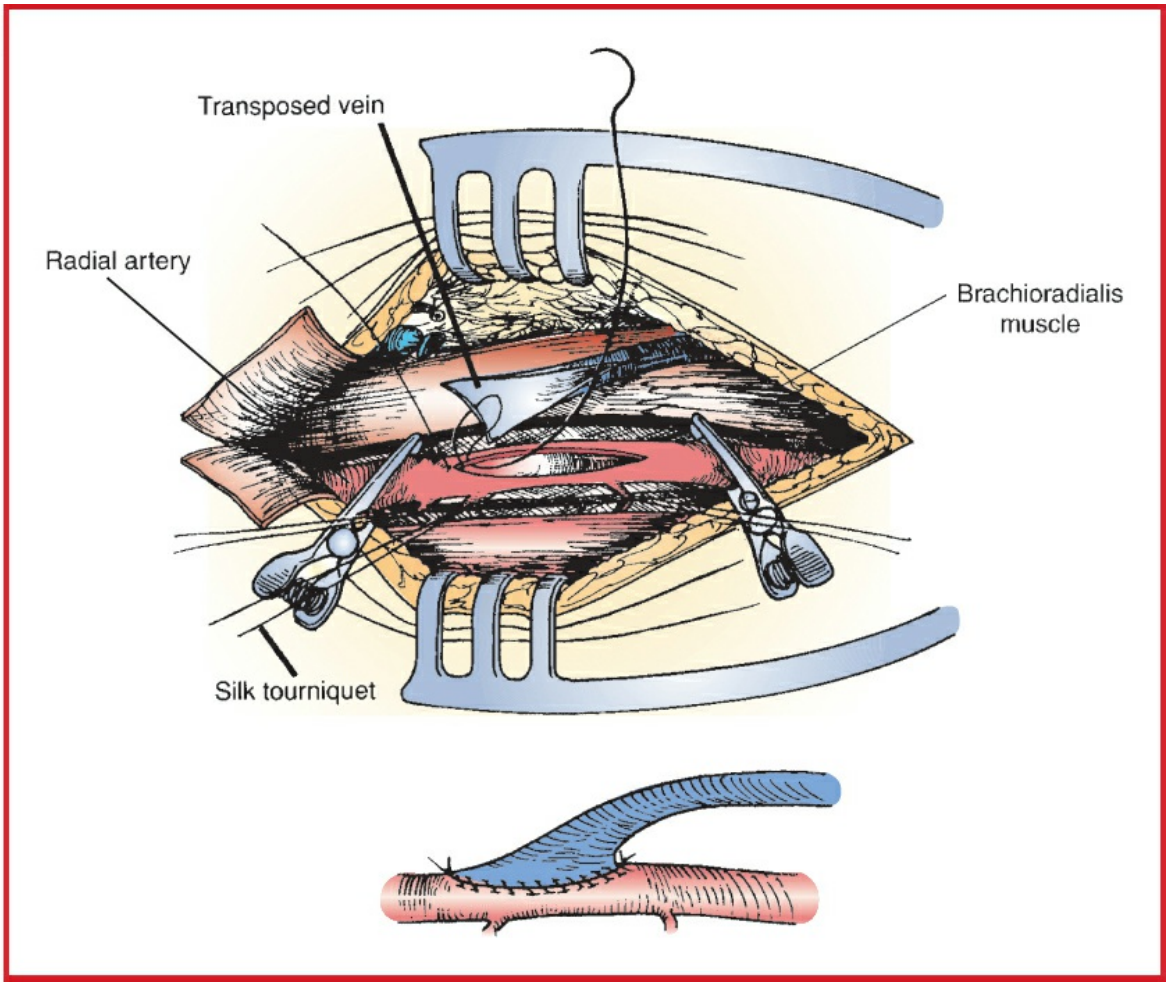

Figure 6.3-14 Brescia-Cimino fistula (side-to-end anastomosis). (Reproduced with permission from Scott-Conner CEH, Dawson DLOperative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

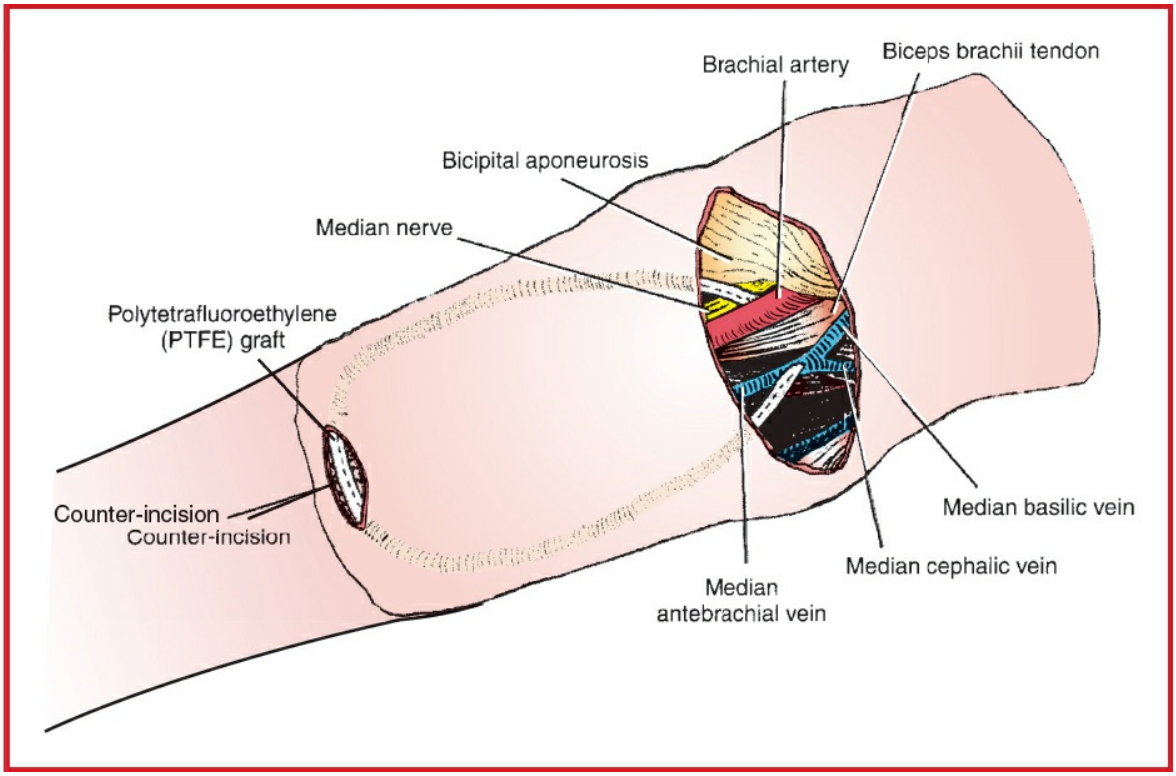

Figure 6.3-15 In arteriovenous hemodialysis access with prosthetic graft, the brachial artery and the median antebrachial, median basilic, and median cephalic veins are exposed via a horizontal incision below the antecubital joint crease. (Reproduced with permission from Scott-Conner CEH, Dawson DL: Operative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Forearm AV Fistula	Forearm Loop or Straight Graft	Upper Arm Straight Graft
Position	Supine, arm abducted	⇐	⇐
Incision	Longitudinal or transverse at wrist, or "snuff box"	Transverse at antecubital fossa and/or at wrist; counterincision in the forearm	Transverse or longitudinal in the upper arm
Special	Arm/hand table	⇐	⇐

instrumentation	(for arm abduction); Doppler flow probe may be used		
Unique considerations	Local anesthesia; consider brachial plexus block (increased incidence of hematoma); heparinization	⇐	⇐
Antibiotics	Cefazolin 2 g iv (3 g if >120 kg)	⇐	⇐
Surgical time	1–2 h	⇐	⇐
Closing considerations	Use of Doppler to 3 shunt patency	⇐	⇐
EBL	25–50 mL	25–100 mL	⇐
Postop care	Hemodynamic monitoring for poor-risk patients; can be done as outpatient	⇐	⇐
Mortality	Minimal, depending on associated risk factors	⇐	⇐
Morbidity	Thrombosis: 20% Technical failure: 10–15% Arterial steal: Rare Cardiac failure: Rare Infection: Rare	8–32% ⇐ ⇐ ⇐ 10% 6% ⇐ ⇐	~8–32% ⇐ ⇐ ⇐ ⇐ ~6% ⇐ ⇐

	No venous outflow: Rare Seroma: Rare Venous aneurysm: Rare Venous HTN: Rare	⇐	⇐
Pain score	1	2	2

PATIENT POPULATION CHARACTERISTICS

Age range	Pediatric and adult population
Male:Female	1:1
Incidence	Hemodialysis access is one of the most commonly performed procedures by vascular surgeons.
Etiology	Glomerulonephritis; diabetes; HTN; pyelonephritis
Associated conditions	Diabetes mellitus; PVD/CAD

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Permanent Vascular Access.

Suggested Readings

1. Bylsma LC, Gage SM, Reichert H, et al: Arteriovenous fistulae for haemodialysis: a systematic review and meta-analysis of efficacy and safety outcomes. Eur J Vasc Endovasc Surg 2017; 54(4):513–22.
2. Rose DA, Sonaike E, Hughes K: Hemodialysis access.Surg Clin N Am 2013; 93:997–1012.
3. Smith GE, Gohil R, Chetter IC: Factors affecting the patency of arteriovenous fistula for dialysis access. J Vasc Surg 2012; 55:849–55.
4. Spergel LM, Ravani P, Asif A, et al: Autogenous arteriovenous fistula options.J Nephrol 2007; 20(3):288–98.

PERMANENT VASCULAR ACCESS

SURGICAL CONSIDERATIONS

Description

Silastic or plastic catheters are placed in patients who require venous access for chronic antibiotic therapy, TPN, chemotherapy, or hemodialysis. **Hickman, Broviac,** and **Groshong catheters** are made of silicone rubber or plastic with a cuff near the skin exit site, which (in theory) serves as a barrier to infection. Access is generally achieved via subclavian, IJ, or femoral vein puncture. These catheters are available in various sizes and in single- or double-lumen configurations. Larger diameter (13 Fr) Hickman or **PermCath DL** catheters have been introduced for hemodialysis. **Mediport** and **Portacath devices** have a metallic or plastic reservoir connected to the catheters and are intended for complete subcutaneous implantation. These catheters are used in chronically ill patients, particularly those requiring chemotherapy. The implantable access ports have been associated with improved patient comfort and reduced infection rates. Long-term catheter survival is limited by infection. Removal and replacement of the catheter is the only way to eradicate the infection.

Variant procedure or approaches

Two major distinctions: Hickman/Broviac catheters (no reservoir) versus Mediport/Portacath catheters (subcutaneous with reservoir). Subclavian, IJ, or femoral vein puncture is selected, depending on vein status, previous operations, and patient comfort.

Usual preop diagnosis

Chronic antibiotic therapy; TPN; chemotherapy; end-stage renal failure

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Hickman/Broviac/Groshong	Mediport/Portacath
Position	Supine, slight Trendelenburg	⇐
Incision	Puncture site (subclavian, IJ, or femoral vein); subcutaneous tunnel for passage of catheter.	Puncture site (subclavian, IJ, or femoral vein); subcutaneous pocket for

	Alternative: cephalic or IJ vein cutdown to achieve access	port. Alternative: cephalic or IJ vein cutdown to achieve access
Special instrumentation	I.I. or fluoroscope	⇐
Unique considerations	Local anesthesia; may need iv sedation; monitor for ectopy during placement	⇐
Antibiotics	Cefazolin 2 g iv	⇐
Surgical time	30–90 min	45–90 min
EBL	10–25 mL	25–50 mL
Postop care	CXR in recovery room; may be outpatient	⇐
Mortality	Minimal	⇐
Morbidity	Catheter thrombosis: 25% Skin exit site infection: 13% Poor flow: 10–13% Catheter sepsis: 5–8% Arterial puncture: 6% Local bleeding: 5% SVC thrombosis: 5% Catheter displacement: 3% Subclavian thrombosis: 2% Pneumothorax: 1–2% Failed attempt: 1% Infection: 3–5/1000 cath days	4% — ~10–13% 2% ~6% — ~5% ~3% ~2% ~1–2% ~1% — Pocket hematoma: 2% Pocket infection: 3% Catheter leakage: 1%
Pain score	1	2

PATIENT POPULATION CHARACTERISTICS

Age range	Pediatrics and adults, 8–80 yr

Male:Female	1:1
Incidence	Depending on underlying disease
Etiology	Access for chemotherapy; infections; hemodialysis; chronic TPN
Associated conditions	Malignancy; chronic illness/infection; renal failure

ANESTHETIC CONSIDERATIONS FOR VASCULAR ACCESS

(Procedures covered: arteriovenous access for hemodialysis; permanent vascular access)

PREOPERATIVE

The patient populations presenting for vascular access surgery are extremely diverse. Patients requiring vascular access for chemotherapy, TPN, and chronic antibiotic therapy frequently can be done with MAC. Also presenting for these procedures are end-stage renal failure patients who need AV access for hemodialysis (generally involving the upper extremity). These patients return to the OR frequently for revising or replacing of fistulas. They are often ASA III and IV patients who may require GA or an upper extremity block. Anesthetic considerations for the **chronic renal failure patient** are discussed below.

Respiratory	Pulmonary edema may be present from fluid overload. CHF and uremic pleuritis can occur. Pneumonia occurs more frequently in these patients due to depressed immune systems. Hemodialysis contributes to hypoxemia due to V/Q mismatch and hypoventilation. **Tests:** CXR; consider ABG
Cardiovascular	Often have HTN related to hypervolemia and a disorder of the renin-angiotensin system. May have LVH 2° to HTN. Cardiomyopathy, pericarditis, and pericardial effusion occur with uremia. Hypervolemia and hypoalbuminemia can contribute to CHF. Uremic patients often have defective aortic and carotid body reflex arcs. Ejection murmurs are common.

	Tests: ECG; echo; others as indicated from H&P
Renal	Full details of recent dialysis therapy; patient optimal and current weight. Dialysis is usually advisable before anesthesia and surgery (<24 h if possible) as complications of uremia (Plt dysfunction, electrolyte/fluid abnormalities, CNS, and GI disturbances) improve with dialysis. If a transfusion is needed, consider giving during dialysis so intravascular volume can be controlled. **Tests:** Serum BUN; Cr. If patient produces urine, consider creatinine clearance and UA.
Hematologic	Chronic anemia with Hct ranging from 15 to 21 g/dL. Normochromic, normocytic anemia presents 2° to bone marrow depression, lack of erythropoietin, nutritional deficiency, and diminished red cell survival time. Patients adjust to chronic anemia through ↑ CO and ↑ 2,3-DPG levels. Accumulation of waste products inhibits Plt function. Defects do occur in the coagulation cascade, but PT and PTT are usually normal. **Tests:** CBC; Plt; PT; PTT
Gastrointestinal	Uremic patients commonly have hiccups, anorexia, N/V, and diarrhea. They are very prone to developing GI bleeds. Renal failure causes ↓ gastric emptying. Premedication with metoclopramide (10 mg iv) and famotidine (20 mg iv) will ↓ gastric volume and pH.
Nervous system	CNS Sx of uremia range from malaise to Sz to coma. Fatigue and intellectual impairment commonly occur. Peripheral and autonomic neuropathies exist. Peripheral neuropathy presents as itching and paresthesia of the lower extremities. Autonomic dysfunction can cause postural ↓ BP. Document deficits carefully.
Endocrine	Diabetes frequently may be the cause of renal failure, with its attendant problems. **Tests:** Glucose
Immune system	Often impaired. Patients prone to sepsis. Hepatitis

	and HIV infections from blood products may exist.
Metabolic and biochemical	Accumulation of K^+ urea, parathyroid hormone (hypercalcemia), Mg, aluminum (neurotoxicity), acid metabolites, and phosphate occurs. Knowing hyperkalemia exists is of importance because of the potential for fatal cardiac dysrhythmias. Shift of the oxyhemoglobin curve to the right occurs due to the metabolic acidosis and ↑ 2,3-DPG (improves tissue oxygenation). Hyponatremia is a common electrolyte disturbance in chronic renal failure.
Premedication	If warranted, it is best to use low-dose premedication with benzodiazepines or opioids due to the possibility of exaggerated effects.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status.

INTRAOPERATIVE

Anesthetic technique

GA, upper extremity block, or MAC

Regional anesthesia

May be advantageous due to decreased number of drug effects. See section on upper extremity blocks (Anesthetic Considerations for Wrist Procedures). If the patient was very recently dialyzed, there may be a residual heparin effect. Regional anesthesia is contraindicated if coagulopathy is present.

General anesthesia

The duration of action and elimination of many anesthetic drugs is altered in the patient with renal failure.

Induction	If general anesthesia is indicated, induction with propofol and low-dose fentanyl (25–50 mcg) is usually well tolerated. Succinylcholine is appropriate if $K^+ < 5.5$ mEq/L. If succinylcholine is contraindicated, cisatracurium (0.1–0.2 mg/kg) is the alternative muscle relaxant of choice because its elimination is not affected by renal failure; if

	sugammadex is available, then rocuronium may also be considered. Etomidate (0.2–0.3 mg/kg) may be used in case of preop hemodynamic instability.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Inhalation anesthetics (isoflurane, sevoflurane) offer the advantage of not requiring renal elimination. Biotransformation may produce some inorganic fluoride (nephrotoxin); however, this is not an issue in dialysis patients. Opioids can produce an increased magnitude and duration of effect. Increased accumulation of morphine glucuronides → prolonged respiratory depression. Fentanyl and remifentanil are good choices, 2° rapid tissue redistribution (fentanyl) or rapid metabolism (remifentanil). Benzodiazepine dosage should be adjusted because protein binding in renal insufficiency/failure is reduced.	
Emergence	Prolonged effect of anticholinesterases (e.g., neostigmine and edrophonium) effectively offsets prolongation of blockade. Other factors affecting reversal of nondepolarizers should be taken into account. These include acid-base status, depth of blockade, temperature, and use of drugs such as diuretics or antibiotics, which can potentiate blockade.	
Blood and fluid requirements	IV: 18–20 ga × 1 BSS @ 1–2 mL/kg/h	IV access may be difficult; avoid iv placement in the operated arm. Minimize fluids in renal failure patients. See Zero Balance Fluid Management, Appendix K, p. K-2.
Monitoring	Standard monitors	Avoid BP cuff placement on the operated arm.

Positioning	✓ and pad pressure points ✓ eyes
Complications	Local anesthetic toxicity

POSTOPERATIVE

Complications	Nerve damage Hematoma	These are rare complications of brachial plexus blocks.
Multimodal pain management	PO analgesics	
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	

Suggested Readings

1. Bour ES, Weaver AS, Yang HC, et al: Experience with the double lumen Silastic catheter for hemoaccess. Surg Gynecol Obstet 1990; 171(1):33–9.
2. Monk J: Hemodialysis catheters and ports. Semin Nephrol 2002; 22:211–20.
3. Vasquez MA: Vascular access for dialysis: recent lessons and new insights. Curr Opin Nephrol Hypertens 2009; 18:116–21.

VENOUS SURGERY—VEIN STRIPPING AND PERFORATOR LIGATION

SURGICAL CONSIDERATIONS

Description

Chronic venous insufficiency results from static blood flow in the deep, superficial, and perforating veins of the lower extremities. Clinical manifestations include pathologic changes in the skin and subcutaneous tissues, such as pigmentation, dermatitis, induration, and ulceration around the lower portion of the leg. The condition is most commonly caused by defective venous valves and less often by obstruction to the venous return or impaired pumping action of the muscles in the leg. The disorder is sometimes the residual of previous iliofemoral thrombophlebitis. Varicose veins of the primary type, particularly those of long duration, are a common cause of chronic venous insufficiency of milder degrees. Most symptoms respond well to conservative

management, which includes compression stockings, elevation of the extremity, and topical treatment of ulcerations. Failure of medical management is an indication for surgical intervention. Split-thickness skin grafting is indicated for large ulcers to accelerate healing and shorten hospitalization time. **Ligation of perforators** is best performed when the ulcer has completely healed. The classic approach of **Linton** is rarely used today. If the quality of the skin overlying the perforators prevents a direct approach, **subfascial ligation** of the perforators may be performed through a short, posterior midline incision. The incompetent greater or lesser saphenous veins are resected only if patency of the deep system is confirmed. Venous ulcers recur in 30% of patients after surgical therapy, and ulcerations persist for prolonged period in 15% of patients. Adjunctive procedures include **valvuloplasty, vein transposition,** and **venous valve transplant.**

Alternative procedures

Minimally invasive radiofrequency techniques have been used successfully for ablation of varicose veins.

Usual preop diagnosis

Chronic deep venous insufficiency

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	**Vein stripping:** longitudinal or oblique groin incision and transverse incision at medial malleolus; transverse incision over posterior lower leg for lesser saphenous vein stripping. **Perforator ligation:** longitudinal incision along medial aspect of tibia to posterior medial malleolus
Special instrumentation	Vein stripper
Antibiotics	If patient has an associated venous ulcer, preop antibiotics should be based on culture results; generally, cefazolin 2 g iv (3 g if >120 kg), if culture

	results are not available.
Surgical time	3 h
EBL	50–250 mL
Postop care	PACU → ward; antiembolism stockings and SCDs
Mortality	Minimal
Morbidity	Persistence of nonhealing ulcer: 20–53%
Pain score	3

PATIENT POPULATION CHARACTERISTICS

Age range	Young adult–elderly (generally older adults, although present in younger patients as well)
Male:Female	1:2
Incidence	6–7 million people in the United States have adverse effects from chronic venous stasis; 500,000 have complications of leg ulceration.
Etiology	Chronic primary varicose veins; defective venous valves; impaired pumping action of muscles in the leg; previous iliofemoral thrombophlebitis; obstruction of venous return
Associated conditions	Varicose veins; Hx of DVT/thrombophlebitis

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Varicose Vein Stripping.

Suggested Readings

1. Geersen DF, Shortell CEK: Phlebectomy techniques for varicose veins.Surg Clin North Am 2018; 98(2):401–14.
2. Roth SM: Endovenous radiofrequency ablation of superficial and perforator veins Surg Clin North Am 2007; 87(5):1267–84.
3. See Suggested Readings for Venous Surgery—Thrombectomy or Vein Excision,p. 493.

VARICOSE VEIN STRIPPING AND ABLATION

SURGICAL CONSIDERATIONS

Description

In patients with primary varicose veins, no definite cause has been identified, although age, female sex, pregnancy, obesity, and positive family Hx are predisposing factors. The causes of secondary varicosity include incompetence or obstruction of the deep veins as a result of previous DVT, tumor, trauma, or congenital or acquired AV fistulas. Usual indications for operative therapy include aching, swelling, heaviness, cramps, itching, cosmesis, stasis dermatitis, pigmentation, burning, and ulcers. Surgical treatment is contraindicated in pregnant patients, elderly patients who are considered high risk, and patients with arterial insufficiency of the lower extremities, lymphedema, skin infection, or coagulopathy. Endovenous thermal (laser/RF) ablation techniques have largely replaced the surgical treatment of varicose veins in the lower leg. These endovenous procedures are usually performed under local anesthesia.

There are two principal approaches: the **stab avulsion technique** and **high ligation and stripping**. With **stab avulsion,** the varicosities are marked preop. Small transverse or longitudinal incisions are made directly over these varicosities, which are dissected from the surrounding subcutaneous tissue (with undermining of the skin) and bluntly removed or avulsed. Firm pressure over the region being operated on will achieve hemostasis. After removal of all marked varicosities, sterile dressings are placed and a compression bandage wrapped around the affected leg. The patient is instructed to keep the leg elevated as much as possible while convalescing at home. The chief advantage of the stab avulsion technique is preservation of the saphenous vein when it is not directly involved with varicosities.

If there is valvular incompetence of the saphenous vein, the treatment of choice is **stripping** (**avulsion**) of the incompetent portion of the greater and lesser saphenous veins, together with avulsion of the superficial varicose veins of the thigh and calf. **High ligation and stripping** refers to the removal of the greater saphenous vein from the level of medial malleolus to the saphenofemoral junction. A small transverse incision is made at the level of the ankle and the saphenous vein is dissected free. A longitudinal or oblique incision at the groin permits isolation of the saphenous vein at the saphenofemoral junction. The greater saphenous vein is ligated proximally and distally. After a **venotomy,** a plastic or metallic vein stripper is passed and the vein is removed or stripped in a distal-to-proximal fashion. Sterile dressings are applied, followed by a compressive dressing.

Although high ligation and stripping is the gold standard in the treatment of varicose veins, it has largely been replaced by thermal ablation in the United States. The use of either RF or laser ablation, which results in closure and often reabsorption of the vein, is highly successful and causes less postop discomfort. However, surgical ligation and stripping still has a role in the management of varicose veins. If all varicose veins are removed and the incompetent segment of the saphenous vein is stripped, 85% of the patients will have good-to-excellent results at late follow-up. These procedures can be performed with regional or general anesthesia.

Usual preop diagnosis

Varicose veins; symptoms of venous insufficiency; cosmetic considerations

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Stab Avulsion Technique	High Ligation and Stripping
Position	Supine	⇐
Incision	Varicosities marked preop; short stab incisions made and veins avulsed with small forceps	Varicosities marked preop; small transverse incision over saphenous vein proximal to medial malleolus; proximal saphenous vein exposed via groin incisions and stripper passed
Special instrumentation	None	Vein stripper
Unique considerations	May be facilitated by tourniquet	⇐
Antibiotics	None	⇐
Surgical time	2–3 h	⇐
Closing	Leg compressed with	⇐

considerations	elastic wrap	
EBL	50–250 mL	50–150 mL
Postop care	PACU → ward; support stockings	⇐ + elevate foot of bed 10°; short periods of ambulation
Mortality	Minimal	⇐
Morbidity	Recurrence: <10% Hematoma: Rare Infection: Rare Lymph fistula: Rare Nerve injury: Rare Postop DVT: Rare Femoral artery injury: Nil	⇐ ⇐ ⇐ ⇐ ⇐ 5% Very rare
Pain score	2	2

PATIENT POPULATION CHARACTERISTICS

Age range	Wide range, young adult–elderly (average = 48 yr)
Male:Female	1:3
Incidence	24,000 in the United States
Etiology	Primary varicose veins: no definite cause (Predisposing factors include age, female sex, pregnancy, obesity, and positive family Hx.) Secondary varicose veins: incompetence or obstruction of the deep veins from DVT, tumor, trauma, or high venous pressures due to congenital or acquired arteriovenous fistulas
Associated conditions	Older age; pregnancy; obesity; DVT; tumor; trauma

ANESTHETIC CONSIDERATIONS

(Procedures covered: vein stripping and perforator ligation; varicose vein stripping)

PREOPERATIVE

Patients presenting for varicose vein surgery are a generally healthy patient population (ASA I & II). Preop considerations and tests, therefore, should be guided by the H&P.

Hematologic	If regional anesthesia planned, check patient's coagulation status. **Tests:** Plt count; Hct
Laboratory	Tests as indicated from H&P
Premedication	If necessary, standard premedication.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status.

INTRAOPERATIVE

Anesthetic technique

General, regional, and local (tumescent) anesthesia, ± sedation, are all appropriate anesthetic techniques. Choice depends on factors such as extent of surgery, patient physical status, and patient and surgeon preference.

Regional anesthesia

Spinal	**Single shot vs. continuous:** Patient in sitting or lateral decubitus position (operative site down) for placement of hyperbaric subarachnoid block. Doses of local anesthetic for T10-T12 level: 0.75% bupivacaine in 8% dextrose (7–10 mg) or 0.5% tetracaine in 5% dextrose (10–12 mg). For continuous spinal (multiorifice catheter), titrate local anesthetic to desired surgical level (T12). Large doses of hyperbaric local anesthetic should be avoided as they may cause postop cauda equina syndrome.
Epidural	Patient in sitting or lateral decubitus position for placement of epidural catheter. After locating the epidural space, administer a test dose (e.g., 3 mL of 1.5% lidocaine with 1:200,000 epinephrine) to elucidate whether the catheter is subarachnoid

	(rapid onset outer block) or intravascular (↑ HR, tinnitus, etc.). Titrate local anesthetic until desired surgical level is obtained (3–5 mL at a time) usually <15 mL.
Local/tumescent	Requires gentle surgical technique. Surgical field block, plus ilioinguinal and iliohypogastric nerve blocks using 0.5% bupivacaine with 1:200,000 epinephrine. Usually done by the surgeon, tumescent anesthesia consists of injecting a dilute buffered solution of lidocaine (0.05%) with epinephrine around the vein with ultrasound guidance. Total lidocaine dose may be up to 10 mg/kg.

General anesthesia

Induction	LMA/mask vs. ETT: Standard induction. LMA or mask GA may be suitable for many patients.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance	
Emergence	No special considerations. PONV prophylaxis should include ondansetron.	
Blood and fluid requirements	Minimal blood loss IV: 18 ga × 1 BSS @ 2–3 mL/kg/h	See Zero Balance Fluid Management, Appendix K, p. K-2 and p. K-4.
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes	

POSTOPERATIVE

Complications	Cauda equina syndrome	The diagnosis of cauda equina syndrome (urinary and fecal incontinence, paresis of lower

		extremities, perineal hypoesthesias) should be sought in the postop period in patients who have received large doses of intrathecal local anesthetic during continuous spinal techniques. ✓ patients for bowel or bladder dysfunction and perineal sensory deficits. If present, consider a neurology consultation and continue follow-up of the patient's neurologic dysfunction.
	Urinary retention common with regional anesthesia	Patients with urinary retention may require intermittent catheterization until urinary function resumes.
Multimodal pain management	PO analgesics: Acetaminophen and codeine Tylenol # 3 1–2 tab q4–6h Oxycodone and acetaminophen Percocet 1 tab q6h	Regional anesthesia should provide sufficient analgesia postop. Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	Encourage early enteral nutrition and mobilization.

Suggested Readings

1. Biemans AA, Kockaert M, Akkersdijk GP, et al: Comparing endovenous laser ablation, foam sclerotherapy, and conventional surgery for great saphenous varicose veins. J Vasc Surg 2013; 58(3):727–34.
2. Brown KR, Rossi PJ: Superficial venous disease. Surg Clin N Am 2013; 93:963–82.
3. Gibson K, Gunderson K. Liquid and foam sclerotherapy for spider and varicose veins. Surg Clin North Am 2018; 98(2):415–29.
4. Holt NF: Tumescent anaesthesia: its applications and well tolerated use in the out-of-operating room setting. Curr Opin Anaesthesiol 2017; 30(4):518–24.
5. Kheirelseid EAH, Crowe G, Sehgal R, et al. Systematic review and meta-analysis of randomized controlled trials evaluating long-term outcomes of endovenous management of lower extremity varicose veins. J Vasc Surg Venous Lymphat Disord 2018; 6(2):256–70.
6. Mowatt-Larssen E, Shortell CK: Treatment of primary varicose veins has changed with the introduction of new techniques. Semin Vasc Surg 2012; 25:18–24.
7. Rasmussen L, Lawaetz M, Bjoern L, et al: Randomized clinical trial comparing endovenous laser ablation and stripping of the great saphenous vein with clinical and duplex outcome after 5 years. J Vasc Surg 2013; 58:421–6.

CHAPTER 6.4

Heart/Lung Transplantation

SURGEON
Hari R. Mallidi, MD

ANESTHESIOLOGISTS
Albert Tsai, MD
Daryl Oakes, MD
Linda E. Foppiano, MD

SURGERY FOR HEART TRANSPLANTATION

SURGICAL CONSIDERATIONS

Description

Although heart transplantation has been practiced since 1967, it has had its greatest expansion since the early 1980s with the introduction of cyclosporine. Currently, there are ~150 transplant centers and 2200 heart transplant procedures performed yearly in the United States. Indications for heart transplantation range from hypoplastic left heart syndrome (HLHS) in the neonate to cardiomyopathy and ischemic heart disease in the adult. Recipients usually have end-stage heart disease manifested by congestive heart failure (CHF) and a prognosis of <1-yr survival. Many patients are on inotropic drugs or on some type of additional mechanical assist, such as the use of an intra-aortic balloon pump (IABP) or an implanted LV assist device. Current immunosuppressive protocols consist of a combination of a calcineurin inhibitor with prednisone and mycophenolate mofetil. Immunosuppression begins either immediately preop or perioperatively and will continue throughout the life of the patient. Induction immunosuppression is commenced in the operating room after protamine administration with methylprednisolone 500 mg iv and basiliximab or rATG in the ICU after transplantation. Current 1-yr survival averages 85% in most centers with 3-yr survival

of ~80% and a median survival approaching 10 yr.

In adult heart transplantation, following median sternotomy, the pericardium is opened with care being taken to preserve the phrenic nerve. The aorta and vena cava are cannulated, the aorta is cross-clamped, and caval tapes (tourniquets to prevent venous air embolism [VAE]) are applied. The aorta and PA are then transected. This is followed by an incision through the atria, and the recipient heart is removed. The donor heart is prepared by opening the left atrium through the pulmonary veins, separating the aorta and PA. The donor heart is attached by a long, continuous suture line around the left atrium (Fig. 6.4-1), followed by separate anastomoses to the inferior and superior venae cavae. Alternatively, the donor right atrium is anastomosed to the recipient right atrium with a single long continuous suture. Next, the PA and aorta are anastomosed to their respective recipient vessels. Multiple deairing maneuvers are followed by aortic unclamping and rewarming and resuscitation of the heart. Normal sinus rhythm (NSR) is established and CPB d/c'd. Heparin is reversed, hemostasis is secured, and the chest is closed in a routine manner. Following chest closure, these patients will often have implanted defibrillators that will be removed. An incision is made to access the pacemaker pocket, and the device is explanted. After hemostasis is established, the pocket is closed (see p. 384 for discussion of cardiopulmonary bypass [CPB]).

Neonatal heart transplantation differs in that the PA is cannulated if the ductus arteriosus is patent. Reconstruction of the aortic arch in the patient with HLHS requires CPB with deep hypothermia (<18°C) and circulatory arrest. The heart is then excised, and the transverse aortic arch is opened beyond the ductus arteriosus to minimize risk of late coarctation. The donor heart is prepared, with special attention given to trimming the transverse aortic tissue for subsequent reconstruction. The left and right atrium, PA, and aorta are sutured in place. The new ascending aorta and right atrium are cannulated, and CPB with rewarming is reinstituted. Chest closure is routine (see Pediatric Transplantation).

Pediatric heart transplantation has become commonplace in the past 10 yr. Patients often have had previous cardiac surgery, and reentry and excision of the native heart are complicated by the presence of adhesions and graft material from previous attempts at palliative/corrective surgery. Patients are often highly sensitized and may require intraoperative plasmapheresis while on CPB. Preparation for CPB is often similar to the adult heart transplant patient, and the implantation procedure is also similar. However, provisions should be made for

prolonged cross-clamp times necessary for implantation in the setting of abnormal systemic-cardiac or pulmonary-cardiac connections (see Pediatric Transplantation).

Usual preop diagnosis

Cardiomyopathy; coronary artery disease (CAD) with ischemic cardiomyopathy congestive heart disease (CHD) (e.g., HLHS or anomalous left coronary artery); end stage valvular heart disease

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, possible need for a chest tube and postop mechanical ventilation, and physiotherapy plan. See Appendix K: Enhanced Recovery After Surgery, p. K-1.

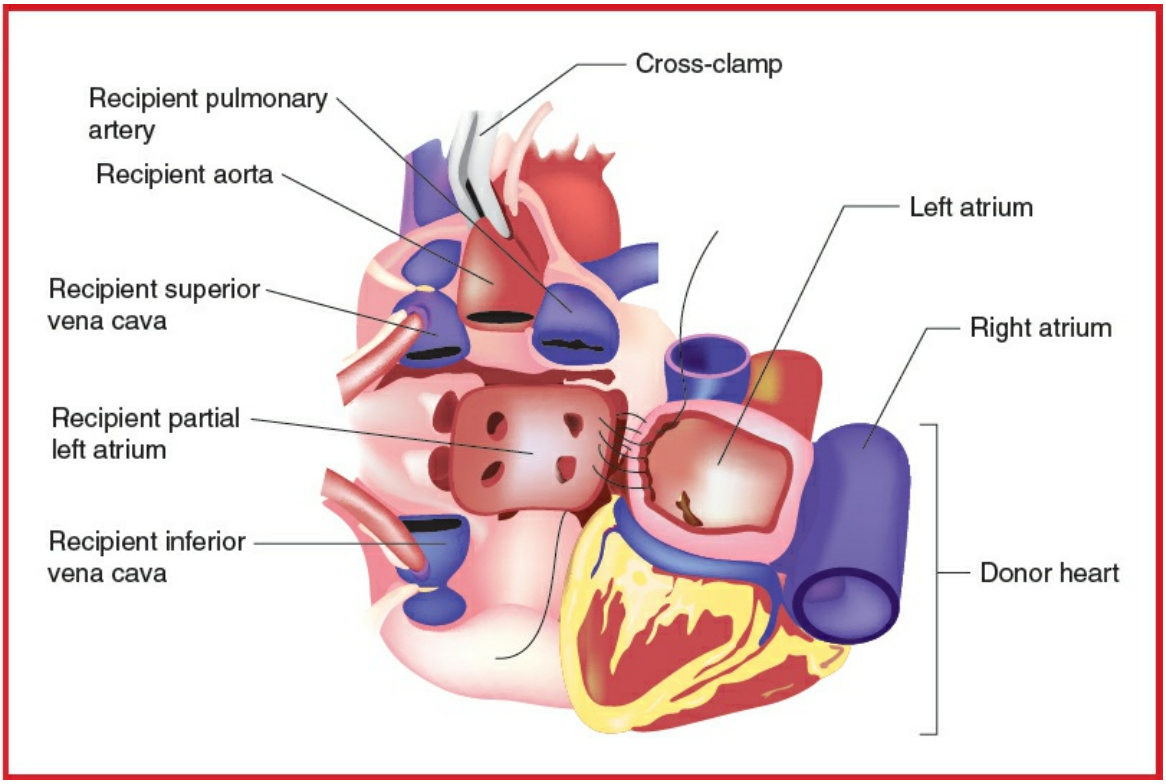

Figure 6.4-1 The donor left atrium is sutured to the recipient left atrial remnant and the graft vessels are anastomosed.

SUMMARY OF PROCEDURES

	Adult Heart Transplantation	Neonatal/Pediatric Heart Transplantation

Position	Supine	⇐
Incision	Median sternotomy	⇐
Special instrumentation	Ascending aortic, SVC, and IVC cannulae	Ascending aortic and right atrial cannulae
Unique considerations	Due to complete excision of the heart, the use of a PA catheter is usually not feasible	Deep hypothermia with circulatory arrest
Antibiotics	Cefazolin 2 g iv	Cefazolin 25–50 mg/kg iv
Surgical time	Cross-clamp: 45–60 min Surgery: 3–4 h	Circulatory arrest: 45–60 min Cross-clamp: 80–100 min Surgery: 4–6 h
Closing considerations	Temporary AV pacing wires are occasionally placed. A PA catheter may be advanced, especially with concerns about residual pulmonary HTN and donor right heart function. An isoproterenol infusion is started intraop to keep HR = 100–110 and help improve right heart function and ↓ PVR. Inhaled NO may be used to further ↓ PVR	Temporary ventricular pacing wire is usually placed. Temporary transthoracic left atrial line may be placed. Extensive aortic suture line requires avoidance of postop hypertensive episodes.
EBL	500–1500 mL	50–100 mL
Postop care	Cardiac ICU × 1–2 d of assisted ventilation, 2- to 3-d stay	Pediatric ICU × 1–2 d of assisted ventilation; 4- to 5-d stay, with attention to pulmonary care
Mortality	<5%	⇐
Morbidity	Early acute rejection	⇐

	episodes from 10–21 d: 50% Infection, particularly pulmonary: 10% Pulmonary HTN with right heart dysfunction: <10% Dysrhythmias with nodal rhythms: 5% Bleeding: 2–4% Hyperacute rejection: rare (<1%) Intracoronary air emboli	Infection: 10% Respiratory problems: 20% Pulmonary vasospasm with right heart dysfunction: <10% Bleeding: 2–4%
Pain score	8–10	8–10

PATIENT POPULATION CHARACTERISTICS		
Age range	18–75+ yr (average 50–55 yr)	1 d to 2 mo (neonatal), 2 mo to 18 yr (pediatric)
Male:Female	7:3	1:1
Incidence	2200/yr (United States)	Rare
Etiology	Cardiomyopathy (50%), CAD with multiple previous infarcts (48%), others (2%)	No apparent correlation with any specific genetic disorder. Cardiomyopathy (49%), CHD (42%), others (7%)
Associated conditions	CHF	Other congenital anomalies

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients scheduled for heart transplantation are functionally compromised, typically with CHF, which is associated with a mortality of >50% in 2 yr. (Studies have shown that patients with severe CHF have a mortality of 50% in 6 mo.) The progression o

cardiovascular disease is usually well documented in these patients. A Hx of recent exacerbation of cardiac dysfunction should be sought, and all data should be interpreted in light of interval changes. Patients may arrive in the operating room from home or in hospital with inotropic infusions (dobutamine, milrinone), VADs, or extracorporeal membrane oxygenation (ECMO) in place.

Respiratory	The presence of pulmonary HTN and ↑ PVR may be disclosed by catheterization. The severity of the abnormality and the responsiveness to specific vasodilators must be determined. **Test:** Right heart catheterization
Cardiovascular	Indicators to consider include hemodynamic status; LV EF (mortality is rapid in patients with EF <10% and is worse for patients with EF of 10–20%, as compared with those with EF >20%); myocardial structure and morphology, symptoms, and functional capacity; neuroendocrine status; serum sodium; and dysrhythmia. Unfortunately, while these measures show trends with mortality, they are not individually strong enough to predict a particular patient's course. Low maximum O_2 consumption (<10 mL/kg/min) is associated with poor survival. Normal O_2 consumption is 40 mL/kg/min. In practice, however, this measure is too severe because many patients awaiting heart transplantation have maximum O_2 consumption of 20 mL/kg/min. Dysrhythmia is a major cause of death; unfortunately electrophysiology studies of these patients may not be helpful because dysrhythmia tends to be noninducible. This phenomenon frustrates efforts to select and test antidysrhythmic drug therapy. The effectiveness of past antidysrhythmic therapy should be reviewed. **Tests:** ECG; cardiac catheterization; ECHO
Hematologic	Patients with dilated cardiomyopathy, previous cardiac surgery including VADs and ECMO, are frequently treated with anticoagulants to reduce the

	risk of thrombus formation. Hepatic dysfunction may result from RV failure and may reduce synthetic function. Mild hepatic dysfunction and chronic anticoagulation may contribute to postop bleeding. The anticoagulant effect of warfarin should be reversed with FFP or prothrombin complex concentrates (PCCs) such as Kcentra™ and vitamin K (iv or subcutaneous). **Tests:** Hct; PT; PTT; fibrinogen; Plts
Endocrine	Neuroendocrine abnormalities are often present in severe CHF cases. The cardiomyopathy produces low CO → compensatory sympathetic activation and renin-angiotensin activity. The result is excessive vasoconstriction with salt and H_2O retention, which further impair myocardial performance. Markedly worse survival is seen in CHF patients with serum sodium <130. This may indicate the importance of neuroendocrine pathophysiology or may simply be evidence of the severity of the CHF. It may also simply indicate that patients with more severe CHF are treated with more diuretics. When patients are treated with an angiotensin-converting enzyme inhibitor, such as enalapril, the serum sodium is normalized, and survival chances are improved because of the slowing of the progression of CHF, not from alteration in the incidence of sudden death. **Tests:** Electrolytes; Cr
Laboratory	Evidence of renal and hepatic dysfunction should be sought by H&P and lab studies. Mild hypokalemia is generally not treated in view of the K^+ in the graft (see CPB).
Premedication	Although anxious, these patients are usually well informed and psychologically prepared to undergo heart transplantation. They respond well to the reassurance of the preop visit, and pharmacologic premedication usually is not necessary. O_2 therapy should commence prior to transport of the patient to the OR. Reassuring the family of a patient who

	suffers from rapidly progressive cardiac dysfunction also is valuable. The patient may be at increased risk for pulmonary aspiration of gastric contents because of the unscheduled nature of the surgery and use of oral cyclosporine immediately preop. Famotidine (20 mg) and metoclopramide (10 mg) may be administered iv, most efficiently accomplished in the OR.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of thoracic epidural, continuous paravertebral, or chest wall nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: After the patient is placed on the operating table, O_2 and noninvasive monitors are applied. Dyspnea (a complication of the supine position) can be treated by raising the back of the table. As infection is a serious complication in the immunosuppressed transplant patient, aseptic technique is extremely important. Aseptic technique is used in inserting and securing all vascular catheters. The anesthesia machine should be equipped with a supply of air to control the FiO_2.

Induction	An arterial line for BP and blood gas monitoring should be inserted, using liberal amounts of local anesthetics before induction. There are rare exceptions to this rule, but the presence of real-time BP monitoring is critical during induction. If infusion drugs (e.g., epinephrine) are necessary before insertion of the CVP catheter, they can be infused temporarily through a separate peripheral iv. In patients who have a ↓ EF, it is often helpful to infuse epinephrine 0.05–0.10 mcg/kg/min during induction to avoid ↓ HR and ↓ CO. Anesthesia is not induced

	until the team harvesting the graft reports that the donor heart appears to be normal. The patient is preoxygenated (FiO_2 = 1.0), and cricoid pressure is applied just before induction. Induction agents include fentanyl (2–4 mcg/kg) or sufentanil (0.5–2 mcg/kg). Propofol (0.5–1 mg/kg, titrated) or etomidate (0.1–0.2 mg/kg) is useful in permitting rapid control of the airway. Midazolam also may be used. Rocuronium 1–1.5 mg/kg should be administered immediately to permit airway control. Care must be taken to avoid bradycardia, which often results in low CO in these patients. Immediate control of the airway is crucial, as hypercarbia and hypoxia must be avoided. The patient can be expected to have a low CO, resulting in a delayed induction of anesthesia, which must be anticipated to avoid anesthetic overdosage. Hypotension should be treated promptly with inotropes (bolus and/or infusion). Fluid boluses may be poorly tolerated in patients with diminished contractility and should be administered cautiously. The usual aids for managing the unexpectedly difficult airway should be readily available. Antibiotics are administered, and additional monitors (urinary catheter with thermistor, TEE) are set up. Nasopharyngeal temperature probes are avoided because full heparinization is needed for CPB. If there is a delay in the anticipated arrival of the graft, the recipient should be covered and kept warm, and skin prep should be delayed. Additional narcotics should be administered only in immediate anticipation of the commencement of surgery.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider placement of parasternal or chest wall nerve blocks if preop blocks have not been placed. Ketamine (0.5 mg/kg iv) at induction may improve pain management and reduce delirium after

	CPB.
Maintenance	Typical cumulative anesthetic doses for the entire intraop course are fentanyl 10–20 mcg/kg or sufentanil 1.5–5 mcg/kg, midazolam 0.15 mg/kg, and rocuronium 3–4 mg/kg. Recommend the use of antifibrinolytics for all cases requiring CPB.
Termination of CPB	Junctional rhythm is common in the denervated transplanted heart. Isoproterenol 20–50 ng/kg/min or epinephrine 50–100 ng/kg/min may be used to achieve a HR of 100–120 bpm. Isoproterenol is also useful in providing inotropic support and pulmonary vasodilation (see below). Atropine and neostigmine do not affect HR. HTN does not produce reflex bradycardia. The graft atrium produces normally conducted P waves if the right atrial cuff anastomosis is used. The graft-conductive tissue contains adrenergic receptors and responds normally to norepinephrine, epinephrine, and isoproterenol. Inotropic support with epinephrine (20–100 ng/kg/min) +/− milrinone 0.2–0.5 mcg/kg/min may be necessary, especially if pulmonary HTN promotes RV failure. Inhaled NO (20 ppm) or epoprostenol (0.05 mcg/kg/min) may provide selective pulmonary vasodilation. Vasoplegia may occur particularly in patients with an LVAD and may require iv vasopressin (0.01–0.06 U/h) or norepinephrine 0.05–0.2 mcg/kg/min. A PA catheter may be helpful in guiding the use of inotropes and vasodilators and may be placed after CPB. After termination of CPB, TEE may be of particular value in assessing RV dysfunction, estimating PA pressures, and guiding appropriate fluid therapy, pharmacologic support, and mechanical support as necessary. RV failure may be produced by the presence of air in the RCA. Visual inspection may demonstrate this problem, and one should wait for the passage of the air and the resolution of ischemia

	before terminating CPB. SNP (0.2–2.0 mcg/kg/min) or clevidipine (1–6 mg/h) is used for afterload reduction. Inhaled NO, epoprostenol or iv prostaglandin E_1 (20–100 ng/kg/min), and NTG (0.2–2.0 mcg/kg/min) may be used for pulmonary vasodilation, especially if a preop catheterization study demonstrates responsiveness of the pulmonary circulation. Isoproterenol infusion (10–100 ng/kg/min) may provide appropriate pulmonary vasodilation, chronotropy, and inotropy. IV fluid and vasodilators must be given with particular care, as the flow produced by the denervated heart is quite sensitive to preload.
Postbypass hemorrhage	Postbypass bleeding is a common problem brought on by the preop use of anticoagulants, the depressed synthetic function of the liver in chronic heart failure, and the effects of CPB. Following administration of protamine, infusion of Plts, FFP, and RBCs may be necessary. Cryoprecipitate is often indicated, especially for patients with previous chest surgery. Also consider PCCs for patients on preop warfarin. Epsilon-aminocaproic acid (EACA) or tranexamic acid may be appropriate in some cases. If bleeding persists, consider recombinant factor VIIa or FEIBA.
Immunosuppression	Methylprednisolone 500 mg is given on bypass by the perfusionist at the time of graft reperfusion.
Diuresis	There may be little urine production, especially if patient received high-dose diuretics preop. Mannitol and furosemide may be needed to induce diuresis.
Transport	A Mapleson D or Jackson-Rees circuit is used in transporting the patient to the ICU. Sedation with iv infusion of propofol (20–50 mcg/kg/min) and/or dexmedetomidine (0.4–0.8 mcg/kg/min) may be used.
Blood and fluid requirements	Possible severe bleeding IV: 14–16 ga × 1–2 BSS @ 4–6 mL/kg/h Bleeding is often a problem after termination of CPB. A second iv

		catheter is inserted in patients with previous chest surgery. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors Arterial line CVP/PA catheter UO	Although it may be helpful to have a triple-lumen CVP line before induction for preload monitoring and infusion of potent infusion drugs, it is not essential. This line is ideally inserted after the patient is intubated to avoid patient dyspnea and discomfort. A PA catheter is usually not advanced before bypass because it must be removed during surgery. An 8.5-Fr introducer is used in anticipation that a PA catheter may be necessary to manage right heart failure following the transplantation. In some institutions (not Stanford), the left IJ vein is the preferred site of cannulation, which leaves the right IJ unscarred for repeated postop endomyocardial biopsy of the transplanted heart.
	Cerebral oximetry	Cerebral oximetry readings may be

	TEE	confounded by changes in scalp perfusion. Be aware that false-positive and false-negative readings are not uncommon. TEE is used to assess air in the heart while weaning from CPB and optimize fluid therapy, inotropic agents, vasodilators, and chronotropic agents. ✓ for any LV regional wall motion abnormalities.
Positioning	✓ and pad pressure points ✓ eyes Arms padded at sides Chest roll	

POSTOPERATIVE

Complications	RV dysfunction	RV failure may occur in patients with pulmonary HTN and high RV afterload (see pulmonary HTN, below). Coagulopathy requiring high-volume resuscitation may also result in RV dysfunction (TACO).
Complications (cont'd)	Pulmonary HTN	Maneuvers that exacerbate pulmonary HTN should be avoided. These include hypoxia, hypercarbia, acidosis, and low minute ventilation. Inhaled NO (20 ppm

Oliguria

Drug side effects:

- Corticosteroids: glucose intolerance, HTN, obesity, hyperlipidemia, aseptic necrosis of the hip, bowel perforation, infection

inspired concentration) or epoprostenol (50 mcg/kg/min) can be used to treat pulmonary HTN (20–40 ppm inspired concentration). Efforts to treat pulmonary HTN with iv vasodilator therapy may be complicated by impaired V/Q matching with hypoxemia and by systemic ↓ BP producing poor coronary perfusion and RV ischemia. Inotropic support of the RV may be necessary (epinephrine 0.02–0.1 mcg/kg/min, milrinone 0.2–0.4 mg/kg/min). Isoproterenol infusion (10–150 ng/kg/min) may be attractive as it combines inotropy, pulmonary vasodilation, and chronotropy. Preexisting impairment may → chronic ↓ UO state. Other renal problems may be related to cyclosporine toxicity, diuretic toxicity, or CPB. Rx by optimizing hemodynamics. Consider reduction or elimination of nephrotoxins and continuing use of diuretics. Cyclosporine nephrotoxicity occurs in

		most patients. A functional toxicity with ↓ GFR occurs at low dose and is reversible. Tubular toxicity with morphologic changes occurs at high doses and is generally clinically unimportant and reversible. The most serious damage is vascular interstitial toxicity, which occurs over months at high doses and is not reversible.
Multimodal pain management	PCA after weaning from mechanical ventilation	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	If postop sedation is required, dexmedetomidine may be preferable to propofol. Encourage fast-track extubation, early enteral nutrition, Foley catheter removal, and mobilization.
Tests	Cr Hct	

Suggested Reading

1. See Suggested Readings on p. 532.

SURGERY FOR THE LUNG AND HEART/LUNG TRANSPLANTATION

SURGICAL CONSIDERATIONS

Description

With the availability of cyclosporine, the ability to successfully transplant the heart and both lungs was proven in monkeys and then successfully applied in a patient in March 1981. Subsequently, single-lung transplantation was successfully performed in 1984 and an en bloc, double-lung transplant in 1986. Clinical lung transplantation of these various types has increased markedly in the last few years, and currently, ~600 single-lung transplants, 1000 bilateral-lung transplants, and 30 heart/lung transplants are performed in the United States each year.

Current indications for heart/lung transplantation are primarily those of combined heart and lung disease, including Eisenmenger syndrome due to a congenital heart defect with irreversible pulmonary hypertension (HTN). Certain types of diffuse lung disease, such as primary pulmonary HTN with significant right heart failure, are also treated in some centers by heart/lung transplantation. Recipients for single-lung transplant usually have end-stage pulmonary disease without significant sepsis. This includes patients with interstitial fibrosis, emphysema, and lymphangioleiomyomatosis. Some patients with pulmonary vascular disease, such as primary pulmonary HTN or pulmonary HTN associated with an ASD, have undergone single-lung transplantation with or without cardiac repair. Bilateral-lung transplantation is now performed usually as a sequential single-lung transplant with the major indications being septic lung disease, such as cystic fibrosis, chronic bronchiectasis, severe bullous emphysema, or pulmonary vascular disease with or without cardiac repair. Current immunosuppressive protocols consist of a combination of tacrolimus with prednisone and mycophenolate mofetil, with or without early induction therapy, using a cytolytic agent (e.g., antithymocyte globulin) or an IL-2 receptor or blocker (e.g., basiliximab). Immunosuppression may begin preop and continue throughout the life of the patient. Current 1-yr survival rates average 70% for heart/lung transplants and 80% for lung transplants.

Heart/lung transplants usually are performed through a median sternotomy, although occasionally bilateral, transsternal thoracotomy has been used. **Single-lung transplants** (usually left side) and **bilateral sequential lung transplants** use a lateral thoracotomy, transsternal bilateral thoracotomy, or median sternotomy. Single- and double-lung transplants are greatly facilitated with one-lung ventilation (OLV), which is essential

for these procedures. If this type of ventilation is not feasible, a bronchial blocker must be inserted through the operative field during pneumonectomy and reimplantation. CPB is routinely used for heart/lung transplantation and is used for either single- or bilateral-lung transplantation, depending on the stability of the patient during OLV and/or clamping of the PA. Patients with severe pulmonary HTN undergoing single- or double-lung transplantation will almost always require CPB to reduce PA pressure during clamping. For combined transplants, the recipient heart is removed as for standard heart transplantation (see Surgery for Heart Transplantation). A portion of the PA near the ligamentum arteriosum, however, is left intact to preserve the recurrent laryngeal nerve. Next, each recipient lung is excised, and the trachea is transected above the carina. For single-lung transplant, usually the recipient lung is excised, leaving a bronchial stump and vascular pedicles for the PA and veins (left atrium). For bilateral-lung transplants, both recipient lungs are removed, both bronchi are resected just distal to the carina, and the main PA and left atrium are prepared for subsequent anastomosis.

Implantation of the grafts involves a tracheal anastomosis, aortic and separate superior vena cava (SVC) and inferior vena cava (IVC) anastomoses for heart/lung transplants, and a bronchial anastomosis with PA and pulmonary venous anastomosis for single-lung transplantation. **Bilateral sequential lung transplants (BSLT)** are performed as if they were single-lung transplants. CPB requires heparinization and protamine reversal. Prior to closure, extensive exploration for potential bleeding sites within the posterior mediastinum is carried out with placement of right and left pleural and mediastinal drainage. Thoracotomies are closed in standard fashion with routine chest tube drainage.

Usual preop diagnosis

End-stage heart and lung disease, such as Eisenmenger syndrome; cystic fibrosis; primary pulmonary HTN; emphysema; bronchiectasis; lymphangioleiomyomatosis; interstitial pulmonary fibrosis; sarcoidosis; other unusual forms of lung disease

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, possible need for a chest tube and postop mechanical ventilation, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Heart/Lung	Single-Lung	Bilateral-Lung

	Transplantation	Transplantation	Transplantation
Position	Supine	Lateral thoracotomy	Supine
Incision	Median sternotomy, usual; bilateral anterior thoracotomy, occasionally	Posterolateral thoracotomy	Transsternal bilateral thoracotomy, median sternotomy
Special instrumentation	Ascending aortic, SVC, and IVC cannulae	Occasional need for BB to be inserted through the operative field	± Aortic, SVC, and IVC cannulation; occasional need for BB
Unique considerations	CPB. If recipient has had previous thoracotomies, mediastinal collaterals may cause troublesome bleeding. Some patients with cystic fibrosis have severe bilateral scarring, requiring extensive dissection to remove the recipient lung.	± CPB. Patient may become severely hypoxic or hypercarbic during OLV, requiring CPB. During right thoracotomy, cannulation can be performed through the thorax, but left thoracotomy may require femoral artery and vein cannulation.	CPB. Thoracotomy usually is performed on the left side first, with implantation of the lung on this side, followed by completion of right-side thoracotomy and right-lung transplantation. If patient becomes unstable, cannulation in the thorax is usually possible to facilitate transplantation.
Antibiotics	Continue specific antibiotic regimen. Coverage for	Cefazolin 2 g iv and then 2 g q4h	⇐ With appropriate coverage for

	pseudomonas is suggested in patients with cystic fibrosis.		pseudomonas in patients with cystic fibrosis
Surgical time	4–5 h	2–3 h	5–6 h
Closing considerations	Temporary pacing wire is applied and isoproterenol infusion is usually started intraop to keep HR between 100 and 110, as with a cardiac transplant.	Ventilation with as low an FiO_2 as possible to maintain a PO_2 >90. Minimize iv fluids.	⇐
EBL	500–2000 mL	<500 mL (more if CPB is used)	500–2000 mL
Postop care	Cardiac ICU: 3–7 d, 1- to 2-d assisted ventilation	⇐	⇐
Mortality	10–15%	5%	5%
Morbidity	Early acute rejection episodes from 10 to 21 d: 75%	—	—
	Infection, particularly pulmonary: 30–40%	⇐	⇐
	Pulmonary interstitial edema: 20%	Bleeding: 2–4% Bronchial leak or stenosis: 2–4%	⇐ ⇐
	Return for bleeding: 4–6% Hyperacute		

	rejection: rare		
Pain score	8–10	8–10	8–10

PATIENT POPULATION CHARACTERISTICS

	Heart/Lung Transplantation	Single-Lung Transplantation	Bilateral-Lung Transplantation
Age range	3 mo to 55 yr (average 30–40 yr)	1–65 yr	⇐
Male:Female	1:1	⇐	⇐
Incidence	~30/yr (United States) 200/yr (worldwide)	600/yr (United States) 1000/yr (worldwide)	1000/yr (United States) 2000/yr (worldwide)
Etiology	Eisenmenger syndrome, CHD, cystic fibrosis, pulmonary HTN, other lung diseases	Acquired chronic lung disease, pulmonary HTN	Cystic fibrosis, interstitial fibrosis, emphysema
Associated conditions	Severe cyanosis and polycythemia, diabetes in patients with cystic fibrosis, sinus infections in patients with cystic fibrosis	Right heart dysfunction, pulmonary valve insufficiency, and tricuspid valve insufficiency	Diabetes mellitus, sinus infections in patients with cystic fibrosis

ANESTHETIC CONSIDERATIONS FOR HEART/LUNG TRANSPLANTATION

PREOPERATIVE

Patients scheduled for heart/lung transplantation are terminally ill, although they may still be able to maintain limited activity. Indications include primary pulmonary HTN with irreversible heart failure, Eisenmenger syndrome, and combined cardiac and pulmonary disease. The standard preanesthetic evaluation is supplemented with considerations particular to these patients. The progression of disease is usually well

documented.

Respiratory	Patients with severe pulmonary HTN (80/50 mm Hg) have enlarged PAs. Vocal cord dysfunction (Sx: hoarseness, inability to phonate "e") may occur when the left recurrent laryngeal nerve is stretched by an enlarged PA, making these patients at increased risk for pulmonary aspiration. Appropriate precautions to avoid aspiration should be taken (see Induction, below). **Tests:** ABG; cardiac catheterization
Cardiovascular	Hx of recent exacerbation of symptoms should be sought and cardiac catheterization data interpreted in light of interval changes. The severity of pulmonary HTN and the responsiveness to specific vasodilators during catheterization should be reviewed. **Tests:** ECG; cardiac catheterization; ECHO
Neurologic	R → L intracardiac shunting may be present in patients with pulmonary HTN, and Hx of embolic episodes should be sought. Extra care should be used to avoid injection of even small quantities of intravenous air.
Hematologic	The medication schedule should be verified with particular attention to the recent use of anticoagulants. **Tests:** Hct; PTT; PT (special tubes required if severe polycythemia is present 2° ↓ plasma volume); Plt count; fibrinogen
Laboratory	Evidence of renal and hepatic dysfunction should be sought by H&P and lab studies. Mild hypokalemia is generally not treated because the heart/lung graft is preserved with K^+ and implantation will reverse hypokalemia.
Premedication	Although anxious, these patients are usually well informed and psychologically prepared. They respond well to the reassurance of the preop visit, and

	pharmacologic premedication usually is not necessary. O_2 therapy should commence prior to transport of patient to the OR. Patient may be at increased risk for pulmonary aspiration of gastric contents because of the unscheduled nature of the surgery and the presence of recurrent laryngeal nerve damage. Famotidine (20 mg) and metoclopramide (10–20 mg) may be administered iv preop.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of thoracic epidural, continuous paravertebral, or chest wall nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: Infection is a serious potential complication in the immunosuppressed transplant patient; thus, aseptic technique is important. Aseptic technique is used in inserting and securing all vascular catheters. The anesthesia machine should be equipped with a supply of air to permit control of the FiO_2, and anesthesia is not induced until the team harvesting the graft reports that it appears to be normal on direct inspection.

Induction	In the OR, the patient should be placed on the operating table and O_2 and noninvasive monitors applied. An arterial line for BP and blood gas monitoring should be inserted, using liberal amounts of local anesthetics before induction. The presence of real-time BP monitoring can be critical during induction. A patient who is dyspneic in the supine position may be treated by raising the back of the table. Cricoid pressure may be used when the patient

	is at risk for aspiration of gastric contents. A major goal of anesthetic induction is the avoidance of further increases in PVR by guarding against respiratory acidosis, hypoxia, N_2O, light anesthesia, and extremes of lung volume. When hemodynamically tolerated, anesthetic is induced with titrated propofol (0.5–1 mg/kg) and fentanyl (2–4 mcg/kg). Etomidate (0.1–0.2 mg/kg) may be used when hypotension limits administration of propofol and narcotics. Rocuronium (1–1.5 mg/kg) should be administered early to permit rapid airway control. Midazolam and scopolamine produce amnesia. N_2O is not used because it may exacerbate pulmonary HTN, reduces FiO_2, and expands intravascular air bubbles. Patient should be ventilated by mask and cricoid pressure released only after the airway has been secured with a cuffed ETT. An ETT of internal diameter of 8.0 mm or greater will facilitate FOB at the end of the procedure and postop.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider placement of parasternal or chest wall nerve blocks if preop blocks have not been placed. Ketamine (0.5 mg/kg iv) at induction may improve pain management and reduce delirium after CPB.
Maintenance	Typical total anesthetic doses for the entire intraop course are fentanyl 10–20 mcg/kg or sufentanil 10–15 mcg/kg, midazolam 0.05–0.15 mg/kg, vecuronium 0.3–0.5 mg/kg, or rocuronium 2–3 mg/kg. Recommend the use of antifibrinolytics for all cases requiring CPB.
Termination of CPB	After the tracheal anastomosis is complete, the lungs are suctioned with a sterile catheter and ventilated manually with air (FiO_2 = 0.21). Tidal volumes should be sufficient to reinflate areas of atelectasis

under direct vision. Steroids (methylprednisolone 250–500 mg) may be given by the perfusionist as the lung is reperfused. Once rewarmed, full ventilation is begun with the lowest FiO_2 to achieve SpO_2 ≥90%, usually FiO_2 = 0.4–0.5. Peak inspiratory pressures are typically 20–30 cm H_2O in the open chest. Optimal tidal volumes 6–8 mL/kg can be in part determined by direct visualization and lung protection strategy. PEEP may be added to optimize SpO_2 as well as inhaled NO.

Junctional rhythm is common in the denervated transplanted heart. Epinephrine (50–100 ng/kg/min) or isoproterenol (10–75 ng/kg/min) is used to achieve a HR of 100–120. When sinus rhythm is achieved, it is common to see two P waves if a biatrial anastomosis has been used. The residual atrial tissue produces nonconducting P waves. Responses mediated by vagal tone will be seen in the rate of the original atrial tissue and have no clinical importance beyond the ease with which the ECG is interpreted.

In the denervated heart, atropine and neostigmine will not affect HR, and HTN will not produce reflex bradycardia. The graft atrium produces normally conducted P waves. The transplanted heart contains adrenergic receptors and responds normally to norepinephrine, epinephrine, and isoproterenol.

The CO of the denervated heart is quite sensitive to preload; thus, iv fluid and vasodilators must be given with particular care. SNP or clevidipine is used for afterload reduction. TEE may be of particular value in assessing RV dysfunction and guiding appropriate fluid therapy, pharmacologic support, and mechanical support as necessary. Inhaled NO or epoprostenol, iv PGE_1 (20–100 ng/kg/min), isoproterenol, and NTG (0.2–2.0 mcg/kg/min) also may be used for pulmonary vasodilation. Inotropic support with epinephrine (0.05–0.10 mcg/kg/min), milrinone (0.2–

	0.4 mcg/kg/min), or isoproterenol may be necessary, especially if pulmonary HTN and RV failure occur. TEE is useful in evaluating the PA anastomosis (diameter >1 cm) and pulmonary veins (diameter >0.5 cm). Flow rates by Doppler should be ≤100 cm/sec.	
Immunosuppression	Methylprednisolone 500–1000 mg iv is given at the time of graft reperfusion while on CPB by the perfusionist.	
Diuresis	There may be little urine production, especially if patient received high-dose diuretics preop. Cyclosporine may exacerbate renal dysfunction. Mannitol and furosemide may be needed to induce diuresis.	
Transport	A sterile, disposable Jackson-Rees system is used in transporting the patient to the ICU.	
Blood and fluid requirements	Anticipate large blood loss IV: 14–16 ga × 2 BSS	Bleeding is often a major problem after termination of CPB. Patients with intracardiac defects are at increased risk for cerebral embolic events. Care must be taken to remove all air bubbles from intravascular lines. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Control of blood loss	Postbypass bleeding is a common problem	Postbypass bleeding is exacerbated by preop use of anticoagulants, depressed synthetic liver function, trauma of CPB, and/or previous chest surgery.
	Coagulation therapy	Coagulation therapy may

	necessary	include protamine (30 mg/kg), Plts, cryoprecipitate, FFP, RBCs, EACA (300 mcg/kg), and DDAVP (0.3 mcg/kg).
	Possible severe bleeding	Severe bleeding prompts further therapy: PCCs, FEIBA® (anti-inhibitor coagulant complex), and/or recombinant factor 7a.
Monitoring	Standard monitors Arterial line CVP/PA catheter UO Cerebral oximetry	The CVP catheter is ideally placed following anesthetic induction. An introducer permits the rapid insertion of a PA catheter when necessary. A "double-stick" technique, placing both a triple-lumen CVL and a 9-Fr introducer in the right IJ, is sometimes used. In some centers (not Stanford), the left IJ vein is the preferred site of cannulation, leaving the right IJ unscarred for repeated endomyocardial biopsies of the transplanted heart. Cerebral oximetry readings may be confounded by changes in scalp perfusion. Be aware that false-

		positive and false-negative readings are not uncommon.
	TEE	TEE is used to optimize volume status (LV + RV size), inotropic agents (LV + RV contractility), vasodilators, and chronotropic agents.

POSTOPERATIVE

Complications	Oliguria	Diuresis may be induced with mannitol and furosemide.
	Pulmonary edema	Given the lack of lymphatic drainage in the transplanted lung, pulmonary edema may occur. Diuresis and restriction of iv fluid may be required.
	RV dysfunction	RV failure may occur in patients with pulmonary HTN and high RV afterload (see Pulmonary HTN Rx, below).
	Hypoxia	If oxygenation does not improve with increasing FiO_2, PEEP, tidal volumes, and/or inhaled NO, ECMO may be considered.
	Pulmonary HTN	Maneuvers that exacerbate pulmonary HTN should be avoided. These include hypoxia, hypercarbia, acidosis, and hypoventilation. Inhaled

	NO can be used to treat pulmonary HTN (20 parts per million inspired concentration). Efforts to treat pulmonary HTN with vasodilator therapy may be complicated by impaired V/Q matching with hypoxemia and by systemic hypotension, producing poor right coronary perfusion and RV ischemia. Inotropic support of the RV may be necessary. Isoproterenol is attractive because it combines inotropy, pulmonary vasodilation, and chronotropy.
Rejection Infection	Monitor rejection Sx with transvenous endomyocardial biopsy and transbronchial biopsy.
Drug side effects: • Cyclosporine: HTN, nephrotoxicity, hepatotoxicity • Corticosteroids: glucose intolerance, HTN, obesity, hyperlipidemia, aseptic necrosis of the hip, bowel perforation, infection • Azathioprine: anemia, thrombocytopenia, leukopenia, hepatotoxicity	Cyclosporine nephrotoxicity occurs in most patients. A functional toxicity with reduced GFR occurs at low dose and is reversible. Tubular toxicity with morphologic changes occurs at high doses and generally is clinically unimportant and reversible. The most serious damage is

		vascular interstitial toxicity, which occurs over months at high doses and is not reversible.
Multimodal pain management	PCA	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	If postop sedation is required, dexmedetomidine may be preferable to propofol. Encourage fast-track extubation, early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Reading

1. See Suggested Readings on p. 532.

ANESTHETIC CONSIDERATIONS FOR LUNG TRANSPLANTATION

PREOPERATIVE

The patient presenting for lung transplantation typically has end-stage pulmonary fibrosis, emphysema, cystic fibrosis, or bronchiectasis. Pulmonary HTN also may be treated by lung transplantation. The progression of the disease is usually well documented; however, Hx of recent exacerbation of symptoms should be sought.

Respiratory	Assess the patient's ability to undergo OLV by review of the V/Q scan. If little perfusion of the nonoperative lung is present, anticipate the need for

	CPB. The extent of the restrictive lung disease and diffusion abnormality must be assessed preop. For example, room-air PaO_2 <45 mm Hg predicts the need for CPB. **Tests:** PFT; V/Q scan; ABG
Airway	Patients with severe pulmonary HTN (80/50 mm Hg) have enlarged pulmonary arteries. Vocal cord dysfunction (Sx: hoarseness, inability to phonate "e") may occur when the left recurrent laryngeal nerve is stretched by an enlarged PA, making these patients at increased risk for pulmonary aspiration; therefore, appropriate precautions to avoid aspiration should be taken (see Induction, below).
Cardiovascular	Evidence of RV dysfunction with tricuspid regurgitation should be sought by physical exam, ECHO, and cardiac catheterization. RV ejection fraction (EF) may be estimated with radionuclide ventriculography (normal EF ≥50%). Pulmonary HTN is considered to be severe and may produce RV failure when pressure is >2/3 of systemic arterial pressure. Note response to specific vasodilators recorded during catheterization. Patients are often aggressively diuresed. Some patients (cystic fibrosis, bronchiectasis) may develop vasoplegia especially on CPB. BP support with iv vasopressin and norepinephrine (infusion and/or boluses) may be necessary. **Tests:** Preview cardiac catheterization data; ECG; mean PAP >40 mm Hg and PVR >5 mm Hg/min/L may predict the need for partial CPB.
Neurologic	R → L intracardiac shunting may be present in patients with pulmonary HTN, and Hx of embolic episodes should be sought. Extra care should be used to avoid injection of even small quantities of intravenous air.
Musculoskeletal	Chronic cachexia precludes the procedure.

Hematologic	Polycythemia 2° chronic hypoxemia is common. Autologous blood is collected as CPB is initiated. **Tests:** Hct; coagulation studies require special blood tubes to correct for low plasma volume in patients with severe polycythemia.
Laboratory	Other tests as indicated from H&P
Premedication	Patients awaiting lung transplantation are generally well informed about the planned perioperative course. These patients respond well to the reassurance of the preop visit, and pharmacologic premedication usually is not necessary. O_2 therapy, with the usual home O_2 regimen, should commence prior to transport to the OR. Patient may be at ↑ risk for pulmonary aspiration of gastric contents because of the unscheduled nature of the surgery, the use of oral cyclosporine immediately before surgery, and the presence of recurrent laryngeal nerve damage. Ranitidine (50 mg) and metoclopramide (10–20 mg) may be administered iv before surgery.

INTRAOPERATIVE

Anesthetic technique

GETA: Typically, OLV through a DLT is required for single-lung transplants and may be requested for BSLT to facilitate pre-CPB dissection and reperfusion. Also, some institutions (not Stanford) perform BSLT without CPB (standby only), thus requiring OLV. Consider ETT/BB in cystic fibrosis patients with tenacious sputum. Infection is a serious complication in the immunosuppressed transplant patient; thus, the aseptic technique is important. Aseptic technique is used in inserting and securing all vascular catheters.

Induction	An arterial line for BP and blood gas monitoring should be inserted, using liberal amounts of local anesthetics before induction. The presence of real-time BP monitoring can be critical during induction. After receiving confirmation from the procurement team regarding donor lung suitability and estimated arrival time, induction is begun. After

	preoxygenation, midazolam 0.05–0.1 mg/kg, fentanyl 2–4 mcg/kg, propofol (0.5–1 mg/kg) or etomidate 0.2–0.3 mg/kg, and rocuronium 1–1.5 mg/kg or vecuronium (0.1–0.2 mg/kg) are typically used. Cricoid pressure must be used when the patient is at risk for aspiration because of the unscheduled nature of the surgery and possible vocal cord dysfunction associated with stretch injury of the recurrent laryngeal nerve. Avoid further increases in PVR by guarding against hypoxemia, acidosis, hypercarbia, light anesthesia, and inadequate minute ventilation.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider placement of parasternal or chest wall nerve blocks if preop blocks have not been placed. Ketamine (0.5 mg/kg iv) at induction may improve pain management and reduce delirium after CPB.
Maintenance	Typically, narcotic/O_2/air/± isoflurane (in the absence of hypoxemia and right heart failure). Typical total anesthetic doses for the entire intraop course: fentanyl 10–20 mcg/kg or sufentanil 10–15 mcg/kg, midazolam 0.2 mg/kg, vecuronium 0.5–1 mg/kg, or rocuronium 0.2–0.3 mg/kg. Inhaled NO or epoprostenol may be initiated after induction to help improve right heart function and/or oxygenation. Patients with end-stage cystic fibrosis may require frequent endotracheal suctioning. Recommend the use of antifibrinolytics for all cases requiring CPB.
Emergence	Before closure of the chest, lungs are inflated under direct vision to reinflate atelectatic areas and check adequacy of bronchial closure. At the conclusion of surgery, if a DLT is used, both lumens should be suctioned and the tube replaced with a single-lumen 8.0-mm or larger ETT to facilitate bronchoscopy. Some prefer to change the DLT for a SLT while on

	CPB with FOB guidance. The patient is transported to the ICU intubated and ventilated. Discuss with surgeon local wound infiltration or chest wall nerve block (e.g., via prefascial plane catheter) placement. Consider iv acetaminophen if po dose is given >4–6 hr ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 14 or 16 ga × 1–2 BSS @ 4 mL/kg/h	Patients with intracardiac defects are at increased risk for cerebral embolic events; take care to remove all air bubbles from intravascular lines and syringes. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors Arterial line PA catheter Urinary catheter with thermistor	ECG leads should be covered with tape to ensure that electrical contact is not degraded by prep solution or blood. Be careful of air embolization during catheter insertion. Patients who are profoundly dyspneic (→ high negative intrathoracic pressure) and have low central heart pressures (2° diuresis) are at high risk for VAE; consider inserting the catheter after GA and IPPV have been instituted. Oxygenation must be watched closely.

	Cerebral oximetry	Cerebral oximetry readings may be confounded by changes in scalp perfusion. Be aware that false-positive and false-negative readings are not uncommon.
	TEE	Assessment of RV size and function (normal EF = 0.5–0.7) may be helpful.
OLV	DLT: typically 39–41 Fr (men), 35–37 Fr (women) OLV: necessary for SLT. May not be feasible for BSLT in the most severely compromised patients	A DLT is inserted in the left mainstem bronchus to permit surgical access. FOB is used to verify proper tube placement. Positioning of the bronchial cuff in the proximal left mainstem bronchus does not interfere with surgical access to the bronchus. The position of the DLT should be verified after the patient is moved to the lateral position for SLT. Finally, verify ventilation and proper functioning of the tube. Apply O_2 with CPAP at 5 cm H_2O to the nondependent lung. Further adjustment of CPAP may enhance oxygenation. Also consider using inhaled NO or epoprostenol. The

		nondependent lung may be reinflated with O_2, if necessary, to achieve adequate oxygenation. If adequate oxygenation cannot be achieved, CPB should be initiated.
	Frequent suctioning	Frequent suctioning is necessary in patients with tenacious secretions.
PA clamping (for CPB S/B cases)	Improve V/Q mismatch Improve oxygenation PAP ↑↑→ RV failure	Clamping of the PA will improve V/Q mismatch and oxygenation; however, severe pulmonary HTN and RV failure may develop. Vasodilators, such as NTG (0.2–2 mcg/kg/min), SNP (0.2–10 mcg/kg/min), PGE_1 (20–100 ng/kg/min), or inhaled NO (20–40 ppm), should be used to treat pulmonary HTN and ↓ RV afterload; however, care must be taken to avoid systemic hypotension. Inotropic support for the RV may be necessary (epinephrine [20–100 ng/kg/min]). TEE and right atrial pressure should be monitored for evidence of tricuspid regurgitation associated with RV dilation.

PA unclamping (for CPB S/B cases)	PIP: 20–25 cm H_2O O_2 sat: 90–100% PEEP: 5–10 mm Hg	Temporary unclamping of the PA may be necessary to allow further pharmacologic therapy. If RV failure cannot be controlled pharmacologically, CPB should be initiated. The PA should not be unclamped until ventilation is possible to the transplanted lung. Perfusion without oxygenation of the transplanted lung would produce profound shunt and hypoxemia. TV should be adjusted to eliminate atelectasis and to achieve a PIP of 20–25 cm H_2O with the chest open. The FiO_2 (0.3–0.5) is limited in the hope of curtailing free radical injury. PEEP and inhaled NO may be used to enhance oxygenation.
Positioning	For single lung: • Supine to lateral decubitus • Axillary roll • Airplane splint • Avoid arm hyperextension (>90°) For double lung: • Supine with arms above head for bilateral subcostal incision ✓ and pad pressure	Verify correct position of DLT or BB after moving patient to the lateral position. Difficult access to airway after patient positioned. **NB:** potential for kinking of iv and arterial lines

	points ✓ eyes	

POSTOPERATIVE

Complications	Pulmonary edema Infection: bacterial, viral, fungal, or protozoan	Given the lack of lymphatic drainage in the transplanted lung, pulmonary edema may occur. Diuresis and restriction of iv fluid may be required. Mannitol and furosemide can be used to induce diuresis.
	Side effects of immunosuppressive agents: • Corticosteroids: HTN, osteoporosis, glucose intolerance, hyperlipidemia • Azathioprine: anemia, thrombocytopenia, leukopenia	Immunosuppression drugs typically include tacrolimus, mycophenolate mofetil, and corticosteroids. Early induction therapy with a cytolytic agent (e.g., antithymocyte globulin) may be used.
Multimodal pain management	Epidural narcotics Parenteral narcotics	Postop analgesia may be provided by infusion of narcotics through an epidural catheter. If CPB is used, the insertion of the epidural catheter should be delayed until normal coagulation function is documented in the ICU. Emphasize multimodal approach combining nonopioid and bolus/PCA opioid

		analgesics with regional anesthetics whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	If postop sedation is required, dexmedetomidine may be preferable to propofol. Encourage fast-track extubation, early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

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SECTION 7.0

GENERAL SURGERY

CHAPTER 7.1

Esophageal Surgery

SURGEONS

Jeffrey A. Norton, MD
Mark F. Berry, MD

ANESTHESIOLOGIST

Vivek Kulkarni, MD, PhD

ESOPHAGOSTOMY

SURGICAL CONSIDERATIONS

Description

Cervical esophagostomy is performed to divert oral secretions away from the esophagus to a stoma in certain types of more distal esophageal perforation. To perform an esophagostomy, the esophagus is approached through a left cervical incision. The sternocleidomastoid muscle and carotid sheath are retracted laterally and the thyroid medially, exposing the cervical esophagus (Fig. 7.1-1). The esophagus is mobilized with care being taken not to injure the left recurrent laryngeal nerve, which typically lies in the tracheoesophageal groove. The esophagus is brought to the skin surface as a loop or end stoma and sutured to the skin with absorbable sutures.

Variant procedure or approaches

The procedure is usually performed via a left cervical approach; however, the right side is an alternative.

Usual preop diagnosis

Distal esophageal perforation; distal esophageal obstruction

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop. See Appendix K: Enhanced Recovery After Surgery, p. K-1.

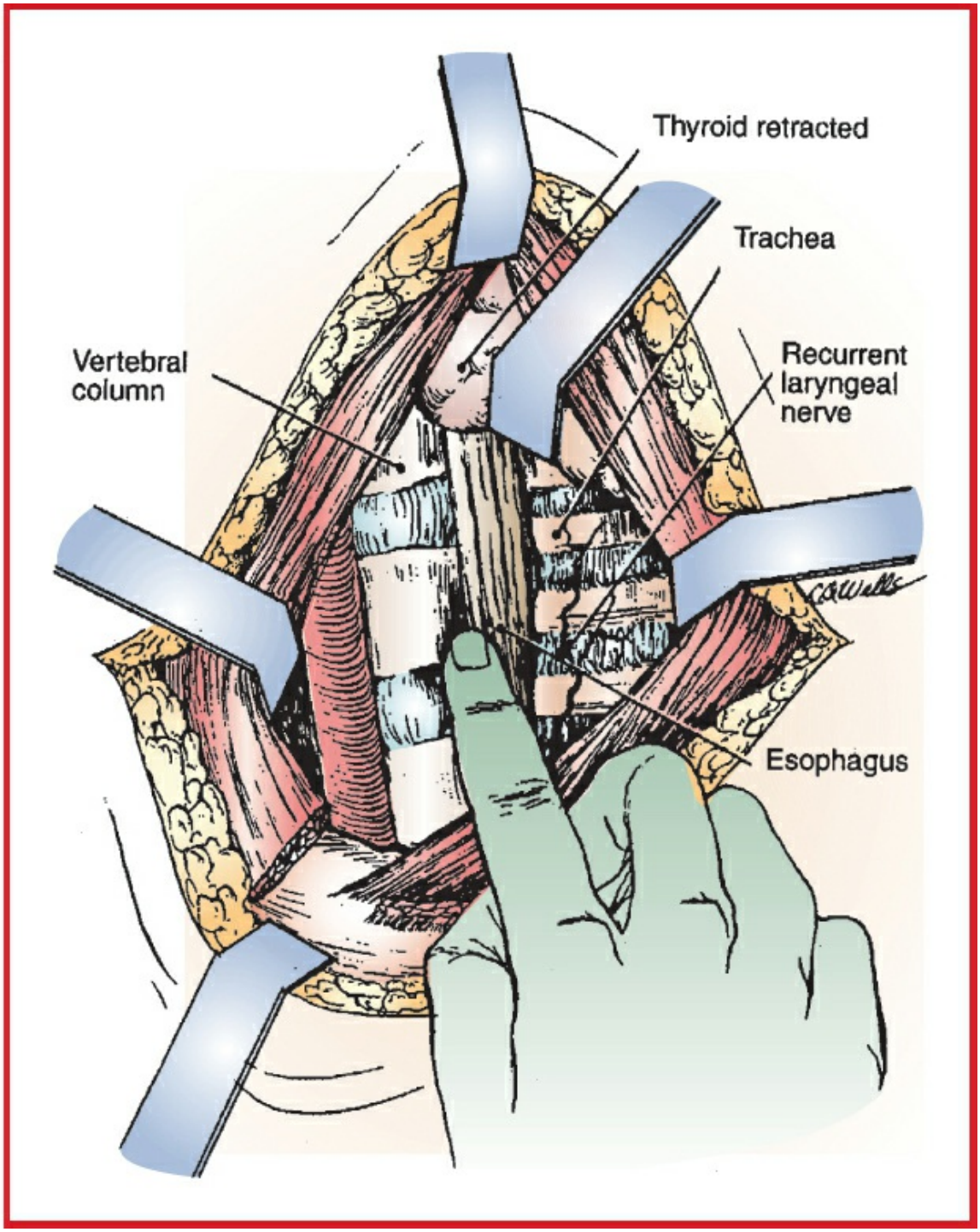

Figure 7.1-1 Surgical anatomy for cervical esophagostomy. (Reprinted from Nora PF, ed:Operative Surgery Principles and Techniques, 3rd edition. WB Saunders, Philadelphia: 1990. Copyright © 1990 Elsevier. With permission.)

SUMMARY OF PROCEDURE

Position	Supine, with head rotated to right
Incision	Cervical
Antibiotics	Cefazolin 2 g iv preop
Surgical time	45 min
EBL	25–50 mL
Postop care	Stoma pouch to collect saliva PACU → ward
Mortality	<0.1%
Morbidity	Skin irritation: 15–20% Saliva leakage: 5–10% Wound infection: <5% Recurrent laryngeal nerve injury: 1–2%
Pain score	5–7

PATIENT POPULATION CHARACTERISTICS

Age range	20–60 yr
Male:Female	1:1
Incidence	Not uncommon
Etiology	Surgically created
Associated conditions	Esophageal perforation; pharyngeal cancer

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Esophageal Surgery following Esophagectomy.

Suggested Readings

1. Carrott PW Jr, Low DE: Advances in the management of esophageal perforation Thorac Surg Clin 2011; 21(4):541–55.
2. Sdralis EIK, Petousis S, Rashid F, et al: Epidemiology, diagnosis, and managemen of esophageal perforations: systematic review. Dis Esophagus 2017; 30(8):1–6.

ESOPHAGEAL DIVERTICULECTOMY

SURGICAL CONSIDERATIONS

Description

Esophageal diverticula are divided into three anatomic types: pharyngoesophageal (Zenker's), midesophageal, and epiphrenic. Structurally, they are either "true" diverticula—meaning they consist of all three layers of the esophageal wall (mucosa, submucosa, and muscularis)—or "false" diverticula consisting of only mucosa (or mucosa and submucosa). Pharyngoesophageal diverticula are the most common, accounting for 60–65% of all cases. These are false diverticula that originate in Killian triangle, a weak point in the posterior wall of the esophagus, just proximal to the transverse fibers of the cricopharyngeal muscle (Fig. 7.1-2A). They are associated with incomplete, or discoordinate, upper esophageal sphincter relaxation, and the resultant increased hypopharyngeal pressure produces a narrow-mouthed posterior diverticulum. These diverticula frequently present in the seventh decade of life and are 2–3 times more common in men. Symptoms depend on the stage of the disease. Early on, patients may complain of vague pharyngeal sensations, dysphagia, cough, and excessive salivation. Later, more severe symptoms—such as severe (or frequent) dysphagia, regurgitation of food, halitosis, voice changes, aspiration, and odynophagia (painful swallowing)—may occur.

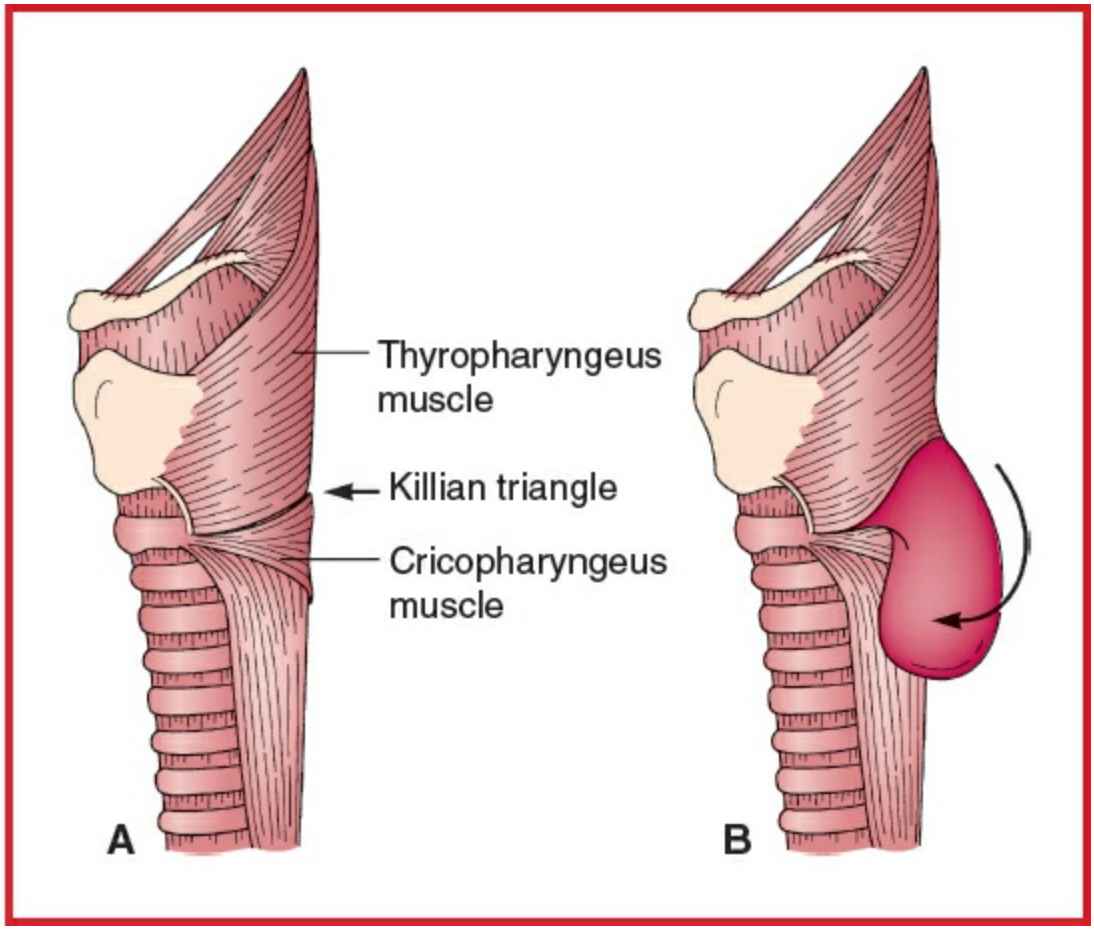

Figure 7.1-2 Formation of Zenker diverticulum. **A:** Herniation of the pharyngeal mucosa and submucosa occurs at the point of potential weakness (Killian triangle [arrow]) between the oblique fibers of the thyropharyngeus muscle and the more horizontal fibers of the cricopharyngeus muscle. **B:** As the diverticulum enlarges, it drapes over the cricopharyngeus sphincter and descends into the superior mediastinum in the prevertebral space. (Reprinted from Greenfield LJ, Mulholland MW, Oldham KT, et al., eds: Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001. After Orringer MB: Diverticula and miscellaneous conditions of the esophagus. In: Sabiston DC Jr, ed. Textbook of Surgery, 13th edition. WB Saunders, Philadelphia: 1986. Copyright © 1986 Elsevier. With permission.)

Surgery is the only effective therapy for Zenker diverticulum. Respiratory complications (aspiration) or nutritional deficiencies (weight loss) may be directly attributable to the diverticulum and should not be contraindications to surgery. Multiple different operative approaches are advocated: diverticulectomy alone, cricopharyngeal myotomy, diverticulectomy with myotomy, and myotomy with suspension of the diverticulum. Myotomy alone, which corrects the underlying physiologic abnormality, is up to 78% effective and may be considered for patients with small (<2 cm) diverticula. Diverticulectomy or suspension should be added if the diverticulum itself is large or dependent. Both procedures are performed via a left cervical incision (Fig. 7.1-3 inset) and are associated with a low rate of recurrence and complications. The upper esophagus is exposed by retracting the sternocleidomastoid muscle and carotid sheath

laterally and the thyroid gland medially. The diverticulum is located in the prevertebral space. Care is taken not to injure the recurrent laryngeal nerve. Following excision of the diverticulum, a cricopharyngeal myotomy may be performed, starting on the upper esophagus and extending across the cricopharyngeal muscle near the neck of the diverticulum and on to the inferior pharyngeal constrictor muscle.

Recent emphasis has been placed on endoscopic treatment of Zenker diverticulum (Dohlman procedure). In this procedure, a modified laryngoscope, tissue coagulator, and endoscopic stapler are used to divide the common wall between diverticulum and true esophageal lumen. This is advantageous because it does not require an incision and it does not injure the recurrent laryngeal nerve. It has similar results to open procedures.

Midesophageal diverticula, by definition, occur in the middle 3rd of the esophagus. These "true" diverticula typically arise in the setting of mediastinal granulomatous disease whereby a fibrotic reaction around inflamed mediastinal lymph nodes results in traction on the muscular wall of the esophagus. Diverticula usually arise within 4–5 cm of the carina and comprise an estimated 10–17% of all esophageal diverticula. Most midesophageal diverticula are asymptomatic and do not require surgical intervention. In cases that require intervention because of either regurgitation or development of an esophagobronchial fistula, the approach is through a right thoracotomy with excision of the inflammatory mass. Primary closure of the fistula and the interposition of viable tissue, such as muscle, should be performed.

Epiphrenic diverticula arise in the distal 10 cm of the esophagus and may be related to an underlying esophageal motility disorder. These false diverticula are most commonly present in the 6th decade. The clinical presentation is variable; most patients have symptoms related to their underlying dysmotility syndrome: dysphagia, chest pain, or regurgitation. Most patients with epiphrenic diverticula are asymptomatic, and there appears to be no relation between size of the diverticulum and symptoms. Surgery for epiphrenic diverticula typically consists of diverticulectomy with myotomy either through a left thoracotomy (Fig. 7.1-4) or via laparoscopy. With the transthoracic approach, a low, left thoracotomy is used, the esophagus is mobilized and encircled, and the diverticulum is mobilized and excised. A myotomy should be performed opposite the diverticulectomy and should extend proximally above the diverticulum and distally onto the stomach. Because there is, by definition, an underlying motility disorder, the myotomy should be carried onto the stomach, and a nonobstructing fundoplication may be added to prevent significant postoperative reflux.

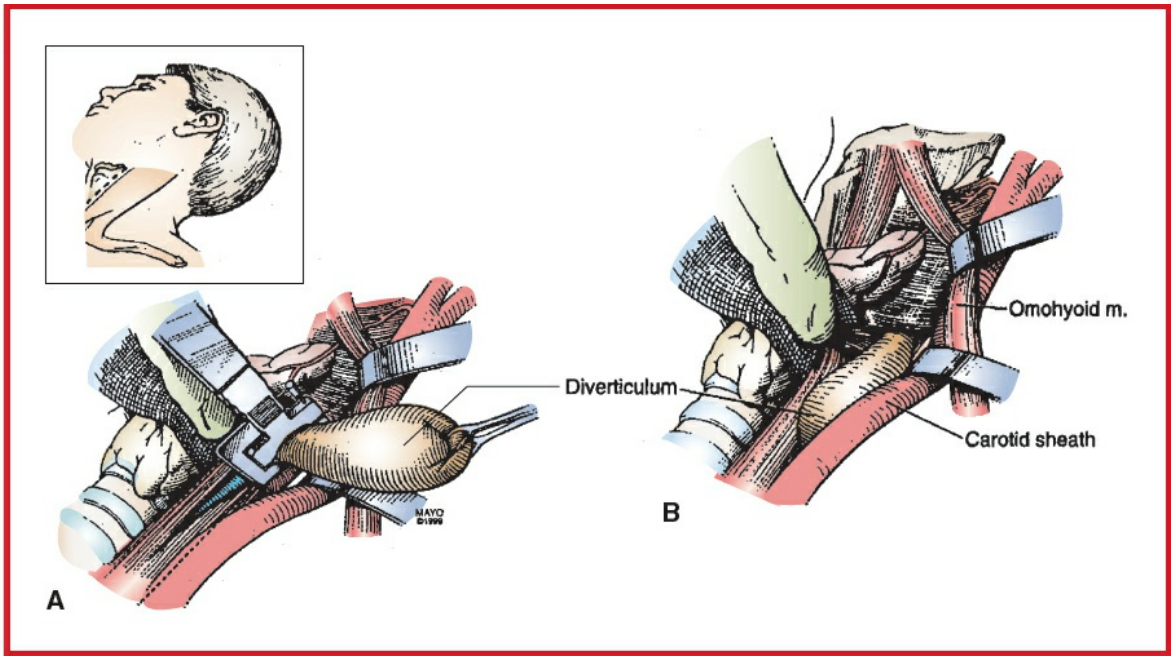

Figure 7.1-3 Zenker diverticulum approached through a left cervical incision (**inset**). **A:** The diverticulum is grasped, and a cricopharyngeal myotomy is extended onto the upper esophagus. **B:** The base of the diverticulum is stapled, and the diverticulum is resected. (Reproduced with permission from Shields TW, LoCicero J III, Ponn RBGeneral Thoracic Surgery, 5th edition. Lippincott Williams & Wilkins, Philadelphia: 2000.)

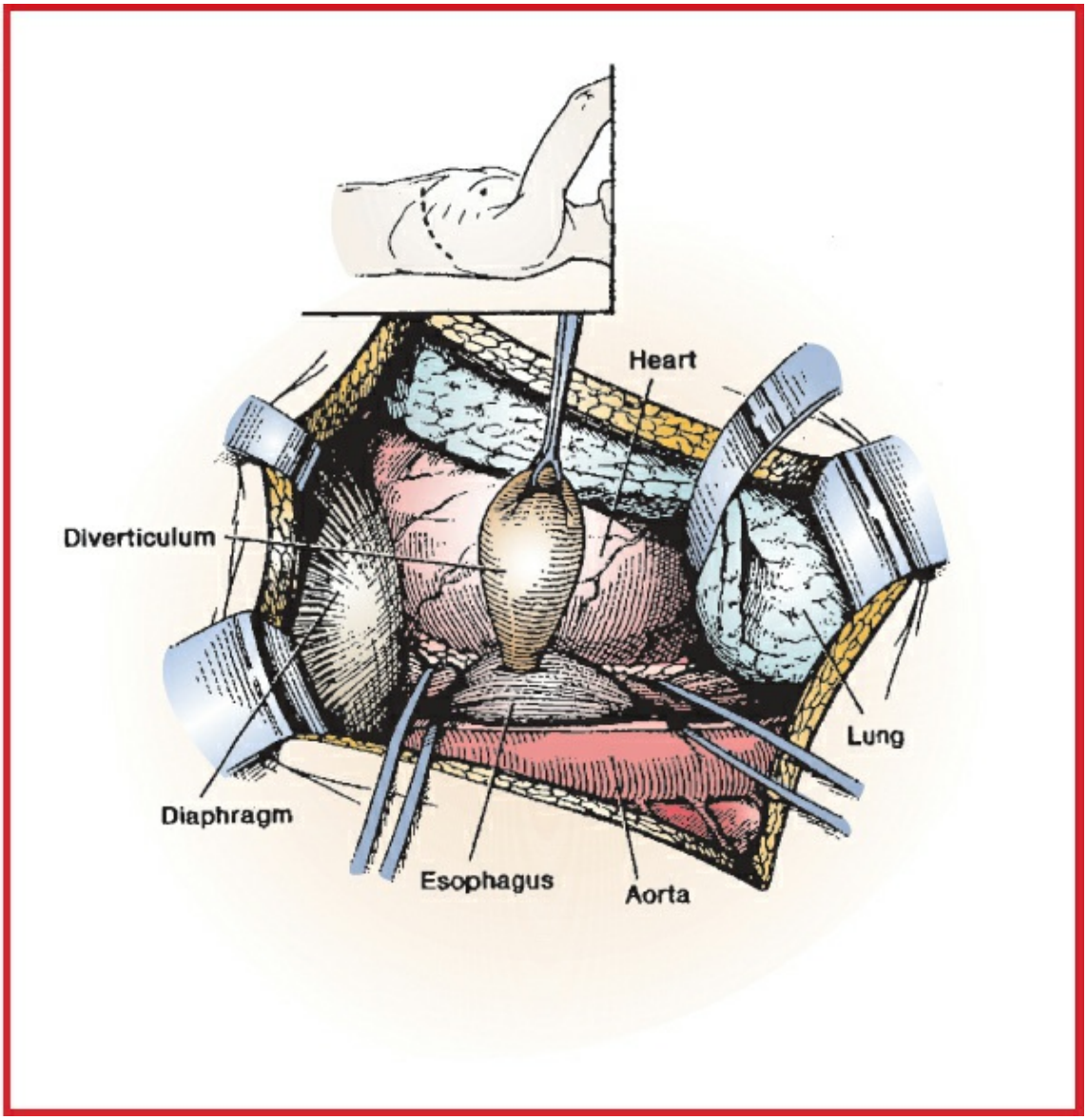

Figure 7.1-4 Epiphrenic diverticulum. Through a left thoracotomy, the diverticulum is mobilized and resected. A contralateral myotomy is then created and extended distally to the stomach to eliminate any functional obstruction secondary to the preexistent dysmotility. (Reproduced with permission from Shields TW, LoCicero J III, Ponn RBGeneral Thoracic Surgery, 5th edition. Lippincott Williams & Wilkins, Philadelphia: 2000.)

Variant procedure or approaches

Laparoscopic diverticulectomy and myotomy has gained increasing acceptance, and reported outcomes are similar to those obtained with the open procedure. The surgical approach is similar to that used during laparoscopic fundoplication. Dissection of the diverticula may be facilitated by the passage of a bougie or video endoscope. After the diverticulum is amputated using an endoscopic stapler, a myotomy is performed opposite the diverticula, and a partial fundoplication is fashioned. Diverticulectomy can also be performed using a robotic approach through the abdomen or through the chest.

Usual preop diagnosis

Esophageal diverticulum

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Hypopharyngeal	Epiphrenic
Position	Supine	Right lateral decubitus
Incision	Left, right cervical, endoscopic	Left thoracotomy
Special instrumentation	None	Chest retractor
Unique considerations	Care not to injure recurrent laryngeal nerve	10 cm myotomy
Antibiotics	Cefazolin 2 g iv preop	⇐
Surgical time	1–2 h	⇐
Closing considerations	Inspect for perforation	⇐
EBL	50–100 mL	100–200 mL
Postop care	PACU → ward	ICU × 1–2 d
Mortality	<1%	⇐
Morbidity	Recurrent nerve paralysis: <5% Temporary phonetic problems: <5% Esophageal stricture: <3% Esophageal fistula: <2%	Atelectasis: 5–10% Esophageal perforation: <2% <2%

Pain score	6–7 (<2 with endoscopic)	7–9

PATIENT POPULATION CHARACTERISTICS	
Age range	35–90 yr (50% of patients >70 yr)
Male:Female	2:1
Incidence	Uncommon
Etiology	Uncoordinated cricoesophageal muscle and lower esophageal sphincter; weakness of esophageal wall
Associated conditions	Cachexia (25–30%); hiatus hernia with or without reflux (25%); chronic pulmonary infection (15–20%); aspiration (30–40%)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Esophageal Surgery following Esophagectomy.

Suggested Readings

1. Dzeletovic I, Ekborn DC, Baron TH: Flexible endoscopic and surgical managemer of Zenker's diverticulum. Expert Rev Gastroenterol Hepatol 2012; 6(4):449–65.
2. Ferreira LE, Simmons DT, Bain TH: Zenker's diverticula: pathophysiology, clinica presentation, and flexible endoscopic management. Dis Esophagus 2008; 21:1–8.
3. Ishaq S, Sultan H, Siau K, et al: New and emerging techniques for endoscopi treatment of Zenker's diverticulum: state-of-the-art review. Dig Endosc 2018; 30(4):449–60.
4. Johnson CM, Postma GN: Zenker diverticulum—which surgical approach i superior? JAMA Otolaryngol Head Neck Surg 2016; 142(4):401–3.

MANAGEMENT OF ESOPHAGEAL PERFORATION

SURGICAL CONSIDERATIONS

Description

Esophageal perforation may be spontaneous, instrumental (iatrogenic), traumatic, or 2° intrinsic esophageal disease. Spontaneous (or emetogenic) perforation most commonly occurs in the lower 3rd of the esophagus. Instrumental perforations may occur at any level, but are most common just above the cardia and in the cervical esophagus. The

level of traumatic perforation depends on the location of the penetrating wound. Symptoms of esophageal perforation at the cricopharyngeal sphincter include neck pain, fever, and crepitations in the substernal and neck areas. Perforation in the mediastinum may result in hydropneumothorax, mediastinitis, fever, and substernal pain. Cervical perforations are managed with antibiotics and drainage in the cervical area. Therapy for intrathoracic perforation generally requires emergent operation. Surgical options include primary repair, drainage and diversion, placement of temporary covered stents, and esophageal resection. The optimal choice depends on the nature and duration of the perforation as well as the clinical condition of the patient. Spontaneous perforations are often amenable to primary repair—either through the abdomen or the left chest. Patients suffering from iatrogenic perforation incurred during dilation of a malignant or nondilatable stricture may require urgent esophagectomy. Patients with delayed recognition of a perforation may be hemodynamically unstable and may only tolerate drainage and diversion (generally through a cervical esophagostomy).

Variant procedure or approaches

Cervical or right thoracic drainage is indicated when the perforation occurs in the neck or high in the mediastinum.

Usual preop diagnosis

Esophageal perforation

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Left Thoracotomy	Cervical or Thoracic Drainage
Position	Right lateral decubitus	Supine or right lateral decubitus
Incision	Left thoracotomy	Cervical or right chest
Antibiotics	Zosyn (piperacillin and tazobactam) 3.375 g iv q6h	⇐

VTE prophylaxis	Heparin 5000 units sq	⇐
Surgical time	2–4 h	1 h
Closing considerations	Chest drain	Cervical or thoracic drain
EBL	100–200 mL	50–100 mL
Postop care	Chest tube to suction; PACU → ward	⇐
Mortality	5–10%	2–5%
Morbidity	Pneumonia: 5–10% Esophageal leak: 2–5% Pericarditis: 1–3%	— 10% —
Pain score	8–10	8–10

PATIENT POPULATION CHARACTERISTICS	
Age range	Variable: 20–80 yr
Male:Female	1:1
Incidence	1 in 8000 admissions
Etiology	Instrumental (endoscopy, dilatation, intubation); traumatic (penetrating, foreign body, caustic agents); intrinsic disease (carcinoma, peptic ulceration); spontaneous
Associated conditions	Esophageal stricture (75%); cancer (25%)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Esophageal Surgery following Esophagectomy.

Suggested Readings

1. Carrott PW Jr, Low DE: Advances in the management of esophageal perforation Thorac Surg Clin 2011; 21(4):541–55.
2. Schembre DB: Recent advantages in the use of stents for esophageal disease Gastrointestinal Endosc Clin N Am 2010; 20:103.

ESOPHAGOMYOTOMY

SURGICAL CONSIDERATIONS

Description

Esophagomyotomy is performed for achalasia and other motility disorders to facilitate esophageal emptying into the stomach. Most authors recommend incising the muscular layer of the distal esophagus and continuing down across the gastroesophageal junction for at least 1 cm (Heller myotomy). The muscle is dissected back from the mucosa so that roughly 180° is exposed (Fig. 7.1-5). The distal esophagus is mobilized either from below the diaphragm or via a left thoracic approach. Care is taken not to injure the vagus nerves.

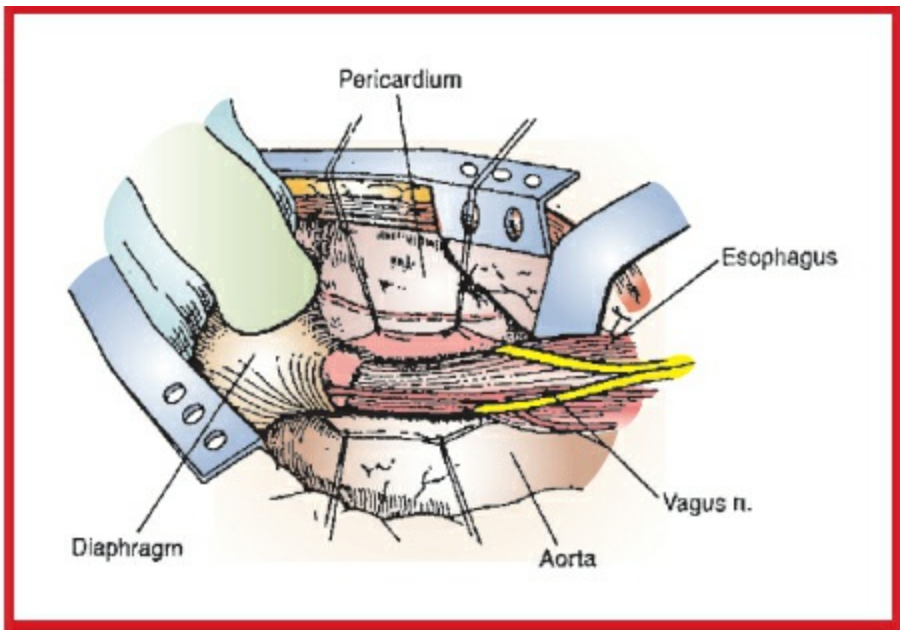

Figure 7.1-5 Surgical anatomy for esophagomyotomy. (Reproduced with permission from Hardy JD: Hardy's Textbook of Surgery, 2nd edition. JB Lippincott, Philadelphia: 1988.)

When approached from the abdomen, the esophagus is exposed by incising the gastroesophageal ligament. The distal esophagus is mobilized and pulled downward to perform the myotomy. The procedure is usually done laparoscopically.

Variant procedure or approaches

The procedure usually is performed through a left thoracotomy, but some surgeons prefer a transabdominal approach. Laparoscopic or thoracoscopic approaches can be used to perform esophagomyotomy.

Peroral endoscopic myotomy (POEM) for achalasia has been developed somewha

recently as an endoscopic alternative to surgical myotomy. This approach involves no external surgical incisions. The procedure is done completely endoscopically, and involves incising the proximal esophageal mucosa, creating a submucosal tunnel that is carried distally and past the gastroesophageal junction, and then performing a myotomy with division of the circular fibers of the muscularis propria. The intentionally created proximal mucosal defect is then closed with sutures or clips. This approach has been shown to be done with very low morbidity even early in a clinician's learning curve, with significant improvement in dysphagia or regurgitation symptoms that are at least similar to surgical myotomies. The main downside of the procedure is a high incidence of postoperative reflux.

Usual preop diagnosis

Achalasia; diffuse esophageal spasm; nutcracker esophagus

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Thoracic Approach	Abdominal Approach	Laparoscopic Approaches	Endoscopic Approaches
Position	Right lateral decubitus	Supine	Supine	Supine
Incision	Left thoracotomy in 6th interspace	Midline upper abdomen	Multiple small abdominal incisions	None
Special instrumentation	Chest retractor	Denier retractor	Laparoscopic instrumentation	Endoscopic instrumentation
Unique considerations	Care should be taken to avoid extending gastric myotomy too far to prevent esophageal reflux.	⇐	Legs spread apart (laparoscopic approach)	None
Antibiotics	Cefazolin 2 g iv preop	⇐	⇐	⇐
VTE prophylaxis	Heparin 5000 units sq	⇐	⇐	⇐

Surgical time	1–2 h	⇐	⇐	90 min for experienced surgeons; 2–4 h early in a clinician's experience
Closing considerations	✓ for perforation. Consider fundoplication to prevent esophageal reflux.	⇐	⇐	⇐
EBL	150–200 mL	100–150 mL	50 mL	Minimal
Postop care	ICU × 1–2 d	PACU → room	⇐	⇐
Mortality	<0.5%	⇐	⇐	
Morbidity	Esophagitis: ≤20% Transient dysphagia/ reflux: 5% Esophageal leak: 1–2%	⇐ ⇐ ⇐	⇐ ⇐ ⇐	Perforation 2% Reflux 20%
Pain score	7–9	6–8	3–4	Minimal

PATIENT POPULATION CHARACTERISTICS

Age range	30–50 yr
Male:Female	1:1
Incidence	0.6/100,000
Etiology	Neuromuscular disorder of unknown etiology often characterized by absence of ganglion cells of Auerbach plexus
Associated conditions	Predisposition to development of carcinoma (1–20%); pulmonary complications 2° aspiration (5–10%)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Esophageal Surgery following Esophagectomy.

Suggested Readings

1. Schlottmann F, Luckett DJ, Fine J, et al: Laparoscopic Heller myotomy versus peroral endoscopic myotomy (POEM) for achalasia: a systematic review and meta-analysis. Ann Surg 2018; 267(3):451–60.
2. Zhu ZJ, Chen LQ, Duranceau A: Long-term results of total vs. partial fundoplicatio after esophagomyotomy for primary esophageal motor disorders. World J Surg 2008; 32:401–7.

ESOPHAGOGASTRIC FUNDOPLASTY

SURGICAL CONSIDERATIONS

Description

Esophagogastric fundoplasty represents a variety of operations designed to prevent esophageal reflux by wrapping the fundus of the stomach around a 3- to 4-cm segment of the lower esophagus. This fundal wrapping acts to reinforce the lower esophageal sphincter. Surgery may be performed transabdominally, transthoracically, or laparoscopically, depending on surgeon's preference. The most common approach is the open or laparoscopic Nissen fundoplication, wherein the anterior and posterior walls of the stomach are sutured together around the lower esophagus with nonabsorbable sutures (Fig. 7.1-6A). This is accomplished by incising the gastrosplenic ligament and ligating three or four short gastric vessels. Care must be taken not to injure the spleen or vagus nerves during the repair.

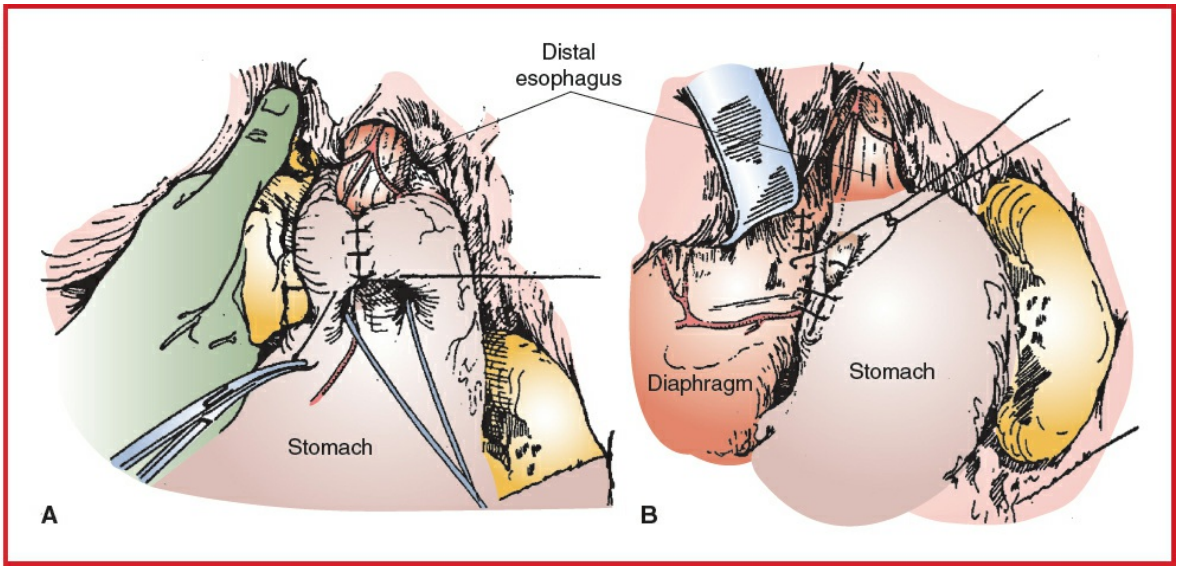

Figure 7.1-6 A: Nissen fundoplication may be performed via either the transabdominal or transthoracic approach. **B:** Hill repair is performed through the abdomen. (Reproduced with permission from Hardy JD: Hardy's Textbook of Surgery, 2nd edition. JB Lippincott, Philadelphia: 1988.)

Variant procedure or approaches

Modifications of the **Nissen** fundoplication include the **Toupet** procedure, a posterior partial fundoplication, and the Hill procedure, in which the gastroesophageal junction is sutured to the median arcuate ligament of the diaphragm or to the preaortic fascia (Fig. 7.1-6B). Compared to the Nissen fundoplication, which involves a complete 360° wrap, these alternative techniques involve a partial fundoplication of 270° or less. Partial

wraps can be more appropriate than a complete wrap in patients with esophageal dysmotility, where a complete wrap will prevent reflux but also may be associated with postprocedure dysphagia. Another modification is the **Belsey Mark IV** repair done through the left chest, in which there is a 240° semifundoplication between the stomach and esophagus, making it easier for the patient to overcome the resistance of the wrap. There are proponents of each repair, although the Nissen fundoplication remains the standard to which others are compared. The laparoscopic approach is widely used, although the left transthoracic approach provides excellent exposure for either Nissen or Belsey repairs. The Belsey repair is associated with excellent outcomes but requires significantly more recovery than a laparoscopic Nissen and is now generally reserved for patients who have recurrent reflux after a previous repair or repairs. In some patients who are felt to have a shortened esophagus associated with their reflux, an esophageal lengthening procedure with gastroplasty will often be performed with fundoplasty to reduce the chance of postsurgical reflux recurrence.

Usual preop diagnosis

Sliding hiatus (hiatal) hernia; paraesophageal hiatus hernia; or free reflux

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

SUMMARY OF PROCEDURES

	Nissen (Toupet) Fundoplication	Laparoscopic Nissen	Hill Procedure	Belsey Mark IV
Position	Supine	Supine, legs apart	⇐	Right lateral decubitus
Incision	Midline abdominal or laparoscopic ports	Laparoscopic ports	Midline abdominal	Left posterolateral thoracotomy
Special instrumentation	No. 40–50 Hurst dilators; NG tube	Laparoscopic instrumentation	NG tube	Chest retractor; NG tube
Unique considerations	Fundoplication should be loose; parietal cell vagotomy performed if peptic ulcer disease present. Fundoplication may be limited to 180–280° posterior wrap (Toupet).	CO_2 insufflation		⇐ 240° semifundoplication
Antibiotics	Cefazolin 2 g iv	⇐	⇐	⇐
VTE prophylaxis	Heparin 5000 units sq	⇐	⇐	⇐
Surgical time	1–2 h	⇐	⇐	⇐
Closing considerations	Inspect spleen for bleeding	⇐	⇐	⇐
EBL	100–150 mL	50 mL	100–150 mL	100–200 mL
Postop care	PACU → ward	⇐	⇐	ICU × 1–2 d
Mortality	<0.5%	⇐	⇐	⇐
Morbidity	Recurrent hernia: 20% Gas-bloat syndrome: 10–20% Temporary dysphagia: 5–10% Gastric fistula: <2%	⇐ ⇐ ⇐ ⇐	⇐ <5% 5% ⇐	⇐ ⇐ 2% ⇐
Pain score	6–8	2–4	7–8	7–9

PATIENT POPULATION CHARACTERISTICS

Age range	46–60 yr
Male:Female	1:2
Incidence	Not uncommon
Etiology	Esophagogastric reflux (100%); esophageal hiatus hernia (80–90%)
Associated	Diverticulosis of colon (30–35%); cholelithiasis (25–

conditions	30%)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Esophageal Surgery following Esophagectomy.

Suggested Readings

1. Joubert KD, Betzold RD, Steliga MA: Successful treatment of esophageal necrosi secondary to acute type B aortic dissection. Ann Thorac Surg 2016; 102(6):e547–9.
2. Patel A, Young LB, Rundback JH: Percutaneous esophagogastrostomy creation fo gastric bypass reversal. J Vasc Interv Radiol 2016; 27(10):1552–3.
3. Weber C, Davis CS, Shankaran V, et al: Hiatal hernias: a review of the pathophysiologic theories and implication for research. Surg Endosc 2011; 25(10):3149–53.

ESOPHAGECTOMY

SURGICAL CONSIDERATIONS

Description

Esophagectomy is most commonly performed for malignant disease of the middle and lower 3rd of the esophagus and gastric cardia. This procedure also may be indicated for intractable benign stricture, Barrett esophagus with in situ multifocal adenocarcinoma, and end-stage achalasia. There are several surgical options for esophageal resection, including the Ivor Lewis approach, which involves a laparotomy and right thoracotomy; the transhiatal approach, whereby the esophagus is mobilized through abdominal and neck incisions; the left thoracoabdominal approach; and the McKeown or three-field approach that involves esophageal mobilization in the right chest along with abdominal and neck incisions (Fig. 7.1-7). Although there are advantages and disadvantages to each, the final result is to use a portion of the stomach to replace the esophagus. In all approaches, the stomach is mobilized while preserving its blood supply from the right gastroepiploic and gastric arteries. The stomach is then transposed into the chest, and a gastroesophageal anastomosis is fashioned either in the chest (Ivor Lewis and left chest approaches) or in the neck (transhiatal approach and three-field approach). To avoid delayed gastric emptying, a pyloroplasty/pyloromyotomy or pyloric Botox® injection is often added, as is placement of a temporary jejunal feeding tube. Regardless of the surgical technique, patients with larger or locally advanced tumors may have received preoperative chemotherapy or radiation. In these patients, the combination of less

distinct tissue planes and radiation-induced inflammation tends to lead to increased bleeding and/or increased insensible fluid losses.

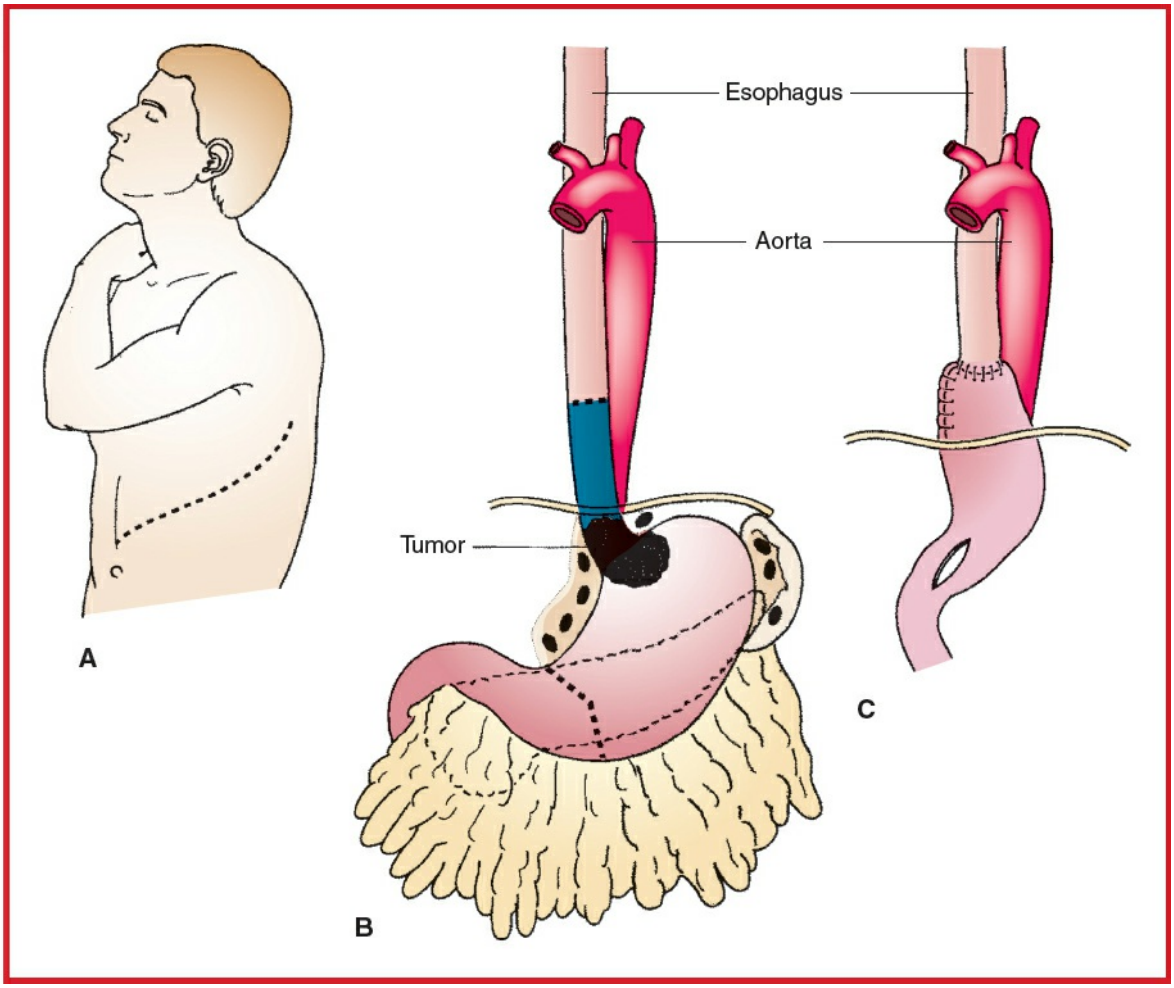

Figure 7.1-7 Standard thoracoabdominal esophagogastrectomy for carcinomas of the distal esophagus and cardia. **A:** Thoracoabdominal incision. **B:** Tissue to be resected (darker area). **C:** Completed reconstruction after intrathoracic esophagogastric anastomosis and either pyloromyotomy or pyloroplasty to prevent postvagotomy pylorospasm. (Reproduced with permission from Greenfield LJ, Mulholland, MW, Oldham KT, et al., eds: Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

The surgical approach for esophageal cancer depends on tumor location, patient comorbidities, and surgeon experience. These approaches up until recently have been performed through open incisions, with postoperative major morbidity rates, particularly pulmonary morbidity, ranging from 27% to 57% and mortality rates ranging from 2% to 14%, depending on hospital volume. Recent advances in laparoscopic and thoracoscopic technologies have given rise to the minimally invasive esophagectomy (MIE), which has the potential benefit of reducing perioperative morbidity and increasing overall utilization of surgical resection of esophageal cancer. However, the benefits of MIE have not been very well characterized. Most single-center or

collaborative multicenter studies that have compared morbidity, mortality, and oncologic efficacy of MIE relative to open esophagectomies have shown that MIE slightly decreases intensive care and total hospital lengths of stay, reduces rates of major morbidity, and produces equivalent or reduced mortality relative to open approaches, though some studies find that MIE patients are more likely to require surgical reintervention. Even with improvements over traditional open techniques, minimally invasive approaches still have mortality rates as high as 6% and morbidity rates as high as 46%.

The previously mentioned variants of esophagectomy all involve the use of the stomach as an esophageal replacement. When the stomach is not available (as with prior resection or caustic injury), the colon can be used as an esophageal substitute. Both the left and right colon can be used, with the vascular supply to the grafts based on either the ascending branch of the left colic artery or the right colic artery. Colon interpositions typically have higher complication rates than esophagectomies using gastric conduits. Supercharged jejunum has also been used with excellent success. Supercharged means an arterial and venous anastomosis is also made in the neck.

Usual preop diagnosis

Carcinoma of esophagus or gastroesophageal junction; Barrett esophagus; benign strictures

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

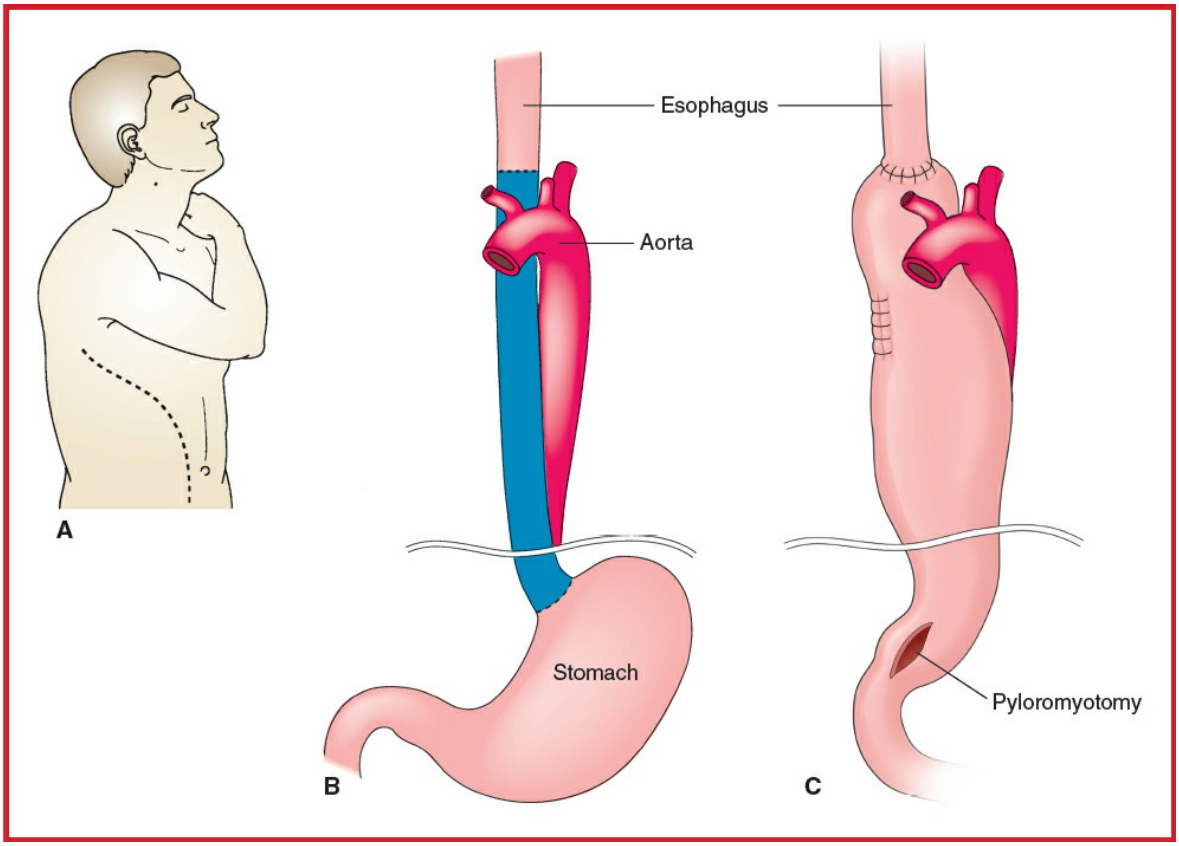

Figure 7.1-8 Standard thoracoabdominal esophagogastrectomy for tumors of the upper and middle 3rd of the thoracic esophagus. **A:** Either a continuous thoracoabdominal incision or separate thoracic and abdominal incisions are used. **B:** Portion of esophagus to be resected (blue) . **C:** Completed reconstruction with high intrathoracic esophagogastric anastomosis and gastric drainage procedure. (Reproduced with permission from Greenfield LJ, Mulholland, MW, Oldham KT, et al., edsSurgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

SUMMARY OF PROCEDURES

SUMMARY OF PROCEDURES

	Ivor Lewis	Transhiatal Esophagectomy	Three-Field Approach	Thoracoabdominal	Total Esophagectomy + Colonic Interposition or Supercharged Jejunum
Position	Supine and left lateral decubitus	Supine	Left lateral decubitus and then supine	Right lateral decubitus	Supine and right lateral decubitus
Incision	Midline abdominal + right chest and/or cervical incisions	Cervical and midline abdominal	Right chest and then midline abdominal and left neck	Thoracoabdominal across costal margin (see Fig. 7.1-8)	Midline + right thoracic and cervical
Unique considerations	DLT	None	DLT for the chest portion	DLT	⇐
Antibiotics	Cefoxitin 2 g iv preop	⇐	⇐	⇐	⇐
VTE prophylaxis	Heparin 5000 units sq	⇐	⇐	⇐	⇐
Surgical time	3–4 h	4–5 h	5–6 h	3–4 h	5–6 h
Closing considerations	Lung reexpansion	Pneumothorax	Lung reexpansion	Lung reexpansion	Vascular integrity of colonic interposition
EBL	300–800 mL	⇐	⇐	⇐	⇐
Postop care	Step-down unit vs. ICU × 1d	⇐	⇐	⇐	ICU × 2–3 d
Mortality	4–5%	⇐	⇐	⇐	5–8%
Morbidity	Respiratory complications: 15–20%	⇐	⇐	⇐	⇐
	Anastomotic leakage: <5%	5–10%	⇐	<5%	10%
	Anastomotic stricture: <5%	⇐	⇐	⇐	10%
	Wound infection: <5%	⇐	⇐	⇐	⇐
Pain score	7–9	6–8	7–9	7–9	7–9

PATIENT POPULATION CHARACTERISTICS

Age range	40–80 yr
Male:Female	2:1 for carcinoma

Incidence	1–2% of malignant disease
Etiology	Alcohol and tobacco; dietary factors—hot spicy foods; lye burns
Associated conditions	Barrett esophagus; hiatus hernia; reflux esophagitis; radiation esophagitis; caustic burns

Suggested Readings

1. Grimminger PP, Goense L, Gockel I, et al: Diagnosis, assessment, and management of surgical complications following esophagectomy. Ann N Y Acad Sci 2018; 1434(1):254–73.
2. Seto Y, Mori K, Aikou S: Robotic surgery for esophageal cancer: merits and demerits. Ann Gastroenterol Surg 2017; 1(3):193–8.
3. Taurchini M, Cuttitta A: Minimally invasive and robotic esophagectomy: state of the art. J Vis Surg 2017; 3:125.

ANESTHETIC CONSIDERATIONS FOR ESOPHAGEAL SURGERY

(Procedures covered: esophagostomy; esophageal diverticulectomy; closure of esophageal perforation; esophagomyotomy; esophagogastric fundoplasty; esophagectomy; colonic interposition.)

Patients presenting for esophageal surgery typically are those with carcinoma, motility disorders, strictures, hiatal hernia, reflux esophagitis, diverticula, and perforation. Patients tend to be elderly, with a history of tobacco abuse and alcohol consumption, and may have associated cardiopulmonary disease. Obesity and ischemic heart disease are increasingly frequent comorbid conditions. Esophageal disorders such as hiatal hernia, Barrett esophagus, and carcinoma with incomplete obstruction predispose the patient to recurrent aspiration pneumonitis from intermittent reflux of gastric contents. Patients with esophageal diverticula, stricture, achalasia, and carcinoma with obstruction may present with retained food and oral secretions. Therefore, patients may need to be considered nonfasted. Minimally invasive techniques for esophagectomy (with laparoscopy and thoracoscopy) have potential benefits of decreased tissue injury, and hence pain, with earlier recovery and reduced hospital stay. These advantages are not yet clearly established. The anesthetic considerations are broadly similar with the additional issues that accompany laparoscopic and thoracoscopic (VATS) procedures.

PREOPERATIVE

Respiratory	Many patients with esophageal cancer have a long history of smoking resulting in COPD. Mediastinal lymphadenopathy and tumors of the upper esophagus may lead to tracheal/bronchial compression or erosion that may be revealed by CT and bronchoscopy. A history of gastric reflux and recurrent aspiration pneumonia → ↓ pulmonary reserve and ↑ risk of regurgitation/aspiration during anesthetic induction. (See Premedication, below.) If thoracotomy is a part of the procedure, the patient should be evaluated to ensure that OLV will be tolerated (see below). Determine if patient has been exposed to radiation and chemotherapeutic agents that may cause pulmonary fibrosis. Some agents, such as Bleomycin, may cause pulmonary toxicity (above a total dose of 300 U) that is worsened by high concentrations of O_2, which should be avoided during the perioperative period. **Tests:** Consider PFTs (FEV1, FVC, DLCO), ABG, and flow-volume loops, if indicated by H&P. They can be helpful in predicting the likelihood of perioperative pulmonary complications and the possible need for postoperative ventilatory support. Patients with baseline hypoxemia/hypercarbia on room air have a greater likelihood of postop complications and ventilatory insufficiency. Severe restrictive or obstructive lung disease also will increase the chance of pulmonary morbidity in the periop period. A-P, lateral CXR (if suggestive of tracheal compression obtain MRI/CT).
Cardiovascular	Elderly patients may have coexisting CAD. In the setting of a recent angioplasty/stent, continued management with antiplatelet agents (clopidogrel) may preclude the use of epidural techniques. Patients may be hypovolemic and malnourished from dysphagia or anorexia. Preop chemotherapy treatment with agents such as doxorubicin may cause acute dysrhythmias and chronic

	cardiomyopathy (seen increasingly in patients if total dose is >550 mg/m^2). Some esophageal tumors are related to alcohol consumption, and chronic abuse may produce a toxic cardiomyopathy. Preop optimization of cardiac status is important. **Tests:** ECG to r/o dysrhythmias, myocardial ischemia, or prior MI. ECHO or dobutamine stress ECHO will provide important functional information about the heart at rest or under stress, respectively. Reversible ischemia and significant cardiomyopathy should prompt further cardiac consultation.
Hematologic	**Tests:** CBC with differential
Laboratory	PT & PTT, basic metabolic profile and tests as indicated from H&P
Premedication	Consider midazolam 1–2 mg iv. Consider H_2 antagonists (e.g., ranitidine 50 mg iv), metoclopramide (10 mg iv 1 h preop), and Na citrate (30 mL po 10 min preop) in patients with reflux and partial obstruction. Patients with esophageal motility disorders and strictures/tumors with complete obstruction may not tolerate oral antacids.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of a thoracic epidural block for postop pain management. Consider preop acetaminophen 1000 mg po and gabapentin 600 mg with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA (with or without epidural for intraop/postop analgesia). If the patient is clinically hypovolemic, restore intravascular volume before epidural placement and induction of GA. Surgeries involving only a cervical or endoscopic approach typically

do not require epidural analgesia. If epidural analgesia is planned, placement and testing of the catheter before anesthetic induction is recommended. This is accomplished by injecting 5–7 mL of 1–2% lidocaine with 1:200,000 epinephrine via the epidural catheter and eliciting a segmental block. If a thoracic or thoracoabdominal approach is performed, placement of a DLT is indicated to provide OLV for optimal surgical conditions. (For additional discussion of DLT placement and OLV, see Anesthetic Considerations in Lobectomy, Pneumonectomy in Thoracic Surgery.)

Induction	Patients with esophageal disease are often at risk for pulmonary aspiration; therefore, the trachea should be intubated after rapid-sequence induction with cricoid pressure. In cases with a difficult airway needing a DLT, placement of a single lumen tube should be accomplished (a) with the aid of a bougie, (b) via an LMA, or (c) with FOB. The single lumen tube is then changed to a DLT using a tube exchange catheter.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Depending on the procedure, consider regional nerve blocks and ketamine or lidocaine infusions as appropriate for multimodal analgesia.
Maintenance	Standard maintenance, with or without N_2O (for OLV). Alternatively, a combined technique may be used. A local anesthetic (e.g., 2% lidocaine with 1:200,000 epinephrine or 0.25% bupivacaine) can be infused or injected into a thoracic (3–5 mL) or lumbar (5–10 mL) epidural catheter to provide both anesthesia and optimal surgical conditions (contracted bowel and profound muscle relaxation). Continuous infusion of local anesthetic generally provides better hemodynamic stability than hourly bolus injections. To enhance the effect of epidural analgesia, a loading dose of opiates (e.g., hydromorphone 0.4–1 mg [thoracic] or 1–1.5 mg [lumbar]) can be administered early during the surgery and at least 1 h before conclusion of the case. Esophagectomy procedures can cause significant third-space losses, thus, the maintenance of euvolemia with close monitoring of BP and UO. Esophageal procedures

	involving transient compression of the myocardium (i.e., thoracic approach for esophagomyotomy or esophagectomy) can induce dysrhythmias and/or ↓ BP. Monitoring of BP with an arterial catheter is recommended. When OLV is necessary there can be ventilation-induced lung injury, oxygen toxicity, atelectasis, and ischemia-reperfusion injury. The use of PEEP, lower tidal volumes, and low ventilatory pressures may be protective ventilator strategies. The goals of fluid management are as follows: (a) optimize the tissue blood flow and oxygen delivery and (b) avoid excessive fluid administration, which could lead to anastomotic edema with impaired wound healing and pulmonary edema with increased cardiopulmonary morbidity. A balance of colloid + crystalloid and blood products when necessary helps achieve this goal-directed fluid therapy.
Emergence	Generally, tracheal extubation should be anticipated at the end of the case. The decision to keep the patient intubated postop depends on cardiopulmonary status and the site and extent of the surgical procedure. Patients with significant intraop fluid shift may develop airway edema that can → airway obstruction if extubated prematurely. This may also occur in operations involving high anastomoses in the neck. For those who may require prolonged postop ventilation, the DLT should be exchanged to a single lumen ETT before transport to ICU. The use of an airway exchange catheter is safe, and direct laryngoscopy during the exchange prevents inadvertent seepage of blood or silent aspiration. Weaning from mechanical ventilation should begin when the patient is awake and cooperative, able to protect the airway, hemodynamically stable, and has adequate return of pulmonary function (as measured by VC ≥ 10 mL/kg; MIF of >30 cm H_2O; rapid, shallow breathing index of ≤100 [RR ÷ TV(L)]; respiratory rate <25; and ABG that demonstrates adequate gas exchange). Discuss with surgeon local anesthetic wound infiltration. Consider iv acetaminophen if po dose is given

	>4–6 hr ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 14–16 ga × l–2 BSS @ up to 10 mL/kg/h Warm fluids Consider T&C for 2–4 U PRBC	Goal-Directed Fluid Management Plt, FFP, and cryoprecipitate (if required) should be administered according to lab tests (Plt count, PT, PTT, DIC screen, thromboelastography [TEG]). Maintain euvolemia based on estimates of blood loss, fluid shifts, fluids administered, and HR, BP, UO, base deficit, and invasive monitoring when employed. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors Urinary catheter ± Arterial line ± CVP	CVP cannulation site determined by surgical approach. Attempt to prevent hypothermia during long operations. Consider forced-air warmer, heated humidifier, warming blanket, warming the OR, keeping patient covered until ready for prep, etc.
Positioning	If lateral decubitus position, use axillary roll, airplane arm holder. ✓ pressure points, including ears, eyes, and genitals ✓ radial pulses to ensure correct placement of axillary roll (if misplaced, will compromise distal	Problems that can arise include brachial plexus injuries and damage to soft tissues, ears, eyes, and genitals from malpositioning. Check down eye at frequent intervals. Placing the oximeter probe on the down arm may assist in monitoring adequacy of

	pulses)	perfusion.
Complications	Hypoxemia	Hypoxemia during OLV most commonly results from luminal obstruction (by blood or pulmonary secretions) of the DLT, ↑ shunting, or malposition of DLT, which can move during surgical manipulation. Rx: suction DLT and ✓ position; PEEP to ventilated lung (but may ↑ shunting); CPAP to nonventilated lung; return to double-lung ventilation. Temporary clamping of the PA (or inflate the balloon of the PA catheter, if available) may be necessary to improve shunting and oxygenation.
	Hypercarbia	Ensure adequate TV and RR.
	Dysrhythmia	✓ for mechanical compression of heart or great vessels. Check K+.
Complications (cont'd)	Hypotension	✓ volume status and cardiac function. Consider phenylephrine for BP support if ↓ BP 2° epidural anesthetic. Avoid epidural bolus dosing (↓ BP). Maintaining an adequate BP is important for adequate perfusion and hence integrity of a newly formed anastomosis.
	VTE prophylaxis	See Appendix B: Standard Adult Anesthetic Protocols.

POSTOPERATIVE

Complications	Aspiration Atelectasis Hemorrhage Pneumothorax Hemothorax	For patients at risk for atelectasis or aspiration, recover in the 45° head up or Fowler position (semisitting) For hemorrhage, ✓ coags; replace factors as necessary. Dx for pneumothorax and hemothorax: wheezing, coughing, dyspnea, ↓ PO_2, ↓ PCO_2. Confirm by CXR. Rx: chest tube drainage as necessary. In emergency (e.g., tension pneumothorax), use needle aspiration. Supportive Rx: O_2, vasopressors, volume, ± ETT, and IPPV.
	Hypoxemia Hypoventilation	For hypoxemia and hypoventilation; Rx: adequate analgesia, minimize sedation, supplemental O_2 may require IPPV.
	Recurrent laryngeal nerve injury	For laryngeal nerve injury, Dx: indirect visualization of vocal cords; patient usually will be hoarse.
	Esophageal anastomotic leak	Surgical repair Rx for esophageal anastomotic leak.
	VTE prophylaxis	Esophageal cancer, like other cancers, predisposes patients to VTE with ↑ risk following the commonly used chemotherapeutic agents cisplatin and 5-FU.
	SVT/AFib	Treat underlying cause, and correct electrolyte

		abnormalities. Adenosine (6 mg iv, push and repeat to 12 mg iv) may be used for SVT. Most postop SVTs are 2° catecholamine surge. AFib may resolve spontaneously. Hemodynamically unstable patients will require cardioversion. β-Blockers, amiodarone, Ca++ channel blockers, and overdrive cardiac pacing are effective in patients with stable AFib.
Multimodal pain management	Lumbar-thoracic epidural analgesia: hydromorphone (0.5–1.5 mg load, 0.1–0.3 mg/h infusion) + local anesthetic PCEA	Patient should recover in ICU or hospital ward that is accustomed to treating side effects of epidural opiates (e.g., respiratory depression, hypotension, breakthrough pain, nausea, pruritus). Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with epidural analgesia (see Appendix K, p. K-6).
	PCA	When an epidural cannot be used, a PCA with an opiate such as fentanyl or morphine/hydromorphone may be used for pain control.
	NSAID	Acetaminophen and ketorolac are helpful as adjuvant therapy for postop pain management.
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

		Consider DVT prophylaxis. Chewing gum may promote return of bowel function.
Tests	CBC, basic metabolic profile ABG CXR (r/o pneumothorax, atelectasis)	

Suggested Readings

1. Findlay JM, Gillies RS, Millo J, et al: Enhanced recovery for esophagectomy: systematic review and evidence-based guidelines. Ann Surg 2014; 259(3):413–31.
2. Hashimi S, Smith M: Medical evaluation of patients preparing for an esophagectomy Surg Clin North Am 2012; 92(5):1127–33.
3. Kingma BF, Steenhagen E, Ruurda JP, et al: Nutritional aspects of enhanced recovery after esophagectomy with gastric conduit reconstruction. J Surg Oncol 2017; 116(5):623–9.
4. Pisarska M, Małczak P, Major P, et al: Enhanced recovery after surgery protocol in oesophageal cancer surgery: systematic review and meta-analysis. PLoS One 2017; 12(3):e0174382.
5. Raymond D: Complications of esophagectomy. Surg Clin North Am 2012; 92(5):1299–313.
6. Veelo DP, Geerts BF: Anaesthesia during oesophagectomy. J Thorac Dis 2017; 9(Suppl 8):S705–12.
7. Visser E, Marsman M, van Rossum PSN, et al: Postoperative pain management after esophagectomy: a systematic review and meta-analysis. Dis Esophagus 2017; 30(10):1–11.

CHAPTER 7.2

Stomach Surgery

SURGEONS

Dan Eisenberg, MD, MS, FACS, FASMBS
Sherry M. Wren, MD, FACS, FCS(ECSA)
Maureen M. Tedesco, MD

ANESTHESIOLOGISTS

Jerry Ingrande, MD, MS
Clifford A. Schmiesing, MD
Brendan Carvalho, MBBCh, FRCA, MDCH

GASTRIC RESECTIONS

SURGICAL CONSIDERATION

Description

A total or partial gastrectomy is performed most commonly for gastric cancers (adenocarcinomas or gastrointestinal stromal tumors [GIST]) and includes **omentectomy, lymph node dissection**, and occasionally resection of adjacent organs such as the **spleen** or **colon**, depending on the pathology, location, and extent of the tumor. Historically, there have been other indications for gastrectomy such as ulcer disease, Zollinger-Ellison syndrome, and uncontrollable hemorrhagic gastritis, but these operations are rare if ever performed for those indications in current surgical practice. Rarely, patients who suffer from severe and uncontrollable gastroparesis postgastric surgery may require total gastrectomy.

In an open gastric resection, the abdomen is entered through an upper midline incision, and the lateral segment of the left lobe of the liver is retracted anteriorly and to the patients right, exposing the esophagogastric junction. The omentum is taken off of the

colon and left attached to the greater curvature of the stomach. The spleen may be removed if involved by tumor or if an unplanned splenic injury occurs. The vessels to the stomach are individually ligated and divided. The short gastric vessels high on the greater curvature are challenging to reach and are a source of potential blood loss. This is also the most likely time that a splenic injury may occur by traction or tearing of the capsule while exposing the short gastric arteries. Currently, most surgeons are using various devices to ligate the arteries, and these occasionally have a technical failure, which can result in blood loss. In the lesser sac, the left gastric artery as it branches from the celiac axis and vein needs to be divided and can be another point of potential unexpected blood loss. A total gastrectomy is performed for more proximal cancers and a partial resection for distal cancers. In all cases of gastric cancer, the antrum and pylorus are resected, leaving a duodenal stump and requiring **gastroenterostomy** to restore intestinal continuity. One area of potential complication when the stomach is resected is the accidental stapling of the gastric tube, which remains undetected until too late. To prevent this, the tube should be pulled back well into the esophagus, preferably with manual confirmation by the surgeon that the tube is no longer present in the stomach.

After completion of the gastric resection, reestablishment of intestinal continuity is performed. In the case of a total gastrectomy, a Roux limb of jejunum is brought up to the distal esophagus; in partial gastrectomies, a Roux limb or loop of jejunum (**Billroth II**) is connected to the remnant stomach. With a Roux limb, the jejunum is divided just beyond the ligament of Treitz, and the distal end is brought up through a hole in the mesentery of the colon and anastomosed to the esophagus or stomach. Intestinal continuity is established by anastomosing the biliary pancreatic limb of the proximal jejunum to the Roux limb of jejunum, ~60 cm distal to the anastomosis with the esophagus. A drain is then placed near the closed end of the duodenum. The anastomosis can either be stapled or hand sewn depending on the preference of the surgeon. At completion of the anastomosis, an NG tube can be advanced across the proximal anastomosis, and the abdomen is irrigated. A number of surgeons then place a **feeding jejunostomy** tube into the jejunum, which adds a few minutes to the procedure prior to fascial closure. Total gastrectomy traditionally has been associated with a morbidity and mortality out of proportion to the operation's apparent magnitude. This is most likely a consequence of the patient's underlying condition, which often includes advanced malignancy and, almost invariably, some degree of malnutrition. Venous thromboembolism (VTE) is a significant concern in these patients because of their increased hypercoagulable state from the cancer and an operation of >1 h in duration. Patients undergoing gastric resection should receive sequential compression devices on the lower extremities and subcutaneous heparin thromboprophylaxis.

Variant procedure or approaches

Occasionally, gastric cancer can have extensive local involvement of adjacent organs requiring an **en bloc resection of the stomach** in addition to the **colon, spleen, or pancreas**. For some distal gastric cancers, a combined gastric resection with a **Whipple procedure (pancreaticoduodenectomy)** may be necessary. The need for en bloc resection of the stomach in combination with other organs increases the complexity of the surgery, risk of blood loss, and postoperative morbidity and mortality. In general, exposure for a **partial gastrectomy** is similar to, but less extensive than, that required for a total gastrectomy. The same cancer principles are followed for either a partial or total resection, including >5 cm proximal margin, **lymphadenectomy**, and **omentectomy**. A partial gastrectomy is a simpler resection. The blood supply to the distal stomach is divided, and the duodenum is divided just beyond the pylorus. The body of the stomach is divided with a stapler (care should be taken not to staple the gastric tube) at a level appropriate for the pathology. Reconstruction after resection may be either to the duodenum (**Billroth I**), loop of jejunum (**Billroth II**; Fig. 7.2-1), or a **Roux-en-Y limb of jejunum.** The anastomoses may be stapled or sewn; then the abdomen is closed. Like many operations, gastric resections are increasingly performed using minimally invasive techniques. The **laparoscopic approach** has the advantages of diminished postoperative pain and quicker recovery, but longer operative time requires a pneumoperitoneum and reverse Trendelenburg positioning.

Tumors (usually adenocarcinoma) of the gastroesophageal (GE) junction are increasing in frequency and may be of either gastric or esophageal origin. If the tumor is associated with Barrett esophagus (intestinal metaplasia in the esophagus, seen on endoscopy), surgery consists of either an **Ivor Lewis** with esophagogastric anastomosis in the mediastinum (combined abdominal and transthoracic approach) or **transhiatal esophagectomy** with GE anastomosis in the neck. Bulky GE junction tumors tha encompass the upper stomach may limit the extent of esophageal resection if stomach pull-up is used. Postop pain can be severe, and most patients benefit from continuous epidural analgesia.

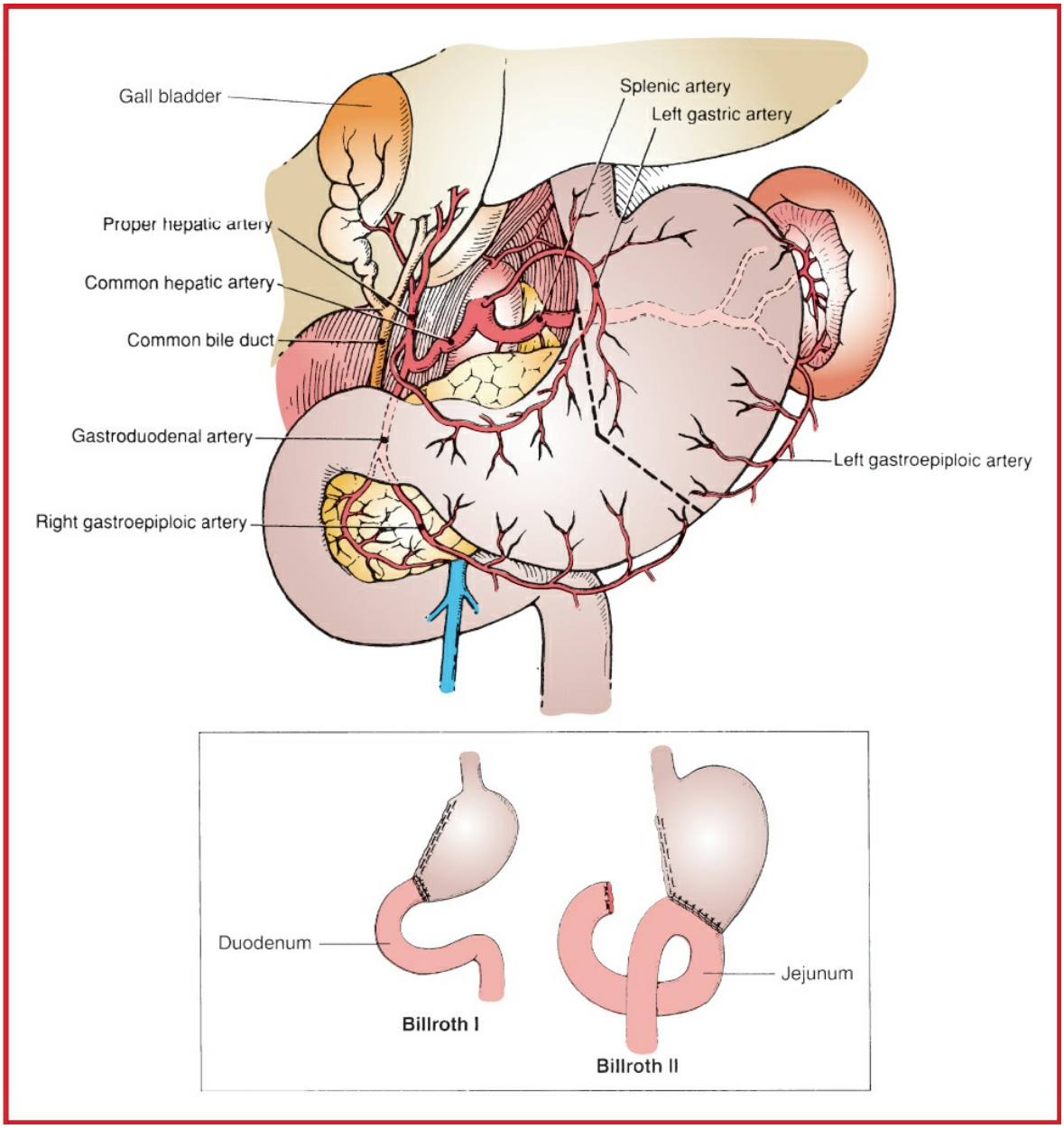

Figure 7.2-1 Anatomy of duodenostomy (Billroth I) and gastrojejunostomy (Billroth II). (Reproduced with permission from Scott-Conner CEH, Dawson DLOperative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

Usual preop diagnosis

Total gastrectomy; gastric cancers; GIST; gastroparesis; partial gastrectomy; gastric cancer; GIST; gastric ulcers

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

SUMMARY OF PROCEDURES

	Total Gastrectomy (Open vs. Laparoscopic)	Partial Gastrectomy
Position	Supine	⇐
Incision	Open: Upper midline or bilateral subcostal; Lap: Multiport incisions	Upper midline or right subcostal
Special instrumentation	Open: Upper hand or other self-retaining costal retractor; Lap: Endoscopic instruments	Upper hand or other costal retractor
Antibiotics	1st (e.g., cefazolin) or 2nd (e.g., cefotetan) generation cephalosporin 2 g iv	⇐
Surgical time	2–4 h	1.5–2 h
Closing considerations	Muscle relaxation required; ±NG suction	⇐
EBL	Open: 500+ mL, with potential for significantly more; Lap: 100–500 mL	100–500 mL
Postop care	PACU → ward or ICU	⇐
Mortality	0–22%	0–1.8% (may be >10% if emergent)
Morbidity	Pulmonary complications: 15% VTE Reoperation: 0–5% Anastomotic leak Sepsis Wound infection Late anastomotic stricture	— ⇐ — ⇐ — ⇐ —

Pain score	7–8	7–8

PATIENT POPULATION CHARACTERISTICS	
Age range	Mostly >50 yr
Male:Female	Male predominance
Incidence	In the United States, people of Korean, Japanese, Latino, and African American race have a higher incidence than Caucasians.
Etiology	Gastric adenocarcinoma, gastrointestinal stromal tumors associated with race, age, alcohol and tobacco use, geographic location, and gastric ulcers
Associated conditions	Weight loss (common); anemia (common); malnutrition (common); VTE

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Operations for Peptic Ulcer Disease.

Suggested Readings

Lee J-H, Lee CM, Son S-Y, et al: Laparoscopic versus open gastrectomy for gastric cancer: long-term oncologic results. Surgery 2014; 155(1):154–64.

Minter RM, Nathin H: Gastric neoplasms. In: Greenfield LJ, et al., edsSurgery: Scientific Principles and Practice, 6th edition. Lippincott Williams & Wilkins, Philadelphia: 2017, 754–67.

Selby LV, DeMatteo RP, Tholey RM, et al: Evolving application of minimally invasive cancer operations at a tertiary cancer center. J Surg Oncol 2017; 115(4):365–70.

GASTRIC OR DUODENAL PERFORATION

SURGICAL CONSIDERATIONS

Description

Patients who present with gastric or duodenal perforations require emergency surgery because they usually have peritonitis at presentation. The primary reason for perforations that present to the emergency room is ulcer disease most likely from Helicobacter pylori infection or from NSAID use. Another cause of gastric perforation

is trauma, but that is not in the scope of this section. Simple closure with an omental patch, also called a **Graham patch**, is the most commonly performed operation to treat a duodenal perforation. It is unusual to perform a definitive ulcer operation unless the patient has failed medical treatment regimens aimed at eradication of H. pylori infection along with proton pump inhibitors to suppress acid production.

Duodenal ulcers are most often caused by a benign process, whereas gastric ulcer perforation without a history of NSAID use is suspicious of a malignant process. For this reason, surgeons may elect to treat a perforated gastric ulcer by resection. Occasionally in patients who have failed maximal medical management of their peptic ulcer disease and who are not systemically ill at the time of operation, some surgeons may perform **vagotomy and pyloroplasty** or **highly selective vagotomy** at the time of closure of the perforation (Fig. 7.2-2).

Many surgeons routinely perform simple closure with **Graham patch** via a **laparoscopic** approach. This requires a few trocars and a pneumoperitoneum and can be combined with abdominal washout and irrigation. If an open approach is used, an upper midline incision is used. The liver is retracted superiorly and the area of perforation identified. An NGT to suction minimizes ongoing leakage from the perforation and decompresses the stomach. Perforation of the stomach may be handled either by resection (see Gastric Resections) or by biopsy and simple suture closure. Perforation of the duodenum is usually repaired by simple suturing of the site. Omentum often is used to buttress (Graham patch) the area of closure of the stomach or duodenum. The abdomen is irrigated and closed.

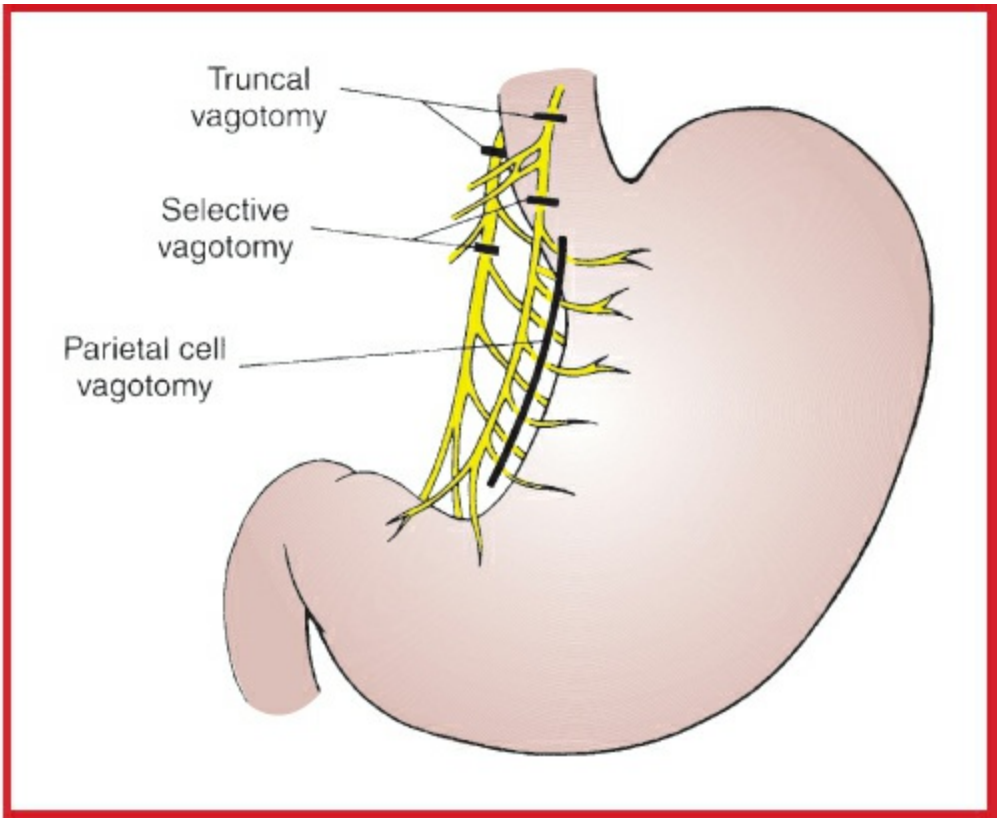

Figure 7.2-2 Types of vagotomy. Heavy lines indicate where vagal trunks are cut.

Variant procedure or approaches

In some patients, **nonoperative management** of perforated ulcer may be appropriate if they have had an upper GI study that shows an ulcer cavity and no extravasation. These patients are treated with NG decompression, antibiotics, and proton pump inhibitors. In general, this has a relatively high likelihood of success if the candidates are chosen well.

Usual preop diagnosis

Free air under diaphragm and peritonitis, perforated peptic ulcer

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE

Position	Supine

Incision	Midline or 3–4 trocars for laparoscopic approach
Special instrumentation	Costal retractor or laparoscopic equipment
Unique considerations	Patients usually have peritonitis.
Antibiotics	Cefotetan 2 g iv or extended spectrum PCN
Surgical time	1 h
Closing considerations	Muscle relaxation required; NG suction
EBL	Minimal
Postop care	PACU → ward
Mortality	5–15%, mostly dependent on patient population
Morbidity	Pneumonia Intra-abdominal abscess Sepsis Wound infection Reperforation
Pain score	7 for open procedure, 3 for laparoscopic

PATIENT POPULATION CHARACTERISTICS

Age range	Adult, more common in socially disadvantaged populations
Male:Female	Previous heavy male predominance still exists for duodenal ulcer, but there has been a significant increase in incidence in gastric perforation in women >65.
Incidence	Fairly common. Stable incidence, but with change in the distribution especially more elderly women.
Etiology	Peptic ulcer disease (PUD); nonsteroidal medications; malignancy (if gastric)
Associated conditions	Malignancy (if perforation is gastric); nonsteroidal medications; steroid use, especially during pulse

	therapy; other risk factors for PUD (e.g., alcoholism, smoking)

Suggested Reading

1. Mulholland MW: Gastroduodenal ulceration. In: Greenfield LJ, et al., eds.Surgery: Scientific Principles and Practice, 6th edition. Lippincott Williams & Wilkins, Philadelphia: 2017, 725–32.

ANESTHETIC CONSIDERATIONS

(Procedures covered: gastric resections; oversew gastric/duodenal perforation operations for peptic ulcer disease; duodenotomy.)

PREOPERATIVE

Patients presenting for gastric surgery generally comprise two groups: (a) those presenting for emergency surgery following GI bleeding or perforation and (b) those presenting with gastric carcinoma. Patients in the first group are often hemodynamically unstable and require rapid preop assessment and appropriate fluid resuscitation.

Respiratory	Patients with GI bleeding are at ↑ risk for aspiration of blood and gastric contents. **Tests:** Consider CXR and ABG if aspiration occurred.
Cardiovascular	Consider hypovolemia if active hemorrhage or peritonitis present. **Tests:** Orthostatic vital signs; ECG, if indicated from H&P
Renal	GI fluid loss can lead to renal and electrolyte abnormalities. **Tests:** Consider electrolytes; BUN; Cr.
Hematologic	Consider GI blood loss occurring acutely or chronically. **Tests:** CBC with Plts, PT/PTT if coagulopathy suspected
Laboratory	Other tests as indicated from H&P
Premedication	Consider midazolam 1–2 mg. Consider H_2-antagonist (ranitidine 50 mg iv slowly), metoclopramide (10 mg

	iv 1 h preop), and Na citrate (30 mL po 10 min preop).
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of a transversus abdominis plane or thoracic epidural block for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA ± epidural for postop analgesia (if hemodynamically stable and no coagulopathy). If postop epidural analgesia is planned, insertion of catheter prior to anesthetic induction is helpful to establish correct placement in the epidural space (accomplished by injecting 5–7 mL of 1% lidocaine via the epidural catheter, eliciting a segmental block).

Induction	The patient with gastric disease or upper GI bleeding is often at risk for pulmonary aspiration, and the trachea should be intubated with a rapid-sequence induction with cricoid pressure. If the patient is clinically hypovolemic, restore intravascular volume (colloid, crystalloid, or blood products) before induction, and titrate induction dose of sedative/hypnotic agents.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Standard maintenance. Balanced anesthesia with inhalational agents and/or propofol infusion and multimodal analgesia (see Appendix B, p. B-3). Maintain muscle relaxation based on nerve stimulator response. Discuss with surgeon the need for postop NG tube. If not needed, place OG tube to evacuate stomach contents intraop. Combined epidural/GA: A local anesthetic (2%

	lidocaine with 1:200,000 epinephrine) can be injected into a thoracic (2–4 mL) or lumbar (3–6 mL q60–90min) epidural catheter to provide both anesthesia and optimal surgical exposure (contracted bowel and profound muscle relaxation). A continuous infusion of local anesthetic (e.g., 2% lidocaine or 0.25% bupivacaine at 2–5 mL/h [lumbar]; 2–4 mL/h [thoracic]) may enhance hemodynamic stability, compared to an intermittent bolus. Be prepared to treat ↓ BP with fluid and vasopressors. GA is administered to supplement regional anesthesia and for amnesia. Systemic sedatives should be minimized during epidural opiate administration as they increase the likelihood of postop respiratory depression. Treat ↓ BP with fluid and vasopressors. If epidural opiates are used for postop analgesia, a loading dose (e.g., hydromorphone 0.6–1.0 mg [lumbar]; 0.4–0.6 mg [thoracic]) may be administered at least 1 h before conclusion of surgery.	
Emergence	The decision to extubate at the end of surgery depends on the patient's underlying cardiopulmonary status and extent of the surgical procedure. Patient should be hemodynamically stable, normothermic, cooperative, and fully reversed from any muscle relaxants and without pulmonary compromise before extubation. Discuss with surgeon local wound infiltration or nerve block (e.g., TAP block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Anticipate large third-space losses IV: 14–16 ga × 1–2 BSS @ 8–12 mL/kg/h Fluid warmer	T&S, consider T&C for 2–4 U PRBC. Plts, FFP, and cryoprecipitate should be administered according to lab tests (Plt count, PT, PTT, DIC screen, thromboelastography). Expect higher fluid

		requirements if epidural used (2° sympathectomy → vasodilation). Maintaining euvolemia is important goal. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors UO ± Arterial line ± CVP	Consider others as indicated by patient's status. Prevent hypothermia: Use forced air warmer, fluid warmer, and warming blanket, warm room temperature, keeping patient covered until ready for prep, etc.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Acute hemorrhage Hypoxemia	

POSTOPERATIVE

Complications	PONV Hemorrhage VTE Ileus Hypothermia	
Multimodal pain management	Epidural analgesics PCA	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with epidural analgesia and/or TAP blocks (see Appendix C, p. C-4).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-	Encourage early enteral nutrition, Foley catheter

	6)	removal, and mobilization. Consider DVT prophylaxis. Chewing gum may promote return of bowel function.
Tests	CXR	If CVL placed periop

Suggested Readings

1. Barton JG: Enhanced recovery pathways in pancreatic surgery. Surg Clin North Am 2016; 96(6):1301–12.
2. Kostakis ID, Alexandrou A, Armeni E, et al.: Comparison between minimally invasive and open gastrectomy for gastric cancer in Europe: a systematic review and meta-analysis. Scand J Surg 2017; 106(1):3–20.
3. Søreide K, Thorsen K, Søreide JA: Strategies to improve the outcome of emergency surgery for perforated peptic ulcer. Br J Surg 2014; 101(1):e51–64.

OPEN OPERATIONS FOR MORBID OBESITY

SURGICAL CONSIDERATIONS

Description

Several studies have demonstrated the superiority of laparoscopic operations for weight loss over open operations. In selected patients (e.g., those with previous upper abdominal surgery), however, open procedures may be appropriate. Open techniques devised to promote weight loss are of two fundamental types: (a) **restrictive procedures**, which work by decreasing the size of the gastric pouch, thereby limiting the amount of food that can be consumed at one time; and (b) **malabsorptive procedures**, which work by bypassing most of the small bowel and creating a state of chronic malabsorption. Of these two general types of procedures, the partitioning procedures may be less effective at promoting weight loss than the malabsorptive procedures but are much more popular because they are associated with far fewer serious side effects.

The **Roux-en-Y gastric bypass** (Fig. 7.2-3) is the most common weight loss operation in the United States. The abdomen is entered through an upper midline incision, and the esophagogastric junction is exposed either by retracting the liver superiorly or by taking down the ligamentous attachments of the lateral segment of the left lobe of the liver and retracting this down and to the patient's right. The upper stomach is mobilized, and two rows of staples are used to partition the stomach into a small proximal and large distal

pouch. A Roux segment of jejunum is then anastomosed to the small proximal pouch to provide drainage. An NG tube is placed, and the abdomen is closed with drains.

Vertical banded gastroplasty (Fig. 7.2-4) has been replaced by the adjustable gastric band. The abdomen is entered similarly to the gastric bypass operation. The pars flaccida is opened by dividing the gastrohepatic ligament. The base of the right crus is identified, and a tunnel behind the stomach is created. The band is then placed and secured. Silastic tubing from the band is then attached to a port placed in the subcutaneous tissue.

An alternative open procedure is the biliopancreatic diversion with duodenal switch, which involves a longitudinal gastric resection with a proximal small bowel bypass. Another alternative open procedure is a **sleeve gastrectomy**, where a gastric tube is created from the GE junction to the pylorus over a 36°F dilator. The remainder of the stomach, based on the greater curvature, is resected. Both of these operations are gaining popularity in the bariatric surgery community.

Variant procedure or approaches

The **jejunoileal (JI) bypass** is of historical interest (Fig. 7.2-5). One of the early bariatric operations in the 1950s, the JI bypass was constructed by connecting the proximal jejunum to the terminal ileum. This procedure has been abandoned mainly because of the many associated complications, including cirrhosis, osteoporosis, kidney stones, and intractable diarrhea.

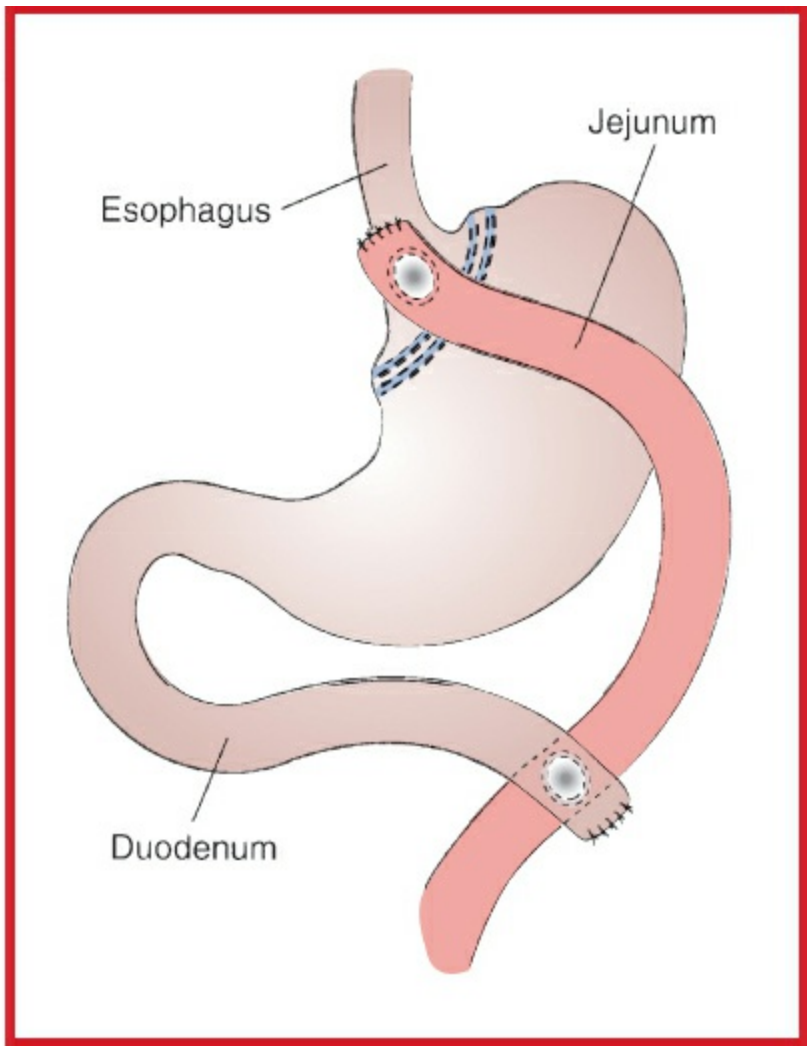

Figure 7.2-3 Proximal Roux-en-Y gastric bypass. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al., eds: Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Usual preop diagnosis

Morbid obesity (BMI > 40 kg/m^2 or >35 kg/m^2 with associated comorbidities). Common obesity-related comorbidities include obstructive sleep apnea, hyperlipidemia, osteoarthritis, diabetes mellitus, GERD, liver disease, respiratory insufficiency, CHF, hypertension, and CAD

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol, and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

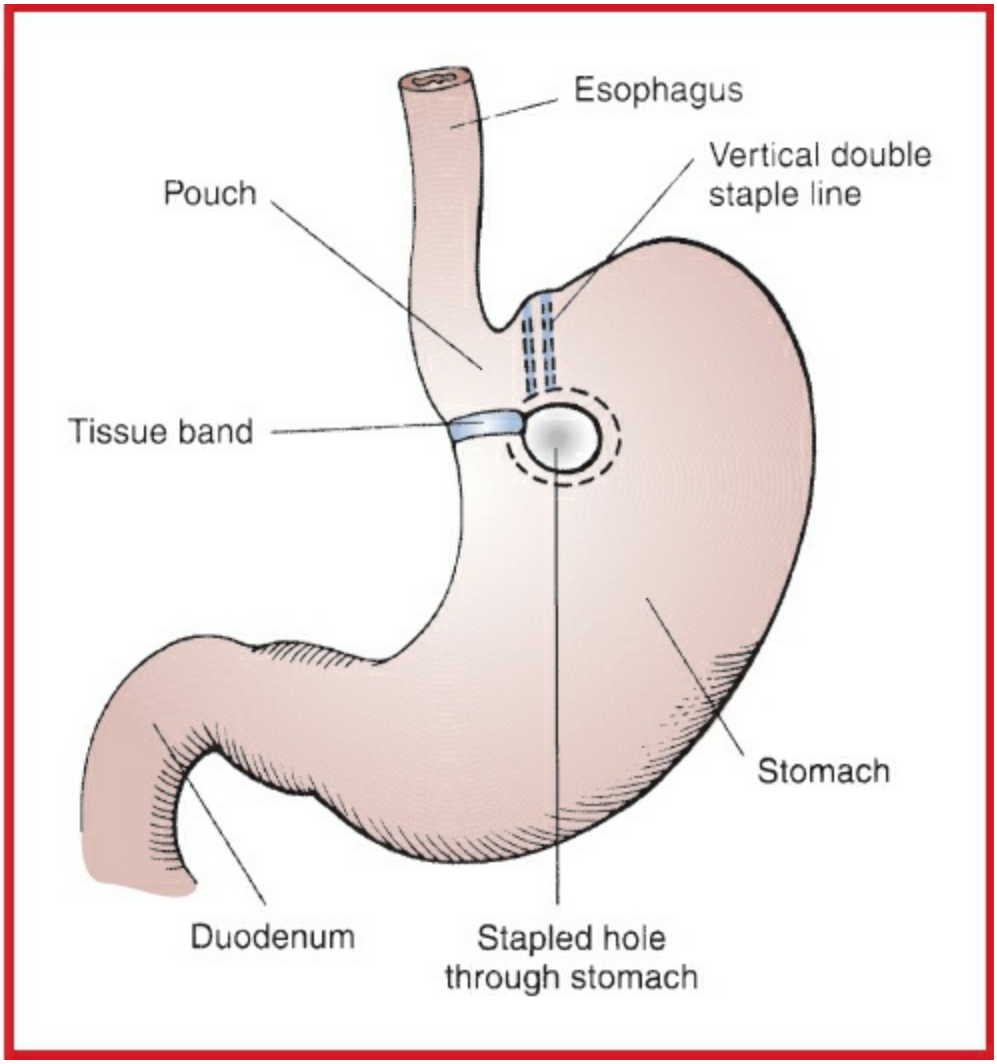

Figure 7.2-4 Vertical banded gastroplasty.

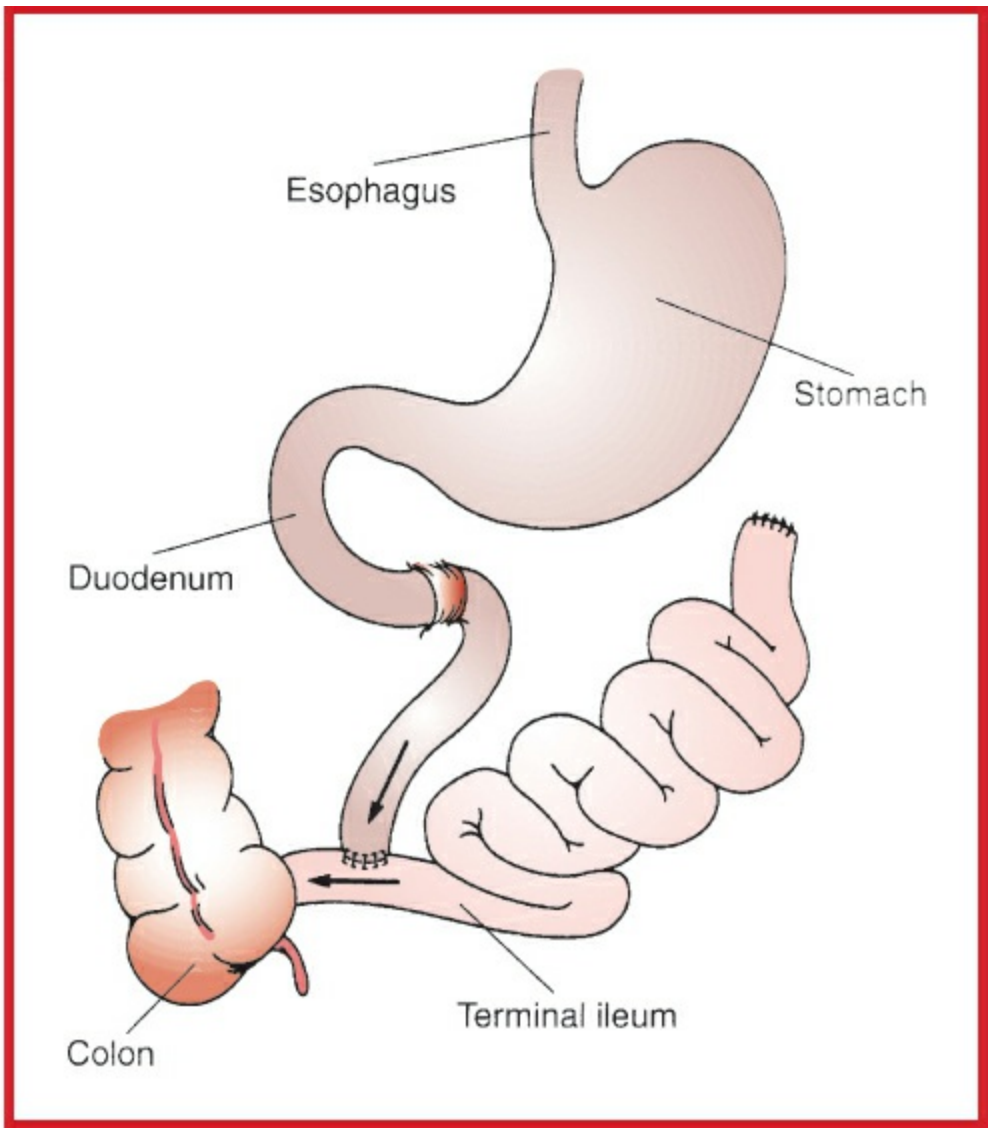

Figure 7.2-5 Schematic representation of jejunoileal bypass. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al., eds:Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

SUMMARY OF PROCEDURE (SLEEVE GASTRECTOMY OR ROUX-Y)

Position	Supine (Fig. 7.2-6) with reverse Trendelenburg
Incision	Midline
Special instrumentation	Large OR tables; heavy-duty retractors; special stapling devices
Unique considerations	Prophylactic cholecystectomy often advocated in symptomatic patients. Pneumatic compression boots may not be large enough; heparin (5000 U sc 2 h

	preop, then q12h) used commonly. ↑↑ aspiration risk + potentially difficult airway
Antibiotics	Cefazolin 3 g iv (or 2 g iv if total body weight <120 kg)
Surgical time	2–3 h
Closing considerations	Anticipate 20 min closure time
EBL	<500 mL
Postop care	Postop ventilation may be necessary; VTE precautions
Mortality	0.5–1.6%
Morbidity	Wound infection: 4–8% Anastomotic leak: 3% Dehiscence: 1.6% PE: 1–1.6%
Pain score	7

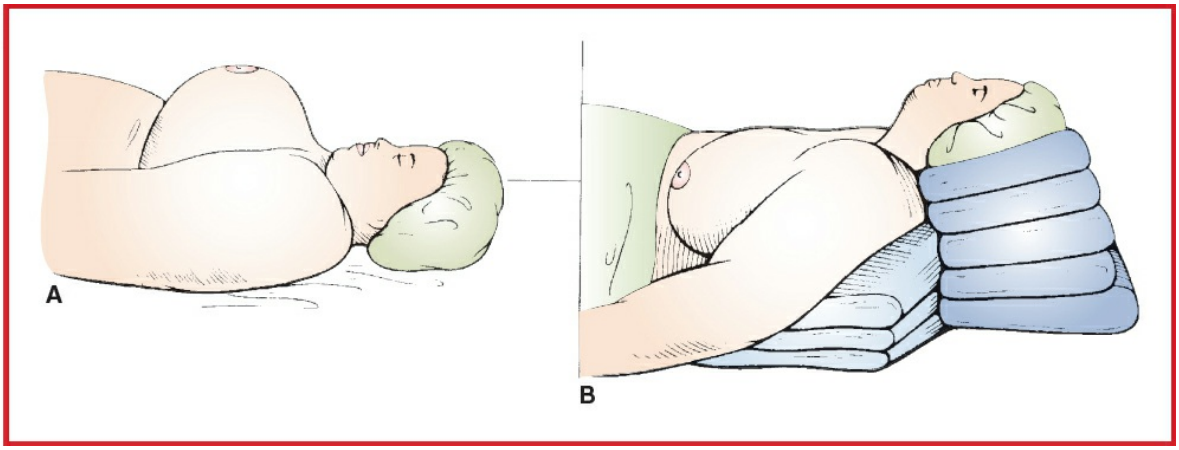

Figure 7.2-6 **A:** In standard supine position, the atlanto-occipital gap of morbidly obese patient is obliterated by fat, and access for laryngoscope is hindered by large breasts. **B:** By elevating the shoulders and occiput so that head is in the "sniffing" position, airway access is greatly facilitated.

PATIENT POPULATION CHARACTERISTICS

Age range	Adult
Male:Female	<1:1 for disease but 80% of patients who undergo surgery are female

Incidence	20% US population considered morbidly obese
Etiology	Multifactorial
Associated conditions	Sleep apnea ± CO_2 retention; CAD/CHF/cardiomyopathy; pulmonary HTN/systemic HTN; diabetes; unusually high risk of DVT and PE; GERD

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Obesity is associated with many chronic medical problems. Morbidity and mortality rise sharply with increasing age and BMI. Obesity, and length of exposure to obesity, increase the risk of hospital admission and lengthen hospital stay. Medical comorbidities must be optimized before elective bariatric surgery. Evaluate any patient who has had previous bariatric surgery for metabolic changes that can include protein, vitamin, iron, and calcium deficiencies.

Review a list of all current medications the patient is taking, including nonprescription appetite suppressors and diet drugs. Many of these drugs can have important side effects. For example, the medication Contrave® is a combination of naltrexone, which is a potent, long-acting opiate antagonist, and the antidepressant bupropion and should be held several days prior to surgery. Another weight loss medication, sibutramine, works in the brain by inhibiting the reuptake of norepinephrine, serotonin, and dopamine, producing a feeling of "anorexia," which limits food intake. Sibutramine has been implicated as a cause of dysrhythmias and hypertension. Orlistat® blocks digestion and absorption of dietary fat by binding lipases in the gastrointestinal tract and can cause deficiencies in fat-soluble vitamins (A, D, E, K). A reduction in vitamin K levels can increase the anticoagulation effects of coumadin (also see Anesthetic Considerations for Laparoscopic Bariatric Surgery).

Respiratory	Increased O_2 consumption and CO_2 production (e.g., ↑ basal metabolic rate), ↓ chest-wall compliance (↓ 20–60%) with normal lung compliance. ↓ ERV and FRC; so tidal breathing may fall within the range of closing capacity → V/Q abnormalities. Supine position further ↓ FRC → worsening hypoxemia. MV is required to remain normocarbic. There is a normal

	response to CO_2 unless patient develops the obesity hypoventilation (Pickwickian) syndrome (↑ $PaCO_2$, ↓ PaO_2, loss of hypercarbic drive, sleep apnea, hypersomnolence, polycythemia, pulmonary HTN, CHF). **Tests:** CXR; PFTs (FVC, FEV_1, $MMEF_{25–75}$ ± bronchodilators; room-air ABG)
Cardiovascular	Blood volume and CO ↑ with increasing weight. HTN is very common (use correct size BP cuff). LV dysfunction may be present; patient unable to increase CO or tolerate ↑ blood volume. Pulmonary HTN may be present in OSA. Obesity is a risk factor for CAD and sudden death. Anticipate problems with vascular access. **Tests:** ECG; others as indicated from H&P. (Patient with SOB may require ECHO for LV function, as SOB can have a cardiac or pulmonary etiology.)
Endocrine	Glucose intolerance and diabetes mellitus (DM) common. **Tests:** Fasting glucose
Hepatic	Liver function is often abnormal. Drug metabolism can be significantly affected. Combined with altered pharmacokinetics, many drugs (e.g., midazolam and vecuronium) may have unpredictably prolonged action.
Gastrointestinal	↑ intra-abdominal pressure, gastric volume, and acidity, with ↑ incidence of hiatal hernia, make this patient population at risk for pulmonary aspiration of gastric contents. There is particular risk in patients with previous restrictive bariatric surgery.
Airway	Obese patients can have airway problems including frequent difficult mask ventilation. Careful airway examination (e.g., mouth opening, Mallampati classification, thyromental distance, neck ROM) is paramount. Awake fiber-optic intubation should be considered if difficult airway access is anticipated.

	Establish availability of OR table large enough to accommodate morbidly obese patient. Special tables are now available.
Hematologic	Polycythemia may occur 2° chronic hypoxemia. **Tests:** CBC
Laboratory	Other tests as indicated from H&P
Premedication	Sedatives are best avoided for patients with OSA. A small dose of iv midazolam (0.5–1.0 mg) may be appropriate for the especially anxious patient. In the bariatric patient, intramuscular medications can be erroneously injected into adipose tissues. Consider anticholinergics if performing awake fiber-optic intubation (glycopyrrolate 0.2 mg iv 30 min preop). Consider full-stomach precautions, including a nonparticulate antacid (3 M Na citrate) 30 mL, 10 min prior to induction.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of a thoracic epidural block for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA ± epidural for postop analgesia in open surgeries. If using a combined anesthetic approach, placement of an epidural catheter should be accomplished before induction, with the patient in the sitting position. A bilateral sensory block (using 5–7 mL 2% lidocaine) helps confirm correct placement of the catheter within the epidural space. Verification of placement is particularly important in this population because regional anesthesia (e.g., transversus abdominis plane block) in the obese patient may be technically more difficult.

Induction	A rapid-sequence induction with propofol (2–2.5 mg/kg LBW) and succinylcholine (1 mg/kg TBW) combined with

	cricoid pressure is optimal. Mask ventilation and ET intubation may be difficult (2° to increased oxygen consumption and rapid desaturation, redundant tissue, cervical immobility). Following successful intubation and induction of anesthesia, an OG/NG tube should be placed and the stomach contents suctioned. Lipophilic drugs have a greater apparent volume of distribution; however, since cardiac output governs drug distribution and is related to lean body weight (LBW), induction doses of hypnotics and opioids should be given based upon LBW (e.g., male LBM = 1.1[weight] − 128[weight/height]^2).
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Patients should be ventilated with an FiO_2 of 0.5–1.0 and tidal volumes of 10–12 mL/kg IBW (ideal body weight [kg] = height [cm] − 100). Inhalational agents (desflurane, sevoflurane, isoflurane) may be given. There are only modest differences in inhalational agent pharmacokinetics between obese and nonobese patients. Open Procedures—**Combined epidural/GA**: A local anesthetic (2% lidocaine with 1:200,000 epinephrine) can be injected into a thoracic (3–5 mL) or lumbar (5–10 mL q60min) epidural catheter to provide both anesthesia and improved surgical exposure (contracted bowel and profound muscle relaxation). A continuous infusion of local anesthetic (e.g., 2% lidocaine or 0.25% bupivacaine at 5–10 mL/h [lumbar], 3–5 mL/h [thoracic]) may enhance hemodynamic stability. The dose of local anesthetic given via epidural catheter should be decreased to 75% of normal dose. Be prepared to treat ↓ BP with fluid and vasopressors (ephedrine 5–10 mg iv, phenylephrine 50–100 mcg iv). GA is administered to supplement regional anesthesia and for amnesia. Sedative drugs (opiates, benzodiazepines, etc.) should be minimized in the presence of epidural opiates, as they increase the likelihood of postop respiratory depression. If epidural

	opiates are used for postop analgesia, a loading dose (e.g., hydromorphone 0.6–1.0 mg with lumbar catheter and 0.4–0.6 mg for thoracic) should be administered 1–2 h before end of surgery.	
Emergence	The decision to extubate at the end of open surgery depends on patient's underlying cardiopulmonary status and the extent of the surgical procedure. Patients should be hemodynamically stable, normothermic, alert, cooperative, and fully reversed from any muscle relaxants before extubation. Elective ICU admission for postop care may be appropriate. Following laparoscopic surgery, in contrast, patients typically are extubated and admitted to PACU. Discuss with surgeon local wound infiltration or nerve block (e.g., TAP block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Anticipate large fluid loss. IV: 14–16 ga × 1–2 BSS @ 10–15 mL/kg/h T&S for 2 U PRBC. Warm fluids.	Third-space losses greatly exceed blood loss. Guide fluid management by UO, filling pressure. Euvolemia is an important goal. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors UO ± Arterial line	Invasive monitoring as clinically indicated. Arterial line if noninvasive BP unreliable 2° extremity size
Positioning	Supine position = ↓ FRC ✓ and pad pressure points ✓ eyes NB: Avoid Trendelenburg	Supine positioning → ↓ lung volumes, which may ↑ V/Q mismatch → hypoxemia. This is exacerbated by use of the Trendelenburg position, which usually is not well tolerated by morbidly obese

Complications	Hypoxemia 2° ↓ FRC	patients. 100% O_2 → absorption atelectasis

POSTOPERATIVE

Complications	Hypoxemia Hypercarbia VTE Atelectasis	Recover patient in sitting position to improve ventilatory mechanics. Give supplemental O_2. Verify VTE prophylaxis.
Multimodal pain management	Epidural analgesia: Hydromorphone (0.6–1.0 mg with lumbar cath and 0.4–0.6 mg for thoracic cath load then 0.1–0.3 mg/h infusion) PCA	If epidural is used for postop analgesia, pain service management recommended. Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with epidural analgesia and/or TAP blocks (see Appendix C, p. C-4).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum may promote return of bowel function.
Tests	ABG CXR	Others as clinically indicated. CXR for central line placement

Suggested Readings

1. Alvarez A, Goudra BG, Singh PM: Enhanced recovery after bariatric surgery.Curr Opin Anaesthesiol 2017; 30(1):133–9.
2. Barton JG: Enhanced recovery pathways in pancreatic surgery. Surg Clin North Am 2016; 96(6):1301–12.
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9. Lukosiute A, Karmali A, Cousins JM: Anaesthetic preparation of obese patients current status on optimal work-up. Curr Obes Rep 2017; 6(3):229–37.
10. Ogunnaike BO, Jones SB, Jones DB, et al: Anesthetic considerations for bariatri surgery. Anesth Analg 2002; 95(6):1793–805.
11. Perilla V, Sollazzi L, Bozza P, et al: The effects of the reverse Trendelenburg position on respiratory mechanics and blood gases in morbidly obese patients during bariatric surgery. Anesth Analg 2000; 91:1520–5.

GASTROSTOMY PLACEMENT

SURGICAL CONSIDERATIONS

Description

A **gastrostomy** is a tube placed through the abdominal wall directly into the stomach. Such tubes can be used for gastric decompression or for feeding, and they may be permanent or temporary. Patients undergoing gastrostomy placement often have neurologic impairment that compromises their ability to handle oral secretions and increases their risk of aspiration. **Percutaneous endoscopic gastrostomy (PEG)**, in contrast to the other techniques, most commonly is performed using iv sedation and local anesthesia.

Variant procedure or approaches

The traditional **Stamm gastrostomy** usually is placed at the time of a **laparotomy** performed for another purpose; or it may be performed through a separate, small laparotomy incision in patients in whom endoscopic placement is not possible for technical reasons. The incision may be upper midline or transverse directly over the

stomach. The anterior wall of the stomach is identified, and two purse-string sutures are placed in the stomach around the site where the tube will enter. The gastrostomy tube is introduced through the abdominal wall directly over the intended site of entry into the stomach. A small hole is made in the stomach in the center of the purse-string sutures, the tube is introduced into the stomach, and the purse-strings are tied securely around the tube. The wound is then closed. GA usually is preferred, but the operation may be performed under local anesthesia in thin patients.

The **Janeway gastrostomy**, a technical modification, also requires a laparotomy. The greater curvature of the stomach is identified and a stapler placed across a portion of this, creating a tube that arises from the main body of the stomach. The staple line may be oversewn, and then the end of the tube is brought through the abdominal wall and matured to the skin as a small stoma. This allows for permanent access to the stomach with removal of the tube between feedings and is useful in patients with long-term dependence on gastrostomy access. The Janeway gastrostomy is rarely used, although young patients with neurologic impairment who are expected to need lifetime gastrostomy feeding are good candidates.

For a **PEG**, the stomach is intubated endoscopically and the gastric and abdominal walls punctured under endoscopic guidance. The gastrostomy tube is introduced through the mouth and passed through the stomach and abdominal wall from inside out. In most centers, this has become the most common technique of gastrostomy placement due to its simplicity, and, in many patients, it can be in many patients, it can be performed under local anesthesia with MAC. Previous gastric operations may make endoscopic placement difficult or dangerous, as may some obstructing lesions of the esophagus or pharynx. To avoid damage to the back wall of the stomach the anesthesiologist may be asked to inject air forcefully into the stomach.

Usual preop diagnosis

Temporary gastrostomies often are used after major abdominal surgery as an alternative to NG suction. Percutaneous gastrostomies often are placed in patients with advanced malignancy and intestinal obstruction or inadequate oral intake and in patients with neurologic impairment and difficulty eating

ERAS: Preop counseling by the surgeon/anesthesiologist should include if appropriate limiting NPO duration, alcohol and, smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, the possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Stamm	Janeway	PEG
Position	Supine	⇐	⇐
Incision	Midline or transverse	⇐	Puncture
Special instrumentation	None	⇐	Endoscope, percutaneous gastrostomy kit
Antibiotics	± Cefazolin 1–2 g iv	⇐	⇐
Surgical time	45 min	1 h	0.5–1 h
Closing considerations	Muscle relaxation for closure	⇐	None
EBL	Minimal	⇐	⇐
Mortality	Minimal	⇐	⇐
Morbidity	Wound infection: 2.1–9% Hemorrhage: 0.9–1.1% Aspiration pneumonia: 2.2% Failure to function: 2.2%	⇐ ⇐ ⇐ ⇐	— ⇐ 1.6% —
Pain score	4–5	5	1–2

PATIENT POPULATION CHARACTERISTICS

Age range	All ages, though with peaks in infancy and the elderly
Male:Female	~1:1
Incidence	Common
Etiology	See Preop Diagnosis, above.
Associated conditions	Gastrostomy placed at time of laparotomy, when NG drainage is anticipated for prolonged period. For feeding in the neurologically impaired or in those with complex upper digestive difficulties. Advanced malignancy (for either feeding or palliative decompression)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Ostomy Procedures in Intestinal Surgery.

Suggested Readings

1. Pennington C: To PEG or not to PEG. Clin Med 2002; 2(3):250–5.
2. Schrag SP, Sharma R, Jaik NP, et al: Complications related to percutaneous endoscopic gastrostomy (PEG) tubes. A comprehensive clinical review. J Gastrointestin Liver Dis 2007; 16(4):407–18.

We gratefully acknowledge the past contributions of surgeon, Myriam J. Curet, MD, FACS.

CHAPTER 7.3

Intestinal Surgery

SURGEON
Jeffrey A. Norton, MD

ANESTHESIOLOGIST
Clifford A. Schmiesing, MD

DUODENOTOMY

SURGICAL CONSIDERATIONS

Description

A **duodenotomy** is performed to ligate a bleeding vessel at the base of a duodenal ulcer or to perform some procedure on the ampulla of Vater or the duct of Santorini or to remove a low-grade duodenal tumor. It is important, therefore, to be familiar with the anatomy of the proximal duodenum in relation to the major and minor pancreatic duct orifices (Fig. 7.3-1). The duodenotomy may be made longitudinally or transversely, depending on the surgeon's preference. A transverse opening allows one to close the duodenotomy without tension; however, it must be made made carefully to ensure adequate exposure. Therefore, a longitudinal duodenotomy is preferred. With mobilization, it can be closed transversely. Bleeding vessels at the base of an ulcer must be secured with suture ligatures. Care must be taken to avoid perforating the duodenum when performing a sphincterotomy.

Usual preop diagnosis

Duodenal ulcer; impacted common duct stone; chronic pancreatitis 2° alcoholism, gallstones, pancreatic divisum, or other obstructions of the main pancreatic duct; benign ampullary tumor; duodenal neuroendocrine tumor

ERAS: **Preop counseling by the surgeon and anesthesiologist should include limiting nothing by mouth (NPO) duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, deep venous thrombosis (DVT) prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop.** **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

SUMMARY OF PROCEDURES

Position	Supine
Incision	Midline abdominal or subcostal
Unique considerations	Magnifying glasses, if operation involves lesser pancreatic sphincter
Antibiotics	Cefoxitin 2 g iv preop
VTE prophylaxis	Heparin 5000 units sq
Surgical time	1–2 h
Closing considerations	Secure closure of the duodenum without tension usually two layers
EBL	Minimal
Postop care	±NG decompression
Mortality	<0.5%
Morbidity	Duodenal leak: <2%; postop pancreatitis: <3%
Pain score	6–8

PATIENT POPULATION CHARACTERISTICS

Age range	Any age
Male:Female	1:1
Incidence	Not uncommon
Etiology	Duodenal ulcer; impacted common duct stone; villous tumors of ampulla; chronic pancreatitis; pancreatic divisum
Associated	Bleeding duodenal ulcer (50–60%); chronic

conditions	pancreatitis (20–25%); impacted common duct stones (10–15%); tumor (2%)

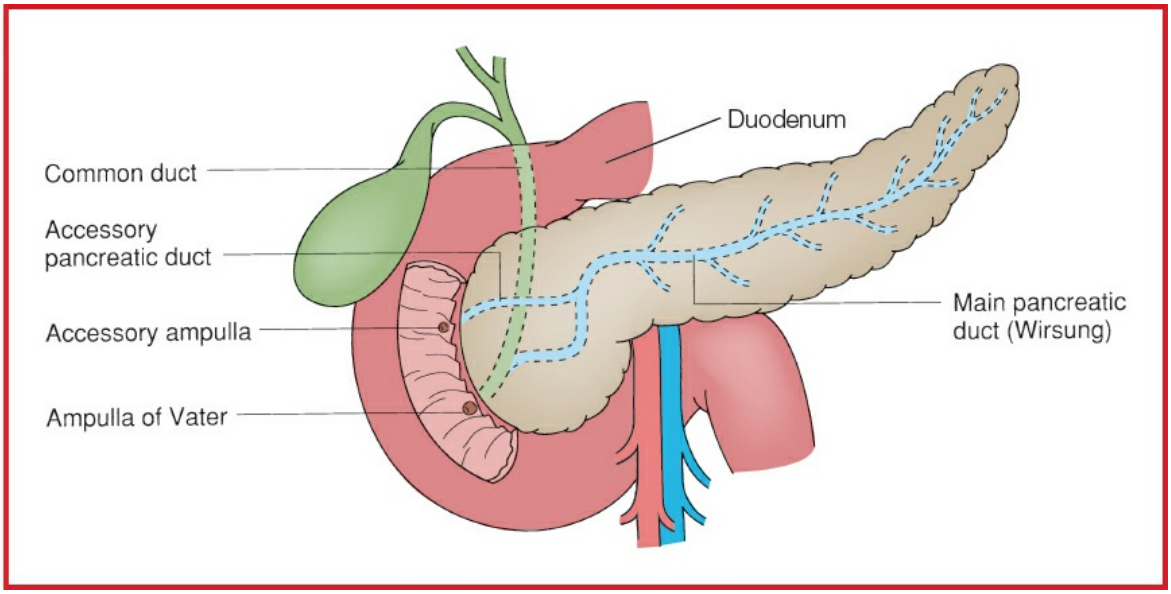

Figure 7.3-1 Anatomy of pancreatic ductal system. In 30% of patients, the accessory duct ends blindly. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et alSurgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Operations for Peptic Ulcer Disease, Stomacl Surgery.

Suggested Readings

1. Cisco RM, Norton JA: Surgery for gastrinoma. Adv Surg 2007; 41:165–76.
2. Norton JA, Foster DS, Ito T, et al: Gastrinomas: medical or surgical treatment Endocrinol Metab Clin North Am 2018; 47(3):577–601.

OPEN APPENDECTOMY

SURGICAL CONSIDERATIONS

Description

Open appendectomy is performed for appendicitis or suspected appendicitis; however, it has been largely replaced by the **laparoscopic** approach (see p. 667). The negative laparotomy rate has been reduced by the judicious use of preop computed tomography (CT) examination. Through a right lower quadrant (RLQ) (McBurney's) o

right paramedian incision, the cecum is exposed and pulled into the wound (Fig. 7.3-2). The appendix is then delivered through the wound; and the mesoappendix is clamped, cut, and ligated. The appendix is removed by crushing, ligating, and then transecting the base. The appendiceal stump may be invaginated into the wall of the cecum or left alone. In some instances, it may be easier to divide the base of the appendix before delivering the appendix into the wound. The wound should be left open, and soft drains are used in cases of a perforated appendix. In children, the appendix may be inverted and allowed to slough off internally. In laparoscopic procedures, the appendix is usually transected with an endoscopic stapling device. This method is also being used in open procedures.

Variant procedure or approach

Laparoscopic appendectomy

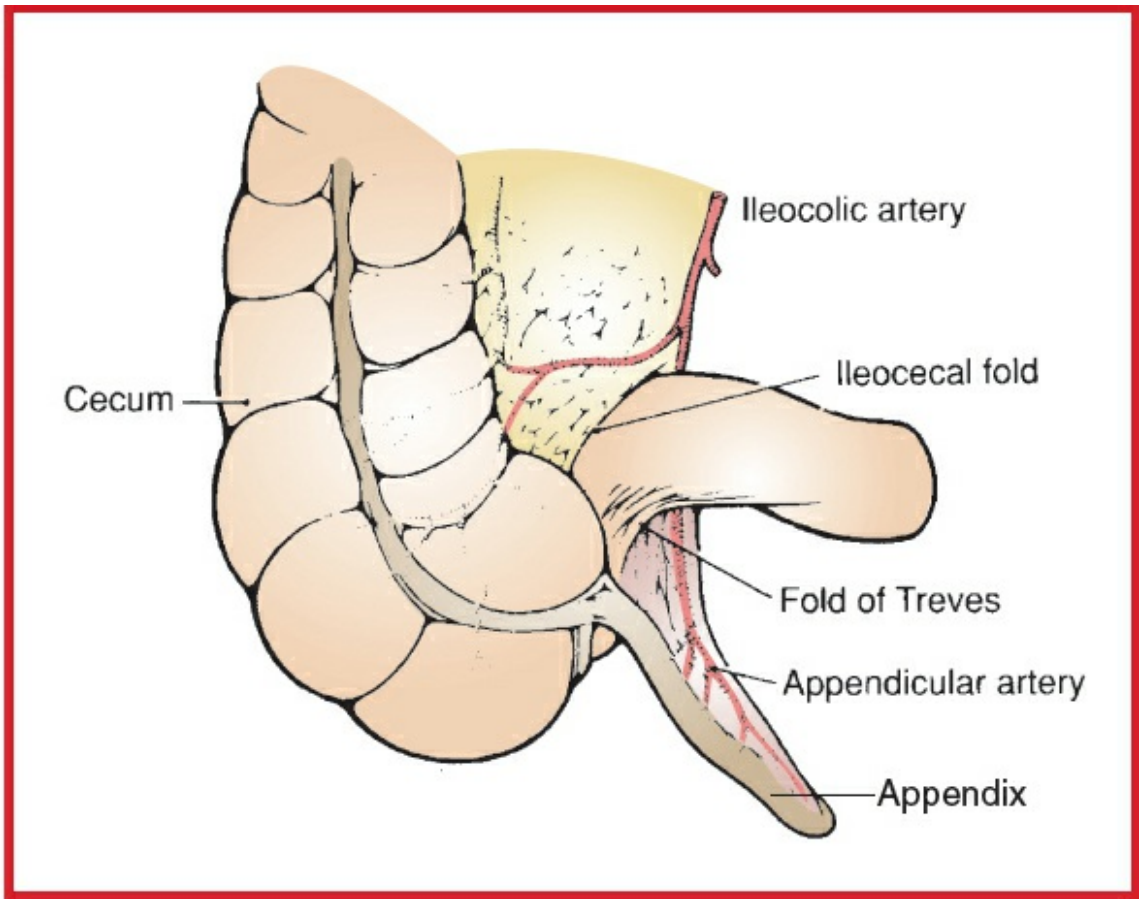

Figure 7.3-2 Relevant anatomy for appendectomy. (Reproduced with permission from Scott-Conner CEH, Dawson DL: Operative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

Usual preop diagnosis

Appendicitis

ERAS: **Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, the possibility of NG tube, and urinary drain postop.** **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

Position	Supine
Incision	RLQ (McBurney's) or right paramedian
Unique considerations	Variation in stump closure; NG tube if prolonged ileus expected
Antibiotics	Cefoxitin 2 g iv preop
VTE prophylaxis	Heparin 5000 units sq
Surgical time	1 h
Closing considerations	Skin wound should not be closed when the appendix is perforated. Drain in the presence of well-defined abscess cavity.
EBL	<75 mL
Postop care	Wound care when left open
Mortality	Perforated: 2% Nonperforated: <0.1%
Morbidity	Pelvic, subphrenic, or intra-abdominal abscess (perforation): 20% Wound abscess: <5% Fecal fistula: <1% Wound hematoma: <0.5% Ileus: variable
Pain score	5–7

PATIENT POPULATION CHARACTERISTICS

Age range	Any age
Male:Female	1:1

Incidence	1/15 persons
Etiology	Obstruction (80–90%); fecaliths (75%); carcinoid tumors (<5%)
Associated conditions	None

ANESTHETIC CONSIDERATIONS

See Anesthetic Consideration following Excision of Meckel Diverticulum.

Suggested Readings

1. Ikard RW, Federspiel CF: Laparoscopic versus open appendectomy. N Engl J Mec 1995; 333(13):881–2.
2. See Suggested Readings following Excision of Meckel diverticulum, pp. 579.

EXCISION OF MECKEL DIVERTICULUM

SURGICAL CONSIDERATIONS

Description

Meckel diverticulum is a true congenital diverticulum, usually arising within 100 cm of the ileocecal valve. It was first described by Meckel in 1809. Excision of Meckel diverticulum is indicated for bleeding, obstruction, perforation, inflammation, intussusception, and when there is a palpable mass near the base of the diverticulum. Ectopic mucosa is present in roughly 50% of symptomatic patients, with gastric mucosa the most frequent. After entering the peritoneal cavity, the distal ileum, along with the diverticulum, is delivered into the wound. The diverticulum is excised, and the wound is closed in two layers. Following excision of the diverticulum, care must be taken not to narrow the bowel lumen during closure. If a diagnosis can be made preop, a **laparoscopic** approach may be used (see Laparoscopic Bowel Resection).

Usual preop diagnosis

Meckel diverticulum

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options,

physiotherapy plan, the possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

PATIENT POPULATION CHARACTERISTICS	
Position	Supine
Incision	Midline abdominal or RLQ (McBurney's)
Antibiotics	Cefoxitin 2 g iv preop
VTE prophylaxis	Heparin 5000 units sq
Surgical time	1–1.5 h
EBL	<100 mL
Mortality	<0.5%
Morbidity	Wound infection: 5% Pulmonary complication: <5% Anastomotic leak: <1%
Pain score	6–8

PATIENT POPULATION CHARACTERISTICS	
Age range	<40 yr
Male:Female	3:1
Incidence	0.3–2.5%
Etiology	Congenital
Associated conditions	Exomphalos; esophageal atresia; anorectal atresia; gross malformations of the CNS or CV system

ANESTHETIC CONSIDERATIONS

(Procedures covered: open appendectomy; excision of Meckel diverticulum)

PREOPERATIVE

This patient population is generally fit and healthy, apart from their acutely presenting illness. These patients are at risk for aspiration pneumonitis due to delayed gastric emptying, ileus, or frank bowel obstruction → full-stomach precautions are appropriate.

Surgery for appendicitis is one of the most common nonobstetric procedures performed on the pregnant patient (~1/1500 pregnancies).

Respiratory	Respiratory impairment may occur 2° the acute abdominal pain and splinting. Tachypnea and hyperpnea can be heralding Sx of appendiceal perforation and sepsis. Patients with an acute abdomen should be treated as if they have full stomachs. **Tests:** As indicated from H&P
Cardiovascular	May be dehydrated from fever, emesis, and ↓ oral intake → ↑ HR + ↑ BP (2° pain) or ↓ BP (sepsis, hypovolemia). Assess volume status appropriately, and hydrate adequately before proceeding with anesthetic induction. **Tests:** ECG, if indicated from H&P
Gastrointestinal	Patient typically has abdominal pain with N/V. Muscular resistance to palpation of the abdominal wall frequently parallels the severity of the inflammatory process. With spreading peritoneal irritation (as with perforation), the patient will develop abdominal distension and paralytic ileus. Consider electrolyte abnormalities 2° N/V. **Tests:** Electrolytes
Hematologic	Leukocytosis (10,000–18,000) with moderate left shift. Look for hemoconcentration which may signify dehydration. **Tests:** CBC
Laboratory	Other tests as indicated from H&P
Premedication	Full-stomach precautions. Consider midazolam 1–2 mg iv. Opiate medications often delayed or minimized until diagnosis made. Opiate analgesics may be used during the evaluation of an acute abdomen including appendicitis.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with the surgeon the possibility of a

	transversus abdominis plane or thoracic epidural block for postop pain management. Consider preop acetaminophen 1000 mg po with a sip of water. Consider aprepitant 40 mg po with a sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA, with rapid-sequence iv induction, followed by ET intubation (see full-stomach precautions).

Induction	Rapid-sequence induction of anesthesia. Restore intravascular volume before anesthetic induction if the patient is hypovolemic.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.	
Maintenance	Standard maintenance. Evacuate stomach with OG or NG tube. Maintain muscle relaxation based on nerve stimulator response.	
Emergence	Patient should be extubated awake after return of airway reflexes. Discuss with the surgeon local wound infiltration or nerve block (e.g., TAP block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 16–18 ga × 1 BSS @ 5–8 mL/kg/h	See Goal-Directed Fluid Management, Appendix K, p. K-4
Monitoring	Standard monitors	Others, as indicated by the patient's status
Positioning	✓pad pressure points	

	✓eyes	
Complications	Bleeding Open technique may follow unsuccessful laparoscopic approach.	

POSTOPERATIVE

Complications	Sepsis (possible with appendiceal rupture) Paralytic ileus Atelectasis PONV	Adequate antibiotic coverage Adequate pain control, incentive spirometry, early ambulation
Multimodal pain management	Multimodal approach	Consider combining PCA or fixed dose po/iv opiates with acetaminophen, po or iv NSAIDs, and gabapentin. Emphasize a multimodal approach combining nonopioid and bolus/PCA opioid analgesics with epidural analgesia and/or TAP blocks (see Appendix C, p. C-4).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum may promote return of bowel function.
Tests	As indicated clinically	

Suggested Readings

1. Liu Q, Jiang H, Xu D, et al: Effect of gum chewing on ameliorating ileus followin

colorectal surgery: a meta-analysis of 18 randomized controlled trials. Int J Surg 2017; 47:107–15.
2. Reitman E, Flood P: Anaesthetic considerations for non-obstetric surgery during pregnancy. Br J Anaesth 2011; 107:i72–8.

ENTEROSTOMY

SURGICAL CONSIDERATIONS

Description

Enterostomy is performed for stenting the small intestine with a long tube for feeding purposes, for bypassing small or large bowel obstructions, and as a permanent or temporary procedure following **proctocolectomy**. An intestinal tube is either purse-stringed into the small bowel and brought through the abdominal wall, or the intestine itself is brought to the exterior and fashioned into a stoma. Different tubes are used for feeding, according to surgeon's preference. After purse-stringing the tube in the bowel, the seromuscular layer of the jejunum is sutured over the tube for a distance of 3–4 cm before exiting through the abdominal wall. This is called a **Witzel feeding jejunostomy**. The **Brooke ileostomy** is created by bringing a 2-inch segment of the ileum through an abdominal wall stab wound. The ileum is folded back on itself and sutured to the skin edge or dermis (Fig. 7.3-3). Some surgeons secure the ileum to the underlying peritoneum and fascia, but this is not necessary.

Variant procedure or approaches

There are various intestinal or drainage tubes that may be inserted into the bowel, depending on the function required. For example, certain tubes are used for feeding, whereas others may be used for drainage or decompression.

Usual preop diagnosis

Intestinal obstruction due to extensive adhesions; following removal of the large intestine (including the rectum); for enteral feedings

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, the possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

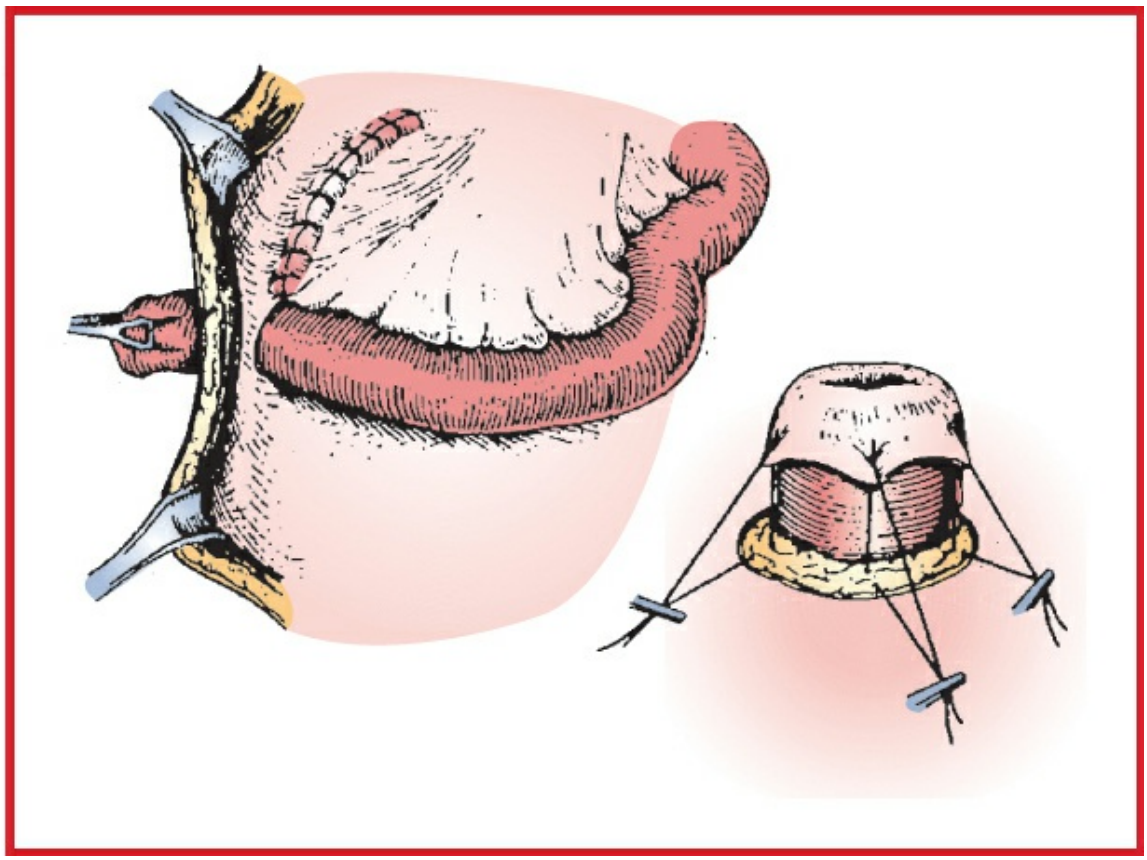

Figure 7.3-3 Brooke ileostomy. (Reproduced with permission from Hardy JD:Rhoad's Textbook of Surgery, 5th edition. JB Lippincott, Philadelphia: 1977.)

SUMMARY OF PROCEDURES

	Enterostomy	Ileostomy
Position	Supine	⇐
Incision	Midline abdominal	⇐
Antibiotics	Cefoxitin 2 g iv preop	⇐
VTE prophylaxis	Heparin 5000 units sq	⇐
Surgical time	1–1.5 h	⇐
Closing considerations	Securing tube to abdominal wall	Viable stoma
EBL	<100 mL	⇐
Postop care	Tube irrigation	Stoma care
Mortality	<0.5%	⇐

Morbidity	Ileus: 60–70% Wound infection: <5%	⇐ ⇐ Stoma necrosis: <2%
Pain score	5–6	5–6

PATIENT POPULATION CHARACTERISTICS	
Age range	20–65 yr
Male:Female	1:1
Incidence	Common
Etiology	Intestinal obstruction (60–70%); diseases resulting in total proctocolectomy (10–15%); inability to eat (5–10%)
Associated conditions	Inflammatory bowel disease (IBD); intestinal adhesions; inability to eat

ANESTHETIC CONSIDERATIONS FOR OSTOMY PROCEDURES

(Procedures covered: enterostomy; continent ileostomy; gastrostomy; gastrojejunostomy)

PREOPERATIVE

This patient population is very diverse and includes those with IBD and cancer and those presenting post-CVA and trauma. Thus, the population ranges from the otherwise healthy to the chronically and critically ill. Many of these patients have abnormal protective airway reflexes and are at risk of aspiration of gastric contents.

Respiratory	Patients post-CVA or head trauma may have abnormal laryngeal reflexes and difficulty swallowing, making them prone to aspiration of gastric contents and associated pneumonitis (evaluate gag reflex). **Tests:** Consider CXR to r/o pneumonia. Consider ABG.
Cardiovascular	Patients may be hypovolemic 2° chronically poor po intake.

	Tests: ECG; orthostatic vital signs
Musculoskeletal	Patients often frail and debilitated (e.g., post-CVA)
Gastrointestinal	Patients often malnourished and prone to electrolyte abnormalities 2° poor po intake **Tests:** Electrolytes; BUN; Cr
Laboratory	CBC with differential; others as indicated from H&P
Premedication	Depends on patient status. Titrate small doses of benzodiazepines (midazolam 0.25–0.5 mg iv) or opiate (fentanyl 25–50 mcg iv).
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with the surgeon the possibility of a transversus abdominis plane or thoracic epidural block for postop pain management. Consider preop acetaminophen 1000 mg po with a sip of water. Consider aprepitant 40 mg po with a sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA is appropriate for most ostomy procedures; MAC with local anesthesia may be appropriate in selected patients.

Induction	Patient may be at risk for pulmonary aspiration. If GA is planned, consider rapid-sequence induction with cricoid pressure. If patient is hypovolemic, restore intravascular volume (colloid, crystalloid, or blood products) before induction and titrate induction doses of sedative/hypnotic agents.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	**MAC:** Titration of sedatives (e.g., propofol 25–150 mcg/kg/min) and analgesics (fentanyl 25–50 mcg

	iv); **GA**: standard maintenance	
Emergence	The trachea should be extubated after the return of protective laryngeal reflexes, if the patient is at risk for aspiration of gastric contents. Discuss with the surgeon local wound infiltration or nerve block (e.g., TAP block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Minimal blood loss IV: 18–20 ga × 1 BSS @ 5–8 mL/kg/h	See Goal-Directed Fluid Management, Appendix K, p. K-4
Monitoring	Standard monitors	Others as clinically indicated
Positioning	✓and pad pressure points ✓eyes	

POSTOPERATIVE

Complications	PONV Aspiration VTE	
Multimodal pain management	Consider combining PCA or fixed dose po/iv opiates with acetaminophen, po or iv NSAIDs, and gabapentin.	Emphasize a multimodal approach combining nonopioid and bolus/PCA opioid analgesics with epidural analgesia and/or TAP blocks (see Appendix C, p. C-4).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6).	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum may promote return of bowel function.

Suggested Readings

1. Hendren S, Hammond K, Glasgow SC, et al: Clinical practice guidelines for ostom surgery. Dis Colon Rectum 2015; 58(4):375–87.
2. Liu Q, Jiang H, Xu D, et al: Effect of gum chewing on ameliorating ileus followin colorectal surgery: a meta-analysis of 18 randomized controlled trials. Int J Surg 2017; 47:107–15.

CONTINENT ILEOSTOMY POUCH (KOCK)

SURGICAL CONSIDERATIONS

Description

A **Kock pouch** consists of an internal reservoir fashioned from the distal ileum and an intussuscepted nipple valve used to provide continence. Approximately 45 cm of the small bowel are required for construction of the pouch and valve. After suturing two limbs of the ileum together over a distance of 15 cm, the distal segment is intussuscepted over itself to form the nipple valve. The pouch is then sutured closed and mounted beneath the abdominal wall stoma site (Fig. 7.3-4A). The stoma is made flush with the skin for cosmetic reasons and left intubated for 1 mo with a special plastic catheter. The pouch remains decompressed for 1 mo before intermittent catheterization is initiated. The continent ileostomy reservoir has been modified by **Barnett** to include the construction of an isoperistaltic valve with an intestinal collar around its base to prevent intussusception and valve prolapse (Fig. 7.3-4B). These procedures are typically performed following a total proctocolectomy or to replace conventional ileostomies.

Usual preop diagnosis

Inflammatory bowel disease; familial polyposis or malfunctioning ileostomies

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, the possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE (KOCK OR BARNETT POUCH)

Position	Supine

Incision	Midline abdominal
Special instrumentation	GIA or TA staplers
Antibiotics	Usual bowel prep with antibiotics; cefoxitin 2 g iv preop
VTE prophylaxis	Heparin 5000 units sq
Surgical time	3–4 h
Closing considerations	Valve vascularity
EBL	200–300 mL
Postop care	Maintain pouch decompression
Mortality	<1%
Morbidity	Intestinal ileus: 5% Wound infection: <5% Intestinal obstruction: 2–3% Pouch fistula: 1–3% Valve necrosis: <0.5%
Pain score	6–8

PATIENT POPULATION CHARACTERISTICS

Age range	18–80 yr
Male:Female	1:1
Incidence	Common
Etiology	Ileostomy (50%); proctocolectomy (5%)
Associated conditions	Extracolonic inflammatory bowel manifestations (10%)

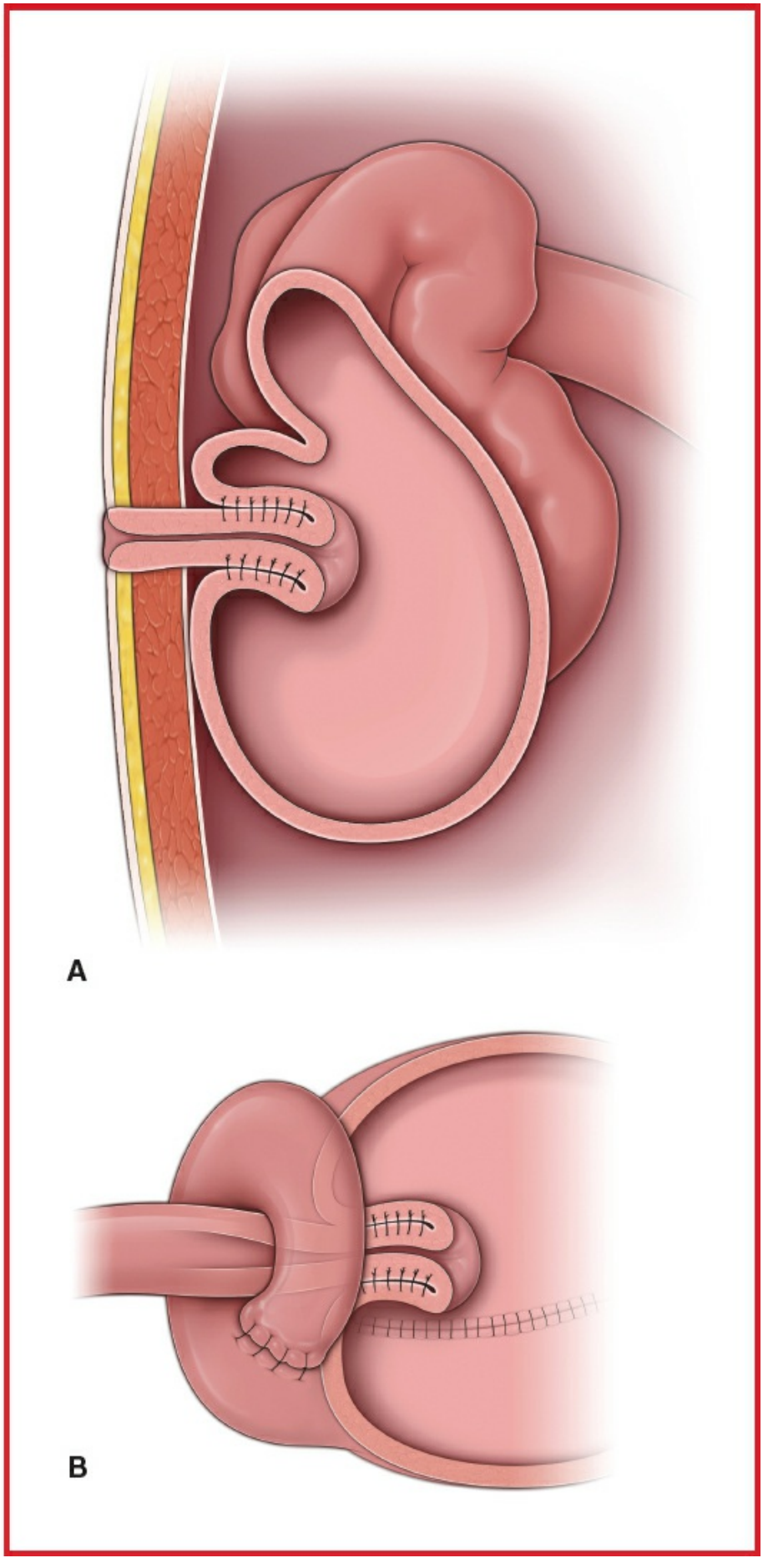
A
B

Figure 7.3-4 **A:** Continent ileostomy or Kock pouch. (Reproduced with permission from Hardy JD: Hardy's Textbook of Surgery, 2nd edition. JB Lippincott, Philadelphia: 1988.)**B:** Barnett modification. The constricting action of the intestinal collar increases with increasing pressure in the pouch.

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Ostomy Procedures.

Suggested Reading

1. Malik T, Lee MJ, Harikrishnan AB: The incidence of stoma related morbidity—a systematic review of randomised controlled trials. Ann R Coll Surg Engl 2018; 100(7):501–8.

SMALL-BOWEL RESECTION WITH ANASTOMOSIS

SURGICAL CONSIDERATIONS

Description

Small bowel resection is performed for several diseases (listed below). This is being done by laparoscopy with increasing frequency. After entering the peritoneal cavity, the involved small bowel is delivered into the wound and the lesion resected between bowel clamps (Fig. 7.3-5). Varying amounts of mesentery are included, depending on the diagnosis. More extensive resections are indicated for malignant disease, including regional lymph nodes. Reanastomosis may be accomplished by various suturing techniques or stapling. The peritoneal cavity may be accessed through vertical or transverse incisions or laparoscopy. Operative techniques include **open end-to-end; closed end-to-end; side-to-side**; or **stapled, functional end-to-end anastomoses**.

Variant procedure or approaches

Laparoscopic small bowel resections are being performed more frequently.

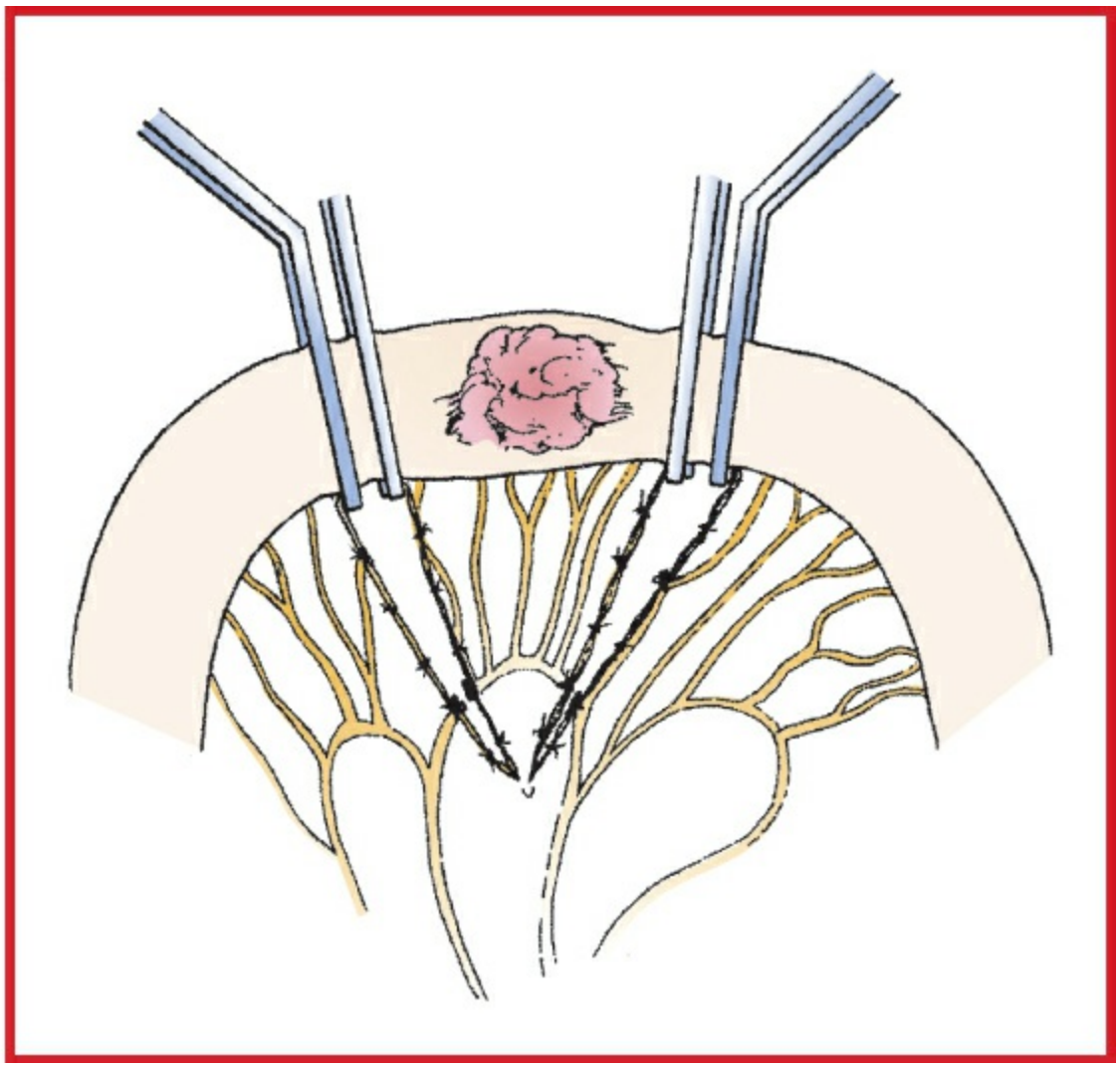

Figure 7.3-5 Block-Potts bowel clamps are applied from the antimesenteric to mesenteric border to avoid twisting. A Kocher clamp is applied on the specimen side, and the bowel is transected with a scalpel. (Reproduced with permission from Baker RJ, Fischer JE, edsMastery of Surgery, Vol. II, 4th edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Usual preop diagnosis

Intestinal obstruction; complicated by intestinal gangrene due to adhesions; internal hernia; volvulus; intussusception; mesenteric vascular occlusion; Crohn disease; radiation enteritis; intestinal fistulae; small bowel tumors; trauma; and carcinoid tumors

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, the possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

Position	Supine
Incision	Vertical or transverse
Unique considerations	Adequate fluid resuscitation; NG tube
Antibiotics	Cefoxitin 2 g iv preop
VTE prophylaxis	Heparin 5000 units sq
Surgical time	1–3 h
EBL	50–100 mL
Postop care	NG or long intestinal tube decompression
Mortality	Varies according to etiology: 1–5%
Morbidity	Atelectasis: <10% Intestinal ileus: <10% Wound infection: <5% Intestinal leak, fistula: <3%
Pain score	7–9

PATIENT POPULATION CHARACTERISTICS

Age range	20–90 yr
Male:Female	1:1
Incidence	Common
Etiology	Interference with blood supply (obstruction, strangulated hernia, volvulus, mesenteric thrombosis); trauma; tumors; Crohn disease
Associated conditions	Multiple, depending on etiology (see Preop diagnosis)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Intestinal and Peritoneal Procedures.

Suggested Readings

1. Aparicio T, Zaanan A, Mary F, et al: Small bowel adenocarcinoma. Gastroenterol Clin North Am 2016; 45(3):447–57.
2. Bower KL, Lollar DI, Williams SL, et al: Small bowel obstruction Surg Clin North Am 2018; 98(5):945–71.

ENTEROLYSIS

SURGICAL CONSIDERATIONS

Description

Enterolysis consists of separating loops of bowel adhesed to other loops or the abdominal wall by sharp dissection and by excising adhesive bands. Care must be taken to avoid producing enterotomies. Covering potential adhesion sites with a hyaluronic carboxymethylcellulose membrane may lessen the formation of intraperitoneal adhesions. This operation can also be done laparoscopically with fewer recurrent adhesions.

Usual preop diagnosis

Intra-abdominal adhesions; intestinal obstruction

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, the possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES	
Position	Supine
Incision	Midline abdominal
Special instrumentation	A long intestinal tube may be necessary for decompression and fixation of bowel loop.
Unique considerations	Bowel decompression
Antibiotics	Cefoxitin 2 g iv preop
VTE prophylaxis	Heparin 5000 units sq

Surgical time	1–4 h
Closing considerations	Adequate decompression to permit wound closure
EBL	150–500 mL
Postop care	PACU; continued intestinal decompression 2–5 d
Mortality	1–3%
Morbidity	Wound abscess: 15–20% Prolonged ileus: 10–20% Fistula formation: <10% Pulmonary complications: 5–10% Recurrent intestinal obstruction: 5–8%
Pain score	5–7

PATIENT POPULATION CHARACTERISTICS	
Age range	Any age
Male:Female	1:1
Incidence	Common
Etiology	Previous intra-abdominal operative procedure (>90%); malignant tumors (15–20%); hernias (10–15%); volvulus (5–10%); inflammatory bowel disease (5%); gallstone ileus (<5%); intussusception (<5%); radiation

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Intestinal and Peritoneal Procedures.

CLOSURE OF ENTERIC FISTULAE

SURGICAL CONSIDERATIONS

Description

Enteric fistulae may occur between the bowel and abdominal wall (enterocutaneous), between loops of the intestine (enteroenteric or enterocolic), or between the bowel and

bladder or vagina (enterovesical or enterovaginal). Surgical repair is usually reserved for fistulae to the abdominal wall, bladder, and vagina and consists of excising the fistula and repairing the bowel and the other organ separately. Most fistulae are characterized by the adherence of the two visceral organs with a communication between their lumens.

The organs involved are separated by blunt-sharp dissection and repaired locally after excision of the indurated margins of the defect. In the case of both the small and large intestines, it may be necessary to resect a segment of the bowel with the defect and to perform an end-to-end anastomosis. If the repair sites involved lie close together, it is important to interpose tissue, such as the omentum, between the viscera to minimize chance of recurrence. Occasionally, a fistula may be bypassed rather than surgically resected.

Usual preop diagnosis

Enteric fistula

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, the possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES	
Position	Supine
Incision	Midline abdominal
Unique considerations	Preop nutritional support and fistula wound care
Antibiotics	Cefoxitin 2 g iv preop
VTE prophylaxis	Heparin 5000 units sq
Surgical time	2–4 h
Closing considerations	Separation of repairs by interposition of the omentum and other tissues
EBL	50–300 mL
Postop care	NG decompression until bowel function returns; TPN

	support.
Mortality	0–5%
Morbidity	Ileus: 60–70% Pulmonary complications: 10% Recurrent fistula: 5–10% Wound infection: 5–10%
Pain score	6–8

PATIENT POPULATION CHARACTERISTICS	
Age range	Any age
Male:Female	1:1
Incidence	Common
Etiology	Anastomotic leaks (60–70%); carcinoma (10–15%); Crohn disease (5–10%); iatrogenic bowel injury (5–10%); perforative diverticulitis (5–10%); radiation enteritis (5%); foreign body perforation (<5%)
Associated conditions	Malnutrition (30%); inflammatory bowel disease (25%); cancer (15%)

Suggested Reading

1. Schecter WP, Hirshberg A, Chang DS, et al: Enteric fistulas: principles o management. J Am Coll Surg 2009; 209(4):484–91.

ANESTHETIC CONSIDERATIONS FOR INTESTINAL AND PERITONEAL PROCEDURES

(Procedures covered: small bowel resection; enterolysis; closure of enteric fistulae; excision of intra-abdominal and retroperitoneal tumor; drainage of subphrenic abscess)

PREOPERATIVE

Patients requiring exploratory laparotomy present both electively and emergently for a very wide range of conditions. As a result of their abdominal pathology, these patients are often at high risk for the pulmonary aspiration of gastric contents. Precautions to prevent this are necessary to help ensure safe patient outcome.

Respiratory	Respiratory insufficiency can be present due to intra-abdominal pathology (e.g., ascites, large tumor, free blood, bowel distension, pain); ↓ FRC → ↑ A-a gradient and arterial hypoxemia; diaphragmatic impairment and splinting → ↑ respiratory insufficiency. **Tests:** Consider CXR; ABG.
Cardiovascular	Patients for emergency surgery are often critically ill and unstable and should be evaluated for the presence of hypovolemia (hypotension, tachycardia) and should receive adequate volume replacement before anesthetic induction. Elective patients may be hypovolemic 2° bowel prep. **Tests:** ECG; consider orthostatic vital signs.
Musculoskeletal	Abdominal rigidity may be present; abdominal pain is common.
Gastrointestinal	Diarrhea, vomiting, and prolonged NPO status can lead to electrolyte abnormalities. Malnutrition may be present. **Tests:** Electrolytes, consider PT/PTT.
Renal	Renal insufficiency/failure may be present, especially in elderly and chronically ill patients and in those who are hypovolemic. **Tests:** Consider BUN; Cr; electrolytes.
Laboratory	CBC with differential; Plt count
Premedication	Consider midazolam 1–2 mg iv and Na citrate (30 mL po 10 min preop).
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with the surgeon the possibility of a transversus abdominis plane or thoracic epidural block for postop pain management. Consider preop acetaminophen 1000 mg po with a sip of water. Consider aprepitant 40–80 mg po with a sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA ± **epidural for postop analgesia.** If postop epidural analgesia is planned, placement of catheter before anesthetic induction is helpful to establish correct placement in the epidural space (accomplished by injecting 5–7 mL of 2% lidocaine via the epidural catheter and confirming segmental block).

Induction	The patient with abdominal pathology is often at risk for pulmonary aspiration. Consider rapid-sequence iv induction with cricoid pressure. (See Rapid-Sequence Induction, Appendix B, p. B-5.) If patient is clinically hypovolemic, restore intravascular volume before induction and titrate induction dose of sedative/hypnotic agents.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	**Balanced anesthesia**. Maintain neuromuscular blockade based on nerve stimulator response. Place gastric tube to evacuate stomach contents. **Combined epidural and GA**: Local anesthetic (2% lidocaine with 1:200,000 epinephrine 5–15 mL initial dose and then 3–5 mL q60min) can be injected into the epidural catheter to provide both anesthesia and optimal surgical exposure (contracted bowel and muscle relaxation). A continuous infusion of local anesthetic (e.g., 2% lidocaine or 0.25% bupivacaine) at 3–5 mL/h may be used in place of bolus redosing. Be prepared to treat hypotension with fluid and vasopressors. GA is administered to supplement regional anesthesia and for amnesia. If epidural opiates are used for postop analgesia, a loading dose (e.g., hydromorphone 0.5–1.0 mg) should be administered at least 1 h before the conclusion of surgery. The use of systemic analgesics may be minimized during this type of anesthetic with the

	benefit of decreasing the likelihood of postop respiratory depression.	
Emergence	The decision to extubate at the end of surgery depends on the patient's underlying cardiopulmonary status and the extent of the surgical procedure. Patients should be hemodynamically stable, warm, cooperative, and fully reversed from any muscle relaxants before extubation. If the above criteria are not met, consider postop ventilation in the ICU setting. Discuss with the surgeon local wound infiltration or nerve block (e.g., TAP block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose is given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Anticipate large fluid shift. IV: 14–16 ga × 1–2 T&S, consider T&C BSS @ 10–15 mL/kg/h Fluid warmer	Plts, FFP, and cryoprecipitate should be administered according to lab tests (Plt count, PT, PTT, DIC screen, thromboelastography [TEG]). Strive to maintain euvolemia based on estimated blood loss and fluid shifts, HR, BP, UO, ABG, and invasive monitors when used. Consider Goal-Directed Fluid Management Appendix K, p. K-4.
Monitoring	Standard monitors UO ± Arterial line ± CVP/PA catheter ± TEE	Invasive monitors, as indicated by the patient's status. Prevent hypothermia: use forced-air warmer; consider warming blanket, warming iv fluids, warm room temperature, keeping the patient covered until ready for prep.

Positioning	✓pad pressure points ✓ eyes	
Complications	Hemorrhage Sepsis Atelectasis Hypoxemia VTE Hemorrhage Ileus PONV	Acute septic shock may require aggressive hemodynamic support. A PA catheter, or TEE may help guide management in the unstable patient. Pulmonary function abnormalities may persist for 1 wk postop (↓ vital capacity and ↓ FRC).
Multimodal pain management	Epidural analgesia PCA	Emphasize a multimodal approach combining nonopioid and bolus/PCA opioid analgesics with epidural analgesia and TAP blocks (see Appendix C, p. C-4). Consider combining PCA or fixed dose po/iv opiates with acetaminophen, po or iv NSAIDs, and gabapentin.
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum may promote return of bowel function.
Tests	CBC; CXR (if central line placed); electrolytes; glucose	Others as directed by intraop course.

POSTOPERATIVE

Suggested Readings

1. Becker HP, Willms A, Schwab R: Small bowel fistulas and the open abdomen. Scand

J Surg 2007; 96:263–71.
2. Liu Q, Jiang H, Xu D, et al: Effect of gum chewing on ameliorating ileus following colorectal surgery: a meta-analysis of 18 randomized controlled trials. Int J Surg 2017; 47:107–15.

CHAPTER 7.4

Colorectal Surgery

SURGEON
Andrew A. Shelton, MD, FACS, FASCRS

ANESTHESIOLOGIST
Clifford A. Schmiesing, MD

ENHANCED RECOVERY AFTER SURGERY (ERAS)

Fast-track or enhanced recovery programs after elective surgery incorporate a variety of evidence-based interventions in an attempt to maintain normal physiologic function, enhance recovery, and prevent or minimize postoperative complications. They provide the patients with optimal means to counteract or minimize the deleterious effects of surgery. These interventions encompass all phases of a patient's periop care from the preop phase, through the intraop phase, and to the end of the postop care. These programs are increasingly used in the perioperative management of patients with colorectal conditions. The anesthesiologist is responsible for several key elements that can affect outcomes after surgery: stress reactions to the surgery, fluid therapy, analgesia, and avoidance of PONV. Typical components of ERAS programs applicable to colorectal surgery are noted below. Additional information can be found in Appendix K: Enhanced Recovery After Surgery, p. K-1.

Preop	Intraop	Postop
Avoid preop fasting; allow clear liquids until 2 h before induction of anesthesia.	Standard anesthetic protocol allowing rapid awakening	Minimize excessive postop fluids.
Preop carbohydrate loading	Use of midthoracic epidural for open	Early resumption of enteral feeding

	surgery	
Avoid long-acting sedative medications before surgery.	Prevention of PONV	Prevention of postop ileus
DVT prophylaxis with compression stockings and LMWH or unfractionated heparin	Maintenance of normothermia	Postop glucose control
Prophylactic antibiotics given 30–60 min before incision	Avoid excessive intraop fluids.	Early mobilization
Preop optimization (smoking cessation, avoidance of alcohol, preop nutritional assessment; correction of preop anemia, prehab)	Use of laparoscopic surgical techniques	Avoid NG tubes. Multimodality postop analgesia minimizing narcotics
	Opioid-sparing analgesia	Opioid-sparing analgesia

Several studies have demonstrated that the ERAS programs compared with traditional postop care are associated with earlier recovery and discharge after colorectal surgery with decreased morbidity.

Suggested Readings

1. Grant MC, Pio Roda CM, Canner JK, et al: The impact of anesthesia-influence process measure compliance on length of stay: results from an enhanced recovery after surgery for colorectal surgery cohort. Anesth Analg 2019; 128(1):68–74.
2. Gustafsson UO, et al: Guidelines for perioperative care in elective colonic surgery: Enhanced Recovery After Surgery (ERAS®) Society recommendations: 2018.World J Surg 2019; 43(3):659–95.
3. Tiernan JP, et al: Enhanced recovery after surgery. Recent developments in colorectal surgery. Surg Clin North Am 2018; 98(6):1241–9.

LAPAROSCOPIC COLORECTAL SURGERY

Laparoscopic surgery has changed the face of general surgery with the widespread use of laparoscopic cholecystectomy, appendectomy, and other surgical procedures. Although across the country, many colorectal procedures continue to be done in the standard open fashion, laparoscopic techniques are being used more and more for

procedures on the colon and rectum. From 2010 to 2014, the number of minimally invasive surgery (MIS) segmental colectomies increased by 157% at academic hospitals, 151% at comprehensive hospitals, and 153% at community hospitals. All of the following procedures can be done, and have been done, laparoscopically. Advantages to the patient include smaller incisions, less postop discomfort, a decreased in-hospital stay, and decreased wound-related complications with early return to work and regular activity. Steep positional changes are often used to facilitate retraction of the small bowel out of the operative field. The patient is often placed on a beanbag to prevent movement. The term **laparoscopic-assisted** is more appropriate for colorectal procedures because the colon often is mobilized laparoscopically. A small incision is then made, through which the bowel is exteriorized, the mesentery is divided, and an anastomosis is created. **Hand-assisted laparoscopy** involves placement of a hand port through a 5- to 10-cm incision. The abdominal cavity is then insufflated as in standard laparoscopy, but the surgeon's hand is used alongside the other laparoscopic instruments. Laparoscopic techniques continue to advance with the development of single-incision laparoscopic surgery (SILS) for resection of the colon and rectum **natural orifice transluminal endoscopic surgery (NOTES)** techniques in which the resected specimen is removed from a natural orifice such as the vagina, and the use of the da Vinci robot for the laparoscopic treatment of rectal cancer as well as for the treatment of benign and malignant conditions of the colon.

Laparoscopic resections of the colon or rectum are done using a pneumoperitoneum with its associated physiologic changes. Laparoscopic surgery involves the insufflation of CO_2 into the peritoneal cavity at a rate of 4–6 L/min to a pressure of 15–20 mm Hg. The raised intra-abdominal pressure (IAP) and the effects of CO_2 can cause changes in the physiology of the respiratory and cardiovascular systems. Increased IAP affects venous return, systemic vascular resistance, and myocardial function. Pneumoperitoneum also results in cephalad shift of the diaphragm, decreasing FRC possibly to values less than the closing volume. This can result in airway collapse, atelectasis, V/Q mismatch, potential hypoxemia, and hypercarbia.

Because of the inability to use retractors as in open surgery, retraction of the bowel out of the operating field is usually accomplished through changes in the patient's position on the operating table, frequently requiring steep degrees of Trendelenburg position. Because of this, the patient must be secured to the operating table. These position changes can further affect the cardiovascular and respiratory systems in addition to those caused by the pneumoperitoneum itself.

An important consideration for any laparoscopic procedure is that the surgeon might

need to convert to an **open laparotomy**. This may occur secondarily for failure to progress or in an emergently for technical difficulties.

Suggested Readings

1. Andolfi C, Umanskiy K: Appraisal and current considerations of robotics in colon and rectal surgery. J Laparoendosc Adv Surg Tech A 2019; 29(2):152–8.
2. Chang J, Rattner DW: History of minimally invasive surgical oncology. Surg Oncol Clin N Am 2019; 28(1):1–9.
3. Cirocchi R, Fearnhead N, Vettoretto N, et al: The role of emergency laparoscopic colectomy for complicated sigmoid diverticulitis: a systematic review and meta-analysis. Surgeon 2018.
4. Fransgaard T, Pinar I, Thygesen LC, et al: Association between robot-assisted surgery and resection quality in patients with colorectal cancer. Surg Oncol 2018; 27(2):177–84.
5. Mege D, Garrett K, Milsom J, et al: Changing trends in surgery for abdominal Crohn's disease. Colorectal Dis 2019; 21(2):200–7.
6. Ng JL, Lai JH, Li HH, et al: Totally-laparoscopic versus laparoscopic-assisted low anterior resection for rectal cancer: are outcomes different? ANZ J Surg 2018; 88(12):E818–23.
7. Stewart CL, Ituarte PHG, Melstrom KA, et al: Robotic surgery trends in general surgical oncology from the National Inpatient Sample. Surg Endosc 2018.

TOTAL PROCTOCOLECTOMY

SURGICAL CONSIDERATIONS

Description

A **total proctocolectomy** involves the removal of the entire colon, rectum, and anus (Fig. 7.4-1). Indications for this operation include ulcerative colitis (UC), Crohn disease (CD), and familial adenomatous polyposis (FAP). Inflammatory bowel disease (IBD) can be diagnosed at any age, but there are peaks in diagnosis in the teens and the 20s and the 60s and 70s. The most common indication for total proctocolectomy in the setting of UC or CD is intractable symptoms despite maximal medical therapy. Patients who come to surgery are often chronically or acutely ill and may be malnourished or anemic. They are frequently on immunosuppressive drugs such as corticosteroids, 6-mercaptopurine, or azathioprine or biologic inhibitors of tumor necrosis factor alpha (infliximab, adalimumab, golimumab, and certolizumab pegol) or anti-integrin molecules (natalizumab and vedolizumab). These medications all predispose these

patients to an increased risk of postop infections and complications due to poor wound healing. Another important indication for proctocolectomy in patients with UC is the presence of dysplasia or cancer.

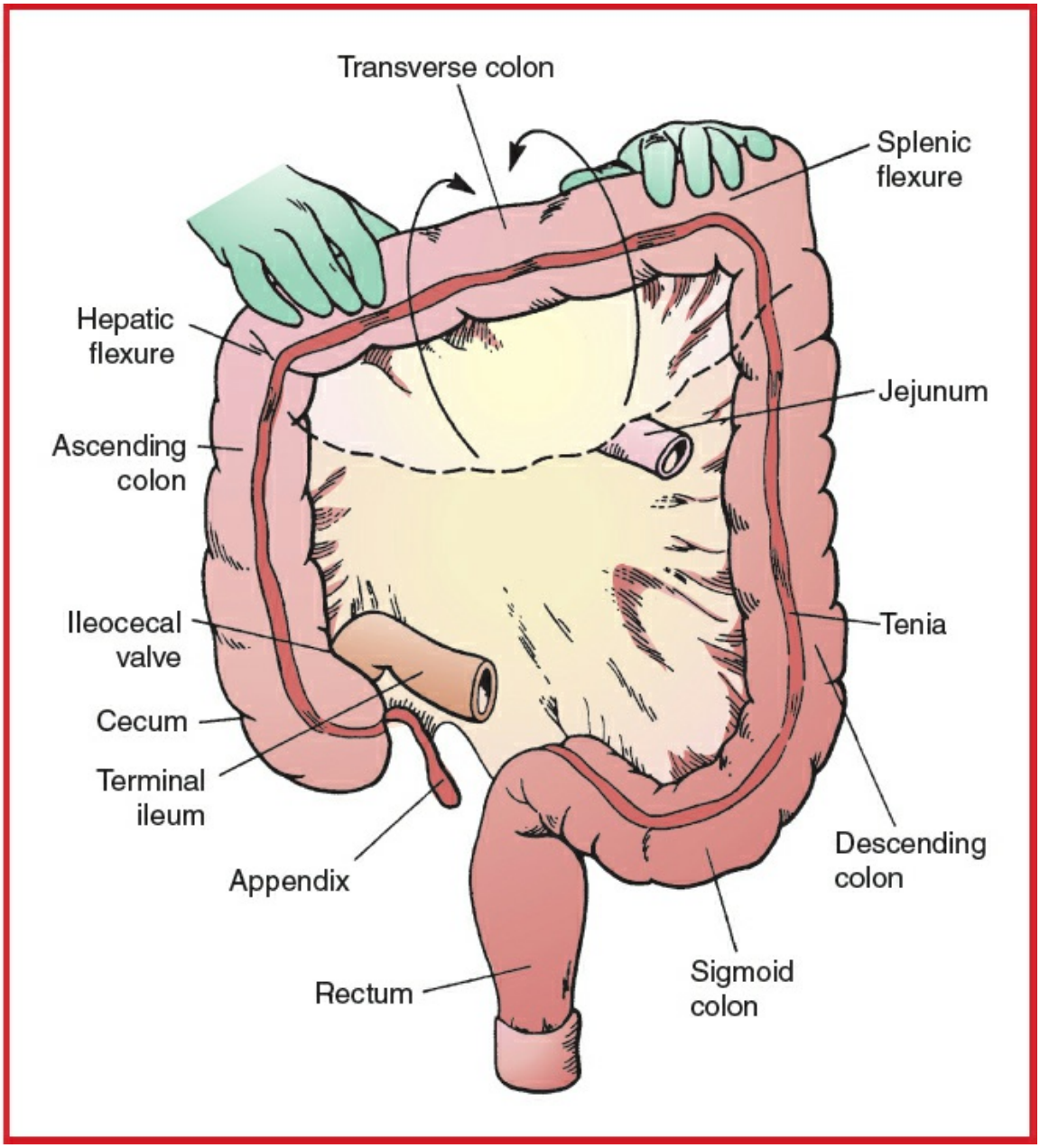

Figure 7.4-1 Anatomy of the colon. (Reproduced with permission from Hardy JD:Hardy's Textbook of Surgery, 2nd edition. JB Lippincott, Baltimore: 1988.)

FAP is an autosomal-dominant disease resulting in colon cancer. Patients develop hundreds to thousands of adenomatous polyps throughout their colon and rectum, as well as elsewhere in the GI tract. Colorectal cancer is inevitable unless proctocolectomy is performed. This is typically done in the late teens or 20s. In contrast to patients with CD or UC, patients with FAP are usually healthy without other medical comorbidities.

Sequential compression stockings are used for thromboprophylaxis. Patients with CD and UC are at ↑ risk for the development of DVT and should be given subcutaneous unfractionated heparin or low-molecular-weight heparin. Patients taking chronic corticosteroids are given stress dose steroids before the procedure. Broad-spectrum antibiotics covering gram-negative rods and anaerobes are given before the incision.

Total proctocolectomy with **end ileostomy**, total proctocolectomy with **continent ileostomy (Koch pouch)**, and restorative **proctocolectomy with ileal pouch anal anastomosis (IPAA)** all involve complete removal of the colon and rectum, down to the level of the pelvic floor or levator ani muscles. They differ in the fate of the anal canal, creation of a stoma, or construction of an anastomosis. The patient is placed in a lithotomy position in padded Allen stirrups. A Foley catheter is placed. If the procedure is done using laparoscopic techniques, a small incision is made in the periumbilical region and the suprapubic region or as a Pfannenstiel incision to extract the specimen. If done as an open procedure, it is commonly performed through a midline incision. The abdomen is explored for evidence of unexpected malignancy or, in the case of FAP, for desmoid tumors. The right colon is mobilized first, and then the small bowel mesentery is mobilized to allow for creation of an ileostomy. The transverse colon may be mobilized by separating it from the greater omentum, or the greater omentum may be resected along with the specimen. The sigmoid and descending colon are mobilized, and the splenic flexure is taken down. The ileum is then divided flush with the cecum, and the vessels in the colon mesentery are ligated. At this point, the entire abdominal colon has been resected. An avascular fascial envelope surrounds the rectum and its mesentery, the mesorectum. It is possible to circumferentially dissect the rectum down to the level of the pelvic floor without ligating any vessels. There may be significant blood loss if an inadvertent injury to the spleen occurs during mobilization of the splenic flexure. Massive blood loss may occur if the presacral venous plexus is entered during posterior rectal mobilization.

Total proctocolectomy with ileostomy

For patients with CD, elderly patients with UC, or FAP patients with low rectal cancer complete removal of the colon, rectum, and anus is the procedure of choice. After completing the abdominal mobilization of the colon and rectum, the perineal phase of the operation begins. Ideally, two teams of surgeons participate in the operation simultaneously. The abdominal surgeon can create the ileostomy and close the abdomen, while the perineal surgeon finishes removal of the rectum and anus. A circumferential incision is made at the anal verge, and the intersphincteric plane is identified. The dissection proceeds cephalad until the abdominal dissection is encountered, and the specimen is removed. The levator ani muscle, external anal sphincter, and skin are

closed. While this is being done, the abdominal surgeon makes a circular incision over the previously marked ileostomy site. A muscle-splitting incision is carried through the rectus fascia. The terminal ileum is then brought through this site. After the fascia and skin are closed, the ileostomy is matured. Some surgeons prefer to do the perineal phase of a proctocolectomy in the prone jackknife position. In this case, after completing the abdominal phase of the operation, the abdomen is closed, the stoma is matured, and the patient is flipped prone to finish the procedure.

Total proctocolectomy with continent ileostomy (Koch pouch)

Because of frequent complications and the development of alternative procedures (see below), this procedure has been largely abandoned.

Restorative proctocolectomy with ileal J-pouch anal anastomosis

IPAA is the procedure most performed for patients with FAP and UC. In this operation the colon and rectum are removed down to the level of the pelvic floor; however, the anal canal and anal sphincter complex are preserved. The rectum is stapled and divided at the level of the surgical anal canal, ~1–1.5 cm above the dentate line. An ileal reservoir is constructed by anastomosing the distal 30 cm of the ileum in a side-to-side fashion, creating a J-pouch. The apex of the pouch is then anastomosed to the anal canal using a circular stapling device (see Fig. 7.4-2). Rarely, a hand-sewn anastomosis is created. A temporary diverting loop ileostomy may or may not be created, depending on the clinical situation.

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

SUMMARY OF PROCEDURES

	Total Proctocolectomy	IPAA	Laparoscopic
Position	Modified lithotomy	⇐	⇐
Incision	Midline	Midline	Suprapubic or Pfannenstiel
Special instruments	Two-table setup (separate	Two-table setup; anal retractors	⇐

	abdominal and perineal instruments); deep pelvic instruments		
Unique considerations	Patients frequently on chronic corticosteroids	⇐; epinephrine solutions injected under the rectal mucosa to facilitate dissection and reduce bleeding	⇐
Antibiotics	Cefazolin 2 g iv and metronidazole 500 mg iv or second-generation cephalosporin (e.g., cefotetan 2 g iv)	⇐	⇐
Surgical time	3–4 h	3–4 h	4–5 h
Closing considerations	Ileostomy completed after skin is closed (15–30 min).	Temporary ileostomy often used, completed after skin closure	⇐
EBL	100–1000 mL (most blood loss during pelvic and perineal dissection)	⇐	⇐
Postop care	Transient inability to void common	Small bowel mesentery lengthened by dissection around duodenum. May lead to PONV; transient inability to void	⇐
Morbidity	Dyspareunia: 30% Stoma	5–10% NA	⇐

	complications: 20% SBO: 10–15% Erectile dysfunction: 2–4%	⇐ ⇐ Nocturnal incontinence Poor function: 5% Pelvic sepsis: 0–4%	
Mortality	2–5% (older patients and those with underlying chronic medical problems)	<1%	⇐
Pain score	8	8	6

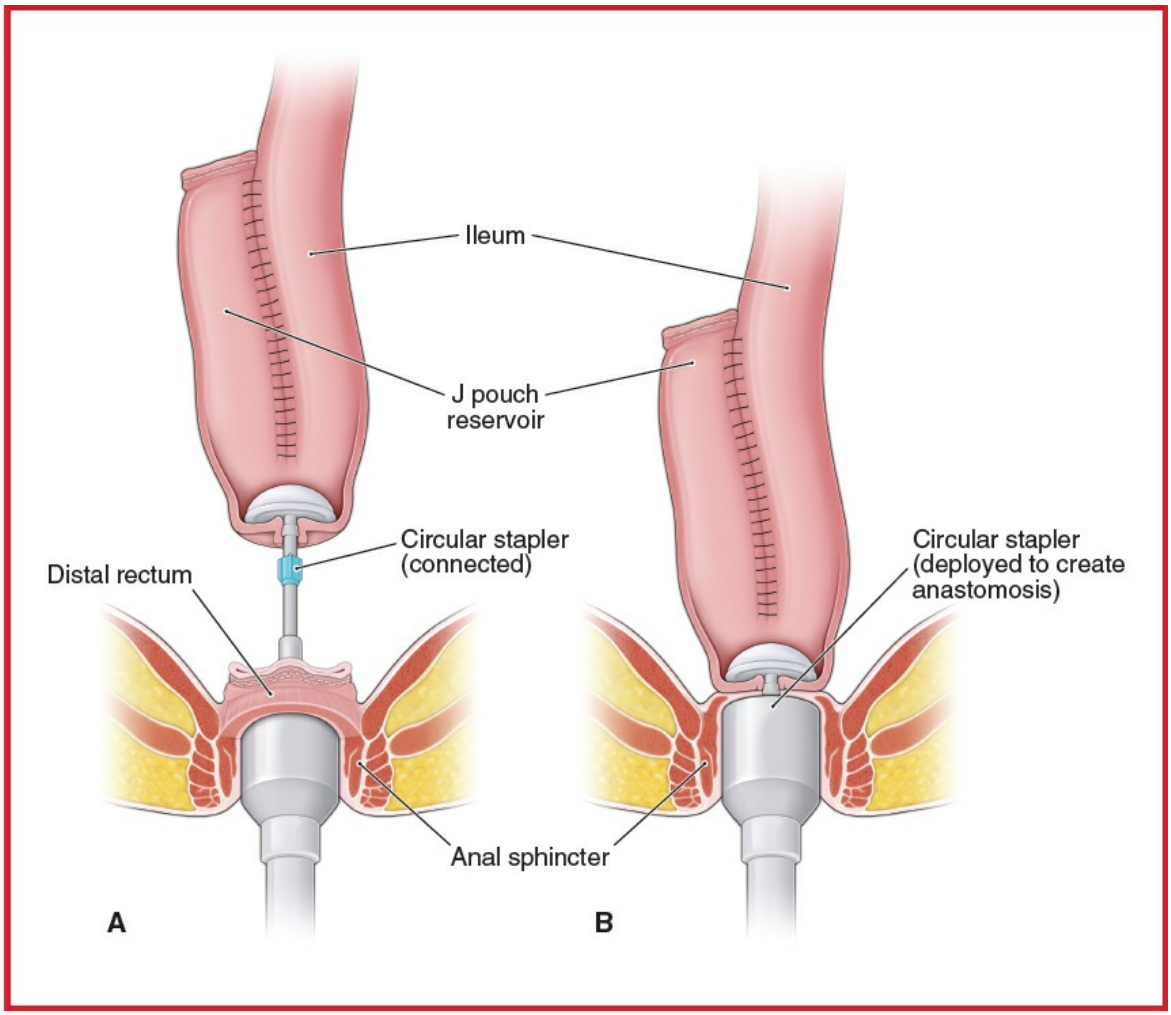

Figure 7.4-2 Creation of a J-pouch using a circular stapler.

PATIENT POPULATION CHARACTERISTICS

	Ulcerative Colitis	Familial Adenomatous Polyposis
Age range	3rd–5th decade	2nd–4th decade
Male:Female	1:1	⇐
Incidence	6–10/100,000	100–150 cases/yr

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Large Bowel Surgery.

Suggested Readings

1. Cohen BL, Sachar DB: Update on anti-tumor necrosis factor agents and other nev drugs for inflammatory bowel disease. BMJ 2017; 357:j2505.
2. Ferrari L, Krane MK, Fichera A: Inflammatory bowel disease surgery in the biologi era. World J Gastrointest Surg 2016; 8(5):363–70.
3. Gajendran M, Loganathan P, Catinella AP, et al: A comprehensive review and update on Crohn's disease. Dis Mon 2018; 64(2):20–57.
4. Holder-Murray J, Marsicovetere P, Holubar SD: Minimally invasive surgery fo inflammatory bowel disease. Inflamm Bowel Dis 2015; 21(6):1443–58.
5. Masaki T, Kishiki T, Kojima K, et al: Recent trends (2016-2017) in the treatment o inflammatory bowel disease. Ann Gastroenterol Surg 2018; 2(4):282–8.
6. Neumann PA, Rijcken E: Minimally invasive surgery for inflammatory bowe disease: review of current developments and future perspectives. World J Gastrointest Pharmacol Ther 2016; 7(2):217–26.
7. Nickerson TP, Merchea A: Perioperative considerations in Crohn disease and ulcerative colitis. Clin Colon Rectal Surg 2016; 29(2):80–4.
8. Øresland T, Faerden AE: Surgery in the age of biological treatment. Scand J Gastroenterol 2015; 50(1):121–7.
9. Shung DL, Abraham B, Sellin J, et al: Medical and surgical complications o inflammatory bowel disease in the elderly: a systematic review. Dig Dis Sci 2015; 60(5):1132–40.

SEGMENTAL (PARTIAL) COLECTOMY

SURGICAL CONSIDERATIONS

Description

Segmental colectomy involves removal of a portion of the colon (Fig. 7.4-1) with the creation of an **anastomosis** or a **stoma**. The most common indications for the operation in the Western world are colon cancer and diverticulitis. Less common indications include traumatic perforation, gastrointestinal hemorrhage, ischemic colitis, volvulus, and IBD. Both colon cancer and diverticular disease occur most often in patients >50 yr. Patients may have any of the comorbid medical conditions associated with aging, as well as complications related to the disease requiring colon resection. Free perforation of the colon can occur from a variety of conditions, including diverticulitis, cancer, and ischemia. Patients may be hypovolemic and have systemic sepsis. **Emergent laparotomy** should follow a period of resuscitation and administration of antibiotics. The involved segment of bowel is resected, the abdomen is irrigated, and a stoma is created.

Colon cancer is the second most common cancer in the United States with 153,000 new cases diagnosed annually. Patients may be entirely asymptomatic, with the diagnosis being made only as the result of a screening exam. Because of the large caliber of the colon and the liquid nature of stool, patients with cancers of the right colon are more likely to present with large cancers and anemia. The caliber of the left colon is smaller and the stool more solid. When symptomatic, symptoms of obstruction and change in bowel habits predominate for left-sided lesions.

Colonic diverticula occur in up to 60–70% of people over 50 yr of age in the United States. A colonic diverticulum is a herniation of the mucosa and submucosa through the relative weakening that occurs in the muscular wall of the bowel at the site of penetrating blood vessels. This occurs predominantly in the sigmoid colon. Most people with colonic diverticula are completely asymptomatic and will never experience any complications related to diverticulosis. Diverticulitis occurs when a microscopic or macroscopic perforation of a colonic diverticulum occurs, resulting in a pericolonic inflammatory and infectious process. The severity of the attack depends on the degree of perforation and how well the body is able to wall it off. This ranges from minor inflammation around the sigmoid colon that can be managed with antibiotics to an intra-abdominal or pelvic abscess requiring **percutaneous drainage** to free perforation with purulent or feculent peritonitis requiring emergency surgery. Repeated bouts of diverticulitis eventually can result in fibrosis of the colon, stricture formation, and obstruction.

Ideally, surgery on the colon is performed in an elective setting; however, perforation with peritonitis or complete obstruction of the colon may require emergency surgery. Most patients presenting for elective colon resection undergo preop bowel preparation

that consists of a combination of mechanical cleaning of the colon as well as oral antibiotics to decrease the bacterial load in the colon. As a result, they are frequently hypovolemic and hypokalemic when they come to the OR.

The patient is positioned either supine or in the modified lithotomy position, depending on the segment of the colon to be removed. Sequential compression stockings are used for thromboprophylaxis, and chemoprophylaxis for DVT with either unfractionated heparin or low-molecular-weight heparin is given. Intravenous antibiotics covering gram-negative rods and anaerobes should be given before the incision with redosing as appropriate for the antibiotic used.

Segmental colectomy

Segmental resection of the colon may be performed laparoscopically or via midline or transverse abdominal incisions, depending on the underlying disease, portion of the colon to be resected, and the surgeon's preference. For open surgery, midline incisions are preferred when a high-lying splenic flexure must be mobilized, IBD is present, or the extent of the colon resection is not known preoperatively. Transverse incisions are most commonly reserved for resections of the right colon. The most commonly performed partial colon resections are **right hemicolectomy**, **sigmoid colectomy**, **left hemicolectomy**, and **abdominal colectomy** with an **ileorectal anastomosis**. The sequence of steps in a **partial colectomy** is the same for all parts of the colon. The right colon and left colon are retroperitoneal structures, whereas the transverse colon and sigmoid colon are primarily intraperitoneal. The first step is mobilization of the colon and its mesentery. Care must be taken not to injure the left ureter during mobilization of the sigmoid colon or the duodenum during mobilization of the right colon. Proximal and distal sites for resection are selected, and the intervening mesentery is divided. The **anastomosis** may be hand sewn or stapled, which is a decision based primarily on the surgeon's preference.

There is no clear advantage to either anastomotic technique. Creation of a **diverting stoma** rather than an anastomosis may be necessary in patients who are hemodynamically unstable or when intra-abdominal conditions, such as inflammation, make an anastomosis unsafe. There may be significant blood loss if an inadvertent injury to the spleen occurs during mobilization of the splenic flexure. Excessive traction of the hepatic flexure can result in difficult-to-control venous bleeding.

Obstruction of the colon most commonly occurs as a result of cancer of the sigmoid colon or repeated bouts of diverticulitis. Patients present with abdominal distension, obstipation, and N/V. Patients are treated with NG tube decompression and correction of hypovolemia. An attempt may be made to stent the obstructing lesion endoscopically

preop to allow decompression and preparation of the colon. If this is not possible, surgical options include segmental resection with a **colostomy**, segmental resection with primary anastomosis, and an on-table colonic lavage or **subtotal colectomy** with an ileorectal anastomosis.

Usual preop diagnosis

Colon cancer; diverticular disease; Crohn disease; ulcerative colitis; trauma; ischemic colitis; lower GI hemorrhage; intractable constipation; colon volvulus

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, and possibility of NG tube and urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine or modified lithotomy
Incision	Transverse, vertical midline, laparoscopic
Unique considerations	Bowel prep, or underlying disease may → dehydration, electrolyte abnormalities, or anemia.
Antibiotics	Cefazolin 2 g iv and metronidazole 500 mg iv or second-generation cephalosporin (e.g., cefotetan 2 g iv)
Surgical time	1–3 h
Closing considerations	Colostomy or ileostomy matured after wound is closed (requires 10–20 min).
EBL	100–300 mL (500–2000 mL if splenic injury, loss of major vascular pedicle, or repeat operation for cancer, Crohn disease)
Postop care	ICU for underlying disease; NG may be used in the setting of obstruction. Avoid use of long-lasting anticholinergic effects.
Mortality	0.5–2% (mostly related to underlying disease)
Morbidity	SBO: 5–10% Wound infection: 4–10% Anastomotic leak: 2–4%

	Wound dehiscence: 1–2% Bleeding: 1% Splenic injury: 1%
Pain score	8

PATIENT POPULATION CHARACTERISTICS

	Crohn Disease	Colon Cancer	Trauma	Diverticulitis
Age range	2nd–4th decade	5th–7th decade	2nd–4th decade	>40 yr
Male:Female	1:1	1.3:1	3:1	1:1
Incidence	1–6/100,000	30/100,000	1–2/100,000	10/100,000
Etiology	Unknown	Genetic: 5%	Trauma	Western countries: low-fiber diet
Associated conditions	Malnutrition; anemia; intra-abdominal sepsis; intestinal fistulae; perianal disease; nephrolithiasis; sclerosing and ankylosing spondylitis	Iron deficiency; colonic obstruction; colonic perforation	Liver fracture; spleen fracture; rib fracture; closed-head injury; penetration of viscera adjacent to colon injury	Hemorrhoids; chronic constipation

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Large Bowel Surgery.

Suggested Readings

1. Atallah C, Efron JE: Laparoscopy for rectal cancer.Clin Colon Rectal Surg 2017; 30(2):104–11.
2. Baer C, Menon R, Bastawrous S, et al: Emergency presentations of colorectal cancer. Surg Clin North Am 2017; 97(3):529–45.
3. Fabozzi M, Cirillo P, Corcione F: Surgical approach to right colon cancer: from open technique to robot. State of art. World J Gastrointest Surg 2016; 8(8):564–73.
4. Liu X, Li JB, Shi G, et al: Systematic review of single-incision versus conventiona multiport laparoscopic surgery for sigmoid colon and rectal cancer. World J Surg Oncol 2018; 16(1):220.
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6. Neale JA: Surgical management of diverticular disease in the elective setting.Clin Colon Rectal Surg 2018; 31(4):236–42.
7. Pai A, Marecik S, Park J, et al: Robotic colorectal surgery for neoplasia.Surg Clin North Am 2017; 97(3):561–72.

3. Salem JF, Gummadi S, Marks JH: Minimally invasive surgical approaches to colo cancer. Surg Oncol Clin N Am 2018; 27(2):303–18.
9. Shaban F, Carney K, McGarry K, et al: Perforated diverticulitis: to anastomose o not to anastomose? A systematic review and meta-analysis. Int J Surg 2018; 58:11–21.
0. Yamamoto R, Logue AJ, Muir MT: Colon trauma: evidence-based practices.Clin Colon Rectal Surg 2018; 31(1):11–6.
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STOMA CLOSURE OR PERISTOMAL HERNIA REPAIR

SURGICAL CONSIDERATIONS

Description

A **temporary colostomy** or **ileostomy** can be made for a variety of staged procedures. An **end colostomy** is often created after resection of obstructing or perforated lesions of the left colon. A proximal **loop ileostomy or colostomy** is often created to protect a "high-risk" anastomosis, such as a low pelvic colorectal or ileoanal anastomosis. A patient with a permanent stoma may develop a hernia at the stoma site. This may result in complications, such as obstruction or strangulation of the bowel, or problems with proper fitting of the stoma appliance. The extent of procedure depends on the type of stoma created.

Closure of loop stoma

Closure of a loop stoma is performed through a circular incision, placed just outside the mucocutaneous junction of the stoma and the skin. The proximal and distal ends of the bowel are separated from the subcutaneous tissue and anterior fascia, and then the posterior fascia. The bowel is cleaned of adherent skin, and the previously opened antimesenteric border of the bowel is simply closed with sutures. Alternatively, the previously exteriorized portion of bowel is resected, and the two ends are anastomosed with sutures or staples. On rare occasions, it is necessary to extend the incision transversely through the abdominal wall to safely perform an anastomosis. The fascia is closed in the standard fashion. Loop ileostomies are most commonly performed for patients who have had surgery for rectal cancer and who have a low colorectal anastomosis. These patients have frequently received chemotherapy and radiation therapy. A loop ileostomy is also created as part of a **restorative proctocolectomy**

with an **ileal J-pouch anal anastomosis**. These patients tend to be significantly younger.

Closure of end stoma

Closure of an end stoma can be attempted as a laparoscopic procedure. Dense adhesions or difficulty defining the intra-abdominal anatomy may necessitate conversion to an open operation. After entering the peritoneal cavity, the stoma is freed from the abdominal wall. The most common indication for closure of an end colostomy is restoration of intestinal continuity after emergent surgery for perforated diverticulitis or an obstructing left-sided cancer. The severity and indication for the original procedure can have a significant impact on the difficulty of the colostomy takedown. Not infrequently, this procedure begins with **cystoscopy** and **placement of bilateral ureteral stents** by an urologist given the risk of ureteral injury in **reoperative pelvic surgery**. Adhesions are lysed, and the dysfunctioned distal segment of the bowel is identified. It may be necessary to mobilize the proximal bowel to provide a tension-free anastomosis. An anastomosis can then be created using either hand-sewn or stapled techniques.

Parastomal hernia repair

Repair of a stoma hernia may be performed as an open operation, as a laparoscopic operation, or as a robotic procedure. After freeing up and dissecting out any intra-abdominal contents from the hernia, the hernia defect is typically closed using prosthetic or biologic mesh. When done as an open procedure, the abdomen may be entered via a midline or a peristomal incision. In some cases, repair of a stoma hernia requires relocation of the stoma to an alternate site on the abdomen.

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, and possibility of urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Closure of Loop Stoma	Closure of End Stoma	Repair of Parastomal Hernia
Position	Supine	Modified lithotomy	Supine
Incision	Circumstomal	Midline or laparoscopic	Midline circumstomal or laparoscopic

Special instruments	Anastomotic staplers	Anastomotic staplers; may undergo cystoscopy and stents before procedure	Prosthetic or biologic mesh
Antibiotics	Cefazolin 2 g iv and metronidazole 500 mg iv or second-generation cephalosporin (e.g., cefotetan 2 g iv)	⇐	⇐
Surgical time	45 min–1.5 h	1.5–3 h	⇐
Closing considerations	Requires only a few fascial sutures; the skin may be left open.	Paralysis for closure of midline fascial incision and stoma site	Stoma matured after fascial and skin closure if it is relocated to a new site.
EBL	25 cc	100–500 cc	<100 cc
Mortality	<1%	1–3%	1%
Morbidity	Anastomotic leak SBO Wound infection	⇐ — —	Recurrent hernia formation — —
Pain score	5	8	6

PATIENT CHARACTERISTICS

	Closure of Loop Stoma	**Closure of End Stoma**	**Repair of Parastomal Hernia**
Age range	Variable; older for patient with cancer, younger	Variable; tend to be older	⇐

	for patients with IBD		
Male:Female	1:1	⇐	⇐
Etiology	Protection of anastomosis after surgery for rectal cancer; IBD; or as treatment of an anastomotic leak	Prior emergent surgery for colon perforation with peritonitis or obstruction	Prior surgery for rectal cancer or inflammatory bowel disease
Associated conditions	Colorectal cancer, ulcerative colitis, diverticulitis	Colorectal cancer, diverticulitis, trauma	Colorectal cancer, Crohn disease, ulcerative colitis

Suggested Readings

1. Colvin J, Rosenblatt S: Surgical management of parastomal hernias.Surg Clin North Am 2018; 98(3):577–92.
2. DeAsis FJ, Lapin B, Gitelis ME, et al: Current state of laparoscopic parastomal hernia repair: a meta-analysis. World J Gastroenterol 2015; 21(28):8670–7.
3. Horesh N, Rudnicki Y, Dreznik Y, et al: Reversal of Hartmann's procedure: still a complicated operation. Tech Coloproctol 2018; 22(2):81–7.
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5. Menahem B, Lubrano J, Vallois A, et al: Early closure of defunctioning loop ileostomy: is it beneficial for the patient? A meta-analysis. World J Surg 2018; 42(10):3171–8.
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ANESTHETIC CONSIDERATIONS FOR LARGE BOWEL SURGERY

(Procedures covered: total proctocolectomy; partial colectomy with anastomosis; colostomy; stoma closure; and peristomal hernia repair.)

PREOPERATIVE

Patients undergoing colorectal procedures present a heterogeneous group regarding their age, nature of the disease, and implications of the surgery. Indications for large bowel

surgery include cancer and IBD, either of which can be elective or emergent.

Respiratory	In addition to the common pulmonary diseases such as COPD, asthma, chronic bronchitis, restrictive lung disease, etc., patients with IBD may have inflammatory lung involvement with frequently negligible clinical consequences. In emergent cases due to obstruction, perforation, or peritonitis (metabolic acidosis, electrolytes abnormalities), pain, cramping, and distension are the predominate features. Limited diaphragmatic excursion (↓ TV, ↓ FRC) leads to rapid desaturation after induction. In cases of large bowel obstruction, sufficient preoxygenation and RSI are advisable. In addition, patients with IBD may have arthritis and reduced neck ROM. **Tests**: Electrolytes, ABG in septic cases
Cardiovascular	Even in elective cases, hypovolemia 2° poor PO intake, vomiting, and diarrhea may be encountered. Antihypertensive drugs can exacerbate the problem (ACE inhibitors). Hemodynamic instability is common in cases of sepsis and peritonitis (↑ HR, ↓ BP). Vasopressor agents may be indicated. **Tests**: ABG, ECG
Renal	Electrolyte abnormalities 2° vomiting or gastric tube suctioning (metabolic alkalosis) are common. Diarrhea and mechanical bowel preparation can cause metabolic acidosis. **Tests**: Electrolytes
Gastrointestinal	Most patients do not have any acute GI symptoms; some may have nausea or abdominal pain without obvious implications for anesthesia. Patients with obstruction either have already an indwelling NG tube or may benefit from decompression of the stomach. Risk of aspiration is prevalent requiring RSI. Pulling the NG tube before the induction of anesthesia is controversial. Patients with IBD may have hepatic function impairments and altered drug

	metabolism.
Hematologic	Chronic bowel inflammation and cancer often associated with chronic and at times acute GI blood loss. Look for anemia. Consider dehydration as well causing hemoconcentration that may mask anemia. Low albumin levels influence the amount of free circulating drugs in the blood. Consider coagulopathy 2° malabsorption. **Tests**: CBC, PLTs, INR
Laboratory	CBC, BMP, T&S vs. T&C. Other tests as indicated by H&P
Premedication	Standard premedication is usually appropriate. Patients with IBD on chronic steroid therapy should receive their usual daily dose of steroids throughout the periop period and may require full stress-dose steroids.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of thoracic epidural block for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water, possibly in combination with gabapentin 300 mg and/or celecoxib 200 mg. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA ± epidural for intra- and postop analgesia for open procedures provided there are no contraindications. The majority of colorectal procedures are performed laparoscopically, with a relatively small incision for the hand port. The postop pain after laparoscopic cases can be treated with a regimen of iv and po analgesics in majority of patients. For open procedures, thoracic epidural is associated with improved postop pain control, earlier return of bowel function, early intake of food, and out-of-bed mobilization. Intraop use of low-concentration bupivacaine or ropivacaine blunts the surgical stress and reduces the intraop opioid requirements.

Induction	RSI with cricoid pressure should be performed for induction in patients with an acute abdomen to ↓ risk of pulmonary aspiration. An NG tube may not interfere with cricoid pressure and may be left in place or removed immediately before induction after suctioning as it may obscure the airway anatomy during laryngoscopy. If patient is clinically hypovolemic, restoring intravascular volume (colloid, crystalloid) before induction may minimize hypotension. Even with titration of induction agents in elderly patients or those with acute abdomen/sepsis, profound hypotension may occur despite fluid resuscitation, requiring the use of vasopressors to blunt the effect of induction agents. RSI is not indicated for elective, fasted patients, without other indications. Preop hypovolemia is less likely with liberalized NPO guidelines commonly part of ERAS protocols.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance without N_2O. Combined epidural/GA and local anesthetic (e.g., 0.125% bupivacaine 3–5 mL q45–60min or 1.5–2% lidocaine with 1:200,000 epinephrine 5–10 mL q60–90min) can be injected into the epidural catheter to provide both anesthesia and optimal surgical exposure (contracted bowel and profound muscle relaxation). A continuous infusion of local anesthetic (e.g., 0.125% bupivacaine at 4–8 mL/h) may enhance hemodynamic stability compared to bolus technique. A loading dose of epidural opiate (e.g., hydromorphone 0.4–0.8 mg) should be administered 1–2 h before conclusion of surgery. Patients receiving epidural opiates should be monitored for development of delayed postop respiratory depression, and systemic sedatives (e.g., opiates, benzodiazepines) should be minimized. If placed intraop, gastric tubes are increasingly removed in the OR at the conclusion of surgery.

Emergence	The decision to extubate at the end of surgery depends on the patient's volume status, underlying cardiopulmonary status, and extent of surgical procedure. Patients should be hemodynamically stable, warm, alert, and cooperative and fully reversed from any muscle relaxants before extubation and have adequate return of pulmonary function. Discuss with surgeon local wound infiltration. Consider iv acetaminophen if po dose given >6 h ago. PONV prophylaxis usually includes dexamethasone and ondansetron.	
Blood and fluid requirements	18 ga iv × 1 for elective cases: Consider additional and larger iv for emergency cases or hemodynamically unstable patients. BSS at 5–10 mL/kg/h Warm fluids Consider T&S or T&C.	Maintain euvolemia based on EBL and estimates of fluid shifts, UO, HR, BP, base deficit, lab studies, and invasive monitoring when used. Third-space losses may be significant in the setting of acute abdomen and systemically ill patients. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors UO ±Arterial line ±CVP Temperature	Arterial line and CVP, as indicated by patient's status. Hypothermia may delay healing and predispose patients to wound infections. Avoid hypothermia with forced-air warming blanket, warming room temperature, and keeping patient covered until ready for prep.
Positioning	Trendelenburg/reverse Trendelenburg ± lithotomy and pad	Both Trendelenburg and reverse Trendelenburg may be used during laparoscopic

	pressure points ✓ eyes	bowel surgery. Position, pad, and secure patient accordingly. Arms usually tucked for laparoscopic cases. ✓ IV access before draping.
Complications	Septic shock Aspiration of gastric contents Hemorrhage Injuries to the spleen, bowel, and ureters Unresectability of tumor	Hemodynamic instability 2° sepsis, hemorrhage, especially during manipulation of necrotic bowel

POSTOPERATIVE

Complications	Atelectasis Hemodynamic instability Sepsis VTE (see Appendix B, p. B-7) Injuries to bowel and ureters PONV (see Appendix B, p. B-6)	Patients may have considerable third-space losses that require invasive monitoring, ICU admission, and vasopressors. If placed intraop, gastric tubes are often removed in the OR at the conclusion of surgery.
Multimodal pain management	Emphasize multimodal approach combining nonopioid ± bolus/PCA opioid analgesics or epidural analgesia and/or nerve blocks (see Appendix C, p. C-4).	Consider use of non-opiate adjuncts: NSAIDS, ketamine, gabapentin, acetaminophen. PCA
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6) DVT prophylaxis	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Chewing gum may promote

	return of bowel function.
Tests	CBC; CXR (if central line placed), electrolytes, glucose

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2. Grant MC, Pio Roda CM, Canner JK, et al: The impact of anesthesia-influence process measure compliance on length of stay: results from an enhanced recovery after surgery for colorectal surgery cohort. Anesth Analg 2019; 128(1):68–74.
3. Gustafsson UO, Scott MJ, Hubner M, et al: Guidelines for perioperative care i elective colorectal surgery: Enhanced Recovery After Surgery (ERAS®) Society Recommendations: 2018. World J Surg 2019; 43(3):659–95. doi: 10.1007/s00268-018-4844-y
4. Helander EM, Webb MP, Bias M, et al: Use of regional anesthesia techniques analysis of institutional enhanced recovery after surgery protocols for colorectal surgery. J Laparoendosc Adv Surg Tech A 2017; 27(9):898–902.
5. Liu Q, Jiang H, Xu D, et al: Effect of gum chewing on ameliorating ileus followin colorectal surgery: a meta-analysis of 18 randomized controlled trials. Int J Surg 2017; 47:107–15.

OPERATIONS FOR RECTAL PROLAPSE

SURGICAL CONSIDERATIONS

Description

Rectal prolapse (procidentia) is intussusception of the full thickness of the rectal wall beyond the anal canal. It must be distinguished from rectal mucosal prolapse, caused by elongation of the mucosal attachments to the underlying sphincter muscle, and internal intussusception, where the upper rectum folds into the lower rectum but does not descend through the sphincter mechanism. Rectal mucosal prolapse is treated as part of the spectrum of hemorrhoidal disease, and mild-to-moderate intussusception does not benefit from surgery. Procidentia is associated frequently with anal incontinence. The surgical approaches to procidentia are determined by patient age, concurrent medical disease, sphincter function, and prior operative history, including previous abdominal surgery and prior attempts at surgical repair. Surgical treatment of procidentia may be

undertaken through an abdominal or a perineal approach. Abdominal repair of rectal prolapse can be performed in either an open, laparoscopic fashion or robotic fashion. The abdominal approaches have a lower recurrence rate and because they do not diminish the capacity of the rectal reservoir and are generally preferable for maintaining fecal continence. **Rectopexy** is an abdominal approach in which the rectum is mobilized in the posterior plane from the sacral promontory to the levator muscles. The rectum is then pulled cephalad and sutured to the presacral fascia with multiple nonabsorbable sutures or tacked to the presacral fascia using surgical tacks. Mesh may or may not be used to fix the rectum to the sacrum depending on the operative preference of the surgeon. Many surgeons routinely perform **sigmoid resection** along with rectopexy. They believe that removal of the redundant sigmoid further diminishes the chance of late recurrence and may alleviate constipation. A number of approaches have been described, the most popular being the **Ripstein procedure**. **Sling procedures** have equivalent recurrence rates but higher complication rates. As in rectopexy, the rectum is mobilized along the presacral plane down to the level of the levators. A band of Marlex mesh is sewn to the presacral fascia at the sacral promontory, upward traction is placed on the rectum, and the mesh is sutured to the rectum. **Transabdominal repair** of rectal prolapse is the favored approach for younger patients with rectal prolapse or older paints with few medical comorbidities due to the significantly lower rate of recurrence of the prolapse.

Not uncommonly, however, patients with rectal prolapse are of advanced in age or have significant medical comorbidities. In these higher-risk patients, prolapse may be repaired via a perineal approach. The most common of these is **perineal rectosigmoidectomy (or Altemeier procedure)**. The prolapsed rectum is withdrawn through the anal canal to its full extent, and a circumferential incision is made in the outer tube of the prolapsed bowel just proximal to the dentate line. This exposes the inner tube of prolapsed bowel and mesentery. Redundant bowel is mobilized from the distal end, up to the point that no additional bowel can be delivered into the operative field. The redundant bowel is transected, and a primary anastomosis is fashioned between the cut ends of the inner and outer bowel. Prior to anastomosis, the levator muscles are often approximated in the midline in an effort to aid continence. When the volume of prolapsed tissue is small, or a previous abdominal approach makes blood supply to the rectum questionable, the **Delorme procedure** often is performed. During this procedure, the mucosa is stripped off the prolapsed rectum, and the prolapsed rectal muscle is foreshortened by plication until it resides above the sphincters. **Perineal repair** of rectal prolapse is most commonly done under a general anesthetic; as the patient is typically positioned prone, the procedure can take 60–90 min; and in the case of a **perineal rectosigmoidectomy**, the peritoneal cavity is entered. However, in very

high-risk patients for whom intubation or general anesthesia is a concern, the procedure can be done under an epidural or local anesthesia with sedation.

Usual preop diagnosis

Full-thickness rectal prolapse

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, and possibility of urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Rectopexy	Rectopexy with Sigmoid Resection	Perineal Rectosigmoidectomy	Delorme Procedure
Position	Lithotomy	⇐	Prone jackknife; lithotomy	⇐
Incision	Low transverse; low midline; laparoscopic or robotic	⇐	No external incision	⇐
Special instrumentation	Deep pelvic instruments; mesh if sling planned	Deep pelvic instruments	Hip roll for jackknife position; anastomosis may be created with EEA stapler.	Hip roll for jackknife position
Unique considerations	Presacral venous plexus bleeding may occur; bowel prep may cause dehydration or hypokalemia.	⇐	Epinephrine solutions may be used to diminish bleeding; bowel prep may cause dehydration or hypokalemia.	⇐
Antibiotics	Ertapenem 1 g iv or second-generation cephalosporin (e.g., cefotetan 2 g iv)	⇐	⇐	⇐
Surgical time	1–2 h	⇐	⇐	⇐
EBL	<100 mL; more if reoperation	100–300 mL; more if reoperation	100–200 mL	100 mL
Postop care	No rectal probes or medications	⇐	⇐	⇐
Mortality	0–2%	0–4%	1–4%	0–1%
Morbidity	Rectal stricture (with sling): 5–10% Recurrent prolapse: 2–8% Pelvic infection: 5%	— 2–5% — Anastomotic leak: 2–4%	— 20–40% — —	— 5–10% — —
Pain score	7	7	2	2

PATIENT POPULATION CHARACTERISTICS	
Age range	Women: peak incidence in 6th–7th decade; men: evenly distributed through age range
Male:Female	1:4
Incidence	Unknown
Etiology	Decreased pelvic muscular support; congenital deficiency of rectal support; pudendal neuropathy; chronic constipation and straining; multiparity; myelomeningocele; spina bifida; cystic fibrosis (children); acute parasitic diarrheal illness (children)
Associated conditions	Fecal incontinence; urinary stress incontinence; rectocele; cystocele

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations Following Operations for Fecal Incontinence.

Suggested Readings

1. Barfield LR: Perineal approaches to rectal prolapse.Clin Colon Rectal Surg2017; 30(1):12–5.
2. Bordeianou L, Paquette I, Johnson E, et al: Clinical practice guidelines for th treatment of rectal prolapse. Dis Colon Rectum 2017; 60(11):1121–31.
3. Emile SH, Elfeki H, Shalaby M, et al: Perineal resectional procedures for th treatment of complete rectal prolapse: a systematic review of the literature. Int J Surg 2017; 46:146–54.
4. Hori T, Yasukawa D, Machimoto T, et al: Surgical options for full-thickness rectal prolapse: current status and institutional choice. Ann Gastroenterol 2018; 31(2):188–97.
5. Joubert K, Laryea JA: Abdominal approaches to rectal prolapse.Clin Colon Rectal Surg 2017; 30(1):57–62.
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RECTAL SURGERY

SURGICAL CONSIDERATIONS

Description

Many lesions within the distal two-thirds of the rectum can be excised through a **transanal approach** (Fig. 7.4-3). The most common benign tumors treated by local excision are adenomas. Lesions such as carcinoid tumor, endometrioma, and solitary rectal ulcer also may be locally excised. Transanal excision of benign lesions may be performed in the submucosal plane, whereas suspected malignancies are excised by removing the entire thickness of the rectal wall. Full antibiotic and mechanical bowel prep are given. Transanal excision usually is performed in the prone jackknife position, although the lithotomy position may be used when the lesion is located on the posterior rectal wall. A local anal block, usually 0.25% bupivacaine with 1:200,000 epinephrine, is performed to relax the sphincter mechanism and minimize sphincter injury, aid in hemostasis, and diminish postoperative pain. An **anoscope** is inserted into the anal canal. Stay sutures may be placed adjacent to the area of resection. On occasion, lesions may be prolapsed all the way through the anus and excised outside the body. Generally, the dissection starts at the distal end of the lesion and proceeds proximally. The **proctotomy** may be closed with running or interrupted sutures. These sutures are then grasped and used for further traction. When the specimen is removed, a few final sutures are needed to close the proximal-most incision. **Rigid proctoscopy** is performed to confirm preservation of an adequate lumen.

Variant procedure or approaches

TEM (transanal endoscopic microsurgery) and TAMIS (transana minimally invasive surgery)

Another technique for the removal of larger lesions or lesions more proximally located in the rectum is **transanal endoscopic microsurgery and** transanal minimally invasive surgery. In these techniques, the patient is placed on the operating table in a position that puts the lesion to be removed posterior. Because of this, the patient may be prone, supine in lithotomy, or in the right or left lateral decubitus position. The procedure is performed through a larger operating proctoscope or transanally placed port. The colon is insufflated using carbon dioxide to provide an operating space. The carbon dioxide will be absorbed through the mucosa of the colon and be exhaled. Laparoscopic-like instruments are passed through the proctoscope, and the surgeon views the operation either through a stereo viewer attached to the proctoscope or on a video screen. The lesion in question is removed and the defect in the rectum sutured closed.

Transsacral Resection

The **transsacral (Kraske) approach** to rectal tumors offers wider exposure than the

transanal approach but is more painful and has a substantially higher likelihood of complications (wound infection, fecal fistula, incontinence). A transsacral approach may be advantageous when the lesion is located behind the rectum (retrorectal tumors) and when resection of the lower sacrum or coccyx is anticipated. Transsacral resection generally is performed in the prone jackknife position. An incision is made from the posterior commissure of the anus to the base of the sacrum. The sphincter muscles are spared, but the levator muscles are divided to expose the posterior wall of the rectum. The coccyx may be disarticulated and removed to improve exposure. It is also possible to remove the lower sacral segments through this approach, but increasing morbidity accrues as the sacral nerve roots are sacrificed. For a posterior wall lesion, the posterior wall of the rectum is opened, and the lesion, along with a full-thickness disc of rectal wall, is excised. If the lesion is on the anterior wall, two proctotomy incisions are necessary. The proctotomy incisions are closed with standard anastomotic techniques. The levator muscles are reapproximated, and the skin is closed. A drain may be placed within the retrorectal space before closing. The transsacral approach may be combined with an **abdominal approach (abdominal-transsacral resection)** in some cases of low rectal cancer.

Transsphincteric

The **transsphincteric (York-Mason)** approach to rectal lesions also gives wider exposure than does the transanal approach, but at the expense of a substantially higher risk of fecal incontinence. Transsphincteric excision is performed with the patient in the prone jackknife position. An incision is made at the posterior commissure of the anus and is extended along the lateral border of the coccyx and sacrum. The external sphincter, internal sphincter, and levator ani muscles are sequentially transected in the posterior midline. As each muscle is cut, the cut edges are tagged with sutures to facilitate accurate reapproximation. The rectal wall is incised, and the lesion is excised. The proctotomy incision is closed via standard anastomotic suturing techniques, and the individual components of the sphincter muscle are reapproximated with interrupted sutures. The overlying skin is closed in a standard fashion.

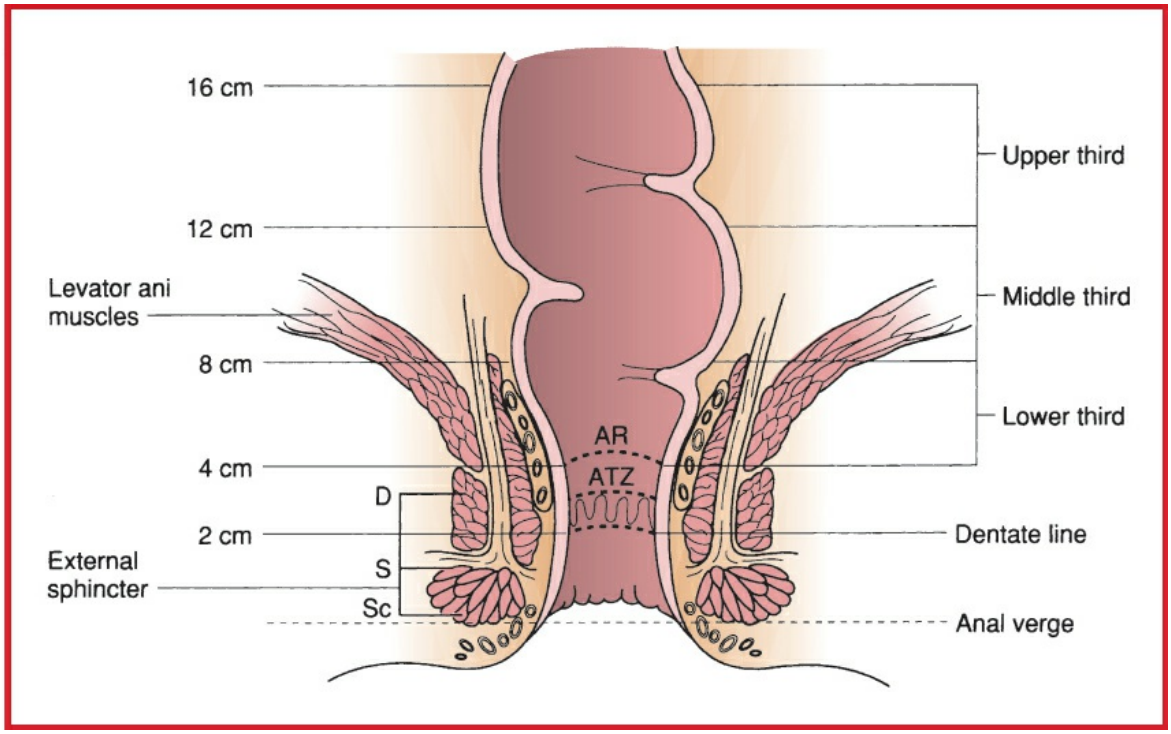

Figure 7.4-3 Anorectal anatomy with important landmarks. Approximate measurements are relative to the anal verge. D, deep; S, superficial; Sc, subcutaneous; AR, anorectal ring; ATZ, anal transition zone. (Reproduced with permission from Yahanda AM, Chang AE: Colorectal cancer. In: Greenfield LJ, Mulholland MW, Oldham KT, et al., eds. Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, and possibility of urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Transanal Excision	Transsacral Excision	Transsphincteric Excision	TEM or TAMIS
Position	Prone jackknife or lithotomy	Prone jackknife	⇐	Prone jackknife, lithotomy, or lateral decubitus
Incision	Intrarectal	Anus to lateral sacral wall	⇐	Intrarectal
Special instrumentation	Rigid proctoscope; headlight and/or fiber-optic retractors; Foley catheter	Gigli or power saw if sacral resection contemplated; headlight and/or fiber-optic retractors; Foley catheter	Headlight and/or fiber-optic retractors; Foley catheter	Proctoscope (40-mm diameter), removable faceplate, optical stereoscope, light cord, pressure transducer, laparoscopic camera, insufflator, instruments (5-mm diameter), Martin arm to hold equipment
Unique considerations	Bowel prep may → dehydration and hypokalemia.	⇐	⇐	⇐
Antibiotics	Cefazolin 2 g iv and metronidazole 500 mg iv or cefotetan 2 g iv	⇐	⇐	⇐
Surgical time	15–120 min	1–2 h	⇐	⇐
EBL	<100 mL	<100 mL (500 mL if sacral resection)	⇐	⇐
Postop care	No rectal temperatures, suppositories, or enemas	⇐	⇐	⇐
Mortality	0–2%	⇐	⇐	0.3–2%
Morbidity	Tumor recurrence: 5–50% Urinary retention: 10–20% Bleeding: 2–5% Pelvic sepsis: 0–4% Ureteral injury: < 1% (minimized by use of Foley)	50% ⇐ ⇐ ⇐ ⇐ Fecal fistula: 10–30% Fecal incontinence: 5–10%	5–50% ⇐ ⇐ ⇐ ⇐ 10–40%	4–20% ⇐ 2% 0.8% Intraperitoneal entry: 1–4% 2%
Pain score	3	7	7	3

PATIENT POPULATION CHARACTERISTICS	
Age range	Rectal adenomas, 5th–7th decades; rectal adenocarcinoma, 6th–9th decades; endometrioma, 2nd–4th decades; solitary rectal ulcer syndrome, 4th–8th decades; carcinoid tumors, 5th–8th decades
Male:Female	1:1
Incidence	Varies with disease; not uncommon
Etiology	Varies with disease
Associated conditions	Preexisting anorectal pathology, such as fecal incontinence, may require concurrent treatment.

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations Following Operations for Fecal Incontinence.

Suggested Readings

1. Beets GL, Figueiredo NF, Beets-Tan RG: Management of rectal cancer withou radical resection. Annu Rev Med 2017; 68:169–82.
2. deBeche-Adams T, Nassif G: Transanal minimally invasive surgery. Clin Colon Rectal Surg 2015; 28(3):176–80.
3. Kelley KA, Tsikitis VL: Endoluminal therapy in colorectal cancer. Clin Colon Rectal Surg 2016; 29(3):216–20.
4. Leong KJ, Evans J, Davies MM, et al: Transanal endoscopic surgery: past, preser and future. Br J Hosp Med (Lond) 2016; 77(7):394–402.
5. Rai V, Mishra N: Transanal approach to rectal polyps and cancer. Clin Colon Rectal Surg 2016; 29(1):65–70.
6. Saur NM, Wexner SD: An update on minimally invasive techniques in colorectal surgery for neoplasia. Minerva Chir 2016; 71(6):377–81.

ANORECTAL SURGERY

GENERAL CONSIDERATIONS

Anorectal procedures are common general surgical operative procedures. The most common anorectal procedures are done for symptomatic hemorrhoids, perianal abscesses and fistulae, and anal fissures. Many of these procedures can be

accomplished under local anesthesia with an anal canal block. This provides anesthesia for the procedure and also provides for postoperative pain control if a long-acting local anesthetic is used. Performing the block can be painful and is usually performed in conjunction with sedation provided by the anesthesiologist. These procedures can be more extensive, and reoperative procedures may require general anesthesia. Anorectal procedures can be safely performed in the prone jackknife position as well as in the lithotomy position at the preference of the surgeon. One of the most common complications after anorectal surgery is urinary retention. This fact should be kept in mind when determining the volume of intravenous fluid to be given during the procedure.

SURGERY FOR ANAL FISTULAE

SURGICAL CONSIDERATIONS

Description

The majority of perianal fistulae are due to infection in the anal glands within the anal canal that communicate with crypts located at the dentate line (cryptoglandular fistula). Fistulae also may be the result of trauma, Crohn disease (CD), inflammatory processes within the peritoneal cavity, neoplasms, or as a consequence of radiation therapy. The ultimate treatment of fistula-in-ano is determined by the etiology and the anatomic course of the fistula. The principle behind treatment of cryptoglandular fistulae is to ablate the offending gland and lay open the tract. Fistulae that track above the majority of the sphincter mechanism must be treated by procedures that either do not cut the overlying sphincter or cut the sphincter and repair it. A fistula may be treated at the time of drainage of a perianal abscess or as a separate, elective operation. The route of a fistula tract is best determined by exploration at the time of operation. Although local anesthesia is acceptable for most fistulae, a few fistula operations require regional or general anesthesia because the ultimate route and depth of the fistula are unknown. Special consideration is given to fistulae that arise in the setting of CD. Poor wound healing and the importance of sphincter function in patients with chronic diarrhea dictate that only the most superficial fistulae are laid open. The primary goal is palliation, specifically abscess drainage and recurrence prevention. This is often accomplished by placing a silastic seton (a loose ligature around sphincter muscles) around the fistula tract and leaving it in place indefinitely. In the absence of active CD in the rectum and anus, attempts at fistula cure may be undertaken.

VARIANT PROCEDURE OR APPROACHES

Fistulotomy

Fistulotomy involves cutting all tissues superficial to a fistula so that the fistula tract is brought to the skin level. The opened, fibrotic fistula wall is often sewn to the skin edge (marsupialized). Fistulectomy involves excision of the entire fistula tract. When conventional fistulotomy would cause incontinence, a seton may be used. Other approaches that may be used to avoid fecal incontinence are complete fistulotomy with immediate reconstruction of the sphincter and excision of the internal opening by an endorectal advancement flap technique.

Fistula plug

The fistula plug involves the use of a bioabsorbable xenograft made of lyophilized porcine intestinal submucosa that is reconstituted in saline and placed in the fistula tract. This method may be preferred for fistulae that would require transection of a significant portion of the anal sphincters such that the surgeon is concerned about the impact on continence. It is used for both cryptoglandular fistulae and CD–related fistulae.

LIFT procedure

A LIFT procedure (ligation of the intersphincteric fistula tract) is a third technique used to treat fistulae that cannot be treated by fistulotomy. An incision is made in the anatomic plane between the internal and external sphincters. After the fistula tract is divided, the openings in the anal canal as well as in the internal and external anal sphincters are sutured closed.

Usual preop diagnosis

Fistula-in-ano

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Fistulotomy or Fistulectomy	Fistulotomy with Seton	Endorectal Advancement Flap	Fistula Plug
Position	Prone jackknife; rarely lithotomy	⇐	Prone jackknife	⇐
Incision	Perianal	⇐	⇐	None
Antibiotics	None	None	Ertapenem 1 g iv or cefotetan 2 g iv	None
Surgical time	10–30 min	⇐	60–90 min	5–10 min
EBL	<50 mL	⇐	⇐	Negligible
Mortality	Minimal	⇐	⇐	⇐
Morbidity	Fecal incontinence: 0–30% Nonhealing or recurrent fistula: 5%	10–30% 10–20% (This procedure is used only in complex fistulae, so complication rate appears higher.)	0–10% 10–40% (This procedure is used only in complex fistulae, so complication rate appears higher.)	0% 25–50%
Pain score	6	6	6	0–1

PATIENT POPULATION CHARACTERISTICS

Age range	2nd–7th decades
Male:Female	2:1
Incidence	Common
Etiology	Infection within anal glands located at dentate line (cryptoglandular fistula); trauma; Crohn disease; inflammatory processes within the peritoneal cavity; neoplasms; consequence of radiation therapy

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations Following Operations for Fecal Incontinence.

Suggested Readings

1. Adegbola SO, Sahnan K, Pellino G, et al: Short-term efficacy and safety of three novel sphincter-sparing techniques for anal fistulae: a systematic review. Tech Coloproctol 2017; 21(10):775–82.

2. Akiba RT, Rodrigues FG, da Silva G: Management of complex perineal fistula disease. Clin Colon Rectal Surg 2016; 29(2):92–100.
3. Jamshidi R: Anorectal complaints: hemorrhoids, fissures, abscesses, fistulae. Clin Colon Rectal Surg 2018; 31(2):117–20.
4. Lee MJ, Heywood N, Adegbola S, et al: Systematic review of surgical intervention for Crohn's anal fistula. BJS Open 2017; 1(3):55–66.
5. Rozalén V, Parés D, Sanchez E, et al: Advancement flap technique for anal fistula in patients with Crohn's disease: a systematic review of the literature. Cir Esp 2017; 95(10):558–65.

HEMORRHOIDECTOMY/STAPLED HEMORRHOIDOPEXY

SURGICAL CONSIDERATIONS

Description

Hemorrhoids are normally occurring vascular tissues located in discrete aggregations known as hemorrhoidal cushions within the distal rectum and anus. Thought to play a role in the fine control of enteric continence, they are only treated if they cause a symptom that persists after conservative therapy. Hemorrhoids may bleed, prolapse, and cause mucous drainage, itching, or pain (when thrombosed). The primary pathophysiologic event in the development of symptomatic hemorrhoids is thought to be mucosal prolapse 2° degeneration of the fibroelastic tissue that tethers vascular cushions and overlying mucosa to the submucosa. Many modern treatments diminish prolapse by fixing the mucosa to the submucosa with scar tissue. Hemorrhoids are classified as internal (when above the dentate line) or external (when below) (see Fig. 7.4-3). Internal hemorrhoids are further classified by symptoms: I, bleed; II, bleed prolapse, and spontaneously reduce; III, bleed, prolapse, and require manual reduction; and IV, bleed, prolapse, and cannot be reduced. The most common symptom from external hemorrhoids is severe pain caused by thrombosis. Surgical treatment involves excision of the thrombosed hemorrhoid, often under local anesthetic, in the office. Internal hemorrhoids may be treated by nonexcisional or excisional techniques. Nonexcisional techniques generally are used in the office or outpatient clinic. They do not require an anesthetic because their use is limited to the insensate tissues above the dentate line. Nonexcisional treatments include rubber-band ligation, infrared coagulation, sclerotherapy, and cryotherapy.

Hemorrhoidectomy

Surgical **hemorrhoidectomy** may be performed in the lithotomy or prone jackknife position. An **anoscope** is placed in the anal canal, and a hemorrhoid column is grasped and tented up into the lumen. A suture is placed at the internal apex of the complex. An incision is started at the external apex of the hemorrhoidal complex, and a plane is developed deep to the hemorrhoidal tissue and superficial to the sphincter muscles. When the internal sphincter is identified, the dissection proceeds in the avascular space along its luminal surface. The dissection is continued up into the rectum to the transfixing suture. Lateral incisions along the redundant tissue are completed to excise the hemorrhoid. Care is taken to leave healthy bridges of mucosa between adjacent hemorrhoidal columns. Hemostasis is obtained with cautery, and the mucosal defect may be closed with a running, absorbable suture. It also is acceptable to leave the mucosal wound open. The procedure is repeated over the other enlarged, symptomatic hemorrhoidal complexes, removing redundant tissue and leaving long, vertical scars to prevent further mucosal prolapse.

VARIANT PROCEDURE OR APPROACHES

Stapled hemorrhoidectomy

A stapled hemorrhoidectomy or hemorrhoidopexy is used for the correction of mucosal hemorrhoidal prolapse. This procedure is performed in the same position and under the same anesthesia as a conventional hemorrhoidectomy. A circular anal dilator is anchored to the skin with heavy sutures, an obturator is passed, and a purse-string is created with absorbable 2-0 suture 3–4 cm above the dentate line. The stapler head is passed above the purse-string, and the sutures are pulled while the stapler is closed. In women, the vaginal wall must be examined to ensure that it has not been incorporated. The stapler is fired, cutting the incorporated mucosal prolapse, pulling the internal and external hemorrhoids proximally. Thus, the hemorrhoids themselves are not removed. Hemostasis is obtained with sutures as needed. Cautery should be used with caution, because of the staples. This procedure is associated with a higher rate of disease recurrence and cost.

Transanal Hemorrhoidal Dearterialization

Transanal hemorrhoidal dearterialization (THD) is an effective treatment for hemorrhoidal disease. The ligation of hemorrhoidal arteries located with a Doppler probe can provide a significant reduction of the arterial overflow to the hemorrhoidal piles. Plication of the redundant rectal mucosa/submucosa (called “mucopexy”) can provide a repositioning of prolapsing tissue to the anatomical site. In long-term follow-up, there is resolution of symptoms in the vast majority of patients. The most common complication is transient tenesmus, which sometimes can result in rectal discomfort or

pain. Rectal bleeding occurs in small number of patients.

Usual preop diagnosis

Symptomatic hemorrhoids; bleeding; and/or prolapse

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Surgical Hemorrhoidectomy	Stapled Hemorrhoidopexy
Position	Prone jackknife, lithotomy, or left lateral decubitus	Prone jackknife, lithotomy
Incision	Series of vertical incisions from anal verge to top of hemorrhoid columns	None
Special instrumentation	Headlight or lighted anoscope; operating anoscope	Circular anal dilator, obturator, stapler
Antibiotics	None	None
Surgical time	30–90 min	10–20 min
EBL	<100 mL	100 mL
Postop care	Sitz baths, oral fluids, fiber supplements	⇐
Mortality	Rare	⇐
Morbidity	Urinary retention: 15–30% Incontinence: 1–6% Bleeding: 2–5% Stricture: 2–5% Infection: 1–2%	⇐
Pain score	9	5

PATIENT POPULATION CHARACTERISTICS	
Age range	Peak prevalence 45–65 yr
Male:Female	1:1
Incidence	Prevalence 75/1000
Etiology	Low-fiber diet; genetic; pregnancy
Associated conditions	Constipation

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations Following Operations for Fecal Incontinence.

Suggested Readings

1. Emile SH, Elfeki H, Sakr A, et al: Transanal hemorrhoidal dearterialization (THD versus stapled hemorrhoidopexy (SH) in treatment of internal hemorrhoids: a systematic review and meta-analysis of randomized clinical trials. Int J Colorectal Dis 2019; 34(1):1–11.
2. Jacobs DO: Hemorrhoids: what are the options in 2018? Curr Opin Gastroenterol 2018; 34(1):46–9.
3. Rakinic J: Benign anorectal surgery: management. Adv Surg 2018; 52(1):179–204.
4. Song Y, Chen H, Yang F, et al: Transanal hemorrhoidal dearterialization versus stapled hemorrhoidectomy in the treatment of hemorrhoids: a PRISMA-compliant updated meta-analysis of randomized control trials. Medicine (Baltimore) 2018; 97(29):e11502.

OPERATIONS FOR FECAL INCONTINENCE

SURGICAL CONSIDERATIONS

Description

In the majority of patients, fecal incontinence is caused by a combination of pudendal neuropathy and atrophy of pelvic floor muscles. Only when an anatomic defect in the sphincter mechanism can be identified is surgery likely to be beneficial. **Sphincteroplasty** is performed in the prone jackknife position after a full mechanical bowel prep. An incision is made at the anal verge, centered over the area of injured sphincter, and extended sufficiently around the anus to reach the retracted, cut edges of

the sphincter. The anoderm and rectal mucosa are dissected off the internal surface of the sphincter. The external surface of the sphincter mechanism is then dissected free to the level of the pelvic diaphragm. Care must be taken not to injure the inferior hemorrhoidal nerves during dissection around the posterolateral sphincter. The fibrotic portion linking the two ends of sphincter is cut, and the ends are overlapped and secured in place with two layers of interrupted horizontal mattress sutures. In women with obstetric injuries, the transverse perineal muscles are reapproximated. The skin may be reapproximated at the anal verge and along the reconstructed perineum or left open. The remainder of the skin is closed as completely as possible.

VARIANT PROCEDURES OR APPROACHES

Parks postanal repair

The surgical options for patients without anatomic defects in their sphincters are generally unsuccessful. The **posterior anoplasty of Parks** was designed to passively enhance continence by increasing the normally occurring angle between the rectum and the anal canal and to increase the mechanical efficiency of weak sphincter muscle by shortening the fiber length. Lack of efficacy has limited its use, although some surgeons still perform it in the setting of continued incontinence after abdominal repair of rectal prolapse. The operation is performed in the prone jackknife position after standard bowel prep. A hemispherical incision is made at the level of the intersphincteric groove over the posterior half of the anus. The plane between the internal and external anal sphincters is identified and developed proximally to above the puborectalis musculus. The puborectalis fibers are "reefed," or pulled together, as far as possible with nonabsorbable sutures. The external sphincter is plicated together in the midline with a series of nonabsorbable sutures that start at the deep external sphincter and progress to the subcutaneous sphincter. Skin is closed with absorbable sutures.

Thiersch procedure

The **Thiersch operation (pinch graft)** has a high complication rate and should be considered primarily in debilitated patients with symptomatic rectal prolapse or fecal incontinence. As initially described the anal canal was encircled with a silver wire, which served as a passive obstacle to prolapse or defecation. In more recent years, an elastic sheet of Dacron-impregnated Silastic mesh has been used. Two small incisions are made on opposite sides of the anal verge. A pathway around the anal canal is created by blunt dissection, and a 1.5-cm-wide piece of mesh is led around the anal canal. The ends of the mesh are overlapped in one of the incisions and either sutured or stapled together at an appropriate level of tension. The wounds are irrigated with antibiotic solution, and the incisions are closed.

Usual preop diagnosis

Fecal (enteric) incontinence

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Overlapping Sphincteroplasty	Parks Repair	Modified Thiersch Procedure
Position	Prone jackknife	⇐	Prone jackknife or lithotomy
Incision	Circumanal	⇐	Two small incisions lateral to the anus
Special instrumentation	Headlight	⇐	Headlight; Silastic mesh
Unique considerations	Urinary catheter preop; standard bowel prep	⇐	None
Antibiotics	Ertapenem 1 g iv or second-generation cephalosporin	⇐	⇐
Surgical time	1–2 h	1 h	30–45 min
EBL	<100 mL	⇐	⇐
Postop care	Early: Sitz baths Late: fiber supplement, stool softener	⇐ ⇐	⇐ ⇐
Mortality	Rare	⇐	⇐
Morbidity	Unimproved incontinence: 20% Improved but minor incontinence: 30%	60–80%	20% Erosion of prosthesis: 30–60%

	Prolonged wound healing: 20% Infection: 1–2%		Obstructed defecation: 20–40% Infection
Pain score	8	7	6

PATIENT POPULATION CHARACTERISTICS

Age range	Bimodal: 3rd–5th decades for obstetric injury, fistulotomy, and perineal trauma; 6th–8th decades for pudendal neuropathy/pelvic floor atrophy
Male:Female	1:4
Incidence	Not uncommon
Etiology	Pudendal neuropathy; pelvic floor atrophy; obstetric injury; injury during anal surgery (fistulotomy, sphincterotomy, hemorrhoidectomy); perineal trauma; neurologic disease; congenital anomalies
Associated conditions	Urinary incontinence; chronic constipation; multiparity

ANESTHETIC CONSIDERATIONS

(Procedures covered: excision or repair of rectal prolapse; rectal surgery; anal fistulotomy/fistulectomy; anal sphincterotomy/sphincteroplasty; hemorrhoidectomy; operations for fecal incontinence.)

Rectal surgery is frequently performed in prone or jackknife positions. Many procedures do not require general anesthesia and can be performed under MAC. Coordination with the surgeon is recommended to determine the type and timing of anesthesia.

PREOPERATIVE

Depending on the institutional preference, rectal procedures are frequently performed in prone or jackknife position. Minor rectal surgeries do not necessarily require general endotracheal anesthesia and can be managed with sedation/deep sedation alone.

Respiratory	A careful evaluation of patient's respiratory status is important. If patient has ↓ reserve, the lithotomy position may be better tolerated than the prone or jackknife positions. **Tests**: As indicated by H&P
Musculoskeletal	Rectoperineal area is very sensitive; thus, it is often difficult for the patient to stay in supine or sitting position. Consider sufficient pain control preinduction and choose lateral decubitus position if spinal anesthesia is planned.
Hematologic	Acute and chronic GI blood loss is not common in this patient population. **Tests**: Consider CBC
Laboratory	Other tests as indicated by H&P
Premedication	Standard premedication
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of a lumbar epidural block for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Sedation, GA, spinal techniques may be used. Epidural anesthesia is less common and may spare the anoperineal region.

General anesthesia

Induction	**General (LMA vs. ETT)**: Standard induction. Procedures planned in prone or jackknife position may require careful airway management. Consider ET intubation if airway concerns exist. Management of the prone patient is more challenging than the supine position.

ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance
Emergence	Standard emergence. Discuss with surgeon local wound infiltration. Consider iv acetaminophen if po dose given >6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.

Regional anesthesia

MAC	iv sedation combined with local perirectal infiltration of local anesthesia by surgeon (such as four-quadrant pudendal nerve block) is appropriate for many outpatient procedures. Perirectal injection of local anesthetic is painful; rapid-acting agents such as propofol, remifentanil, alfentanil, and ketamine (hypersalivation may require anticholinergic agents) should be administered to minimize patient discomfort during the injection. As drug effect will vary widely among patients, careful titration of the drugs to desired level of sedation is warranted. Consider need to return patient to supine position quickly (keep bed/gurney at the ready).	
Spinal	Patient may be in either sitting, lateral decubitus, prone, or jackknife position for placement of a subarachnoid block. Doses of local anesthetics should be adequate to provide a high lumbar level (L1-L2) of sensory anesthesia (e.g., bupivacaine 8–12 mg). Patients should remain in relative head-up position with hyperbaric solutions and in head-down position with hypobaric solutions to limit cephalad spread of block.	
Blood and fluid requirements	iv: 18–20 ga × 1+ (depending on scope of rectal procedure) BSS at 3–5 mL/kg/h	Blood products rarely needed. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	Others as clinically indicated

Positioning	Prone, jackknife, or lithotomy may be used. ✓ and pad pressure points ✓ eyes and arm positioning ✓ empty stoma bags before turning prone	Chest support or bolsters to optimize ventilation in the jackknife position; care in positioning the patient's extremities and genitals after turning into jackknife position. Avoid pressure on eyes and ears after turning patient.
Complications	Apnea Peripheral nerve injury	May need to convert emergently from MAC to GA. Lithotomy position can damage the peroneal nerve, resulting in foot drop. Improper arm positioning can lead to axillary plexus stretch and nerve damage.

POSTOPERATIVE

Complications	Urinary retention	Catheterize until return of urinary function especially after spinal anesthesia and may be prevented by restricting the volume of iv fluids administered.
Multimodal pain management	Emphasize multimodal approach combining nonopioid ± bolus/PCA opioid analgesics with epidural analgesia (see Appendix C, p. C-4).	Consider use of nonopiate adjuncts: NSAIDs, ketamine, gabapentin, acetaminophen
ERAS	PONV protocol (Appendix B, p. B-4 and B-6) Consider DVT prophylaxis.	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Chewing gum may promote return of bowel function.

Tests	As indicated by patient status

Suggested Readings

1. Baldini G, Fawcett WJ: Anesthesia for colorectal surgery. Anesthesiol Clin 2015; 33(1):93–123.
2. Helander EM, Webb MP, Bias M, et al: Use of regional anesthesia techniques analysis of institutional enhanced recovery after surgery protocols for colorectal surgery. J Laparoendosc Adv Surg Tech A 2017; 27(9):898–902.
3. Kim AJ, Yong RJ, Urman RD: The role of transversus abdominis plane blocks i enhanced recovery after surgery pathways for open and laparoscopic colorectal surgery. J Laparoendosc Adv Surg Tech A 2017; 27(9):909–14.
4. Liu Q, Jiang H, Xu D, et al: Effect of gum chewing on ameliorating ileus followin colorectal surgery: a meta-analysis of 18 randomized controlled trials. Int J Surg 2017; 47:107–15.

CHAPTER 7.5

Hepatic Surgery

SURGEON
Samuel K. S. So, MD, FACS

ANESTHESIOLOGIST
Hendrikus J. M. Lemmens, MD, PhD

HEPATIC RESECTION

SURGICAL CONSIDERATIONS

Description

Liver resections usually are performed to remove primary or metastatic tumors to the liver. The most common malignant primary liver tumor is hepatocellular carcinoma (HCC), usually caused by chronic hepatitis B or C, and cirrhosis due to chronic alcoho abuse. Liver resection is also performed for an enlarging hepatic adenoma, which is a benign primary tumor that is susceptible to rupture. The most common secondary tumors are metastases from colorectal cancer. In rare cases, it may be necessary to resect a devitalized area of the liver following trauma. The mortality and morbidity following liver resection depend on the extent of the surgery, experience of the surgeon, and the patient's hepatic function. In general, the risk of resection is higher in patients with primary HCC where the uninvolved part of the liver frequently is cirrhotic or diseased from chronic hepatitis B or C. Cirrhotic patients with Plt counts <80,000, portal HTN with varices, ascites, albumin <3.5 g/L, and prolonged international normalized ratio (INR) are generally unsuitable candidates for major liver resection because of the high risk of postop liver failure.

Intraop blood loss is the most important predictor of short-term survival. Bleeding is mostly from intrahepatic branches of portal and hepatic veins injured during the

dissection, potentially leading to massive blood loss within minutes. Liver resection performed by an experienced liver surgeon using modern dissection techniques often can be accomplished without the need for blood transfusions (cell salvage techniques should not be used when operating on cancer patients). The mortality rate of major liver resection should be <2–5%. In my experience, most patients do not require postop ICU care and are usually discharged within 4–5 d. Improved outcomes result from better surgical exposure and mobilization of the liver combined with the standard adoption of new dissection tools to minimize blood loss. These include new ablation devices to coagulate along the planned line of a resection combined with the use of high-pressure water jet (Hydrojet) or ultrasonic pulses (CUSA) to expose the intrahepatic vessels and bile ducts. Intraop ultrasound is important for two reasons: (a) in planning the line of resection and mapping out its relationship with the large intrahepatic portal and hepatic veins and (b) in surveying the entire liver to look for multifocal lesions.

Anatomic versus nonanatomic liver resection

Until the last decade, most liver surgeons performed **anatomic liver resections** in which the porta hepatis is dissected and the corresponding extrahepatic branches of the hepatic artery, portal vein, bile duct, and hepatic vein are mobilized and ligated before resection of the liver parenchyma (Fig. 7.5-1). In **nonanatomic liver resections**, only the tumor with a margin of 1–2 cm is removed instead of the entire anatomic lobe or segment. This approach is particularly appropriate in patients with cirrhosis or chronic hepatitis, in whom removing too much of the liver predisposes them to hepatic decompensation, and in patients with liver metastases where the risk of recurrence remains high. When nonanatomic resection is performed, dissection of the porta hepatis is unnecessary. Instead, branches of the vessels and hepatic ducts are ligated and resected as they are encountered during the resection of the liver parenchyma. All patients undergoing liver resection should also be electrically grounded with the appropriately placed pads prior to draping for possible RF ablation of lesions found not to be suitable for resection.

Laparoscopic liver resection is an emerging approach that is increasingly used for selected cases by liver surgeons experienced in laparoscopic surgery. Some have also begun exploring the use of robotic-assisted liver resection. For minor liver resection by experienced surgeons, a laparoscopic approach has been reported to be associated with shorter hospital stay, less or comparable blood loss, less postop pain, and similar outcome compared with open liver resection. The role and safety of a laparoscopic approach for major liver resection have not been determined and should not be undertaken lightly. A CO_2 pneumoperitoneum of 10–14 mm Hg and lowering the central venous pressure (CVP) to <5 mm Hg are recommended to reduce venous bleeding

associated with laparoscopic liver resection. For severe bleeding, briefly increasing the pneumoperitoneum pressure and decreasing the airway pressure with a pause in artificial ventilation are approaches that can be used to facilitate hemostasis.

Temporary occlusion of the hepatoduodenal ligament that contains the main portal vein, hepatic artery, and common bile duct (**Pringle maneuver**) can be used during resection to minimize blood loss. Most patients will tolerate this maneuver for 15–20 min. In some patients, it may be necessary to repeat the maneuver twice to complete a major resection. However, with good surgical exposure and use of newer dissection tools to minimize blood loss, the Pringle maneuver is rarely necessary.

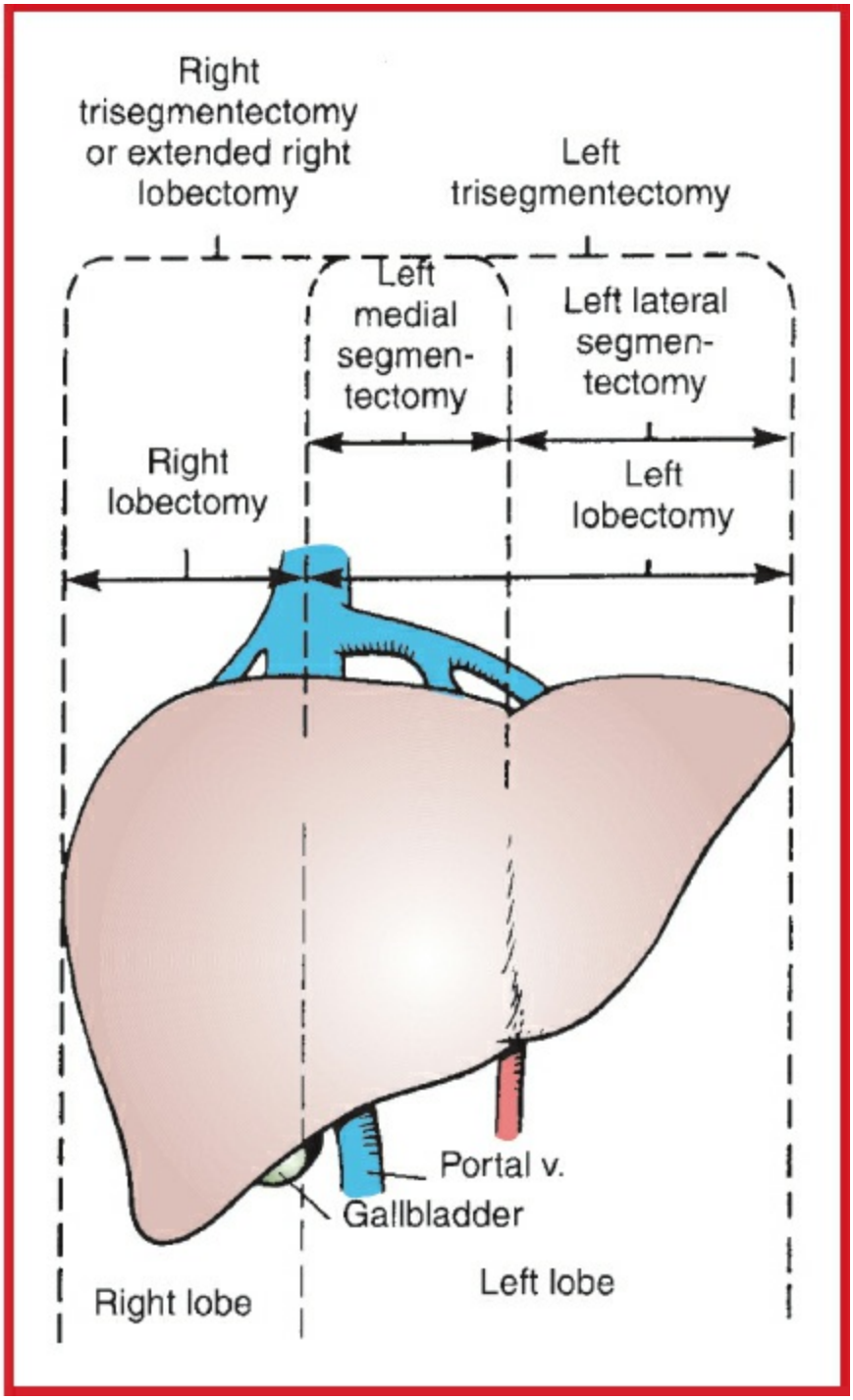

Figure 7.5-1 Types of traditional anatomic liver resection. (Reproduced with permission from Hardy JD: Hardy's Textbook of Surgery, 2nd edition. JB Lippincott, Philadelphia: 1988.)

Usual preop diagnosis

Benign and malignant primary or metastatic tumors of the liver

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration and alcohol and smoking cessation. A review of nutritional status should include the possible benefit of oral nutritional supplements for 1–2 wk

preop in malnourished patients. Additional discussion of carb loading, deep venous thrombosis (DVT) prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop. Oral bowel prep is usually avoided. See Appendix K: Enhanced Recovery After Surgery, p. K-1.

SUMMARY OF PROCEDURES

	Right/Left Lobectomy/Trisegmentectomy	Partial Right Lobectomy	Left Latera Segmentec
Position	Supine	⇐	⇐
Incision	Upper midline, extending to right subcostal (Lexus incision)	⇐	Upper midli
Special instrumentation	Thompson liver retractor; InLine™, Helix Hydrojet™, or CUSA™; TissueLink™ dissecting sealer; argon beam laser; tumor ablation device; intraop ultrasound; microwave or RF tumor ablation devices	⇐	⇐
Unique considerations	Maintain normal core temp. Most intrahepatic bleeding can be controlled temporarily by compression. Note the duration of Pringle maneuver, if applied. Give mannitol furosemide for hemoglobinuria associated with extensive microwave or radiofrequency ablation of the liver to reduce the risk of postoperative acute tubular necrosis.	⇐	⇐
Antibiotics	Vancomycin/cefazolin iv preop	⇐	⇐
Surgical time	3–8 h	4–6 h	<3 h
Closing considerations	Secure meticulous hemostasis; place two to three subphrenic or	⇐	⇐

	perihepatic Jackson-Pratt flat bulb suction drains.		
EBL	Variable (50–800 mL)	50 mL	50 mL
Postop care	PACU → ward	⇐	⇐
Mortality	<2–5%	⇐	<1%
Morbidity	Ascites: 20–30% Wound infection: 5–10% Liver failure: <5% Bile leak: <5% Postop bleeding: <2–5%	10–20% ⇐ ⇐ <2–5% ⇐	<10% ⇐ <2% ⇐ ⇐ —
Pain score	7–8	7–8	7

PATIENT POPULATION CHARACTERISTICS

Age range	19–85 yr
Male:Female	4:1 in primary HCC 2:1 in liver metastases
Incidence	Metastatic colorectal cancer is the most common disease requiring liver resection in the United States. The incidence of primary HCC is rising 2° the prevalence of chronic hepatitis C; however, because of delayed Dx and associated hepatitis C cirrhosis, many are not suitable resection candidates. Primary HCC is a common cancer in Asian Americans because of the high prevalence of chronic hepatitis B. Many young Asians (30–50 yr) with HCC 2° chronic hepatitis B may not have cirrhosis.
Associated conditions	Cirrhosis, chronic hepatitis, and, rarely, hemochromatosis; Hx of colorectal surgery in patients with liver metastases

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Hepatorrhaphy.

Suggested Readings

1. Farges O, Goutte N, et al: ACHBT-French Hepatectomy Study Group: Incidence an risks of liver resection: an all-inclusive French nationwide study. Ann Surg 2012; 256(5):697–704; discussion 704–5.
2. Hughes MJ, McNally S, Wigmore SJ: Enhanced recovery following liver surgery: systematic review and meta-analysis. HPB (Oxford) 2014; 16(8):699–706.
3. Joliat G-R, Labgaa I, Hübner M, et al: Cost–benefit analysis of the implementation o an enhanced recovery program in liver surgery. World J Surg 2016; 40(10):2441–50.
4. Melloul E, Hübner M, Scott M, et al: Guidelines for perioperative care for live surgery: enhanced recovery after surgery (ERAS) society recommendations. World J Surg 2016; 40(10):2425–40.
5. Tan MCB, Jarnagin WR: Surgical management of non-colorectal hepatic metastasis. J Surg Oncol 2014; 109(1):8–13.
6. Wakabayashi G, Cherqui D, Geller DA, et al: Recommendations for laparoscopic liver resection: a report from the second international consensus conference held in Morioka. Ann Surg 2015; 261(4):619–29.

HEPATORRHAPHY

SURGICAL CONSIDERATIONS

Description

Although most liver lacerations have stopped bleeding by the time a surgeon sees them or after selective hepatic arterial embolization by interventional radiology, others may require suturing, packing, or **partial liver resection** to control bleeding. Various techniques are available to control hemorrhage in the OR including packing, suturing, inflow occlusion, and resection. Small lacerations that have stopped bleeding require no specific therapy other than possible drainage. Lacerations that continue to bleed usually can be sutured and drained. Extensive tears of the liver that are actively bleeding may require temporary occlusion of the porta hepatis, containing the hepatic artery, portal vein, and bile duct (**Pringle maneuver**) to excise devitalized parenchyma and control bleeding with sutures, clips, and coagulators. Occasionally, the hepatic vein draining the involved lobe will require clamping to control back-bleeding. When the bleeding cannot be controlled, it is expedient to pack the wound, drain the abdomen, and close. The pack can be removed without much risk of rebleeding within 48–72 h. Correction of hypothermia is important to prevent coagulopathy.

Usual preop diagnosis

Trauma with CT evidence of hepatic laceration

ERAS: **Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration and alcohol and smoking cessation. A review of nutritional status should include the possible benefit of oral nutritional supplements for 1–2 wk preop in malnourished patients. Additional discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop. Oral bowel prep is usually avoided.** **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE

Position	Supine
Incision	Midline abdominal
Special instrumentation	Denier retractor
Antibiotics	Cefazolin 2 g iv
Surgical time	1–2 h
EBL	~300–2000 mL
Mortality	1–2%
Morbidity	Continued bleeding: 2–3% Biliary fistula Perihepatic abscess Intrahepatic hematoma Arterioportal fistula Hepatic and renal failure
Pain score	7–9

PATIENT POPULATION CHARACTERISTICS

Age range	Variable
Male:Female	1:1
Incidence	Rare
Etiology	Trauma (blunt vs. penetrating); surgical; hepatic adenomas; needle biopsies of liver

ANESTHETIC CONSIDERATIONS FOR HEPATIC PROCEDURES

(Procedures covered: hepatic resection; hepatorrhaphy.)

PREOPERATIVE

Patients presenting for hepatic surgery may have primary or metastatic tumors from GI and other sources. Liver function may be entirely normal in these patients. HCC is seen commonly in males >50 yr and is associated with chronic active hepatitis B or C and cirrhosis. The preop considerations listed below describe patients without cirrhosis. (See Preoperative Considerations for Surgery for Portal Hypertensionfor evaluation of patients with cirrhosis).

Respiratory	Respiratory function is typically normal; however, patients with ascites may have respiratory compromise. **Tests:** CXR; others as clinically indicated
Cardiovascular	Patients may be hypovolemic, and volume status should be carefully assessed before induction of anesthesia (skin turgor, UO, orthostatic BP, and HR). Tumors may surround major vascular structures and impede venous return. Consider evaluation with CT/MRI scan.
Hepatic	Liver resection can be indicated for hemangiomas, hydatid cysts, and tumors. It is important to determine the size of the tumor and involvement of vascular structures preop to be adequately prepared for major intraop blood and fluid losses. **Tests:** LFTs; albumin; ultrasound/CT/MRI
Hematologic	The liver produces all clotting factors except VIII, and the degree of hepatic insufficiency determines the extent of any coagulopathy. T&C 2–4 U PRBCs. **Tests:** CBC; PT; PTT; Plt count; others as indicated from H&P
Laboratory	Tests as indicated from H&P. **NB:** For elective cases, if abnormal LFTs are present on preop labs, it is

	important to perform a complete medical workup. This can include reviewing old lab data, hepatitis serology, and an abdominal ultrasound to r/o cholestatic causes of liver dysfunction. Surgery and anesthesia in the presence of acute hepatitis are associated with high mortality.
Premedication	Consider midazolam 1–2 mg iv. If PT significantly prolonged, consider 10 mg vitamin K iv/po 24 h before surgery. Consider FFP for rapid correction of PT.
ERAS	DVT prophylaxis usually includes LMWH started 2–12 h preop. Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of a transversus abdominis plane for postop pain management. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: For major liver resections, the surgeon may attempt to reduce blood loss by applying intermittent vascular inflow occlusion or total vascular exclusion. As the result of ischemia induced by vascular occlusion and the loss of liver mass during resection, liver function may be significantly abnormal in the postop period. Coagulation abnormalities may exist; consequently, an epidural catheter for postop pain relief may be associated with ↑ risk of hematoma formation. Hypovolemia (CVP < 5 mm Hg) prevents liver congestion and results in less bleeding but may increase the likelihood of postop renal failure. Euvolemia (CVP 7–10 mm Hg) results in more bleeding and a higher transfusion rate.

Induction	Standard induction. Restore intravascular volume before induction. Trauma patients or those with ascites require rapid-sequence induction with cricoid pressure until intubation has been confirmed. If patient is hemodynamically unstable, consider etomidate (0.2–0.4 mg/kg) or ketamine (1–3 mg/kg) in place of propofol.
ERAS	Verify preincision antibiotics. Assess volume status (see

	Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.	
Maintenance	Standard maintenance; N_2O can be used if bowel distention will not impede surgical exposure/closure. If total vascular occlusion is used, elevate CVP to at least 12 mm Hg by rapid fluid administration before cross-clamping. Have phenylephrine and epinephrine infusions ready to treat ↓ BP. After major resections, significant hemodynamic changes occur. CO and HR increase and SVR decreases.	
Emergence	For major hepatic resections, the patient is best cared for in an ICU. After major blood loss, consider keeping the patient mechanically ventilated. Discuss with surgeon local wound infiltration or nerve block (e.g., TAP block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen (liver function permitting). PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Anticipate large blood loss. IV: 14–16 ga × 2 NS/BSS @ 10–20 mL/kg/h Fluid warmer Humidify gases Consider utilizing rapid-transfusion device.	Blood loss can be significant; keep at least 2 U PRBC ahead. Lobectomies often are associated with more blood loss than wedge resections. Massive transfusions (e.g., 10+ u RBC/24 h) may be required, and appropriate blood products should be available (e.g., PRBC + FFP + Plt). If procedure does not involve cancer, blood salvage devices may be used. See Goal-Directed Fluid Management, Appendix K, p. K-4. CVP < 5 cm H_2O is recommended to ↓ hepatic venous congestion.

Control of blood loss	Surgical control Pringle maneuver Total vascular exclusion	Surgical occlusion of the main blood vessels entering the hilar area (Pringle maneuver) or total vascular occlusion. Total vascular exclusion is accomplished by complete occlusion of liver inflow and outflow.
Monitoring	Standard monitors UO Arterial line ± CVP ± TEE	Others as clinically indicated. If the extent of the resection is not known at the beginning of surgery, appropriate monitoring (CVP, arterial line, additional iv's) should be established before beginning resection. Forced-air warmer
Positioning	✓and pad pressure points ✓eyes	
Complications	Massive hemorrhage	Ensure adequate vascular access. Consider rapid-transfusion device.

POSTOPERATIVE

Complications	✓liver function Hemorrhage Electrolyte imbalance Hypoglycemia Hypothermia, shivering DIC Pulmonary insufficiency	Patients with normal liver function preop may have significant postop impairment of liver function 2° loss of liver mass or ischemic injury induced by vascular occlusion. >90% of patients will develop some form of respiratory complication (atelectasis, effusion,

		pneumonia).
Multimodal pain management	PCA	Patient should be recovered in ICU or hospital ward that is accustomed to treating the side effects of opiates (e.g., respiratory depression, breakthrough pain, nausea, pruritus). Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with TAP blocks (see Appendix C, p. C-4).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6) Maintain normoglycemia.	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum may promote return of bowel function.
Tests	ABG; CXR; others as clinically indicated	

Suggested Readings

1. Clavien PA, Petrowsky H, DeOliveira ML, et al: Strategies for safer liver surgery and partial liver transplantation. N Engl J Med 2007; 356(15):1545–59.
2. Clavien Pierre-A, Barkun J: Consensus conference on laparoscopic liver resection A jury-based evaluation. Ann Surg 2015; 261(4):630–1.
3. Egger ME, Gottumukkala V, Wilks JA, et al: Anesthetic and operative considerations for laparoscopic liver resection. Surgery 2017; 161(5):1191–202.
4. Hughes MJ, McNally S, Wigmore SJ: Enhanced recovery following liver surgery: systematic review and meta-analysis. HPB (Oxford) 2014; 16(8):699–706.
5. Niemann CU, Roberts JP, Ascher NL, et al: Intraoperative hemodynamics and live function in adult-to-adult living liver donors. Liver Transpl 2002; 8:1126–32.
6. Suman A, Carey W: Assessing the risk of surgery in patients with liver disease. Cleve Clin J Med 2006; 73(4):398–404.
7. Wakabayashi G, Cherqui D, Geller DA, et al: Recommendations for laparoscopic liver resection: a report from the second international consensus conference held in Morioka. Ann Surg 2015; 261(4):619–29

3. Xiong J-J, Altaf K, Javed MA, et al: Meta-analysis of laparoscopic vs open live resection for hepatocellular carcinoma. World J Gastroenterol 2012; 18(45):6657–68.

CHAPTER 7.6

Biliary Tract Surgery

SURGEON
C. Andrew Bonham, MD

ANESTHESIOLOGIST
Hendrikus J. M. Lemmens, MD, PhD

OPEN CHOLECYSTECTOMY AND COMMON BILE DUCT EXPLORATION

SURGICAL CONSIDERATIONS

Description

With the advent of laparoscopic cholecystectomy, the traditional **open cholecystectomy** has become a rarity and is generally reserved for gallbladders that are expected to be difficult to remove due to inflammation, previous operations, and adhesions or because of other medical problems, such as coagulopathy or cirrhosis. In most institutions, fewer than 10% of cholecystectomies begin as open procedures, and approximately 5% of **laparoscopic cholecystectomies** are converted to open cholecystectomies during the course of the operation due to technical difficulties, complications, or unexpected findings. Because of its rarity, the open cholecystectomy may be a more challenging operation for both surgeon and anesthesiologist than it was in previous decades. A small number of open cholecystectomies are performed urgently following a complication of an attempted laparoscopic cholecystectomy and may be associated with significant instability from hemorrhage or sepsis related to an iatrogenic injury of abdominal or retroperitoneal structures.

The technical aspects of open cholecystectomy have not changed since its original

description over 100 years ago. The operation can be performed through a right subcostal **(Kocher)**, paramedian, or midline incision. Upward traction is applied to the liver or gallbladder, whereas downward traction on the duodenum exposes the region of the cystic duct and artery and common duct. Adequate exposure is critical to performing a safe operation. Depending on local conditions and the surgeon's preference, the gallbladder may be removed from the top down, excising the gallbladder from the liver bed and isolating the cystic duct and artery as the final stage of the operation. The cystic duct and artery may be isolated and divided first, and the gallbladder removed retrograde from the gallbladder bed as the final step of the procedure. The anatomy of the biliary tree is quite variable, with the classic anatomy present in only 30% of patients, and few surgeons always remove the gallbladder in the same way every time. (Fig. 7.6-1 shows exposure of the gallbladder.)

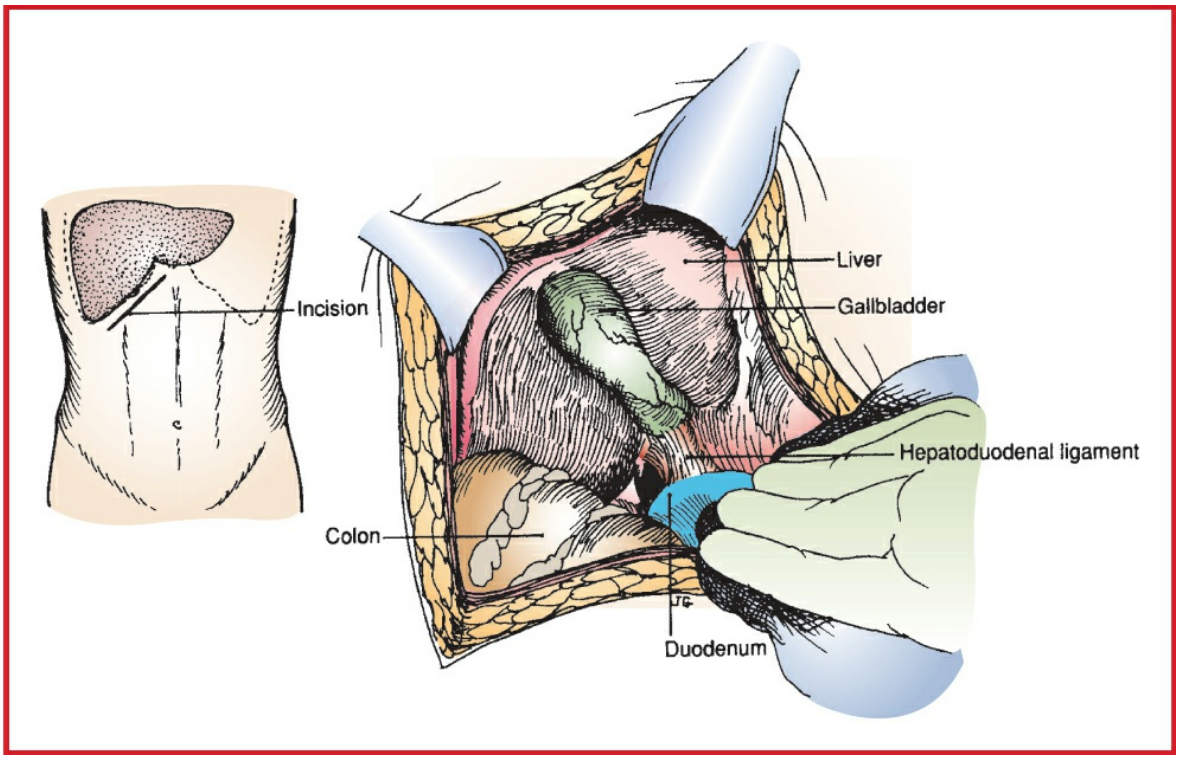

Figure 7.6-1 Incision and exposure of the gallbladder. (Reproduced with permission from Scott-Conner CEH, Dawson DL: Operative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

Cholangiography may be performed at the discretion of the surgeon. Some surgeons perform it in all patients, and others perform it only in patients in whom there is some clinical evidence of choledocholithiasis. The cystic duct is opened, and a catheter is placed into the duct and secured with a ligature, tie, or special cholangiogram clamp. Dye is injected into the biliary tree via the catheter, and x-rays are taken. If stones are found, a **common duct exploration** may be performed. Alternatively, an **endoscopic retrograde cholangiogram (ERCP)** with stone extraction may be carried out postop.

Cholangiography usually adds 10–15 min to the procedure.

Choledochotomy, or **"common duct exploration,"** is the opening and exploration of the common duct for the purpose of extracting stones. Once commonly performed, it is a procedure reserved chiefly for patients who have failed management of common duct stones with endoscopic (ERCP) or laparoscopic techniques. Common duct stones are visualized by operative cholangiography to determine the number of stones, position, and the anatomy of the duct. Ducts smaller than 5 mm in diameter are at greater risk of injury with common duct exploration and should be managed endoscopically. An extensive **Kocher maneuver** is performed to allow exposure and palpation of the entire duct, including the intrapancreatic portion. A longitudinal incision is made in the duct, and exploration is carried out through this incision. The duct may be irrigated with NS, balloon catheters may be passed, and various instruments may be introduced to grasp, remove, or crush retained stones. The duct may be biopsied by this approach, and **choledochoscopy**—the direct visualization of the duct's interior using a small flexible scope—can be performed. Rarely, an impacted stone may require electrohydraulic or laser lithotripsy through the choledochoscope, adding considerable time to the operation in centers equipped to perform the procedure. The choledochotomy is closed over a T-tube to allow decompression of the edematous duct, and later extraction of stones missed at the initial exploration. In the past, **transduodenal sphincteroplasty** was utilized for stones impacted near the sphincter of Oddi, but this procedure has largely been replaced by endoscopic or percutaneous techniques at specialized centers. It is reserved for highly unusual cases, such as a patient with a previous **Billroth II gastrectomy**. Depending on the complexity of the findings, a common duct exploration can be expected to add from 30 min to over 1 h to the cholecystectomy. In general, the mortality of patients undergoing common duct exploration is ~2–5 times that of a simple cholecystectomy. This difference can be explained by the fact that patients undergoing common duct exploration tend to be older and sicker or suffering from concomitant cholangitis—the opening of the duct itself is not necessarily a significant physiologic insult.

Variant procedure or approaches

Cholecystectomy remains the mainstay of treatment for symptomatic biliary stone disease. **Nonsurgical treatment of cholelithiasis**, particularly by oral dissolution and/or **lithotripsy**, has very limited usefulness and is rarely used in clinical practice. **Tube cholecystostomy** can be performed as an open procedure or percutaneously. It is generally reserved as a temporary measure in patients too ill to tolerate a more extensive procedure.

Usual preop diagnosis

Symptomatic cholelithiasis; acute cholecystitis; chronic cholecystitis; biliary dyskinesia; gallbladder polyps or carcinoma; choledocholithiasis

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting nothing by mouth (NPO) duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, deep venous thrombosis (DVT) prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

SUMMARY OF PROCEDURES

	Cholecystectomy	Cholecystectomy/Common Duct Exploration
Position	Supine	⇐
Incision	Right subcostal or midline	Right subcostal or midline
Special instrumentation	Costal margin retractor; cholangiocatheter	Choledochotomy instruments; choledochoscope
Unique considerations	Requires intraop x-ray for cholangiogram	May include choledochoscopy
Antibiotics	Ampicillin, piperacillin, or mezlocillin (1–3 g iv); ± gentamicin; or cefotetan (2 g iv)	⇐
Surgical time	45–90 min	1–2.5 h
Closing considerations	Muscle relaxation	⇐
EBL	Minimal to 250 mL	⇐
Postop care	PACU → ward	⇐
Mortality	0.1% under 50 yr; 0.5% over 50 yr	0–1.5% under 60 yr; 5% in advanced age
Morbidity	Postop bile leak: 0–9%	⇐
	Pancreatitis: 0–4.6%	2–5%

	Bile duct injury: 0–0.25%	—
	Cardiac and respiratory complications: Rare, but the leading cause of death	—
	Hemorrhage: rare	—
Pain score	6	6–7

PATIENT POPULATION CHARACTERISTICS	
Age range	Mostly adult; increases with age
Male:Female	1:2–3
Incidence	600,000/yr in the United States; ≥90% performed laparoscopically
Etiology	See associated conditions (below).
Associated conditions	Ileal disease; cirrhosis; hemolytic disorders; choledocholithiasis; cholangitis; or active pancreatitis

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Biliary Tract Surgery.

Suggested Readings

1. Coccolini F, Catena F, Pisano M, et al: Open versus laparoscopic cholecystectomy in acute cholecystitis. Systematic review and meta-analysis. Int J Surg 2015; 18:196–204.
2. Thangavelu A, Rosenbaum S, Thangavelu D: Timing of cholecystectomy in acute cholecystitis. J Emerg Med 2018; 54(6):892–7.

BILIARY DRAINAGE PROCEDURES

SURGICAL CONSIDERATIONS

Description

Biliary drainage procedures may be performed for malignant and nonmalignant

indications, and the type of drainage procedure performed depends on factors such as the nature of the biliary obstruction, the patient's overall condition and prognosis, the need for other surgical procedures, and institutional expertise. Most drainage procedures of the biliary tree are performed with **endoscopic** or **transhepatic techniques**. These techniques allow concomitant treatment of biliary stone disease, decompression of obstructive jaundice, relief of cholangitis, and delineation of the anatomy of the biliary tree. There remain a significant number of patients, however, for whom a traditional surgical procedure is the most appropriate. With the advent of laparoscopic cholecystectomy, surgical bile duct injuries have become the most common reason for surgical biliary drainage procedures. In general, the biliary drainage procedures' complexity of the different operations that may be performed and the morbidity attendant to these have more to do with the indications for operation than with the procedure that is performed.

All of these operations are performed under GA through an upper midline or right subcostal incision. Self-retaining retractors are used to retract the liver superiorly to expose the region of the porta hepatis. If the gallbladder will not be used for the bypass procedure (**cholecystojejunostomy**), then it usually is removed as the first step in the procedure (see **Open Cholecystectomy**). If the patient has had previous upper right quadrant surgery, the complexity and duration of the procedure and blood loss may increase significantly. Any associated hepatic cirrhosis may make the procedure particularly demanding. Most patients undergoing surgical biliary drainage procedures have had several nonsurgical instrumentations of the bile duct prior to presenting for surgery. Indwelling stents result in colonization of the biliary tract with any number of bacterial or fungal organisms from which the patient may have already suffered bouts of cholangitis. It is not unusual for the patient to develop bacteremia during the operation while these stents are being manipulated.

Transduodenal sphincteroplasty for benign obstruction of the ampulla of Vater or extensive choledocholithiasis has largely been abandoned in favor of the more well-tolerated and less-invasive **endoscopic sphincterotomy**. It remains the treatment of choice for rare cases of early ampullary carcinoma. Endoscopic sphincterotomy or placement of an internal stent is the most commonly performed technique for opening the ampulla and usually is performed by gastroenterologists outside the operating room (OR) with iv sedation. **Open sphincteroplasty** is usually reserved for patients in whom **endoscopic retrograde cholangiopancreatogram (ERCP)** has been unsuccessful or in whom a laparotomy is required for other reasons. For these open procedures, the second portion of duodenum is incised over the region of the ampulla, and the ampulla is cannulated. A longitudinal incision is made over the course of the ampulla, and the

mucosa of the ampulla is sutured to the mucosa of the duodenum with fine interrupted sutures with care being taken not to compromise the pancreatic duct. The duodenum is closed with suture, a small closed suction drain is placed, and the wound is closed. A postop stay of 5–7 d can be expected.

Cholecystojejunostomy usually is performed as palliation for malignant obstruction of the distal bile duct. Its advantage is that it does not require dissection of the portal triad, but the long-term results are poor as biliary obstruction typically recurs as the malignancy advances. The abdomen is opened as described above and the region of the porta hepatis examined to ensure that the cystic duct is not imminently compromised by tumor. The jejunum is then brought up to the gallbladder, usually bypassing the jejunum through the transverse mesocolon. The anastomosis may be performed either to an intact loop of jejunum (**loop cholecystojejunostomy**) or a Roux-en-Y loop of jejunum (**Roux-en-Y cholecystojejunostomy**) and is carried out with one or two layers of sutures, depending on surgeon's preference. If a Roux-en-Y is created, a second jejunojejunal anastomosis must be performed. This procedure has largely been replaced by transhepatic and endoscopic techniques.

Choledochoduodenostomy is an archaic procedure in which the bile duct is incised longitudinally and anastomosed directly to the adjacent duodenum. This was performed historically in patients with gallstones impacted at the ampulla. However, loss of the normal sphincter mechanism at the ampulla allows reflux of duodenal contents directly into the bile duct. Patients may suffer from repeated episodes of cholangitis or obstructive jaundice from debris occluding the anastomosis. Secondary biliary cirrhosis may occur, and the author has seen one case proceed to liver transplantation in which a cast of the biliary tree comprised of fibrous food material was extracted from the choledochoduodenal anastomosis. **Roux-en-Y choledochojejunostomy or hepaticojejunostomy** remains the gold standard by which all other biliary drainage procedures are measured. An anastomosis is fashioned between the common bile duct, common hepatic duct, or even the lobar or segmental bile ducts and a Roux-en-Y loop of jejunum. This is often a relatively demanding operation because it requires dissection deep in the porta hepatis to gain access to the bile duct. Furthermore, many patients have had previous surgery in the porta hepatis with extensive formation of adhesions. Long-term results are more reliable, however, and thus surgical drainage is preferred to less-invasive procedures for benign disease. Exposure of the biliary tree is the same as for the above procedures. The gallbladder is always removed (if it is still present). The bile duct is dissected free from the surrounding structures in the porta hepatis and traced proximally into the liver to healthy tissue above the level of obstruction.

Variant procedure or approaches

Endoscopic or transhepatic placement of temporary or permanent **biliary stents** is an increasingly common alternative to surgical drainage in patients with incurable pancreatic or biliary tract disease.

Usual preop diagnosis

Transduodenal sphincteroplasty: extensive choledocholithiasis, often after failed attempt at ERCP; rarely, malignant disease. Cholecystojejunostomy: malignan obstruction of the distal common bile duct, usually due to pancreatic cancer. Choledochojejunostomy or hepaticojejunostomy: benign strictures of the distal bile duct; long-standing stone disease; pancreatitis; iatrogenic injury; Oriental cholangiohepatitis; after resection of some tumors of the pancreas or bile duct

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Cholecysto-jejunostomy	Choledocho-jejunostomy	Choledocho-duodenostomy	Transduodenal sphincteroplasty
Position	Supine	⇐	⇐	⇐
Incision	Midline or right subcostal	⇐	⇐	⇐
Special instrumentation	Costal retractor	⇐	⇐	⇐
Unique considerations	Consider usual prep for patients with obstructive jaundice.	⇐	⇐	⇐
Antibiotics	Ampicillin, piperacillin or mezlocillin (1–3 g iv) ± gentamicin; or cefotetan (2 g iv)	⇐	⇐	⇐
Surgical time	1 h; may be significantly longer for resection of tumor	1.5–3 h	⇐	⇐
Closing considerations	Muscle relaxation; NG suction	⇐	⇐	⇐
EBL	<250 mL (greater if tumor resection performed, or in presence of portal HTN)	250–500 mL (greater if tumor resection performed, or in presence of portal HTN)	⇐	<250 mL (transfusion rarely needed)
Postop care	PACU	⇐	⇐	⇐
Mortality	≤35% in advanced pancreatic cancer; otherwise, <10%	≤29%, with pancreatic cancer; 0.5% for benign disease	0–5.4% (usually for benign disease)	0–7%
Morbidity	Sepsis Respiratory complications Renal failure Hemorrhage Wound infection Breakdown of biliary anastomosis Thrombotic complications	⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐	⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐	Pancreatitis: rare Recurrent Cholangitis: rare
Pain score	7	7	7	6

PATIENT POPULATION CHARACTERISTICS

Age range	5th–7th decade; may be younger for repair of laparoscopic cholecystectomy injuries
Male:Female	1.1:2.1

Incidence	Procedure-related incidence not available, but declining in favor of techniques by interventional gastroenterology and radiology
Etiology	See Usual Preop Diagnosis, above.
Associated conditions	Jaundice (very common); fat-soluble vitamin deficiencies; malignancy, especially pancreatic (common); malnutrition (common)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Biliary Tract Surgery.

Suggested Readings

1. Pavlidis ET, Pavlidis TE: Pathophysiological consequences of obstructive jaundice and perioperative management. Hepatobiliary Pancreat Dis Int 2018; 17(1):17–21.
2. Quencer KB, Tadros AS, Marashi KB, et al: Bleeding after percutaneous transhepatic biliary drainage: incidence, causes and treatments. J Clin Med 2018; 7(5). pii: E94.

EXCISION OF BILE DUCT TUMOR

SURGICAL CONSIDERATIONS

Description

Primary tumors (cholangiocarcinomas) of the extrahepatic bile ducts, including the hepatic bifurcation (Klatskin tumors), are uncommon malignancies, with the only curative treatment for them being surgical excision. Such tumors are usually classified as being proximal bile duct tumors, involving the hepatic bifurcation and above; middle bile duct tumors, involving the midportion of the common hepatic and common bile duct; and distal bile duct tumors, which involve the distal bile duct, including the intrapancreatic or intraduodenal portion of the bile duct (Fig. 7.6-1). The gallbladder usually will be removed in any such operation.

Distal bile duct tumors, which carry a significantly higher cure rate than either proximal bile duct or pancreatic tumors, may be treated by **pancreaticoduodenectomy**. (See p. 691 for discussion of this operation.)

Mid-bile duct tumors usually are excised by removing a generous portion of the mid

bile duct, resecting the ducts up to the hepatic bifurcation, and sometimes performing a **pancreaticoduodenectomy**. Biliary drainage usually is established by anastomosing the proximal bile duct to a Roux loop of jejunum. For proximal bile duct tumors, most of the extrahepatic bile ducts are excised, and biliary drainage is established by anastomosis of the right and left hepatic ducts or even multiple segmental ducts to a Roux loop of jejunum. These are often technically demanding operations with the potential for major blood loss. It may be necessary to perform a major hepatic resection at the same time, and the possibility of this should always be assumed when an operation of this sort is carried out. Often, a transhepatic catheter will have been placed radiographically preoperatively to provide relief of jaundice and to facilitate identification of the bile ducts. Colonization of the biliary tract with enteric bacteria or yeast is common and may result in bacteremia during surgical manipulation. Prolonged cholestasis may lead to fat-soluble vitamin deficiencies, in particular vitamin K deficiency, which may cause coagulopathy. Long-standing biliary obstruction may cause moderate atrophy and portal venous compromise.

Surgical exposure for any of these operations usually is achieved through a long midline or transverse subcostal incision with midline extension and the use of self-retaining retractors. The liver and gallbladder are retracted superiorly while downward traction is placed on the duodenum. If the gallbladder is still in place, a **cholecystectomy** is performed. For proximal bile duct tumors and mid-bile duct tumors not requiring pancreaticoduodenectomy, the bile duct is divided distally, just above the duodenum, and the pancreatic portion of the bile duct is oversewn. The bile duct is then resected proximally to the level of the bifurcation of the hepatic ducts. A Roux-en-Y loop of jejunum is anastomosed to the hepatic ducts to establish biliary drainage. Drains are placed, and most surgeons place an NG tube for such cases.

Variant procedure or approaches

Endoscopic or **transhepatic stenting** of areas of stricture often is used as a palliative alternative to surgical excision. These are usually performed radiographically and do not require GA. They may be used as an alternative to resection or in preparation for surgery.

Usual preop diagnosis

Cholangiocarcinoma (common); benign strictures of the bile ducts (infrequent); sclerosing cholangitis (rare)

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status,

discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Midline or subcostal
Special instrumentation	Costal retractor
Unique considerations	Many cases prove unresectable at operation. Intraoperative radiation therapy may be used.
Antibiotics	Ampicillin, piperacillin, or mezlocillin, 1–3 g iv, ± gentamicin; or cefotetan 2 g iv; fluconazole 200 mg iv; antibiotics may be adjusted based on preop bile cultures
Surgical time	3–8 h
Closing considerations	Muscle relaxation required for closure; NG suction
EBL	500–5000 mL, depending on need for liver resection and presence of portal HTN
Postop care	ICU postoperatively
Mortality	5–10%
Morbidity	Sepsis; hemorrhage; anastomotic leakage; wound infection; liver failure; VTE
Pain score	7–8

PATIENT POPULATION CHARACTERISTICS	
Age range	50–70
Male:Female	Male > female
Incidence	4500 cases of bile duct cancer/yr in the United States
Etiology	Multifactorial

Associated conditions	Ulcerative colitis; sclerosing cholangitis; typhoid carrier state; Clonorchis sinensis; choledochal cyst; Caroli disease; gallstones

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Biliary Tract Surgery.

Suggested Readings

1. Lidsky ME, Jarnagin WR: Surgical management of hilar cholangiocarcinoma a Memorial Sloan Kettering Cancer Center. Ann Gastroenterol Surg 2018; 2(4):304.
2. Madadi-Sanjani O, Petersen C, Ure B: Minimally invasive hepatobiliary surgery Clin Perinatol 2017; 44(4):805–18.
3. Najran P, Lamarca A, Mullan D, et al: Update on treatment options for advanced bile duct tumours: radioembolisation for advanced cholangiocarcinoma. Curr Oncol Rep 2017; 19(7):50.
4. Razumilava N, Gores GJ: Cholangiocarcinoma. Lancet 2014; 383(9935):2168–79.

CHOLEDOCHAL CYST EXCISION OR ANASTOMOSIS

SURGICAL CONSIDERATIONS

Description

This rare congenital anomaly includes various types of dilatation of the biliary tree, and patients may present with cystolithiasis, cholangitis, pancreatitis or, rarely, malignancy. Adults with long-standing obstructive jaundice from a choledochal cyst may present with secondary biliary cirrhosis. Although four types of cysts are commonly recognized, the vast majority consists of fusiform dilatation of much or most of the extrahepatic biliary tree. Although the traditional description of choledochal cyst is that of an infant with a palpable abdominal mass and jaundice or cholangitis, this is a relatively rare presentation today. Today, many cysts are found in adults undergoing evaluation for symptoms thought to be due to gallbladder disease. These patients may present with biliary colic, pancreatitis, or cholangitis. Recommended treatment consists of **excision of the cyst** when technically safe. **Cyst-enteric bypass**, usually to a Roux loop of jejunum, is rarely performed today because of the small but real risk of developing malignancy in these cysts. Only in an elderly patient under unusual technical

circumstances would this be appropriate. The operation is performed through a midline or right subcostal incision. The liver is retracted superiorly and the duodenum inferiorly, exposing the biliary tree. The gallbladder is excised, along with as much of the cyst as possible. Intraoperative cholangiogram demonstrates the transition from cyst to normal biliary tract. The duct is divided as distally as possible, just above the duodenum, and the cyst reflected superiorly. The entire cyst should be excised to prevent the development of malignancy in the remnant. This not infrequently requires excision to the hepatic bifurcation, and an anastomosis is performed at this level, often between the common orifice of the right and left hepatic ducts and a Roux loop of jejunum. Diffuse involvement of the intrahepatic bile ducts (Caroli disease) may require liver resection or transplantation.

Reoperative cases are increasingly common; most follow a cyst-enteric bypass. These cases may be significantly more difficult than first-time operations.

Variant procedure or approaches

There is an increasing tendency among gastroenterologists to perform **endoscopic sphincterotomy** in these patients, rather than to refer them for surgical resection, particularly in older patients. It remains to be seen if these patients will develop cancer in the retained cysts.

Usual preop diagnosis

Choledochal cyst, the most common type involving fusiform enlargement of the entire extrahepatic biliary tree

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Midline or right subcostal
Special instrumentation	Costal retractor
Antibiotics	Ampicillin, piperacillin, or mezlocillin (1–3 g iv); ±

	gentamicin; or cefotetan (2 g iv)
Surgical time	2–4 h
Closing considerations	NG suction
EBL	250 mL, with potentially greater blood loss in reoperations
Postop care	PACU → ward
Mortality	Very rare
Morbidity	Anastomotic leak Wound infection Pulmonary complications Pancreatitis
Pain score	5–7

PATIENT POPULATION CHARACTERISTICS	
Age range	Classically, 60% <10 yr of age, although this may be changing; also adults of all ages
Male:Female	1:3
Incidence	Rare in the United States; more common in Japan
Etiology	Unclear
Associated conditions	Jaundice; pancreatitis; malignancy within the cyst

Suggested Readings

1. Ronnekleiv-Kelly SM, Soares KC, Ejaz A, et al: Management of choledochal cysts Curr Opin Gastroenterol 2016; 32(3):225–31.
2. Soares KC, Arnaoutakis DJ, Kamel I, et al: Choledochal cysts: presentation, clinica differentiation, and management. J Am Coll Surg 2014; 219(6):1167.

ANESTHETIC CONSIDERATIONS FOR BILIARY TRACT SURGERY

(Procedures covered: open cholecystectomy; cholangiography; choledochotomy; biliary drainage procedures; transduodenal sphincterotomy or sphincteroplasty; cholecystojejunostomy; excision of bile duct tumor; choledochal cyst excision/anastomosis.)

PREOPERATIVE

Patients presenting for biliary tract surgery are an extremely diverse group, ranging from the otherwise healthy to the extremely ill. With the increasing popularity of laparoscopic surgery, open cholecystectomies will be performed rarely or when it is not possible to complete the laparoscopic procedure. Cirrhosis, even of a mild degree, substantially increases the risk of cholecystectomy, with hemorrhage and postoperative liver failure being the greatest danger. Patients with bile duct tumors are usually jaundiced at presentation and have undergone transhepatic or endoscopic studies for diagnostic purposes. Often an external transhepatic biliary drain or common bile duct stent placed endoscopically may be present, and jaundice may have been relieved. Rarely, a hepatic resection may be performed as part of the procedure. Prior operation or the presence of portal HTN may substantially increase the duration, complexity, and blood loss of the procedure.

Respiratory	Pain 2° an acute abdominal process may impair respiratory function (↓ FRC, hypoventilation, atelectasis). For patients undergoing laparoscopic cholecystectomy, intra-abdominal CO_2 insufflation may → atelectasis, ↓ FRC, ↑ PIP, and ↑ $PaCO_2$. Tachypnea, hyperpnea, and acute respiratory alkalosis can be signs of sepsis or due solely to pain associated with inflammation of the gallbladder. **Tests:** Consider CXR and others as indicated from H&P.
Cardiovascular	Patients may be dehydrated from fever, vomiting, and decreased oral intake; assess hemodynamic status by evaluating BP and HR in the supine and standing positions. Fluid resuscitate if patient shows Sx of orthostatic ↓ SBP until hemodynamic status improves. Patients undergoing laparoscopic cholecystectomy may experience hemodynamic compromise 2° positioning (reverse Trendelenburg

	→ excessive intra-abdominal pressure with subsequent impairment of venous return). Epigastric discomfort is common with biliary tract disease and can mimic symptoms of myocardial ischemia. **Tests:** ECG; others as indicated from H&P
Renal	In patients with obstructive jaundice, preop administration of bile salts po may prevent renal insufficiency following surgery. **Tests:** UA and others as indicated from H&P
Gastrointestinal	Patients with peritonitis will exhibit guarding and may develop abdominal distention and paralytic ileus. Therefore, full-stomach precautions are warranted. Laparoscopic approach is contraindicated in these patients. Ensure adequate hydration and consider administration of lactulose or bile salts. **Tests:** Bilirubin; AST (SGOT); ALT (SGPT); alkaline phosphatase; albumin
Hematologic	Leukocytosis is often present with a moderate left shift. ✓coags. Administer vitamin K as needed (10 mg iv/SC). **Tests:** CBC, with differential and Plt. Consider T&S.
Laboratory	Other tests as indicated from H&P
Premedication	Meperidine (0.5–0.6 mg/kg iv) is thought to cause less sphincter of Oddi spasm than other opiates. Sphincter spasm can interfere with intraop cholangiograms and cause pain; reverse opiate-induced spasm with naloxone in 40 mcg increments. Atropine (0.4–0.6 mg im or iv) or glycopyrrolate (0.2–0.3 mg im or iv) may help decrease spasm of the sphincter and can be given in combination with the opiate. Parenteral vitamin K is indicated if PT is prolonged (10 mg/d po or im for 3 d). Administer H_2 antagonists (ranitidine 50 mg iv), if patient is at risk for gastric aspiration.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status.

	Discuss with surgeon the possibility of a transversus abdominis plane or thoracic epidural block for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: In patients at risk for aspiration, ET intubation should be accomplished following a rapid-sequence iv induction.

Induction	Standard induction if no aspiration risk. In patients at risk of aspiration, a rapid-sequence induction should be performed.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.	
Maintenance	Standard maintenance. Muscle relaxants facilitate surgery and are indicated.	
Emergence	If there is a risk for aspiration of gastric contents, patient should be extubated awake after return of protective airway reflexes; otherwise, no special considerations. Discuss with surgeon local wound infiltration or nerve block (e.g., TAP block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Minimal blood loss	Blood products usually not required. Anticipate that patient may be dehydrated and require generous iv hydration (e.g., 10–15 mL/kg) before anesthetic induction. See Goal-Directed

		Fluid Management, Appendix K, p. K-4.
	Possible 3rd-space loss IV: 16–18 ga × 1–2 BSS @ 5–8 mL/kg/h	IV size and number according to risk of significant blood loss
Monitoring	Standard monitors	Others as clinically indicated
Positioning	✓ and pad pressure points ✓ eyes	A steep, reverse Trendelenburg position may be required, causing cardiorespiratory impairment: venous return → ↓ CO.
Complications	Atelectasis 2° surgical retraction ↓ BP	These complications are unique to laparoscopic procedures.

POSTOPERATIVE

Complications	Ventilatory impairment	Monitor patients for hypoxemia in the postop period.
	Pneumothorax	Administer supplemental O_2, and consider a portable.
	Atelectasis	CXR to aid in the diagnosis
	PONV	Appendix B, p. B-4 and B-6.
	VTE	
	Subcutaneous emphysema	
Multimodal pain management	PCA	Prolonged PCA meperidine is associated with ↑ normeperidine → CNS disorder, seizures.
	Shoulder pain	2° subdiaphragmatic gas trapping Emphasize multimodal approach combining

		nonopioid and bolus/PCA opioid analgesics with epidural analgesia and/or TAP blocks (see Appendix C, p. C-4).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum may promote return of bowel function.

Suggested Readings

1. Barton JG: Enhanced recovery pathways in pancreatic surgery. Surg Clin North Am 2016; 96(6):1301–12.
2. Lee A, Chiu CH, Cho MW, et al: Factors associated with failure of enhanced recovery protocol in patients undergoing major hepatobiliary and pancreatic surgery: a retrospective cohort study. BMJ Open 2014; 4(7):e005330.
3. Mitra S, Khandelwal P, Roberts K, et al: Pain relief in laparoscopic cholecystectomy —a review of the current options. Pain Pract 2012; 12(6):485–96.
4. Rondelli F, Manina G, Agnelli G, et al: Venous thromboembolism after laparoscopic cholecystectomy: clinical burden and prevention. Surg Endosc 2013; 27(6):1860–4.
5. Snowden C, Prentis J: Anesthesia for hepatobiliary surgery. Anesthesiol Clin 2015; 33(1):125–41.

CHAPTER 7.7

Laparoscopic General Surgery

SURGEONS

Sherry M. Wren, MD, FACS, FCS(ECSA)
Anthony J. Carden, MD
Maureen M. Tedesco, MD
Ruth M. Fanning, MB, BCh, MRCPI, FFARCSI

ANESTHESIOLOGISTS

Clifford A. Schmiesing, MD (Laparoscopic general surgery)
Jerry Ingrande, MD, MS (Laparoscopic bariatric surgery)
Brendan Carvalho, MBBCh, FRCA, MDCH (Laparoscopy in pregnancy)

LAPAROSCOPIC REPAIR OF PERFORATED PEPTIC ULCER

SURGICAL CONSIDERATIONS

Description

Ulcer perforation occurs in 5–10% of peptic ulcer patients and is responsible for more than 70% of deaths associated with peptic ulcer disease (PUD). These patients can present in shock and often are extremely volume depleted. **Open repair** is indicated if the patient has a "hostile" abdomen, if there is simultaneous bleeding and perforation, if the patient is hemodynamically unstable, if the patient has significant cardiovascular or respiratory risk factors that would make them not tolerate a pneumoperitoneum, or if the surgeon has inadequate experience with the laparoscopic approach. Also trained operating room (OR) personnel and equipment must be available. Risk factors associated with unsuccessful **laparoscopic repair** include shock on admission, delayed presentation (>24 h), underlying comorbidities, age >70 yr, and ASA III–IV. For

laparoscopic repair, the patient is often placed in a modified lithotomy position with the surgeon standing between the legs. In this case, both arms can be left out. Alternatively, the patient may be in a supine position with the surgeon standing on the patient's left side. The patient should be placed in a reverse Trendelenburg position (RTP). Access to the abdomen is obtained at the umbilicus or left upper quadrant (LUQ) Palmer point with a Veress needle and/or optical trocar entry. Alternatively, a **Hasson technique** (peritoneal entry through a ~1-cm skin incision) can be employed at the umbilicus. Two to four additional ports are placed. Generally, the perforation site can be easily identified by laparoscopy. Occasionally, the surgeon may ask the anesthesiologist to insufflate air through an orogastric or nasogastric tube to help localize the perforation site. Several methods of repair have been reported. The most common involves suture closure of the perforation with **omentopexy**. Air leak testing post leak closure can be done either via the OR or NG tube, or some surgeons will perform **endoscopy** to ensure adequate closure. The peritoneal cavity is then irrigated. The position of the operating table is frequently changed during irrigation to allow better access to the entire abdominal cavity. Adequate irrigation can take 20–30 min. Conversion rates are quite high (10–15%) with inability to localize the perforation the most common reason for conversion to open surgery.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting nothing by mouth (NPO) duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading deep venous thrombosis (DVT) prophylaxis, and postop pain management options. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

SUMMARY OF PROCEDURE

Position	Supine, low lithotomy
Incision	3–5 ports
Antibiotics	Extended spectrum PCN (e.g., ticarcillin, piperacillin), 2nd-generation cephalosporin (e.g., cefotetan, cefoxitin) given preincision
Surgical time	1–1.5 h
Closing considerations	Port closure only Placement of a drain
Special instrumentation	Gastroscope; oro- or nasogastric tube

EBL	<75 mL
Postop care	2–4-d hospital stay; liquids on postop day 1; consider upper GI.
Mortality	Typically <0.1% (as high as 3% in some series)
Morbidity	6–10% overall, including: Abscess (2–8%) Leak (~5%) Ileus (3–6%) Pneumonia
Pain score	3

PATIENT POPULATION CHARACTERISTICS

Age range	40–60 yr
Male:Female	May be slightly more common in males
Incidence	~10% lifetime risk for perforation in PUD
Etiology	May be related to Helicobacter pylori infection; NSAID use; stress; corticosteroid use
Associated conditions	Gastrinoma; MEN type 1; COPD; CRF; up to 20% may be in shock at the time of admission.

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations Following Laparoscopic Cholecystectomy.

Suggested Readings

1. Søreide K, Thorsen K, Søreide JA: Strategies to improve the outcome of emergency surgery for perforated peptic ulcer. Br J Surg 2014; 101(1):e51–64.
2. Wilhelmsen M, Møller MH, Rosenstock S: Surgical complications after open and laparoscopic surgery for perforated peptic ulcer in a nationwide cohort. Br J Surg 2015; 102(4):382–7.

LAPAROSCOPIC ESOPHAGEAL FUNDOPLICATION

SURGICAL CONSIDERATIONS

Description

Approximately 40% of Americans suffer from heartburn, and most cases are treated medically. Indications for **esophageal fundoplication** (to ↑ lower esophageal sphincter pressure) include complications of gastroesophageal reflux disease (GERD), such as stricture, respiratory problems, esophageal ulcerations, and Barrett esophagus (a premalignant condition). Other indications include failure of medical management or unwillingness to submit to a lifetime of medication. Most patients with GERD are treated laparoscopically; those undergoing **laparoscopic fundoplication** have the benefits of a minimally invasive approach—decreased pain, earlier return of GI function, earlier ambulation, earlier discharge, quicker return to normal activities, and reduced incidence of wound infections and hernias. The most common fundoplication is the **Nissen (360°) wrap,** and its variations include the Toupet **(270° posterior) wrap** and the Dor **(anterior) wrap**. Before surgery, patients with GERD should have documented esophageal hyperacidity (by either pH probe or by esophagitis revealed on upper endoscopy) and also should have a hypotensive sphincter (demonstrated on manometry). Typically, they will have been treated with proton pump inhibitors (e.g., lansoprazole) and sometimes with prokinetic agents (e.g., metoclopramide). The patient is placed supine in a low lithotomy position, with the surgeon standing between the legs. The abdomen is entered with a Veress needle ~2 cm above the umbilicus or in the left upper quadrant (LUQ) Palmer point or with an open Hassan placement 2 cm above the umbilicus. A total of five trocars are inserted—two in the LUQ, two in the right upper quadrant (RUQ), and one at the umbilicus. The stomach should be decompressed either with an OG tube or with a gastroscope. The liver is elevated with a liver retractor, and the gastroesophageal (GE) junction and both diaphragmatic crura are dissected out. The hiatus should be closed with one or two sutures. The esophagus is encircled (Fig. 7.7-1A), and the vagal nerves are identified and preserved. The short gastrics are then taken down to decrease tension on the wrap. The fundus is brought in through the retroesophageal window (Fig. 7.7-2). An esophageal dilator (56–60 Fr) generally is placed (often by the anesthesiologist) to calibrate the wrap. Passage of the dilator is possibly the most hazardous part of the procedure because it may cause perforation of the esophagus at the GE junction. As the dilator approaches the stomach, it is important to watch the junction on the video monitors to ensure that the dilator is not being held at an angle that will risk perforation. The anesthesiologist should stop passing the dilator immediately if any resistance is felt. Communication between the surgeon and the anesthesia team is critical during the passage of the dilator.

The dilator is withdrawn. An NG tube may be placed at this time.

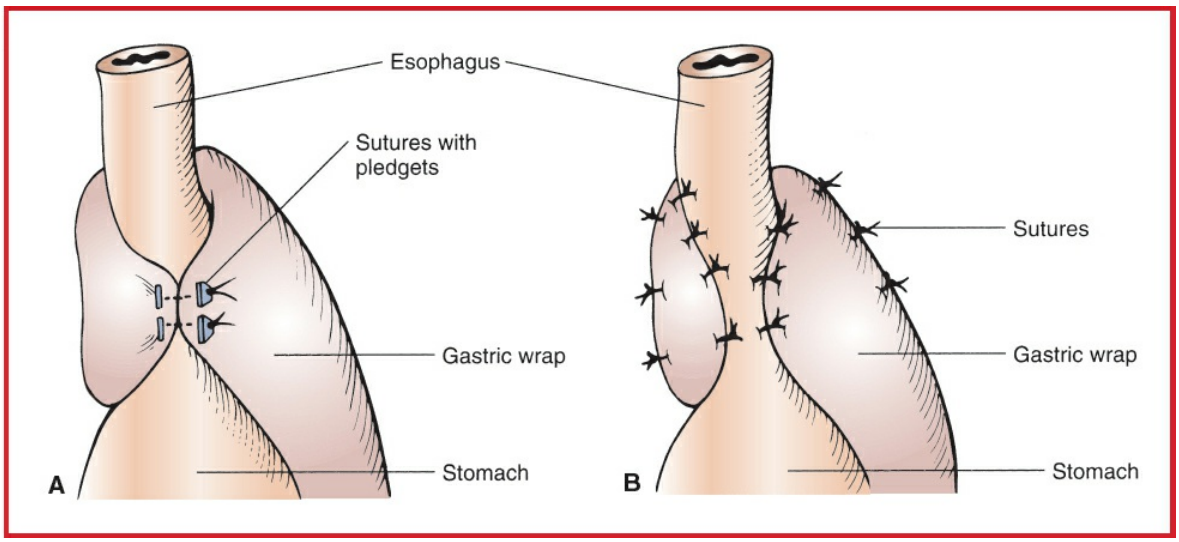

Figure 7.7-1 **A:** Nissen fundoplication. **B:** Partial fundoplication (Toupet procedure).

Variant procedure or approaches

Open surgery may be indicated if the patient has had previous gastric surgery or if there is a complication with an ongoing laparoscopic procedure. Some surgeons may elect not to divide the short gastrics, which decreases operative time. The Dor fundoplication is an anterior hemifundoplication in which the fundus is wrapped and sutured to the left and right sides of the esophagus and the left and right crura, but anteriorly. A Dor fundoplication is often used in combination with a **Heller myotomy** for treatment of achalasia. A Toupet procedure (Fig. 7.7-1B) is a posterior hemifundoplication in which the two walls of the fundus do not meet. The stomach is sewn to the left and right walls of the esophagus and then is anchored to the right and left crura. In the past, these procedures were performed commonly in patients with a high risk of postop dysphagia (e.g., those who have impaired esophageal peristalsis or a preop stricture). Now, because of their higher failure rate, they are seldom performed except in patients with severe esophageal dysmotility, such as patients with scleroderma. These procedures are identical to the Nissen fundoplication except for the wrap itself.

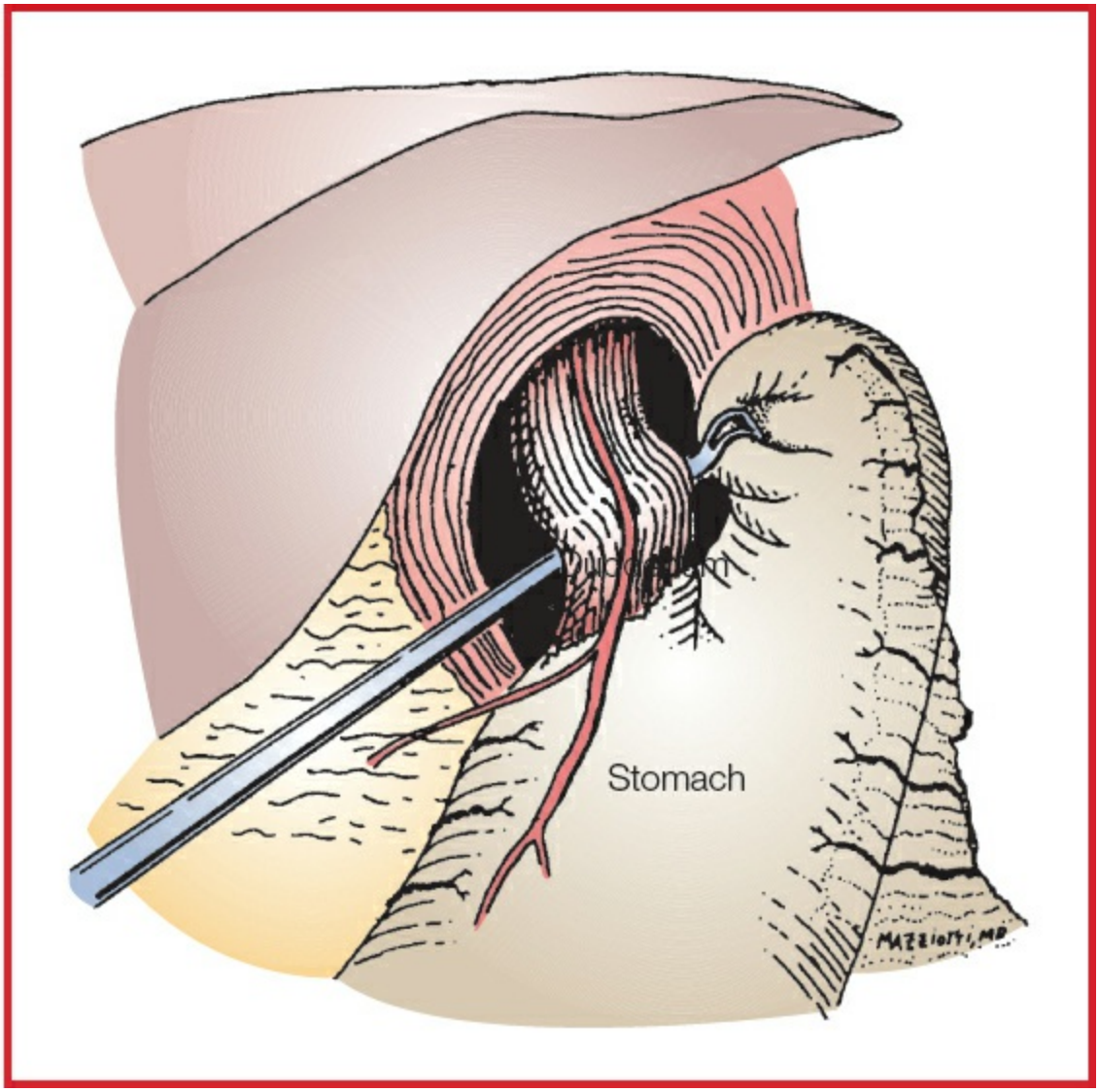

Figure 7.7-2 Gastric fundus is pulled posteriorly and to the right of the esophagus, with the fundus itself used as a retractor, reaching from right to left behind the esophagus to grasp the fundus and retract it back to the right side behind the esophagus. Placing caudad traction on the wrapped fundus, the GE junction, and distal esophagus can be brought further into the abdominal cavity. (Reproduced with permission from Baker RJ, Fischer JE, edsMastery of Surgery, 4th edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Usual preop diagnosis

GERD; with or without esophagitis; esophageal stricture; or Barrett esophagus

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading DVT prophylaxis, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE

Position	Supine low lithotomy
Incision	Five ports, upper abdomen
Special instrumentation	Harmonic scalpel; bipolar cautery; endoscope. Esophageal dilators should be available.
Antibiotics	Cefazolin 2 g iv preincision (weight-based dosing recommended)
Surgical time	1.5–3 h
Closing considerations	Port closures only; muscle relaxation may be needed for fascial closure.
EBL	<75 mL
Postop care	1–2-d hospital stay; liquids on pod 1; consider a postoperative upper GI.
Mortality	<0.1%
Morbidity	Overall: 8% Atelectasis: common Esophageal or gastric perforation: rare (most commonly associated with passage of NG tube or esophageal dilator) Hemorrhage from short gastrics or splenic tear Pneumothorax (does not usually require treatment) Postop dysphagia
Pain score	4

PATIENT POPULATION CHARACTERISTICS

Age range	All ages (incidence ↑ with age). May be performed in infants; next peak occurs in adulthood; rare in children and adolescents
Male:Female	1:1
Incidence	1% (increasing significantly over the past 5 yr)
Etiology	Unknown
Associated	Aspiration risk; reactive airway disease; occasionally,

conditions	respiratory problems associated with chronic aspiration

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations Following Laparoscopic Cholecystectomy.

Suggested Readings

1. Broeders JA, Roks DJ, Jamieson GG, et al: Five-year outcome after laparoscopi anterior partial versus Nissen fundoplication: four randomized trials. Ann Surg 2012; 255(4):637–42.
2. Cowgill SM, Gillman R, Kraemer E, et al: Ten year follow up after laparoscopic Nissen fundoplication for gastroesophageal reflux disease. Am Surg 2007; 73(8):748–53.
3. Rebecchi F, Allaix ME, Cinti L, et al: Comparison of the outcome of laparoscopic procedures for GERD. Updates Surg 2018; 70(3):315–21.

LAPAROSCOPIC HELLER MYOTOMY ± ANTIREFLUX PROCEDURE

SURGICAL CONSIDERATIONS

Description

Laparoscopic and thoracoscopic esophageal myotomies have become much more common. These procedures are performed for achalasia, an uncommon condition in which the lower esophageal sphincter fails to relax with swallowing and in which the body of the esophagus is aperistaltic and dilates. Patients typically complain of dysphagia with chest pain and may experience regurgitation. The etiology of this condition remains unknown.

Treatment options consist of pneumatic dilation, botulinum toxin injection of the lower esophageal sphincter, or surgical myotomy. **Pneumatic dilation** remains the most common procedure performed for achalasia and is effective in ~60% of patients. Many gastroenterologists are reluctant to perform this procedure, however, because of the risk of esophageal perforation, which is generally considered to be ~3–5%, but may be as high as 10%. **Botulinum toxin injection** is a newer technique that is effective to some degree in most patients, but the duration of its effectiveness is short. Most patients require retreatment within 1.5 yr, and the efficacy of retreatment may diminish over

time. In many centers, **surgical myotomy (Heller operation)** has become the procedure of choice for the treatment of achalasia.

The patient is positioned as for a laparoscopic antireflux procedure—supine in the lithotomy position with reverse Trendelenburg. The abdomen is usually entered with a **Veress needle** at the umbilicus or left upper quadrant Palmer point or **Hasson trocar** at the umbilicus, and five laparoscopic ports are placed across the upper abdomen—two beneath the left costal margin, two beneath the right costal margin, and one in the midline either at the umbilicus or midway between the umbilicus and the xiphoid. The liver is elevated, and the ligamentous attachments anterior to the esophagus are divided. The esophagus is not usually encircled, and, as hiatal hernias are uncommon with achalasia, crural repair is seldom necessary.

The myotomy is begun at the gastroesophageal junction using monopolar cautery, bipolar scissors, or a harmonic scalpel (ultrasonic cutting/coagulation). It is carried proximally until normal musculature is encountered. Some surgeons perform intraop **esophagoscopy** to ensure that the myotomy has been carried proximally enough and that there has not been a mucosal perforation. Generally, a myotomy of 5–8 cm is adequate, although sometimes a longer myotomy may be necessary. Some surgeons then perform a very loose, **partial fundoplication** to prevent reflux. This can be performed as an anterior or posterior fundoplication, bringing the fundus either anterior (Dor fundoplication—our preference) or posterior (Toupet fundoplication) to the esophagus. The stomach is secured to the esophageal wall and crura with sutures, and an NG tube may be passed. The ports are removed, and port closure is carried out.

Variant procedure or approaches

Although most of these procedures are being performed laparoscopically, they also can be performed by **thoracoscopy or thoracotomy**. If a thoracoscopy or thoracotomy is performed, a double lumen tube (DLT) is placed to allow collapse of the left lung.

Usual preop diagnosis

Achalasia

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading DVT prophylaxis, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE

Position	Supine lithotomy, reverse Trendelenburg
Incision	Five ports, upper abdomen
Special instrumentation	Laparoscopic instrumentation ± gastroscope
Antibiotics	Cefazolin 2 g iv pre-incision (weight-based dosing)
Surgical time	1.5–2 h
Closing considerations	None
EBL	Minimal
Postop care	2-d hospital stay; liquids on pod 1
Mortality	Rare
Morbidity	Insignificant atelectasis: Common Esophageal or gastric perforation: Rare Pneumothorax (does not usually require treatment) Gastroesophageal reflux: >15%
Pain score	4

PATIENT POPULATION CHARACTERISTICS	
Age range	20–40 yr
Male:Female	1:1
Incidence	Achalasia: 1 in 20,000 adults
Etiology	Unknown
Associated conditions	None. Chagas disease may produce identical esophageal findings.

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations Following Laparoscopic Cholecystectomy.

Suggested Readings

1. Bhayani NH, Kurian AA, Dunst CM, et al: A comparative study on comprehensive objective outcomes of laparoscopic Heller myotomy with per-oral endoscopic

myotomy (POEM) for achalasia. Ann Surg 2014; 259(6):1098–103.
2. Bonatti H, Hinder RA, Klocker J, et al: Long-term results of laparoscopic Helle myotomy with partial fundoplication for the treatment of achalasia. Am J Surg 2005; 190(6):874–8.
3. Jeansonne LO, White BC, Pilger KE, et al: Ten-year follow-up of laparoscopi Heller myotomy for achalasia shows durability. Surg Endosc 2007; 21(9):1498–1502.
4. Sharp KW, Khaitan L, Scholz S, et al: 100 minimally invasive Heller myotomies lessons learned. Ann Surg 2002; 235(5):631–9.

LAPAROSCOPIC CHOLECYSTECTOMY, ± COMMON DUCT EXPLORATION

SURGICAL CONSIDERATIONS

Description

This operation is usually performed for symptomatic gallstones, gallstone pancreatitis, or acute cholecystitis. A laparoscopic approach is preferred over an open cholecystectomy because of its minimally invasive nature, which allows earlier recovery and return to normal activities. **Laparoscopic cholecystectomy** may be contraindicated for patients with uncorrectable coagulopathy, severe chronic obstructive pulmonary disease (COPD), or severe cardiac disease (unable to tolerate 1 intra-abdominal pressure). In addition, patients with prior abdominal surgery or with acute cholecystitis are at a higher risk for conversion to open surgery. The operation begins with access to the abdominal cavity at the umbilicus, either with a **Veress needle** (closed technique: blind placement) or a **Hasson trocar** (open technique). The patient will need an OG tube to decompress the stomach before proceeding. CO_2 is insufflated to an intra-abdominal pressure of 15 mm Hg (or up to 18 mm Hg in super obese patients). If the patient develops ventilatory or hemodynamic problems, consider decreasing the intra-abdominal pressure to 10–12 mm Hg. A total of four trocars are used—one at the umbilicus and three in the RUQ. The patient is placed in a RTP and rotated to the left to move the stomach, duodenum, and transverse colon away from the operative field. The cystic artery and cystic duct (with hepatic duct = triangle of Calot) are clipped and cut (Fig. 7.7-3). The gallbladder is then dissected off the liver with monopolar cautery, placed in a bag, and brought out, usually through the umbilical port or subxiphoid port sites. Hemostasis is then achieved, the area is irrigated, and the 10-mm trocar sites are closed. The rate of conversion to an open operation is 2–3% for

elective gallbladder surgery and ~10% for acute cholecystitis. Should this occur, the operation is then converted to an **open cholecystectomy**.

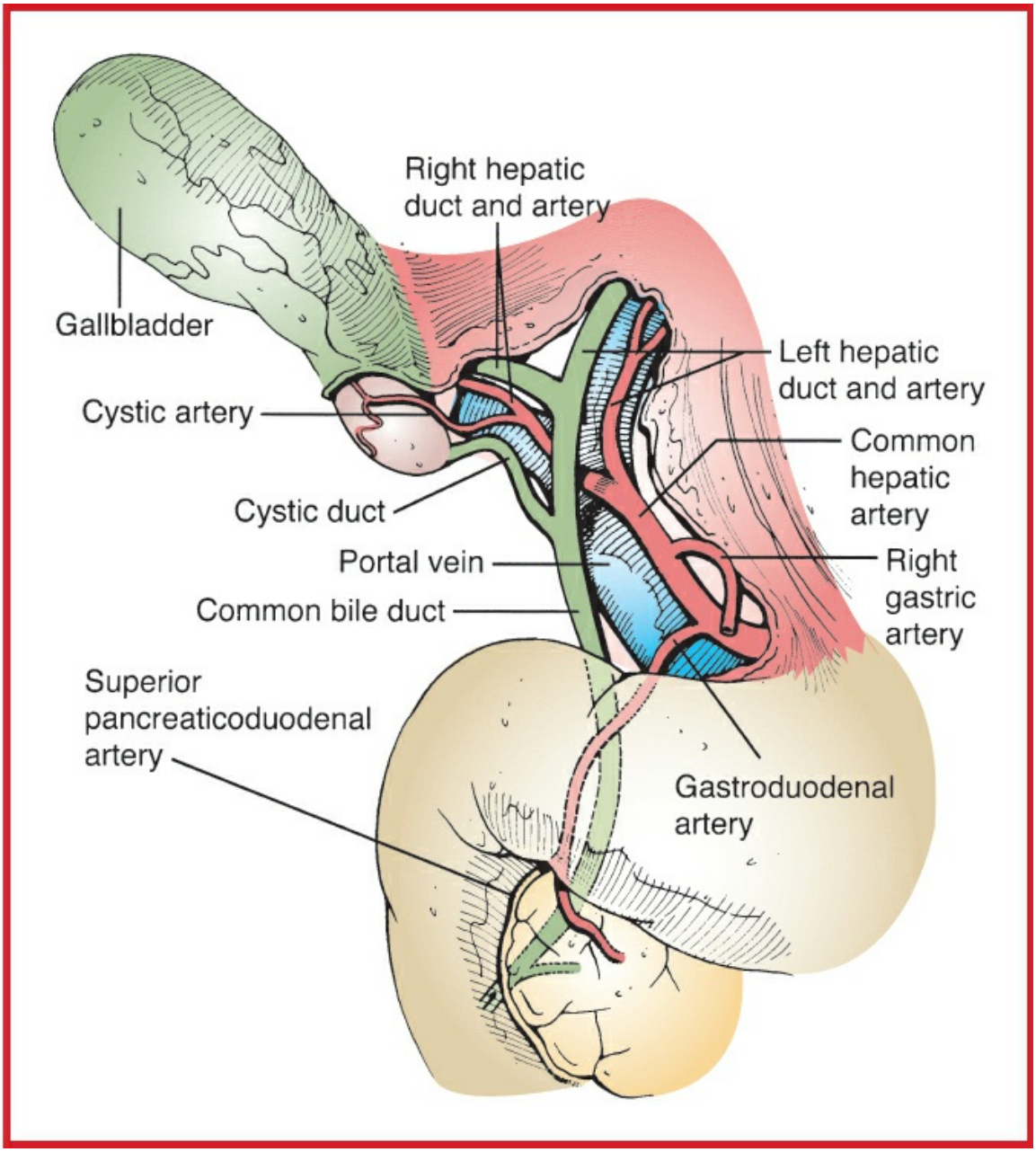

Figure 7.7-3 Surgical anatomy for laparoscopic cholecystectomy and common duct exploration.

Cholangiography can be added easily to the laparoscopic cholecystectomy. A clip is placed high on the cystic duct; then, a small incision is made in the duct just beneath the clip. A cholangiocatheter may be introduced, and dye injected into the biliary tree. X-rays—either fluoroscopy or—are used to assess the biliary anatomy and to look for stones within the ductal system. Cholangiography carries few risks, generally adds about −15 min to the procedure, and can be used to identify the important anatomy ~85% of the time. Some surgeons perform it routinely during all cholecystectomies;

others perform it selectively and only if there is evidence that the patient has had common duct stones or if the anatomy is in question.

Newer technology allows for less invasive imaging of the biliary tree using indocyanine green dye imaging 45 min before imaging, and often before the first incision, 3 mg of ICG is administered intravenously. A specialized camera is used to visualize the biliary tree when ICG is taken up in the bile glows and gives an outline of the anatomy.

In rare circumstances, **laparoscopic common duct exploration** may be carried out to treat common duct stones. A number of techniques have been used, most employing a thin fiberoptic choledochoscope passed through the cystic duct into the common duct. The anesthesiologist may be asked to administer 1-mg glucagon to relax the sphincter of Oddi. This procedure is performed in only a relatively few centers. More commonly, **endoscopic retrograde cholangiopancreatography (ERCP)** will be used, either preop or postop, to demonstrate the presence or absence of stones and to remove any stones that are found.

Variant procedure or approaches

Open cholecystectomy remains the major alternative to laparoscopic cholecystectomy, either because the cholecystectomy is predicted to be technically difficult or because of the illness of the patient. Approximately 5% or less of laparoscopic cholecystectomies are converted to open cholecystectomy intraop because of difficulties with the procedure. **ERCP** remains the most common means of treating choledocholithiasis in the industrialized world with laparoscopic techniques used in a relatively small number of centers and by a small number of surgeons. **Open common duct exploration** is occasionally necessary for stones not retrievable by ERCP (generally <5%).

Usual preop diagnosis

Acute or chronic cholecystitis, usually with cholelithiasis, with or without choledocholithiasis

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading DVT prophylaxis, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Four upper abdominal ports

Special instrumentation	Routine laparoscopic instruments. May require fluoroscopy and choledochoscope for cholangiography, common duct exploration; OG tube.
Antibiotics	Cefazolin 2 g iv preincision (weight-based dosing)
Surgical time	0.5–2 h; may be longer for common duct exploration
Closing considerations	Muscular relaxation helpful for closure of 10-mm port site
EBL	Minimal
Postop care	Usual discharge from PACU or within 24 h
Mortality	<1/1000
Morbidity	Bile leak: 1% Common duct injury: 0.1–0.5% Hemorrhage (requiring transfusion) Infection Injury to bowel Major vascular injury: Uncommon
Pain score	3

PATIENT POPULATION CHARACTERISTICS

Age range	Typically adult, increasing in the pediatric patient population
Male:Female	Female > male
Incidence	Common
Etiology	Stone disease. Risk factors = female gender, age, parity, obesity
Associated conditions	Hemolytic anemia for pigmented stones

ANESTHETIC CONSIDERATIONS

(Procedures covered: repair of perforated peptic ulcer; laparoscopic esophageal fundoplication; laparoscopic Heller myotomy and antireflux surgery; laparoscopic

cholecystectomy.)

PREOPERATIVE: LAPAROSCOPIC FUNDOPLICATION/HELLER MYOTOMY

Indications for surgery include failed optimal medical management, high-volume reflux, severe esophagitis, and benign stricture. Severe reflux may lead to airway and pulmonary symptoms, as well.

Respiratory	Patients may have a history of gastroesophageal reflux resulting in aspiration, particularly when recumbent. Recurrent aspiration may result in bronchospasm, pneumonia, and chronic pneumonitis. A prolonged history of reflux may give rise to premalignant Barrett esophagus, which may result in stricture formation and weakness of the esophageal wall. Achalasia may result in severe regurgitation and aspiration. Pulmonary physiologic changes include both restrictive and obstructive lung defects and bronchoalveolar injury. Physical exam may show wheezing and rhonchi. **Tests:** Consider PA and lateral CXR. Consider baseline arterial blood gases and pulmonary function tests if significant compromise of pulmonary function is present.
Cardiovascular	Patients with both reflux and achalasia may present with chest pain. Typically, the pain of reflux is sharp and substernal. Chest pain in achalasia may radiate to the neck, back, and arms and may be difficult to differentiate from pain of cardiac origin. Differentiation should be made before surgery both by careful history taking and appropriate tests. **Tests:** Consider ECG, exercise, or chemical stress testing if source of chest pain remains unclear. Other tests as indicated from H&P.
Laboratory	Patients with severe inflammation and erosion may suffer from an iron deficiency anemia. Consider CBC.

	Otherwise as indicated from H&P.
Premedication	These patients may be at risk for aspiration and should be treated with full-stomach precautions.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with a sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

PREOPERATIVE: LAPAROSCOPIC CHOLECYSTECTOMY

The preop evaluation of patients undergoing open cholecystectomy is discussed under Anesthetic Considerations for Biliary Tract Surgery.

Respiratory	Patients presenting for laparoscopic cholecystectomy may present electively or acutely. Increasingly, cholecystectomy is performed in patients with acute cholecystitis. Patients presenting acutely may experience severe abdominal pain, leading to diaphragmatic splinting and basal lung atelectasis. During the procedure, intra-abdominal CO_2 insufflation → atelectasis, ↓ FRC, ↑ PIP, ↑ $PaCO_2$, and ↓ PaO_2; therefore, laparoscopic procedures may be contraindicated in patients with severe respiratory or cardiovascular disease. Postop respiratory function, however, is less impaired (e.g., ↓ FRC 30% vs. 50%) and is recovered more quickly (24 vs. 72 h) in patients undergoing laparoscopic cholecystectomy than in the open procedure.
Systemic	Patients presenting for laparoscopic cholecystectomy with acute cholecystitis may have evidence of mild to moderate sepsis. They may be febrile, tachycardic, and hypotensive and need resuscitation before surgery.
Laboratory	CBC. Consider T&S in patients with recurrent and chronic gallbladder disease. They may have liver adhesions. During the acute inflammatory stage, there may be ↑ vascularity → bleeding.

Premedication	Consider midazolam 1–2 mg iv unless the patient is unstable or septic. If urgent surgery, check for recent administration of analgesics.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA

Induction	**Laparoscopic fundoplication and Heller myotomy:** Consider full stomach precautions and rapid-sequence intubation technique. Additional iv access may be required if the arms are inaccessible. **Laparoscopic cholecystectomy:** Standard induction. In acutely unwell patients, despite resuscitation, patients may be more susceptible to the effects of anesthesia and positive pressure ventilation. Consider additional iv access, invasive arterial pressure monitoring, and central access in unstable patients. Etomidate may be a useful induction agent in this setting. OG/NGT before incision to ensure stomach decompressed.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance. Continue muscle relaxation. Intra-abdominal CO_2 insufflation will → ↑ intra-abdominal pressure, which will predispose to passive regurgitation of gastric contents. Also, intra-abdominal pressure >15 mm Hg → ↓ venous return + ↑ SVR → ↓ CO. Controlled ventilation will minimize the possibility of hypercarbia from absorbed CO_2.
Emergence	Given the high incidence of PONV, prophylactic

	antiemetic Rx (e.g., ondansetron 4 mg iv) recommended and should be given 30–60 min before the end of the case. Discuss with surgeon local wound infiltration. PONV prophylaxis may include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 16–18 ga × 1 BSS @ 8–12 mL/kg/h Fluid warmer	Blood loss typically minimal with these procedures, but potential for major bleeding exists. Consider additional iv access, conversion to open procedure if risk factors for increased bleeding present. See Zero Balance Fluid Management, Appendix K, p. K-2 and K-4.
Monitoring	Standard monitors Urinary catheter OG/NG tube	Others as clinically indicated. Prevent hypothermia (forced-air warmer, warming blanket, warm OR, etc.)
Positioning	✓ and pad pressure points ✓eyes	Initially in Trendelenburg position (↑ venous return, ↓ lung volumes, potential for mainstem intubation) for trocar placement; then reverse Trendelenburg (↓ venous return, ↑ lung volumes) during subsequent portions of the surgical procedure
Complications	Respiratory: Pneumoperitoneum Hypercarbia/hypoxemia Pneumothorax	Pneumoperitoneum with CO_2 allows the surgeon to operate laparoscopically. This creates cephalad displacement of the diaphragm with ↓ FRC, ↓ pulmonary compliance, and atelectasis. This can manifest as ↑ PIP, ↓ PO_2, and ↑ PCO_2.

Pneumomediastinum Endobronchial intubation	Ventilation should be controlled during the operation to minimize the effects of pneumoperitoneum and hypercarbia. An increase in MV is appropriate. Pneumothorax can occur 2° retroperitoneal dissection of insufflated CO_2. Pneumothorax will manifest as ↓ PO_2, ↑ PIP, hemodynamic instability (↑ HR, ↓ BP), and possibly subcutaneous emphysema. The position of the ETT may change with altered patient position → endobronchial intubation.
Cardiovascular: ↓ BP Hemorrhage Dysrhythmias	↓ BP can occur 2° patient positioning (reverse Trendelenburg) and from ↓ venous return 2° pneumoperitoneum (↑ intra-abdominal pressure >15 mm Hg). Hemorrhage can result from inadvertent injury to blood vessels (during trocar placement). Vascular injection of CO_2 (air embolism) can cause ↓ BP, dysrhythmias, and even cardiovascular collapse. If cardiopulmonary compromise occurs, the pneumoperitoneum can be released to allow for differential diagnosis and treatment.

	Visceral injury	Injury to the viscera may necessitate an open procedure or may go undiagnosed and → other postop complications, depending on the organ that is injured. Always be prepared to convert to an open procedure.
	Hypothermia	2° dry gas insufflations
	Subcutaneous emphysema	Keep CO_2 insufflation pressure <12 mm Hg.

POSTOPERATIVE

Complications	PONV (common)	
	Shoulder pain	From pneumoperitoneum; usually self-limited
	Respiratory	Typical postop complications are secondary to pneumoperitoneum and pain.
Multimodal pain management	PCA; consider multimodal analgesia.	Consider combining PCA or fixed dose po/iv opiates with acetaminophen, po or iv NSAIDs, and gabapentin. Emphasize nonopioid analgesics (see Appendix K, p. K-5).
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition and mobilization. Consider need for DVT prophylaxis.
Tests	As indicated from H&P	

Suggested Readings

1. Abeles A, Kwasnicki RM, Darzi A: Enhanced recovery after surgery: curren

research insights and future direction. World J Gastrointest Surg 2017; 9(2):37–45.
2. Barazanchi AWH, MacFater WS, Rahiri JL, et al: Evidence-based management c pain after laparoscopic cholecystectomy: a PROSPECT review update.Br J Anaesth 2018; 121(4):787–803.
3. De Oliveira GS, Castro-Alves LJ, et al: Transversus abdominis plane block t ameliorate postoperative pain outcomes after laparoscopic surgery: a meta-analysis of randomized controlled trials. Anesth Analg 2014; 118(2):454–63.
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6. Kim AJ, Yong RJ, Urman RD: The role of transversus abdominis plane blocks i enhanced recovery after surgery pathways for open and laparoscopic colorectal surgery. J Laparoendosc Adv Surg Tech A 2017; 27(9):909–14.
7. Li Z, Zhao Q, Bai B, et al: Enhanced recovery after surgery programs fo laparoscopic abdominal surgery: a systematic review and meta-analysis. World J Surg 2018; 42(11):3463–73.

LAPAROSCOPIC SPLENECTOMY

SURGICAL CONSIDERATIONS

Description

Laparoscopic-assisted splenectomy is best suited for normal or slightly enlarged spleens (e.g., idiopathic thrombocytopenic purpura [ITP]). Laparoscopic splenectomy usually is contraindicated in patients with large hilar lymph nodes or portal hypertension. Massive splenomegaly, with spleens >30 cm in the longitudinal axis, can be considered a relative contraindication with some surgeons electing to have the splenic artery embolized the day before surgery to cause shrinkage and lower the risk of hemorrhage. There is a high conversion rate (to open surgery) if the size of the spleen is between 20 and 30 cm. Sometimes, a hand-assisted approach may be helpful for spleens in this size range. Conversion rates are higher in patients with perisplenitis and morbid myeloproliferative disorders. For the procedure, patients should be placed on a beanbag in a 45° lateral decubitus position or a full lateral decubitus position. The advantage of the 45° right lateral decubitus position is that it is easy to rotate the table and place the patient in a supine position if there is an urgent need for conversion. With the 45° lateral decubitus or the full lateral decubitus position, the kidney rest should be elevated and the OR table should be flexed to increase the area between the costal

margin and the superior iliac crest. All pressure points should be padded, and the patient should be secured firmly to the table. The first trocar site is generally in the LUQ (see Fig. 7.7-5). Access can be with a closed (Veress needle or Optiview trocar) or open (Hasson trocar) approach. The initial approach may be to the hilum, short gastrics, or inferior pole. Most surgeons use the harmonic scalpel or LigaSure to take down the various ligaments and to dissect out the hilum, which generally is stapled with an endo gastrointestinal anastomosis (GIA). The short gastrics are either taken down with the harmonic scalpel or are LigaSure. The lateral and superior attachments are taken down last. The spleen is then placed in a bag. Removal of the spleen can be done in several ways. Some surgeons remove it with a morselizer placed through one of the trocar sites. Others enlarge one trocar site slightly and remove the spleen in chunks. For very large spleens, some surgeons make a Pfannenstiel incision and extract it through the pelvis.

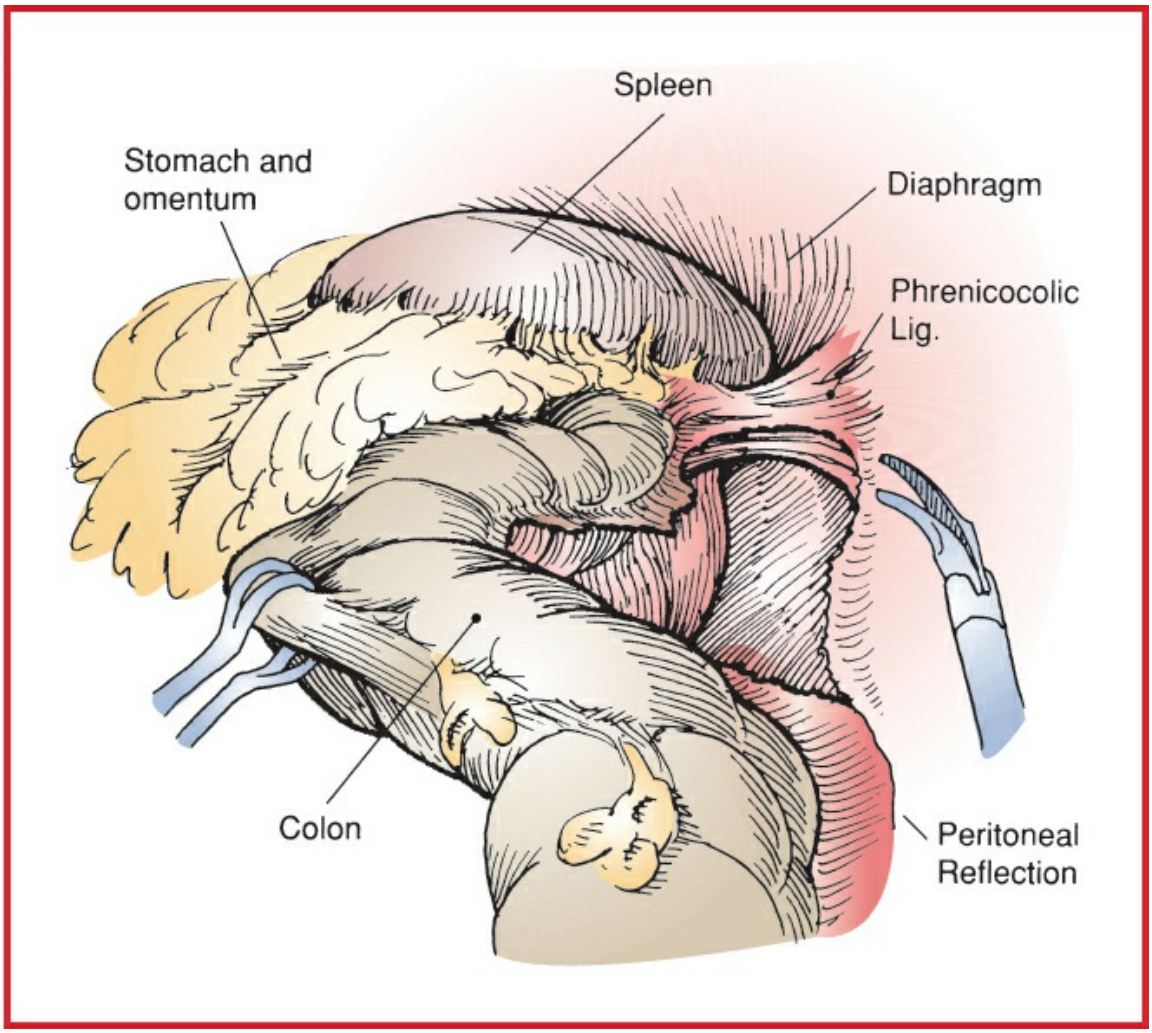

Figure 7.7-4 Anatomy of the spleen. (Reproduced with permission from Wind GG: The spleen. In: Wind GG, Dudai M, eds.Applied Laparoscopic Anatomy: Abdomen and Pelvis Williams & Wilkins, Baltimore: 1997.)

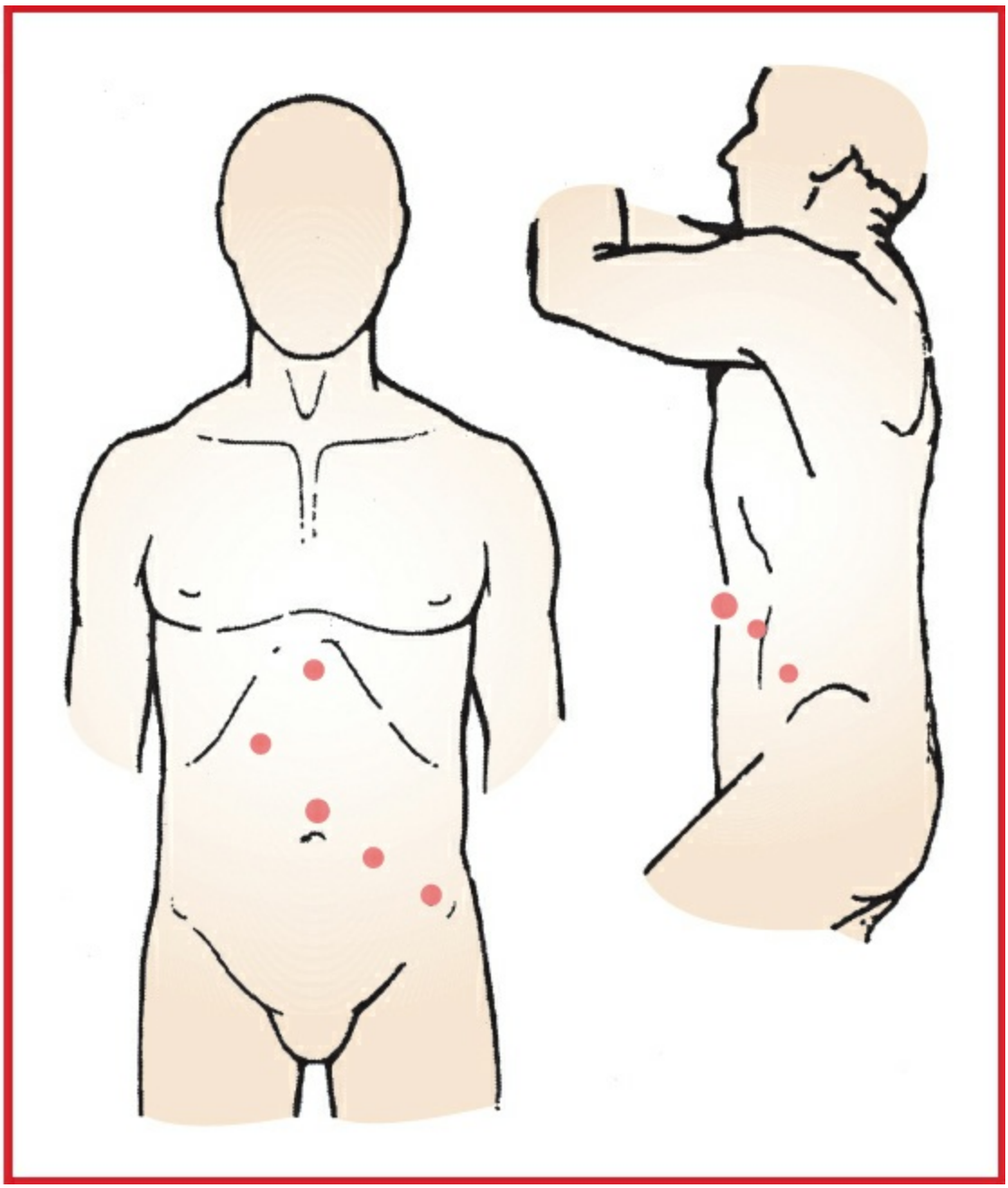

Figure 7.7-5 Trocar location for splenectomy. (Reproduced with permission from Scott-Conner CEH, Dawson DL: Operative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

Variant procedure or approaches

Open splenectomy (described on p. 714). A hand-assisted device can be used for larger, and a larger incision (~5 cm) is made either in the midline or the pelvis. A hand is inserted to assist in retracting and dissecting the spleen while improving visualization.

Usual preop diagnosis

Idiopathic thrombocytopenic purpura (ITP) (60%); hereditary spherocytosis (10%)

hemolytic anemia (5%); thrombotic thrombocytopenic purpura (TTP) (5%); lymphoma (5%); hypersplenism (5%)

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading DVT prophylaxis, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Usually 45° lateral decubitus, OR table flexed, beanbag
Incision	3–5 trocar ports; 1 enlarged to extract spleen
Special instrumentation	Vascular staplers; Harmonic scalpel; LigaSure instruments
Unique considerations	Patients should have received vaccinations (pneumococcal, meningococcal, Haemophilus influenzae) preop. DVT prophylaxis; ± stress steroids; ± Plt transfusion
Antibiotics	Cefazolin 2 g iv preop (weight-based dosing)
Surgical time	1–3 h
Closing considerations	Rapid closure not requiring muscle relaxation (following search for accessory spleen)
EBL	<100 mL; if significant enough to require transfusion, may require conversion to laparotomy
Postop care	PACU → ward. Generally, begin liquids pod 0, and discharge pod 1 or 2.
Mortality	0.1% (predominately related to underlying disease)
Morbidity	5% Hemorrhage Pulmonary complications Injury to the pancreas, stomach, or splenic flexure of the colon
Pain score	5–6

PATIENT POPULATION CHARACTERISTICS	
Age range	All ages; more common in adults
Male:Female	1:1
Incidence	Uncommon
Etiology	Hematologic disorders (e.g., ITP, TTP); hemolytic anemia, tumor of the spleen (e.g., Hodgkin disease); hypersplenism
Associated conditions	Steroid dependence; neutropenia; thrombocytopenia; hemolytic anemias

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients present for laparoscopic splenectomy with a variety of diseases, including ITP, lymphomatous disease (Hodgkin's and non-Hodgkin's), autoimmune hemolytic anemia, TTP, hereditary spherocytosis, Evans syndrome, hairy cell leukemia, hypersplenism 2° portal HTN, sarcoidosis, polycythemia vera, and myelofibrosis. Open splenectomy is usually reserved for traumatic laceration of the spleen. Laparoscopic cases tend to take longer than open splenectomies. Patients who have been treated with chemotherapeutic drugs will require careful preop exam to evaluate for potentially toxic side effects. See Anesthetic Considerations for (open) Splenectomy. Patients should receive pneumococcal, meningococcal, and H. influenzae vaccinations 2 wk preoperatively. If they do not receive preop vaccines, these should be given 2 wk postop.

Respiratory	Splenomegaly may cause left lower-lobe atelectasis. As intra-abdominal CO_2 insufflation → further atelectasis, ↓ FRC, ↑ PIP, ↑ $PaCO_2$, and ↓ PaO_2; therefore, laparoscopic procedures may be contraindicated in patients with advanced lung disease. **Tests:** Consider PA and lateral CXR; ABG and PFTs, if clinically indicated.
Cardiovascular	Cardiovascular changes caused by the pneumoperitoneum include ↓ venous return → ↓ CO, and ↑ SVR.

Hematologic	Cytopenias are very common. **Tests:** CBC with differential and Plt count, T&S, consider T&C. Antibodies may be present → allow ↑ time for T&S/T&C. Platelet counts are typically low, but preop platelet transfusion is usually not helpful due to immediate splenic sequestration.
Hepatic	Consider the presence of coexisting hepatic dysfunction due to primary disease or therapy for it. **Tests:** Hepatic panel, PT/PTT
Laboratory	See above. As indicated from H&P.
Premedication	Standard premedication
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA

Induction	Standard induction. In patients with coexisting liver disease, modify medication choice and dosage accordingly. Place OG/NGT before incision to ensure the stomach is decompressed.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance	
Emergence	No special considerations. Prophylactic antiemetics are appropriate. Discuss with surgeon local wound infiltration. PONV prophylaxis may include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 18–16 ga × 1 BSS @ 8–12 mL/kg/h	Blood loss should be 100 cc. If Plt transfusion is necessary,

	Fluid warmer	it should be given after ligation of splenic vessels (↓ sequestration). Be prepared to obtain more iv access if bleeding is excessive. Consider extra iv access if arms are inaccessible at the start of the case. See Zero Balance Fluid Management, Appendix K, p. K-2 and K-4.
Monitoring	Standard monitors Urinary catheter OG/NGT	Others as indicated by patient status. Prevent hypothermia (forced-air warmer, heated and humidified inspired gases, warming blanket, warm OR, etc.)
Positioning	✓ and pad pressure points ✓ eyes	Careful positioning and padding of patient are essential.
General considerations		If the spleen is large (>20 cm), there is a higher rate of conversion to an open procedure. In particular, intraoperative pain will be greater; hence, analgesic requirements will be higher.
Complications	Respiratory: Cardiovascular: ↓ BP Hemorrhage Visceral injury Hypothermia Subcutaneous emphysema	The complications of laparoscopy are discussed in Anesthetic Considerations for Laparoscopic Cholecystectomy (see p. 652). Conversion to open may be associated with significant hemorrhage. Plt transfusion may be necessary.

POSTOPERATIVE

Complications	Shoulder pain	2° pneumoperitoneum; usually self-limited. Ketorolac (30 mg iv) or other NSAIDs effective
	PONV	
	Atelectasis	Usually left lower lobe
Multimodal pain management	Emphasize nonopioid analgesics including acetaminophen and NSAIDs (see Appendix K, p. K-5).	Consider combining PCA or fixed dose po/iv opiates with acetaminophen, po or iv NSAIDs, and gabapentin.
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	Encourage early enteral nutrition and mobilization. Consider the need for DVT prophylaxis.
Tests	As indicated by patient status	

Suggested Readings

1. Abeles A, Kwasnicki RM, Darzi A: Enhanced recovery after surgery: curren research insights and future direction. World J Gastrointest Surg 2017; 9(2):37–45.
2. Cavaliere D, Solaini L, Di Pietrantonio D, et al: Robotic vs laparoscopi splenectomy for splenomegaly: a retrospective comparative cohort study. Int J Surg 2018; 55:1–4.
3. Grahn SW, Alvarez J, Kirkwood K: Trends in laparoscopic splenectomy for massive splenomegaly. Arch Surg 2006; 141(8):755–62.
4. Kim AJ, Yong RJ, Urman RD: The role of transversus abdominis plane blocks i enhanced recovery after surgery pathways for open and laparoscopic colorectal surgery. J Laparoendosc Adv Surg Tech A 2017; 27(9):909–14.
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LAPAROSCOPIC ADRENALECTOMY

SURGICAL CONSIDERATIONS

Description

Laparoscopic adrenalectomy typically is performed for a variety of adrenal problems including Conn disease, functioning adenoma, pheochromocytoma, Cushing disease, hyperplasia, virilizing or feminizing tumors, and an enlarging, nonfunctioning adenoma. Urologists generally use a retroperitoneal approach, whereas other surgeons use a transabdominal approach. The patient should be on a beanbag in the full lateral decubitus position (Fig. 7.7-6). The kidney rest should be elevated, and the table should be flexed to open up the area between the costal margin and iliac crest. On the left side, three trocars are required along the costal margin. Surgery begins by immobilizing the spleen and the tail of the pancreas medially, and the colon laterally, which allows the spleen to fall away completely from the adrenal gland. The adrenal is then seen behind the hilum of the spleen. Care should be taken to minimize manipulation of a pheochromocytoma to prevent sudden, unexpected HTN during the operation. In general, most surgeons prefer to clip and cut the adrenal vein first. After the adrenal is completely mobilized, it is removed through one of the port sites. For a right-sided approach, four trocars generally are required along the right costal margin. The fourth trocar is used to retract the liver. The first step on the right side is to mobilize the lateral attachments of the liver to expose the adrenal. An enlarged right adrenal may be difficult to mobilize enough to see the adrenal vein because the right adrenal vein empties directly into the inferior vena cava (IVC). The right adrenal vein may be transected with a stapler or divided between clips.

For a pheochromocytoma, seek preoperative consultation with an endocrinologist >4 wk in advance to manage alpha-blockade and possible beta-blockade to avoid sympathetic overstimulation during surgery (see Anesthetic Considerations for Pheochromocytoma, p. 755).

Variant procedure or approaches

Open procedure or retroperitoneal approach

Usual preop diagnosis

Indeterminate adrenal mass (nonfunctional adenoma); also can be performed for

functional adenomas, rarely for pheochromocytoma. Contraindicated for known carcinoma

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading DVT prophylaxis, and postop pain management options. **See Appendix K, p. K-1.**

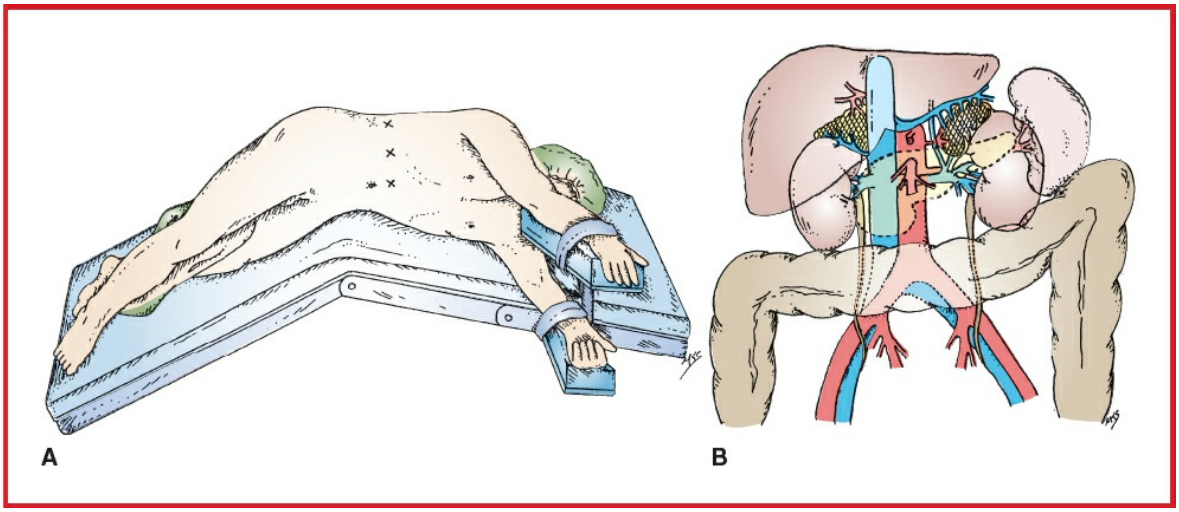

Figure 7.7-6 Laparoscopic adrenalectomy. **A:** Patient positioning and port locations. **B:** Anatomic relationships of adrenals (sutured) to adjacent and overlying structures. (Reproduced with permission from Scott-Conner CEH, Dawson DLOperative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

SUMMARY OF PROCEDURE

Position	Lateral decubitus. A patient with bilateral disease may need repositioning between sides, or surgeon may use a supine approach.
Incision	Three ports on the left side; four ports on the right side
Antibiotics	Cefazolin 2 g iv preincision
Surgical time	1–2 h
Closing considerations	Brief closure; muscle relaxation helpful for fascial repair
EBL	<75 mL, although occasionally significant blood loss may occur

Postop care	Patient is usually discharged on pod 1 or 2, depending on BP control.
Mortality	<0.1%
Morbidity	Hemorrhage/hematoma Injury to the pancreas or kidney UTI DVT
Pain score	4–5

PATIENT POPULATION CHARACTERISTICS

Age range	All ages
Male:Female	1:1
Incidence	Varies with underlying disorder
Etiology	Pheochromocytoma (25%); nonfunctioning adenomas, aldosteronoma (21%); cortisol-producing adenoma (15%); Cushing disease (8%)
Associated conditions	Depending on the function of tumor (e.g., HTN for aldosteronoma, Cushing disease)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

The preop evaluation of patients undergoing laparoscopic adrenalectomy is discussed under Anesthetic Considerations for (open) Adrenalectomy.

Cardiovascular	Cardiovascular changes caused by the pneumoperitoneum include ↓ venous return → ↓ CO and ↑ SVR. Decreased blood flow to the splanchnic and renal circulations (→ ↓ UO) may result from high intra-abdominal pressures.

INTRAOPERATIVE

Anesthetic technique

GETA: An epidural should not be necessary for postop analgesia if the procedure is performed laparoscopically. If the surgical team feels that there is a high likelihood of conversion to an open procedure, consider placement of an epidural catheter for postop analgesia.

Induction	See induction under (open) Adrenalectomy.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.	
Maintenance	See maintenance under (open) Adrenalectomy.	
Emergence	See emergence under (open) Adrenalectomy. The case is likely to take longer if performed laparoscopically, but usually has a less painful postop course. Prophylactic antiemetics are appropriate. Discuss with surgeon local wound infiltration. PONV prophylaxis may include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 16–14 ga × 1 BSS @ 3–5 mL/kg/h	Warming techniques important (forced-air warmers, fluid warmers, humidified inspired gases, etc.). See Zero Balance Fluid Management, Appendix K, p. K-2 and K-4.
Monitoring	Standard monitors arterial line ±CVP catheter ±PA catheter UO TEE	A PA catheter may be useful in the management of patients with pheochromocytoma. TEE may be helpful to evaluate cardiac function and filling.
Positioning	✓ and pad pressure points ✓ eyes	Careful support and padding of extremities and torso are very important.
Complications:	Respiratory:	The complications of

laparoscopic	Pneumoperitoneum Hypercarbia/hypoxemia Pneumothorax Pneumomediastinum Endobronchial intubation Cardiovascular: ↓ BP Hemorrhage Dysrhythmias Visceral injury Subcutaneous emphysema Hypothermia	laparoscopy are discussed in Anesthetic Considerations for Laparoscopic Cholecystectomy (p. 652).
Complications: endocrine	Pheochromocytoma: BP lability Myocardial dysfunction Conn syndrome: CHF 2° hypervolemia ↓ BP Electrolyte disturbances Hyperglycemia Cushing syndrome: ↓ BP Acute adrenal insufficiency	Rx: intraop HTN with SNP or phentolamine (2.5–5 mg q5min); ↑ HR with esmolol; ↓ BP with phenylephrine or dopamine. (See Anesthetic Considerations for Adrenalectomy, p. 661.) See Anesthetic Considerations for Adrenalectomy. Continue replacement steroids. (See Anesthetic Considerations for Adrenalectomy, p. 661.)

POSTOPERATIVE

Complications	PONV Shoulder pain	 Consider ketorolac 30 mg iv.

Multimodal pain management	PCA (see Appendix C, p. C-4)	See Anesthetic Considerations for Adrenalectomy (see p. 661). Emphasize nonopioid analgesics including acetaminophen and NSAIDs (see Appendix K, p. K-5).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	Encourage early enteral nutrition and mobilization. Consider the need for DVT prophylaxis.
Tests	As indicated	

Suggested Readings

1. Abeles A, Kwasnicki RM, Darzi A: Enhanced recovery after surgery: curren research insights and future direction. World J Gastrointest Surg 2017; 9(2):37–45.
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4. Kim AJ, Yong RJ, Urman RD: The role of transversus abdominis plane blocks i enhanced recovery after surgery pathways for open and laparoscopic colorectal surgery. J Laparoendosc Adv Surg Tech A 2017; 27(9):909–14.
5. Li Z, Zhao Q, Bai B, et al: Enhanced recovery after surgery programs fo laparoscopic abdominal surgery: a systematic review and meta-analysis. World J Surg 2018; 42(11):3463–73.
6. Livingstone M, Duttchen K, Thompson J, et al: Hemodynamic stability durin pheochromocytoma resection: lessons learned over the last two decades. Ann Surg Oncol 2015; 22(13):4175–80.
7. Lodin M, Priitera A, Giannone G: Laparoscopic adrenalectomy: keys to success correct surgical indications, adequate preoperative preparation, surgical team experience. Surg Laparosc Endosc Percutan Tech 2007; 17(5):392–5.
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LAPAROSCOPIC AND ROBOTIC BOWEL RESECTION

SURGICAL CONSIDERATIONS

Description

Laparoscopic and robotic bowel surgeries have increased in acceptance and are now considered routine. There are clear advantages to a laparoscopic approach to bowel resection, including decreased pain, earlier return of GI function, earlier ambulation, and earlier discharge from the hospital.

For a **left-sided colon resection**, the patient is placed in a low lithotomy position, while in other bowel resections, a supine position is used. The patient's arms should be tucked to improve access to all four quadrants. Generally, four to five ports are required, one in each quadrant (Fig. 7.7-7). For a **laparoscopic-assisted approach**, one of these ports will be enlarged slightly for removal of the specimen. Very often, the operating table will need to be tilted or rotated throughout the course of the procedure to help move the small intestines away from the surgical dissection site. The procedure typically begins with localization of the pathology. This may require an intraop **sigmoidoscopy** if the lesion has not already been marked on colonoscopy or if it is not grossly apparent. The involved section of the intestine is then mobilized. Often, division of the mesentery is done intracorporeally. Occasionally, surgeons will exteriorize the bowel and do extracorporeal division of the mesentery and extracorporeal division of the bowel. For right-sided lesions, the anastomosis typically is done extracorporeally; however, for left-sided lesions, once the bowel is removed, the pneumoperitoneum will be reinsufflated, and the anastomosis will be performed intracorporeally with an end-to-end stapler placed through the anus.

Some surgeons evaluate blood flow to anastomoses, either routinely or selectively, using indocyanine green imaging. 3 mg of ICG should be administered intravenously approximately before evaluation. When an appropriate camera is utilized, blood flow to the anastomosis appears green, ensuring that it is perfused.

Unipolar and bipolar cautery, the Harmonic scalpel, LigaSure™, and many different surgical staplers may be used during these procedures. These generally require longer operative times than the corresponding open procedures, but typically, they are associated with shorter hospitalization stays and earlier return to work than traditional laparotomy.

Variant procedure or approaches

Open surgery, robotic, laparoscopic-assisted, or totally laparoscopic procedures. Some surgeons also have recommended a hand-assisted procedure where a pneumoperitoneum is still used, but the port site of extraction is enlarged at the beginning of the operation. The surgeon's hand can be placed through a special sleeve that maintains pneumoperitoneum, but also allows the surgeon to retract and dissect manually. Occasionally, the specimen is removed via the anus or through a vaginotomy.

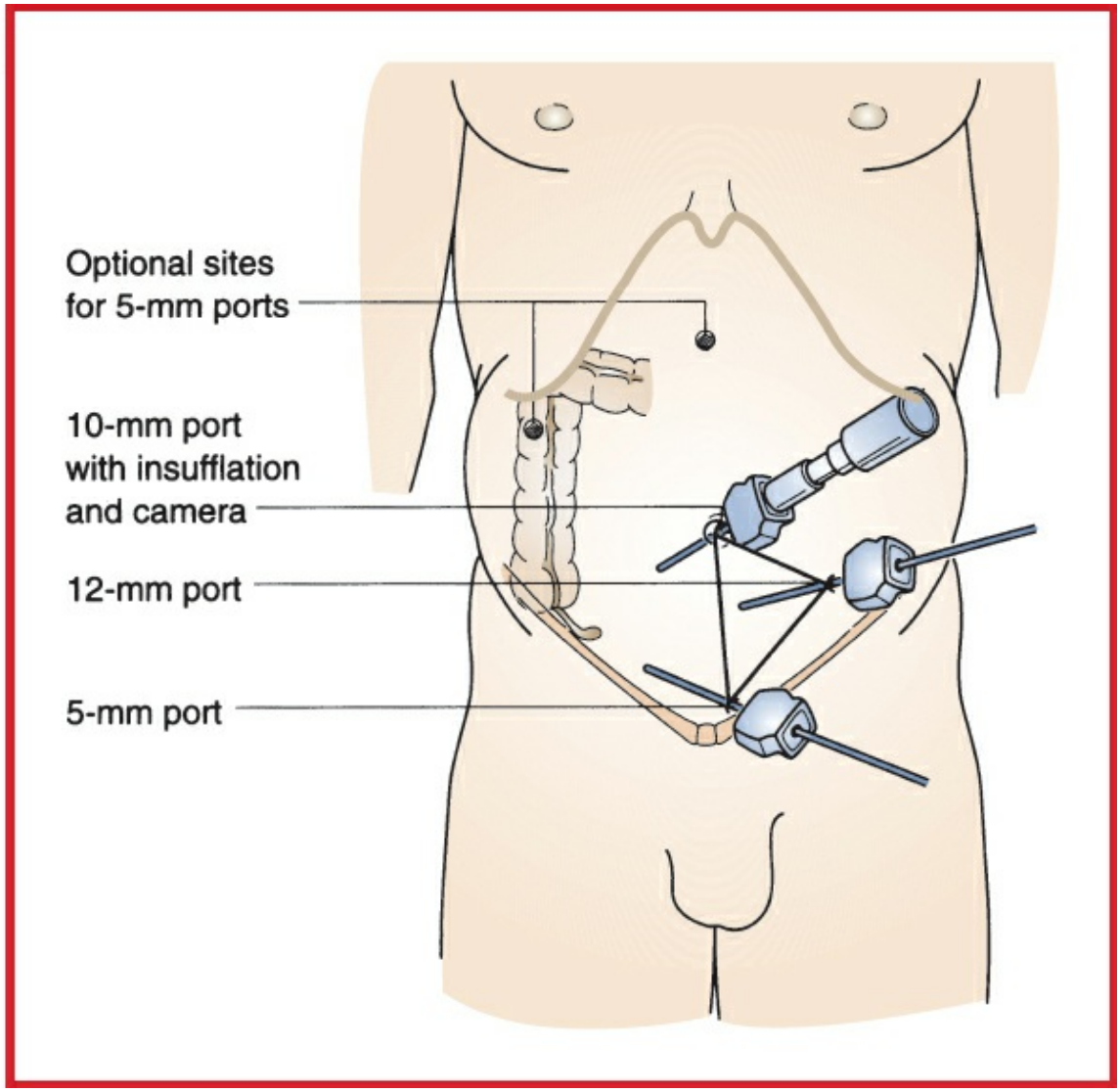

Figure 7.7-7 Trocar placement for a right colectomy. The general principle is to place the camera port so that the surgeon's visual axis is parallel to the telescope and to place the working ports so that the operative site is at the apex of an isosceles triangle. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al., eds. Surgery: Scientific Principles and Practice, 2nd edition. Lippincott-Raven Publishers, Philadelphia: 1997.)

Usual preop diagnosis

Intestinal obstruction; inflammatory conditions (e.g., diverticulitis, bleeding, neoplasms); cancer (controversial)

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading DVT prophylaxis, and postop pain management options. ERAS programs to standardize perioperative care have resulted in reduced narcotic requirements, shorter length of stay, and reduced complications in colectomy patients. The main anesthesia adjustments in these programs are the use of multimodality pain control, including epidural analgesia, regional blocks, and nonnarcotic iv analgesia to supplement narcotics. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE

Position	Usually supine; sometimes lithotomy for left-sided procedures
Incision	4–5 trocar sites, one in each quadrant. One site will be enlarged for specimen removal and anastomosis in laparoscopic-assisted procedures.
Special instrumentation	Harmonic scalpel, various laparoscopic stapling instruments
Unique considerations	The operating table will be moved quite frequently to help with visualization.
Antibiotics	2nd-generation cephalosporin (e.g., cefotetan, or cefoxitin) or cephalexin and Flagyl preincision
Surgical time	1.5–2 h (small bowel resection); 3–4 h (colonic resection). Surgical times will ↑ in the presence of acute inflammation and as the bowel resection becomes more extensive.
Closing considerations	Usually requires closure of several port sites and extraction site. Muscle relaxation helpful
EBL	<200 mL
Postop care	NG tube seldom used. Most patients start a full liquid diet on pod 0; discharge home generally 1–4 d
Mortality	<0.1%

Morbidity	<5% (similar in magnitude to those seen with open operations) Complications include: Hemorrhage Infection Anastomotic leak Intestinal obstruction
Pain score	6–7

PATIENT POPULATION CHARACTERISTICS

Age range	All ages (increases with age)
Male:Female	1:1
Incidence	Varies with disease process
Etiology	Diverticulitis; polyps; inflammatory bowel disease (IBD); cancer
Associated conditions	None

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

For respiratory, cardiovascular, musculoskeletal, gastrointestinal, and renal considerations, see Anesthetic Considerations for Intestinal and Peritoneal Procedures.

Additional considerations	Laparoscopic bowel resection is performed for both malignant and benign diseases. Patients presenting may have a long history of inflammatory bowel disease such as ulcerative colitis or Crohn disease. Typically, they have received medical therapy, surgical treatments, or both. Medical therapies include 5-aminosalicylic acid compounds and immunosuppressants, such as corticosteroids and methotrexate. Side effects of medical therapies include interstitial nephritis, pancreatitis, pleuropericarditis (5-aminosalicylic acids), immunosuppression, truncal obesity, diabetes, and

	hypertension (corticosteroids). Patients who have had previous surgery or severe disease may have adhesions making the impending laparoscopic surgery more technically challenging. Inflammatory bowel disease is associated with a number of coexisting conditions including arthritis, uveitis, and biliary stasis, which may impact on anesthetic management.
Tests	CBC, basic metabolic panel, T&S. Others as per history and physical exam.
Premedication	Midazolam 1–2 mg. Consider po acetaminophen 650–1000 mg, gabapentin 300–600 mg, and celecoxib 200 mg.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA

Induction	Standard induction. Standard rapid-sequence induction if at risk for aspiration. OG/NGT placed before incision for gastric decompression.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Standard maintenance
Emergence	No special considerations unless the patient is at risk for aspiration; extubation should then occur after the patient is fully awake and has protective airway reflexes. Discuss with surgeon local wound infiltration. PONV prophylaxis may include dexamethasone and ondansetron.

Blood and fluid requirements	IV: 16–18 ga × 1 BSS @ 8–12 mL/kg/h Fluid warmer	Blood loss should be <200 cc. See Zero Balance Fluid Management, Appendix K, p. K-2.
Monitoring	Standard monitors Urinary catheter	Others as indicated by patient status. Prevent hypothermia (forced-air warmer, warming blanket, warm room, etc.)
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Respiratory: Pneumoperitoneum Hypercarbia/hypoxemia Pneumothorax Pneumomediastinum Endobronchial intubation Cardiovascular: ↓ BP Dysrhythmias Hemorrhage Visceral injury Hypothermia Subcutaneous emphysema	These complications (associated with the preperitoneal approach), as well as the general complications of laparoscopy, are discussed in Anesthetic Considerations for Laparoscopic Cholecystectomy (p. 652).

POSTOPERATIVE

Complications	PONV Shoulder pain	Ketorolac (30 mg iv) or other NSAIDs
Multimodal pain management	PCA and multimodal analgesia	Consider combining PCA or fixed dose po/iv opiates with acetaminophen, po or iv NSAIDs, and gabapentin. Consider iv ketamine or iv

		lidocaine. Emphasize nonopioid analgesics including acetaminophen and NSAIDs (see Appendix K, p. K-5).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	Encourage early enteral nutrition and mobilization. Consider the need for DVT prophylaxis.
Tests	As indicated by patient status	

Suggested Readings

1. Aarts MA, Rotstein OD, Pearsall EA, et al: Postoperative ERAS interventions hav the greatest impact on optimal recovery: experience with implementation of ERAS across multiple hospitals. Ann Surg 2018; 267(6):992–7.
2. Abeles A, Kwasnicki RM, Darzi A: Enhanced recovery after surgery: curren research insights and future direction. World J Gastrointest Surg 2017; 9(2):37–45.
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5. Feldheiser A, Aziz O, Baldini G, et al: Enhanced Recovery After Surgery (ERAS for gastrointestinal surgery, part 2: consensus statement for anaesthesia practice. Acta Anaesthesiol Scand 2016; 60(3):289–334.
6. Keshava A, Young CJ, Richardson GL, et al: A historical comparison of single incision and conventional multiport laparoscopic right hemicolectomy. Colorectal Dis 2013; 15(10):e618–22.
7. Kim AJ, Yong RJ, Urman RD: The role of transversus abdominis plane blocks in enhanced recovery after surgery pathways for open and laparoscopic colorectal surgery. J Laparoendosc Adv Surg Tech A 2017; 27(9):909–14.
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LAPAROSCOPIC APPENDECTOMY

SURGICAL CONSIDERATIONS

Description

Appendectomy generally is performed for suspected appendicitis. The patient is placed in the supine position with the left arm tucked. An OG/NG tube should be inserted to decompress the stomach. Access is obtained at the umbilicus, either through a closed (**Veress needle**) technique or open (**Hasson trocar**) technique. Two additional trocars are inserted—one suprapubic and the other in the left lower quadrant (LLQ). Occasionally, a fourth trocar may be placed in the RUQ to help with mobilization and retraction. The table will then be rotated to the left side, and the surgeon may ask for it to be placed in Trendelenburg or reverse Trendelenburg position, depending on the location of the cecum. The base of the cecum is identified and the appendix is mobilized (Fig. 7.7-8B). This may require dissection of the peritoneal edge along the right gutter. After the appendix is mobilized, a window is created in the mesoappendix, and the base of the appendix is stapled with an endo GIA. The mesoappendix is then stapled with a vascular-cartridge endo GIA. The appendix generally is placed in a bag before delivering it, or it may be brought directly through the 10-/12-mm trocar (at the umbilicus or other location). The fascia is closed, and the skin is closed. When unexpected pathology is identified, it can be dealt with by laparoscopy or by laparotomy, with incision placement dependent on findings.

Variant procedure or approaches

Open appendectomy via RLQ or midline incision

Usual preop diagnosis

Acute abdomen; possible acute appendicitis

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading DVT prophylaxis, and postop pain management options. **See Appendix K, p. K-1.**

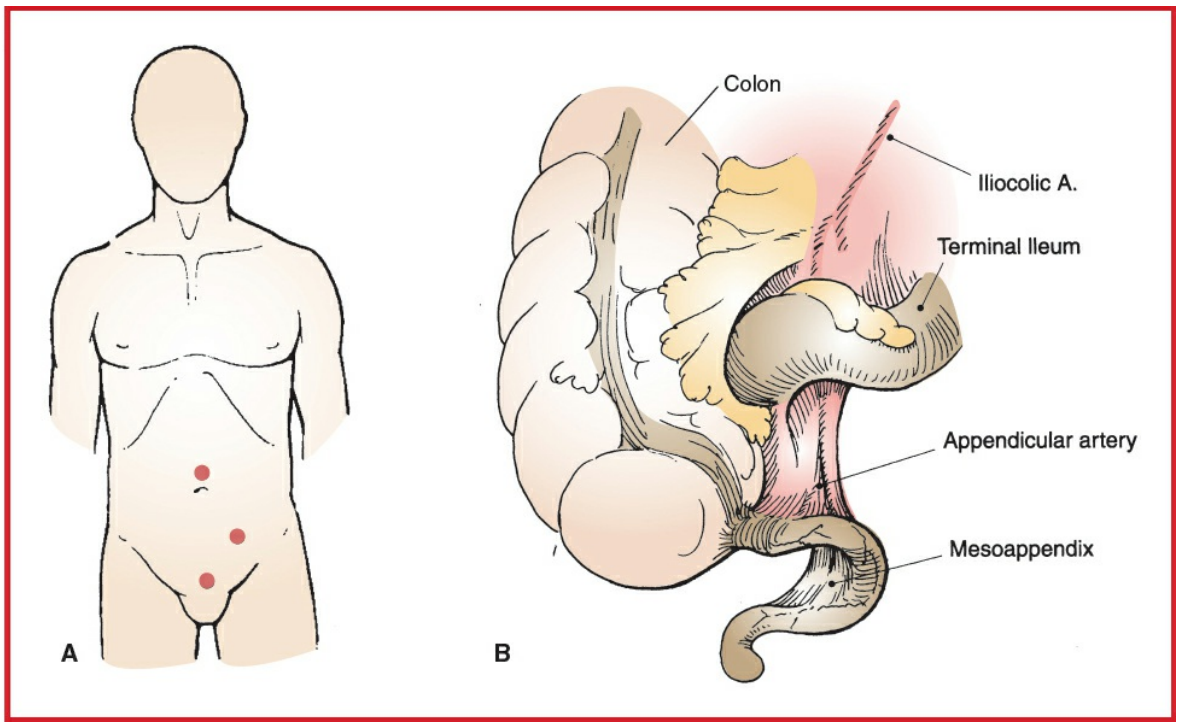

Figure 7.7-8 Setup and initial view for laparoscopic appendectomy. **A:** Reproduced with permission from Scott-Conner CEH, Dawson DLOperative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003. **B:** Reproduced with permission from Wind GG: The spleen. In: Wind GG, Dudai M, eds. Applied Laparoscopic Anatomy: Abdomen and Pelvis. Williams & Wilkins, Baltimore: 1997.

SUMMARY OF PROCEDURE

Position	Supine
Incision	3–4 ports (see Fig. 7.7-8A)
Antibiotics	Broad-spectrum antibiotics such as cefotaxime (1-2 g iv), Zosyn (piperacillin and tazobactam)
Surgical time	30–90 min
Closing considerations	Muscular relaxation helpful for umbilical closure; NG tube if prolonged ileus anticipated
EBL	<75 mL
Postop care	Patients are hospitalized for varying lengths of time, depending on their need for antibiotics. Many with simple acute appendicitis can go home from the PACU or within 24 h.
Mortality	Perforated: 2–5% (nonperforated: <0.1%); increased in elderly patients and infants

Morbidity	Overall: 3% if nonperforated; 20–50% with perforation Intra-abdominal abscess Hematoma Ileus Risk of intra-abdominal abscess, mostly dependent on pathology (e.g., early acute inflammation vs. perforation) Hemorrhage Infection Stump leak: exceedingly rare Conversion to open procedure: dependent on pathology and experience of surgeon
Pain score	4

PATIENT POPULATION CHARACTERISTICS

Age range	All ages; commonly, 19–25 yr
Male:Female	1:1
Incidence	Common (7%)
Etiology	Acute appendicitis; etiology unknown
Associated conditions	Consider other pelvic pathology in women of childbearing age.

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

This patient population is generally fit and healthy, apart from their acutely presenting illness. Full-stomach precautions are appropriate in these patients.

Respiratory	Respiratory impairment can occur 2° acute abdominal pain and splinting. Patients with acute abdomen should be treated as if they have full stomachs. **Tests:** As indicated from H&P
Cardiovascular	Cardiovascular changes caused by the pneumoperitoneum include ↓ venous return → ↓ CO

	and ↑ SVR. Decreased blood flow to the splanchnic and renal circulations (→ ↓ UO) may result from high intra-abdominal pressures. May be dehydrated from fever, emesis, and decreased oral intake. Assess volume status with VS and hydrate adequately before anesthetic induction. **Tests:** As indicated from H&P
Gastrointestinal	Patient typically has abdominal pain with N/V. Muscular resistance to palpation of abdominal wall frequently parallels the severity of the inflammatory process. With spreading peritoneal irritation (as with perforation), patient will develop abdominal distension and paralytic ileus. **Tests:** Renal panel; consider pregnancy test.
Hematologic	Moderate leukocytosis (10,000–18,000) with left shift. Hemoconcentration likely if patient dehydrated **Tests:** CBC
Laboratory	Others as indicated from H&P
Premedication	Patients with acute appendicitis should be treated as if they have full stomachs. Ascertain if patient received opiates during ED eval and management. Consider midazolam 1–2 mg iv.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA, with rapid-sequence iv induction

Induction	Preoxygenate patient and have an assistant apply cricoid pressure. Etomidate 0.1–0.4 mg/kg or propofol 1.5–3 mg/kg + succinylcholine 1.5 mg/kg, for intubation.

	OG/NGT placed before incision to decompress the stomach.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.	
Maintenance	Standard maintenance, without N_2O	
Emergence	Extubate when the patient is awake and with active laryngeal protective reflexes. Discuss with surgeon local wound infiltration. PONV prophylaxis may include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 16–18 ga × 1 BSS @ 3–5 mL/kg/h	See Zero Balance Fluid Management, Appendix K, p. K-2 and p. K-4.
Monitoring	Standard monitors. Urinary catheter	Others as indicated by patient status. Prevent hypothermia (forced-air warmer, warming blanket, warm room, etc.)
Positioning	✓ and pad pressure points ✓ eyes Secure or tuck arms.	Trendelenburg position with elevation of the right side of the abdomen improves surgical exposure.
Complications	Respiratory: Pneumoperitoneum Hypercarbia/hypoxemia Pneumothorax Pneumomediastinum Endobronchial intubation Cardiovascular: Hypotension Dysrhythmias Visceral injury Hypothermia Subcutaneous emphysema	These complications (associated with the preperitoneal approach), as well as the general complications of laparoscopy, are discussed in Anesthetic Considerations for Lap Cholecystectomy.

POSTOPERATIVE

Complications	PONV Urinary retention	Straight catheterization of the bladder
Multimodal pain management	PCA Oral analgesics Ketorolac	See Appendix C, p. C-4. Acetaminophen 650–1000 mg po q6h or Percocet: 1–2 tab po q6h 30 mg iv. Emphasize nonopioid analgesics including acetaminophen and NSAIDs (see Appendix K, p. K-5).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	Encourage early enteral nutrition and mobilization. Consider the need for DVT prophylaxis.
Tests	As indicated by patient status	

Suggested Readings

1. Abeles A, Kwasnicki RM, Darzi A: Enhanced recovery after surgery: curren research insights and future direction. World J Gastrointest Surg 2017; 9(2):37–45.
2. Bennett J, Boddy A, Rhode M: Choice of approach for appendectomy: a meta analysis of open versus laparoscopic appendectomy. Surg Laparosc Endosc Percutar Tech 2007; 17(4):245–55.
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4. Kim AJ, Yong RJ, Urman RD: The role of transversus abdominis plane blocks i enhanced recovery after surgery pathways for open and laparoscopic colorectal surgery. J Laparoendosc Adv Surg Tech A 2017; 27(9):909–14.
5. Li Z, Zhao Q, Bai B, et al: Enhanced recovery after surgery programs fo laparoscopic abdominal surgery: a systematic review and meta-analysis. World J Surg 2018; 42(11):3463–73.

LAPAROSCOPIC INGUINAL HERNIA REPAIR

SURGICAL CONSIDERATIONS

Description

Laparoscopic inguinal hernia repair is clearly preferred in patients with recurrent or bilateral hernias (Fig. 7.7-9). In patients with first-time unilateral hernias, there are no clear advantages in terms of operative time, postop pain, or time to discharge, compared with tension-free open repair. There are three types of laparoscopic hernia repairs. The first, **ONLAY**, generally has been discarded because of high recurrence rates. The other two are the **totally extraperitoneal (TEP)** and the **transabdominal preperitoneal (TAPP)** techniques. Of these, the TEP is somewhat more difficult to learn, but is associated with lower recurrence rates and complications than is the TAPP. For both the TEP and the TAPP, the patient is placed in the supine position with both arms tucked. Some surgeons insert a Foley catheter, but many do not. A small incision is made at the umbilicus. For a **TEP**, this incision only goes to the preperitoneal space, and a balloon is then used for dissection. Two additional ports are placed in the midline —one suprapubic and one halfway between the umbilicus and the suprapubic port. Further dissection is required to identify the hernia defects, which are then reduced. The cord structures are completely freed, and any cord lipomas are dissected. Mesh is placed to cover the entire area and may be tacked to Cooper ligament. For a **TAPP** repair, the umbilical incision extends into the abdomen. Two additional ports are placed at the level of the iliac crest—one in the RLQ and one in the LLQ. A peritoneal flap over the hernia defect is created, and the preperitoneal space is entered. The rest of the dissection and the placement of the mesh are the same as with the TEP repair. At the end of the TAPP procedure, the peritoneal flap is placed over the mesh and tacked into place to prevent exposure of the bowel to the mesh. Increasingly, the robotic surgical platform is being used for the TAPP approach.

Variant procedure or approaches

Open hernia repair (see Inguinal Herniorrhaphy)

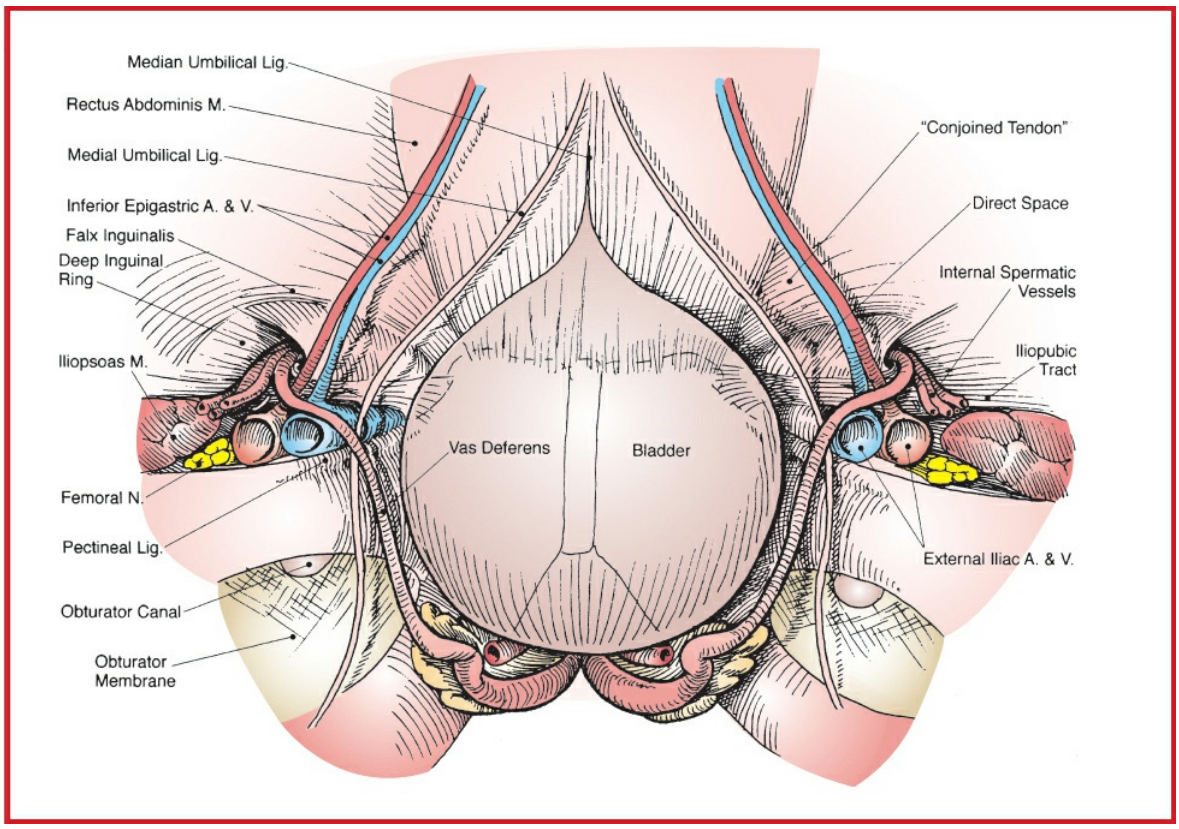

Figure 7.7-9 The inguinal region. (Reproduced with permission from Wind GG: The spleen. In: Wind GG, Dudai M, eds. Applied Laparoscopic Anatomy: Abdomen and Pelvis. Williams & Wilkins, Baltimore: 1997.)

Usual preop diagnosis

Inguinal hernia

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading DVT prophylaxis, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine, arms tucked
Incision	3 ports—1 at the umbilicus; 2 either in the midline or RLQ or LLQ, depending on the laparoscopic approach
Special instrumentation	Balloon dissector and structural balloon for TEP repair
Antibiotics	Cefazolin 2 g iv preop (weight-based dosing)

Surgical time	1–2 h
Closing considerations	Minimal time; muscle relaxation may be helpful.
EBL	<50 mL
Postop care	1–2 h in PACU/holding area → home
Mortality	<0.1%
Morbidity	2% Orchialgia, neuralgia Recurrence of hernia: significant learning curve Bowel obstruction Bladder injury: rarely reported
Pain score	3–4

PATIENT POPULATION CHARACTERISTICS	
Age range	Mostly adults
Male:Female	Male > female
Incidence	Common
Etiology	Most hernias congenital; chronically increased intra-abdominal pressure (e.g., chronic cough, obesity)
Associated conditions	None important

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

The preop evaluation of patients undergoing laparoscopic hernia repair is discussed in Anesthetic Considerations for Inguinal Hernia. Patients presenting for this procedure are generally healthy. Laparoscopic repair of inguinal hernia is usually associated with less pain and earlier return to preop function when compared to the open procedure. Patients with strangulated or incarcerated hernias usually require emergent open procedures.

Cardiovascular	Cardiovascular changes caused by the pneumoperitoneum include ↓ venous return →↓ CO

	and ↑ SVR. Decreased blood flow to the splanchnic and renal circulations (→ ↓ UO) may result from high intra-abdominal pressures.
Laboratory	Hgb/Hct (healthy patients); otherwise, as indicated from H&P
Premedication	Standard premedication
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA

Induction	Standard induction. OG/NG tube before incision to decompress the stomach	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance	
Emergence	No special considerations except to minimize coughing on emergence. Consider 1 mg/kg iv lidocaine for cough suppression. Discuss with surgeon local wound infiltration. PONV prophylaxis may include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 18 ga × 1 BSS @ 3–5 mL/kg/h	Blood loss should be minimal. See Zero Balance Fluid Management, Appendix K, p. K-2 and K-4.
Monitoring	Standard monitors Urinary catheter	Others as indicated by patient status Prevent hypothermia (forced-air warmer, heated and humidified gases, warming

		blanket, warm OR, etc.)
Positioning	✓and pad pressure points ✓ eyes	Careful positioning and padding of the patient are essential.
Complications	Hemorrhage from trocar insertion. Subcutaneous emphysema	These complications (associated with the preperitoneal approach), as well as the general complications of laparoscopy, are discussed in Anesthetic Considerations for Laparoscopic Cholecystectomy.

POSTOPERATIVE

Complications	PONV Urinary retention	See p. B-6. Straight catheterization of the bladder
Multimodal pain management	Consider multimodal analgesia.	Consider combining PCA or fixed dose po/iv opiates with acetaminophen, po or iv NSAIDs, and gabapentin. Consider iv ketamine or iv lidocaine. Emphasize nonopioid analgesics including acetaminophen and NSAIDs (see p. C-2).
ERAS	PONV protocol (see p. B-1)	Encourage early enteral nutrition and mobilization. Consider need for DVT prophylaxis.
Tests	As indicated by patient status	

Suggested Readings

1. Abeles A, Kwasnicki RM, Darzi A: Enhanced recovery after surgery: curren research insights and future direction. World J Gastrointest Surg 2017; 9(2):37–45.
2. Bittner R, Schwarz J: Inguinal hernia repair: current surgical techniques Langenbecks Arch Surg 2012; 397(2):271–82.
3. Kim AJ, Yong RJ, Urman RD: The role of transversus abdominis plane blocks i enhanced recovery after surgery pathways for open and laparoscopic colorectal surgery. J Laparoendosc Adv Surg Tech A 2017; 27(9):909–14.
4. Li Z, Zhao Q, Bai B, et al: Enhanced recovery after surgery programs fo laparoscopic abdominal surgery: a systematic review and meta-analysis. World J Surg 2018; 42(11):3463–73.
5. Matthews RD, Anthony T, Kim LT, et al: Factors associated with postoperative complications and hernia recurrence for patients undergoing inguinal hernia repair: a report from the VA Cooperative Hernia Study Group. Am J Surg 2007; 194(5):611–7.
6. Neumayer L, Giobbie-Hurder A, Jonasson O, et al: Open mesh versus laparoscopi mesh repair of inguinal hernia. N Engl J Med 2004; 350(18):1819–27.

LAPAROSCOPIC BARIATRIC SURGERY

SURGICAL CONSIDERATIONS

Description

Currently, nearly two-thirds of Americans are overweight (BMI 25–30 kg/m²) or obese (BMI > 30 kg/m²). According to the United States Centers for Disease Control and Prevention, 35% of American adults are obese. Many obese patients have associated comorbidities, including HTN, diabetes, and sleep apnea, which they have been unable to correct by dieting and exercise. In 1998, the NIH recommended bariatric surgery as the primary treatment for morbid obesity (BMI > 40 kg/m² or >35 kg/m² with associated comorbidities). Surgical treatment results in weight loss of ~2/3–3/4 of excess body weight, usually with consequent correction of comorbidities. Operations for morbid obesity are classified as restrictive, such as the **adjustable gastric banding** and **vertical banded gastroplasty;** malabsorptive, such as a **jejunoileal bypass**; or a combination, such as the **Roux-en-Y gastric bypass**. The 1991 NIH consensus statement identified the Roux-en-Y bypass as the best surgical treatment for morbid obesity. In general, this operation is approached laparoscopically in most patients because of the decreased pain, earlier ambulation, earlier discharge from the hospital, quicker return to regular activity, and decreased wound complication rates, when compared with an open approach. Open approaches, though very rare, are undertaken in

patients with previous upper abdominal surgery, patients who may not tolerate an increased intra-abdominal pressure (e.g., CHF, severe CAD, severe pulmonary disease), patients undergoing revision bariatric surgery, and occasionally patients who fall into a super morbidly obese group (BMI > 60 kg/m^2). Surgery is indicated in patients with a BMI of 35–40 kg/m^2, if they have associated comorbidities, or >40 kg/m^2, if they have no associated comorbidities.

For laparoscopic procedures, the patient generally is placed in reverse Trendelenburg-head-elevated laryngoscopic position (RT-HELP). Some surgeons prefer a split-leg table, with the surgeon standing between the legs. For a laparoscopic Roux-en-Y bypass, the first incision is made in the midline, approximately halfway between the umbilicus and the xiphoid; 4–5 additional ports are then placed in the LUQ and the midline (Fig. 7.7-10). Most surgeons begin by performing a jejunojejunostomy. During this time, the patient is placed in a RTP to drop the small intestines into the pelvis. The omentum is placed in the upper abdomen, and the ligament of Treitz is identified. The jejunum is divided with an endo GIA stapler ~20 cm from the ligament of Treitz. A Roux limb of 100 cm is then measured. (Occasionally, this Roux limb may be 150 cm, if the patient's BMI is >50 kg/m^2.) The jejunojejunostomy is created with a stapler, and the enterotomy is closed. Some surgeons prefer a **retrocolic approach**, wherein a passage is made through the transverse mesocolon. Other surgeons prefer an **antecolic approach**, in which the omentum is divided to allow for a place where the Roux limb can pass without tension. At this point, the liver retractor is placed, and the gastric pouch is created. Before stomach stapling, everything in the stomach, OG tubes and calibrating tubes, should be removed. The gastric pouch is then stapled and cut. Often, a calibrating tube is placed after the first two staple firings to help maintain the size of the pouch and the anastomosis. Some surgeons hand-sew the gastrojejunostomy, and some staple it with a linear stapler. Some surgeons staple the anastomosis and place the anvil of the end-to-end anastomotic stapler through the mouth (rarely done). Other surgeons place the anvil through a separate gastrotomy before complete division of the pouch. At the end, the gastrojejunostomy typically is tested by inflating air into the gastric pouch, either through an OG tube, the sizing laparoscopic bariatric surgery tube, or a gastroscope. Generally, the NG or OG tube is removed at the end of the procedure. Often, at this point, surgeons will close the defect of the transverse mesocolon.

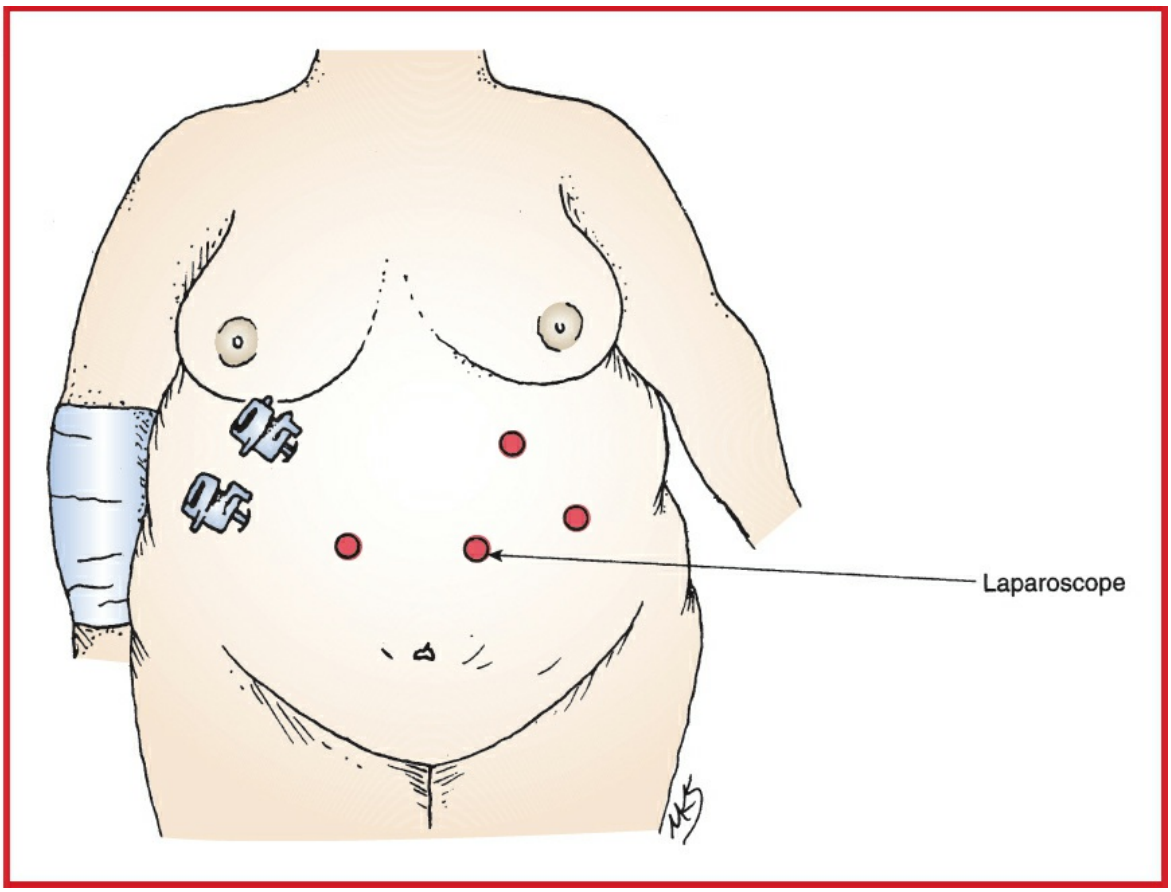

Figure 7.7-10 Patient position and trocar position for bariatric laparoscopic surgery. (Reproduced with permission from Scott-Connors CEH, Dawson DLOperative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

Variant procedure or approaches

Open bypass

Usual preop diagnosis

Morbid obesity generally in combination with a medical condition(s) felt to be worsened by the obesity (e.g., osteoarthritis, diabetes mellitus, respiratory insufficiency, CHF, hypertension, sleep apnea); BMI > 40 kg/m² or BMI > 35 kg/m² if associated comorbidities present

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading DVT prophylaxis, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE

Position	Supine or split leg (see Fig. 7.2-6 in Open Operations

	for Morbid Obesity for suggested positioning)
Incision	Five to six port sites
Unique considerations	Patients are at high risk for aspiration, and airway management may be difficult. Patients are at high risk for thromboembolic events and VTE prophylaxis is critical. Patients are at risk for postop opioid-induced respiratory depression.
Antibiotics	Cefoxitin 3 g iv (or 2 g iv if total body weight <120 kg)
Surgical time	2–4 h
Closing considerations	Typically, fascial defects are not closed.
EBL	<50 mL
Postop care	Most patients receive an upper GI study the next day. Clear liquids are begun if the study is normal, and most patients are discharged within 48 h.
Mortality	<1%
Morbidity	Overall: 10% Stricture: 10% Leak: 1–2% VTE Pneumonia Hemorrhage Hernia Obstruction Infection
Pain score	5–6

PATIENT POPULATION CHARACTERISTICS

Age range	Generally, between 18 and 60 yr
Male:Female	Female > male
Incidence	5%

Etiology	Genetic; environmental
Associated conditions	Sleep apnea; HTN; diabetes; GERD; osteoarthritis

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Obesity is associated with many chronic medical problems. Morbidity and mortality rise sharply with increasing age and BMI. Obesity and length of exposure to obesity increase the risk of hospital admission and lengthen hospital stay. Medical comorbidities must be optimized before elective bariatric surgery. Evaluate any patient who has had previous bariatric surgery for metabolic changes that can include protein, vitamin, iron, and calcium deficiencies.

Review a list of all current medications the patient is taking, including nonprescription appetite suppressors and diet drugs. Many of these drugs can have important side effects. For example, the combination of phentermine and fenfluramine ("phen-fen"), which is no longer prescribed in the United States, is associated with persistent, serious, heart, and lung problems. Another weight loss medication, sibutramine, works in the brain by inhibiting the reuptake of norepinephrine, serotonin, and dopamine, producing a feeling of "anorexia," which limits food intake. Sibutramine has been implicated as a cause of dysrhythmias and hypertension. Orlistat blocks digestion and absorption of dietary fat by binding lipases in the gastrointestinal tract and can cause deficiencies in fat-soluble vitamins (A, D, E, K). A reduction in vitamin K levels can increase the anticoagulation effects of warfarin.

Respiratory	Adipose tissue is metabolically active. Oxygen consumption and CO_2 production rise with increasing weight 2° ↑ metabolic demands. The work of breathing is increased, while respiratory muscle performance is impaired. Mass loading of the thoracic and abdominal walls causes abnormalities in both lung volume and gas exchange, especially when the patient is supine. The increased total respiratory resistance and decreased compliance associated with extreme obesity result in shallow, rapid breathing. Decreased FRC 2° ↓ ERV → ↓ TLC. Airways close during normal ventilation → ↑ pulmonary shunt →

	hypoxemia. These changes increase in direct proportion with increasing BMI. General anesthesia and the supine position further reduce FRC. Preop PFTs show a restrictive breathing pattern. For symptomatic patients, an ABG can be obtained while the patient breathes room air to establish a baseline. However, this is rarely necessary. Younger obese patients have an increased ventilatory response to hypoxia and a relatively decreased response to hypercapnia. Their arterial blood sample often demonstrates alveolar hyperventilation ($PaCO_2$ 30–35 mm Hg) and relative hypoxemia (PaO_2 70–90 mm Hg) while breathing air. With increasing age, sensitivity to CO_2 decreases, so that $PaCO_2$ rises and PaO_2 falls further. Preop assessment of a patient's face, neck, and upper airway is required because mask ventilation and tracheal intubation can be a challenge in some obese patients. A large neck circumference and high Mallampati score may predict difficult intubation. A review of the patient's previous anesthetic records will reveal whether airway problems had been encountered during previous surgical procedures. A thorough preparation requires that multiple laryngoscopy blades and sizes, a gum elastic bougie, and laryngeal mask airway are readily available before laryngoscopy. Video laryngoscopes and fiberoptic intubation are increasingly used for known or anticipated problematic laryngoscopy. **Tests:** As indicated from H&P
Cardiovascular	Cardiac output rises proportionally with increased weight. Lean body weight, which increases with increasing obesity, is significantly related to cardiac output. ↑ CO and normal PVR → ↑ BP. Mild-to-moderate hypertension is seen in most morbidly obese patients. The increased left ventricular wall stress caused by increased stroke volume and the resultant ventricular dilation leads to cardiac

	hypertrophy. Left ventricular dysfunction is often present in young, asymptomatic patients. Even normotensive patients have increased preload and afterload, ↑ PAP (which may be exacerbated with hypercarbia and hypoxia) and elevated right and left ventricular stroke work. Because these patients are often not physically active, they may appear to be asymptomatic even in the presence of significant cardiovascular disease. Signs of pulmonary HTN (exertional dyspnea, fatigue, syncope) should be sought and TEE obtained in symptomatic patients. RV failure is common in older patients. A medical consultation with a cardiologist may be indicated before bariatric surgery. The ECG may show increased rate, changes in QRS voltage, left QRS axis shift, slowed conduction, and evidence of ischemia or previous myocardial infarction. Polycythemia suggests chronic hypoxemia. **Tests:** ECG and others as indicated from H&P
Obstructive sleep apnea (OSA) syndrome	Many obese patients maintain a normal $PaCO_2$ during the day, but have CO_2 retention, sleep disturbances, intermittent airway obstruction with hypoxemia, pulmonary hypertension, and cardiac dysrhythmias at night. OSA syndrome is characterized by frequent episodes of apnea (>10-sec cessation of airflow, despite continuous respiratory effort against a closed airway) and hypopnea (50% reduction in airflow or reduction associated with a decrease of SpO_2 > 4%). OSA is frequently undiagnosed in patients scheduled for bariatric surgery. OSA occurs more often in patients with large necks and high Mallampati (III and IV) scores. The patient may not be aware of symptoms, so it is important to interview the patient's sleeping partner. If OSA is present, the partner will describe loud snoring followed by silence as airflow ceases with obstruction and then gasping or choking as the patient awakes and airflow restarts. The STOP-BANG questionnaire is a useful

	screening tool for OSA. A recent study found that a STOP-BANG score of 5–8 identified patients with a high probability of moderate/severe OSA. However, a definitive diagnosis of OSA can only be confirmed by polysomnography. Because of fragmented sleep patterns, OSA patients may complain of daytime sleepiness and headaches. Chronic sleep apnea leads to secondary polycythemia, hypoxemia, and hypercapnia, all of which increase the risk of cardiac and cerebral vascular disease. Patients with a history of snoring or OSA are often difficult to ventilate by mask, and their tracheas may be more difficult to intubate than those of similar weight patients without OSA. OSA patients who use CPAP devices at home should be instructed to bring them to the hospital to use following surgery. A patient known or even suspected of having OSA should be continuously monitored by pulse oximetry in the postop period, even following a completely uneventful operation. Patients are at highest risk for hypoxic respiratory failure 72 h after tracheal extubation.
Obesity hypoventilation syndrome	A small number of patients have obesity hypoventilation syndrome (OHS), characterized by somnolence, cardiac enlargement, polycythemia, hypoxemia, and hypercapnia. OHS patients tend to be older, are super obese (BMI > 50 kg/m^2), and have more restricted pulmonary function than other patients with OSA. Hypoventilation that is central and independent of intrinsic lung disease is probably caused by the respiratory center's progressive desensitization to hypercapnia from nocturnal sleep disturbances. In the most severe form of OHS, the "Pickwickian syndrome," hypersomnolence, hypoxia, hypercapnia, pulmonary hypertension, right ventricular enlargement, and hypervolemia occur. These patients rely on a hypoxic ventilatory drive

	and may hypoventilate or even become apneic following emergence from general anesthesia after being given 100% O_2 to breathe.
Gastrointestinal	It is widely believed that morbidly obese patients are at greater risk for acid aspiration during induction of general anesthesia. Recently, this belief has been challenged. One study reported that fasting obese patients actually had a lower incidence of high-volume, low-pH gastric fluid than lean patients, whereas another found no differences in gastric volume or pH between lean and moderately obese surgical patients. Obese patients without GERD symptoms have relatively normal gastroesophageal sphincter tone. Obese patients at special risk for gastric acid aspiration may be those with diabetes and gastroparesis. Nonalcoholic steatohepatitis (NASH, "fatty hepatitis"), with or without liver dysfunction, is extremely common. Histologic abnormalities are present in the livers of as many as 90% of morbidly obese patients. Preop liver function tests should be obtained, but they often do not reflect the actual severity of liver dysfunction. Alanine aminotransferase (ALT) is the most frequently elevated liver enzyme. Hepatic metabolism of many anesthetic agents is usually not clinically altered with NASH.
Renal	There is ↑ RBF and ↑ GFR associated with obesity. Renal clearance of drugs may be greater than in the normal weight patient. The most common renal abnormality seen is proteinuria. **Tests:** As indicated from H&P
Premedication	Sedative drugs should be avoided whenever possible. For the very anxious patient, small amounts of midazolam (1–2 mg, iv) can be given. If a fiberoptic airway intubation is planned, atropine or glycopyrrolate will decrease oral secretions. Most medications for chronic HTN are continued before

	surgery. An exception are the angiotensin-converting enzyme (ACE) inhibitor and angiotensin II receptor blocker (ARB) classes of antihypertensives, which should be stopped preop because they can cause ↓↓ BP following induction of anesthesia. Diabetic medications (insulin, oral hypoglycemics) are usually withheld on the morning of surgery, but blood sugar levels must be closely monitored in the perioperative period. Antibiotics and heparin (VTE prophylaxis) are usually administered before surgery at the surgeon's request. For protection against acid aspiration an H2-receptor antagonist can be given the night before and again on the morning of surgery.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Despite conflicting evidence that morbidly obese patients are at greater risk for acid aspiration, it remains prudent to establish a secure airway as quickly and safely as possible. Patients cannot tolerate the supine position and should be preoxygenated in the reverse Trendelenburg position (RTP) until SPO_2 is 100% for several min. With apnea, expect rapid desaturation because FRC is reduced and O_2 reserves are limited. Preoxygenation in the RTP can increase O_2 reserves, but may cause pooling of blood and → ↓ BP. The increase in adipose tissue seen in obese patients increases apparent volume of distribution of lipophilic anesthetic agents. However, drug distribution is dependent on cardiac output, which is strongly related to lean body mass. Administration of intravenous induction agents and opioids should be based on lean body weight (LBW) to avoid drug overdose.

Tracheal intubation is necessary for controlled ventilation and airway protection. High Mallampati score and large neck circumference are the most reliable predictors of potential intubation difficulties. If a problem is anticipated preop, an "awake intubation" with a fiberoptic bronchoscope or video laryngoscope is recommended.

Appropriate nerve blocks and topical anesthesia to the airway are applied, and sedative drugs are kept to a minimum. It is important that the patient breathes supplemental O_2 during the intubation procedure. Successful direct laryngoscopy requires proper patient position. The patient must be placed with the head, upper body, and shoulders significantly elevated ("stacked" or "ramped") so that the ear is level with the sternum (head-elevated laryngoscopic position, HELP; see Fig. 7.2-6). When a morbidly obese patient is in this position, the endoscopist's view during direct laryngoscopy is significantly improved.

Induction	For most patients, a rapid-sequence induction with propofol (2–2.5 mg/kg LBW) and succinylcholine (1 mg/kg TBW), combined with cricoid pressure (~10 lb), is the best means for securing the airway. Bag and mask ventilation is often difficult 2° upper airway obstruction and ↓ pulmonary compliance. Gastric insufflation during ineffective mask ventilation will further increase the risk of regurgitation and acid aspiration. A second person experienced with airway management, preferably another anesthesiologist, must always be present to assist when difficulty is anticipated. Aids for difficult intubation, including a short laryngoscope handle, a variety of laryngoscope blades, video laryngoscopes, a gum elastic bougie, and equipment for cricothyroidotomy and transtracheal jet ventilation, should be available. An LMA can serve as a "bridge" until an endotracheal tube is placed when difficulty is encountered.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Patients should be ventilated with a FiO_2 of 0.5–1.0 and a tidal volume 10–12 mL/kg IBW, preferably in the RTP. Larger tidal volumes will only marginally improve oxygenation while producing hypocapnia and potentially causing lung trauma. PEEP

superimposed on a large tidal volume can actually worsen hypoxemia by ↓ CO, which in turn will ↓ O_2 delivery. Placement of subdiaphragmatic packs or retractors or changing to lithotomy or Trendelenburg positions will also impair ventilation.

The patient is ventilated with an inhalational anesthetic (isoflurane, sevoflurane, or desflurane) with a FiO_2 of 50–100% O_2. All inhalational anesthetics, including isoflurane, are rapidly eliminated. With appropriate timing, there are no clinical differences in the recovery time after general anesthesia with any inhalational anesthetic agent. N_2O can be used because it does not dilate the bowel during laparoscopic bariatric surgery, but its role is limited due to the high oxygen demand of many patients. For analgesia, incremental boluses of fentanyl (50–100 mcg) or sufentanil (5–10 mcg) or a remifentanil infusion (0.05–0.2 mcg/kg/min) are commonly used. Fentanyl and sufentanil infusions have also been used successfully in this patient population. Dexmedetomidine may be used as a supplemental infusion as it may minimize opioid requirements. Morphine and hydromorphone, which have prolonged onset and duration of action, should be avoided.

The anesthesiologist is usually responsible for proper placement of the gastric tube to decompress the stomach and to help size the gastric pouch. The anesthesiologist may be asked to help perform leak tests for anastomotic integrity, either by insufflation of the gastric tube or placement of saline or dye down the tube. It is extremely important that the gastric tube be completely withdrawn before the gastric pouch is stapled. Esophageal or nasopharyngeal temperature probes are not recommended as they may be inadvertently stapled if not completely withdrawn. Heat loss may be exaggerated by the CO_2 pneumoperitoneum and by

	cold irrigating fluids. Warming blankets and other devices should be employed intraop, and warmed iv and irrigating fluids are occasionally needed if there is a significant drop in temperature. Loss of pneumoperitoneum may indicate incomplete paralysis. Because nondepolarizing muscle relaxants are hydrophilic, there is limited distribution to adipose tissue and no clinical advantage between any of the commonly used agents. Neuromuscular recovery time is similar in obese and nonobese patients with atracurium, vecuronium, or rocuronium. Relaxants should be administered in incremental doses based on IBW, and neuromuscular blockade must be completely reversed before extubation of the trachea. This can be done with either neostigmine/glycopyrrolate or sugammadex. If sugammadex is given to a woman of childbearing potential, postoperative counseling regarding the interaction of sugammadex and oral contraceptives should be given.
Emergence	The inhalation agent is discontinued several min before surgery is completed. Once the patient is spontaneously ventilating, fentanyl may be titrated according to respiratory rate. If a remifentanil infusion is being used, it should be turned off just before extubation to allow spontaneous ventilation. The patient should be extubated when fully awake. In most cases, a nasal trumpet may be inserted to minimize upper airway obstruction after extubation. If hemodynamically stable, the patient's airway should be extubated with the upper body elevated 30–45°. Then, the patient should be transferred from the OR in that position. Postop admission to an ICU and mechanical ventilation is rarely needed. Factors that may necessitate ventilatory support include extremes of age, super obesity, coexisting cardiac disease or pulmonary disease and CO_2 retention, fever or infection, an uncooperative or extremely anxious patient, or incomplete reversal of

	neuromuscular blockade. The need for postop admission to an ICU is relatively common after open bariatric procedures, but rare after laparoscopic surgery. Discuss with surgeon local wound infiltration. PONV prophylaxis may include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 16–18 × 1 BSS @ 8–12 mL/kg/h Fluid warmer	Intraop fluid requirements are usually greater than would be anticipated in a normal weight patient. 2–3 L of crystalloid should be given during a laparoscopic bariatric operation. It is essential that adequate amounts of iv fluid be given to reduce postop renal failure and to avoid other rare but serious complications such as rhabdomyolysis.
Monitoring	±CVP Standard monitors	Noninvasive cuff pressure may be inaccurate if the anatomy of the upper arm does not allow a proper fit. Cuff pressures can be obtained from the forearm or ankle. A central line should only be considered if reliable peripheral venous access cannot be obtained. Note that the length of a standard iv catheter placed percutaneously in the neck of a very large patient may not be long enough to reach an intrathoracic location.

Positioning	RTP ✓and pad pressure points ✓eyes SCDs	In the supine position, FRC is ↓↓ → V/Q mismatch + ↑ O_2 consumption, ↑ CO, and ↑ PAP. A left lateral tilt will prevent inferior vena cava compression in the supine patient. The Trendelenburg and lithotomy positions further decrease lung volumes. If possible, the patient should always be in the reverse Trendelenburg position (RTP) during surgery because in this position, the diaphragm is "unloaded" and FRC is maximized.
CO_2 pneumoperitoneum	↑ PIP + ↓ TV ↑ $ETCO_2$ + $PaCO_2$ ↑ HR + ↑ MAP	The physiologic effects of the CO_2 pneumoperitoneum are usually well tolerated by the patient and require no intervention. Maintaining the patient in the RTP minimizes the restriction of respiratory mechanics from the CO_2 insufflation. All changes return to normal once the pneumoperitoneum is relieved. However, complications can occur.
Complications	Hypoxemia Massive gas embolism Pneumothorax Pneumomediastinum	The pneumoperitoneum can displace the diaphragm cephalad, causing the position of the

		endotracheal tube to change. Occasionally, the endotracheal tube's tip can enter a bronchus, so always consider tube displacement in the differential diagnosis of hypoxemia during laparoscopy.

POSTOPERATIVE

Position and oxygenation	Semirecumbent and RTP	Maximize oxygenation by allowing the diaphragm to fall and FRC to increase. Patients can become hypoxemic if supplemental O_2 is withheld in the immediate recovery period. Restoration of normal pulmonary function after open abdominal surgery may take several days.
	CPAP/BiPAP	In theory, CPAP could distend the gastric pouch, but its use following bariatric surgery has not been associated with anastomotic leaks. Patients who use nocturnal CPAP/BiPAP should be encouraged to bring their equipment the day of surgery for use during the postoperative period.
Complications	Venous thromboembolism	VTE prophylaxis should always be considered in the postop period, even for patients with epidural

		catheters. A vena cava umbrella is occasionally placed preop in older and high-risk patients (BMI > 60 kg/m^2, history of DVT/hypercoagulable state). Early ambulation significantly minimizes the risk of VTE and must be encouraged.
Complications (cont'd)	PONV	Multimodal intraop prophylaxis with several antiemetic agents will reduce but not eliminate PONV. Dexamethasone (4–8 mg) should be part of the therapeutic regimen.
Multimodal pain management	PCA	PCA with opioid dose based on LBW is usually satisfactory. Avoid morphine and hydromorphone as their prolonged onset and duration of action increase the risk of postoperative opioid-induced respiratory depression. The use of nonopioid analgesic adjuncts should be instituted early. Dexmedetomidine, which has no respiratory depressant effects, is a useful alternative or supplement to opioids. IV acetaminophen can be a useful adjunct in patients with minimal liver disease. Nonsteroidal anti-inflammatory drugs are helpful initially, but should be discontinued within a day or two to avoid the potential

		complication of gastric ulceration. Emphasize nonopioid analgesics including acetaminophen and NSAIDs (see p. C-2).
ERAS	PONV protocol (see p. B-1)	Encourage early enteral nutrition and mobilization. Consider the need for DVT prophylaxis.
Tests	As indicated by patient status	

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ANESTHESIA FOR LAPAROSCOPY IN PREGNANCY

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Approximately 0.75–2% of pregnant woman require nonobstetric surgery, accounting for more than 80,000 anesthetics for nonobstetric surgery per year, and 10–20% of those will require intra-abdominal surgery (diagnostic or therapeutic), most commonly for appendectomy, cholecystectomy, trauma, or gynecologic indications. If surgery cannot be avoided, it is best carried out in the second trimester. Warn patients about possible fetal loss (3–12% in first trimester) and premature labor (5–8% in second and 25–40% in third trimesters). Anesthesia and surgery are associated with increased spontaneous abortion, growth retardation, and perinatal mortality; however, no increase in congenital abnormalities has been found. Rates of fetal loss, premature labor, and maternal mortality are higher among sicker patients. It is unclear whether adverse outcomes after surgery relate to the disease process itself, disturbances in nutrition, the surgical procedure, exposure to radiation, or drugs. No correlation has been found between outcome and any specific anesthetic technique or agent (including N_2O).

Laparoscopy is the procedure of choice for many surgeries in nonpregnant patients. Historically, its use in pregnancy was controversial, although significant experience now supports its safety and efficacy. Advantages of laparoscopy include more rapid recovery, shorter hospital stays, less postop narcotic use (→ ↓ fetal depression), lower risk of wound infection, less postoperative ileus, and better cosmesis. No differences in fetal outcome or incidence of preterm labor have been found when compared to open procedures. However, regardless of the method of abdominal access, the laparoscopic or open appendectomy and cholecystectomy population is at high risk (37–41%) for perinatal complications. Risks of laparoscopy include difficult surgical access and potential uterine injury with Veress needles or trocars. Current recommendations suggest that either an open technique (e.g., Hasson cannula) or Veress needle/optical trocar is appropriate for obtaining laparoscope access with adjustments for fundal

height.

Note that acute appendicitis and cholecystitis often present with advanced or complicated disease because of difficulty diagnosing the "acute abdomen" and a reluctance to use radiation-based diagnostic tests in pregnancy.

Respiratory	Pregnant patients have ↑ MV with respiratory alkalosis ($PaCO_2$ = 32–34 mm Hg) and are subject to the rapid onset of hypoxemia if ventilation is compromised due to alterations in lung and metabolic functions, including a 20% ↓ in FRC and a 20% ↑ in O_2 consumption. Avoid hyperventilation ($PaCO_2$ < 30), which causes decreased uterine artery blood flow. Uptake of and sensitivity to inhalational anesthetics are enhanced (↓ FRC, ↓ MAC, and hyperventilation). During laparoscopy, peritoneal insufflation and head-down positioning may further compromise lung function (↓ FRC and ↓ lung compliance). Mucosal capillary engorgement in upper airways may necessitate a smaller ETT and mandates careful airway suctioning to avoid bleeding. Airway management is more difficult in this patient population. **Tests:** As indicated from H&P
Cardiovascular	Pregnancy → ↑ CO, ↓ MAP, ↑ HR, ↑ blood volume, and ↓ oncotic pressure → ↑ risk of pulmonary edema. Supine hypotensive syndrome: To minimize aortocaval compression and → ↓ ↓ BP (>20-wk gestation), the supine position should be modified by the use of a left lateral pelvic tilt to displace the uterus. Moderate abdominal insufflation pressures (10–15 mm Hg) should be used to minimize further caval compression and ↓ uterine blood flow. **Tests:** As indicated from H&P
Hematologic	WBC count is elevated during pregnancy (8000–12,000/mm) and may delay the diagnosis of concurrent infections (e.g., appendicitis). Iron deficiency anemia often is superimposed on the

	dilutional anemia of pregnancy (Hct 33%). Pregnant patients are hypercoagulable, and antiembolic compression devices should be used. **Tests:** Hgb/Hct. T&S if significant blood loss is anticipated. Coag studies and Plt count if + PIH
Gastrointestinal	Emergency surgery, ↑ GERD, ↑ intragastric pressure, ↓ lower esophageal sphincter tone, and gastric hyperacidity → ↑ risk of aspiration pneumonitis. All pregnant patients (>16–20 wk) should be considered to have full stomachs and should receive a nonparticulate antacid (e.g., 0.3 M Na citrate 30 mL) immediately before GA, as well as iv metoclopramide 10 mg and ranitidine 50 mg 30–60 min before surgery.
Renal	Pregnancy → ↑ renal blood flow and ↑ creatinine, clearance and ↓ serum creatinine and ↓ BUN. Dependent edema results from increased water and sodium retention and ↓ oncotic pressure. **Tests:** As indicated from H&P
Laboratory	Others tests as indicated from H&P
Premedication	Full-stomach precautions (see Gastrointestinal, above); midazolam (1–2 mg) given as appropriate to decrease anxiety
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

After 16-wk gestation, anticipate ↑ risks of aspiration and difficult intubation. Plan ahead for management of a potentially difficult airway. GA is the preferred technique because laparoscopy and abdominal surgery are poorly tolerated under regional anesthesia. A lead shield should be used to protect the fetus during fluoroscopy.

Fetal monitoring

The primary obstetric care provider should be notified, and a qualified person should be readily available to interpret the fetal heart rate (FHR) and perform cesarean delivery if indicated. If the fetus is considered to be viable (~24-wk gestation), FHR and contraction monitoring should be performed at a minimum before and after the procedure to confirm fetal well-being and the absence of uterine contractions. If feasible, continuous intraoperative monitoring of FHR during surgery (electronic FHR monitoring, transvaginal Doppler) is recommended. Each case requires a team approach and a management plan for evaluation and action if a nonreassuring trace develops. Surgery should only be done at an institute with adequate facilities and neonatal services.

General anesthesia

If difficult intubation is anticipated, an awake fiberoptic intubation or video laryngoscopy is recommended. In any event, emergency airway management equipment (e.g., LMA, transtracheal jet ventilator) must be immediately accessible in the OR. Communication with the surgeon and obstetrician regarding maternal and fetal condition is essential.

Induction	Left uterine displacement is best achieved by elevating the right hip with a wedge, towel, or equivalent device. Standard rapid-sequence induction with cricoid pressure as appropriate. To optimize intubation, place patient in maximal "sniff" position and consider ramping obese patients (Fig. 7.2-6). If tracheal intubation is unsuccessful, follow the difficult intubation/ventilation drill. After ETT is secured, pass OG tube and decompress the stomach to minimize injury from the Veress needle or trocar.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	0.8–1% isoflurane or 1.5–2.0% sevoflurane in air/O_2 (50%) mixture. Avoid N_2O → distension of the bowel and PONV. Administer an opioid (e.g., fentanyl 50–200 mcg iv) or midazolam (1–2 mg) to ↓ volatile requirements and ↓ maternal awareness. Administer muscle relaxants

	(e.g., vecuronium 0.1 mg/kg). Control ventilation, avoiding hypocapnia (PCO_2 < 30 mm Hg) → ↓ uterine blood flow, and hypercapnia (PCO_2 > 36 mm Hg) → fetal acidosis. Maintain $ETCO_2$ or $PaCO_2$ at 32–36 mm Hg by ↑ MV. Use low insufflation cutoff pressure (8–12 mm Hg, not 15 mm Hg as for nonpregnant patient). Maintain adequate placental perfusion by keeping maternal blood pressure at preoperative baseline levels. Fluids and vasopressors (phenylephrine, ephedrine) should be utilized as indicated.	
Emergence	Reverse muscle relaxation with neostigmine 0.05 mg/kg and glycopyrrolate 0.01 mg/kg or atropine 0.02 mg/kg. Anticholinergics (glycopyrrolate/atropine) given before neostigmine may minimize possible ↑ uterine tone 2° neostigmine. Delay extubation until patient is fully awake and muscle strength has returned to normal. O_2 by mask and transport in the lateral position. Consider metoclopramide (10 mg iv) or ondansetron (4 mg iv) PONV prevention. Discuss with surgeon local wound infiltration. PONV prophylaxis may include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 16–18 ga × 1 BSS @ 3–5 mL/kg/h	Laparoscopy is associated with minimal blood loss; however, inadvertent vascular injury may occur. See Zero Balance Fluid Management, p. K-2.
Monitoring	Standard monitors ±Arterial line (major surgery) FHR monitor (see above) Uterine contraction monitor	Maternal and neonatal outcome good, and severe acidosis absent when maternal ventilation controlled by $PaCO_2$ or $ETCO_2$ measurement. Clinical experience indicates no long-term adverse neonatal effects.
Positioning	✓ and pad pressure	Changes in position have

	points ✓ eyes	marked effects on respiration (↓ compliance, ↑ pressure, hypoxemia) and hemodynamics. Head-up position + GA + peritoneal insufflation → 50% ↓ CO in the nonpregnant patient and even greater decrease in late pregnancy. **Position changes should be gradual** to minimize adverse effects.
	±Left uterine displacement	If >20-wk gestation, left uterine displacement to avoid aortocaval compression
CO_2 peritoneum: Maternal effects	↓ ventilation ↓ BP ↑ GI reflux (↑ abdominal pressure) CO_2 absorption	Maternal hypoxemia and respiratory acidosis ↓ venous return → ↓ BP. → ↑ MAP and ↑ SVR
CO_2 peritoneum: Fetal effects	↓ uterine blood flow ↑ preterm labor Fetal acidosis Fetal ↑ HR/↑ BP	Up to 60% (in animal studies) → fetal hypoxia. 2° ↑ abdominal pressure 2° absorbed CO_2
Complications	Uterine injury Bowel/organ injury Venous air embolism Thromboembolism/PE Pneumothorax	Dx: ↓ $ETCO_2$, hypoxemia, hypotension. Rx: 100% O_2, stop insufflation immediately, volume and pressors, attempt CVP air aspiration. Prevention: Pneumatic compression devices, ± thromboprophylaxis (e.g., heparin, LMWH) Rx: Supportive

		Dx: ↑ airway pressure, ↓ breath sounds, and hyperresonance. Rx: 100% O_2, stop insufflation, tube thoracostomy

POSTOPERATIVE

Multimodal pain management	Standard pain management	Avoid NSAIDs (e.g., ibuprofen) → pulmonary and CV fetal effects (closure of ductus venosus). Consider intravenous acetaminophen 1000 mg. Pre-emptive or rescue transversus abdominis plane blocks may be appropriate in select patients. Emphasize nonopioid analgesics including acetaminophen and NSAIDs (see p. K-5).
ERAS	PONV protocol (see p. B-1)	Encourage early enteral nutrition and mobilization. Consider the need for DVT prophylaxis.
Tests	Hct/CBC Others as indicated by operative course	

Suggested Readings

1. Abeles A, Kwasnicki RM, Darzi A: Enhanced recovery after surgery: curren research insights and future direction. World J Gastrointest Surg 2017; 9(2):37–45.
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CHAPTER 7.8

Pancreatic Surgery

SURGEON
Jeffrey A. Norton, MD

ANESTHESIOLOGIST
Martin S. Angst, MD

OPERATIVE DRAINAGE FOR PANCREATITIS

SURGICAL CONSIDERATIONS

Description

Surgical treatment for pancreatitis is indicated for drainage or debridement of infected necrotic peripancreatic tissue or pancreatic necrosis. Pancreatic necrosis is defined by areas of poor perfusion in the pancreas on CT angiogram. Infected pancreatic necrosis occurs with the presence of gas and/or bacterial invasion. Pancreatic abscesses usually develop in the lesser sac but may spread to the subphrenic spaces or into the pericolic gutters. Fistulization into adjacent organs, particularly the transverse colon and duodenum, may occur. Severe intra-abdominal hemorrhage from erosion into major arteries lying adjacent to the pancreas is uncommon but may occur before, during, or after operative drainage. Intraop, exploration of the peritoneal cavity is performed before opening the lesser sac. Areas lateral to the left and right sides of the colon, as well as the base of the transverse mesocolon and the subhepatic areas, should be palpated to identify fluid or abscess collections. The gastrocolic ligament is then incised to approach the pancreas through the lesser sac. There are different operative approaches, depending on the location of involved tissue and surgeon's preference. Upper midline or transverse abdominal incisions are used most often. Posterior drainage through the bed of the 12th rib, or retroperitoneal lateral approaches, may be used (Fig. 7.8-1).

VARIANT PROCEDURE OR APPROACHES Minimally invasive approaches to the distal pancreas (laparoscopic pancreatectomy) and the retroperitoneal space are being used for peripancreatic drainage and debridement. In minimally invasive retroperitoneal pancreatectomy (**MIRP**), a large catheter is placed by interventional radiology and used as an avenue to débride necrotic pancreatic tissue. Recently, a laparoscopic opening between the stomach and retroperitoneum has also been used for drainage and debridement in select cases.

Usual preop diagnosis

Severe pancreatitis 2° to gallstones; alcohol; or post ERCP

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting nothing by mouth (NPO) duration, alcohol, and smoking cessation, review of nutritional status, discussion of carb loading, deep venous thrombosis (DVT) prophylaxis, postop pain management options, physiotherapy plan, possibility of NG/jejunal feeding tubes, and urinary drain postop. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

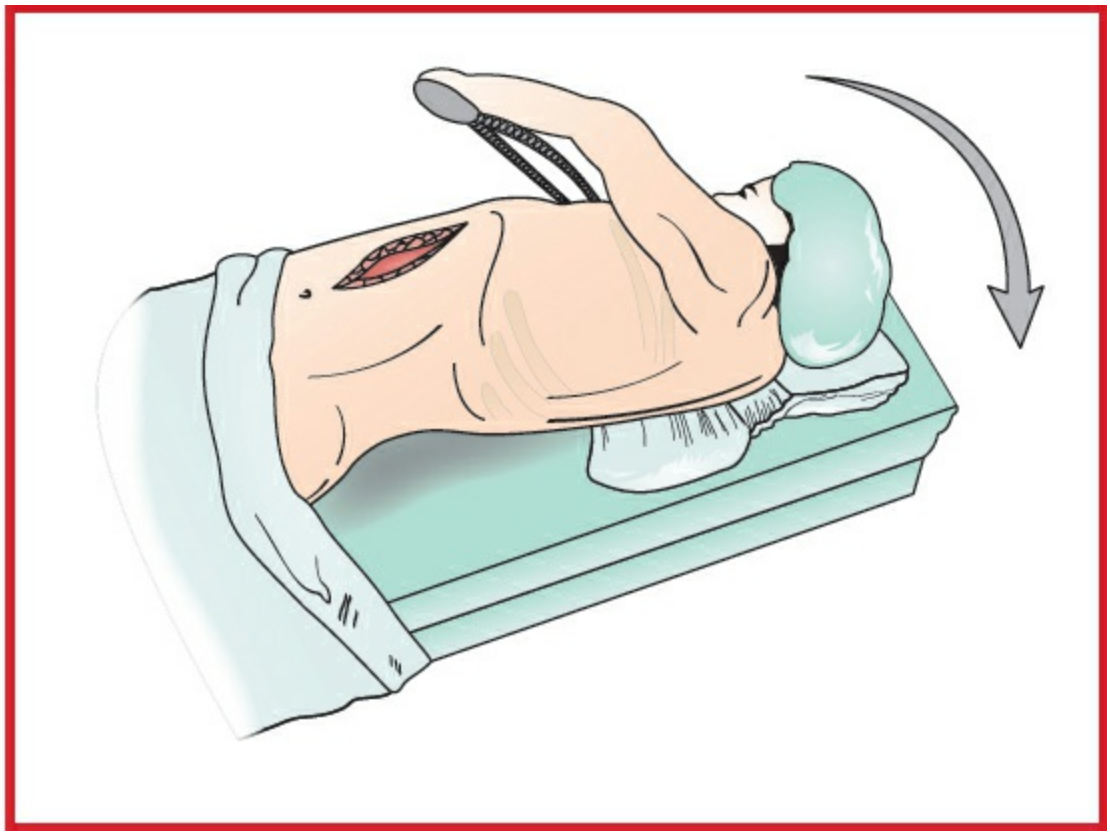

Figure 7.8-1 Incision for anterior and posterior drainage in pancreatitis. Note that bed or table is rotated until patient is almost supine. (Reproduced with permission from Berne TV, Donovan AJ: Synchronous anterior and posterior drainage of pancreatic abscess. Arch Surg 1981; 116:527–33. Copyright © 1981 American Medical Association. All rights reserved.)

SUMMARY OF PROCEDURE	
Position	Supine or rotated slightly (Fig. 7.8-1) for posterior approach
Incision	Midline, transverse, flank, or synchronous anterior and posterior
Unique considerations	Must perform adequate debridement of necrotic tissue and provide adequate drainage of abdomen; NG tube; jejunal feeding tube
Antibiotics	Cefoxitin 2 g 30 min preop or antibiotic directed at cultured organisms
VTE prophylaxis	Heparin 5000 units sq
Surgical time	1–2 h
Closing considerations	Adequate drainage of pancreatic bed and fluid resuscitation of patient
EBL	300–750 mL
Postop care	Routine wound and drain care; usually ICU and intubated; often, subsequent operative procedures are required.
Mortality	8–30%
Morbidity	Fistulae formation: 18–55% Delayed gastric emptying: 50% Unremitting sepsis: 10–30% Atelectasis: 5–10% Respiratory deterioration: 5% Hemorrhage Bowel perforations
Pain score	7–9

PATIENT POPULATION CHARACTERISTICS	
Age range	30–60 yr
	1:1

Male:Female	
Incidence	10–30% of patients with pancreatitis
Etiology	Alcoholism (30–50%); postop pancreatitis (15–40%); biliary tract disease (20–30%); idiopathic pancreatitis (15–20%)
Associated conditions	Malnutrition; glucose intolerance; multiorgan dysfunction

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pancreatic Surgery.

Suggested Readings

1. da Costa DW, Boerma D, van Santvoort HC, et al: Staged multidisciplinary step-up management for necrotizing pancreatitis. Br J Surg 2014; 101(1):e65–79.
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DRAINAGE OF PANCREATIC PSEUDOCYST

SURGICAL CONSIDERATIONS

Description

Internal **drainage of a pancreatic pseudocyst** may be accomplished by anastomosing the cyst to the stomach, duodenum, or other small bowel via a Roux-en-Y loop of jejunum. The procedure of choice for internal decompression depends on the location of the pseudocyst in relation to the portion of the GI tract that will provide maximal dependent drainage of the cyst. Open, laparoscopic, and endoscopic procedures have

been used with success. The three approaches are equivalent. Operation is reserved for patients with refractory symptoms. At operation, the abdomen is entered via a midline incision or laparoscopically. The pseudocyst is localized by palpation with or without intraop ultrasound. If the pseudocyst lies behind the stomach (or duodenum), it is approached anteriorly, through the posterior wall of the stomach (or duodenum). A portion of the posterior wall is incised, allowing entry into the cyst cavity, which is then drained. An anastomosis is created between the cyst and stomach (or duodenum). The anterior wall of the stomach (or duodenum) is then closed. If the cyst presents inferior to the stomach, it is anastomosed in a similar fashion to a Roux-en-Y loop of jejunum (Fig. 7.8-2). Drains are placed; external drainage is sometimes necessary, especially in the setting of infection. Spontaneous resolution of pancreatic pseudocyst may be expected in most patients with cysts <6 cm. If infection of the pseudocyst occurs with clinical signs of sepsis, percutaneous drainage under CT guidance can be performed, although subsequent operative drainage is often necessary.

Usual preop diagnosis

Pancreatic pseudocyst 2° to acute pancreatitis refractory to medical management

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Midline abdominal or transverse
Unique considerations	Location of pseudocyst in relation to GI tract; NG tube
Antibiotics	Cefoxitin 2 g iv 30 min preop
VTE prophylaxis	Heparin 5000 units sq
Surgical time	1–2 h
Closing considerations	Adequate drainage
EBL	100–300 mL

Postop care	± NG decompression
Mortality	5–10%
Morbidity	Bleeding: 5–7% Sepsis: <5% Recurrence: 2–3%
Pain score	6–8

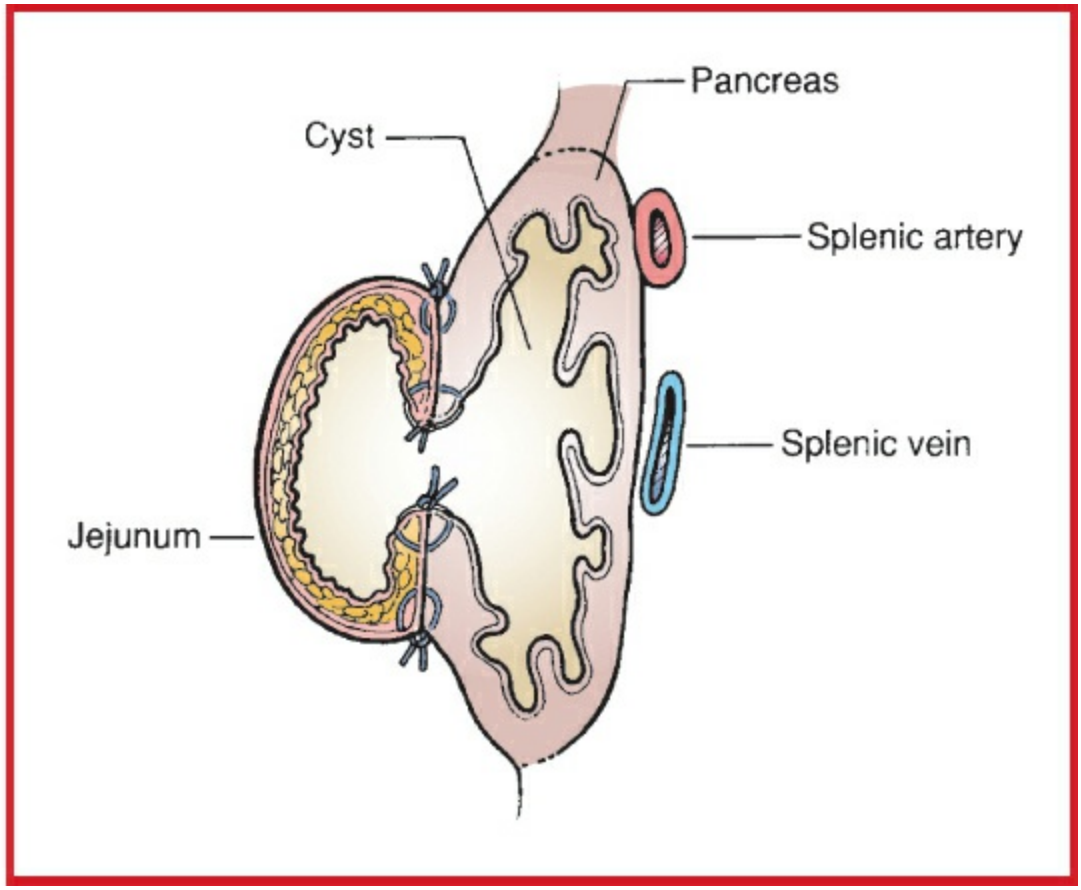

Figure 7.8-2 Roux-en-Y drainage of a pseudocyst. (Reproduced with permission from Scott-Conner CEH, Dawson DL: Operative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

PATIENT POPULATION CHARACTERISTICS

Age range	15–80 yr
Male:Female	1:1
Incidence	Rare
Etiology	Acute pancreatitis; trauma
Associated	Acute pancreatitis: 90%; gallstones; alcohol use;

conditions	chronic pain

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pancreatic Surgery.

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LONGITUDINAL PANCREATICOJEJUNOSTOMY

SURGICAL CONSIDERATIONS

Description

Pancreaticojejunostomy, as described by **Puestow**, is typically done for chronic pancreatitis with pancreatic ductal obstruction. It consists of a longitudinal opening of the pancreatic duct, which is then anastomosed to a Roux-en-Y loop of jejunum (Fig. 7.8-3). This approach is necessary to ensure adequate drainage of a duct with multiple strictures and dilations. Through a midline or transverse abdominal incision, the pancreas is exposed by mobilizing the duodenum (**Kocher maneuver**), exposing the head of the pancreas and opening the lesser sac to visualize the body and tail. The pancreatic duct may be aspirated to identify its location, and intraop ultrasound is commonly used, and then it is incised longitudinally. A Roux-en-Y loop of jejunum is then brought up to the pancreas and anastomosed to the opened duct. A drain is left along the anastomosis, and the wound is closed in the usual fashion.

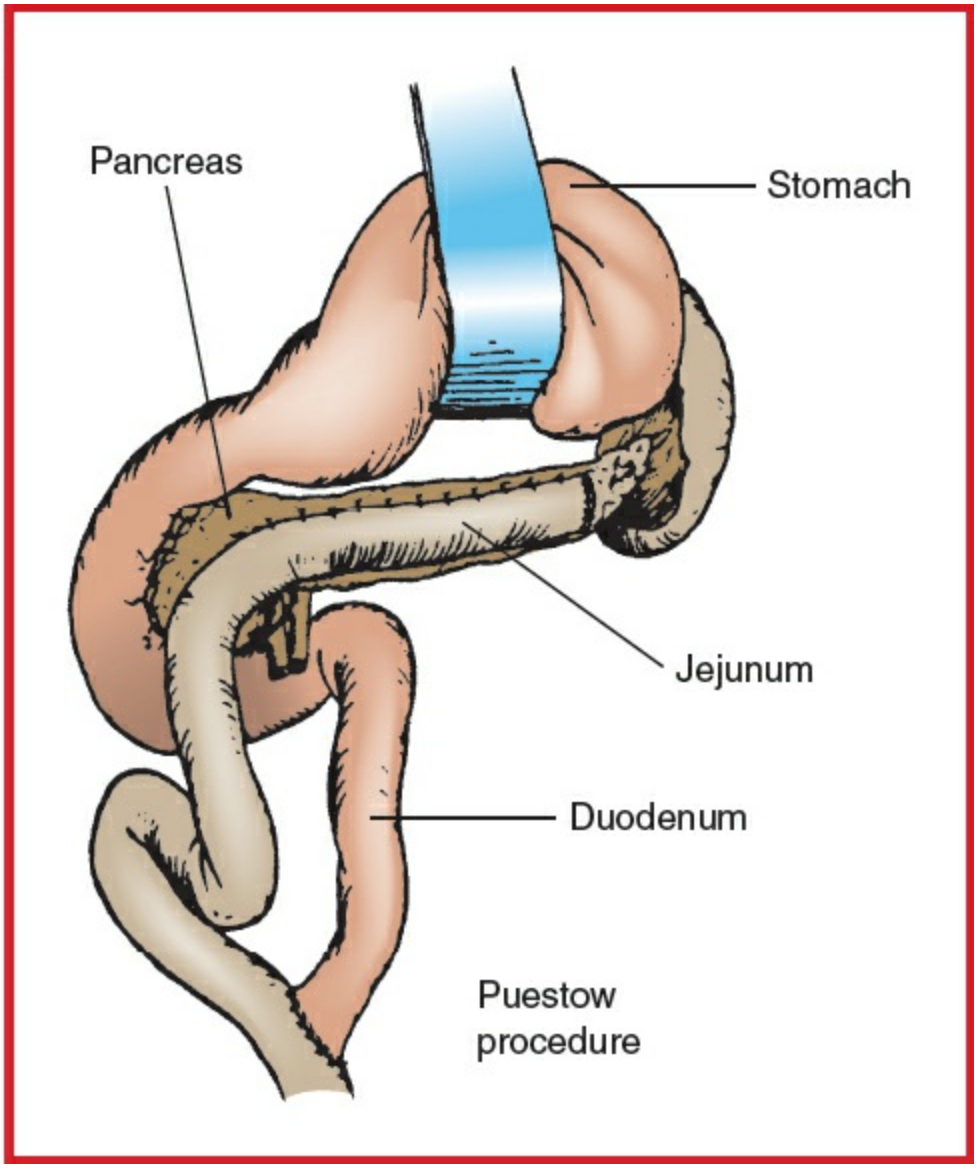

Figure 7.8-3 Operative management of chronic pancreatitis with onlay Roux-en-Y pancreaticojejunostomy (Puestow). (Reproduced with permission from Hardy JD:Hardy's Textbook of Surgery. JB Lippincott, Philadelphia: 1988.)

Variant procedure or approaches

A **Whipple resection (pancreaticoduodenectomy)** is an alternative surgical treatment for chronic pancreatitis confined to the head of the gland. Rarely, subtotal or near-total pancreatectomy is indicated. **Fry procedure** is near-total pancreatectomy with Roux-en-y drainage of the pancreatic head, and **Beger procedure** is duodenum-preserving pancreatic head resection.

Usual preop diagnosis

Abdominal pain with chronic pancreatitis and dilated pancreatic duct (chain of lakes)

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting

NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Midline abdominal or transverse
Antibiotics	Cefoxitin 2 g iv
VTE prophylaxis	Heparin 5000 units sq
Surgical time	2–3 h
Closing considerations	Adequate drainage
EBL	300–400 mL
Postop care	Monitor for glucose intolerance
Mortality	1–4%
Morbidity	Failure to relieve pain: 25–50% Pancreatic leak: 5–10% Wound infection: 5%
Pain score	6–8

PATIENT POPULATION CHARACTERISTICS	
Age range	17–72 yr
Male:Female	2.5:1
Etiology	Alcoholism; biliary tract disease; idiopathic; trauma; familial pancreatitis
Associated conditions	Biliary tract disease (25–50%); hyperparathyroidism (<5%); chronic pain; narcotic dependency

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pancreatic Surgery.

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PANCREATECTOMY

SURGICAL CONSIDERATIONS

Description

Distal pancreatectomy is performed for tumors in the distal half of the pancreas (Fig. 7.8-4). It can be done by open or laparoscopic techniques. The lesser sac is opened by dividing the gastrocolic ligament. After entering the lesser sac, the gastrosplenic ligament is divided, ligating the short gastric vessels and the left gastroepiploic vessel. If splenic preserving, the short gastric vessels are not divided. The peritoneum is incised along the inferior surface of the pancreas, with care being taken to avoid injury to the middle colic vessels. Following mobilization of the spleen, the splenic artery is ligated where the pancreas is to be divided. The inferior mesenteric vein is ligated sometimes at the inferior border of the pancreas, and the splenic vein is ligated at the proposed point of transection. The transected pancreas (Fig. 7.8-5) is usually stapled and drained, although some surgeons suture the cut end and ligate the duct. The spleen may be preserved when operating for benign disease. This surgery is being done laparoscopically. One method to preserve the spleen is not dividing the short gastric vessels but still dividing the splenic artery and vein.

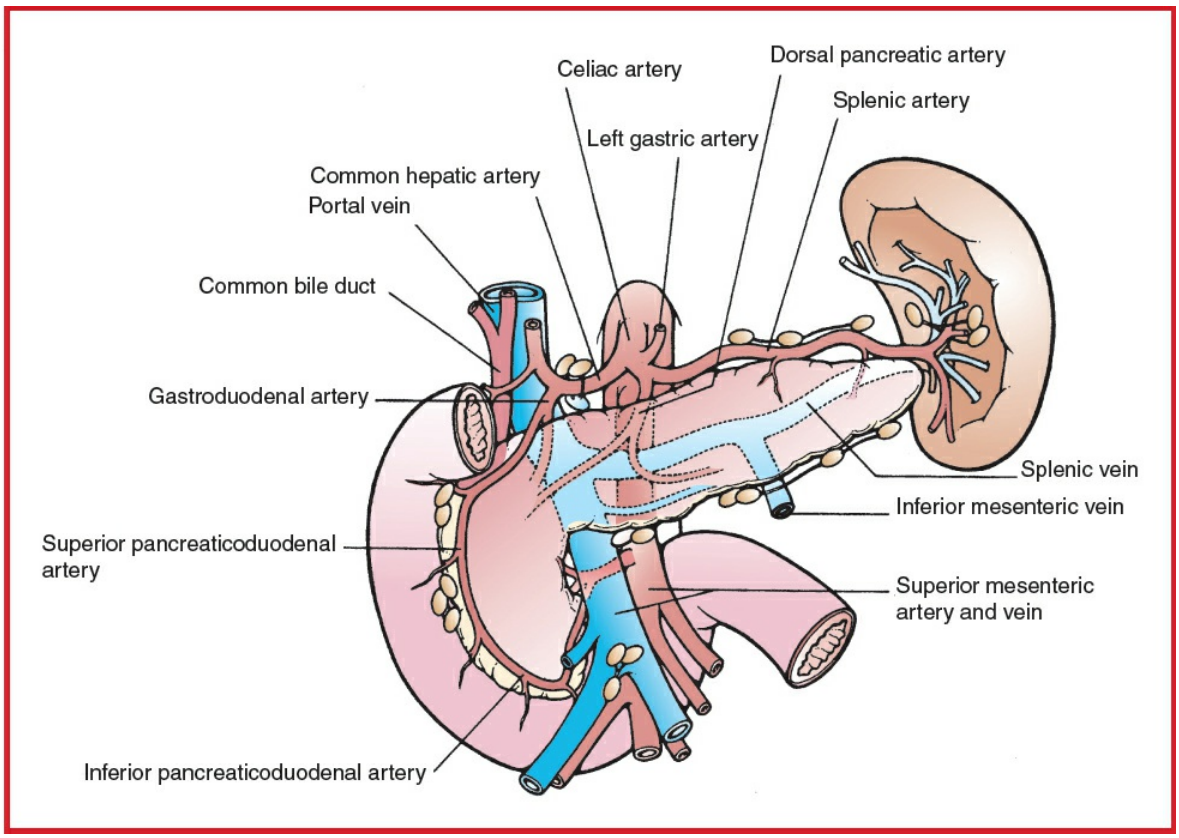

Figure 7.8-4 Pancreatic anatomy. (Reproduced with permission from Scott-Conner CEH, Dawson DL: Operative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

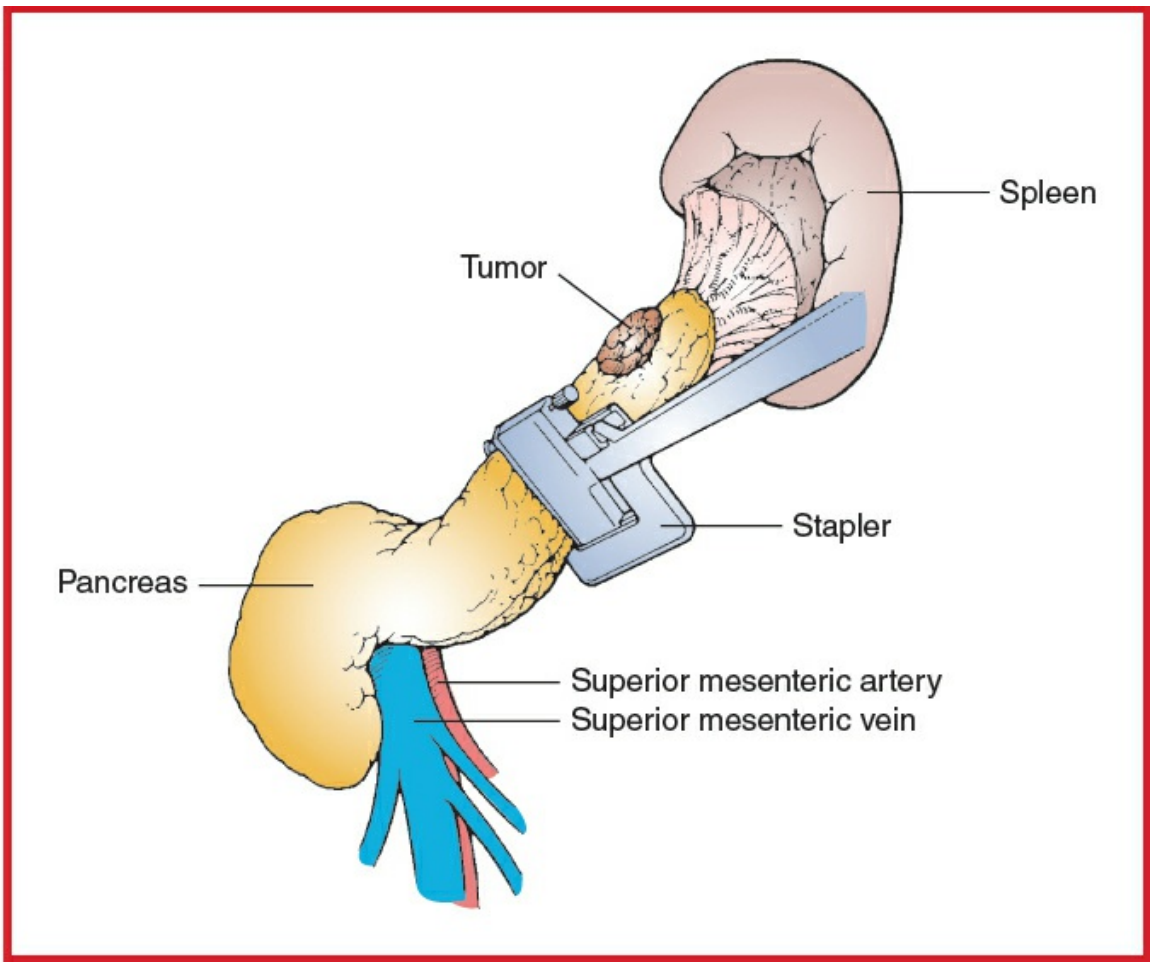

Figure 7.8-5 Resection of distal pancreas. (Reproduced with permission from Scott-Conner CEH, Dawson DL: Operative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

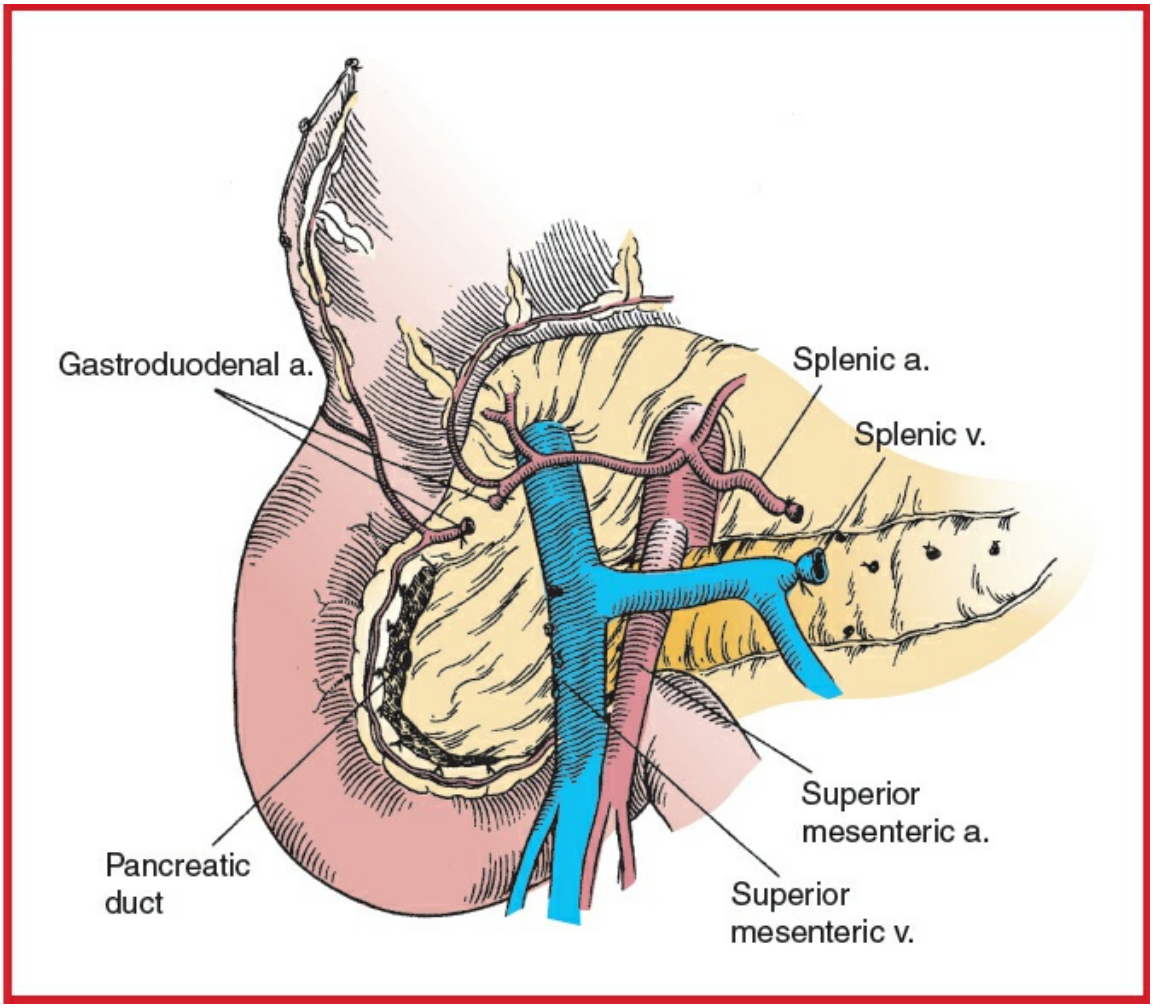

Figure 7.8-6 Near-total pancreatectomy. Shown is the operative field at the conclusion of the procedure. (Reproduced with permission from Baker RJ, Fischer JEMastery of Surgery, 4th edition. Lippincott Williams & Wilkins, Philadelphia: 1997.)

Variant procedure or approaches

Subtotal pancreatectomy usually implies resecting the pancreas from the mesenteric vessels distally, leaving the head and uncinate process intact. This procedure may be performed for tumor or chronic pancreatitis. **Child procedure** (near-total pancreatectomy) consists of removing the entire pancreas except a rim of tissue along the lesser curvature of the duodenum (Fig. 7.8-6); preserving the duodenum makes it unnecessary to reconstruct the bile duct. This procedure is usually reserved for patients with chronic pancreatitis.

Usual preop diagnosis

Carcinoma of pancreas; islet cell tumors; cystic neoplasms; chronic pancreatitis; solid pseudopapillary tumors

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting

NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Distal Pancreatectomy	Subtotal Pancreatectomy	Child Procedure
Position	Supine	⇐	⇐
Incision	Midline abdominal or transverse	⇐	⇐
Unique considerations	NG tube	⇐	Preservation of vasculature of duodenum
Antibiotics	Cefoxitin 2 g iv	⇐	⇐
VTE prophylaxis	Heparin 5000 units sq	⇐	⇐
Surgical time	2–3 h	⇐	3–4 h
Closing considerations	Adequate drainage	⇐	⇐
EBL	300–500 mL	500–750 mL	500–1000 mL
Postop care	NG decompression; PACU	⇐	⇐
Mortality	<5%	⇐	⇐
Morbidity	Diabetes: 5% Wound infection: 5% Pancreatic fistula: <5% Common bile duct injury Hemorrhage	⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐	⇐ ⇐ 90% ⇐ ⇐ ⇐ ⇐ ⇐

	Duodenal necrosis Pancreatic leakage Pancreatic insufficiency		
Pain score	6–8	6–8	6–8

PATIENT POPULATION CHARACTERISTICS	
Age range	30–60 yr
Male:Female	1:1
Incidence	~26,000/yr in the United States
Etiology	Adenocarcinoma; chronic pancreatitis; islet cell tumors
Associated conditions	Alcoholism and biliary tract disease with chronic pancreatitis (90%); other endocrine disorders (3–5%)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pancreatic Surgery.

Suggested Readings

1. Chen BP, Chen M, Bennett S, et al: Systematic review and meta-analysis o restrictive perioperative fluid management in pancreaticoduodenectomy. World J Surg 2018; 42(9):2938–50.
2. Ding X, Tan J, Qian J: Laparoscopic spleen preserving distal pancreatectomy Hepatogastroenterology 2013; 60(123):605–10.
3. Jin Z, Hartgers ML, Sanhueza CT, et al: Prognostic factors and benefits of adjuvan therapy after pancreatoduodenectomy for ampullary adenocarcinoma: Mayo Clinic experience. Eur J Surg Oncol 2018; 44(5):677–83.

WHIPPLE RESECTION

SURGICAL CONSIDERATIONS

Description

A **Whipple resection** is usually done for pancreatic cancer. It consists of a

pancreaticoduodenectomy, followed by a **pancreaticojejunostomy**, an **ampullary or duodenal hepaticojejunostomy**, and a **gastrojejunostomy** (Fig. 7.8-7). On entering the peritoneal cavity, the resectability of the pancreatic tumor is determined. Contraindications to standard resection include liver or peritoneal metastases, involvement of the superior mesenteric vessels, infiltration by tumor into root of the mesentery, and extension into the porta hepatis, with involvement of the hepatic artery. If the tumor is deemed resectable, further mobilization of the head of the pancreas is performed. The common duct is transected above the cystic duct entry, and the gall bladder is removed. After the superior mesenteric vein (SMV) is freed from the pancreas, the neck is transected, with care being taken not to injure the splenic vein, portal vein, or SMV. For a pylorus-preserving Whipple, the duodenum is transected 2 cm distal to the pylorus or, for a standard Whipple, the stomach proximal to the pylorus. The jejunum is transected 20 cm beyond the ligament of Treitz, and the specimen is removed by severing the vascular connections with the mesenteric vessels. Reconstitution is achieved by anastomosing the pancreatic stump, bile duct, and duodenum into the jejunum. Drains are placed adjacent to the pancreatic anastomosis.

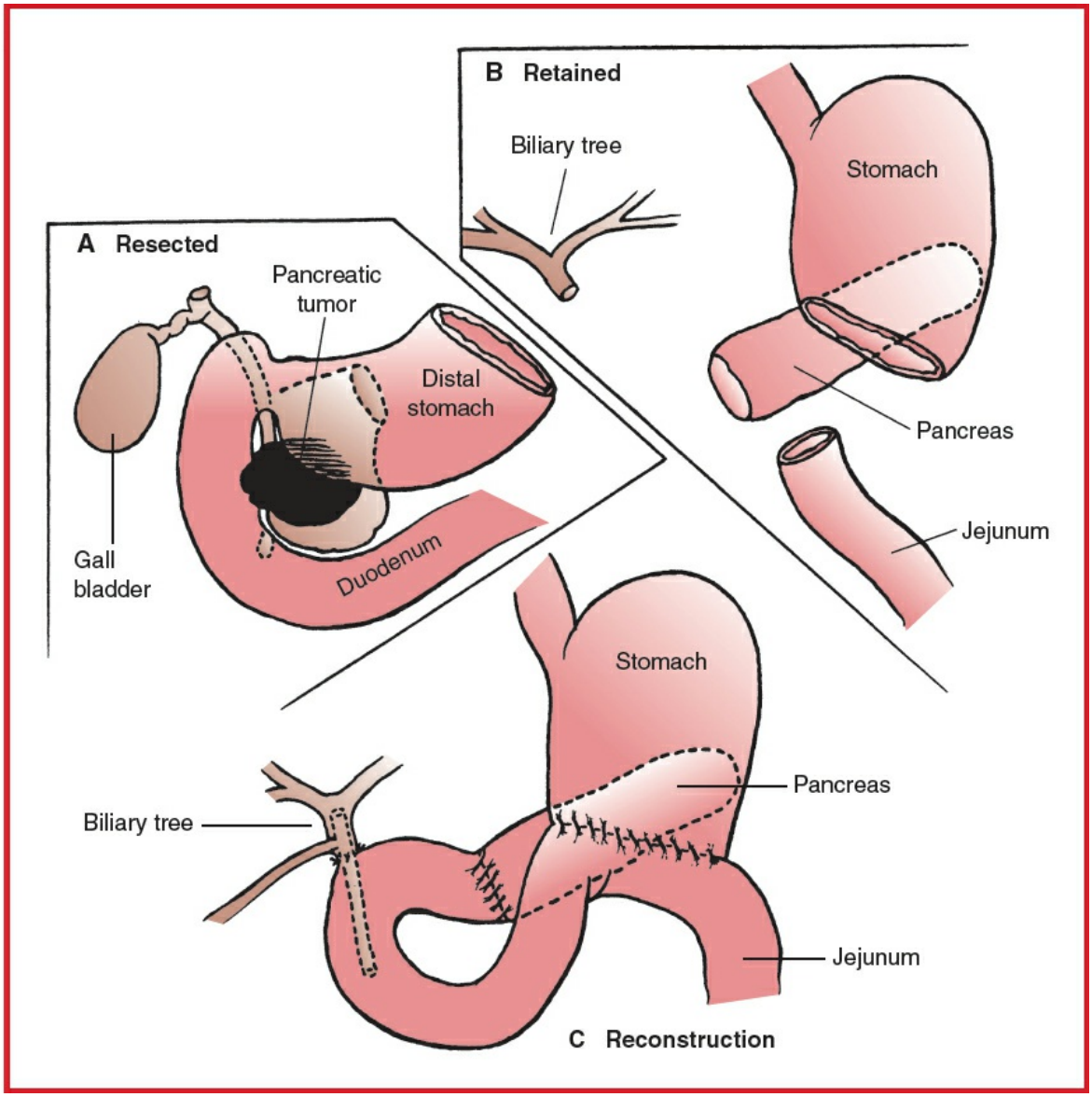

Figure 7.8-7 Standard pancreaticoduodenectomy. **A:** Structures resected, including distal stomach, entire duodenum, head and neck of pancreas with tumor, gallbladder, and distal extrahepatic biliary tree. **B:** Structures retained, including proximal stomach, body and tail of pancreas, proximal biliary tree, and jejunum distal to ligament of Treitz. **C:** Reconstruction: proximal pancreaticojejunostomy, hepaticojejunostomy over T-tube, and distal gastrojejunostomy. (Reproduced with permission from Hardy JD: Hardy's Textbook of Surgery, 2nd edition. JB Lippincott, Philadelphia: 1988.)

Variant procedure or approaches

There are several variants that consist of extensions of the Whipple procedure: **total pancreatectomy; regional pancreatectomy**, involving resection and reconstruction of the retropancreatic SMV and artery; and the pylorus-preserving **pancreaticoduodenectomy** as described above. In addition, the distal pancreatic stump may be anastomosed to the posterior wall of the stomach.

Usual preop diagnosis

Carcinoma of the pancreas; malignant cystadenomas; chronic pancreatitis

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Whipple	Total Pancreatectomy	Regional Pancreatectomy
Position	Supine	⇐	⇐
Incision	Midline abdominal or transverse (chevron)	⇐	⇐
Unique considerations	Large-bore iv lines	⇐	⇐
Antibiotics	Cefoxitin 2 g iv	⇐	⇐
VTE prophylaxis	Heparin 5000 units sq		
Surgical time	4–5 h	4–6 h	5–6 h
Closing considerations	Adequate drainage	⇐	⇐
EBL	500–750 mL	750–1000 mL	750–1500 mL
Postop care	NG decompression; PACU/ICU	NG decompression; diabetes management	
Mortality	5–10%	12%	15%
Morbidity	Delayed gastric emptying: 25% Pancreatic fistula: 10–20% Sepsis: 5–15%	⇐ NA 5% <5% ⇐	⇐ 10–20% 25% 5% <5%

	Hemorrhage: 5% MI: 1–3% Biliary fistula: <2%	<1%	<2%
Pain score	7–9	7–9	7–9

■ PATIENT POPULATION CHARACTERISTICS (FOR CANCER PANCREAS)	
Age range	40–80 yr
Male:Female	1:1
Incidence	10th most common cancer in the United States (~33,000/yr)
Etiology	Familial and genetic factors (p16, K-vas); tobacco; diabetes; alcohol; diet; pancreatitis
Associated conditions	See Etiology, above.

Suggested Readings

1. Boone BA, Zenati M, Hogg ME, et al: Assessment of quality outcomes for roboti pancreaticoduodenectomy: identification of the learning curve. JAMA Surg 2015; 150(5):416–22.
2. Callery MP, Chang KJ, Fishman EK, et al: Pretreatment assessment of resectable an borderline resectable pancreatic cancer: expert consensus statement. Ann Surg Oncol 2009; 16(7):1727–33.
3. Fernandez-del Castillo C, Morales-Oyarvide V, McGrath D, et al: Evolution of th Whipple procedure at Massachusetts General Hospital. Surgery 2012; 152:556.
4. Lavu H, Sell NM, Carter TI, et al: The HYSLAR trial: a prospective randomize controlled trial of the use of a restrictive fluid regimen with 3% hypertonic saline versus lactated Ringers in patients undergoing pancreaticoduodenectomy. Ann Surg 2014; 260(3):445–53.
5. Limongelli P, Docimo L, Malleo G, et al: Delayed gastric emptying after pancreaticoduodenectomy: the hunt continues. J Am Coll Surg 2018; 226(3):333–4.

ANESTHETIC CONSIDERATIONS FOR PANCREATIC SURGERY

(Procedures covered: drainage for pancreatitis; drainage of pancreatic pseudocyst; pancreaticojejunostomy; pancreatectomy; Whipple resection.)

PREOPERATIVE

Patients presenting for pancreatic surgery can be divided into four groups: (a) those with acute pancreatitis, who failed medical treatment and may be extremely ill, presenting for operative excision or drainage of necrotic or infected foci, (b) patients with adenocarcinoma of the pancreas, (c) patients with neuroendocrine active (60–70%) or inactive islet cell tumors (mainly insulinoma and gastrinoma; rarely VIPoma and glucagonoma), and (d) patients suffering from the sequelae of chronic pancreatitis (e.g., pseudocyst or abscess).

Respiratory	Respiratory compromise—such as pleural effusions, atelectasis, and ARDS, progressing to respiratory failure—may occur in patients with acute pancreatitis. Postop mechanical ventilation may be needed for these patients. **Tests:** Consider CXR; ABG; others as indicated from H&P
Cardiovascular	Patients with acute pancreatitis may suffer from severe intravascular volume depletion 2° plasma exudation and in severe cases 2° hemorrhage (erosion of blood vessels). Aggressive volume resuscitation with crystalloids, colloids, and blood products may be required during surgery. Hypocalcemia is often present (arrhythmias and ↓ myocardial contractility). Serum K^+ may be elevated (2° acidosis or renal failure associated with acute pancreatitis) or decreased (2° watery diarrhea associated with gastrinoma, VIPoma, prolonged NG suction) and should be corrected before surgery. Hypokalemia resistant to K^+ replacement may point to ↓ Mg^{++} and warrants replacement. **Tests:** ECG; electrolytes; others as indicated from H&P
Gastrointestinal	Jaundice and abdominal pain are common presenting Sx in this group of patients. The presence of ileus

	(common in acute pancreatitis) or intestinal obstruction should mandate full-stomach precautions and rapid-sequence induction (see Rapid-Sequence Induction, p. B-5). Electrolyte abnormalities are common and may be 2° metabolic acidosis (↑ K^+ 2° acute pancreatitis) or alkalosis and intestinal losses (↓ K^+ and ↓ Mg^{++} 2° diarrhea, NG suction). Acute pancreatitis is associated with ↓ Ca^{++} (omental fat saponification) and ↑ Na^+ (dehydration). Gastrinoma (Zollinger-Ellison syndrome) is associated with diarrhea, severe peptic ulcer, and GERD. VIPoma often causes massive watery diarrhea (up to 20 L). Electrolyte abnormalities should be treated preop. **Tests:** Electrolytes; glucose; LFTs; others as indicated from H&P
Renal	Patients should be evaluated for renal insufficiency predominantly 2° dehydration, with anesthetic plan adjusted accordingly. Renal insufficiency may also occur in the context of multiorgan failure associated with acute pancreatitis or sepsis. **Tests:** BUN; creatinine; others as indicated from H&P
Endocrine	Many patients with acute pancreatitis have diabetes 2° loss of islet cells. Endocrine tumors of the pancreas are linked (10–30%) with multiple endocrine syndrome type I (MEN 1; Wermer syndrome), including adenoma of the parathyroid gland (>90%), the pituitary gland (20–30%), and the pancreas (~50%). Hyperparathyroidism is common (Ca^{++}↑), some pituitary adenomas secrete prolactin > growth hormone > ACTH, and some pancreatic island cell tumors secrete gastrin > insulin ≫ VIP, glucagon. Insulinoma can result in severe hypoglycemia necessitating frequent periop blood glucose measurements. Surgical manipulation of the insulinoma may result in massive release of insulin. VIPoma (Verner-Morrison syndrome) is often associated with hypokalemia but can also result in hypercalcemia and hyperglycemia (insulin

	resistance). Glucagonoma can be associated with hyperglycemia. **Tests:** Electrolytes; glucose; others as indicated from H&P
Hematologic	Hct may be falsely elevated, 2° hemoconcentration, or low, 2° hemorrhage. Coagulopathy may be present (DIC in the context of SIRS or sepsis). **Tests:** CBC with differential; Plt; consider PT, PTT, fibrinogen, D-dimer, or thromboelastogram (TEG)
Laboratory	Other tests as indicated from H&P
Premedication	Consider midazolam 1–2 mg. Note: Full-stomach precautions in patients with intestinal obstruction, and consider placement and suctioning of a NGT before induction.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of a transversus abdominis plane or thoracic epidural block for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA ± epidural for postop analgesia or alternative regional anesthetic techniques including paravertebral and possibly transversus abdominis plane (TAP) blocks (see p. 1788–1789). However, whether TAP blocks provide meaningful opioid-sparing and analgesic effects in abdominal pancreatic surgery is uncertain. The choice of an appropriate regional anesthetic technique can be significantly restricted by a patient's health status (e.g., coagulopathy or sepsis) (see Adjuvant Regional Anesthetic Techniques, p. 1738). If postop epidural analgesia is planned, establishing correct catheter placement in the epidural space can be accomplished by injecting 1–2% lidocaine (50–100 mg) via the catheter to elicit a segmental block. The use of epidural anesthetic techniques for postop pain management in patients undergoing major, nonvascular abdominal surgery has been shown to provide superior pain control

compared with IV-PCA (20–30% difference on postop days 1–3). However, adequate pain control can be achieved with the use of IV-PCA.

Epidural anesthetic techniques may be particularly beneficial in patients undergoing upper abdominal procedures and at risk for postop respiratory failure (preop hypoxia and/or hypercarbia, severe chronic lung disease, recent admission for acute respiratory failure). A recent cumulative meta-analysis of all published and unpublished randomized trials examining epidural anesthetic techniques indicates reduced overall mortality in patients undergoing major abdominal and thoracic surgeries (prevention of one death per 60 patients receiving epidural anesthesia). Epidural anesthetic techniques also decreased cardiovascular (arterial fibrillation, supraventricular tachycardia, heart block), pulmonary (emboli, atelectasis, pneumonia), and gastrointestinal (ileus) morbidity, while they increased the incidence of urinary retention and arterial hypotension. Beneficial effects may be particularly pronounced in patients with limited physiologic reserve. This important meta-analysis included trials published between 1971 and 2011, documenting steady mortality risk rates over the entire period. However, whether and to what extent the reduced mortality risk associated with the use of epidural techniques will remain significant when adhering to today's clinical practice guidelines and surgery-specific ERAS protocols (enhanced recovery after surgery) are not certain.

ERAS pathways (Appendix K) emphasize opioid-sparing and multimodal analgesic techniques for the management of periop pain. These techniques aim at providing superior pain control while reducing the incidence of opioid side effects including dizziness (impaired early mobilization), slow recovery of bowel function (delayed discharge from hospital), nausea and vomiting (decreased patient satisfaction), and potentially life-threatening events (severe respiratory depression). Multimodal approaches include the use of regional anesthesia techniques and nonopioid drug classes, including nonsteroidal anti-inflammatory drugs (NSAIDs), acetaminophen,N-methyl-D-aspartate (NMDA) antagonists, local anesthetics, and gabapentinoids.

Induction	The patient with bowel obstruction or ileus is at risk for pulmonary aspiration, and rapid-sequence induction with cricoid pressure is indicated. If the patient is clinically hypovolemic, restore intravascular volume (colloid, crystalloid, or blood products) before induction and titrate induction dose of sedative/hypnotic agents. Etomidate (0.2–0.4 mg/kg iv) or ketamine (1–3 mg/kg iv) may provide better hemodynamic stability during

	induction of anesthesia. Propofol is associated with a significant reduction of SVR.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Standard maintenance. **Combined epidural/GA:** The epidural catheter ideally is placed at the level of a dermatome corresponding to the surgical site (generally midthoracic spine). This allows the use of both lipophilic and hydrophilic drugs at the lowest possible dose and adds flexibility to the anesthesiologist's drug selection while also minimizing the likelihood of side effects. A continuous infusion (after an initial bolus) is the preferred mode of administering local anesthetics via the epidural catheter because satisfactory analgesia can be achieved without major fluctuations in BP. Lower concentrations (e.g., bupivacaine 0.125–0.25%) are used to provide supplemental analgesia, while higher concentrations (e.g., bupivacaine 0.5%) generally provide optimal surgical conditions (i.e., a complete sensory and motor block). The infusion rate is contingent on the desired segmental spread but often ranges between 5 and 10 mL/h. Lipophilic opioids can effectively be given by continuous infusion (e.g., fentanyl 2 mcg/mL) and offer the advantage of limited segmental spread. Longer-acting hydrophilic opioids (e.g., hydromorphone 0.1–0.4 mg or morphine 1–2 mg for epidural placement at midthoracic spine) can be injected as a bolus along with an initial bolus dose of local anesthetics. However, hydrophilic opioids tend to spread rostrally within the intrathecal space and may cause sedation and respiratory depression if dosed too aggressively. Vulnerable patients include the elderly, patients with obstructive airway disease, and patients with ↑ BMI. The use of epidural local anesthetics is associated with sympatholysis, and ↓ BP has to be anticipated. Critical ↓ BP is treated with fluids and/or vasopressors (e.g., phenylephrine 50–100 mcg iv). In

patients undergoing a surgical procedure with a significant risk for major bleeding, it is prudent to delay administration of epidural local anesthetics until the critical part of surgery has been completed. Systemic sedatives (e.g., opiates and benzodiazepines) should be minimized, particularly in patients receiving opioids by the neuraxial route as they increase the likelihood of postop respiratory depression.

Low-dose ketamine: If the placement of an epidural catheter is not an option, the use of ketamine may be considered as an adjuvant analgesic regimen. Low-dose ketamine provides opioid-sparing effects (30–50%), which can be accompanied by a simultaneous reduction of postop pain (up to ~30%). Administration of ketamine reduces the incidence of opioid-mediated side effects including PONV and decreases postop wound hyperalgesia, which may attenuate the risk for developing persistent pain after surgery. A low-dose ketamine infusion (e.g., 0.5 mg/kg bolus before surgical incision, followed by an infusion of 0.2 mg/kg/h), may be particularly appropriate in patients at risk for developing persistent pain after surgery, including patients on chronic high-dose opioid therapy and patients with widespread pain complains. For the sole alleviation of acute postop pain, doses >30–50 mg may not provide additional benefits. The risk for occurrence of psychomimetic side effects appears to be low in patients undergoing general anesthesia. Adding ketamine to a postop IV opioid-PCA regimen (typically 1–2 mg per bolus) decreases postop opioid use and pain (~30%), and lowers the incidence of PONV (~40%). At reported doses, the risk of hallucination is not significantly increased.

Magnesium: The intraop or periop use of iv Mg^{++} (typically 2–4 g as a bolus/infusion regimen) has some opioid-sparing (15–30%) and modest analgesic effects (pain 10–20%). However, it is unclear whether administration of Mg^{++} reduces the incidence of opioid-

	related side effects.
Maintenance (cont'd)	**Gabapentin/pregabalin:** Single-dose administration of 100–300 mg pregabalin or 600–1200 mg gabapentin is a consideration in patients not eligible for epidural anesthesia. Pregabalin and gabapentin can provide opioid-sparing effects (15–40%), reduce the incidence of the opioid-related side effects PONV and pruritus (~30%), and exert modest analgesic effects (10–30%). However, administration of pregabalin and gabapentin increases the incidence of sedation (20–45%), and complaints of visual disturbance are much more likely. As such, the periop use of pregabalin and gabapentin may hamper early postop mobilization and increase fall risks in vulnerable patients (e.g., the frail and elderly). Repeated dosing of pregabalin and gabapentin within a 24-h interval does not offer clear benefits but increases the risk of sedation when using higher doses. There is also no compelling evidence to suggest that pregabalin or gabapentin reduce the incidence of persistent pain after surgery. **Nonsteroidal anti-inflammatory drugs and acetaminophen:** Perioperative administration of nonselective NSAIDs (e.g., ketorolac 30 iv) COX2-selective NSAIDs (e.g., 200–400 mg celecoxib po) and/or acetaminophen (e.g., 1000 mg po) is associated with moderate opioid-sparing effects. Overall, NSAIDs seem to be about twice as effective (~25%) as paracetamol and only NSAIDs have conclusively been shown to reduce opioid-mediated side effects (e.g., PONV ~30%, sedation ~40%). NSAID but not paracetamol can also significantly reduce postop pain (up to ~30%). The continued use of NSAIDs or paracetamol in the postop period is meaningful to sustain opioid-sparing effects and further reduce the incidence of opioid-related side effects. Potential benefits of adding NSAIDs need to be balanced against the risk of drug-related side effects including bleeding and renal failure. A large postmarketing study

	(>10,000 patients) suggests that nonselective NSAIDs at recommended doses (e.g., ketorolac <100 mg/d) do not increase the risk of surgical site bleeding or GI bleeding in patients <65 yr and exposed for <5 d. However, in the elderly and in patients exposed >5 d, the risk of GI bleeding is increased. A small but elevated risk for surgical site bleeding has also been reported by several randomized clinical trials. NSAIDs should not be withheld from adults with normal preop renal function. However, if patients are at risk for postop renal impairment (e.g., impaired intraop renal perfusion), NSAIDs are best avoided. **Intravenous lidocaine infusion:** IV infusion of lidocaine (e.g., 1.5 mg/kg bolus followed by 1–2 mg/kg/min) in abdominal surgery modestly reduces postop pain and opioid consumption (10–30%), decreases the incidence of PONV (~20–30%), accelerates recovery of bowel function, decreases the incidence of postop ileus (2–3×), and moderately reduces the average length of hospital stay. It is uncertain that these benefits translate to other types of surgery. At this time, it is also uncertain whether continuation of the infusion into the postop period provides additional benefits (frequent monitoring of lidocaine plasma concentrations strongly recommended).
Emergence	The decision to extubate a patient at the end of surgery depends on the patient's underlying cardiopulmonary status. Patients undergoing extensive surgery with major fluid shifts may require prolonged intubation until sufficient reduction of soft tissue edema (compromised airway) is achieved. Discuss with surgeon local wound infiltration or nerve block (e.g., TAP block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose is given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.

Blood and fluid requirements	Anticipate large fluid loss IV: 14–16 ga × 2 (particularly Whipple, pancreatectomy, and drainage/debridement for pancreatitis) Warm fluids T&C or T&S	Blood loss can be significant, and blood products should be immediately available. Adequate large-bore iv access is mandatory. Procedures tend to be long and extensive, leading to hypothermia and large 3rd-space fluid loss. If procedure does not involve cancer or infection, cell-saving devices can be utilized. Intraoperative fluid management should be titrated to a patient's particular needs (adequate peripheral perfusion, urine output >0.5 mL/kg/min, no base deficit). Overly generous intraop fluid administration may be associated with increased postop morbidity (e.g., delayed recovery of bowl function) and extended hospital stay. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors UO Arterial line ± CVP or PA catheter	Pancreatic surgery can be associated with major fluid shifts and fluid loss. Availability of an infusion device assisting rapid delivery of intravenous fluids at body temperature is advised. Invasive monitoring is often required. In patients with severe cardiovascular impairment, the use of a PA catheter or TEE to guide

	± TEE	intraop management (the use of pressors and iv fluids) should be considered. Use forced-air warmer to maintain normothermia.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Hypocalcemia	Release of pancreatic lipase → omental fat saponification
	Hypovolemia	Extensive 3rd spacing, major hemorrhage during pancreatic dissection
	Severe hypoglycemia	Uncontrolled insulin release from insulinoma
	Sepsis/SIRS	Manipulation of infected tissue → cardiovascular instability, respiratory deterioration, DIC

POSTOPERATIVE

Complications	Hyperglycemia Electrolyte imbalance Hypovolemia Hypothermia Hypocalcemia PONV VTE	Total pancreatectomy is associated with brittle diabetes that can be very difficult to control. Subtotal resections lead to variable hyperglycemia.
Multimodal pain management	Continuous epidural analgesia PCA	Patient should be recovered in an ICU or hospital ward that is accustomed to treating the side effects of epidural analgesic techniques using opiates and local anesthetics (e.g., arterial hypotension,

		respiratory depression, breakthrough pain, nausea, pruritus). Postop pain control with an epidural rather than a PCA regimen is superior in patients undergoing major abdominal surgery. Particularly in high-risk patients suffering from pulmonary impairment, an epidural regimen may reduce the incidence of respiratory failure. The use of epidural (or systemic) local anesthetics can speed up bowel recovery and reduce hospital length of stay. The use of epidural anesthetic techniques in the postop period has also been associated with reduced mortality and morbidity. Widely adapted ERAS protocols emphasize the continued use of multimodal analgesic techniques to alleviate postop pain and minimize the use of opioids (these aspects are discussed in more detail in section Intraoperative Management).
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum may promote return of bowel function.
Tests	CXR (if CVP placed); ABG;	Electrolytes; Ca^{++}; glucose;

	Hct, CBC, metabolic panel, and coagulation as indicated	Plts—as indicated for postop management

Suggested Readings

1. Assouline B, Tramèr MR, Kreienbühl L, et al: Benefit and harm of adding ketamine to an opioid in a patient-controlled analgesia device for the control of postoperative pain: systematic review and meta-analyses of randomized controlled trials with trial sequential analyses. Pain 2016; 157(12):2854–64.
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5. Chaparro LE, Smith SA, Moore RA, et al: Pharmacotherapy for the prevention of chronic pain after surgery in adults. Cochrane Database Syst Rev 2013; (7):CD008307.
6. De Oliveira GS Jr, Castro-Alves LJ, Khan JH, et al: Perioperative systemic magnesium to minimize postoperative pain: a meta-analysis of randomized controlled trials. Anesthesiology 2013; 119:178–90.
7. Doleman B, Heinink TP, Read DJ, et al: A systematic review and meta-regression analysis of prophylactic gabapentin for postoperative pain. Anaesthesia 2015; 70:1186–204.
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CHAPTER 7.9

Peritoneal Surgery

SURGEON
Jeffrey A. Norton, MD

ANESTHESIOLOGIST
Martin S. Angst, MD

EXPLORATORY OR STAGING LAPAROTOMY

SURGICAL CONSIDERATIONS

Description

Exploratory laparotomy is indicated primarily in patients suffering from abdominal trauma or other acute abdominal catastrophes. It is important that a thorough and systematic intra-abdominal examination be carried out to prevent missing significant injuries (e.g., ruptured duodenum or transected pancreas). Any active bleeding should be controlled before a systematic examination. Other indications for laparotomy include certain patients with fever of undetermined origin or those in whom a specific diagnosis cannot be made or for staging of selected patients with Hodgkin disease. A **staging laparotomy** (Fig. 7.9-1) consists of **splenectomy**, **wedge**, and **needle biopsies** of both lobes of the liver and biopsies of the periaortic, celiac, mesenteric, and porta hepatis lymph nodes. In young women, suturing (pexing) the ovaries in the midline protects them from radiation. Indications for staging in Hodgkin disease and lymphomas vary from institution to institution, but PET/CT scans have limited their use.

The procedure begins with a midline abdominal incision; then the abdomen is explored, and both needle and wedge biopsies of the liver may be performed. The spleen may be removed by incising the lateral peritoneal attachment and delivering the spleen into the wound. The short gastric vessels are cut and ligated and the splenic vessels exposed.

These are cut individually and ligated, and the spleen is removed. Paraaortic nodes are exposed through a left paraaortic incision in the retroperitoneum and removed for biopsy. Lymph channels are clipped to prevent lymphatic leakage. The nodes dissected extend to the inferior margin of the duodenum. It may be necessary to cross the aorta and biopsy any enlarged nodes on the right side. More recently, **laparoscopy** is being performed for staging of certain intra-abdominal malignancies (e.g., pancreatic and gastric cancer); however, its use has decreased with improved multiphasic CT scans.

Usual preop diagnosis

Abdominal trauma; Hodgkin disease or other lymphomas

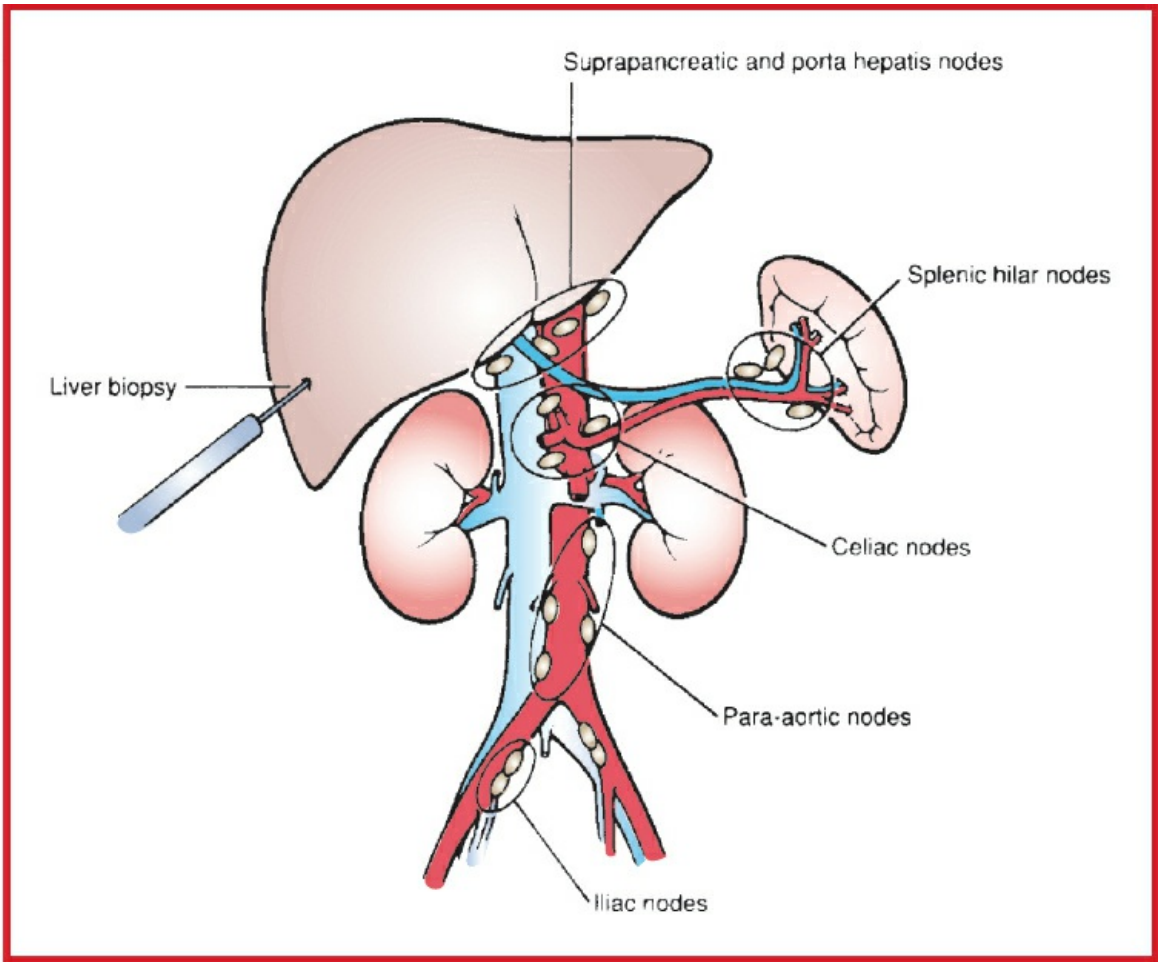

Figure 7.9-1 Staging laparotomy. (Reproduced with permission from Scott-Conner CEH, Dawson DL: Operative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol, and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

SUMMARY OF PROCEDURES

	Staging Laparotomy	Exploratory Laparotomy
Position	Supine	⇐
Incision	Midline abdominal	⇐ or transverse
Special instrumentation	Abdominal retractor	⇐
Unique considerations	Ovarian pexy	Careful monitoring of VS in trauma patients
Antibiotics	Cefoxitin 2 g iv	Cefazolin 2 g iv
VTE prophylaxis	Heparin 5000 units sq	⇐
Surgical time	1.5–2 h	Variable, 1–2 h+
Closing considerations	Splenic bed hemostasis	Hemostasis
EBL	100–200 mL	Variable, 200–500 mL
Postop care	± NG decompression (especially trauma patients); PACU → ward	ICU for trauma patients
Mortality	<1%	2–5%
Morbidity	Prolonged ileus: 10–15% Pulmonary complications: 5–10% Wound infection: 2–3% Small bowel obstruction: 1% Intraperitoneal bleeding: <1%	⇐ Atelectasis: 5–10% Wound infection: 5–10% Hemorrhage: 1–3% Pneumonia: <1%
Pain score	6–8	6–8

PATIENT POPULATION CHARACTERISTICS

Age range	15–60 yr	15–75 yr
Male:Female	1:1.5	1:1

Incidence	Common	⇐
Etiology	Unknown	Trauma
Associated conditions	Hodgkin disease (95%); lymphoma (5%)	Other visceral or vascular injuries in trauma

ANESTHETIC CONSIDERATIONS

(Procedures covered: exploratory/staging laparotomy that is not trauma-related; excision of intra-abdominal and retroperitoneal tumors; splenectomy.)

PREOPERATIVE

Patients presenting for staging laparotomy typically have lymphomatous or cancerous disorders. Apart from the primary disease, these patients are often in reasonably good health and will not have had radiation or chemotherapy before the staging laparotomy. Patients undergoing resection of intra-abdominal or retroperitoneal tumors vary widely in their overall health status (e.g., progression of tumor and concomitant diseases). Accordingly, the extent of surgery and the potential for intraoperative complications (e.g., major vascular injury) are case-specific and highly variable. Consequently, a thorough understanding of the patient's pathology and close communication with the surgical team (sometimes multidisciplinary) about planned surgical intervention are essential to devise a compelling anesthetic management plan."

Patients presenting for splenectomy may be divided into two groups: (a) trauma patients (whose management is described in Trauma Surgery) and (b) a group with myeloproliferative and other disorders resulting in hypersplenism. Patients may have received chemotherapy and/or radiation therapy, which may affect a variety of organ systems. It is incumbent on the anesthesiologist to be aware of the periop implications of these adjunctive treatments.

Respiratory	Patients who have splenomegaly and other intra-abdominal mass lesions may have a degree of atelectasis and compromised ventilation 2° intra-abdominal pathology: ↓ FRC → ↑ A-a gradient + ↓ PaO_2. This should be evaluated by physical exam and close evaluation of diagnostic studies. Some may have been treated with chemotherapeutic agents (e.g., bleomycin at a total dose >200 mg/m^2) that

	cause pulmonary pathology, including fibrosis. Toxic drug effects are potentiated by smoking, XRT, and high FiO_2. **Tests:** CXR, PFTs, and ABG as clinically indicated
Gastrointestinal	Prolonged diarrhea and/or vomiting can result in electrolyte abnormalities. **Tests**: electrolytes
Cardiovascular	Patients with systemic disease requiring splenectomy may be chronically ill and have ↓ cardiovascular reserve. Patients who have received certain chemotherapeutic agents (e.g., doxorubicin at a dose >550 mg/m^2) may suffer from cardiotoxic side effects that can be worsened by XRT. Manifestations include CHF and dysrhythmias. **Tests:** ECG, ECHO, and stress test as clinically indicated
Neurologic	Patients may have neurologic deficits from receiving certain chemotherapeutic agents (e.g., peripheral neuropathies caused by vinblastine and cisplatin or CNS pathology caused by 5-fluorouracil and mithramycin). Evidence of neurologic dysfunction should be documented in the preop evaluation.
Hematologic	Patients are likely to present with splenomegaly 2° hematologic disease (e.g., Hodgkin disease, non-Hodgkin lymphoma, chronic leukemia, myeloid metaplasia, thrombotic thrombocytopenic purpura, idiopathic autoimmune hemolytic anemia, and sickle-cell disease). Cytopenia is very common. Preop replacement of platelets is often a consideration in patients with severe thrombocytopenia. However, the effectiveness of preop platelet replacement is limited in patients with hypersplenism because transfused platelets are mostly sequestrated by the spleen. Myelosuppression should be anticipated in all patients receiving active chemotherapy. **Tests:** CBC
Hepatic	Some chemotherapeutic agents (e.g., methotrexate

	and mithramycin) may be hepatotoxic. Evaluation of LFTs should be considered in patients at risk. **Tests:** LFTs including INR as clinically indicated
Renal	Some chemotherapeutic drugs (e.g., methotrexate and cisplatin) are nephrotoxic, and patients may present with impaired renal function. **Tests:** BUN, creatinine, and electrolytes
Laboratory	A T&S and T&C are mandatory in all patients with significant relevant intraoperative bleeding risk. Other tests may be indicated based on the H&P.
Premedication	Consider midazolam 1–2 mg iv. In patients with suspected gastrointestinal stasis, the use of full-stomach precautions should be considered to minimize the risk of pulmonary aspiration. Consider placement and suctioning of an NGT before induction.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with the surgeon the possibility of a transversus abdominis plane or thoracic epidural block for postop pain management. Consider preop acetaminophen 1000 mg ± gabapentin 300 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA ± epidural for postop analgesia or alternative regional anesthetic techniques including paravertebral and possibly transversus abdominis plane (TAP) blocks. However, whether TAP blocks provide meaningful opioid-sparing and analgesic effects in abdominal surgery is uncertain. The choice of an appropriate regional anesthetic technique can be significantly restricted by a patient's health status (e.g., coagulopathy) see p. 1788–1789. If postop epidural analgesia is planned, placement of catheter before anesthetic induction is helpful to establish correct placement in the epidural space (accomplished by injecting 1–2% lidocaine (50–100 mg) via the epidural catheter to elicit a segmental block). The use of epidural anesthetic techniques for postoperative

pain control in patients undergoing major, nonvascular abdominal surgery has been shown to provide superior pain control compared with IV-PCA (20–30% difference on postoperative days 1–3). However, adequate pain control can be achieved with the use of IV-PCA. ERAS pathways seeAppendix K, p. K-1 emphasize opioid-sparing and multimodal analgesic techniques for the management of perioperative pain. These techniques aim at providing superior pain control while reducing the incidence of opioid side effects including dizziness (impaired early mobilization), slow recovery of bowl function (delayed discharge from hospital), nausea and vomiting (decreased patient satisfaction), and potentially life-threatening events (severe respiratory depression). Multimodal approaches include the use of regional anesthesia techniques and nonopioid drug classes, including nonsteroidal anti-inflammatory drugs (NSAIDs) acetaminophen, N-methyl-D-aspartate (NMDA) antagonists, local anesthetics, and gabapentinoids.

Induction	Standard induction except in patients at risk for pulmonary aspiration, who require a rapid-sequence induction (see Appendix B, p. B-5)
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Standard maintenance. High inspired O_2 concentrations (>30%) may aggravate chemotherapy-induced (e.g., bleomycin) lung injuries. **Combined epidural/GA:** The epidural catheter ideally is placed at a dermatome level corresponding to the surgical site (generally low to midthoracic). This allows the use of both lipophilic and hydrophilic drugs at the lowest possible dose, adds flexibility to the anesthesiologist's choice of agents, and minimizes the likelihood of side effects. A continuous infusion (after an initial bolus dose) is the preferred mode of administering epidural local anesthetics because satisfactory analgesia can be achieved with fewer fluctuations in BP and offer the advantage of limited segmental and rostral spread. Lower concentrations of bupivacaine (0.125–0.25%) can be infused to provide supplemental analgesia, whereas higher concentrations (0.5%) may improve surgical conditions (complete sensory and motor block). The infusion rate is contingent

	on the desired segmental spread but often ranges between 5 and 10 mL/h. Lipophilic opioids (e.g., fentanyl) 2 mcg/mL can effectively be given by continuous infusion. Longer-acting hydrophilic opioids (e.g., hydromorphone 0.1–0.4 mg or morphine 1–2 mg for an epidural placement at the lower to midthoracic spine) can be injected as a bolus along with the initial bolus dose of a local anesthetic. However, hydrophilic opioids tend to spread rostrally within the intrathecal space and may cause sedation and respiratory depression if dosed too aggressively. Vulnerable patients include the elderly, patients with obstructive airway disease, and patients suffering from obesity. The use of epidural local anesthetics is associated with sympatholysis, and ↓ BP has to be anticipated. Critical ↓ BP is treated with fluids iv and/or vasopressors (e.g., ephedrine 5–10 mg iv). In patients undergoing a surgical procedure with a significant risk for major bleeding, it is prudent to delay administration of epidural local anesthetics until the critical part of surgery has been completed. Systemic sedatives (e.g., opiates and benzodiazepines) should be minimized, particularly in patients receiving neuraxial opioids as they increase the likelihood of postop respiratory depression. **Low-dose ketamine:** If the placement of an epidural catheter is not an option, the use of low-dose ketamine provides opioid-sparing effects (30–50%), which can be accompanied by a simultaneous ↓ of postop pain (up to ~30%). Administration of ketamine ↓ the incidence of opioid-mediated side effects including PONV and ↓ postoperative wound hyperalgesia, which may ↓ the risk for developing persistent pain after surgery. Adding ketamine to a postoperative IV opioid-PCA regimen (typically 1–2 mg per bolus) ↓ postoperative opioid use and pain (~30%) and ↓ the incidence of PONV (~40%). At reported doses, the risk of hallucination is not significantly ↑'d.
Maintenance	**Magnesium**: The intraop use of iv Mg^{++} (typically 2–4 g

(cont'd)	as a bolus/infusion regimen) has some opioid-sparing (15–30%) and modest analgesic effects (pain 10–20%). However, it is unclear whether administration of Mg^{++} ↓'d the incidence of opioid-related side effects. **Gabapentin/pregabalin:** Single-dose administration of 100–300 mg pregabalin or 600–1200 mg gabapentin is a consideration in patients not eligible for epidural anesthesia. Pregabalin and gabapentin can provide opioid-sparing effects (15–40%), ↓ the incidence of the opioid-related side effects PONV and pruritus (~30%), and exert modest analgesic effects (10–30%). However, administration of pregabalin and gabapentin ↑'s the incidence of sedation (20–45%), and complaints of visual disturbance are much more likely. As such, the perioperative use of pregabalin and gabapentin may hamper early postop mobilization and ↑ fall risks in vulnerable patients (e.g., the frail and elderly). Repeated dosing of pregabalin and gabapentin within a 24-h interval does not offer clear benefits but ↑'s the risk of sedation. There is also no compelling evidence to suggest that pregabalin or gabapentin will ↓ the incidence of persistent pain after surgery. **Nonsteroidal anti-inflammatory drugs and acetaminophen:** Perioperative administration of nonselective NSAIDs (e.g., ketorolac 30 iv), COX2-selective NSAIDs (e.g., 200–400 mg celecoxib po), and/or acetaminophen (e.g., 1000 mg po) is associated with moderate opioid-sparing effects. Overall, NSAIDs seem to be about twice as effective (~25%) as acetaminophen, and only NSAIDs have conclusively been shown to ↓ opioid-mediated side effects (e.g., PONV ~30%, sedation ~40%). NSAID but not acetaminophen can also significantly ↓ postop pain (up to ~30%). The continued use of NSAIDs and/or acetaminophen postop per is meaningful to sustain opioid-sparing effects and further ↓ the incidence of opioid-related side effects. Potential benefits of adding NSAIDs need to be balanced against the risk of drug-related side effects, including

	bleeding and renal failure. A large postmarketing study (>10,000 patients) suggests that nonselective NSAIDs at recommended doses (e.g., ketorolac <100 mg/d) do not ↑ the risk of surgical site bleeding or GI bleeding in patients <65 yr and exposed for <5 d. However, in the elderly and patients exposed >5 d, the risk of GI bleeding is ↑'d. Several clinical trials have also reported a small risk for surgical site bleeding. NSAIDs should not be withheld from adults with normal preop renal function. However, if patients are at risk for postop renal impairment (e.g., impaired intraop renal perfusion), NSAIDs are best avoided.	
	Intravenous lidocaine infusion: IV infusion of lidocaine (e.g., 1.5 mg/kg bolus followed by 1–2 mg/kg/min) in abdominal surgery will modestly ↓ postop pain and ↓ opioid consumption (10–30%), ↓ the incidence of PONV (~20–30%), ↑ the recovery of bowel function, ↓ the incidence of postop ileus (2–3×), and moderately ↓ the average length of hospital stay. It is uncertain that these befits translate to other types of surgery. At this time, it is also uncertain whether continuation of the infusion into the postop period provides additional benefits (frequent monitoring of lidocaine plasma concentrations strongly recommended).	
Emergence	Most patients can be extubated at the end of surgery. Patients undergoing extensive surgery with major fluid shifts may require prolonged intubation until cardiovascular stability and sufficient reduction of soft-tissue edema (compromised airway) is achieved. Discuss with surgeon local wound infiltration or nerve block (e.g., TAP block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 14–16 ga × 1–2 (particularly major staging laparotomy and excision of tumors)	Potential for major blood loss. Adequate large-bore iv access is mandatory (particularly major staging laparotomy

	BSS @ 3–10 mL/kg/h (see Goal-Directed Fluid Management, p. K-4)	and excision of tumors). In patients with difficult iv access, postinduction placement of additional access is prudent. In splenectomy patients with hypersplenism, Plt transfusion is best given after ligation of the splenic vessel (avoid sequestration). Availability of a rapid infusion device for delivery of IV fluids at body temperature should be considered in patients at risk for large blood loss.
Blood and fluid requirements (cont'd)	Warm fluids T&C or T&S	Intraop fluid therapy should be titrated to a patient's particular needs (adequate peripheral perfusion, urine output >0.5 mL/kg/h, no base deficit). Overly generous intraop fluid administration may be associated with postop morbidity (e.g., delayed recovery of bowl function) and extended hospital stay.
Monitoring	Standard monitors UO ± Arterial line ± CVP ± TEE	Place an arterial line in patients with hemodynamic instability or those at risk for significant intraop bleeding (major staging laparotomy and excision of tumors). Large volume shifts, need for vasoactive drugs, postop care Assessment of volume status

Positioning	✓ and pad pressure points ✓ eyes	
Complications	Unexpected bleeding	Plt transfusion may be necessary

POSTOPERATIVE

Complications	Bleeding PONV VTE	Patient should be recovered in ICU or hospital ward that is accustomed to treating side effects of epidural local anesthetics and opiates (e.g., arterial hypotension, respiratory depression, breakthrough pain, nausea, pruritus).
Multimodal pain management	Epidural analgesia PCA	Postop pain control with an epidural rather than a PCA regimen is superior in patients undergoing major abdominal surgery. In high-risk patients with pulmonary impairment, an epidural regimen may reduce the incidence of respiratory failure. The use of epidural (or systemic) local anesthetic can speed up bowel recovery and reduce hospital length of stay. The use of epidural anesthetic techniques in the postop period have also been associated with ↓ mortality and morbidity. Emphasize multimodal approach combining nonopioid and

		bolus/PCA opioid analgesics with epidural analgesia, and/or TAP blocks (see p. K-2).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum may promote return of bowel function.
Tests	CXR CBC, metabolic panel, and coagulation as indicated	If CVP has been placed perioperatively

Suggested Readings

1. Barton JG: Enhanced recovery pathways in pancreatic surgery. Surg Clin North Am 2016; 96(6):1301–12.
2. Brogi E, Kazan R, Cyr S, et al: Transversus abdominal plane block for postoperative analgesia: a systematic review and meta-analysis of randomized-controlled trials. Can J Anaesth 2016; 63:1184–96.
3. Guay J, Nishimori M, Kopp S: Epidural local anaesthetics versus opioid-based analgesic regimens for postoperative gastrointestinal paralysis, vomiting and pain after abdominal surgery. Cochrane Database Syst Rev 2016; (7):CD001893.
4. Ljungqvist O, Scott M, Fearon KC: Enhanced recovery after surgery: a review JAMA Surg 2017; 152:292–8.
5. Nisanevich V, Felsenstein I, Almogy G, et al: Effect of intraoperative fluid management on outcome after intraabdominal surgery. Anesthesiology 2005; 103:25–32.
6. Strom BL, Berlin JA, Kinman JL, et al: Parenteral ketorolac and risk of gastrointestinal and operative site bleeding. A postmarketing surveillance study. JAMA 1996; 275(5):376–82.
7. Vlassakov KV, Zinner MJ: Putting the patient first. Ann Surg 2014; 259:1070–2.
8. For additional references on multimodal pain management, see Appendix C and Appendix K.

SPLENECTOMY

SURGICAL CONSIDERATIONS

Description

Through a midline abdominal or left subcostal incision or laparoscopically, the spleen is mobilized by dividing the lateral peritoneal attachments while the spleen is retracted medially. (Relevant anatomy is shown in Fig. 7.9-2.) Once the spleen is delivered into the operative wound, the short gastric vessels are clamped, cut, and ligated. This can be done with the LigaSure device. The splenic artery and vein are then exposed with care being taken not to injure the tail of the pancreas. By keeping the splenic hilum between the operator's fingers and thumb, inadvertent bleeding can be controlled easily. Accessory spleens (incidence, 15–30%) also should be looked for if the splenectomy is being done for ITP. They are found along the cephalad and caudad edges of the pancreas behind the stomach and in the area of the gastrohepatic ligament, greater omentum, and the splenic hilum. All patients undergoing splenectomy should receive polyvalent pneumococcal, meningococcal, and Haemophilus influenza vaccines.

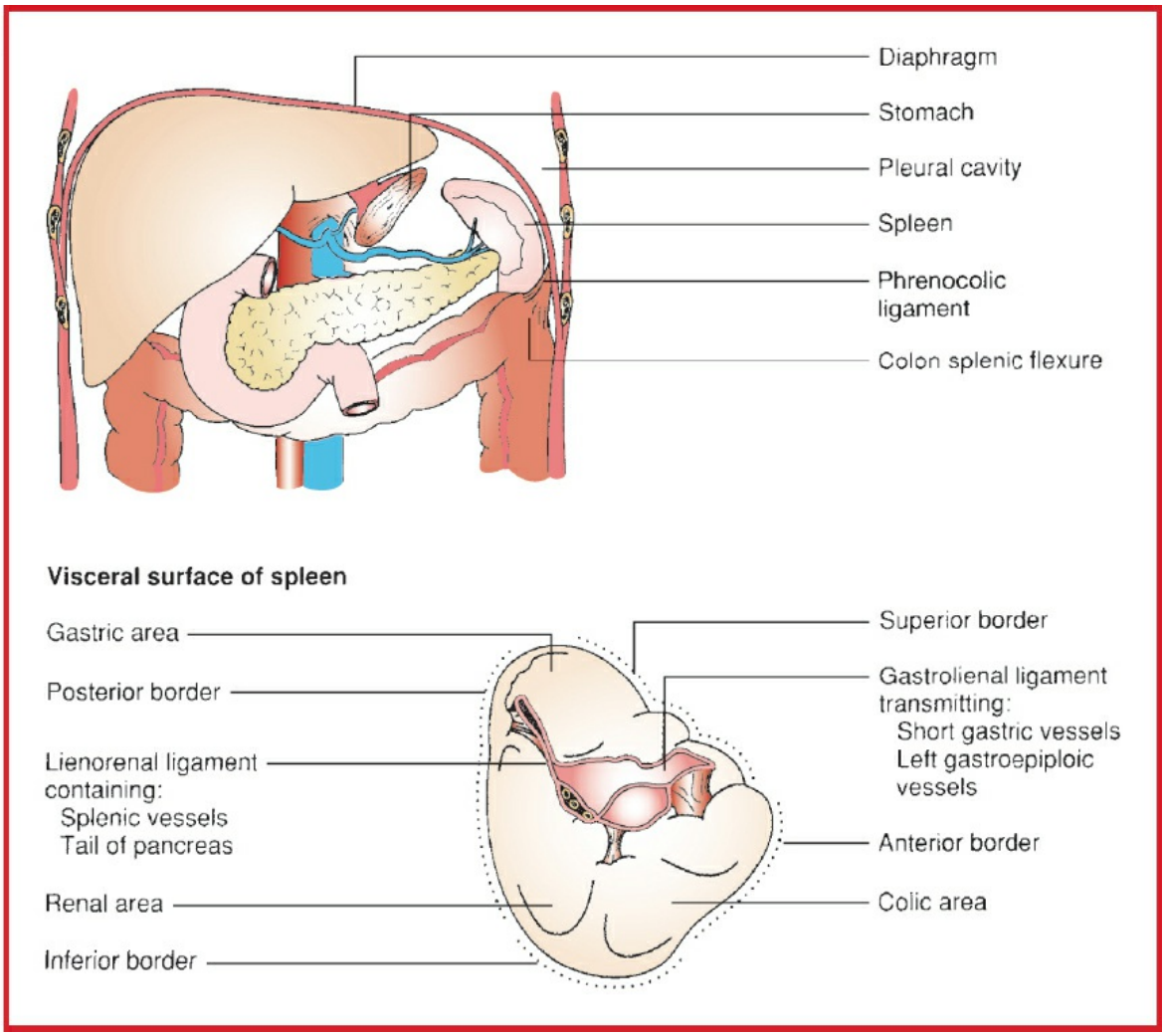

Figure 7.9-2 Anatomic relation of the spleen to the liver, diaphragm, pancreas, colon, and kidney. The

stomach is sectioned to illustrate the anatomic relations in situ. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al., eds:Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Variant procedure or approaches

Following trauma, efforts at splenic salvage (**splenorrhaphy**) may be made, if possible, to preserve all or part of the spleen. This may be accomplished by the use of local hemostatic techniques (electrocoagulation, argon beam coagulator, Surgicel or Gelfoam soaked in thrombin, microfibrillar collagen, and the use of fine sutures or mattress sutures with Teflon felt pledgets). Recently, splenectomy has been performed laparoscopically if the spleen is near-normal size (see Laparoscopic Splenectomy).

Usual preop diagnosis

Staging laparotomy results; trauma; immune thrombocytopenic purpura; hereditary spherocytosis; other hereditary hemolytic anemia types; or a variety of myeloproliferative disorders

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol, and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop (see Appendix K, p. K-1).

SUMMARY OF PROCEDURES

	Splenectomy	Splenorrhaphy
Position	Supine	⇐
Incision	Midline or left subcostal	⇐
Special instrumentation	Suitable abdominal retractors	⇐
Unique considerations	Potential for major blood loss during procedure; avoid splenic laceration and damage to tail of pancreas.	⇐
Antibiotics	Cefoxitin 2 g iv	⇐

VTE prophylaxis	Heparin 5000 units sq	⇐
Surgical time	1–2 h	1–2 h
Closing considerations	Adequate hemostasis	⇐
EBL	50–100 mL	200–500 mL
Postop care	PACU (nontrauma)	⇐
Mortality	0–3%	⇐
Morbidity	Thrombocytosis: >1,000,000 → VTE Pulmonary complications: 3–23% Pancreatitis and/or pancreatic fistula: 1–8% Subphrenic abscess: 0–6% Bleeding: 1–5% Overwhelming sepsis: 0.3–2%	⇐
Pain score	5–7	5–7

PATIENT POPULATION CHARACTERISTICS

Age range	Any age
Male:Female	1:1
Incidence	Common
Etiology	See Usual preop diagnosis, above.
Associated conditions	Blood dyscrasia (30–50%); abdominal or thoracic trauma (25%); Hodgkin disease (5–10%); tumors (5%)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Exploratory or Staging Laparotomy.

Suggested Readings

1. Crary SE, Buchanan GR: Vascular complications after splenectomy for hematologic disorders. Blood 2009; 114(14):2861–8.
2. Davidson RN, Wall RA: Prevention and management of infection in patients without a spleen. Clin Microbiol Infect 2001; 12:657–60.
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EXCISION OF INTRA-ABDOMINAL AND RETROPERITONEAL TUMORS

SURGICAL CONSIDERATIONS

Description

Intra-abdominal and retroperitoneal tumors, other than those of visceral origin, consist primarily of sarcomas (liposarcoma, fibrous histiocytomas, mesenteric fibromas, and gastrointestinal stromal tumors). They are usually approached through a long midline incision for adequate exposure and to assess their resectability. Resection of such lesions may require excision of adjacent or involved small bowel or large intestine or other involved abdominal viscera. Care must be taken not to injure the ureters or major vessels, particularly at the root of the mesentery to the small bowel. It may be prudent to have ureteral stents placed to avoid injury to the ureters. If residual microscopic tumor remains, intraoperative radiation therapy (IORT) may be indicated. In certain tumors the patient may still benefit from "tumor debulking" (removing as much tumor as possible and treating the remaining tumor with radiation and/or chemotherapy). Operative approaches are dictated by location of tumor. Although most operative approaches are transabdominal, some retroperitoneal tumors may be approached retroperitoneally via oblique incision on either side of the abdomen. Some require thoracoabdominal incisions.

Usual preop diagnosis

Intra-abdominal or peritoneal tumor

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol, and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options,

physiotherapy plan, possibility of NG tube, and urinary drain postop (see Appendix K, p. K-1).

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Midline abdominal or transverse
Unique considerations	Availability of blood
Antibiotics	Cefoxitin 2 g iv preop
VTE prophylaxis	Heparin 5000 units sq
Surgical time	3–4 h
Closing considerations	Hemostasis
EBL	300–1000 mL
Mortality	1–3%
Morbidity	Respiratory problems: 5–10% Wound infection: 2–4% Hemorrhage: 1–3%
Pain score	8–10

PATIENT POPULATION CHARACTERISTICS	
Age range	Variable, 20–75 yr
Male:Female	1:1
Incidence	Common
Etiology	Unknown
Associated conditions	Partial bowel obstruction (10–15%); hydronephrosis (10–15%)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Intestinal and Peritoneal Procedures, and for

Exploratory or Staging Laparotomy.

Suggested Readings

1. Gholanai S, Jacobs CD, Kapp DS, et al: The value of surgery for retroperitonea sarcoma. Sarcoma 2009; 2009:605840.
2. Gladdy RA, Gupta A, Catton CN: Retroperitoneal sarcoma: fact, opinion, an controversy. Surg Oncol Clin N Am 2016; 25(4):697–711.
3. Shukla PJ, Bareto SG, Shrikhande SV: Retroperitoneal sarcoma.Br J Surg 2007; 94:1057–8.

DRAINAGE OF SUBPHRENIC ABSCESS

SURGICAL CONSIDERATIONS

Description

Abscesses may occur in subphrenic spaces, including the right subphrenic, right subhepatic, left subphrenic, lesser sac, or bare area of the liver (Fig. 7.9-3), following peritonitis, abdominal surgery, or trauma. It is essential to know the anatomy of these spaces for making a correct diagnosis and for treatment. Most commonly abscesses are drained by interventional radiology (85%), but some may require an open surgical approach.

Drainage is accomplished by a **posterior** or **anterior extraperitoneal approach** or by a **transpleural approach**, depending on location of the abscess. Lesser sac abscesses are best approached by an **anterior transperitoneal route**. Abscesses in the bare area of the liver are drained posteriorly. After the abscess is localized, the cavity is entered by finger dissection and drained. Loculations are broken up and the cavity thoroughly irrigated with NS or a suitable antibiotic solution. Appropriate drains are placed, and the wound is closed in a conventional manner. Cultures are routinely obtained.

Variant procedure or approaches

Percutaneous approaches have become more popular as interventional radiologists gain experience. This technique should be reserved for unilocular collections, where sterile cavities are not penetrated, and a safe route is available.

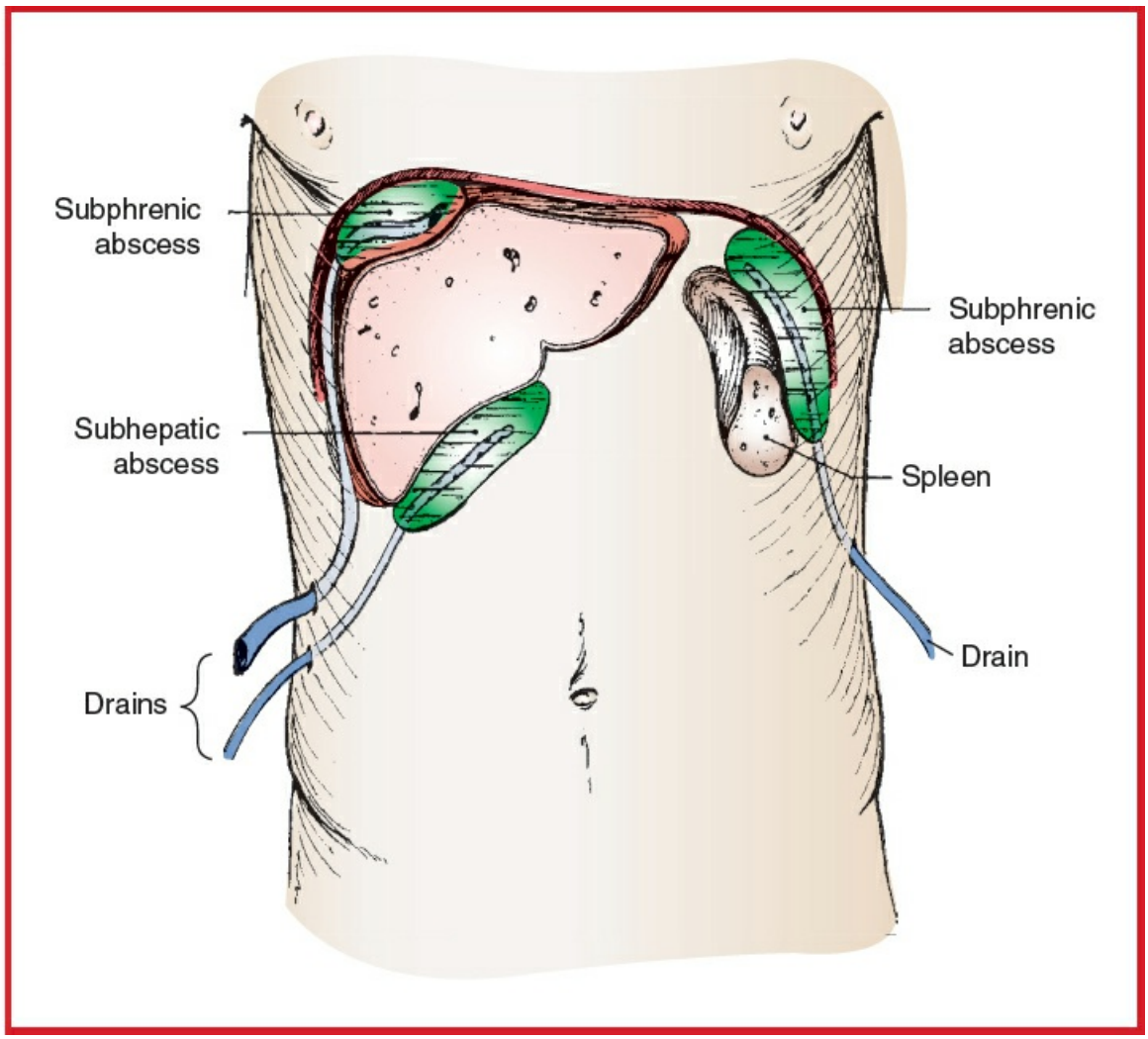

Figure 7.9-3 Anatomy of subphrenic abscess. (Reproduced with permission from Baker RJ, Fischer JE, eds: Mastery of Surgery, Vol. I, 4th edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Usual preop diagnosis

Subphrenic abscess

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol, and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop (see Appendix K, p. K-1).

SUMMARY OF PROCEDURES

	Subphrenic Abscess Drainage	Percutaneous Approach
	Supine or lateral	⇐

Position	decubitus, right or left	
Incision	Subcostal or oblique abdominal	None
Special instrumentation	Drainage tubes	Special catheters; CT guidance
Antibiotics	Zosyn® (Piperacillin and Tazobactam) 3.375 g q6h	⇐
VTE prophylaxis	Heparin 5000 units sq	⇐
Surgical time	1–1½ h	⇐
EBL	50–100 mL	10–25 mL
Postop care	Maintain patency of the drainage tubes	⇐
Mortality	<5%	⇐
Morbidity	Inadequate drainage: 5–10% Pulmonary complications: 5–10% Bowel perforation: <2%	⇐
Pain score	7–9	4–5

PATIENT POPULATION CHARACTERISTICS

Age range	Variable, 15–80 yr
Male:Female	1:1
Incidence	Common
Etiology	Postop (70–80%); peritonitis (25–30%); trauma (5–10%)
Associated conditions	See Etiology, above.

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Intestinal and Peritoneal Procedures.

Suggested Readings

1. Goulet CJ: Endoscopic transgastric drainage of subphrenic abscess.Gastrointest Endosc 2007; 65:733–5.
2. Morita S, Kamimura K, Suda T, et al: Endoscopic ultrasound-guided transmura drainage for subphrenic abscess: report of two cases and a literature review. BMC Gastroenterol 2018; 18(1):55.

INGUINAL HERNIORRHAPHY

SURGICAL CONSIDERATIONS

Description

Groin hernias are defects in the transverse abdominis layer, where a direct hernia comes through the posterior wall of the inguinal canal, and an indirect hernia comes through the internal inguinal ring (Fig. 7.9-4). Direct hernias are medial to the inferior epigastric artery and vein, whereas indirect hernias are lateral to these vessels. Surgical approach can be either anterior or posterior. In general, an **anterior approach** (Bassini, McVay, Shouldice, or mesh repair) is used for primary repair of an indirect or direct inguinal hernia. The **Bassini repair** consists of ligation of the hernia sac and suturing the conjoint tendon to the shelving edge of Poupart ligament. **McVay repair** sutures the conjoint tendon to Cooper ligament and usually is reserved for femoral inguinal hernias. **Shouldice** emphasizes the closing of the transverse fascia and transversus abdominal muscle layers. Currently, the interposing of Marlex mesh or insertion of a Marlex plug between the conjoint tendon, the internal oblique muscle, and the inguinal ligament is commonly used. Mesh is associated with improved outcomes and less pain. Other modifications are indicated in special situations.

A **posterior approach** is used by some surgeons for the repair of femoral hernias and recurrent inguinal hernias and for treating incarcerated and strangulated hernias. The **posterior preperitoneal approach** is usually performed by suturing the transversus abdominis arch on the superior aspect of the hernia defect to Cooper ligament and the iliopubic tract on the inferior aspect of the defect.

The **laparoscopic approach** is indicated for the repair of recurrent or bilateral inguinal hernias and utilizes a **preperitoneal patch repair** and results in less postop pain and an earlier return to regular physical activity (see Laparoscopic Inguinal Hernia Repair)

Randomized studies suggest that laparoscopic repair has inferior results.

Usual preop diagnosis

Groin pain or lump

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol, and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, possibility of NG tube, and urinary drain postop (see Appendix K, p. K-1).

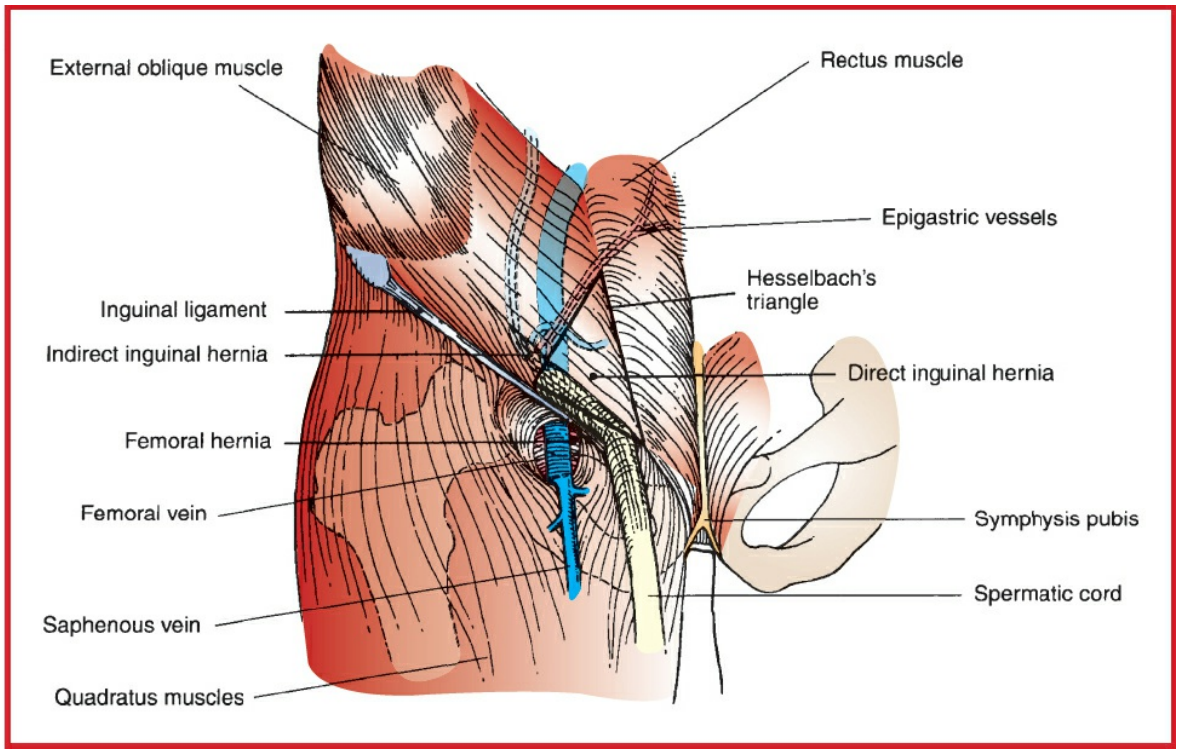

Figure 7.9-4 Inguinal anatomy. (Reproduced with permission from Scott-Conner CEH, Dawson DL: Operative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

SUMMARY OF PROCEDURE

Position	Supine
Incision	Oblique or transverse
Unique considerations	Avoid damage to nerve structure and spermatic cord. Avoid interfering with blood supply to testes.
Antibiotics	Cefazolin 2 g iv preop
Surgical time	1–1.5 h

Postop care	PACU → ward or d/c to home in some cases
EBL	25–50 mL
Mortality	3/100,000
Morbidity	Wound abscess: <3% Wound hematoma: <2%
Pain score	4–5

PATIENT POPULATION CHARACTERISTICS

Age range	1–90 yr
Male:Female	85:15
Incidence	15/1000
Etiology	Congenital variants; reduced collagen synthesis in adults
Associated conditions	Chronic cough; urinary retention; chronic constipation

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Repair of Abdominal Dehiscence.

Suggested Readings

1. Aquina CT, Probst CP, Kelly KN, et al: The pitfalls of inguinal herniorrhaphy surgeon volume matters. Surgery 2015; 158(3):736–46.
2. Gray SH, Hawn MT, Itani KM: Surgical progress in inguinal and ventral herni repair. Surg Clin North Am 2008; 88:17–26.
3. Hallen M, Bergenfelz A, Westerdahl J: Laparoscopic extraperitoneal inguinal hernia repair versus open mesh repair: long-term follow-up of a randomized control trial. Surgery 2008; 143:313–7.
4. Suzuki S, Furui S, Okinaga K, et al: Differentiation of femoral vs. inguinal hernia: C findings. AJR 2007; 189:78–83.

FEMORAL HERNIORRHAPHY

SURGICAL CONSIDERATIONS

Description

The hernia sac is exposed as it exits the preperitoneal space through the femoral canal (Fig. 7.9-5). If the hernia cannot be reduced, the possibility of strangulation needs to be kept in mind. The peritoneal sac in most cases should be opened proximal to the femoral canal to gain control of the intestine before it reduces itself into the peritoneal cavity. If the bowel is ischemic, it may require resection. The repair consists of suturing the iliopubic tract to Cooper ligament, taking care not to compromise the femoral vein (McVay repair).

Usual preop diagnosis

Bulging of tissues over femoral canal

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol, and smoking cessation, discussion of carb loading, DVT prophylaxis, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Oblique
Antibiotics	Cefazolin 2 g iv
Surgical time	1–1.5 h
EBL	25–50 mL
Postop care	PACU → ward or d/c to home in some cases
Mortality	<1% (6–20%, if strangulated)
Morbidity	Recurrence: 6%
Pain score	5–6

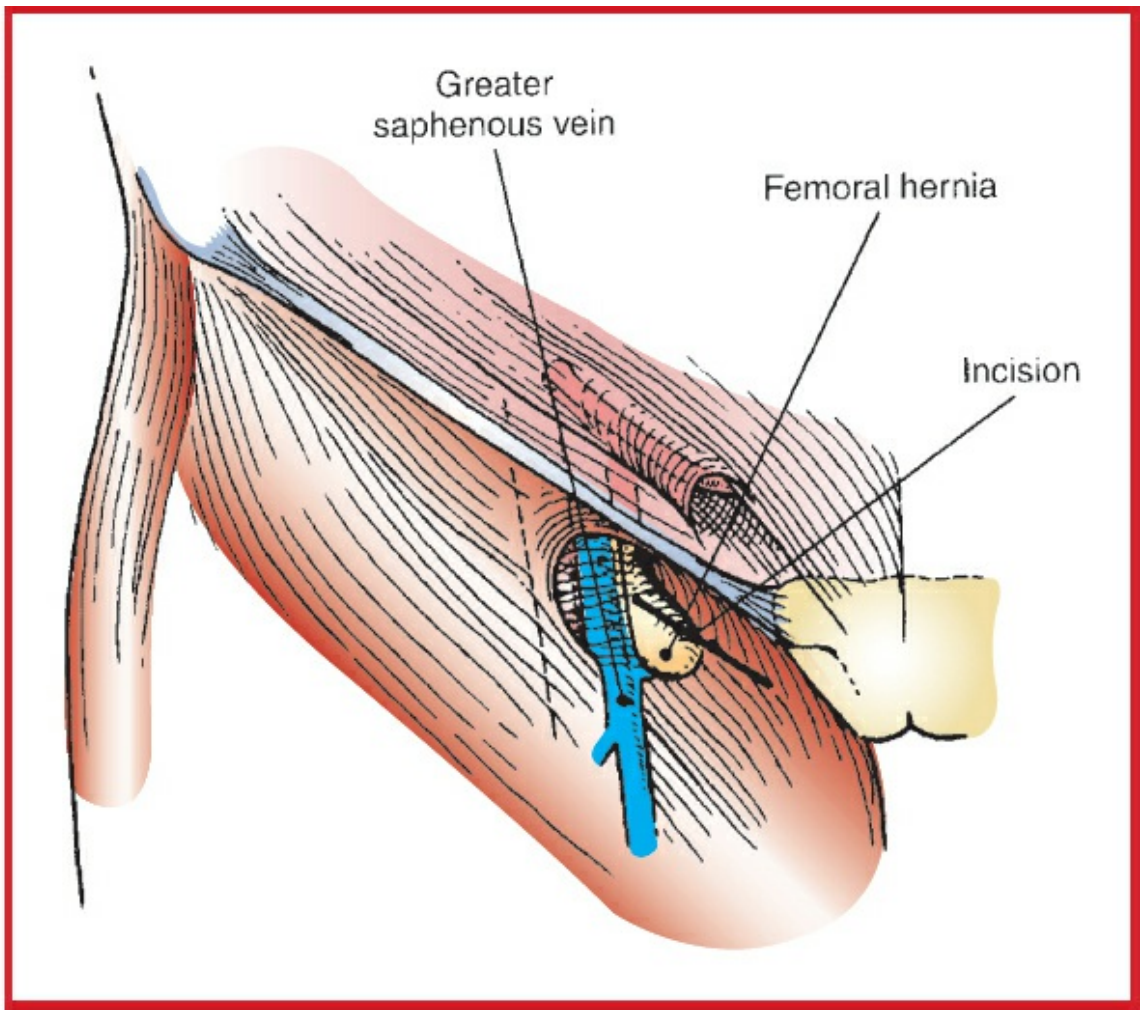

Figure 7.9-5 Femoral hernia repair. (Reproduced with permission from Scott-Conner CEH, Dawson DL: Operative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

PATIENT POPULATION CHARACTERISTICS

Age range	Adults; rare in children
Male:Female	1:4
Incidence	1.5% of all groin hernias
Etiology	Failure of preformed peritoneal sac to obliterate; muscle atrophy in older age group

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Repair of Abdominal Dehiscence.

Suggested Readings

1. Earle DB, McLellan JA: Repair of umbilical and epigastric hernias.Surg Clin North

Am 2013; 93(5):1057–89.
2. Suzuki S, Furui S, Okinaga K, et al: Differentiation of femoral vs. inguinal hernia: CT findings. AJR 2007; 189:78–83.

REPAIR OF INCISIONAL HERNIA

SURGICAL CONSIDERATIONS

Description

Incisional hernias can occur after any abdominal incision but are most common following midline incisions. Factors leading to herniation include wound infection, trauma, inadequate suturing, and ischemia. Following skin incision, the skin edges and subcutaneous fat are retracted, and the dissection is carried down to the hernia defect. The redundant hernia sac is excised, and the fascia is freed up on both sides of the wound. Primary closure is preferred, if possible.

Variant procedure or approaches

In addition to primary repair, the latter may be reinforced by an onlay mesh prosthesis, or the prosthesis may be used to fill the hernial defect or placed behind the muscle layer. In the repair of incisional hernias, laparoscopic tacking of mesh is gaining in popularity.

Usual preop diagnosis

Incisional hernia

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol, and smoking cessation, discussion of carb loading, DVT prophylaxis, and postop pain management options (see Appendix K, p. K-1).

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Vertical or transverse
Special instrumentation	Mesh prosthesis (when indicated)
Antibiotics	Cefoxitin 2 g iv
VTE prophylaxis	Heparin 5000 units sq

Surgical time	1–2 h
Closing considerations	Retention sutures
EBL	100–200 mL
Postop care	± NG decompression; abdominal binder; PACU → ward
Mortality	<1%
Morbidity	Ileus: 5–10% Respiratory complications: 5–10% Wound infection: 1–2%
Pain score	5–6

PATIENT POPULATION CHARACTERISTICS

Age range	20–70 yr
Male:Female	1:1
Incidence	3–5% of midline abdominal incisions
Etiology	Wound infection; trauma; inadequate suturing; weak tissues
Associated conditions	Obesity; malnutrition

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Repair of Abdominal Dehiscence.

Suggested Readings

1. Gray SH, Hawn MT, Itani KM: Surgical progress in inguinal and ventral herni repair. Surg Clin North Am 2008; 88:17–26.
2. Lockhart K, Dunn D, Teo S, et al: Mesh versus non-mesh for inguinal and femora hernia repair. Cochrane Database Syst Rev 2018; (9):CD011517.
3. Nilsson H, Angerås U, Sandblom G, et al: Serious adverse events within 30 days o groin hernia surgery. Hernia 2016; 20(3):377–85.
4. Yeh DD, Alam HB: Hernia emergencies. Surg Clin North Am 2014; 94(1):97–130.

REPAIR OF ABDOMINAL DEHISCENCE

SURGICAL CONSIDERATIONS

Description

Dehiscence implies a "splitting apart" or "bursting open" of the abdominal wall fascia. A complete dehiscence is a separation of all layers of the abdominal wall and often is associated with an extrusion of abdominal viscera. If incomplete, the separation of fascial and muscular layers results in an incisional hernia or an obstruction of a herniated loop of intestine. The earliest sign of a wound dehiscence is the presence of serosanguineous drainage from the wound. Minimal disruptions may be treated conservatively with occlusive dressings and an abdominal binder. Major dehiscence requires operative repair using careful fascial closure and retention sutures.

Variant procedure or approaches

Variations in the type of closure depend on surgeon's preference. Interrupted, nonabsorbable sutures and skin bridges are often used.

Usual preop diagnosis

Wound dehiscence

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol, and smoking cessation, discussion of carb loading, DVT prophylaxis, and postop pain management options (see Appendix K, p. K-1).

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Closure of previous incision
Unique considerations	Adequate muscle relaxation essential
Antibiotics	Cefoxitin 2 g iv
VTE prophylaxis	Heparin 5000 units sq
Surgical time	1–2 h
EBL	50–100 mL

Postop care	Abdominal binder to relieve tension on suture line; PACU → ward
Mortality	5–10%
Morbidity	Recurrent incisional hernia: 5–10% Wound infection: <5% Wound ischemia: 1–2%
Pain score	4–5

PATIENT POPULATION CHARACTERISTICS

Age range	25–90 yr
Male:Female	1:1
Incidence	1.3% in patients <45 yr 5.4% in patients >45 yr
Etiology	Wound infection; excessive coughing or sneezing; excessive abdominal distention; weak tissue; poor nutrition; hematoma formation; poor surgical technique with tissue ischemia
Associated conditions	Malnutrition (25–30%); ascites (20–25%); hypoproteinemia (20%); chronic anemia (5–10%); vitamin C deficiency (<5%)

ANESTHETIC CONSIDERATIONS

(Procedures covered: inguinal herniorrhaphy; femoral herniorrhaphy; incisional hernia repair; repair of abdominal dehiscence.)

PREOPERATIVE

Predisposing factors for hernia often include increased abdominal pressure 2° chronic cough, bladder outlet obstruction, constipation, pregnancy, vomiting, ↑ BMI, and acute or chronic muscular effort. These factors should ideally be managed preop to avoid postop recurrence. The patient population may range from premature infants to the elderly, who have the potential for presenting with multiple medical problems.

Musculoskeletal	Pain is likely to be present in area of hernia;

	evaluate bony landmarks if regional anesthesia is planned.
Gastrointestinal	Hernias may become incarcerated, obstructed, or strangulated, requiring emergency surgery. Fluid and electrolyte imbalance is likely. **Tests:** Electrolytes, if indicated from H&P
Hematologic	For regional anesthesia, three patient's coagulation status, if indicated from H&P. **Tests:** As indicated from H&P
Laboratory	Other tests as indicated from H&P
Premedication	If necessary, standard premedication.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. If appropriate, discuss with surgeon the possibility of a transversus abdominis plane or thoracic epidural block for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GA, regional, or local anesthesia ± iv sedation (MAC) may all be appropriate anesthetic techniques for uncomplicated cases (e.g., without incarceration or obstruction). GA and epidural for postop pain control may be appropriate for patients with unusually large incisional hernias or abdominal dehiscence (see Anesthetic Considerations for Exploratory or Staging Laparotomy). Choice depends on factors such as site of incision, patient physical status, and preference of both patient and surgeon. Profound muscle relaxation may be necessary to facilitate exploration and repair.

Regional anesthesia

Spinal	**Single-shot vs. continuous:** Patient in sitting or lateral decubitus position (operative site down) for placement of hyperbaric subarachnoid block. Doses of local anesthetics are as follows for T4-T6 level:

	0.75% bupivacaine in 8.25% dextrose (10–15 mg); 0.5% tetracaine in 5% dextrose (12–16 mg). Consider adding fentanyl (10–20 mcg) and/or morphine (100–200 mcg).
Epidural	Patient in sitting or lateral decubitus position for placement of epidural catheter. After locating the epidural space, administer a test dose (e.g., 3 mL of 1.5% lidocaine with 1:200,000 epinephrine) to determine whether the catheter is subarachnoid or intravascular. Titrate local anesthetic (e.g., 2% lidocaine or 0.5% bupivacaine or ropivacaine) until desired surgical level is obtained (5–7 mL at a time), usually about 20 mL. Consider adding fentanyl (25–100 mcg). Consider adding single-shot morphine (3–5 mg) rather than fentanyl if the epidural catheter is removed shortly after the end of surgery (prolonged duration of action; requires monitoring for 16–24 h after injection).
Local	Requires gentle surgical technique. Surgical field block, plus ilioinguinal and iliohypogastric nerve blocks, using 0.5% bupivacaine with 1:200,000 epinephrine. Often performed by surgeon.

General anesthesia

Induction	**LMA vs. ETT:** Standard induction. LMA may be suitable for the patient who presents with a uncomplicated chronic hernia. If there is obstruction, incarceration, or strangulation, however, a rapid-sequence induction with ET intubation is indicated. GETA also may be indicated in the patient with wound dehiscence and large incisional hernias.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Standard maintenance. Muscle relaxants may be necessary to facilitate surgical repair.

Emergence	Consider extubating the trachea while patient is still anesthetized to prevent coughing and straining. Patients who are at risk for pulmonary aspiration and require awake intubation or rapid-sequence induction are not candidates for deep extubation. Discuss with surgeon local wound infiltration or nerve block (e.g., TAP block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Minimal blood loss IV: 16–18 ga × 1 BSS @ 2–4 mL/kg/h	See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitoring	
Positioning	✓ and pad pressure points ✓ eyes	
Complications	↓↓ HR + ↓ BP	Vagal reflex evoked by bowel traction

POSTOPERATIVE

Complications	PDPH after neuraxial block Urinary retention, common with regional anesthesia Wound dehiscence with coughing/straining	Patients with urinary retention may require catheterization.
Multimodal pain management	PO analgesics: acetaminophen alone or combined with codeine (Tylenol no. 3, 1–2 tab q4–6h) or oxycodone (Percocet 1 tab q6h)	Surgical field block or regional anesthesia should provide sufficient analgesia postop.
ERAS	PONV protocol (see	Encourage early enteral

	Appendix B, p. B-4 and B-6)	nutrition and mobilization. Consider DVT prophylaxis.

Suggested Readings

1. Abbott DE, Dumanian GA, Halverson AL: Management of laparotomy woun dehiscence. Am Surg 2007; 73:1224–7.
2. Barton JG: Enhanced recovery pathways in pancreatic surgery. Surg Clin North Am 2016; 96(6):1301–12.
3. Cousins MJ, Bridenbaugh PO, eds:Neural Blockade Pain Management, 4th edition. Lippincott-Raven Publishers, Philadelphia: 2008.

CHAPTER 7.10

Breast Surgery

SURGEONS

Irene L. Wapnir, MD, FACS
Deshka S. Foster, MD, MA
Arash Momeni, MD

ANESTHESIOLOGIST

Clifford A. Schmiesing, MD

BREAST BIOPSY

SURGICAL CONSIDERATIONS

Description

Breast biopsy and **lumpectomy** entail the surgical removal of breast tissue for histopathologic examination. The term **excisional biopsy** is usually applied to benign entities and implies the complete removal of the lesion in question (e.g., fibroadenoma). The term **lumpectomy** is used to characterize cancerous lesions that are removed with a rim of normal breast tissue to achieve tumor-free margins.

Breast lesions subjected to definitive open or surgical excision can be classified as palpable or nonpalpable. Accompanying abnormal visual changes in the breast usually denote locally advanced disease. These include edema, redness, ulceration, and brawny discoloration of the skin with or without alterations in the contour or size of the breast. Palpable lesions can be described as nodules or masses having distinct or indistinct borders or subtle parenchymal thickening. Nonpalpable lesions are discovered on routine screening mammography and MRI or diagnostic ultrasound. Microcalcifications masses, densities, architectural distortion, and abnormal enhancement on MRI fall intc the category of potentially malignant lesions. Ultrasound can help characterize palpable

or nonpalpable lesions as cystic or solid. MRI is not a routine screening test except ir populations at high risk for developing breast cancer. It is particularly useful as an adjunct diagnostic tool in dense breasts, to delineate the extent of cancer and identify other occult lesions in the ipsilateral or contralateral breast.

Most patients undergoing a surgical procedure have had a prior diagnostic biopsy: fine needle aspiration cytology, core needle biopsy, or vacuum-assisted core needle biopsy. Hence, these results guide the extent of surgical resection. Typically, a radiologist will place one or more percutaneous hook wires to delineate the nonpalpable lesions. Instead of a hook wire, radioactive seeds or optical reflectors placed close to the lesion may be used for guiding the surgeon to the desired target. These operative procedures are referred to as **image-guided or wire-localized breast biopsies or lumpectomies**. The aim of these procedures is to remove the breast tissue surrounding the wire including the lesion and biopsy marker. Surgeons may, in some instances, use intraop ultrasound to identify the area of interest instead. A specimen radiograph is performed to confirm that the desired target has been excised.

Although less common, another reason for excisional biopsy is the occurrence of bloody or pathologic **nipple discharge**. The underlying cause of this abnormality typically is a benign intraductal papilloma or, infrequently, carcinoma. The surgeon inserts progressively larger lacrimal probes into the duct with the abnormal discharge and then injects 0.5 mL methylene blue via an ophthalmic needle to internally delineate the duct system. In some institutions, a ductoscope may be used to explore breast ducts.

Most newly diagnosed breast cancers are invasive, but ~20–25% of newly diagnosed breast cancers are noninvasive or ductal carcinoma in situ (DCIS).**Lumpectomy** is typically offered for invasive or in situ cancers that are 5 cm or smaller. **Mastectomy** is also an option (discussed below). Recently, two consensus statements have been published delineating recommendations regarding tumor-free margins. New technologies and contrast agents are under investigation to assess margins intraoperatively.

Commonly, surgeons will demarcate the lumpectomy area with metal clips or insert an interstitial tissue marker to serve as a guide for future radiation therapy planning. **Intraoperative radiation** is combined in some cases with lumpectomy for small breast cancers. Radiation is routinely administered weeks to months after surgery either using partial breast irradiation or whole breast irradiation regimens.

Intravenous sedation/MAC and GA are most commonly used for these procedures When lumpectomies are coupled with nodal staging operations, GA is the preferred

modality and is facilitated by using a laryngeal mask. The latter is preferred for deeper, larger, or multiple lesions and in cases involving soft-tissue mobilization. Field blocks or regional anesthesia may also be considered.

Usual preop diagnosis

Breast mass; nipple discharge; atypical hyperplasia; known in situ, or invasive cancer; mammographic, sonographic, or MRI abnormalities

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, DVT prophylaxis, and postop pain management options. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

SUMMARY OF PROCEDURES

	Breast Biopsy/Lumpectomy	Image-Guided Breast Biopsy
Position	Supine with ipsilateral arm abducted (see Fig. 7.10-1)	⇐
Incision	Overlying the lesion, periareolar, radial, or along the inframammary fold	⇐
Special instrumentation	Ultrasound	⇐ Optical reflector to detect biopsy markers Specimen radiograph
Antibiotics	Cefazolin 2 g iv (optional)	⇐
Surgical time	0.5–1.5 h	⇐
Closing considerations	Wound dressings	⇐
EBL	<25 mL	⇐
Postop care	PACU → home	⇐

Mortality	Extremely rare	⇐
Morbidity	Postop wound seroma: common Ecchymosis or hematoma: <10% Infection: ~1%	⇐ ⇐ Wire transected; target lesion is missed; metallic marker not removed
Pain score	2–5	2–5

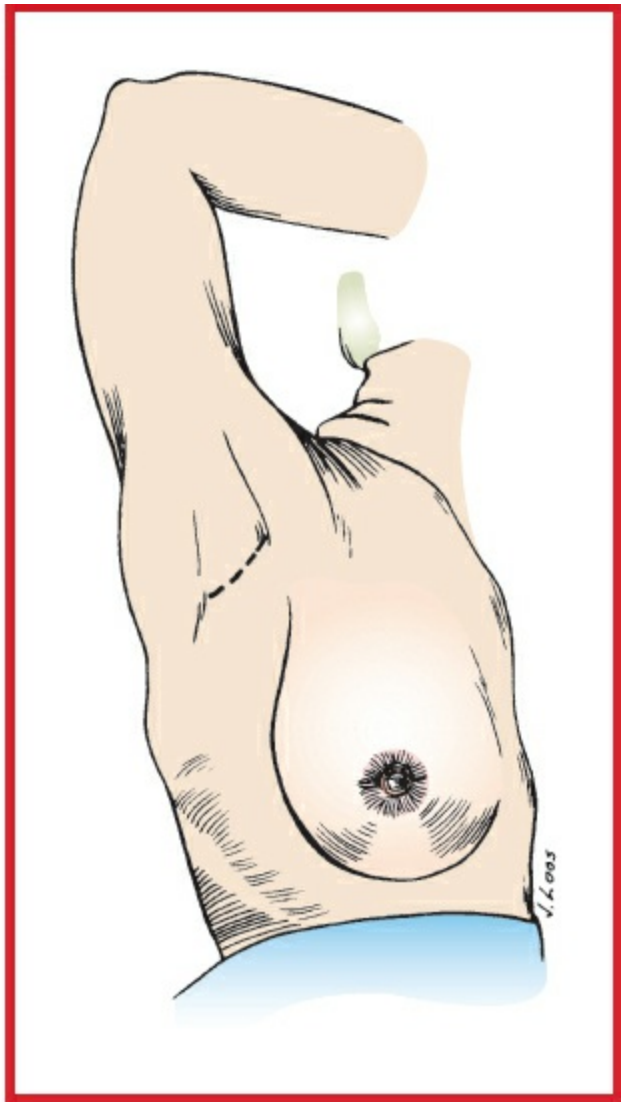

Figure 7.10-1 Arm may be draped into field and positioned on arm board at 90° or suspended overhead as shown. Incision site for lymph node biopsy is indicated by dotted line. (Reproduced with permission from Baker RJ, Fischer JE, edsMastery of Surgery, 6th edition. Lippincott Williams & Wilkins, Philadelphia: 2012.)

PATIENT POPULATION CHARACTERISTICS

Age range	>15 yr	>25 yr

Male:Female	Mainly female	⇐
Incidence	Common	⇐
Etiology	Unknown	⇐

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Breast Biopsy and Sentinel Lymph Node Surgery.

LYMPH NODE SURGERY

SURGICAL CONSIDERATIONS

Description

Sentinel lymph node biopsy (SLNB) is a technique applied to patients with invasive breast cancers who are deemed to have clinically or radiologically negative lymph nodes. SLNB is generally not done for DCIS cancer with the exception of some larg tumors or those associated with a mass on imaging. SLNB may be performed in selec patients undergoing **mastectomy** for DCIS where there may be some risk of discovering an occult invasive carcinoma. Of note, SLNB is also used for patients who received neoadjuvant chemotherapy.

Ultrasound interrogation of the axilla and biopsy of abnormal-appearing sentinel nodes has become a routine practice. Subclinical nodal disease is often discovered among patients without palpable adenopathy via this approach. The biopsied lymph nodes may be marked with a clip, radioactive seed, or black ink tattoo. A localizing hook wire may be placed to guide the surgeon to the biopsied node as well as a specimen radiograph to verify the resection of the targeted clip.

Sentinel lymph node(s) (SLNs) are the first nodes to drain afferent lymphatics from the breast and the region where the cancer is located and therefore are most likely to harbor metastatic tumor cells. The confluence of lymphatic channels at the subareolar plexus of Sappey accounts for the fact that periareolar injections are comparable to peritumoral injections. Most frequently lymphatic channels drain to the axilla and less commonly to the internal mammary chain or other extra-axillary sites.

The absence of metastasis on histologic examination of SLNs predicts tumor-free status of non–sentinel lymph nodes. In the context of breast conservation and planned whole

breast radiotherapy, completion axillary node dissection can be safely avoided in clinically negative cases with one to two positive nodes. These techniques have been validated in institutional and multicenter studies and prospective randomized trials.

Two types of agents have been principally tested for lymphatic mapping and sentinel node identification procedures: vital blue dyes (1% isosulfan blue or methylene blue) and 99^{m}-technetium–labeled sulfur colloid (TSC; unfiltered or filtered). Differen injection sites of these agents may be used: peritumoral or around biopsy cavity, periareolar/subareolar, or in combination. Isosulfan blue (3–5 mL) is injected in the operating room. The breast can be massaged to promote lymphatic uptake of tracers. The surgeon should inform the anesthesiologist when injecting the dye because a transient drop in the pulse oximeter reading of 2–5% is frequently seen, with maximal drop occurring within 20–25 min after injection. This is artifactual due to effects of blue dye spectral absorption, and blood oxygen remains normal. Patients' skin may retain a bluish hue, most noticeable in the recovery room. The urine, stool, or emesis can be blue for up to 24 h or more (the patient needs to be advised of this prior to discharge). Allergic reactions consisting of "blue hives" to full-blown, life-threatening anaphylaxis have been reported following the injection of isosulfan blue dye. Methylene blue can be used in place of isosulfan blue and has a lower incidence of allergic reactions but can cause skin necrosis if injected undiluted intradermally.

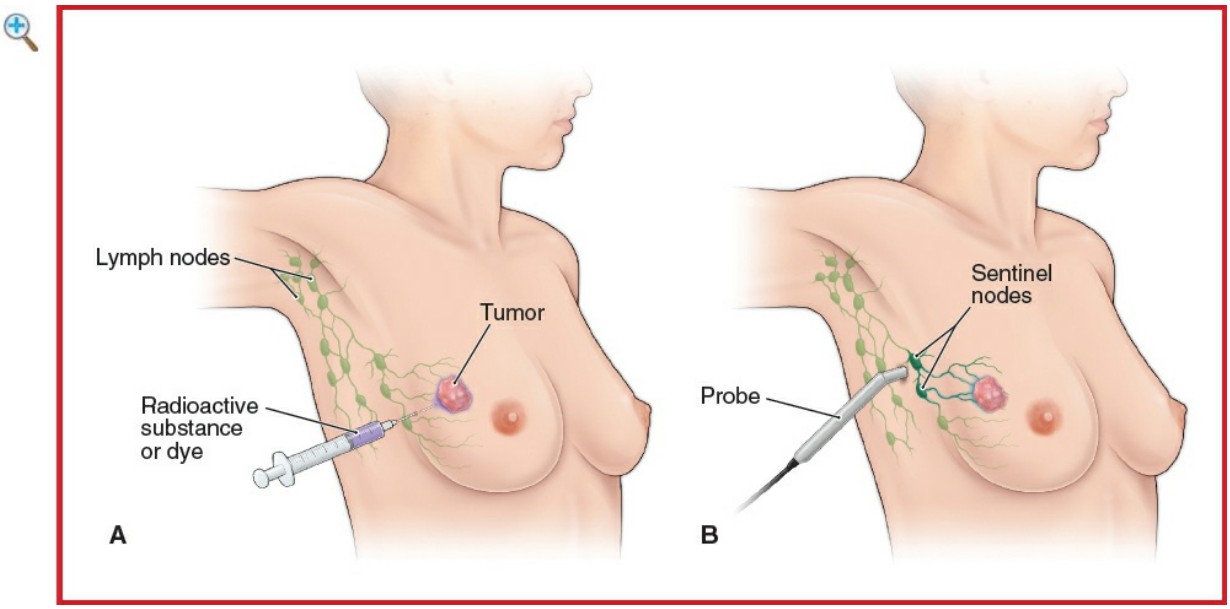

Figure 7.10-2 A radioactive tracer or dye is injected in/around the tumor and an external probe is used to identify the sentinel nodes.

TSC (~1–2 mCi) is usually injected in the nuclear medicine department the day of or the day before the operative procedure. The tracer has very low radioactivity, and no

special protection is required around the patient or in handling tissue specimens. Postinjection lymphoscintigraphy is considered optional. After induction of GA or regional anesthesia, the operative field (chest and lymph node–bearing areas) is surveyed with a handheld gamma probe (a slim rod, similar to a Geiger counter). The "hot" spot(s), denoting accumulated tracer in lymph nodes, are identified (Fig. 7.10-2). A curvilinear incision along the inferior aspect of the hair-bearing area of the axilla is made 3–7 min after injecting the blue dye in the breast. Typically, blue afferent lymphatics and blue nodes are identified below the clavipectoral fascia.

The combination of blue dye and TSC yields the highest sentinel node identification rates. Some surgeons prefer to use one of these two agents alone. Sentinel node mapping should be done with radiotracer alone in pregnant women. Of note, hard, palpable nodes discovered during the axillary exploration are considered sentinel nodes even if not blue or radioactive, as the lymphatic channels may be obstructed.

Sentinel nodes may be examined intraoperatively using touch-prep cytology or frozen section to identify node-positive cases. The number of positive nodes dictates whether the surgeon proceeds to **axillary node dissection** when breast-conserving surgery is performed. In the scenario of mastectomy or when surgery is preceded by neoadjuvant chemo or endocrine therapy, **completion axillary dissection** is performed if sentinel nodes are involved.

Whenever sentinel nodes cannot be identified, a conventional **level I and II axillary dissection** is indicated, although other factors may be taken into consideration influencing this decision. These nodes lie behind and lateral to the edge of the pectoralis minor muscle. The level III, or highest group of axillary lymph nodes, are medial to the pectoralis minor muscle and are not routinely removed unless clinically involved. As part of the axillary dissection, the surgeon preserves the thoracodorsal nerve (innervates the latissimus dorsi muscle) and the long thoracic nerve (innervates the serratus anterior muscle), as well as the blood and nerve supply to the pectoral muscles. The intercostobrachial nerves (sensory to the upper arm) course through the axillary contents, and its preservation usually can be accomplished, avoiding the occurrence of permanent dysesthesias.

Lymphedema can be a consequence of axillary nodal surgery. **Axillary reverse mapping** is a procedure that maps the arm draining nodes and lymphatics in the axilla of the ipsilateral breast. Blue dye (3–5 mL) or indocyanine green (0.5–1 mL) can be used for the procedure. The latter is visualized with the aid of an infrared camera (SPYElite system, Novadaq Inc.). Visualization of these structures allows the surgeon to preserve them, unless suspicious to harbor tumor, and lessen the chances of developing

lymphedema of the arm. Of note, indocyanine green should be avoided in patients with iodine allergies.

Usual preop diagnosis

Invasive breast cancer

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, and physiotherapy plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Small transverse or curvilinear axillary incision
Special instrumentation	Handheld gamma detection probe
Unique considerations	Avoid BP cuff or iv in ipsilateral arm. Possible need to avoid muscle relaxants. Isosulfan blue vital dye → allergic reaction (1–2/100). Methylene blue can cause skin necrosis when injected intradermally but does not cause anaphylaxis.
Antibiotics	Cefazolin 2 g iv (optional)
Surgical time	10–30 min, up to 1.5 h for axillary lymph node dissections
EBL	Minimal
Postop care	PACU → home
Mortality	Rare
Morbidity	Discoloration of urine and stool up to 48 h (usually gone by 24 h) Permanent tattooing of skin with blue dye Transient blue staining of skin Allergic reaction to dye or radioisotope: ~1–2% Anaphylaxis: 1/2000

Pain score	2–5

PATIENT POPULATION CHARACTERISTICS	
Age range	>25 yr
Incidence	~1/8 American women will develop breast cancer.
Etiology	Unknown in most cases; familial history may be related to genetic mutation (BRCA 1 and 2).

ANESTHETIC CONSIDERATIONS FOR BREAST BIOPSY AND SENTINEL LYMPH NODE BIOPSY

PREOPERATIVE

Breast masses may vary in size and depth, which will, in part, determine what type of anesthetic is most suitable for the procedure in these often healthy patients. Excisional biopsies can usually be accomplished with iv sedation and local anesthesia; however, patient wishes must be considered in the anesthetic plan. The suitability of local/MAC versus GA is best addressed by preoperative discussion with the surgical team. A paravertebral block (PVB) may be considered for more extensive breast tissue excisions and when a separate incision is made for lymph node removal (see Anesthetic Technique for Mastectomy section).

Psychosocial	Patients are likely to be anxious concerning the possibility of breast cancer and should be supported and premedicated appropriately.
Laboratory	As indicated from H&P. No testing may be appropriate.
Premedication	Consider midazolam 1–2 mg iv.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GA or local anesthesia + iv sedation are both appropriate techniques. Choice of anesthetic technique depends on the size and depth of lesion and the wishes of the patient. Surgery is routinely done on an outpatient basis.

MAC	Propofol infusion (25–100 mcg/kg/min), combination of analgesics (e.g., fentanyl/remifentanil), and anxiolytics (e.g., midazolam), titrated to effect, are most commonly used. Adding Na bicarbonate to 1% lidocaine (1:10) will reduce injection pain. The anesthesiologist may give remifentanil 0.5–1 mcg/kg 90 sec before initial injection of local anesthetic into the skin.	
Induction	Standard induction. Mask or LMA anesthetic may be appropriate.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance. Muscle relaxants are not necessary for surgical procedure.	
Emergence	No special considerations. Discuss with surgeon local wound infiltration. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Minimal blood loss IV: 20 ga × 1 BSS @ 3–5 mL/kg/h	See Goal-Directed Fluid Management, Appendix K, p. K-4
Monitoring	Standard monitors. If MAC, then monitor adequacy of ventilation and depth of sedation.	Other monitors as clinically indicated. Isosulfan blue vital dye → artifactual ↓ O_2 sat as low as 92–94%
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Inadequate analgesia	May have to supplement surgical field block with local anesthetic or convert to GA

	Isosulfan dye reaction	Pruritus, localized swelling, blue hives. Rx: diphenhydramine (10–50 mg iv). ↓ BP may require epinephrine.

POSTOPERATIVE

Complications	No specific complications anticipated	Inform patients that urine, emesis, or stool may be blue for 24–48 h.
Multimodal pain management	PO analgesics	Emphasize multimodal approach (see Appendix K, p. K-5).
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition and mobilization. Consider DVT prophylaxis.
Tests	As clinically indicated	

Suggested Readings

1. Barton JG: Enhanced recovery pathways in pancreatic surgery. Surg Clin North Am 2016; 96(6):1301–12.
2. Guiliano AE, Hunt KK, Ballman KV, et al: Axillary dissection vs. no axillary dissection in women with invasive breast cancer and sentinel node metastasis randomized clinical trial. JAMA 2011; 305(6):569–75.
3. Moran MS, Schnitt SJ, Giuliano AE, et al: Society of Surgical Oncology-America Society for Radiation Oncology consensus guideline on margins for breast-conserving surgery with whole-breast irradiation in stages I and II invasive breast cancer. Int J Radiat Oncol Biol Phys 2014; 88(3):553–64.
4. Morrow M, Van Zee KJ, Solin LJ, et al: Society of Surgical Oncology-America Society for Radiation Oncology-American Society of Clinical Oncology Consensu Guideline on margins for breast-conserving surgery with whole-breast irradiation in ductal carcinoma in situ. Pract Radiat Oncol 2016; 6(5):287–95.
5. Vokach-Brodsky L, Jeffrey SS, Lemmens HJM, et al: Isosulfan blue affects puls oximetry. Anesthesiology 2000; 93:102–3.

MASTECTOMY ± RECONSTRUCTION

SURGICAL CONSIDERATIONS

Description

The treatment of invasive and in situ breast cancer has signficantly evolved. **Modified radical mastectomy** refers to removal of the breast and the axillary lymph nodes. **Total mastectomy** (simple mastectomy) refers to removal of the breast alone. It is done mainly for treatment of extensive duct carcinoma in situ or prophylaxis in high-risk patients such as those that are mutation carriers of breast cancer susceptibility genes.

Modified radical mastectomy is performed through a single elliptical incision, whereas lumpectomy and sentinel lymph node, or axillary lymph node dissection, are normally done through separate incisions. Postop adjuvant radiation therapy is routinely recommended in breast-conserving surgery and is administered following the completion of adjuvant chemotherapy.

Skin-sparing or **nipple-sparing mastectomies** with immediate breast reconstruction (see below) are increasingly performed to preserve the natural appearance of the breast. These operations are offered to women who have had a good response to neoadjuvant therapies. During the mastectomy, the surgeon preserves the entire skin envelope, including the nipple-areolar complex. A variety of incisions can be used, as shown in Figure 7.10-3. Ischemic skin complications are more likely when a large skin envelope is retained. Skin perfusion can be monitored via fluorescent-based skin angiography using indocyanine green. Oncologic safety should not be compromised, and skin flap thickness should be the same as for total mastectomy. Considerations of skin envelope size or potential ischemic complications may prompt two-staged operations. **Breast reduction surgery** with concomitant lumpectomy and nodal staging is one approach to downsize the skin envelope. In other cases, where obesity and breast ptosis are indicators of ischemic complications, devascularization of the central breast skin, primarily the nipple-areolar complex, is used to stimulate collateral circulation and lessen the likelihood of nipple or skin necrosis with second-stage completion mastectomy. The placement of incisions is radial-lateral, inframammary fold, or vertical in lower half of the breast. Sometimes, they may be extended around part of the areolar edge.

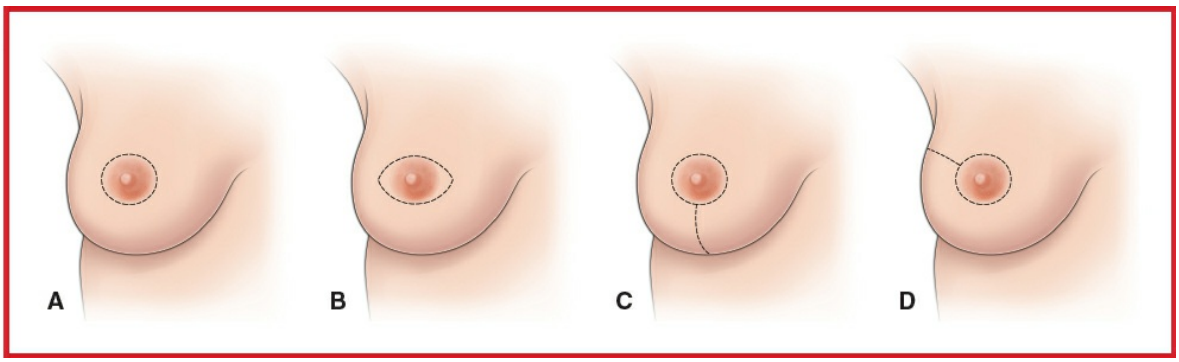

Figure 7.10-3 Examples of skin and nipple-sparring incisions.

Postmastectomy reconstruction is an option for most women undergoing mastectomy. Patients undergoing mastectomy are generally presented with two options for breast reconstruction, that is, implant-based versus autologous reconstruction. Additionally, the issue of timing is discussed, that is, immediate versus delayed reconstruction.

Today, most women opting for postmastectomy reconstruction undergo **immediate reconstruction**. The benefit of immediate reconstruction, particularly in cases of skin- and nipple-sparing mastectomy, is that optimal reconstructive outcomes can be achieved without the patient having to experience the psychological trauma of iatrogenic amastia.

Both reconstructive options have distinct advantages and disadvantages. Implant-based reconstruction is characterized by technical simplicity and absent donor-site morbidity. However, the most commonly chosen approach, that is, 2-stage expander-implant reconstruction, necessitates a period of expansion that separates two surgical procedures. The first stage occurs at the time of mastectomy. Here, a tissue expander is placed either in the submuscular, subpectoral (dual-plane), or prepectoral plane. The advantages and disadvantages of each plane are beyond the scope of this chapter. Of note, the majority of surgeons today use acellular dermal matrices when using the dual-plane or prepectoral approach to optimize outcomes. At the second stage, the tissue expander is removed and the final implant, typically a silicone gel implant, is inserted.

Autologous reconstruction utilizes the patient's tissue for breast reconstruction and as such adheres to the time-honored principle of replacing like with like. Benefits include the ability to recreate a natural breast ptosis as well as absence of implant-related complications (e.g., capsular contracture, or implant malposition.). It is noteworthy that long-term patient satisfaction has been demonstrated to be higher with autologous versus implant-based reconstruction. The most common donor site is the abdomen. However, alternative donor sites include the thighs and buttocks. Advances in surgical technique have resulted in flap survival rates of 98–99% at microsurgical centers. Hence, over the past four decades, focus has shifted away from flap survival rates and toward donor-

site morbidity. This shift is best exemplified when analyzing the various techniques that allow transfer of abdominal tissue. While pedicled transverse rectus abdominis myocutaneous flaps were popular in the 1980s, the development of perforator-based techniques that spare the rectus abdominis muscle entirely (i.e., deep inferior epigastric artery perforator [DIEP] flaps) is considered the gold standard today.

It is important to consider the effects of radiation on postoperative outcome. Radiation is associated with a marked increase of implant-related complications, which is why many surgeons advise against implant-based reconstruction in these cases. However, radiotherapy following autologous reconstruction can likewise be associated with untoward sequelae, including flap fibrosis, and volume loss. Hence, the issue of radiation needs to be taken into account when deciding on the reconstructive plan. An elegant approach in patients who are known to require postmastectomy radiotherapy is a delayed immediate approach. Here, a tissue expander is placed at the time of mastectomy. Subsequent expansion maximizes preservation of native breast skin. The patient then proceeds with radiotherapy. Approximately 6 mo post radiotherapy, the tissue expander is removed and autologous reconstruction performed. The key principle is that preserving native breast skin leads to a better reconstructive outcome.

Usual preop diagnosis

Invasive or in situ breast cancer; high-risk patients (e.g., genetic susceptibility to breast cancer; family history of breast cancer)

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, physiotherapy plan, and possibility of urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Modified Radical Mastectomy	Total Mastectomy	Lumpectomy, Axillary Lymph Node Dissection
Position	Supine with ipsilateral arm abducted and may be prepped on field. Avoid brachial plexus stretch. Repositioning may be	⇐	⇐

	required (latissimus dorsi reconstruction).		
Incision	Elliptical oblique or elliptical transverse to include nipple/areola and previous biopsy; periareolar, or "tennis racquet."	⇐	Incision over breast mass or previous biopsy site. Separate transverse or oblique incision in axilla.
Unique considerations	Avoid iv and BP cuff on ipsilateral arm; many surgeons prefer no paralytics during axillary portion of surgery.	⇐	⇐
Antibiotics	Cefazolin 2 g iv	⇐	⇐
Surgical time	1.5–3 h (+1–7 h, if immediate breast reconstruction performed); longer for bilateral surgery	1–2 h (+1–7 h, if immediate breast reconstruction performed)	1–3 h
Closing considerations	Gauze bandage over incision	⇐	⇐
EBL	150–500 mL, depending on whether scalpel or electrocautery is used.	⇐	25–100 mL
Postop care	PACU → 2 d hospitalization	PACU → 1–2 d hospitalization or occasionally → home	PACU → home
Mortality	Rare	⇐	⇐
Morbidity	Lymphedema: 5–30%	⇐	⇐

	(depending on extent of axillary dissection)		
	Seroma: 25%	⇐	⇐
	Infection: 2–10%	⇐	⇐
	Flap necrosis: <5%	⇐	—
	Hematoma: <5%	⇐	<10%
	Injury to axillary neurovascular structures: Rare		
	Pneumothorax: Rare (may occur with attempts to obtain hemostasis of intercostal perforating vessels)	⇐	⇐
Pain score	4–8	4–6	4–8

PATIENT POPULATION CHARACTERISTICS

Age range	20–90 yr (generally >40 yr)
Incidence	Over their lifetime, ~1/8 of American women develop breast cancer. In 2013, according to American Cancer Society, it is estimated that there will be 232,340 new cases of invasive breast cancers in women and 2240 in men; there are also expected to be 64,640 new cases of carcinomas in situ.
Etiology	Unknown in most cases; about 5–10% of female breast cancers and 4–40% of male breast cancers may be related to a gene such as BRCA1 and BRCA2.

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Invasive breast cancer is frequently treated with multiple therapies, including surgery,

radiation therapy, and chemotherapy. Patients often have received neoadjuvant therapy (before surgery) and may include chemotherapy, hormonal therapy, or biologic therapy to induce tumor response before surgery and enable breast conservation. Less than 5% of patients will have distant metastasis at time of diagnosis. In that small group, consider implications of distant spread, typically to the lung, brain, liver, and bone. Consider systemic effects of recent neoadjuvant therapies.

Respiratory	Respiratory compromise can be present if patient has received XRT to the thorax as part of treatment. **Tests:** Consider CXR if pulmonary Sx or signs of disease present. Others as indicated by H&P
Cardiovascular	Cardiac toxicity may occur from chemotherapy for breast cancer. Anthracyclines (e.g., doxorubicin at doses >550 mg/m^2) may cause significant and often irreversible cardiomyopathy. The monoclonal antibody trastuzumab may cause ↓ in LV function that is usually reversible. **Tests:** ECG if age >65 or if cardiac disease or Sx present. Review any relevant cardiac studies. Consider echo if at risk for cardiomyopathy or HF Sxs present.
Neurologic	Breast cancer may metastasize to the CNS and can present with focal neurologic deficits, ↑ ICP, or altered mental status. **Tests:** As indicated by H&P
Hematologic	Look for anemia and thrombocytopenia following chemotherapy. **Tests:** CBC, with differential and Plt count
Laboratory	Others as indicated by H&P
Premedication	Anxiolysis: Consider midazolam 1–2 mg iv. Analgesia: Consider acetaminophen 1000 mg po, gabapentin 300–600 mg po, and/or celecoxib 400 mg po.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of a transversus abdominis plane or thoracic epidural block for postop

	pain management. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA or GA with LMA. Regional anesthesia (PVB) in breast surgery is associated with less PONV, less postop pain, earlier discharge from the hospital, and less chronic incisional pain.

General anesthesia

Induction	Standard induction
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Standard maintenance. The use of muscle relaxants during axillary dissection should be avoided to permit surgical identification of nerves by nerve stimulator or if electrocautery is used in the axilla.
Emergence	Pressure dressings may be applied with the patient anesthetized and "sitting up" at the end of the procedure. Discuss with surgeons whether they intend to apply this type of dressing, to enable appropriate timing of emergence. Consider PONV prophylaxis. Discuss with surgeon local wound infiltration or nerve block (e.g., TAP block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >46 h ago. PONV prophylaxis should include dexamethasone and ondansetron.

Regional anesthesia

Unilateral multiple-level PVB provides satisfactory anesthesia for modified radical mastectomy and lumpectomy with axillary lymph node dissection. A block from T1-T6 is required. Suitable local anesthetics (4–5 mL/level) are 0.5% bupivacaine or 0.5%

ropivacaine with 1:400,000 epinephrine. Sedation is useful during block placement and is continued intraop. (See Anesthetic Considerations for Breast Biopsy.) PVB is contraindicated for the following reasons: (a) patient refusal, (b) local anesthetic allergy, (c) pathology or previous surgery → anatomic distortion of paravertebral space, or (d) infection at sites of injection.

Blood and fluid requirements	EBL 25–500 cc depending on extent of surgery. IV: 18 ga × 1–2 (avoid operative side) BSS @ 3–5 mL/kg/h	See Goal-Directed Fluid Management, p. K-4
Monitoring	Standard monitors	Others as indicated by patient status. BP cuff on arm opposite surgical site or leg
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Pneumothorax	Deep surgical exploration may cause inadvertent pneumothorax; monitor patient for Sx (e.g., ↑ PIP, ↓ $PaCO_2$, asymmetric breath sounds, hemodynamic instability). Dx: CXR. Rx: Chest tube and ↑ FiO_2
Complications 2° PVB	Inadequate block (10%) Pleural puncture Pneumothorax Horner syndrome Inadvertent epidural spread of local anesthetic	

POSTOPERATIVE

Complications	Pneumothorax PONV Psychological trauma	If index of suspicion for pneumothorax is high, maintain oxygenation (100% FiO_2) and ventilation; inform surgeons of the likelihood of the Dx. If patient is hemodynamically stable and not hypoxemic, a portable CXR may aid in diagnosis. Consider multimodal intraoperative prophylaxis based on PONV risk: i.e., ondansetron 4–8 mg, dexamethasone 4–8 mg, propofol infusion, scopolamine patch.
Multimodal pain management	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with epidural analgesia or TAP blocks (see p. K-5) RA PCA	PO/IV analgesics: Consider appropriate combination of acetaminophen 1000 mg po/iv q6h, gabapentin 100–600 mg po tid, ibuprofen 200–800 mg po/iv q6h, celecoxib 200 mg po q12h. Supplemented if necessary with oxycodone 5–10 mg po q6h or hydromorphone 0.2–.05 mg iv for breakthrough pain.
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum may promote return of bowel function.
Tests	Postop portable CXR, if pneumothorax is suspected	

Suggested Readings

1. Andreae MH, Andreae DA: Regional anaesthesia to prevent chronic pain afte surgery: a Cochrane systematic review and meta-analysis. Br J Anaesth 2013; 111(5):711–20.
2. Barton JG: Enhanced recovery pathways in pancreatic surgery. Surg Clin North Am 2016; 96(6):1301–12.
3. Bertoni DM, Nguyen D, Rochlin D, et al: Protecting nipple perfusion b devascularization and surgical delay in patients at risk for ischemic complications during nipple-sparing mastectomies. Ann Surg Oncol 2016; 23(8):2665–72.
4. Greengrass RA, Duclas R: Paravertebral blocks.Int Anesthesiol Clin 2012; 50(1):56–73.
5. Wu J, Buggy D, Fleischmann E, et al: Thoracic paravertebral regional anesthesi improves analgesia after breast cancer surgery: a randomized controlled multicentre clinical trial. Can J Anaesth 2015; 62(3):241–51.

CHAPTER 7.11

Endocrine Surgery

SURGEONS
Hadiza S. Kazaure, MD
Dana T. Lin, MD

ANESTHESIOLOGISTS
Javier Lorenzo, MD
Frederick G. Mihm, MD

EXCISION OF THYROGLOSSAL DUCT CYST

SURGICAL CONSIDERATIONS

Description

Thyroglossal duct cysts typically are located in the midline at or below the hyoid bone (Fig. 7.11-1). Differential diagnoses after initial physical exam include epidermoid cysts or lymph nodes. Cysts should be removed because of an associated high risk of infection with oral flora and a slight (<1%) risk of either squamous cell or papillary thyroid cancer developing in the cyst itself. A transverse skin incision is made over the cyst, and if the cyst was previously infected and sinus tracts through the skin are present; the skin should be removed along with the cyst. The cyst is identified and followed cephalad to the hyoid bone (Fig. 7.11-2). Then, the midportion of the hyoid bone is resected to minimize recurrence. There may be many small tracts associated with the cyst that tend to attenuate beyond the hyoid bone. The base of the tract or tracts is resected up to the level of the floor of the mouth at the foramen cecum and ligated with absorbable suture (**Sistrunk procedure**). The wound is irrigated copiously and closed in layers. The wings of the hyoid bone are not reapproximated.

Usual preop diagnosis

Thyroglossal duct cyst

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol, and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, and postop pain management options. See Appendix K: Enhanced Recovery After Surgery, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine, with neck in hyperextended position
Incision	Transverse skin incision
Unique considerations	Surgeon may request assistance, by placing finger at base of tongue to identify the cephalad extent of the needed dissection.
Antibiotics	Cefazolin 2 g iv
Surgical time	1–1.5 h
Closing considerations	Careful hemostasis. Coughing may be associated with venous congestion and hematoma formation.
EBL	5–10 mL
Mortality	<0.1%
Morbidity	Bleeding: <5% Infection: <5%
Pain score	3–4

PATIENT POPULATION CHARACTERISTICS	
Age range	6 mo to 30 yr (40% present at <10 yr)
Male:Female	1:1
Incidence	~1:3000
Etiology	Persistence of undifferentiated epithelial cells in area of hyoid bone that later become squamous cell epithelium or glandular tissue

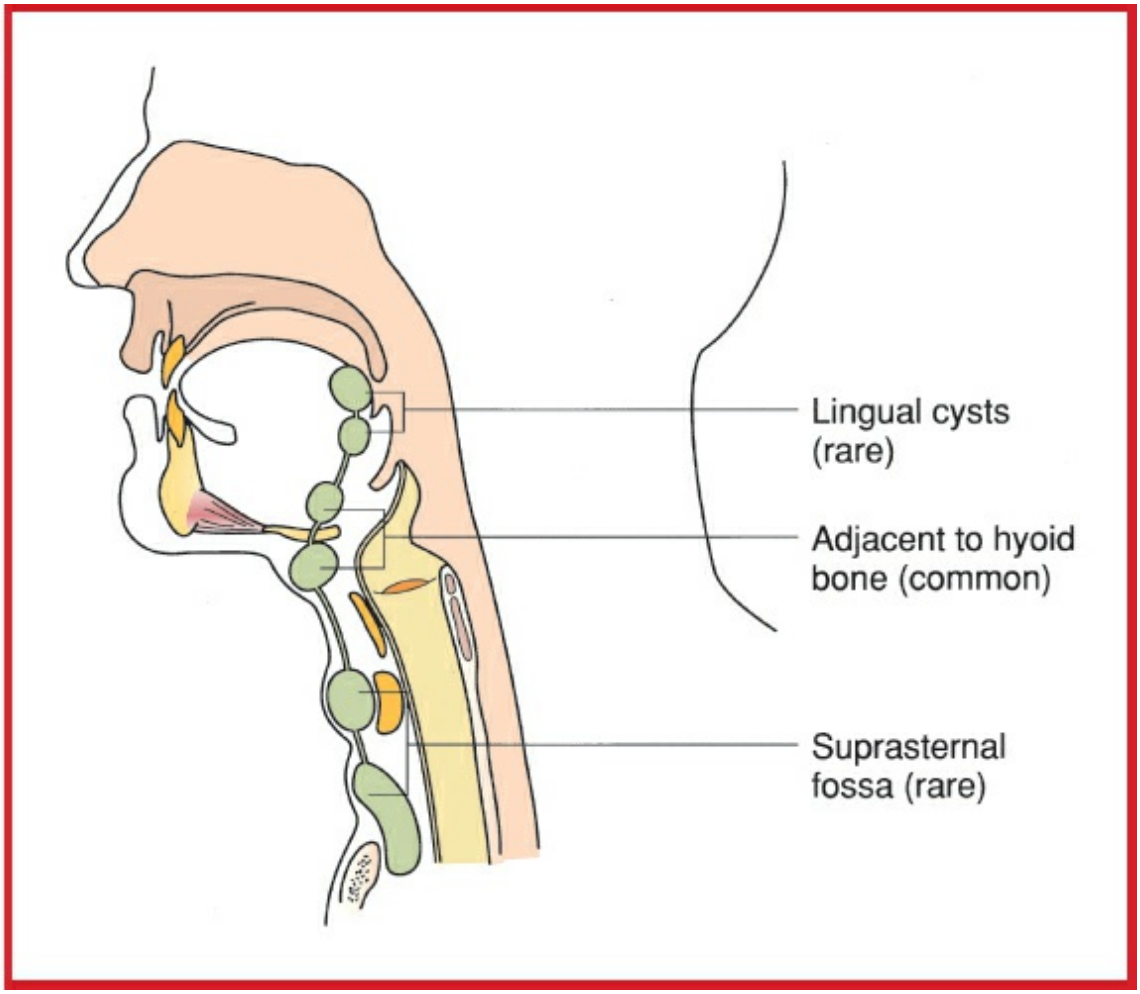

Figure 7.11-1 Location of thyroglossal duct cysts. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al., eds: Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

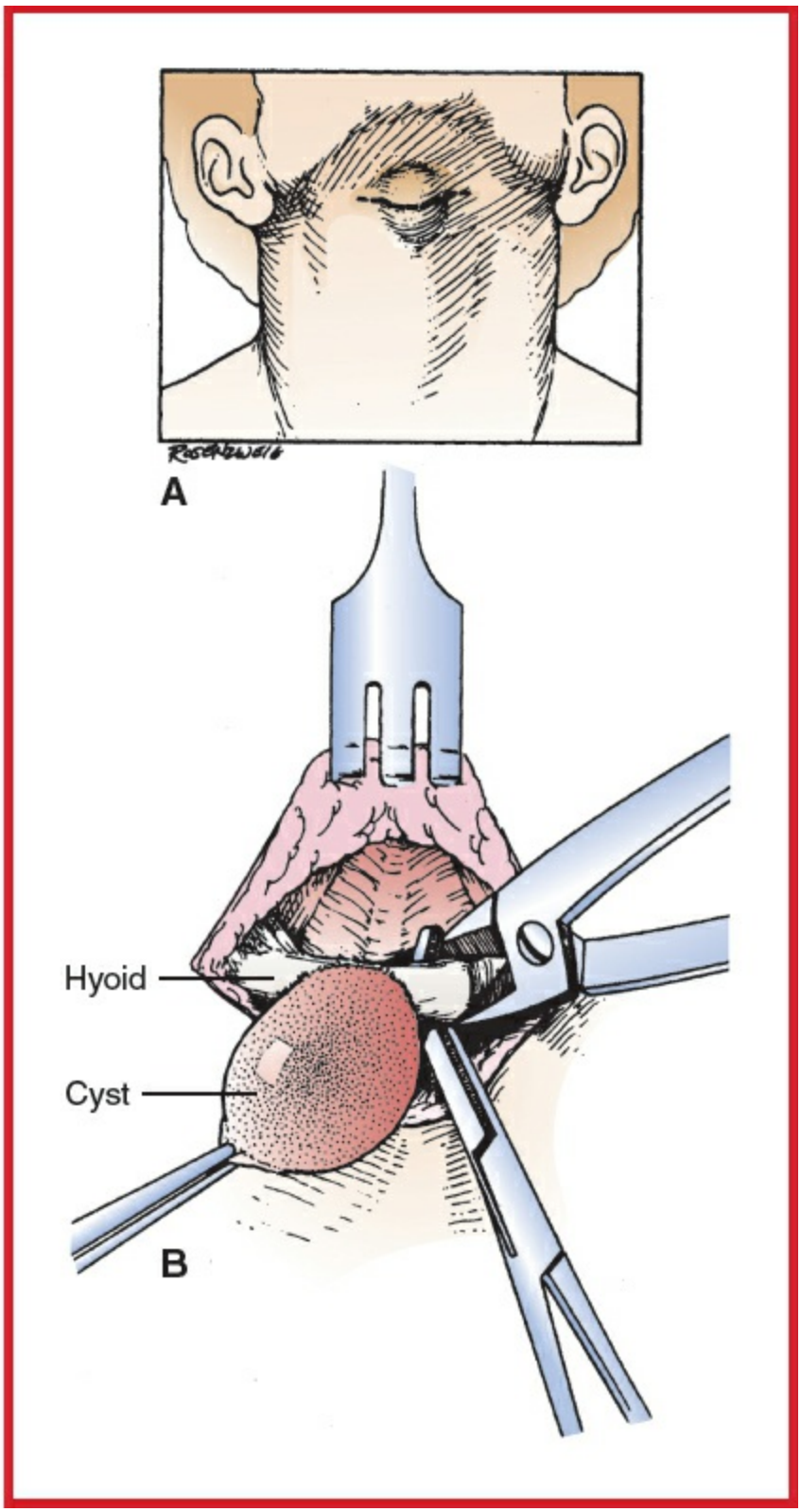

Figure 7.11-2 Thyroglossal duct cyst excision. **A:** Incision placed over presenting cyst; no skin excised. **B:** Cyst has been dissected from surrounding tissues, and hyoid is exposed after division of sternohyoid and thyrohyoid muscles at insertion. The bone is encircled with a short right-angle clamp 1 cm from its midpoint, where it is divided with a bone cutter or cautery. (Reproduced with permission from Baker RJ, Fischer JE: Mastery of Surgery, 4th edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Thyroidectomy, p. 748.

Suggested Readings

1. Oomen KPQ, Modi VK, Maddalozzo J: Thyroglossal duct cyst and ectopic thyroic surgical management. Otolaryngol Clin North Am 2015; 48(1):15–27.
2. Ross J, Manteghi A, Rethy K, et al: Thyroglossal duct cyst surgery: a ten-year singl institution experience. Int J Pediatr Otorhinolaryngol 2017; 101:132–6.

THYROIDECTOMY

SURGICAL CONSIDERATIONS

Description

Thyroidectomy is performed through a transverse neck incision (Fig. 7.11-3), usually 6–8 cm long. In the **traditional approach**, the platysma muscle is divided sharply, and subplatysmal flaps are developed superiorly and inferiorly. The two large anterior jugular veins must be avoided and are occasionally a source of blood loss, although rarely of any hemodynamic significance. Once the flaps are adequately developed, a spring or self-retaining retractor may be placed to expose the midline prethyroid fascia (median raphe). This is divided in the midline to expose the strap muscles, which can then be separated from the thyroid gland.

After the thyroid gland is exposed, resection can proceed. Resection may be total, subtotal (lobe + isthmus ± partial remaining lobe), or lobar. Degree of resection depends on diagnosis and may be modified based on operative findings. During this portion of the operation, hemostasis is critical to maintain adequate visualization. Resection of a lobe usually begins with ligation and division of the middle thyroid vein along the midlateral aspect of the gland (Fig. 7.11-4).

The superior pole is mobilized by controlling and dividing the superior thyroid vessels close to the thyroid capsule to avoid injury to the external branch of the superior laryngeal nerve. As the dissection proceeds, care is taken to identify and preserve the superior and inferior parathyroid glands. The lobe is retracted medially to expose the tracheoesophageal groove. The recurrent laryngeal nerve (RLN) is then visualized and traced along its entire course. Its function may be confirmed using a nerve monitor. The gland is gently dissected away from the nerve and then mobilized off the trachea to

complete the resection. Any enlarged or suspicious lymph nodes are also excised and sent for pathologic examination. Before closing, hemostasis is ensured and can be tested with a Valsalva maneuver. The midline fascia and platysma are closed using absorbable suture and the skin with a running monofilament suture. The use of drains remains controversial and has not been shown to decrease the rate of hematoma formation.

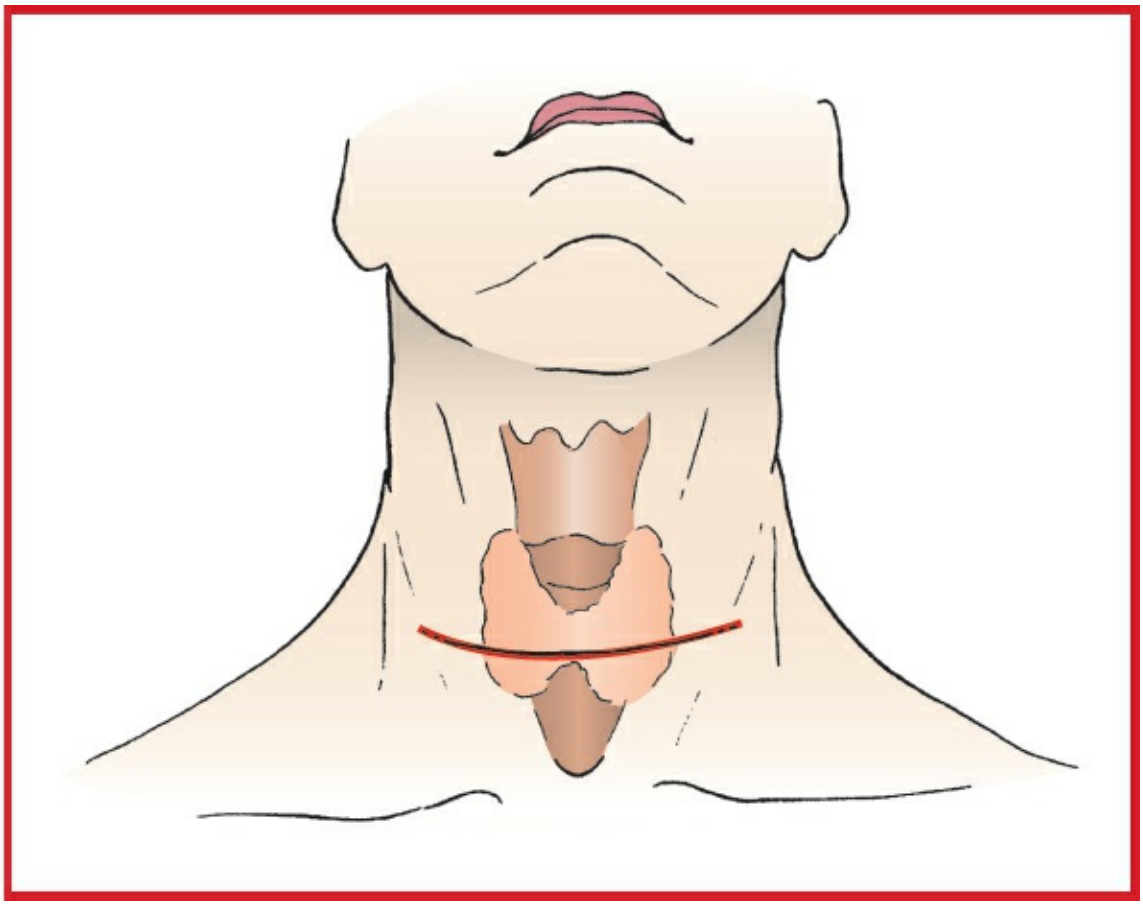

Figure 7.11-3 Transverse incision at base of neck for thyroidectomy. (Reproduced with permission from Baker RJ, Fischer JE:Mastery of Surgery, 4th edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

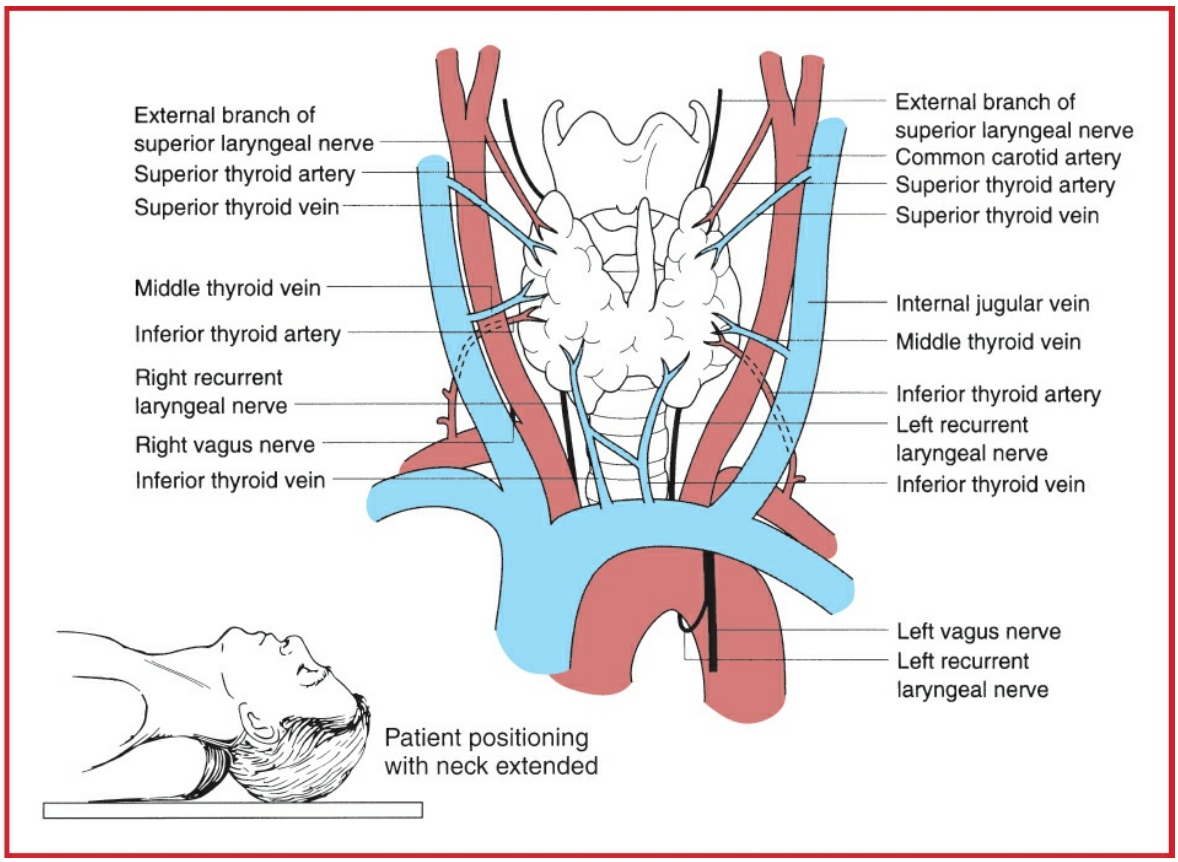

Figure 7.11-4 Vascular relationships to the thyroid gland. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al., eds:Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.) **Inset** shows patient positioning with neck extended.

Minimally invasive techniques, such as video-assisted mini-incision or remote-access thyroidectomy via an endoscopic, transoral, or robotic approach, have been described but have not gained widespread use. Video-assisted thyroidectomy has been shown to have similar rates of cure with superior voice preservation, improved cosmesis, shortened hospitalizations, and faster patient recovery when compared with conventional open surgery. Remote-access procedures have utilized various entry sites to reach the thyroid, namely, the mouth, anterior chest wall, breast, axilla, and postauricular area through a facelift incision. Remote-access surgery avoids the presence of a cervical scar altogether while offering enhanced visualization and dexterity as well as comparable postoperative outcomes. Limitations that have prevented widespread adoption of these minimally invasive approaches include narrow patient selection criteria (based on the nature, size, and extent of thyroid pathology as well as body habitus), surgeon inexperience, lengthy operative time, and higher cost.

Intraoperative nerve monitoring (IONM) is increasingly being used as an adjunct to identify, dissect, and confirm the function of the recurrent laryngeal nerve. Specialized endotracheal tubes are inserted with surface electrodes contacting the luminal surface of

the vocal cords on either side. The electrodes are connected to a monitoring device that continually senses EMG activity of the thyroarytenoid muscles. When the surgeon stimulates the RLN using a probe wired to the monitor, the device detects the electrical impulse from the vocal cords and sounds an audible alert, as well as a visual signal in some systems.

Usual preop diagnosis

FNA findings of definite/suspicious/inconclusive for malignancy; goiter; thyroid cancer (papillary, follicular, medullary, anaplastic); thyroid nodule; hyperthyroidism; Graves disease

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol, and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine with head elevated to 30° and neck extended (see Fig. 7.11-4, **inset**)
Incision	Transverse cervical
Unique considerations	Patients with uncontrolled hyperthyroidism are at ↑ risk for developing thyroid storm during surgery. Hyperthyroidism may be controlled preop with either ß-adrenergic blockade or propylthiouracil. Preop iatrogenic hypothyroidism may be associated with ↓ BP and circulatory collapse during induction of anesthesia.
Antibiotics	None routinely used
Surgical time	1–2 h
Closing considerations	Adequate hemostasis; minimize coughing
EBL	50–75 mL
Postop care	Observe for postop respiratory problems 2° recurrent laryngeal nerve injury (bilateral), hematoma, or ↓ Ca^{++}. Admit × 24 h. ✓ Ca^{++} the night of surgery and the

	following a.m. Same-day surgery is gaining ground, especially for thyroid lobectomy. Patients who undergo total thyroidectomy are often kept overnight to monitor for development of delayed hematoma (16 h) and hypocalcemia.
Mortality	<0.5%
Morbidity	Hypoparathyroidism (↓ Ca^{++}): 3–5% Hematoma: 1–2% Thyroid storm (usually in association with Graves disease) Wound infection: 0.2–0.5% Recurrent laryngeal nerve damage Unilateral (hoarseness): 0.77% Bilateral (aphonia, respiratory obstruction): 0.39%
Pain score	3–4

PATIENT POPULATION CHARACTERISTICS

Age range	15–80 yr
Male:Female	Overall: 1:8 Cancer: papillary (1:2); follicular (1:3); medullary; anaplastic; lymphoma (1:1)
Incidence	Cancer (uncommon) Benign (relatively common)
Etiology	Cancer (50%): papillary (80%); follicular (10%); medullary (5%); anaplastic (1%); lymphoma (1%) Benign lesions (50%): nontoxic goiter (20%); thyrotoxicosis (10%); thyroiditis (5%); benign nodules (5%); other (10%)
Associated conditions	Other endocrine disorders (e.g., pheochromocytoma in association with medullary thyroid carcinoma in patients with MEN 2A and 2B)

ANESTHETIC CONSIDERATIONS

(Procedures covered: excision of thyroglossal duct cyst; thyroidectomy.)

PREOPERATIVE

Hyperthyroidism may be 2° Graves disease (common), toxic multinodular goiter, thyroid adenomas, TSH-secreting tumor (rare), or overdosage of thyroid hormone. Common Sx are fatigue, sweating, intolerance to heat, ↑ appetite, ↑ HR, ↑ BP, ↑ pulse pressure, ↑ T, weight loss or gain, thyroid goiter, and exophthalmos. Some older patients exhibit apathetic thyrotoxicosis, which is often mistaken for hypothyroidism. CHF and AF are common with these patients. Hypothyroidism may be iatrogenic or 2° autoimmune thyroiditis. Common Sx are intolerance to cold, anorexia, fatigue, weight gain or loss, constipation, ↓ HR, ↓ pulse pressure, ↓ DTR, ↓ T, and ↓ mentation. With very few exceptions thyroidectomy is an elective surgery. An important aspect of the preop visit is to ensure that the patient is in a physiologically euthyroid state (normal T, HR, pulse pressure, reflexes). Patients presenting for thyroidectomy usually are made euthyroid before surgery and may be taking one or more of the following medications: propylthiouracil, methimazole, potassium iodide, glucocorticoids, or ß-blockers.

According to the 2016 American Thyroid Association Guidelines, patients undergoing thyroid surgery for hyperthyroidism should receive oral Lugol solution (potassium iodide, SSKI) to block iodine uptake and the secretion of thyroid hormone and should receive a synthesis blocker (propylthiouracil or methimazole) at least 1 h before. Lugol solution may also decrease intraoperative bleeding by decreasing vascularity of the gland. Preoperative vitamin D and calcium supplementation are also recommended for the risk of symptomatic hypocalcemia postoperatively.

General

Although cases have been reported describing total thyroidectomy for noneuthyroid patients with worsening cardiac function who have failed aggressive medical therapy.

Respiratory

Beware of tracheal compression with large goiters, → tracheal deviation, stridor, and intolerance of the supine position.
Tests: CXR; consider preop ultrasound or CT scan of neck to evaluate possible tracheal involvement, especially in patients with large goiters.

Endocrine

	T4	T3ru	T3	TSH
Hyperthyroid	↑	↑	↑	Normal or ↓
1° hypothyroid	↓	↓	↓ or normal	↑
2° hypothyroid	↓	↓	↓	↓

Tests: Thyroid function; Ca^{++}; Mg^{++}; phosphate; alkaline phosphatase; glucose

Hyperthyroidism

Respiratory	↑ BMR → ↑ VO_2 → rapid desaturation on induction
Cardiovascular	↑ HR, AF (10–40% incidence), palpitations, CHF. A normal resting HR helps determine whether the patient is ready for surgery. If the situation calls for it (e.g., emergency surgery), the patient can be treated with ß-blockers to blunt the sympathomimetic effects of the hyperthyroid state. ß-blocker therapy can be problematic in patients with CHF (titrate while monitoring filling pressures and CO). **Tests:** ECG; consider preoperative ECHO for evaluation of LV function.
Neurologic	Warm, moist skin, nervousness, anxiety (may require generous sedation), tremor, ↑ DTRs
Musculoskeletal	Higher incidence of myasthenia gravis and skeletal muscle weakness (↑ sensitivity to muscle relaxants), clubbing of the fingers, weight loss, myopathy **Tests:** CK, urine myoglobin, BMP
Hematologic	Mild anemia, thrombocytopenia **Tests:** CBC
Gastrointestinal	Weight loss and diarrhea **Tests:** BMP + others as indicated from H&P
Laboratory	Other tests as indicated from H&P
Premedication	Midazolam 1–2 mg iv. Continue antithyroid medications preop. Hyperthyroid patients must be made euthyroid before **elective** surgery and may be on the following drugs: propylthiouracil, methimazole, potassium iodide, ß-blockers, and glucocorticoids.
ERAS	Check compliance with preop ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.
Thyroid storm	A life-threatening exacerbation of hyperthyroidism

	occurring during periods of stress, which is manifested by hyperthermia (>40°C), tachycardia, widened pulse pressure, anxiety, altered mental state → psychosis → coma, and myopathy (rhabdomyolysis in 50%; severe in 4%). (Thyroid storm has been mistaken intraop for malignant hyperthermia, sepsis, anaphylaxis, and other hypermetabolic reactions, e.g., neuroleptic malignant syndrome.) Thyroid storm is most often associated with Graves disease that has been incompletely treated before surgery. **General Rx:** ↑ FiO_2; fluid resuscitation; electrolyte replacement/correction (↑ Ca^{++}); cooling blankets; acetaminophen; maintain diuresis (**maintain euvolemia**) if rhabdomyolysis; treat precipitating event (infection, CHF, DKA, pregnancy). **Specific Rx:** propylthiouracil (block synthesis) (200–250 mg po q4h); sodium iodide (block release; 1–2.5 g iv); steroids (mechanism unclear)—hydrocortisone (100 mg iv q8h), or dexamethasone (4 mg iv q24h); ß-blockers (use with caution in patients with reactive airway disease, AV block, or CHF)—propranolol (20–120 mg po qh or 0.25–1.0 mg iv q5min), and/or esmolol (50–300 mcg/kg/min). Note: Block synthesis **before** (1 h is adequate) giving iodides to block release, otherwise "iodine escape" will occur later.

Hypothyroidism

Respiratory	Beware of tracheal compression with large goiters → tracheal deviation, stridor. ↓ ventilatory response to ↑ CO_2 and ↓ O_2 (caution with opioids and sedatives). **Tests:** CXR; consider preop CT scan of the neck to evaluate possible tracheal involvement, especially in patients with large goiters.
Cardiovascular	Bradydysrhythmias, diastolic HTN, pericardial effusions, ECG → ↓ voltage, ST-T wave Δ's, ↑ QT, occasional VT (Torsades de pointes—pause-

	dependent). This type of VT is treated with $MgSO_4$, cardioversion; then isoproterenol or pacing to shorten QT. Thyroid replacement must be weighed against the risk of precipitating myocardial ischemia in patients with known CAD. Diastolic dysfunction, ↓ LV compliance → **cautious** volume expansion. **Tests:** ECG; consider preop ECHO for evaluation of LV systolic/diastolic function, pericardial effusion/tamponade.
Endocrine	Addison disease occurs in 5–10% of patients with severe hypothyroidism; some patients may receive a "stress dose" of steroids (hydrocortisone 100 mg iv q8h × 3) in the periop period. **Tests:** Cortisol stimulation test
Neurologic	↓ BMR → slow mentation and movement, cold intolerance, ↓ reflexes with "hang up" (delayed relaxation phase)
Musculoskeletal	Arthralgias and myalgias
Renal	Impaired renal function 2° amyloidosis, urinary retention, oliguria. (50% incidence of ↓ Na^+) **Tests:** Consider BUN; Cr; Na^+
Hematologic	Coagulation abnormalities, anemia **Tests:** CBC
Gastrointestinal	GI bleeding, constipation, ileus **Tests:** As indicated from H&P
Laboratory	Other tests as indicated from H&P
Premedication	Midazolam 1–2 mg iv. (None in the patient who is clinically hypothyroid and requires emergent surgery.) Hypothyroid patients can safely undergo anesthesia/surgery if they have mild-to-moderate disease. Clinically hypothyroid patients (↓ HR, ↓ T, ↓ pulse pressure, ↓ DTRs) should be given thyroid replacement before elective surgery.
ERAS	Check compliance with preop ERAS recommendations (see above) including NPO status. Consider preop

	acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.
Myxedema comma	Severe hypothyroidism constituting a medical emergency, with mortality of >50%. Manifestations include stupor or coma, hypothermia (which correlates inversely with mortality), hypoventilation with hypoxemia, bradycardia (HR 50–60), hypotension, apathy, hoarseness, and hyponatremia. **Supportive measures:** early intubation and mechanical ventilation; treat ↓ BP with **cautious** volume expansion (risk of pulmonary edema), inotropes (risk of arrhythmias), pacing (carefully, 60–70 b/min), and r/o pericardial effusion, passive rewarming only, especially if ↓ BP (active warming for T < 30°C); correct ↓ Na^+ carefully (risk of central pontine myelinolysis); correct ↓ glucose. **Specific Rx:** L-thyroxine (T_4; 200–500 mcg iv loading dose, 100–300 mcg iv the next day); or tri-iodothyronine (T_3; 20–50 mcg iv q6–12h); hydrocortisone (100–300 mg iv q d). T_4 onset is slow (6 h after iv administration) and has to be converted peripherally (slowed in hypothyroid state) to biologically active T_3. Also, T_4 may be converted in some critically ill patients to biologically inactive rT_3 ("reverse T_3"). ↓ TSH level is the earliest sign of response.

INTRAOPERATIVE

Anesthetic technique

Normally GETA, infrequently under local anesthesia. If using IONM, insert th specialized endotracheal tube, preferably with the aid of a video laryngoscope, and ensure direct contact of the electrodes with the vocal cords on either side. A short-acting, nondepolarizing paralytic may be given to allow for full relaxation during intubation. For inadequately treated hyperthyroid patients, it is key to establish an adequate depth of anesthesia to prevent an exaggerated sympathetic response to surgical stimulation. Avoid agents that stimulate the sympathetic nervous system (e.g., ketamine, pancuronium, meperidine). Hypothyroidism may be associated with ↑

sensitivity to anesthetic agents and muscle relaxants.

Induction	Standard induction for euthyroid patients. If the patient has airway compromise 2° a large thyroid goiter, consider awake fiberoptic intubation. If using IONM, intubation via a video laryngoscope allows the anesthesiologist and surgeon to visualize and confirm the position of the ETT electrodes in relation to the vocal cords.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance. Maintain muscle relaxation, except if using IONM (avoid paralytic agents). Use nerve stimulation to guide relaxant dosing.	
Emergence	Airway obstruction 2° recurrent laryngeal nerve damage, tracheomalacia (especially in patients with large destructive goiters), or hematoma can occur. Consider visualizing vocal cord function before extubation. Discuss with surgeon local wound infiltration. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Minimal blood loss IV: 18 ga × 1 BSS @ 5–8 mL/kg/h Head-up position	Slight head-up position can help make for a bloodless surgical field without substantially increasing the risk of VAE. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors EMG ETT for IONM (e.g., NIM TriVantage®)	+ Others as indicated by patient's status (i.e., pulmonary artery catheter in the setting of emergent surgery in thyrotoxic patients with congestive heart failure). **Maintain normothermia,** especially in hypothyroid

		patients.
Positioning	✓ pad pressure points ✓ eyes	Supine, with head slightly hyperextended allows for surgical exploration of the neck.
Complications	Cardiorespiratory depression	In hypothyroid patients, marked ↓ BP and ↓ RR may occur with minimal anesthetic doses.

POSTOPERATIVE

Complications	Recurrent laryngeal nerve damage	Bilateral: patient will be unable to speak and will require reintubation. CPAP may temporize situation and make reintubation less emergent. Unilateral: characterized by hoarseness.
	Tracheomalacia or hematoma with airway compromise	Acute airway obstruction may occur immediately postop, and rapid reintubation may be lifesaving. If airway compromise is 2° hematoma, reopen incision and drain remaining blood; if patient still requires artificial airway, consider CPAP or awake reintubation.
	Acute hypoparathyroid state (hypocalcemia)	Acute hypocalcemia can present as laryngeal stridor (24–48 h postop), although it most often presents with tingling in the fingertips and lips. If untreated and severe, this can progress to tetany and seizures. Administering 1

		amp Ca^{++} gluconate given iv over 20 min usually alleviates symptoms. Rx: measure Ca^{++}; replace if necessary. CPAP is effective for airway compromise.
	Thyroid storm	Can mimic MH (see Rx above).
Multimodal pain management	PCA hydromorphone or fentanyl Oral narcotic analgesics	Emphasize nonopioid analgesics, including acetaminophen and NSAIDs (see Appendix K, p. K-5).
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition and mobilization. Consider DVT prophylaxis.
Tests	Vocal cord function	Ability to phonate "e" implies continued vocal cord function.

Suggested Readings

1. Abbas G, Dubner S, Heller KS: Re-operation for bleeding after thyroidectomy and parathyroidectomy. Head Neck 2001; 23(7):544–6.
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5. Ross DS, Burch HB, Cooper DS, et al: 2016 American Thyroid Associatio Guidelines for diagnosis and management of hyperthyroidism and other causes of thyrotoxicosis. Thyroid 2016; 26(10):1343–421.
6. Scotto L, Citron L, Mihm FG, et al: Airway ultrasonography and its clinica application to airway management. In: Orloff LA, ed.Head and Neck Ultrasonography, 2nd Edition. Plural Publishing, Inc., San Diego: 2017, 283–304.
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PARATHYROIDECTOMY

SURGICAL CONSIDERATIONS

Description

The traditional approach for primary hyperparathyroidism requires **four-gland visualization** with removal of any abnormally large glands. Newer methods of localization and confirmation of adenomas have ushered in an era of **minimally invasive parathyroid surgery**. Minimally invasive techniques involve a focused operative dissection via **mini-incision, endoscopic, or robotic approach**. **Focused parathyroidectomy** is aided by the preop localization studies, the mainstays of which are ultrasound and sestamibi scanning. If localization fails to identify the correct gland, then the minimally invasive approach is converted to the standard incision, and all four glands are explored until the diseased gland is identified.

For the standard open operation, an incision in the lower neck (Fig. 7.11-5) is made, and the platysma is divided. Subplatysmal flaps are created superiorly and inferiorly to allow for increased working space and to expose the prethyroid fascia. The midline between the strap muscles is opened, exposing the thyroid gland. The superior parathyroids are located behind the upper pole, which may be mobilized to reveal the parathyroid. The inferior glands are located near the junction of the inferior thyroid artery and the recurrent laryngeal nerve (Fig. 7.11-6). Hemostasis is crucial to maintaining adequate visualization in the surgical field. In the traditional approach, all four glands are identified and biopsied for confirmation of parathyroid tissue. Abnormal glands are removed. If four-gland hyperplasia is found, which may occur with multiple endocrine neoplasia (MEN) 1 or 2A, secondary or tertiary hyperparathyroidism, then either a 3.5-gland parathyroidectomy or total parathyroidectomy with forearm reimplantation is performed.

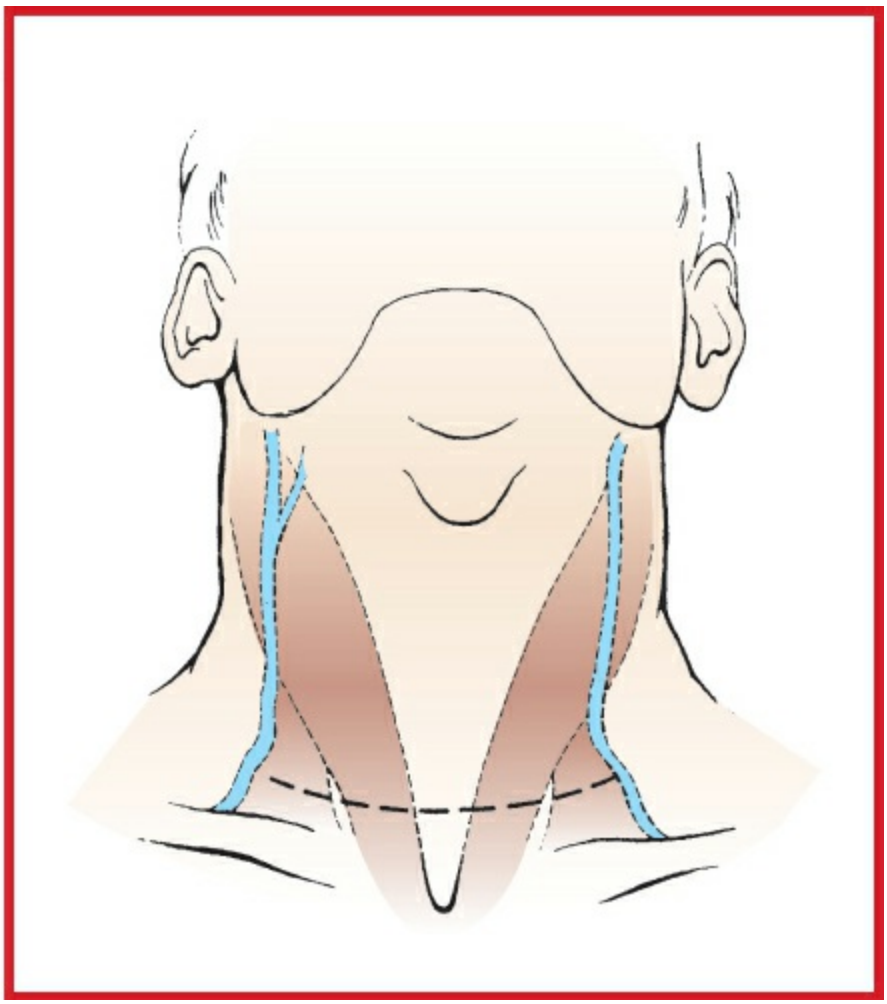

Figure 7.11-5 Skin incision for parathyroid exploration, made 1–2 fingerbreadths superior to sternal notch, as far lateral as the external jugular veins on both sides. (Reproduced with permission from Baker RJ, Fischer JE: Mastery of Surgery, 4th edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

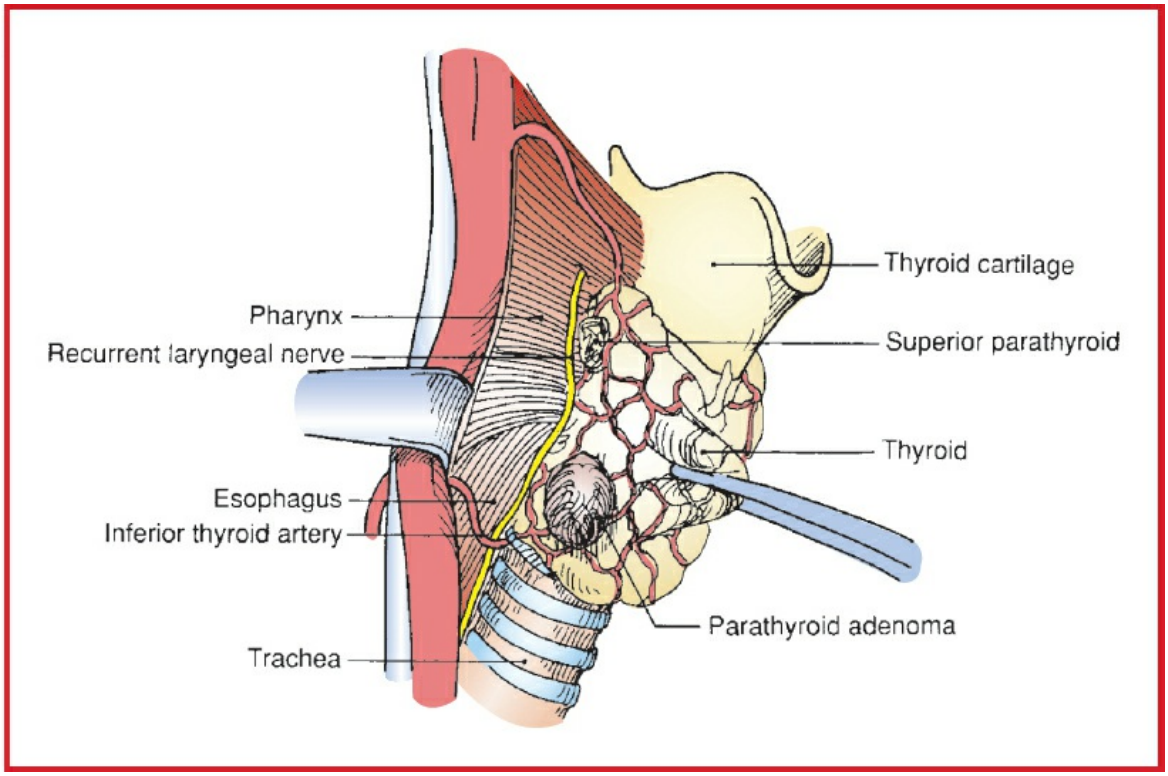

Figure 7.11-6 Identification of upper parathyroid gland on right side. (Reproduced with permission from Scott-Conner CEH, Dawson DLOperative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

With preop imaging studies, dissection may be limited to the area of suspicion, and the abnormal gland or glands are removed. Successful resection is confirmed by observing a 50% decrease in or normalization of the parathormone level 5–10 min after removal, as compared to preop value. This very sensitive assay is rapidly becoming the standard of care in the treatment of primary hyperparathyroidism. The administration of preop methylene blue or radioactive tracers may aid in localizing parathyroid tissue. If the parathyroid adenoma cannot be found, the surgeon should explore other areas of the neck, including the paraesophageal and retroesophageal space, carotid sheath, and thymus. Unilateral thyroid lobectomy may be performed when three normal glands have been found, and the fourth gland is missing, as the adenoma may be within the thyroid substance. Mediastinal exploration should not be done on primary exploration.

IONM can be used during parathyroid surgery to assist in identifying and preserving the recurrent laryngeal nerves. IONM is particularly helpful in the reoperative setting for persistent or recurrent hyperparathyroidism.

Variant procedure or approaches

Variations of minimally invasive parathyroid surgery utilizing endoscopic and robotic techniques have been described. Those involving a mini-incision in the neck include

video-assisted and endoscopic parathyroidectomy. "Scarless" remote-access endoscopic and robotic procedures via extracervical sites are also being performed in select centers. Several studies have demonstrated similar morbidity and cure rates between the video-assisted and traditional approach, with improved visualizations of neck structures, less postop pain, and better cosmetic results. However, cost, lengthy operative time, and surgeon inexperience have limited wide adoption of many of these techniques.

Usual preop diagnosis

Primary hyperparathyroidism due to a single adenoma (most common, 85%), double adenoma, hyperplasia, or carcinoma (very rare, <1%); secondary or tertiary hyperparathyroidism in patients with a history of renal failure.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol, and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine; shoulder roll; reverse Trendelenburg or 30° tilt; headrest (gel donut)
Incision	Transverse cervical (4–8 cm; see Fig. 7.11-5)
Unique considerations	Methylene blue (7.5 mg/kg in 500 mL of NS) may be administered in the preop holding area 30 min before surgery → spurious ↓ SpO_2. Radioactive technetium sestamibi (20 mCi) may be administered 60–90 min before operation. Methylene blue and radioactive tracers may be used independently or simultaneously to aid in identification of parathyroid tissue.
Antibiotics	None routinely used
Surgical time	1–2 h
Closing considerations	Coughing may be associated with venous congestion and hematoma formation.
EBL	25–50 mL
Postop care	Monitor serum Ca^{++} (nl = 8.5–10.5 mg% total Ca; 1–

	1.3 mM ionized Ca^{++}). Patients typically admitted for 24 h observation to check serum Ca^{++} levels and monitor for hematoma/airway compromise.
Mortality	<0.5%
Morbidity	Hypocalcemia: <15% Hypoparathyroidism: <5% Hematoma: 1% Infection: 1% Recurrent laryngeal paralysis: <1%
Pain score	3–4

PATIENT POPULATION CHARACTERISTICS

Age range	Increases with age
Male:Female	4:1
Incidence	50–100/100,000 (1.5/100 in elderly)
Etiology	Single adenoma (85%); double adenoma (2–3%); hyperplasia (10–15%); cancer (<1%)
Associated conditions	Bone disease (5–15%); duodenal ulcer (5–10%); renal calculi (60–70%); MEN-1 (parathyroid + hyperplasia + pituitary adenoma + pancreatic neuroendocrine tumor); MEN-2A (parathyroid hyperplasia + medullary thyroid cancer + pheochromocytoma); HTN (20–50%)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

These patients typically present with hypercalcemia (hyperparathyroidism), which must be controlled before surgery. Although 25–50% of cases are asymptomatic, many will present with a variety of Sx, including fatigue, muscle weakness, depression, anorexia, nausea, constipation, abdominal and bone pain, HTN, renal stones, polydipsia, muscle cramps, bronchospasm, and anxiety. Differential diagnosis for the hypercalcemic patient includes metastatic disease, multiple myeloma, milk-alkali syndrome, vitamin D intoxication, sarcoidosis, hyperthyroidism, thiazide diuretics, adrenal insufficiency, Paget disease, immobilization, or an exogenous parathyroid hormone-producing tumor.

Respiratory	Hyperparathyroidism is associated with ↓ clearance of secretions from the tracheobronchial tree → postop atelectasis. Avoid respiratory or metabolic acidosis, which will ↑ the free fraction of Ca^{++} → hypercalcemia (↑ BP, ↑ muscle weakness, ↑ HR). **Tests:** As indicated from H&P
Airway	Hyperparathyroidism and thyroid nodules often coexist. Being aware of their presence, size, extension, and effect on the airway is crucial for airway management (Eur J Anaesthesiol 2008; 25(9):772–4).
Cardiovascular	HTN (usually resolves with treatment; if severe or episodic, r/o pheochromocytoma); ECG may show tachycardia with ↓ PR and ↓ QT intervals. Patients may be hypovolemic (2° anorexia, N/V, and polyuria) and have ↑ sensitivity to digitalis + resistance to catecholamines. ↓ BP may result from polyuria → hypovolemia. **Preop management** includes correction of intravascular volume and electrolyte abnormalities. Preop treatment of hypercalcemia includes aggressive expansion of intravascular volume, followed by diuresis (**maintain euvolemia**), to ↑ renal Ca^{++} excretion, usually accomplished with iv NS, and then furosemide. Calcium channel blockers (verapamil, nifedipine, diltiazem) can be used. Hypophosphatemia can impair myocardial contractility and should be corrected; hemodialysis or peritoneal dialysis can be performed to lower dangerously elevated serum Ca^{++} levels. Mithramycin, calcitonin, bisphosphonates, cisplatin, or steroids are not useful for acute Rx of ↑ Ca^{++} (too slow). **Tests:** ECG; electrolytes; others as indicated from H&P
Neurologic	Patient may present with seizures, hyporeflexia, mental status changes (somnolence, depression,

	memory loss, psychosis, coma), or peripheral neuropathy. Significant improvement often follows correction of hypercalcemia.
Musculoskeletal	These patients may have muscle atrophy and weakness, osteopenia, arthralgia, pathologic fractures (take care during laryngoscopy and positioning), and osteitis fibrosa cystica. Response to NMBs may be enhanced 2° ↑ Ca^{++} → muscle weakness.
Hematologic	Patients also tend to be hypophosphatemic and may show signs of hemolysis, plt dysfunction, impaired ventricular contractility, and leukocyte dysfunction. **Tests:** CBC with Plt count, PO_4^{-2}
Endocrine	Primary hyperparathyroidism is most commonly due to benign parathyroid adenoma (90%) or hyperplasia (9%) and rarely carcinoma. It may be associated with MEN syndrome. MEN-1 consists of tumors of the pituitary, parathyroid, and pancreatic islets; MEN-2 is characterized by parathyroid tumors, medullary thyroid carcinoma, pheochromocytoma, and mucosal neuromas. *__NB: Anesthetizing a patient with an unrecognized pheochromocytoma could result in a fatality.__ **Tests:** As indicated from H&P
Renal	Patients may have renal dysfunction 2° nephrolithiasis, nephrocalcinosis, renal tubular disorders, and glomerular disorders. Polyuria 2° ↑ Ca^{++} → electrolyte disturbances. **Tests:** BMP, Mg^{++}
Gastrointestinal	These patients may have constipation, anorexia, N/V, and epigastric pain.
Laboratory	Symptoms not related as well to absolute Ca^{++} level but to rate of change. Serum Ca^{++} <12 mg/dL, likely asymptomatic; 12–14 mg/dL, mild symptoms; >16 mg/dL, life-threatening. Albumin (↑ albumin by 1 g/dL will ↑ total serum Ca^{++} by 0.8 mg/dL); electrolytes; Mg^{++}; phosphate (usually low).

Premedication	All medications to lower hypercalcemia should be continued unless Ca^{++} levels have normalized. Often, this strategy includes a combination of hydration and diuresis to increase urinary secretion of calcium. If patient has been treated with steroids in the preop period, administer a stress dose (hydrocortisone 100 mg iv q8h × 24 h) before induction of anesthesia and continue into the early postop period. Standard premedications are usually appropriate in this patient group, unless patient has mental status changes.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA, with head slightly hyperextended, allows for adequate exposure of the neck. Cervical plexus blocks may be appropriate in selected patients; however, phrenic nerve block → respiratory compromise. For minimally invasive surgery, a superficial cervical block may be as effective as the combination of a superficial/deep block.

Induction	Standard induction. If patient is clinically hypovolemic, restore intravascular volume before induction, and titrate induction dose of sedative/hypnotic agents. If using IONM, insert specialized ETT (CMAC helpful), and ensure direct contact of the electrodes with the vocal cords on either side. A short-acting, nondepolarizing paralytic may be used to facilitate intubation; however, long-acting neuromuscular blocking agents should be avoided.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of

	nerve blocks.	
Maintenance	Standard maintenance, with muscle relaxant titrated to effect. Avoid hyperventilation or hypoventilation (acidosis will ↑ Ca^{++} levels, while alkalosis will ↓ Ca^{++} levels). Maintain adequate hydration and UO throughout the procedure. There is no evidence to support the avoidance of propofol-based anesthetic (TIVA) for parathyroid surgery.	
Emergence	No special considerations (see Postop Complications, below). Discuss with surgeon local wound infiltration. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Minimal blood loss IV: 18 ga × 1 BSS @ 5–8 mL/kg/h	Avoid Ca^{++} containing iv solution (e.g., LR), use Normosol. Surgeon may request blood samples to be drawn for pre- and postexcision PTH levels. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors ± arterial line	Others as indicated by patient status. Frequent blood samples for PTH are required during a parathyroidectomy. Arterial line is helpful for frequent blood draws.
Positioning	✓ and pad pressure points ✓ eyes	Patients should be positioned carefully as they tend to be osteopenic and are prone to pathologic bone fractures. Slight head-up positions may ↓ blood loss and improve surgical visibility without significantly ↑ risk of VAE.

POSTOPERATIVE

Complications	Hypocalcemia Hypocalcemic tetany	Hypocalcemia may occur in the immediate postop period. Sx include paresthesias, muscle spasm, tetany, laryngospasm, bronchospasm, and apnea. Rx: oral Ca^{++} supplementation; if severe, 10–20 mL Ca^{++} gluconate 10% over 10 min. Follow levels and repeat therapy until the clinical signs of hypocalcemia are controlled. CPAP is effective for airway obstruction.
	Recurrent laryngeal nerve injury Hematoma with airway compromise	Having the patient vocalize the letter "e" can monitor recurrent laryngeal nerve dysfunction. Unilateral vocal cord dysfunction results in hoarseness, whereas bilateral vocal cord dysfunction results in aphonia. CPAP is effective for airway obstruction.
Multimodal pain management	Oral narcotic analgesics	Emphasize nonopioid analgesics, including acetaminophen and NSAIDs (see Appendix K, p. K-5).
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition and mobilization. Consider DVT prophylaxis.
Tests	Serial measurements	The lowest Ca^{++} level usually

	of: Ca^{++} phosphate Mg^{++} others as clinically indicated	is seen after 4–5 d postop. Follow clinical Sx of hypocalcemia: Trousseau sign (carpopedal spasm in response to application of a BP cuff at a pressure > SBP for 3 min); Chvostek sign (contracture of the facial muscles produced by tapping on the facial nerve).

Suggested Readings

1. Betea D, Potorac I, Beckers A: Parathyroid carcinoma: challenges in diagnosis and treatment. Ann Endocrinol (Paris) 2015; 76(2):169–77.
2. Callender GG, Udelsman R: Surgery for primary hyperparathyroidism.Cancer 2014; 120(23):3602–16.
3. Dumitras M, Strambu V, Radu PA, et al: Technical factors involved in parathyroid surgery. Chirurgia (Bucur) 2015; 110(5):425–9.

ADRENALECTOMY

SURGICAL CONSIDERATIONS

Description

Adrenalectomy can be performed by different approaches, each with its own merits. Traditionally, the adrenal glands have been removed with an open incision through either the **transperitoneal** or **extraperitoneal** (flank) approach (Fig. 7.11-8). With some exceptions (see below), **laparoscopic** approaches are becoming the favored methods. Indication in malignant disease or metastasis remains controversial and is currently being evaluated. Relative contraindications include large adrenal adenocarcinomas (>5 cm), malignant pheochromocytoma, invasive adrenal mass, large adrenal mass (>8–10 cm), or other contraindications to abdominal laparoscopic surgery (e.g., multiple previous abdominal surgeries). Each approach is discussed individually, but their underlying principles remain the same. The anatomy of the retroperitoneum is shown in Figure 7.11-7.

Open transperitoneal approach

This approach allows for easy access to both adrenals and is preferred for large tumors.

A midline or bilateral subcostal incision (Fig. 7.11-8) is used, with the patient in the supine position. The left adrenal is accessed by incising the lateral peritoneal attachments of the spleen. The spleen and tail of the pancreas are reflected medially, Gerota fascia is incised, and the upper pole of the kidney is separated from the adrenal gland. The left adrenal vein is identified arising from the renal vein and is ligated and divided between ties or using an endovascular stapler. A combination of blunt and sharp dissection is used to fully mobilize and resect the gland. The right gland is exposed by retracting the liver cephalad and taking down the hepatic flexure inferiorly. The duodenum and pancreas are rotated medially to expose the inferior vena cava (IVC). Downward traction is placed on the right kidney, and the right adrenal vein is identified entering the IVC. The adrenal vein is circumferentially controlled and divided, and the gland is excised.

Open extraperitoneal approach (flank)

Before the advent of laparoscopic surgery, this approach was favored to minimize pain and improve postop recovery of adrenalectomy through the use of a smaller incision and by remaining extraperitoneal. In general, this approach is best used for unilateral, smaller tumors. The patient is placed in the prone jackknife position, and a dorsal curved flank incision is made, exposing the 12th rib. The rib is resected, Gerota fascia is identified and incised, and the adrenal gland is removed.

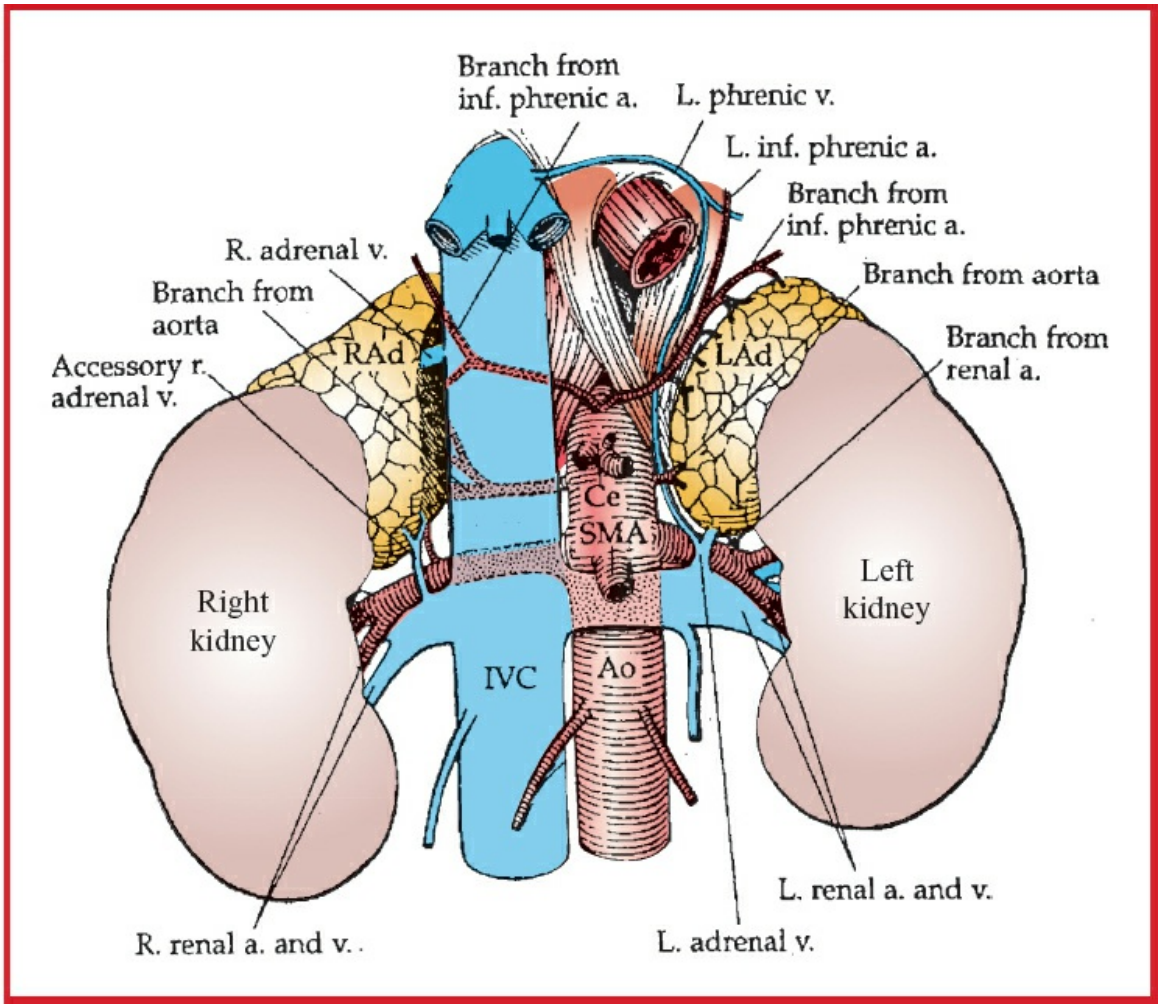

Figure 7.11-7 Anatomic relationships of the adrenal glands. Note the origins of the three main arteries: inferior phrenic, aortic, and renal branches. Note also the single draining veins (except for a small accessory right adrenal vein): the right-located superior and medial and the left-found inferior and medial. (Ao, aorta; Ce, celiac; LAd, left adrenal gland; RAd, right adrenal gland; SMA, superior mesenteric artery.) (Reproduced with permission from Baker RJ, Fischer JEMastery of Surgery, 4th edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Laparoscopic anterior transperitoneal approach

This approach may be used for **bilateral adrenalectomy** with the patient in the supine position. The surgical plan is similar to that of the transabdominal open approach but is associated with longer operating times and additional trocar sites for placement of more retractors to mobilize the intra-abdominal organs.

Laparoscopic lateral transperitoneal approach

This is the preferred approach for adrenalectomy in most centers. The patient is positioned in the lateral decubitus position with the operative site up and is immobilized with a carefully placed beanbag to minimize nerve compression injuries. The patient is prepped for either an open or laparoscopic approach (so that conversion

to an open procedure may be done swiftly, if necessary). When adrenal glands are removed, the right is done because there is a higher risk of converting to an open procedure due to the proximity of the adrenal vein to the IVC.

For **right adrenalectomy**, pneumoperitoneum is established, and four ports are inserted several fingerbreadths below the costal margin between the mid abdomen and midaxillary line (Fig. 7.11-9). Attachments to the right lobe of the liver are divided, and the liver is reflected medially to bring the adrenal and IVC into view. The retroperitoneum is incised too close to the IVC to expose the right adrenal vein, which is carefully isolated, clipped, and divided. Dissection of the gland then proceeds out laterally and up superiorly using a laparoscopic energy device. Once fully mobilized, the gland is removed through a laparoscopic retrieval bag.

The **left adrenal gland** is approached similarly. After placement of the trocars, the lateral splenic attachments are incised, and the spleen and tail of the pancreas are rotated medially to expose the anterior surface of the kidney (Fig. 7.11-10); the inferior and medial edges of the gland are mobilized first, allowing for the left adrenal vein to be identified. After the vein is controlled, the remaining gland is dissected free, and the gland is withdrawn.

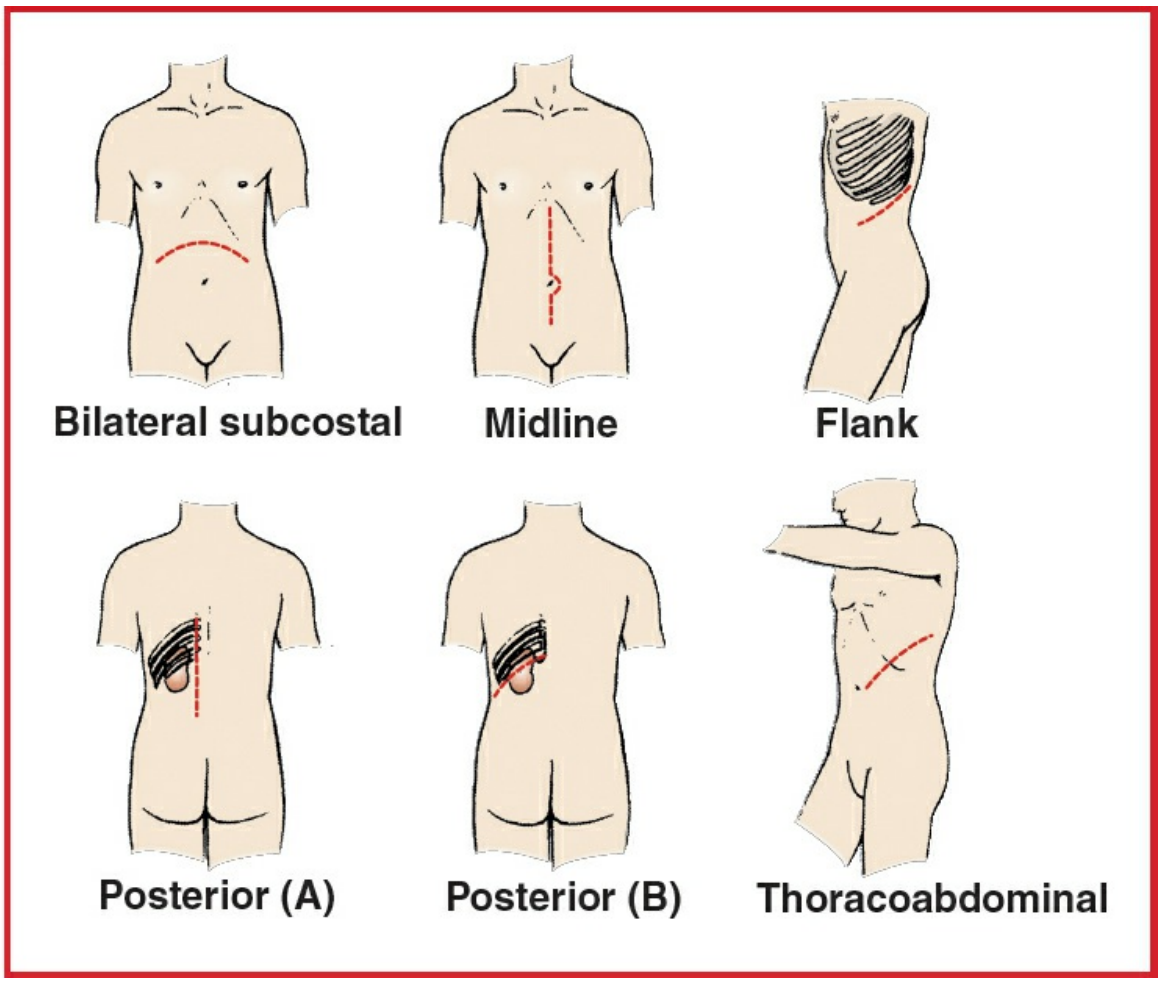

Figure 7.11-8 Potential incisions for adrenalectomy. (Reproduced with permission from Baker RJ, Fischer JE: Mastery of Surgery, 4th edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Laparoscopic retroperitoneal approach

This technique is particularly good for patients who have undergone previous abdominal surgery as it avoids the peritoneal cavity and adhesions altogether. The patient is intubated on the stretcher and positioned prone on the operating table with slight flexion at the hips and knees. Bolsters are placed under the hips and chest to allow space for the abdomen and pannus. Three ports are placed horizontally below the costal margin into the retroperitoneal space. The posterior retroperitoneal plane is developed, separating perinephric and periadrenal fat away from the peritoneum and paraspinous muscles. The inferior border of the adrenal is divided from the superior pole of the kidney, which is rotated inferiorly and medially to help expose the adrenal vein. Medial dissection of the adrenal gland from the paraspinous muscles will reveal the inferior phrenic vein on the left and IVC on the right. These structures further facilitate identification of the adrenal vein, which is ligated and divided with clips or an energy sealant device. Once controlled, the adrenal gland is separated from the filmy attachments to the peritoneum and removed via an extraction bag.

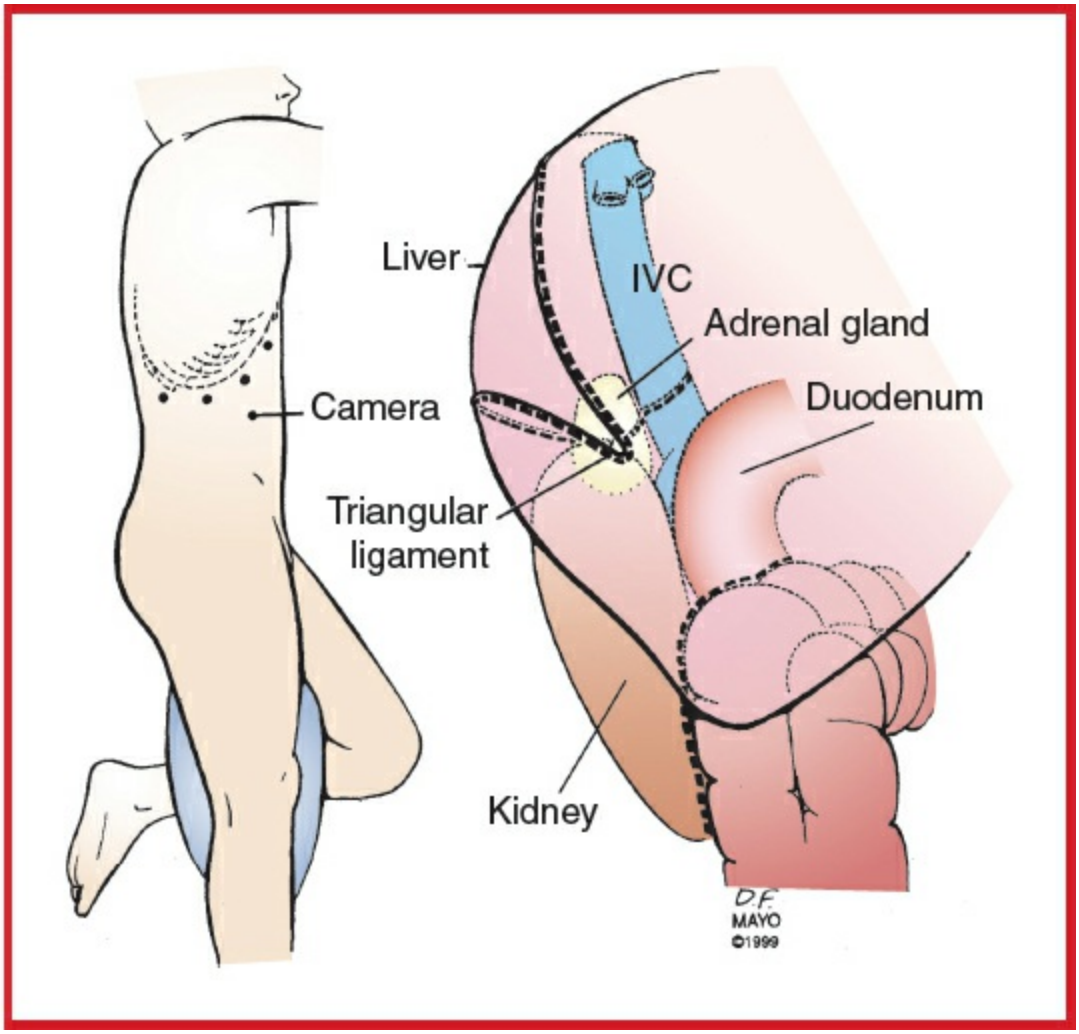

Figure 7.11-9 Port placement for laparoscopic right adrenalectomy. Relevant anatomy is displayed through the right lobe of the liver. (Reproduced with permission from Baker RJ, Fischer JEMastery of Surgery, 4th edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

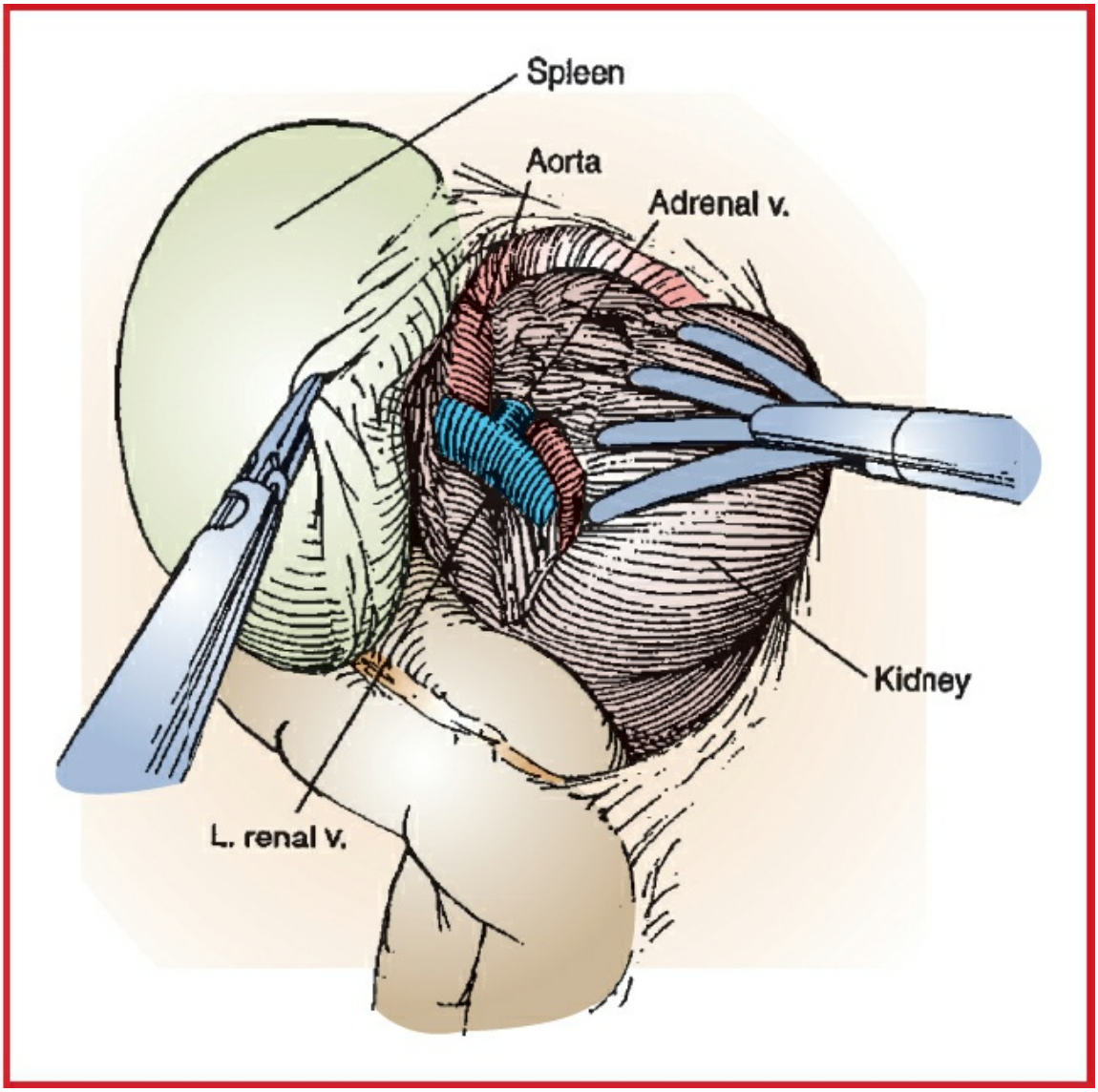

Figure 7.11-10 Exposure of left adrenal after mobilization of the spleen. (Reproduced with permission from Baker RJ, Fischer JEMastery of Surgery, 4th edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Robot-assisted approach

Both **robotic transperitoneal and retroperitoneal adrenalectomy** have been described. Advantages of the robot include a three-dimensional view of the operative field, superior ergonomics, and a stable camera platform. Although patient outcomes have been comparable to that of laparoscopic adrenalectomy, training and cost are significant drawbacks to the approach.

Usual preop diagnosis

Functioning adrenal tumors (i.e., aldosteronoma, pheochromocytoma, cortisol-producing adrenal tumor); nonfunctioning adrenal lesions (i.e., incidentaloma, angiomyolipoma); and solitary adrenal metastasis with otherwise negative metastatic

survey, adrenocortical carcinoma.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPC duration, alcohol, and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Open Adrenalectomy	Laparoscopic Adrenalectomy
Position	Transperitoneal, supine; extraperitoneal, prone jackknife	Transperitoneal anterior, supine; transperitoneal lateral, decubitus; retroperitoneal, prone
Incision	Transperitoneal, midline or bilateral subcostal (Fig. 7.11-8); extraperitoneal, dorsal flank oblique or curved posterior	Transperitoneal anterior, 4–5 trocar incisions (Fig. 7.11-9); transperitoneal lateral, 3–4 trocar incisions; retroperitoneal, 3 trocar incisions
Special instrumentation	Transperitoneal, Denier or Bookwalter retractor; extraperitoneal, none	Transabdominal anterior/lateral; retroperitoneal, video setup
Unique considerations	BP monitoring essential for pheochromocytoma patients	⇐
Antibiotics	Cefazolin 2 g IV	⇐
Surgical time	1–2 h	1–3 h
Closing considerations	Hemostasis; hemodynamic stability	⇐
EBL	100–250 mL	⇐
Postop care	Continue monitoring BP; PACU → ward; ± ICU,	⇐

	based on hemodynamic stability	
Mortality	<0.5%	⇐
Morbidity	Overall: 1–12% Bleeding: <10% Pancreatic fistula: <1% DVT: 0.8% PE: 0.5% Renovascular HTN: <1% Peroneal nerve palsy: <1% Venous thrombosis with embolism (Cushing's): 2%	⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐
Pain score	6–8	5–6

PATIENT POPULATION CHARACTERISTICS

Age range	13–75 yr
Male:Female	1:2.8
Incidence	Pheochromocytoma: 0.4–2% of all hypertensive patients Primary hyperaldosteronism: ~4% of all hypertensive patients Cushing syndrome: 6/1 million
Etiology	Functional cortical adenoma (aldosteronoma, cortisol-secreting tumor), adrenocortical carcinoma, pheochromocytoma (benign or malignant), large nonfunctioning incidentaloma, solitary adrenal metastasis; palliation for persistent Cushing disease, ectopic ACTH syndrome. Idiopathic bilateral hyperplasia is usually treated medically.
Associated conditions	HTN (75–80%); diabetes mellitus (10–15%)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Cushing syndrome

Hyperadrenocorticism can be due to adrenal hyperplasia, adrenal carcinoma, pituitary hypersecretion (Cushing disease), hypersecretion from exogenous tumor, or exogenous steroid administration (most common). Adrenalectomy is the traditional treatment for hyperadrenocorticism 2° adrenal carcinoma. These typically moon-faced patients present with one or more of the following: HTN 2° glucocorticoids, renin (usually not severe); renal calculi; osteoporosis; glucose intolerance; personality changes; and myopathy. In addition, a fragile vasculature predisposes these patients to easy bruising and difficult vascular access.

Respiratory	Patient may be obese with all attendant problems of morbid obesity (see Preoperative Considerations in Operations for Morbid Obesity). **Tests:** As indicated from H&P
Cardiovascular	HTN and hypervolemia due to Na^+ retention, dysrhythmias 2° hypokalemia **Tests:** ECG; orthostatic vital signs; consider ECHO to evaluate LV function, if indicated from H&P
Renal	Excess steroid production → Na^+ retention, K^+ excretion, and insulin intolerance (hyperglycemia) **Tests:** UA; creatinine; glucose; urine concentrations of catecholamine metabolites; others as appropriate
Neurologic	Psychiatric changes, headache
Musculoskeletal	Striae, muscular wasting, buffalo hump, truncal obesity, thin skin, easy bruisability, osteopenia (compression fractures), weakness
Hematologic	Polycythemia
Laboratory	Tests as indicated from H&P
Premedication	Midazolam (1–2 mg iv), consider withholding if morbidly obese
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip

	of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

Conn syndrome

Hyperaldosteronism can be primary (Conn syndrome–adrenal adenoma or hyperplasia) or secondary (caused by excess renin secretion related to renal dysfunction). These patients are typically hypokalemic and alkalotic → muscle weakness, paresthesias, tetany, and polyuria. They may also be hypervolemic → CHF, hypernatremic, and hypertensive (diastolic).

Respiratory	Respiratory muscle weakness. **Tests:** As indicated from H&P
Cardiovascular	HTN, dysrhythmias, T wave, + U wave **Tests**: ECG; orthostatic vital signs; consider ECHO to evaluate LV function, if indicated from H&P
Renal	Renal HTN, polyuria, polydipsia, ↓ K, ↑ Na. Correction of hypokalemia requires >24 h supplemental K infusion (e.g., 5–20 mEq/h). **Tests:** UA; creatinine; glucose; urine concentrations of catecholamine metabolites; others as appropriate
Musculoskeletal	Conn syndrome: muscle weakness, tetany, sensitivity to muscle relaxants, osteoporosis
Laboratory	Tests as indicated from H&P
Premedication	Spironolactone often given to inhibit excess aldosterone effects. Midazolam (1–2 mg iv); hydrocortisone 100 mg q8h.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA (± **epidural for postop analgesia).** If postop epidural analgesia is planned, placement of catheter before anesthetic induction is helpful to establish correct placement in the epidural space and ensuring a bilateral block (accomplished by placing 5–7 mL of 1% lidocaine via the epidural and eliciting a segmental block). Epidurals cannot be used for a posterior approach because they are in the operative field.

Induction	Gentle iv induction and muscle relaxation. The patient should be adequately anesthetized before to any stimulation. Unopposed parasympathetic response to laryngoscopy may → bradycardia/asystole.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Volatile anesthetic (sevoflurane), opiate, muscle relaxant. N_2O may cause bowel distention. Local anesthetic (2% lidocaine 3–5 mL q60min) can be injected into the epidural catheter to provide both anesthesia and optimal surgical exposure (contracted bowel and profound muscle relaxation). A continuous infusion of local anesthetic (e.g., 2% lidocaine or 0.25% bupivacaine) at 3–5 mL/h may enhance hemodynamic stability. Some anesthesiologists will not use the epidural catheter intraop because chemical "sympathectomy" is more difficult to reverse. If epidural opiates are used for postop analgesia, a loading dose (e.g., hydromorphone 0.4–1.0 mg) should be administered at least 1 h before the conclusion of surgery. Systemic sedatives (opiates and benzodiazepines) should be minimized during this type of anesthetic as they increase the likelihood of postop respiratory depression.
Emergence	Depends on ease of the surgical procedure and the hemodynamic stability of the patient intraop. If patient is hemodynamically unstable, hypothermic, or has a large third-space fluid requirement consider

	postop ventilation. Discuss with surgeon local wound infiltration. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Anticipate large fluid loss. IV: 14–16 ga × 2 BSS @ 10–15 mL/kg/h Warm all fluids. ± Cell saver central line	As blood loss can be significant, blood should be immediately available. If procedure does not involve cancer, cell-saving devices can be utilized. Guide fluid management by EBL, known volume deficits, UO, and filling pressures/CO if available. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors UO	Others as clinically indicated. Forced air warmer useful for maintaining body temperature.
Complications	Labile HTN	Surgical manipulation of the adrenal may cause ↑↑ BP and dysrhythmias. Rx: Alert surgeon and control BP with esmolol/SNP/clevidipine
Positioning	✓ and pad pressure points ✓ eyes	Strict attention to patient positioning, padding, and taping is important in patients with glucocorticoid excess because of osteopenia and thin, easily traumatized skin.

POSTOPERATIVE

Complications	Pneumothorax Hypoglycemia Hypoadrenocorticism	Dx: pleuritic chest pain, dyspnea, ↑ RR, ↓ breath sounds, hypoxemia,

	after tumor resection Cushing syndrome: hypoventilation 2° to obesity (hypoxemia, hypercarbia) HTN	lethargy, or altered mental status. Frequent glucose checks and CXR. Treat with glucose, O_2, chest tube, and reintubation as necessary. Consider glucocorticoid and mineralocorticoid replacement—hydrocortisone 100 mg q8h.
Multimodal pain management	Epidural analgesia PCA	Patient should be recovered in an ICU or ward accustomed to treating the side effects of epidural opiates (e.g., respiratory depression, breakthrough pain, nausea, pruritus). Emphasize nonopioid analgesics, including acetaminophen and NSAIDs (see Appendix K, p. K-5).
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition and mobilization. Consider DVT prophylaxis.
Tests	CXR; ECG; electrolytes; glucose	

ANESTHETIC CONSIDERATIONS FOR PHEOCHROMOCYTOMA

PREOPERATIVE

Pheochromocytoma

Tumors of chromaffin tissue origin release massive amounts of catecholamines (norepinephrine > epinephrine) and are responsible for the patient's clinical presentation. The tumor is usually found unilaterally in one of the adrenal glands but also can be found anywhere in the body that chromaffin tissue arises (e.g., urinary bladder, sympathetic chain). There is an increased incidence of pheochromocytoma in certain inherited diseases (multiple endocrine neoplasia type II, neurofibromatosis type I, tuberous sclerosis, Sturge-Weber syndrome, von Hippel-Lindau disease) and with specific gene mutations involving mitochondrial succinate dehydrogenase SDH (B, C, D subtypes). These patients require extensive preop evaluation for cardiac injury (myocarditis, cardiomyopathy, arrhythmias) and preparation, consisting of α-blockade (phenoxybenzamine 10–400 mg/d). Ideally, this care should be monitored closely by the anesthesiologist/intensivist who can provide the preoperative, intraoperative management, and intensive care as needed.

In contrast to its use in essential HTN, ß-blockade is not indicated to control hypertension in patients with pheochromocytoma and is dangerous when used alone. Alone, ß-blockade may cause marked hypertension, ↓ CO, intense vasoconstriction → CHF, organ ischemia, and shock (unopposed α-agonism). Patients with tachydysrhythmias may require ß-blockade to control persistent reflex tachycardia but only after institution of α-blockers. Titration of adrenergic blockade may take 2–8 wk and should be titrated to relief of all episodic symptoms (HAs, sweating, palpitations) and control of blood pressure. Patients should receive **effective** α-blocker dose for 1–2 wk before surgery. Inadequate preop preparation will increase the perioperative morbidity of patients with pheochromocytomas. The adequacy of medical therapy is assessed by the absence of symptoms of catecholamine excess and BP in the normal range measured multiple times/day. The point of delaying surgery for several weeks is to allow recovery, recovery from catecholamine-induced ECG changes, myocarditis, and cardiomyopathy and recovery from other organ injuries (brain, kidney, and bowel) caused by ischemia. These patients may also need recovery time to reset abnormal shifts in autoregulation. All of these "recovery" events are considered essential to enable the patient to tolerate surgery and the post-tumor removal shock period.

Anticipate that some degree of postural hypotension will be observed during titration of phenoxybenzamine, and patients should be educated to avoid sudden postural movements. There is no rush to surgery.

Respiratory	Cardiogenic pulmonary edema
Cardiovascular	Paroxysmal/continuous HTN, tachydysrhythmias, orthostatic hypotension, hypovolemia, myocardial

	dysfunction, cardiomyopathy, ventricular ectopy, ↓ intravascular volume, ↓ sensitivity of α- and β (cardiac)-receptors to normal levels of catecholamines, CHF and acute myocarditis. **Tests:** ECG; ± CK/TP enzymes, orthostatic vital signs; ECHO to evaluate LV function and mitral valve, and r/o cardiomyopathy (hypertrophic, takotsubo, or dilated).
Renal	HTN from excess catecholamine state may damage kidneys; hyperglycemia. **Tests:** UA; creatinine; glucose; HbA_{1c} urine concentrations of catecholamine metabolites; others as appropriate
Neurologic	Sx include: Tremulousness, headache, anxiety, nervousness, personality changes, psychosis (rare), paresthesia in arms, hypertensive retinopathy, dilated pupils.
Musculoskeletal	Weight loss, weakness, fatigue
Hematologic	Polycythemia 2° hemoconcentration (common) or tumor erythropoietin production (rare)
Laboratory	Tests as indicated from H&P
Premedication	± Midazolam (0.025–0.05 mg/kg iv). Preop steroid replacement if bilateral adrenalectomy is contemplated.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: Establish invasive hemodynamic monitoring (arterial and PA lines) BEFORE to induction using iv fentanyl (50–200 mcg) and generous local anesthesia. These procedures are not difficult and can be done safely with ultrasound. This not only

establishes the patient's true hemodynamic baseline but also, equally important, allows the anesthesiologist to pay full attention to the patient at the start of anesthesia/surgery, rather than being distracted with placing invasive lines after induction. Femoral or axillary arterial pressure monitoring is preferred over radial artery because of the need to monitor "**central**" arterial pressures in a patient who may experience high catecholamine levels during surgery with intense vasoconstriction. The use of a PA catheter with continuous CO and SvO_2 delivers valuable "hands-free" information during the case. If postop epidural analgesia is planned (open surgical procedures), placement of catheter before anesthetic induction helps establish correct placement in the epidural space and ensuring a bilateral block (accomplished by placing 5–7 mL of 2% lidocaine **without** epinephrine) via the epidural and eliciting a segmental block. Administering epidural narcotic (hydromorphone 0.4–1.0 mg) before skin incision will enhance preemptive analgesia effect if lidocaine test dose is not used. Epidural catheters cannot be used for a posterior approach because they are in the operative field. Epidurals are not indicated for laparoscopic procedures.

Epidurals block neurally mediated sympathetic responses which are amplified by sympathetic nerve endings that are supersaturated with catecholamines and may → ↓ tumor release of catecholamines but do not block catecholamine release resulting from direct surgical manipulation of tumor. Local anesthetic-induced sympathetic block after tumor resection may compound ↓ BP at this important stage in the operation. If the patient's BP is stable at the time of skin closure and is not on vasopressors, the epidural can be bolused with long-acting local anesthetic to allow for a comfortable emergence.

Induction	Gentle iv induction (titration to effect with propofol) and muscle relaxation (vecuronium 0.1 mg/kg or rocuronium 0.8 mg/kg). Deep mask GA before laryngoscopy. Double DL with LTA spray (4% lidocaine, 4 mL) will minimize the response to intubation.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Volatile anesthetic (isoflurane, sevoflurane), opiate (hydromorphone), and muscle relaxant. Most patients who undergo laparoscopic surgery can be extubated at the end of the case, so use of sedatives

(opiates, and benzodiazepines. etc.) should be minimized during this type of anesthetic to avoid postop respiratory depression.

Intraop HTN Rx:

1. Nitroprusside 0.5–3.0 mcg/kg/min
   Note: This drug has the best profile but is now prohibitively expensive.
2. Clevidipine 0.1–4 mcg/kg/min or 1–10 mg/h
3. Fenoldopam 0.1–1.5 mcg/kg/min
4. Nitroglycerin 0.5–10 mcg/kg/min

$MgSO_4$, (1–2 g iv) may provide some additional BP control. The surgeon may need to interrupt the tumor manipulation to control BP.

Note: Titrating volatile anesthetic depth for BP control is too slow.

Intraop Arrhythmia Rx:

Esmolol is **not** used to control htn but can be used (50–300 mcg/kg/min) for controlling reflex tachycardia from the above agents or excessive β stimulation from tumor-released catecholamines.

Amiodarone (150 mg bolus, then infusion 1 mg/min) may be needed for supraventricular/ventricular ectopy (especially with epinephrine-secreting tumors).

Excellent communication with surgical team is essential especially when the adrenal gland is being mobilized and when the tumor veins are ligated.

Relax BP control (i.e., accept MAP 90–110), and lighten volatile depth nearing tumor removal.

Hypotension (after tumor removal) Rx:

1. Anticipation → fluid loading before tumor removal
2. Fluid resuscitation based on PA pressures, TEE, stroke volume response, SvO_2, pulse pressure variation (PPV)
3. Inotropes (epinephrine) if ↓ CO continuous CO and S_vO_2 will guide effective dosing of inotrope.
4. Vasopressor (vasopressin) if ↓ MAP with normal

	or ↑ CO monitoring "central" MAP will guide effective dosing of vasopressor.	
Emergence	Depends on ease of the surgical procedure and the hemodynamic stability of the patient after tumor removal. If patient is hemodynamically unstable, hypothermic, or has a large third-space fluid requirement, consider postop ventilation, as with any other surgical case. Most cases done laparoscopically can be extubated. Discuss with surgeon local wound infiltration. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Prepare for large fluid loss (unusual). IV: 14–16 ga × 2 BSS @ 10–15 mL/kg/h Warm all fluids.	As blood loss may be significant (especially with R-sided tumors near IVC), blood should be available. Guide fluid management by UO, filling pressures, CO, TEE, SvO_2, PPV, SVV. See Goal-Directed Fluid Management, Appendix K, p. K-4. Normosol (with K, Mg) is ideal fluid for these patients + can be given with blood.
	± Cell Saver	? safety of cell saver blood if tumor margins breached.
Monitoring	Standard monitors UO Arterial line (femoral/axillary) CVP/± PA catheter with continuous $ScvO_2$ or SvO_2	Forced air warmer useful for maintaining body temperature.
	± TEE	The use of TEE may be help establish fluid

		balance depending on other monitors used.
Complications	↑↑↑ BP and dysrhythmias	Surgical manipulation of the tumor will cause ↑↑ BP ± dysrhythmias. Rx: Control BP with SNP/fenoldopam/TNG and HR with esmolol, and alert surgeon if you need him to interrupt dissection.
	↓↓ BP (postexcision—most dangerous part of anesthetic)	↓↓ BP common after removal of tumor. May be severe and life-threatening. Rx: anticipate event; fluids, vasopressin, or epinephrine infusions depending on need for inotropic support. Standard vasopressors (phenylephrine) may not be effective in face of residual α-blockade.
Positioning	✓ and pad pressure points ✓ eyes	

POSTOPERATIVE

Complications	Pneumothorax	Dx: pleuritic chest pain, dyspnea, ↑ RR, ↓ breath sounds, hyperresonance to percussion on side of ptx, hypoxemia. ✓ CXR. Rx: O_2; chest tube and reintubation as necessary.

	Hypoglycemia	Return of normal insulin sensitivity can cause profound hypoglycemia. Rx: anticipate + use D5LR as maintenance fluids.
	Hypoadrenocorticism after tumor resection (usually only with bilateral tumors)	Consider glucocorticoid and mineralocorticoid replacement → hydrocortisone 100 mg q8h.
	HTN	Patient may have other cause for HTN (e.g., essential HTN).
	Hypotension	Continue vasopressor/inotropes, fluids as indicated.
	Myocardial dysfunction	Patient should be recovered in ICU overnight.
	Pulmonary edema	
Multimodal pain management	Epidural analgesia PCA	After leaving an ICU, patients with epidurals should be recovered on a ward accustomed to treating the side effects of epidural opiates (e.g., respiratory depression, breakthrough pain, nausea, pruritus). Emphasize nonopioid analgesics, including acetaminophen and NSAIDs (see Appendix K, p. K-5).
ERAS	PONV protocol (see Appendix B, p. B-4 and p.	Encourage early enteral nutrition and

	B-5)	mobilization. Consider DVT prophylaxis.
Tests	CXR; ECG; electrolytes; close glucose monitoring q1–2h × 12 h	

Suggested Readings

1. Brunt LM: Laparoscopic adrenalectomy. In: Cameron JL, ed.Current Surgical Therapy, 7th edition. Mosby Inc., St. Louis: 2001, 1460–7.
2. Colen TY, Mihm FG, Mason TP, Roberson JB: Catecholamine-secretin paragangliomas: recent progress in diagnosis and perioperative management. Skull Base 2009; 19(6):377–85.
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5. Nigri G, Rosman AS, Petrucciani N, et al: Meta-analysis of trials comparing laparoscopic transperitoneal and retroperitoneal adrenalectomy. Surgery 2013; 153(1):111–9.
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7. Schwartz JJ, Rosenbaum SH: Anesthesia and the endocrine system. In: Barash PG Cullen BF, Stoelting RK, eds.Clinical Anesthesia, 5th edition. Lippincott Williams & Wilkins, Philadelphia: 2006, 1129–51.
8. Taskin H, Berber E: Robotic adrenalectomy. J Surg Oncol 2012; 106(5):622–5.
9. Witteles RM, Kaplan EL, Roizen MF: Safe and cost-effective preoperativ preparation of patients with pheochromocytoma. Anesth Analg 2000; 91:302–4.

CHAPTER 7.12

Liver/Kidney/Pancreas Transplantation

SURGEON
Marc L. Melcher, MD, PhD (Kidney, pancreas, liver transplantation)

ANESTHESIOLOGISTS
Timothy P. Angelotti, MD, PhD (Kidney, pancreas transplantation, multiorgan procurement)
Hendrikus J. M. Lemmens, MD, PhD (Liver transplantation)

We gratefully acknowledge the past contributions of surgeon, Amy E. Gallo, MD.

KIDNEY TRANSPLANTATION: CADAVERIC AND LIVE DONOR

SURGICAL CONSIDERATIONS

Description

Kidney transplantation offers patients with end-stage renal disease (ESRD) freedon from dialysis. The source of the renal graft may be a deceased donor, a relative (e.g., parent, sibling), or a genetically unrelated donor such as a spouse, friend, or person through paired donor exchange.

After induction of anesthesia, a 3-way Foley catheter is placed into the bladder. The

kidney allograft is placed in the extraperitoneal iliac fossa. A curvilinear incision is made in the right or left lower quadrant. The retroperitoneal space is developed by retracting the peritoneum medially and cephalad, exposing the iliac vessels. A self-retaining retractor is placed to maintain exposure. The lymphatics surrounding the external iliac artery and vein are ligated and divided. Several centimeters of the vessels are mobilized.

The external iliac vein is clamped first, and the renal vein-to-iliac vein anastomosis is performed. When a right deceased donor kidney is used, the renal vein will often have been extended using the donor cava, since the right renal vein is often quite short. Then, the external iliac artery is clamped, and a renal artery-to-iliac artery anastomosis is performed. Usually, deceased donor kidneys will come with a "Carrel" patch of the aorta to allow for a larger anastomosis. The living donors do not have the patch and therefore have a smaller arterial anastomosis. The patient should be euvolemic at this point; mannitol and/or furosemide can be given. The clamps are then released starting with the renal vein (Fig. 7.12-1).

The bladder is filled with an antibiotic irrigation solution to facilitate its identification and exposure for the implantation of the ureter. The spatulated ureter is anastomosed to the mucosa of the bladder with fine monofilament absorbable sutures, often over a stent. The detrusor muscle is then reapproximated over 3–4 cm of the ureter to create an antireflux valve. The wound is closed, normally leaving native kidneys intact. Many surgeons will leave a closed-suction drain around the kidney.

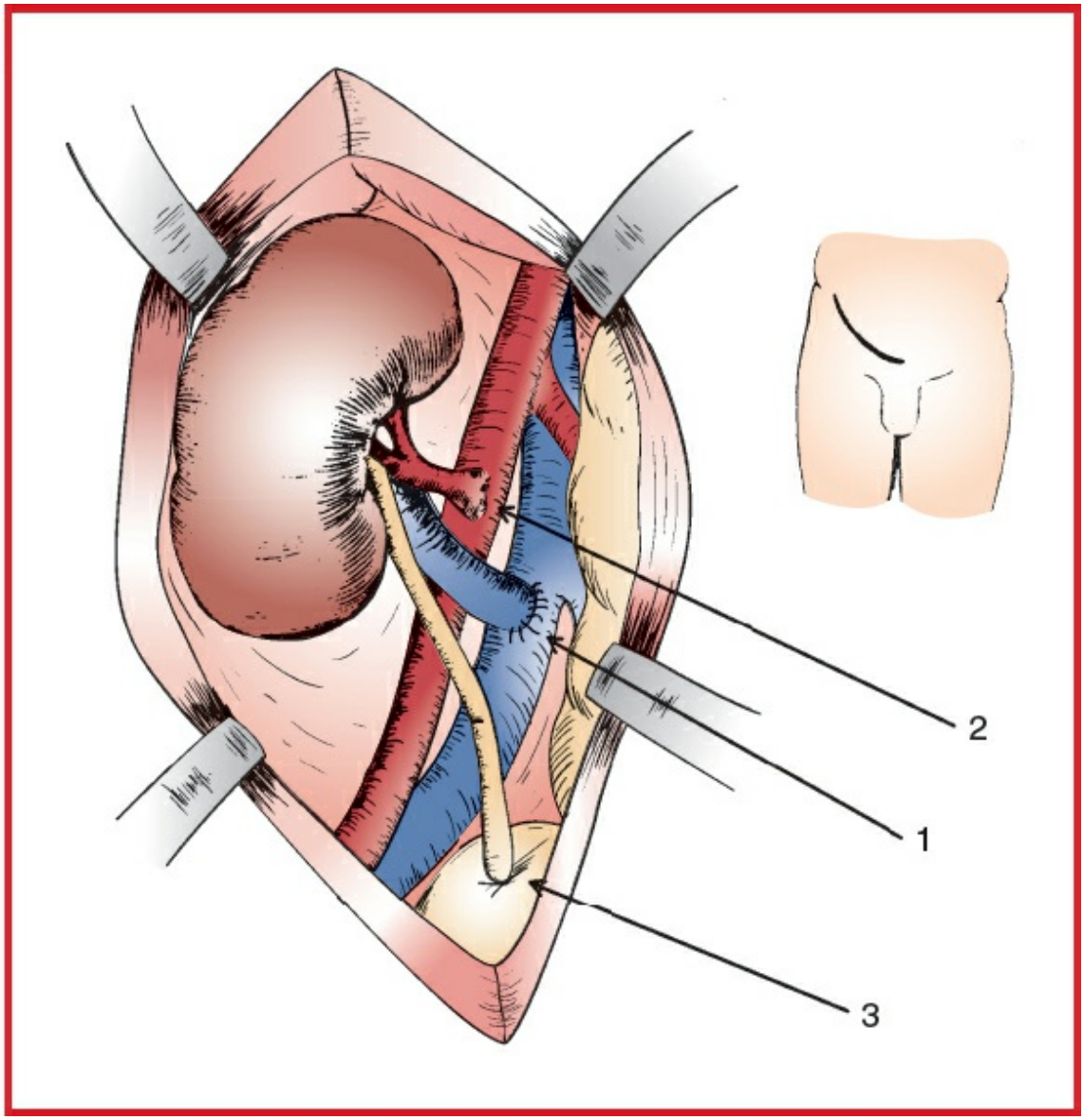

Figure 7.12-1 Sketch of a kidney transplant labeled 1, 2, 3 in the order of the surgical anastomoses. 1, renal vein to external iliac vein; 2, renal artery to external iliac artery, and 3, ureter to bladder. The **inset** shows the lower quadrant curvilinear incision (Paul Gallo, DDS).

Variant procedure or approaches

Cadaveric or live-donor transplantation

Usual preop diagnosis

ESRD

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, urinary drain, pain management options, and postop recovery plan. See Appendix K: Enhanced Recovery After

Surgery, p. K-1.

SUMMARY OF PROCEDURES

	Cadaveric Kidney	Live-Donor Kidney
Position	Supine	⇐
Incision	Lower quadrant curvilinear (Fig. 7.12-1 **inset**)	⇐
Special instrumentation	Self-retaining retractor; vascular instruments; CVP; Foley catheter (3-way)	⇐
Unique considerations	CVP 10–12 mm Hg; mannitol 12.5–25 g and furosemide 40–80 mg; intraop immunosuppression before reperfusion (steroids, antilymphocyte preparation); potassium-free iv fluid; protection of shunt or fistula is important.	⇐
Antibiotics	Piperacillin/tazobactam 3.375 g iv, within 1 h preincision	Cefazolin 2–3 g iv, 1 h preop
Surgical time	1.5–3 h	⇐
EBL	100–200 mL	⇐
Postop care	Replace urine output mL for mL with iv fluids; may have delayed graft function 2° prolonged cold storage; monitored bed	⇐ Delayed graft function unlikely
Mortality	1–2%	⇐
Morbidity	Lymph or serous leak/stenosis: 3–5% Postop bleeding: 3–5% MI: 2–3% Ureteral leak/stenosis: 2–3%	⇐ 1–2% ⇐ ⇐ ⇐

	Wound infection: 2–3% Arterial thrombosis: 1–2% Venous thrombosis: 1–2% Wound hematoma: 1–3% Other infectious complications: 15–40%	⇐ ⇐ ⇐ ⇐
Pain score	5	5

PATIENT POPULATION CHARACTERISTICS	
Age range	3–80 yr
Male:Female	1:1
Incidence	60/1,000,000
Etiology	Diabetes mellitus (45%); HTN (20%); polycystic disease and others (20%); glomerulonephritis (15%)
Associated conditions	CAD (40%); HTN (25%); uremic and/or diabetic neuropathy (25%); hyperparathyroidism (15–20%); SVC syndrome

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Cadaveric Kidney/Pancreas Transplantation.

Suggested Readings

1. Black CK, Termanini KM, Aguirre O, et al: Solid organ transplantation in the 21(st) century. Ann Transl Med 2018; 6(20):409.
2. Palamuthusingam D, Johnson DW, Hawley CM, et al: Perioperative outcomes and risk assessment in dialysis patients: current knowledge and future directions. Intern Med J 2019;49(6):702–10.
3. Sen A, Callisen H, Libricz S, et al: Complications of solid organ transplantation cardiovascular, neurologic, renal, and gastrointestinal. Crit Care Clin 2019; 35(1):169–86.

CADAVERIC KIDNEY/PANCREAS TRANSPLANTATION

SURGICAL CONSIDERATIONS

Description

Pancreas transplantation: Combined kidney and pancreas transplantation not only provides renal replacement for type I diabetes patient with ESRD but also controls diabetes. Over 80% or more of pancreas transplants are performed in combination with kidney transplantation from the same donor (**simultaneous pancreas-kidney [SPK] transplant**). Pancreas transplantation also can be performed for patients who have already received a kidney transplant (**pancreas after kidney [PAK]**). Less commonly, pancreas transplantation is done for patients with brittle diabetes or with impending complications while they still enjoy normal or near-normal kidney function. Immunosuppression regimen for pancreas transplantation is generally more aggressive than that used for kidney transplantation, and induction therapy with antilymphocyte preparation (ATG, IL-2 blockers) is commonly used.

The pancreas transplant is placed in the right iliac fossa, and the kidney transplant is placed in the left iliac fossa. This can be done through a transperitoneal lower midline incision or through two separate extraperitoneal lower quadrant incisions in the same manner as kidney transplantation. The graft is first prepared on the back table. For arterial inflow, a Y-graft is fashioned using the donor iliac artery bifurcation to provide circulation to both the superior mesenteric and the pancreatic artery. The portal vein coming off the pancreatic graft is anastomosed to the external iliac vein. The Y extension arterial graft is then anastomosed to the recipient external or common iliac artery. The donor duodenum is anastomosed to a loop of small bowel or to the urinary bladder to drain the exocrine secretions (Fig. 7.12-2A). With pancreas transplantation, there may be significant blood loss if the graft mesenteric vessels are not occluded properly. After the pancreas is implanted, the kidney transplant is placed into the opposite iliac fossa (as described in Kidney Transplantation).

Variant procedure or approaches

The pancreas may be placed in the upper abdomen with the portal vein anastomosed to the superior mesenteric vein. The exocrine secretions are bowel-drained. This more physiologic approach, however, is associated with a higher technical failure rate and requires a long upper midline incision (Fig. 7.12-10). Pancreatic islet cells may be infused via a radiologic **portal vein approach**, a procedure that is usually performed in the radiology/angiography suite.

Usual preoperative diagnosis

ESRD 2° diabetes mellitus (DM)

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status and preop supplementation, discussion of carb loading, DVT prophylaxis, urinary drain, pain management options, and postop recovery plan. See Appendix K, p. K-1.

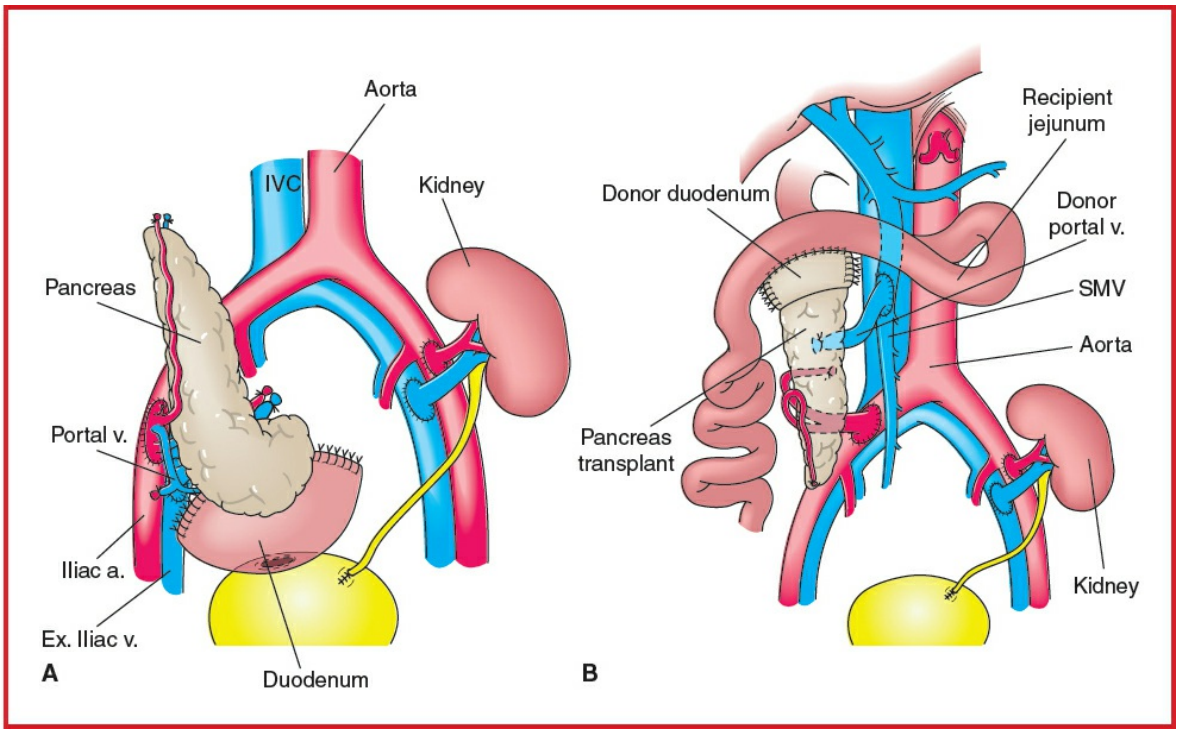

Figure 7.12-2 A: SPK transplantation, with drainage of pancreatic exocrine secretions into the bladder. Note that portal vein drains into iliac vein (systemic venous [SV] drainage). In normal individuals, 50% of secreted insulin is extracted from the circulation in the first pass through the liver. Transplant recipients with SV have peripheral insulin levels 2–2½ × higher than normal. **B:** SPK transplantation with drainage of pancreatic exocrine secretions into the proximal jejunum (enteric drainage [ED]). This technique has been adopted for SPK by most transplant centers in the United States for solitary pancreas transplantation; most centers still utilize ED to allow monitoring of the urinary amylase. Note that donor portal vein drains into the recipient superior mesenteric vein (portal venous [PV] drainage) preventing peripheral hyperinsulinemia. Most centers continue to place the pancreas in the pelvis, combining ED and SV, which requires enteric anastomosis to a more distal segment of the jejunum or ilium. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al., eds:Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

SUMMARY OF PROCEDURE

Position	Supine; cushion heels
Incision	Midline or bilateral lower quadrant
Special instrumentation	Thompson retractor; vascular instruments; Foley catheter; NG tube; CVP; arterial line
Unique	Do not correct hyperglycemia <300 mg/dL. Maintain

considerations	adequate hydration, CVP 10–12 mm Hg; mannitol 0.25–0.5 g/kg on unclamping; intraop immunosuppression before reperfusion (125–250 mg methylprednisolone, monoclonal or polyclonal preparation [e.g., ATG, Zenapax, OKT3, Simulect]).
Antibiotics	Piperacillin/tazobactam 3.375 g iv q6h × 5 d; fluconazole 200–400 mg (nl creatinine clearance)
Surgical time	4–6 h
EBL	250–500 mL
Postop care	ICU × 1–2 d, hourly monitoring of glucose; serum glucose should decline by 50 mg/dL each hour and remain <200 mg/dL.
Mortality	2%
Morbidity	Thrombosis of graft: 5–10% Postop bleeding: 5–10% Wound infection: 2–6% Pancreatitis: 2–4% Anastomotic leak: 1%
Pain score	7

■ PATIENT POPULATION CHARACTERISTICS	
Age range	15–55 yr
Male:Female	1:1
Incidence	15–20% of all patients with ESRD
Etiology	Type I diabetes
Associated conditions	Retinopathy (100%); uremic and/or diabetic neuropathy (50%); CAD (25–50%); gastropathy (25%); hyperparathyroidism (15–20%)

Suggested Reading

1. Sharples EJ, Mittal SM, Friend PJ: Challenges in pancreas transplantationActa Diabetol 2016; 53(6):871–8.

ANESTHETIC CONSIDERATIONS FOR KIDNEY AND KIDNEY/PANCREAS TRANSPLANTATION

PREOPERATIVE

Typically, patients presenting for renal transplantation fall into two patient populations: (a) the young and relatively healthy (following dialysis) or (b) an older, more chronically ill group. Rarely, patients will present for transplant surgery without adequate preparation (e.g., ↑ K^+, ↓ pH, hypervolemia). Patients presenting for pancreas transplantation are usually severe diabetics with many of the associated problems, such as CAD, autonomic neuropathy, gastroparesis, and stiff joint syndrome (difficult intubation).

Respiratory	Pleuritis and pleural effusions may occur in this patient population. Increased susceptibility to infection is common in the patient with chronic uremia.
Cardiovascular	Pericarditis (acute or constrictive), HTN, CHF, dysrhythmias, and pericardial effusion are common, especially in the undialyzed patient. Diabetes, a common cause of ESRD, is often associated with PVD, CAD, and autonomic neuropathy. **Tests:** ECG (rhythm, CAD, electrolyte abnormalities, pericarditis, LVH). Other tests (ECHO, stress, etc.) as indicated by the H&P
Gastrointestinal	Gastroparesis may occur, especially in diabetic patients with autonomic neuropathy. Consider full stomach precautions. Ranitidine (50 mg iv) and metoclopramide (10 mg iv) should be given 60 min preop to aid gastric emptying and ↓ acidity.
Renal	Patients are usually on dialysis. Postdialysis goals include K^+ = 4–5 mEq/L, BUN < 60 mg%, creatinine <10 mg%. Metabolic acidosis, hypocalcemia, and hypermagnesemia often present and may require preop correction. Patients may be hypovolemic following dialysis; ✓ pre- and postdialysis weight (>2 kg loss is significant). Rapid correction of severe hyperkalemia can be achieved by giving 50 mL of

	50% glucose iv, together with 10 U regular insulin and 50 mEq NaHCO. Further correction can be obtained by coadministration of an inhaled β-agonist (e.g., albuterol, 5–10 puffs). **Tests:** Cr; BUN; creatinine clearance; electrolytes
Hematologic	These patients are frequently anemic. Preop correction usually not needed. A coagulation disorder may be present with abnormal platelet function (improved by dialysis) as well as thrombocytopenia, resulting in a prolonged bleeding time. There is a high incidence of posttransfusion hepatitis in this patient population. **Tests:** Hct; PT; PTT; platelet count; hepatic screen, consider platelet function assay.
Endocrine	Assess glycemic control preop. Individualize diabetic Rx for the day of surgery. In general, hold oral agents 12–24 h, and ↓ or hold usual insulins, and consider sliding scale insulin on the day of surgery. Favor hyperglycemia (≥120–200 mg/dL) over tight glucose control. Preop/intraop corticosteroid immunosuppressive Rx will likely → hyperglycemia. Postop glycemic management complex and dynamic **Tests:** Serial glucose levels
Neurologic	Peripheral neuropathy may occur, and specific deficits should be documented. Autonomic neuropathy can → cardiac problems (e.g., orthostatic hypotension, ↑ HR, or ↓ HR), silent MI, and GI problems.
Premedication	Consider midazolam 1–2 mg iv.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA favored. Spinal, epidural, or combined spinal-epidural anesthesia may be considered for renal transplantation, if coagulation and platelet function are acceptable. Ilioinguinal-iliohypogastric and intercostal nerve blockade can be utilized as an alternative method for postop pain control, although their efficacy in this patient population has yet to be demonstrated. Avoidance of hypotension after organ(s) transplantation is an important consideration that may limit effectiveness of RA techniques.

Induction	Rapid sequence induction. ET intubation is aided by succinylcholine (1 mg/kg), if $K^+ < 5.5$ mEq/L; otherwise, use cisatracurium (0.2–0.5 mg/kg) or rocuronium (1.2 mg/kg). Fentanyl (2–5 mcg/kg) may be used to suppress the cardiovascular response to intubation.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Standard maintenance w/ potent inhalational agent, though their effects on ischemia-reperfusion injury are being assessed in multiple clinical studies. Maintain muscle relaxation with cisatracurium or rocuronium, titrated to effect using a nerve stimulator. Avoid meperidine (accumulation of normeperidine → CNS toxicity). Anticipate prolonged drug effects, and avoid agents that are primarily excreted by the kidney.
Emergence	Usually extubated in the OR after protective laryngeal reflexes have returned. Ensure adequate reversal of NMB drugs. Sugammadex can be considered for reversal; however, the rocuronium/sugammadex complex is renally excreted and may be a problem in an anuric patient. However, it can be removed by hemodialysis. Pancreatic transplant patients (e.g., brittle diabetics, hemodynamically unstable) are sent to the ICU for

	close glycemic management. Discuss with surgeon local wound infiltration. PONV prophylaxis may include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 14–16 ga × 1 NS/BSS/colloid to keep CVP = 10–15 mm Hg Warm fluids	Preop fluid status is highly variable (hypovolemia→ hypervolemia). Give fluids to maintain CVP 10–15 mm Hg. Important to maintain adequate vascular volume and BP. Mannitol (0.25–1 g/kg), furosemide (5–20 mg), and norepinephrine can be used. Empiric dopamine is no longer recommended. Recent evidence suggests that balanced crystalloid solutions containing K^+ can be used without concern about elevating K^+ levels, instead of normal saline, to better preserve acid-base profiles. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors. Arterial line CVP/PA line	Arterial pressure is often monitored. Avoid the side of AV fistulae. The axillary artery is a useful alternative. CVP is essential, and a PA line is needed occasionally (severe cardiac disease). CVP is kept at 10–15 mm Hg, especially after the new kidney is reperfused, to ensure adequate renal blood flow. Dynamic parameters such as pulse pressure or systolic volume variation can

		be easily assessed in real time and utilized instead.
	Hct, K^+, and glucose	In pancreatic transplant patients, glucose should be checked q30min and then q10min for the first hour following reperfusion. Keep glucose <300 mg/dL prior to reperfusion but do not fully correct to <150 mg/dL.
	Neuromuscular	Monitor neuromuscular block to avoid excessive use of neuromuscular relaxants; anticipate prolonged effects.
Positioning	✓ and pad pressure points ✓ eyes	
	Protect/pad AV fistulas	Pressure on AV fistula may lead to thrombosis. Document bruit q15min.
Complications	Disruption of renal anastomoses Hemorrhage Low UO Reperfusion injury (pancreas transplant)	Bucking or coughing during emergence or at any time after kidney implanted may lead to "popping" and vascular disruption and need for urgent repair.

POSTOPERATIVE

Complications	Fluid overload and CHF Femoral neuropathy Hemorrhage Electrolyte abnormalities	Monitor UO. Dialysis may be needed until renal function returns, in cases with delayed graft function. Sudden cardiac arrest can complicate pancreatic transplantation

	Hypo-/hyperglycemia PONV VTE	(due to autonomic neuropathy). Especially dynamic in pancreas tx
Multimodal pain management	PCA Epidural	Anticipate prolonged effect of some opiates. Strive to avoid hypotension. Emphasize nonopioid analgesics including acetaminophen (see Appendix K, p. K-5).
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition and mobilization. DVT prophylaxis
Tests	Hct Electrolytes Cr, BUN Amylase Glucose	A rise in amylase and blood glucose may indicate failure of the pancreatic transplant.

Suggested Readings

1. Barton JG: Enhanced recovery pathways in pancreatic surgery. Surg Clin North Am 2016; 96(6):1301–12.
2. Calixto Fernandes MH, Schricker T, Magder S, et al: Perioperative fluid management in kidney transplantation: a black box. Crit Care 2018; 22(1):14.
3. Mittel AM, Wagener G: Anesthesia for kidney and pancreas transplantation. Anesthesiol Clin 2017; 35(3):439–52.
4. Motayagheni N, Phan S, Eshraghi C, et al: A review of anesthetic effects on renal function: potential organ protection. Am J Nephrol 2017; 46(5):380–9.
5. Pędziwiatr M, Mavrikis J, Witowski J, et al: Current status of enhanced recovery after surgery (ERAS) protocol in gastrointestinal surgery. Med Oncol 2018; 35(6):95.

LIVE-DONOR NEPHRECTOMY: LAPAROSCOPIC AND OPEN

SURGICAL CONSIDERATIONS

Description

Use of a kidney donated by a healthy genetically or emotionally related donor greatly increases the number and quality of kidneys available for transplantation. Kidney transplantation from living donors is associated with a better patient and graft survival rate. **A laparoscopic (LSC) approach** for kidney donation was introduced in 1995 as an alternative that would reduce postop pain, wound morbidity, and recovery time associated with open nephrectomy. Now the LSC approach is the procedure of choice for more than 75% of the live kidney donations in the United States. Initial concerns regarding ureteral complications and longer warm ischemic time have mostly subsided with the improvement of the surgical technique and greater experience. The left kidney is preferred for the LSC approach, as the renal vein is longer. Some centers use the LSC approach for the right kidney with comparable results.

The patient is positioned in lateral decubitus over a cushioned beanbag, the kidney rest is slightly elevated, and pillows and an axillary roll are used to prevent compression injuries. Three or four ports are used for the pure laparoscopic approach. The hand-assisted approach, however, has gained popularity over the years and is currently the preferred technique of the majority of transplant centers in the United States. In this approach, two or three ports are used with a 6–8-cm incision made at the level of the umbilicus or infraumbilical. The pneumoperitoneum is kept <15 mm Hg to avoid decreased perfusion to the kidney. Aggressive hydration and intermittent use of iv mannitol help improve kidney perfusion.

On the left side, the descending colon and spleen are mobilized medially; the renal vessels are exposed; the adrenal, lumbar, and gonadal veins are clipped and divided; the ureter is mobilized en bloc, along with the gonadal vein, down to the pelvic inlet. The artery is freed from surrounding lymphatic and neural tissue as it comes off the aorta (Fig. 7.12-3). Gerota fascia is mobilized to completely free the kidney. The ureter is transected distally.

If the procedure is done purely laparoscopically, a 6-cm suprapubic incision is then made, the peritoneum is exposed in the midline, and an 18-mm port is used to insert a 15-mm Endocatch retrieval bag. The kidney is placed in the bag as it continues to be perfused, avoiding warm ischemia. With the hand-assisted approach, the incision is already made for retrieval with the surgeon's hand. The patient is fully heparinized. An endo TA vascular stapler is used to staple and transect the artery close to the aorta and the vein close to the vena cava. An endo GIA vascular stapler can also be used. The

kidney is brought to the suprapubic incision and gently extracted. The kidney is immediately immersed in cold slush. The kidney is perfused with preservation solution in the usual manner. The heparin is reversed with protamine, the suprapubic incision is closed, and homeostasis is verified before extracting the ports. For a right nephrectomy, the right colon and duodenum are mobilized medially and the liver is retracted upward. The remainder of the operation is as described for the left kidney.

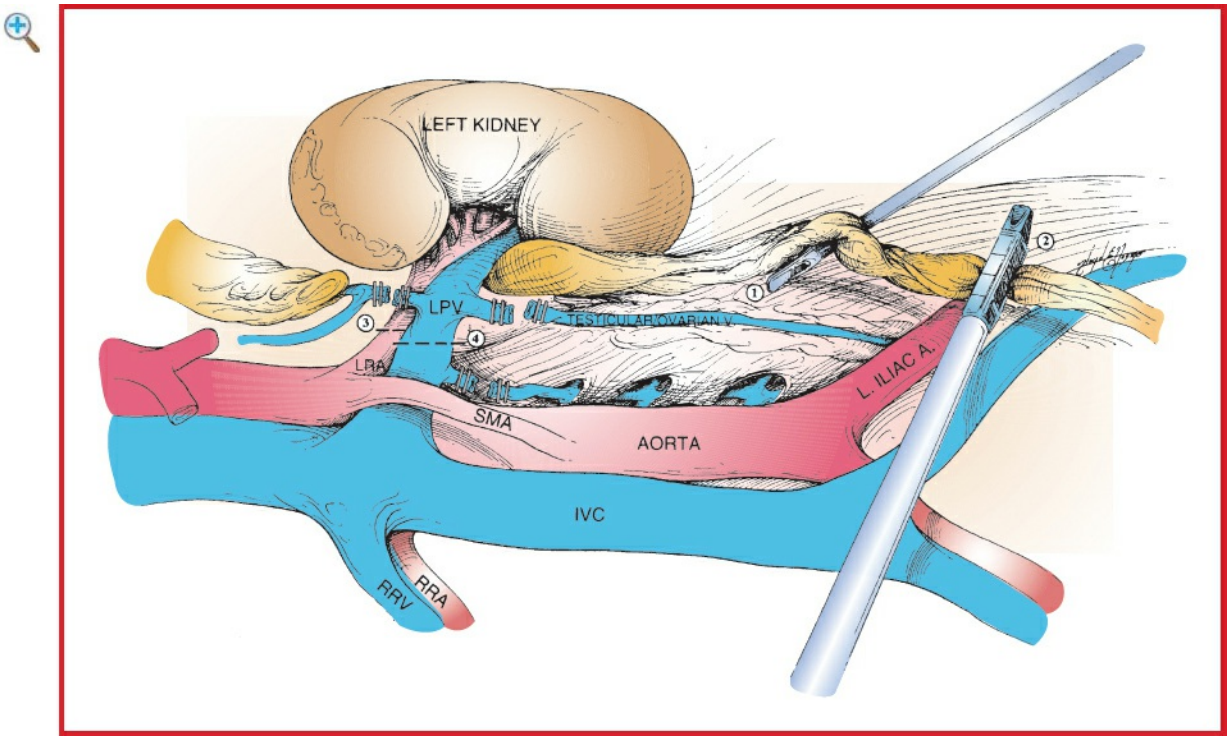

Figure 7.12-3 Anatomy for laparoscopic live-donor nephrectomy. (Reproduced with permission from Cho ES, Flowers JL: Laparoscopic live-donor nephrectomy. In: Zuker KA, edSurgical Laparoscopy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

In **open nephrectomy**, the **donor/patient** is placed in a lateral decubitus position on a flexible OR table with a kidney rest. A beanbag or sandbags are also helpful for positioning. An incision is made from the rectus muscle, angling slightly cephalic to cross into the flank just below the tip of the 12th rib. The retroperitoneum is exposed using a Thompson retractor. The kidney is then mobilized, and the ureter is transected. A clamp is placed across the renal artery at the aorta and the renal vein at the IVC. Just before clamping the renal artery, furosemide and/or mannitol may be given to stimulate diuresis. It is important to keep the vascular volume expanded in these patients before kidney removal. The kidney is removed and taken to the back table, where it is flushed with a cold preservation solution. It is then transported to the recipient room for reimplantation. Some surgeons use a full dose of heparin (75 U/kg) before clamping and use protamine for reversal. Smaller incisions and muscle-sparing incisions are now

used to improve postop recovery.

Usual preop diagnosis

Donor nephrectomy

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, pain management options, and postop recovery plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Laparoscopic Nephrectomy	Open Nephrectomy
Position	Lateral decubitus	⇐
Incision	Three to four ports; retrieval incision, Pfannenstiel's or vertical suprapubic	Flank; may require 12th rib resection
Special instrumentation	Foley catheter; flexible OR table with kidney rest; beanbag; SCDs for DVT prophylaxis; harmonic scalpel	Foley catheter; Thompson retractor; flexible OR table with kidney rest; beanbag or sandbags; SCDs for DVT prophylaxis
Unique considerations	Avoid ETT dislodgement when turning patient from supine to flank position; vigorous hydration	Possible pneumothorax; avoid ETT dislodgement when turning patient from supine to flank position. Vigorous hydration to encourage urine production
Antibiotics	Cefazolin 2–3 g iv	Cefazolin 2–3 g iv
Surgical time	2.5–4.5 h	2–2.5 h
Closing considerations	—	Deflex table to facilitate closure
EBL	Minimal	100 mL

Postop care	PACU → ward; PCA for pain management	PACU → ward; PCA for pain management
Mortality	<0.1%	⇐
Morbidity	Ileus: 2–5% Urinary retention: 2–5% Wound infection: 1–2% Bleeding: 0.1–0.5%	5–10% 5–10% 1–3% Pneumothorax: 1%
Pain score	3–5	7

PATIENT POPULATION CHARACTERISTICS		
Age range	18–70 yr	⇐
Male:Female	1:1	⇐
Incidence	Up to 50% of all kidney transplants at some centers	⇐
Etiology	N/A	⇐
Associated conditions	Good health is mandatory for kidney donation.	⇐

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Kidney Transplant Nephrectomy.

KIDNEY TRANSPLANT NEPHRECTOMY

SURGICAL CONSIDERATIONS

Description

With improvements in graft survival and immunosuppressive therapy, the necessity of removing a kidney transplant graft for uncontrolled rejection has decreased significantly. This operation is divided into categories: **early nephrectomy**, performed during the first month post transplant, and **late nephrectomy**, thereafter. **Early transplant nephrectomy** may be required for primary nonfunction, vascular thrombosis, and, rarely, refractory rejection. In these cases, an **extracapsular**

approach, through the original transplant incision, is used. The kidney is freed from the surrounding adhesion to obtain vascular control of the renal artery and renal vein. These structures are clamped and oversewn individually. The ureter is ligated as close as possible to the bladder and excised completely, with primary repair of the bladder. A suction drain is used if minimal oozing or lymph drainage is present. **Late transplant nephrectomy** is performed most commonly for acute, irreversible rejection with failure of the renal allograft. Most of these patients have returned to dialysis, and the immunosuppressive medications are stopped. Chronic infection and hypertension (HTN) associated with nonfunctional grafts are also an indication for surgical removal of the kidney allograft. It may be a difficult operation, as intense inflammatory adhesions are present between the renal capsule and the surrounding tissue. In the setting of acute late rejection, the graft is usually swollen and enlarged. Hematuria may be present, and the graft is friable. Spontaneous rupture and hemorrhage have been reported. The surgical approach is through the same incision as the implantation. In contrast to early transplant nephrectomy, extracapsular dissection may not be possible with late nephrectomy. To avoid injury to extrarenal structures, such as the iliac vessels, an **intracapsular approach** may be preferred. The kidney is mobilized gently from within the capsule toward the hilum. The capsule is reopened on the medial side to have access to the renal vessel high in the hilum. When the hilum is sufficiently mobilized, a strong vascular clamp is applied high in the hilum of the kidney away from the iliac vessels. After clamping the hilum en bloc, confirmation of distal pulses is obtained; then the kidney is excised over the vascular clamp. A running suture is used over the clamp, which is then released, and hemostasis is obtained. The ureter is identified and excised as close as possible to the bladder. The intracapsular dissection of the kidney may be associated with significant bleeding, as the kidney may fracture. This step should be done expeditiously to avoid excessive bleeding. The patient must have good vascular access for fluid resuscitation. Blood must be available for transfusion. After hemostasis is obtained, a low-pressure suction drain may be placed before closing.

Usual preop diagnosis

Transplant rejection

ERAS: Time permitting, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE

Position	Supine
Incision	Previous incision used for kidney transplant
Instrumentation	Self-retaining retractor; vascular instruments
Unique considerations	Large-bore vascular access; PRBCs available; stress dose of steroids, if chronic usage; protection of shunt or fistula
Antibiotics	Cefazolin 2–3 g iv
Surgical time	1–2.5 h
EBL	200–1000 mL
Postop care	PCA for pain management → PACU → ward
Mortality	1–3%
Morbidity	Overall: 3–5% Wound infection: 3–5% Abscess formation: 1–2% Exsanguinating hemorrhage: <1%
Pain score	5

PATIENT POPULATION CHARACTERISTICS	
Age range	3–75 yr
Male:Female	1:1
Incidence	60/1,000,000
Etiology	Failed kidney transplant
Associated conditions	CAD (40%); HTN (25%); uremic and/or diabetic neuropathy (25%); hyperparathyroidism (15–20%)

ANESTHETIC CONSIDERATIONS FOR LIVE-DONOR AND POSTTRANSPLANTATION NEPHRECTOMY

PREOPERATIVE

In order to be a live donor, one must be in good health with bilaterally functional kidneys. Diabetes, HIV infection, liver disease, and malignancy are all

contraindications to kidney donations.

Cardiovascular	Assess for HTN and CAD.
Renal	Normal bilateral renal function is required. **Tests:** IVP; Cr, creatinine clearance
Fluid status	Adequate hydration is important, and UO should be >1.5 mL/kg/h. Various regimens are used to ensure adequate hydration, usually with iv fluid starting the night before.
Premedication	Consider midazolam 1–2 mg iv. Organ donors are making a great sacrifice and should be treated with special care. Standard premedication.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA ± epidural for postop pain management. Epidurals are not necessary for most laparoscopic donor nephrectomies.

Induction	Standard induction
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Standard maintenance. Avoid long-acting, renally excreted drugs. Ventilate to maintain normocapnia to avoid possible renal artery vasoconstriction. Use of an epidural with local anesthetic and/or narcotic may aid both intraop and postop pain relief, but ↓ BP should be avoided.
Emergence	Routine extubation in OR. Discuss with surgeon local

	wound infiltration. PONV prophylaxis may include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 16–18 ga × 2 NS/BSS @ 6–8 mL/h Warm fluids UO ≥ 1.5 mL/kg/h	Aim for a minimum of 1.5 mL/kg/h UO. Mannitol (0.25–1 g/kg) given iv once the kidney is being manipulated and if UO decreases. Consider dopamine infusion to ↑ BP as needed. Limit use of direct vasoconstrictors. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	CVP or invasive arterial monitoring is rarely required. Lower extremity NIBP measurements on the same side as implant will be inaccurate during period of iliac vessel clamping.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Hemorrhage Pneumothorax	Because the vessels are tied close to the aorta and IVC, the possibility of severe hemorrhage exists. Pneumothorax is always possible, especially when the 12th rib is resected.

POSTOPERATIVE

Complications	Pneumothorax/pulmonary problems Hemorrhage Infection PONV

	Electrolyte abnormalities VTE Ileus	
Multimodal pain management	Epidural narcotics. Avoid hypotension. PCA	Emphasize nonopioid analgesics including acetaminophen and NSAIDs (see Appendix K, p. K-5).
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition and mobilization. Consider DVT prophylaxis.
Tests	CXR Hct, electrolytes, BUN/Cr	

Suggested Readings

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4. Maggiore U, Budde K, Heemann U, et al: Long-term risks of kidney living donation review and position paper by the ERA-EDTA DESCARTES working groupNephrol Dial Transplant 2017; 32(2):216–23.
5. Nasrallah G, Souki FG: Perianesthetic management of laparoscopic kidney surgery Curr Urol Rep 2018; 19(1):1.
6. Pędziwiatr M, Mavrikis J, Witowski J, et al: Current status of enhanced recover after surgery (ERAS) protocol in gastrointestinal surgery. Med Oncol 2018; 35(6):95.
7. Sener M, Torgay A, Akpek E, et al: Regional versus general anesthesia for donor nephrectomy: effects on graft function. Transplant Proc 2004; 36(10):2954–8.
8. Ucar AR, Demir E, Sever MS: Transplant patients with failing renal allografts.Exp Clin Transplant 2018; 16(Suppl 1):4–8.

LIVER TRANSPLANTATION

SURGICAL CONSIDERATIONS

Description

Liver transplantation is the treatment of choice for patients with acute and chronic end-stage liver disease (ESLD). Metabolic orders can also be cured or improved with liver transplant but are more often performed in the pediatric population and will not be discussed below. Patients with ESLD, besides intrinsic liver dysfunction, also may have other organ system diseases including hepatorenal and hepatopulmonary syndrome resulting in oliguria and hypoxia, respectively, and hepatic hydrothorax. Patients with alcohol-mediated cirrhosis and Wilson disease are at risk for significant cardiomyopathy, whereas those with fulminant hepatic failure may have significantly elevated intracranial pressures. These additional comorbidities present an added level of complexity to the anesthetic and surgical management of the liver transplant recipient. The liver transplant operation can be divided into three stages: (a) **hepatectomy**; (b) **anhepatic phase**, which involves the implantation of the liver; and (c) **post revascularization**, which includes hemostasis and reconstruction of the hepatic artery and common bile duct. Many variations in the technical aspects of the liver transplant operation contribute to physiologic changes during anesthesia. The anesthesiologist must be aware of these technical variations to optimize the intraoperative management of the liver transplant recipient. Examples of these variations include cross-clamping of the vena cava during the implantation of the liver, which results in impairment of the systemic venous return, with possibility of profound hypotension; utilization of the venovenous bypass, which may be associated with thrombus or air embolism, and/or fibrinolysis; and the use of a "cutdown liver," which may result in significant bleeding from the cut surface following revascularization.

Table 7.12-1 Contributing Factors Associated with Increased Blood Loss in Liver Transplantation

1. Severe coagulopathy
2. Severe portal HTN
3. Portal or splenic vein thrombosis
4. Previous surgery in the RUQ
5. Renal failure

6. Uncontrolled sepsis
7. Retransplantation
8. Transfusion reaction
9. Venous bypass–induced fibrinolysis
10. Primary graft nonfunction
11. Intraop vascular complications

The **hepatectomy** may be a formidable task in patients with severe portal hypertension (HTN), coagulopathy, and previous surgery in the upper abdomen. In such circumstances, blood loss is significant and may be minimized by placing the patient on venovenous bypass or by creating a temporary portacaval shunt to relieve the portal HTN. Table 7.12-1 lists factors that may be associated with significant blood loss during the transplant operation. The hepatectomy is usually much easier in patients with acute fulminant hepatitis, primary biliary cirrhosis, or inborn errors of metabolism than in patients with shrunken cirrhotic livers, such as in postnecrotic cirrhosis from hepatitis B or C, alpha-1 antitrypsin deficiency, or Wilson disease, among others. The liver transplant incision is traditionally subcostal, extending from the left midclavicular line across the midline to just medial of the right 12th rib, with a vertical midline extension from the xiphoid process to the transverse incision. This provides wide exposure to the upper abdomen.

The hepatectomy begins with a manual exploration of the abdomen to ensure there are no occult malignancies, abscesses, or other abdominal processes that may contraindicate proceeding with the transplant. The liver is then mobilized by freeing the falciform and left cardinal ligaments, followed by entering the lesser sac through the division of the gastrohepatic ligament. The mobilization of the liver and the subsequent dissection of the porta hepatis may be significantly complicated and a tedious process due to large, thin-walled varices that require careful dissection and ligation. The dissection of the porta hepatis begins with identification and ligation of the hepatic artery, followed by the common bile duct. The portal vein is carefully dissected from its bifurcation into left and right branches, proximally to its emergence from behind the pancreas. If the degree of portal HTN is severe—such that mobilization of the liver may result in significant blood loss—or the patient is hemodynamically unstable, then portal vein mobilization may be performed early so that a temporary portacaval shunt or venous bypass may be instituted to allow decompression of the varices and enhance venous return to the heart.

After the portal dissection is complete, the right lobe of the liver is mobilized. The infrahepatic vena cava is carefully dissected to prevent injury to the right renal and adrenal veins, followed by mobilization of the suprahepatic vena cava. The liver can be removed easily by cross-clamping and dividing the supra- or infrahepatic vena cava, with or without the use of venous bypass. Alternatively, the recipient vena cava may be left in situ (piggyback technique) by further mobilization of the liver by dividing the short hepatic veins that run from the anterior surface of the vena cava directly into the posterior aspect of the liver. To gain access to the short hepatic veins, the liver must be lifted and rotated to the left. This maneuver may result in partial occlusion of the inferior vena cava, which may impair venous return causing a temporary drop in blood pressure. The piggyback technique, where the recipient vena cava is left in situ, has the advantage that venous return is not compromised during the anhepatic phase and thus precludes the need for venous bypass; however, the hepatectomy phase is longer and can be associated with greater bleeding.

The **anhepatic phase** may be associated with significant hemodynamic changes, depending on the technique used for vascular control. This stage of the operation consists of implantation of the liver allograft, with or without venous bypass. The use of venous bypass is particularly helpful in coagulopathic patients with severe portal HTN. In these high-risk patients, the goal of the venous bypass system is to relieve the portal HTN by "bypassing" the liver. Cannulae, placed in the femoral and portal veins, draw the blood out of the systemic and splanchnic venous systems into a pump that delivers the blood into the axillary or jugular vein, maintaining the venous return (Fig. 7.12-4). This system allows the interruption of the vena cava with mild-to-moderate hemodynamic changes, depending on the blood flow rate through the system. The benefits and potential complications of the venous bypass system are listed in Table 7.12-2.

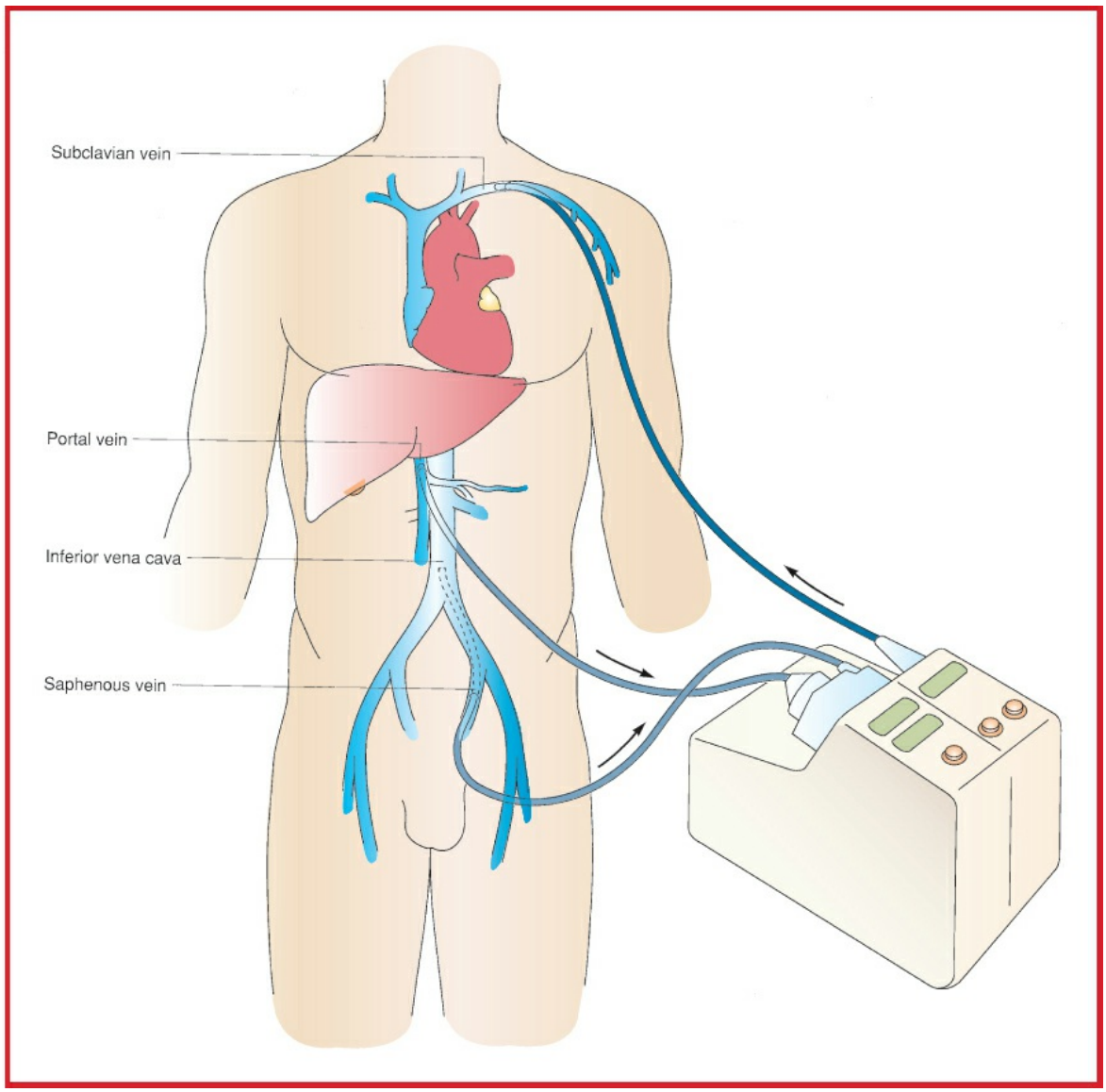

Figure 7.12-4 Setup for venovenous bypass during hepatic transplantation. Cannulae are placed into the portal vein to decompress the splanchnic bed and inferior vena cava (through the greater saphenous vein) to decompress the lower extremities and kidneys during the anhepatic phase of the transplant. A peristaltic pump is used to deliver bypassed blood to the central circulation by means of a cannula introduced into the axillary veins. Cannulae also may be placed percutaneously directly into the femoral and subclavian veins. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al., eds: Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Wound complications and nerve injuries may be prevented by introducing the bypass cannulae percutaneously, rather than approaching the vessels through a surgical incision. An internal jugular bypass cannula can be placed preoperatively using the **Seldinger technique.** A femoral line can also be placed preoperatively and replaced by a bypass cannula intraoperatively. When venous bypass is utilized, vascular control is obtained by placing vascular clamps across the supra- and infrahepatic vena cava or the confluence of the hepatic veins (piggyback technique) and the portal vein. The

splanchnic venous return is interrupted during the anhepatic phase. The systemic venous return is interrupted in the case of formal cross-clamping of the supra- and infrahepatic vena cava and mildly diminished when the piggyback or venous bypass techniques are used These can lead to significant hypotension unless preventive measures, as reviewed in Anesthetic Considerations, are taken (Fig. 7.12-5).

In a **standard orthotopic liver transplant**, with or without venous bypass, the recipient's vena cava is removed, leaving two cuffs—one just below the diaphragm and the other distal to the confluence of the renal veins. The deceased donor liver, with the corresponding segment of the vena cava, is used for restoring the continuity of the recipient's vena cava. The first vascular anastomosis consists of an end-to-end anastomosis of the allograft suprahepatic vena cava and the cuff of the recipient's infradiaphragmatic vena cava. This is followed by the reconstruction of the infrahepatic vena cava with an end-to-end anastomosis. Immediately prior to completion of the infrahepatic vena caval anastomosis, the liver is purged with chilled or room temperature albumin and/or crystalloid solution via the allograft portal vein to remove the preservative solution, which may contain high concentrations of potassium (~145 mEq/L K^+). In addition, flushing the liver also removes a significant amount of the air that gets introduced during the procurement and preparation of the allograft for transplantation. Finally, the portal vein reconstruction is completed with an end-to-end anastomosis. At this point, the clamps are removed, ending the anhepatic phase of the operation.

Table 7.12-2 Benefits and Potential Complications of the Venovenous Bypass System

Benefits	Complications
Improved hemodynamics during anhepatic phase	PE
↓ blood loss	Air embolism
May improve perioperative renal function*	Brachial plexus injury Wound seroma/infection Vascular injury

*In a prospective randomized trial comparing venovenous bypass with no bypass, no difference was found in the periop renal function between the two groups.

Venous bypass is not necessary when the **piggyback technique of liver transplantation** is utilized because the diseased liver is separated from the vena cava (systemic venous

return remains unimpaired), and vascular control is obtained by placing a clamp across the confluence of the hepatic veins as they join the vena cava (Fig. 7.12-6). A temporary portacaval shunt may be created to minimize bleeding in cases of severe portal HTN. The first anastomosis is between the suprahepatic vena cava of the liver allograft and the cuff created from the hepatic veins. The infrahepatic vena cava of the liver allograft is ligated, and the portal vein reconstruction is then completed. The clamps are then removed and the liver is revascularized.

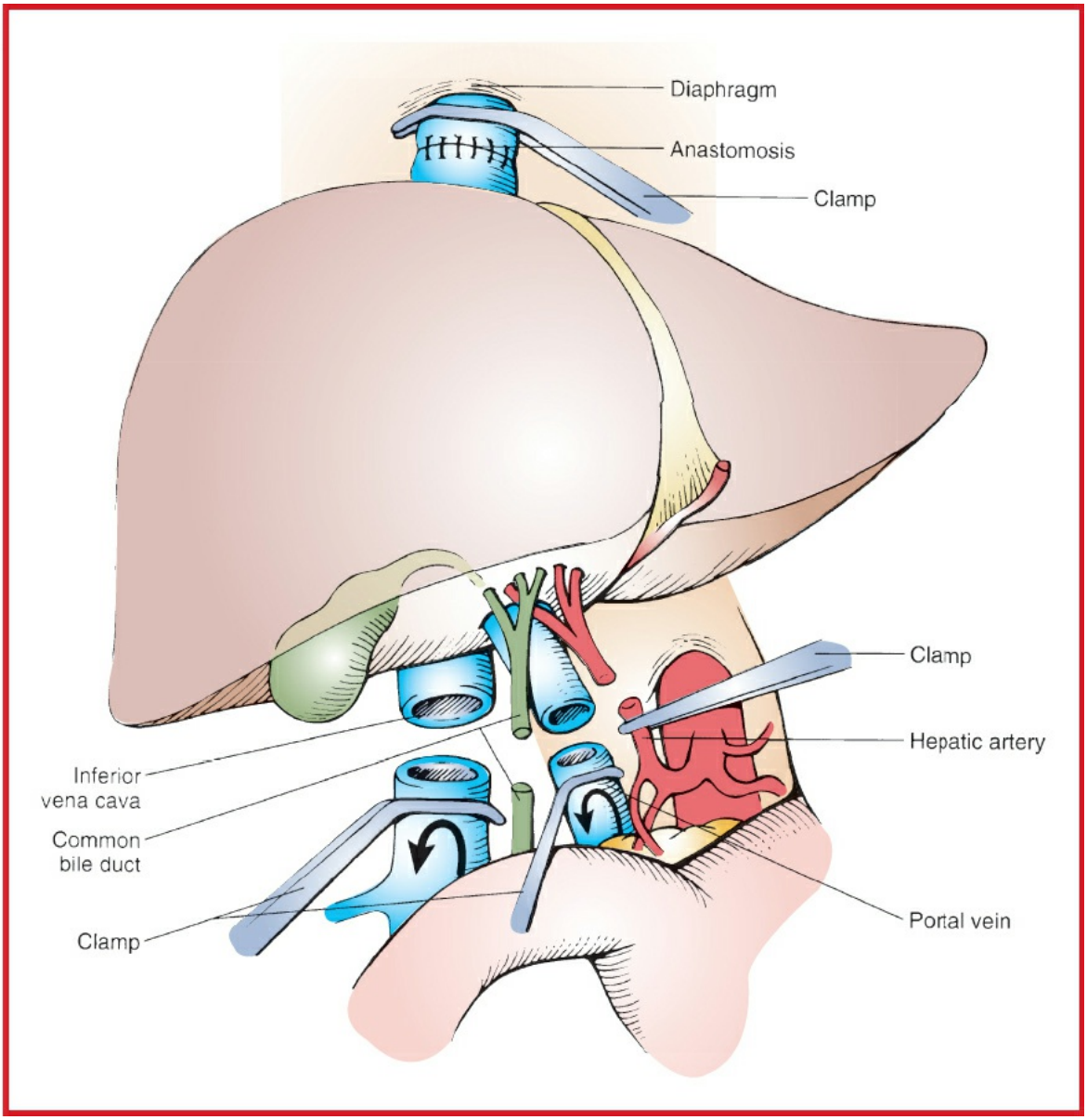

Figure 7.12-5 Standard liver transplantation without venovenous bypass. Venous return is significantly impaired.

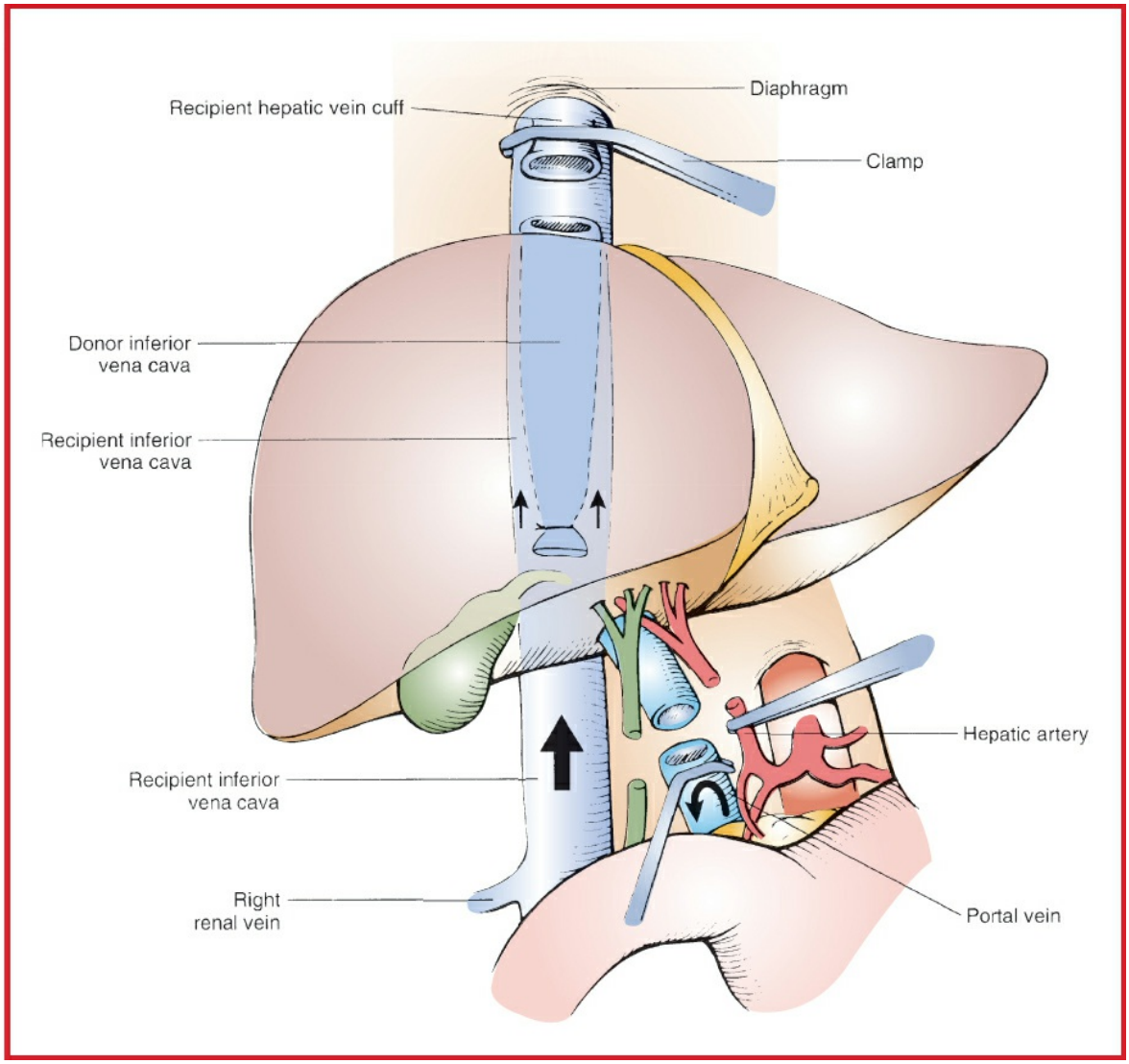

Figure 7.12-6 Piggyback liver transplantation. Note that the recipient's vena cava is left intact and systemic venous return is unimpaired.

The **postrevascularization stage** of the transplant begins with the removal of the vascular clamps. The reperfusion of the liver may be the most critical part of the operation. Despite flushing the liver to remove the high K^+-containing organ preservation solution, hyperkalemia may cause cardiac arrhythmias following liver reperfusion, particularly with livers that sustained significant injury during preservation and reperfusion. In addition, massive air embolism is an immediate concern following revascularization, as it may quickly lead to cardiac arrest. It is also during this stage that the patient may experience increased right heart pressures, which can lead to right heart failure and severe systemic hypotension. Pulmonary HTN and right heart failure must be treated aggressively with inotropic agents; otherwise, the liver is subjected to high outflow resistance resulting in congestion and worsening of the allograft preservation injury. The cause of this phenomenon is not well understood; fortunately, it is seen in

very few patients. Another reperfusion phenomenon is that of systemic hypotension secondary to peripheral vasodilation. This may be due to the release of systemic inflammatory mediators, which include kinins, cytokines, and free radicals from the liver allograft. Reperfusion of the liver also can have dramatic effects on coagulation, such as fibrinolysis resulting in severe hemorrhage or hypercoagulation that can result in venous thrombosis and a massive pulmonary embolism with cardiovascular collapse.

Immediately prior to revascularization, the patient is usually given methylprednisolone (250–1000 mg) as part of the immunosuppressive regimen, as well as an adjunct to counteract the systemic effects of ischemia-reperfusion injury of the liver. At this point, all of the vascular anastomoses, the peritoneum, and the liver (especially the cut surface in segmental or reduced-size grafts) are inspected for surgical bleeding.

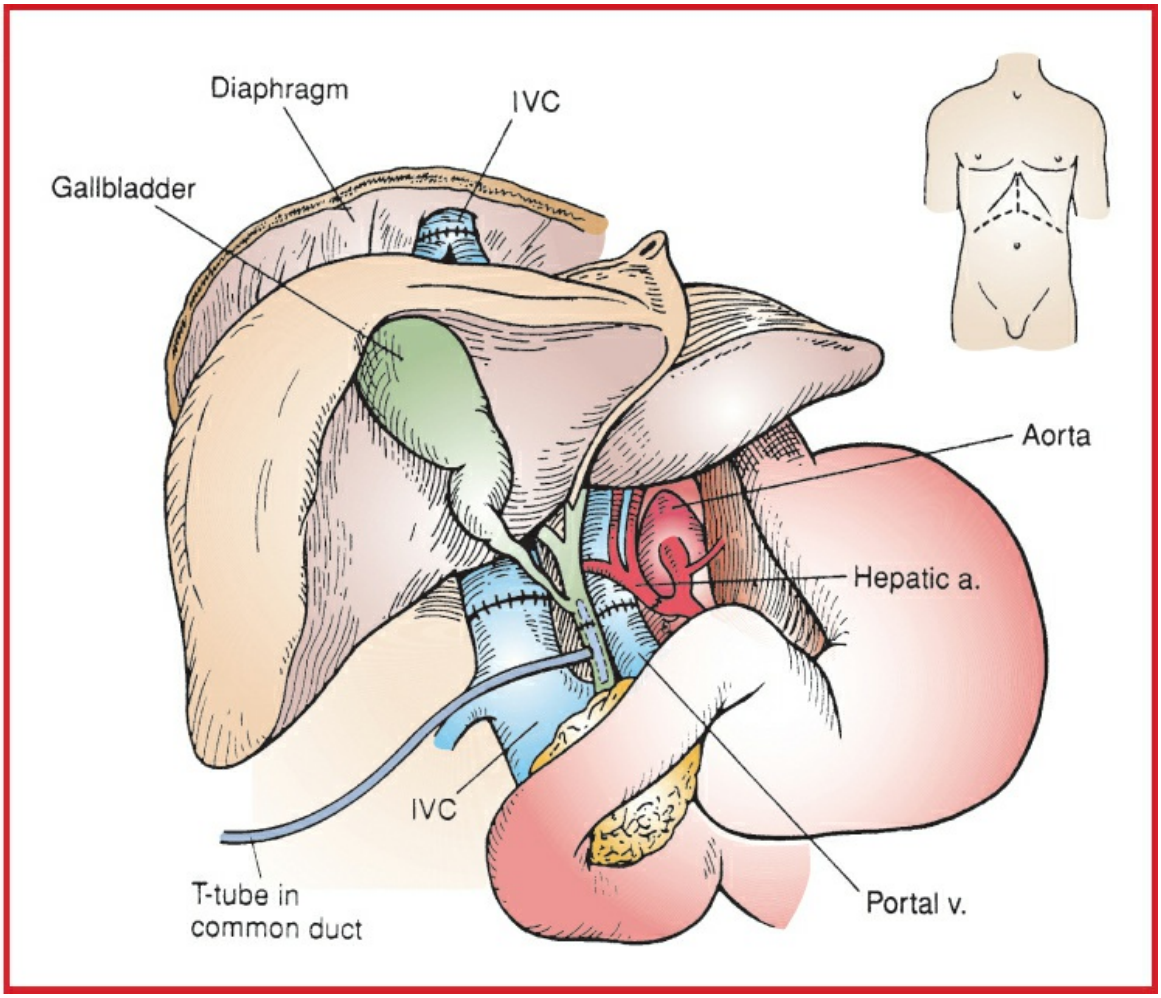

Figure 7.12-7 Liver transplantation. Anastomoses—including suprahepatic and infrahepatic IVC, portal vein, hepatic artery, and common bile duct—are complete as shown here. Roux-en-Y loop of the small intestine is an alternative biliary drainage conduit. **Inset** shows a chevron incision with midline extension. (Reproduced with permission from Hardy JD:Hardy's Textbook of Surgery, 2nd edition. JB Lippincott, Philadelphia: 1988.)

The hepatic artery reconstruction is performed after stabilization of the patient following revascularization of the liver. After the hepatic arterial anastomosis is completed, it is important to maintain adequate arterial BP (MAP > 65 mm Hg) to prevent hepatic artery thrombosis. This is especially critical in pediatric transplant recipients, where the hepatic artery diameter ranges from 1 to 3 mm. The last part of the procedure involves hemostasis, removal of the gallbladder, and reconstruction of the bile duct (Fig. 7.12-7). There are three basic methods for the **bile duct reconstruction:** (a) an end-to-end anastomosis, with or without a T-tube (in patients with normal common bile ducts), and (b) a choledochojejunostomy to a Roux-en-Y limb of the jejunum (Fig. 7.12-8; in patients with biliary atresia, primary sclerosing cholangitis, and diseased common bile ducts or when there is a size discrepancy between the donor and recipient common bile duct), (c) a choledochoduodenostomy (in patients with congested bowel or extensive bowel adhesions and an indication for a Roux-en-Y). In cadaveric or live-donor segmental transplantation, the technique for the recipient's hepatectomy and the implantation of the allograft is not different from that of full-size liver transplantation; however, the technique of piggyback liver transplantation must be used with live donors because the allograft segment does not include the vena cava. The anesthesiologist must be alert during the reperfusion of a segmental graft because significant bleeding may ensue from the raw surface of the liver.

After the biliary reconstruction is completed and bleeding controlled, a feeding jejunostomy tube and two to three closed-suction drains may be placed. The position of an OG or NG tube (placed at the beginning of the case) is confirmed and the abdomen is closed.

Usual preoperative diagnosis

ESLD

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status and possible optimization, discussion of carb loading, DVT prophylaxis, urinary drain, pain management options, and postop recovery plan. See Appendix K, p. K-1.

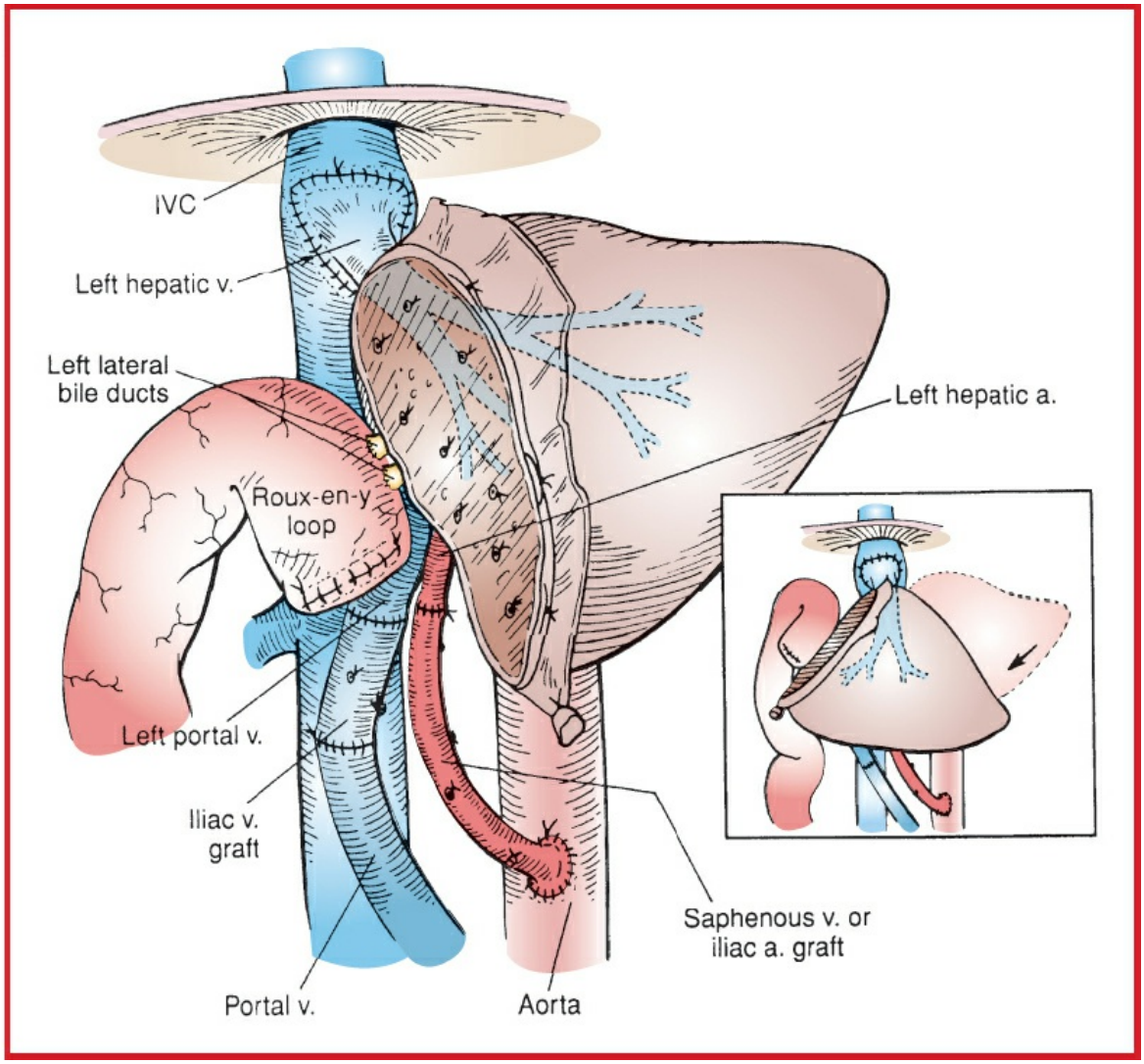

Figure 7.12-8 Liver transplantation (child) using left lateral segment from an adult liver. The hepatic artery and portal vein are extended with donor iliac artery and vein, respectively. The final position of the graft is shown (**inset**). A Roux-en-Y loop of the small intestine is used to drain the bile duct(s). The IVC is left intact. The cut surface of the liver can bleed excessively if the central venous pressure is too high. (Reproduced with permission from Broelsch CE, Whitington PF, Emond JC, et al: Liver transplantation in children from living related donors: surgical techniques and results. Ann Surg 1991; 214(4):432.)

SUMMARY OF PROCEDURE

Position	Supine; arms tucked. Left arm and left groin area out for access to the axillary and femoral veins if venous bypass is anticipated
Incision	Bilateral subcostal, in children; in adults, incision must extend cephalad to the xiphoid process.
Special instrumentation	Upper hand or Thompson retractor; venous bypass pump; rapid-infusion system; cell salvage system;

	argon beam coagulator, ultrasound
Unique considerations	Thrombus or air embolism may occur during removal of clamps from vena cava or with the use of venovenous bypass. Right heart failure, ↓ BP, and ↓ SVR may be observed after revascularization. Continuous AV hemofiltration may be required if renal failure is present. Head and extremities should be covered with plastic to maintain core body temperature, particularly in children. Gastric tube is required.
Antibiotics/drugs	Third-generation cephalosporin (e.g., cefotaxime 1 g q3h intraop) or broad-spectrum penicillin/beta-lactamase prior to incision. Methylprednisolone and antilymphocyte antibody preparations for immunosuppression
Surgical time	4–12 h
EBL	6 U average blood loss (range 0–100 U)
Postop care	ICU: 1–2 d. HTN commonly seen
Mortality	3% at 1 yr
Rejection	10–30% during the first yr
Morbidity	Infectious complications: 20–50% Biliary stenosis or leaks: 5–15% Retransplantation: 6–14% Primary graft nonfunction: 2–5% Hepatic artery thrombosis: 0–6% Portal vein thrombosis: 1–4%
Pain score	7–8

PATIENT POPULATION CHARACTERISTICS

Age range	Neonate–70 yr
Male:Female	1:1
Incidence	10/million/yr (15% pediatrics)
Etiology	Adult: hepatitis C cirrhosis; alcoholic cirrhosis; primary

	biliary cirrhosis; primary sclerosing cholangitis; hepatitis B cirrhosis; hepatocellular carcinoma. Pediatric: biliary atresia; inborn errors of metabolism, hepatoblastoma
Associated conditions	Coagulopathy; hypoalbuminemia; ascites; cardiomyopathy (in alcoholic patients, hemochromatosis, and Wilson disease); hepatorenal syndrome; hepatopulmonary syndrome, portopulmonary hypertension/GI bleed, hepatic encephalopathy, and hypoglycemia in acute fulminant hepatitis

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients needing liver transplantation represent a formidable challenge to the anesthesiologist. Frequently, these patients present for surgery with multiorgan system failure.

Respiratory	Patients are often hypoxic because of ascites, pleural effusions, atelectasis, V/Q mismatch, pulmonary AV shunting, or hepatopulmonary syndrome. As a result, they are usually tachypneic and have a respiratory alkalosis. Evidence of pulmonary infection is usually a contraindication to surgery, but ARDS that may occur with hepatic failure is not. **Tests:** ABG; PFTs, as indicated. CXR: infection, effusions, atelectasis
Cardiovascular	These patients demonstrate a hyperdynamic state with ↑ plasma volume, ↑ CO, and ↓ SVR 2° arteriolar vasodilation in the splanchnic circulation, with intense vasoconstriction in other vascular territories (e.g., renal, brain, muscle, spleen). The SVR usually is not responsive to α-agents. AV fistulae may occur across the pulmonary circulation, so that precautions to prevent air embolism are important. Ejection fraction (EF) is usually high (>60%), but some

	patients have cirrhotic cardiomyopathy → ↓ contractility 2° ↓ β-receptors, alterations in myocardial cell membrane properties, and ↑ myocardial depressant substances. This cardiac dysfunction, however, usually is masked by a reduction in afterload. Pericardial effusions may be present and should be drained at surgery. Many of these patients will have dysrhythmias, HTN, pulmonary HTN (very high risk), valvular disease, cardiomyopathy (alcoholic disease, hemochromatosis, Wilson disease), and CAD. These patients will require appropriate preop consultation and workup. **Tests:** ECG; stress ECHO: EF, contractility, pulmonary HTN, wall motion abnormalities, valve problems. If abnormal, right and left heart catheterization with coronary artery angiography should be performed.
Neurologic	Patients are often encephalopathic and may be in hepatic coma; however, other organic causes of coma should be ruled out. In fulminant hepatic failure, ↑ ICP is common, accounting for 40% of mortality (herniation) and may require prompt treatment (mannitol, hyperventilation, etc.). **Tests:** Continuous ICP monitoring in fulminant hepatic failure
Hepatic	Hepatitis serology and the cause of hepatic failure should be determined. Vascular abnormalities, previous RUQ surgery, or portal vein decompressive surgery places the patient in a high-risk group. Albumin is usually low, with consequent low plasma oncotic pressure → edema, ascites. The magnitude and duration of drug effects may be unpredictable, but generally, these patients have ↑ sensitivity to all drugs and their actions are prolonged. **Tests:** Bilirubin; PT; ammonia level; SGOT; SGPT; albumin

Gastrointestinal	Portal HTN, esophageal varices, and coagulopathies ↑ risk of GI hemorrhage. Gastric emptying is often slow and, together with the emergent nature of this surgery, warrants rapid-sequence induction. H_2 antagonists are indicated preop.
Renal	Renal function ↓, especially in fulminant hepatic failure (hepatorenal syndrome). The kidneys often recover after transplantation, but simultaneous kidney transplantation may be justified. These patients are often hypervolemic, hyponatremic, and possibly hypokalemic. Ca^{++} is usually normal. Metabolic alkalosis may be present. **Consider preop dialysis and intraop continuous venovenous hemofiltration (CVVH)**. CVVH corrects fluid overload, acidosis, and electrolyte abnormalities and results in the washout of released cytokines after reperfusion of the graft liver. Mannitol (0.5–1 g/kg) may be used intraop to maintain renal function. **Tests:** BUN; Cr, creatinine clearance; electrolytes; ABG
Endocrine	Patients are often glucose intolerant or frankly diabetic, although acute hypoglycemia may be seen in acute hepatic failure. Hyperaldosteronism may be present. **Tests:** Glucose; electrolytes
Hematologic	These patients are often anemic 2° either blood loss or malabsorption. Coagulation is impaired because of ↓ hepatic synthetic function (all factors except VIII and fibrinogen are ↓), abnormal fibrinogen production, ↓/impaired Plt, fibrinolysis, and low-grade DIC. **Tests:** PT; PTT; Plt count; bleeding time; fibrinogen; fibrin split products (FSP); TEG
Premedication	Low doses of benzodiazepines may be used judiciously, but often nothing is given prior to surgery. Usually good preop evaluation and discussion suffice. Intramuscular injection should be

	avoided. Full-stomach precautions are justified.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of a transversus abdominis plane or thoracic epidural block for postop pain management. Consider aprepitant 40–80 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: These patients are extremely complex to manage because of the hemodynamic instability, massive blood loss, coagulopathy, and metabolic problems. It is convenient to divide the operation into three stages: preanhepatic, anhepatic, and neohepatic (discussed later).

Induction	Often, a narcotic (e.g., fentanyl 2–5 mcg/kg) is given just before induction; and rapid-sequence induction is preferred. Etomidate (0.3 mg/kg) with succinylcholine (1–2 mg/kg), together with cricoid pressure
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Standard maintenance with fentanyl 10–50 mcg/kg. A benzodiazepine (e.g., midazolam 0.1–0.3 mcg/kg) often is given to ensure amnesia during periods of hemodynamic instability when the volatile agent may need to be off. N_2O is avoided because of bowel distension and possible air embolism. Ventilation with FiO_2 > 0.5 and $PaCO_2$ = ~35 mm Hg. Occasionally, PEEP (5 cm H_2O) is added. Antibiotics and immunosuppressants should be given per surgeon's direction. Muscle relaxation usually is maintained.
Preanhepatic phase	The **preanhepatic phase** starts at skin incision and ends with removal of the recipient liver. Pleural and pericardial effusions are drained, which may improve

oxygenation. Hyperglycemia is common during this period. A drop in filling pressures may be 2° hemorrhage or vascular compression. Hemorrhage can be severe 2° portal HTN. Coagulation problems usually increase during this stage, although fibrinolysis is not usually a problem. Blood loss replacement is accomplished with blood (PRBC) and FFP. Cryoprecipitate and Plts are given as needed, but a hypercoagulable state should be avoided, particularly if venovenous bypass is contemplated. Hemodynamic instability is not uncommon during the hepatic vascular dissection 2° manipulation of the liver and ↓ venous return.

Venovenous bypass relieves most of the complications of portal and IVC cross-clamping (↓ venous return, low CO, tachycardia, acidosis, ↓ renal function, intestinal swelling). Blood is pumped from the femoral vein and the portal system (either portal vein or inferior mesenteric) via a centrifugal pump to the right internal jugular vein. Generally, no heparin is used. Bypass flow needs to be at least 1 L/min to avoid possible thromboembolism. Bypass flow depends on venous inflow and is drawn into the pump by negative pressure. Low flows may be caused by hypovolemia or obstructed cannulae. Complications include unexpected decannulation, thromboembolism, and air embolism, all of which may need rapid termination of bypass and treatment of ↓ BP; fibrinolysis is seen with prolonged venovenous bypass.

Massive blood transfusion is associated with ↓ Ca^{++}, and replacement is usually needed (±500 mg/1000 mL of blood/FFP/Plasma-Lyte mixture). If hyperkalemia occurs, it should be treated aggressively. Metabolic acidosis >5 mEq/L should be treated with bicarbonate or THAM acetate (tris-hydroxymethyl aminomethane) to avoid a rapid increase in sodium. Typical loading dose: mL of 0.3M THAM = lean body weight [kg] × base deficit [mmol/L]. Occasionally, inotropic support

	is needed, but α-adrenergic agents should be avoided because of ↓ renal and peripheral perfusion. UO needs to be maintained by ensuring adequate intravascular volume; occasionally mannitol may be needed.
Anhepatic phase	The **anhepatic phase** begins with clamping of the hepatic vessels and vena cava and removal of the liver; it ends with the reperfusion of the donor liver. Problems during this period include hemorrhage, increasing coagulopathy and fibrinolysis, acidosis, hypothermia, and ↓ renal function. The hemodynamic instability associated with clamping of the hepatic vessels and the congestion of the bowel that occurs can be decreased by venovenous bypass (see the previous text). Care should be taken to maintain intravascular volume, while avoiding volume overload, because this would worsen fluid overloading on reperfusion. At the completion of vena caval anastomoses, the liver is flushed via the portal vein to remove air, preservation fluid, and metabolites. Reperfusion may take place after completion of the portal vein anastomosis or after both portal vein and hepatic artery anastomoses are completed. As in the preanhepatic phase, acidosis, ↓ Ca^{++}, glucose, coagulation, and other electrolyte abnormalities should be treated. Fibrinolysis usually starts in this period but is not usually treated unless severe because of the potential for embolism during venovenous bypass.
Neohepatic phase	The **neohepatic phase** begins with the unclamping of the portal vein, hepatic artery, and vena cava and reperfusion of the donor liver. Preparation for this phase is important because this may be a period of great hemodynamic instability. Before removal of the clamps, acidosis should be corrected, ionized Ca^{++} should be normal, and K^{+} should be <4.5 mEq/L. $CaCl_2$, $NaHCO_3$, and epinephrine should be readily available. Fluid overload prior to declamping should be avoided. High venous filling pressures decrease hepatic perfusion, especially prior to hepatic artery

	anastomosis. Declamping can be attended by ↓ BP, ↓ HR, dysrhythmias, hypothermia, lactic acidosis, coagulopathy, hyperglycemia, and thromboembolism.
Reperfusion syndrome	The **reperfusion syndrome** (which can occur in this phase) is characterized by ↓ HR, ↓ BP (30% of patients develop MAP < 70% of baseline), conduction defects, and ↓ SVR in the face of acutely ↑ RV filling pressures. Cause unknown. A rapid ↑ K^+ can → cardiac arrest. (Rx: ensure normal pH and electrolytes prior to unclamping, rapid therapy when it occurs.) ↓ BP and ↓ HR are treated with epinephrine (10 mcg increments), whereas $CaCl_2$ and $NaHCO_3$ are used to correct hyperkalemia and acidosis. Pulmonary edema may occur as a result of fluid overload and can be treated with diuretics, inotropes, and phlebotomy. A high venous pressure will cause graft congestion and should be avoided. Reperfusion is associated with severe coagulopathy due to fibrinolysis (usually primary), release of heparin, and hypothermia. As liver function returns, there should be an improvement in coagulation, acid-base status (metabolic alkalosis may occur), ↓ lactic acidosis, return of glucose to normal, and bile production. Hypokalemia may occur 2° uptake by the liver. Graft failure is associated with coagulopathy, ↑ lactic acid, citrate intoxication, hyperglycemia, and ↓ bile formation.
Emergence	Extubation is deferred. These patients are generally ventilated postop in ICU until stable and able to be weaned from ventilatory support. Apart from the usual tests, monitor hepatic function. Also ensure immunosuppression provided, infection controlled, analgesia adequate (usually fentanyl), and peptic ulcer prophylaxis given (ranitidine preferred). Discuss with surgeon local wound infiltration or nerve block (e.g., TAP block) placement or reinforcement if initially placed >4 h ago. PONV prophylaxis may include dexamethasone and ondansetron.

Blood and fluid requirements	Massive blood loss IV: 10 Fr × 2 BSS UO > 1 mL/kg/h Warm all fluids Humidify gases Rapid-infusion system Cell salvage system 20 U PRBC 20 U FFP 2 U PLT	Generally, ivs are placed in the right antecubital fossa, left IJ or EJ. The right IJ is reserved for venovenous bypass. Plasma-Lyte A™ and Normosol™ are preferred (absence of glucose, Ca^{++}, and lower Na^{+} content) over NS or LR. Hypernatremia may occur due to administration of $NaHCO_3$. The ability to infuse up to 1.5 L/min of blood should be available. Usually a mixture of Normosol (250 mL), PRBC (1 U), and FFP (1 U) is used, yielding Hct = 26–30%. Actual blood loss estimation is extremely difficult, and usually replacement is judged by hemodynamic status, UO, and S_vO_2. Cell salvage systems are used to conserve blood. Anticoagulation is achieved with citrate solution to avoid heparin contamination, and cells are washed with Normosol/Plasma-Lyte A. Discontinue use before biliary reconstruction (infection) or in neoplasms, hepatitis B, or spontaneous bacterial peritonitis. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors ECG (5-lead) Temp bladder	Include 5-lead ECG and bladder T. (These patients sustain significant heat loss.) A full-time anesthesia technologist and lab/blood bank runner are useful. Lab and blood

	bank should be notified of the expected transplant.
Arterial line(s)	One or two arterial lines are placed at the outset—one in the right radial, for ongoing lab and blood gas sampling; another line, in the right femoral artery, is utilized for continuous pressure measurement.
PA catheter/S_vO_2/CO	A PA catheter is essential for management of hemodynamics in these patients because of the rapid changes in VS and the fact that a significant number of patients have recognized or unrecognized pulmonary hypertension. A catheter capable of measuring mixed venous O_2 sat is very useful because it gives early clues to impending decompensation. Coagulopathy complicates the placement of central lines, and the use of ultrasound guidance is recommended.
TEE	TEE is useful to monitor cardiac filling and function and to diagnose problems such as PE or air embolism. Care needs to be taken in placing the TEE because many of these patients have esophageal varices.
ICP	ICP should be measured in patients with fulminant hepatic failure if ↑ ICP is a concern.
Laboratory	ABG, acid-base status, electrolyte, lactate, osmolality, Ca^{++}, PT, PTT, Plt, Hct—all

	Thromboelastograph (TEG)	should be monitored on a regular basis (hourly or half-hourly; occasionally, more frequently). TEG is useful for monitoring coagulation (see the subsequent discussion of coagulation management).
Coagulation management	PT PTT Plt counts Fibrinogen FSP TEG	Patients are prone to a variety of coagulopathies (↓ Plt, ↓ coagulation factors, DIC, fibrinolysis, etc.) because of preop factors, massive hemorrhage, anhepatic period, and reperfusion of the new liver; therefore, monitoring and treatment are necessary. Also, states of hypercoagulopathy need to be avoided because of unheparinized venovenous bypass. Although PT, PTT, Plt counts, fibrinogen, and FSP may provide relevant information, they may not reflect the true coagulability of patient's blood and tend to take considerable time to perform. Thus, in some centers, TEG has gained in popularity. It measures whole blood coagulability, not specific factors. TEG works by measuring viscoelastic properties of blood as it forms clot (fibrin connections) between a rotating cuvette and a spindle. Characteristic patterns are formed by the various coagulopathies with the common

		types shown in Figure 7.12-9. Evaluation of the TEG leads to more rational transfusion therapy, reducing the number of units of blood products used. Comparing specimens of native whole blood vs. blood mixed with EACA or protamine can guide pharmacologic therapy of coagulopathies. Table 7.12-3 gives specific recommendations.
Positioning	✓ and pad pressure points ✓ eyes	Table and arm boards should be very well padded. The head should be placed on a foam rest. Particular care should be taken to pad the retractor supports where they may impinge on the arms and on the radial nerve as it curls around the humerus.
Temperature control	Warming blanket Humidifier	Patient's arms, head, and legs should be wrapped in plastic to protect against heat loss. Plastic drapes and the use of a cesarean section–type drape to protect the ECG electrodes and direct fluid flow off the table are useful to prevent the patient from lying in a pool of fluid. A warming blanket under the patient and over the lower legs is very useful.
Complications	Coagulopathy Hemorrhage Air embolism RV failure Metabolic acidosis	

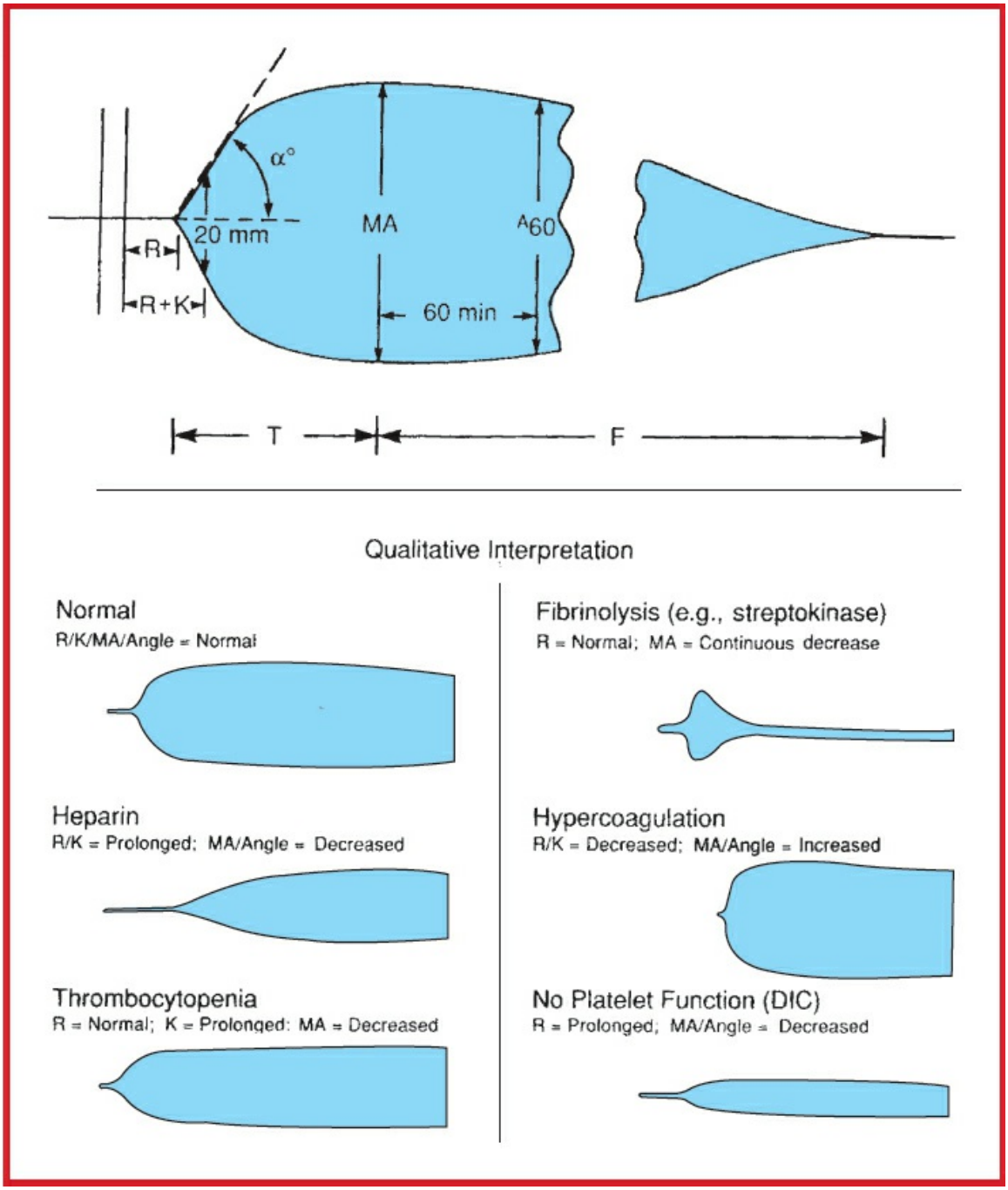

Figure 7.12-9 Variables and normal values measured by TEG: R = reaction time, 6–8 min; R + k = coagulation time, 10–12 min; α = clot formation rate, >50°; MA = maximum amplitude, 50–70 mm; A_{60} = amplitude 60 min after MA; A_{60}/MA-100 = whole blood clot lysis index, >85%; F = whole blood clot lysis time, >300 min. (Reproduced with permission from Kang YG, Martin DJ, Marquez J, et al: Intraoperative changes in blood coagulation and thromboelastographic monitoring in liver transplantation. Anesth Analg 1985; 64:891.)

Table 7.12-3 Coagulation Therapy Guided by TEG Monitoring

1. Maintenance fluid

RBC:FFP:Plasma-Lyte A = 300:200:250 mL

2. Replacement therapy
   a. FFP (2 U) for prolonged reaction time (R > 15 min)
   b. Plt (10 U) for small MA (MA < 40 mm)
   c. Cryoprecipitate (6–12 U) for persistent slow clot formation rate (α < 40°) with normal MA
3. Pharmacologic therapy
   a. Compare coagulability of whole blood, blood treated with protamine sulfate, and blood treated with epsilon aminocaproic acid.
   b. Epsilon aminocaproic acid (1 g) for severe fibrinolysis (F < 60 min)
   c. Protamine sulfate (50 mg) for severe heparin effect
   d. Heparin (1000–2000 U) for hypercoagulable state

POSTOPERATIVE

Monitoring of hepatic function	Serial LFTs PT, PTT Ammonia level Lactate TEG Bile output	Initial LFTs often show very high liver enzymes, which subside over a period of days. PT generally improves to normal levels, while lactic acidosis usually corrects quickly. Often, a metabolic alkalosis follows and may need HCl treatment.
Complications	Bleeding Partial vein thrombosis Hepatic artery thrombosis Biliary tract leaks Primary nonfunction Rejection Infection Pulmonary complication	This is not a complete list. Feared complications that may → graft loss include portal vein thrombosis, hepatic artery thrombosis, bile leaks, and rejection. These are attended by ↑ LFTs, lactic acidosis, coagulopathy, hypoglycemia, ↓ renal function, and poor bile formation.

	HTN Electrolyte abnormalities (hypokalemia, ↓ Ca^{++}, ↑ Na) Alkalosis Renal failure Peptic ulceration Neurologic

Suggested Readings

1. Adelmann D, Kronish K, Ramsay MA: Anesthesia for liver transplantation Anesthesiol Clin 2017; 35(3):491–508.
2. Black CK, Termanini KM, Aguirre O, et al: Solid organ transplantation in the 21(st) century. Ann Transl Med 2018; 6(20):409.
3. Cleland S, Corredor C, Ye JJ, et al: Massive haemorrhage in liver transplantation consequences, prediction and management. World J Transplant 2016; 6(2):291–305.
4. Lemon K, Al-Khafaji A, Humar A: Critical care management of living donor liver transplants. Crit Care Clin 2019; 35(1):107–16.
5. Melloul E, Hübner M, Scott M, et al: Guidelines for perioperative care for live surgery: Enhanced Recovery After Surgery (ERAS) Society recommendations.World J Surg 2016; 40(10):2425–40.

LIVING-DONOR LIVER TRANSPLANTATION

SURGICAL CONSIDERATIONS

Description

The success of deceased donor liver transplantation has resulted in an ever-increasing number of patients with ESLD waiting for transplantation; however, the number of deceased donors has remained relatively constant. Consequently, the waiting time to receive an organ has increased significantly, and ~15% of patients will die while waiting. The success of **living-donor renal transplantation**, coupled with the experience in adult-to-pediatric living-donor liver transplantation, as well as advances in surgical and postsurgical care of patients undergoing major liver resections, has lead to the implementation of adult-to-adult living-donor liver transplantation.

Potential living liver donors undergo extensive medical and psychosocial evaluation to ensure psychological as well as physical fitness to undergo a major surgical procedure that provides no medical benefits to the donor. Donors must have full blood typing to ensure compatibility with the recipient and then fill out an extensive medical questionnaire, followed by a complete physical exam and screening lab tests. Any evidence of diabetes, HTN, or renal, pulmonary, living-donor liver transplantation, cardiovascular, or hepatic abnormalities usually is a contraindication to donation. After the potential donor is medically and psychosocially cleared, they undergo a detailed magnetic resonance imaging study of the liver to assess liver segment size, anastomosis, and possible anatomical contraindications.

The donor and recipient operations are usually conducted simultaneously to minimize the ischemic injury to the donor liver segment. The donor operation, however, is initiated first, with the recipient operation commencing only after the donor liver has been directly examined and no unforeseen anatomic barriers to donation are found. The living donor operation is similar to a right or left hepatic lobectomy undertaken for hepatic disease, although there are some differences that can have a significant impact on anesthetic management.

The donor may elect to have an epidural catheter for postop analgesia, and this usually is placed before surgery. Living donor liver resection has been successfully performed laparoscopically; however, due to limited experience and utilization of this technique, it will not be detailed here. A vertical midline incision is made from the xiphoid to just above the umbilicus and extended transversely to the right anterior axillary line. Occasionally, bisubcostal incisions are required. Following exploration of the abdomen, intraoperative ultrasound may be performed to map the hepatic venous anatomy so the plane of resection can be delineated. In addition, an intraoperative cholangiogram is performed via the cystic duct (a cholecystectomy is performed in either right or left hepatic lobectomy) or the common bile duct, to define the biliary anatomy. After this is performed, the corresponding portal vein and hepatic artery are isolated. Unlike in a hepatic lobectomy for tumor, the venous and arterial inflow to the liver segment is not ligated; thus, the transaction of the liver parenchyma may result in significant hemorrhage. The respective lobe of the liver is mobilized from its attachments, and the liver is dissected from the retrohepatic vena cava, with ligation of the short hepatic veins. This maneuver can cause transient hypotension secondary to torque and compression of the IVC and hepatic veins, as well as potential bleeding from the vena cava itself. Next, the hepatic vein is isolated, and the liver parenchyma is then divided, which can be a slow and tedious process. Following division of the hepatic parenchyma, the liver segment is ready to be removed. Heparin (80–100 U/kg) is given

to prevent intrahepatic clot formation. Following heparinization, the hepatic artery and portal vein are ligated and divided, followed by the hepatic vein. The donated hepatic lobe is immediately placed in ice and flushed with organ preservation solution. Once the donated liver segment has been removed, the abdomen and cut surface of the remaining liver are inspected for hemostasis and bile leak. Closed drains are placed, after which the abdomen is closed. Essentially, the same procedure is followed for a left lateral segmentectomy (adult to child), except that the amount of donor liver removed is about 25%, compared with 40% and 60% for a left or right hepatic lobectomy, respectively.

Usual preop diagnosis

Healthy, living liver donor

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, and possibility of urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine; arms tucked
Incision	Vertical midline with a right and/or left subcostal extension, depending on liver segment being utilized. Laparoscopic or laparoscopically assisted technique described
Special instrumentation	Retractor; laparoscopic or laparoscopically assisted technique described ultrasonic or hydrojet dissection/aspirator; irrigating bipolar cautery; argon beam coagulator; cell salvage system; rapid-infusion system
Unique considerations	Intraop cholangiogram and/or ultrasound. Hemodilution immediately before surgery, with removal of 1 U whole blood if Hct ≥ 40. Patients also may have donated 1–2 U of autologous blood. Heparin 80–100 U/kg
Antibiotics	Ampicillin 1 g and ceftriaxone 1 g iv before skin incision

Surgical time	3–5 h
EBL	250–500 mL
Postop care	ICU overnight or surgical floor. Hospital stay 5–7 d
Mortality	34 deaths reported worldwide (as of August 2010) following ~11,553 donor operations
Morbidity	Infectious complications: 15% Biliary leak: 8% Reoperation: 3–5% Acute hepatic failure: <0.1%
Pain score	7–9

PATIENT POPULATION CHARACTERISTICS

Age range	18–55 yr
Male:Female	1:1
Incidence	Uncommon

ANESTHETIC CONSIDERATIONS

See Anesthesia for Hepatic Resection.

Suggested Readings

1. Abecassis MM, Fischer RA, Olthoff KM, et al: Complications of living donc hepatic lobectomy—a comprehensive report. Am J Transplant 2012; 12(5):1208–17.
2. Au KP, Chok KSH: Minimally invasive donor hepatectomy, are we ready for prime time? World J Gastroenterol 2018; 24(25):2698–709.
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4. Brige P, Hery G, Chopinet S, et al: Morbidity and mortality of hepatic right lobe living donors: systematic review and perspectives. J Gastrointestin Liver Dis 2018; 27(2):169–78.
5. Chen KH, Siow TF, Chio UC: Laparoscopic donor hepatectomy.Asian J Endosc Surg 2018; 11(2):112–7.

MULTIORGAN PROCUREMENT

SURGICAL CONSIDERATIONS

Description

The families of brain-dead patients may allow donation of the patient's functioning organs—which may include, but is not limited to, the heart, lungs, liver, kidneys, pancreas, and small intestine. The process of organ procurement can be chaotic, with multiple operative teams and technicians working simultaneously. Moreover, brain-dead patients may be hemodynamically unstable, sometimes requiring multiple pressors, and the possibility of acute decompensation is ever present.

The donor patient's chest and abdomen are opened in the midline from the sternal notch to pubis (Fig. 7.12-10). The chest is opened with a sternal saw, and generally an extra-large Balfour retractor is used to widely retract the abdomen. The aorta and IVC are dissected first to allow rapid placement of a flush line in the event that the patient experiences a cardiovascular collapse. Following this, the liver vasculature is identified in the hepatoduodenal ligament and is dissected out. This part of the procedure generally takes about 1.5 h. In cases where the pancreas is procured, an additional 45–60 min is required for mobilization of the pancreas. During pancreas procurement, a Betadine/amphotericin B solution is administered through an NG tube into the stomach and duodenum. A total of about 300–500 mL of the Betadine solution is passed in two divided aliquots. After the heart, liver, pancreas, and kidneys have been mobilized, the supraceliac aorta just below the diaphragm is dissected for placement of the aortic cross-clamp. Immediately before cross-clamping, 30,000 U of heparin (300 U/kg) is given systemically, with the α-antagonist phentolamine in some cases. The supraceliac aorta is then clamped, and the organs are perfused with an organ preservation solution. At this point, the ventilator can be turned off, except in cases where the lungs are procured. The lungs must be inflated with 100% O_2 just before removal. The heart is the first organ to be removed, followed by the lungs.

If the lungs are procured, an extra 20–30 min of perfusion time is required. After removal of the heart and/or lungs, the liver can be removed, followed by the pancreas, small intestines, and kidneys. After the organs are removed, spleen and lymph nodes for tissue typing are obtained from the abdominal and thoracic cavities; and because of the possible need for vascular reconstruction in the recipients, bilateral iliac veins and arteries are removed. The total time for multiorgan procurement is ~4 h, although the anesthesia time typically ends with aortic cross-clamping.

Variant procedures

During the **rapid-flush technique** used by some procurement teams, the dissection of

individual abdominal organs is minimized, and an en bloc resection is done after clamping the aorta below the diaphragm and flushing preservation solution through the distal aorta. The en bloc organs are then dissected ex vivo, often at the transplant center, in preparation for transplantation. This technique is more rapid, requiring only about 1.5 h.

A second variant procedure, developed in response to the chronic shortage of transplantable organs, is the use of non–heart-beating donors. Patients, who are not brain dead, but who have no hope of recovery (due to irreversible brain injury or pulmonary or cardiac failure), may be suitable donors. In this case, the patient is taken to the OR and, under the supervision of a physician who is not part of the transplant team, the life-sustaining treatment (e.g., pressors, ventilator) is D/C'd. When it has been determined that the donor has suffered cardiac death, the body is rapidly cooled with ViaSpan through a cannula that is located in the aorta at the level of the renal arteries. Depending on the regional regulations, this cannula may be placed before cardiac death or immediately following the declaration of cardiac death. After the preservative flush is initiated, the abdomen is entered as rapidly as possible, the peritoneal cavity is packed with ice, and the organs are removed expeditiously. The anesthesiologist's role is ended when cardiac death has been declared. The disadvantage of this approach is that there can be significant warm ischemia from the time the life-sustaining treatment is stopped to the time that cardiac death is reached.

Usual preop diagnosis

Brain death

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Midline only, neck to pubis, ± bilateral transverse extensions
Special instrumentation	Chest and abdominal retractors
Unique considerations	Maintain oxygenation and BP as if a live patient. May require pressors and/or blood transfusion. Temporarily deflate lungs for sternal sawing.
Antibiotics	Ampicillin (1 g iv), ceftriaxone (1 g iv); Betadine/amphotericin B via NG tube for pancreas (with duodenal segment) procurement

Surgical time	4 h; rapid-flush technique: 1.5 h
EBL	200 mL

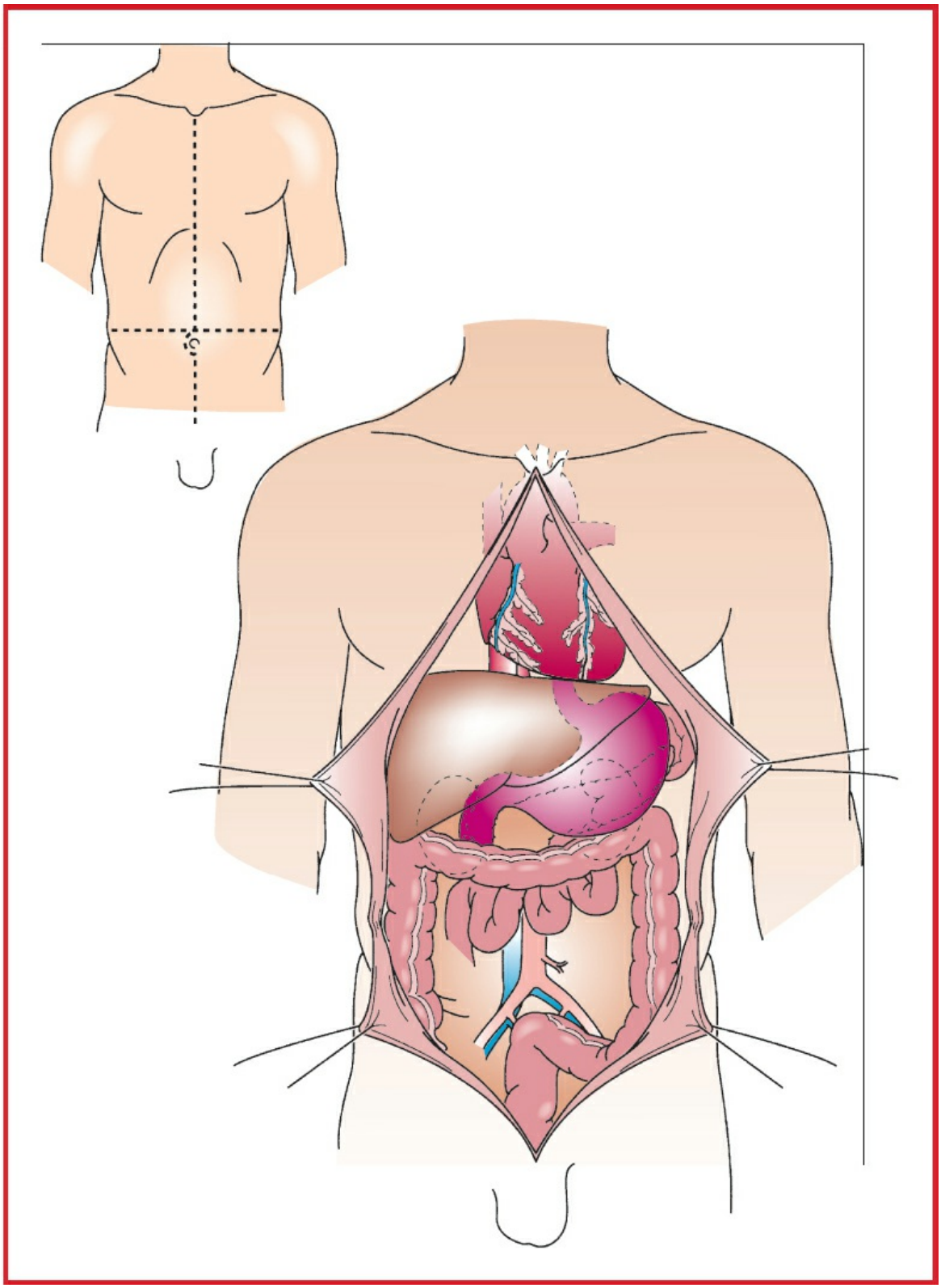

Figure 7.12-10 A complete midline incision, from the suprasternal notch to pubis, is made for multiple organ procurement, and the sternum is split. If necessary, cruciate abdominal incisions are added to

facilitate exposure of the intra-abdominal organs. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al., eds: Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

PATIENT POPULATION CHARACTERISTICS

Age range	Neonate–70 yr
Male:Female	N/A
Incidence	~5000/yr in the United States
Etiology	Usually head trauma (e.g., motor vehicle accidents, gunshot wounds to the head) or intracranial bleeding
Associated conditions	Vasomotor instability; diabetes insipidus; intracranial HTN

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

In general, organ donors are previously healthy individuals who have suffered catastrophic, irreversible brain injury of known etiology, most commonly due to blunt head trauma, penetrating head injury, or intracranial hemorrhage. A declaration of brain death by physicians not participating in the organ procurement must be documented. This documentation, together with certification of death and familial consent, should be verified by the anesthesiologist before organ procurement. The United Network for Organ Sharing (UNOS) has produced the Critical Pathway for the Organ Donor to facilitate the administrative aspects of organ procurement (http://www.unos.org/docs/Critical_Pathway.pdf). There should be no evidence of disease or trauma involving the organs targeted for donation, and in general, the patient should be hemodynamically stable with minimal inotropic requirements. After brain death has been declared, it is important to shift the emphasis away from cerebral resuscitation efforts and to focus instead on the maintenance of adequate tissue perfusion and oxygenation. Brain death is frequently followed by a series of pathophysiologic events that may complicate the management of these patients.

Recently, Donation after Circulatory Death (DCD) has been instituted at many medical centers, where a non–brain-dead patient is brought to the operating room for withdrawal of life support and subsequent removal of organs for transplant. Although the ethics of such organ donation had been debated, the ASA and other organizations have developed

protocols to separate the teams caring for the patient during the withdrawal of life support and the operating room team responsible for organ retrieval. However, in most institutions, an anesthesiologist is present in the operating room as a member of the latter team. After withdrawal of life support has been initiated and the patient meets the criteria for cessation of cardiopulmonary function, organ removal is initiated as quickly as possible to limit warm ischemia time and possible damage to the organs to be removed. DCD patients often do not have as serious pathophysiologic alterations as patients who meet brain-death criteria.

Respiratory	Pulmonary dysfunction following brain death has many possible etiologies: aspiration, atelectasis, pneumonia, and pulmonary edema. In addition, trauma may cause pulmonary dysfunction related to contusion, pneumothorax, or hemothorax. Meticulous pulmonary toilet is essential to prevent atelectasis and pneumonia. Maintenance of adequate oxygenation is requisite to ensure preservation of other organs for transplantation. Use mechanical ventilation with TVs of 8–10 mL/kg and a minute ventilation that maintains $PaCO_2$ 30–35 mm Hg and pH 7.35–7.45. The FiO_2 should ensure a PaO_2 75–150 mm Hg and arterial saturation >95%. PEEP usually is applied at 3–5 cm H_2O and should not exceed 7.5 cm H_2O because of the deleterious effects on CO and regional blood flow and possible barotrauma. The FiO_2 generally should be increased to 100% before transport to the OR. An important exception is in the case of heart-lung or lung retrieval, where it is important to maintain FiO_2 < 40% to minimize possible effects of O_2 toxicity. Ideally, PIP should be <30 cm H_2O to minimize possible barotrauma to the lungs. The use of lung protective ventilation (LPV = tidal volume of 6–8 mL/kg with PEEP 8–10 cm H_2O) strategies may be considered to improve donor lung function. **Tests:** Frequent ABGs, including immediate preop period. Proper position of the ETT should be confirmed preop.

Cardiovascular	Hypotension should be anticipated in all organ donors. However, shortly after brain death, a prolonged period of ↑ sympathetic tone and cardiac output ("catecholamine storm") may lead to hypertension. This results most commonly from neurogenic shock (derangement of descending vasomotor control → progressive ↓ SVR and venous pooling) and hypovolemia. Hypovolemia is usually the result of dehydration therapy for cerebral edema, hemorrhage, DI, or osmotic diuresis 2° hyperglycemia. Hypothermia, LV dysfunction, and endocrine abnormalities also can contribute to ↓ BP. Fluid resuscitation with crystalloid, colloid, and PRBCs to maintain Hct > 30% should be initiated preop. Hemodynamic goals are (a) CVP 4–8 cm H_2O; (b) MAP > 70 mm Hg; (c) SBP > 100 mm Hg; (d) HR 60–12 bpm; (e) PCWP ≤ 12 mm Hg; (f) SVR 800–1200 dynes/sec × cm^{-5} (or 800–1200 woods units); and (g) UO > 1 mL/kg/h. Donors are often placed on inotropic therapy to maintain these parameters; however, following adequate volume resuscitation, preop inotropic therapy often may be gradually decreased or D/C'd. If inotropic therapy remains necessary, typically it would consist of dopamine (2–10 mcg/kg/min), followed by dobutamine (3–15 mcg/kg/min) or epinephrine (0.1–1.0 mcg/kg/min), then norepinephrine. The latter three agents may be combined with dopamine (2–3 mcg/kg/min) in an attempt to augment or preserve renal, mesenteric, and coronary arterial blood flow. It should be noted that brain death may be accompanied initially by a transient hypertensive crisis that may require short-term treatment with SNP and/or esmolol. ECG abnormalities are common in patients with intracranial injury and are of no pathologic consequence. Atrial and ventricular dysrhythmias and various degrees of conduction block occur frequently in organ donors; the etiology may be electrolyte

	imbalance, ABG disturbance, ↑ ICP, loss of the vagal motor nucleus, inotropic therapy, hypothermia, or myocardial contusions or ischemia. Antidysrhythmic therapy should follow the usual guidelines except for ↓ HR, which is resistant to atropine in this setting. Bradycardia, if accompanied by ↓ BP, should be treated with isoproterenol, dopamine, epinephrine, or temporary cardiac pacing. **Tests:** ECG; ECHO (to assess wall motion abnormalities) and possibly coronary angiography (if CAD is suspected)
Neurologic	Diabetes insipidus (DI) frequently occurs in brain-dead donors; it is likely the result of destruction of the hypothalamic-pituitary axis. Untreated, it may cause marked hypovolemia and electrolyte disturbances (↑ Na^{+}, ↑ Mg^{++}, ↓ K^{+}, ↓ PO^{-}_{4}, ↓ Ca^{++}). Therapy with iv vasopressin (titrated from 2 mcg/kg/min) or DDAVP (titrated from 0.3 mcg/kg/min) often is initiated to maintain UO < 1.5–3 mL/kg/h. Many believe that the benefits of minimizing electrolyte imbalance, fluid shifts, and reduction of core T outweigh the risks of vasopressin or desmopressin therapy, including coronary and renal vasoconstriction and possible organ ischemia or uneven distribution of the preservation solutions during flushing. It may be prudent, however, to D/C vasopressin or DDAVP infusions for at least 1 h prior to aortic cross-clamping and infusion of preservation solutions. Thermoregulation is abnormal in brain-dead donors due to hypothalamic dysfunction, and core T should be monitored (bladder or esophageal). Aggressive warming techniques may have to be employed early to maintain a core T > 34–35°C, as there are numerous undesirable consequences of significant hypothermia (<32°C) in the organ donor (e.g., cardiac dysrhythmia, cardiac instability, ↓ GFR and cold diuresis, a left shift in the oxyhemoglobin dissociation curve, and pancreatitis). Although other

	endocrine or metabolic disturbances may exist as a result of destruction of the hypothalamic-pituitary axis, currently there is no consistent recommendation for any other hormonal replacement therapy. **Tests:** Serum electrolytes and osmolality q4h
Hematologic	Donors may be anemic from hemodilution and/or hemorrhage. To ensure adequate tissue O_2 delivery, PRBCs are transfused to maintain Hgb > 7–8 g/dL. Some donors may exhibit a coagulopathy; clinically significant bleeding should be treated with clotting factors and Plts. Persistent or severe primary fibrinolysis or DIC may require rapid transfer of the donor to the OR for organ retrieval. Administration of epsilon-aminocaproic acid to treat fibrinolysis is avoided for fear of microvascular thrombosis in the donor organs. **Tests:** Hgb/Hct; PT; PTT; Plt count; DIC screen as clinically indicated
Others	The role of oxygen-free radicals, with regard to reperfusion injury, has prompted the suggested use of mannitol and steroids (and other compounds) as scavengers.

INTRAOPERATIVE

Anesthetic technique

Although anesthesia is unnecessary in brain-dead organ donors, both visceral and somatic reflexes can lead to physiologic responses during the procedure. The goals of intraoperative management with regard to respiratory, cardiovascular, hematologic, and neurologic status are identical to those discussed under preop considerations earlier.

Induction	Settings for mechanical ventilation parallel those of the ICU, although it may be advisable to begin with an FiO_2 of 100% until the first ABG result is obtained. The exception is when procurement of the lungs or heart-lungs is anticipated; then FiO_2 should not

	exceed 40%. To eliminate reflex neuromuscular activity and to facilitate surgical retraction, a longer-acting neuromuscular blocking agent should be given at the beginning of the procedure and supplemented as necessary.	
Maintenance	Reflex hypertensive responses to surgical stimulation occur frequently and may → excessive intraop blood loss and damage to donor kidneys; management should include the weaning of vasopressors and the initiation of vasodilator therapy with isoflurane, SNP, or NTG. Anesthetic care continues until the proximal aortic cross-clamp is applied. D/C all monitoring and supportive therapy at this point. The notable exception is the case of heart-lung or lung procurement; in this situation, all monitoring except FiO_2 should cease with proximal aortic cross-clamping. All supportive care is terminated, with the exception of mechanical ventilation of the lungs at 4 breaths/min or as directed by the transplant team and suctioning of the ETT after cessation of mechanical ventilation just prior to removal of the tube. Extubation marks the termination of anesthetic care of the heart-lung or lung donor.	
Blood and fluid requirements	IV: 14–16 ga × 1–2 BSS @ 2–4 mL/kg/h	Significant third-space losses may require large volumes of crystalloid, colloid (up to 1 L), and PRBCs (not uncommon to transfuse 2 or more U to maintain Hct > 30). Central venous access is necessary for monitoring and for vasoactive drug delivery. Volume repletion can be guided by arterial waveform analysis (pulse pressure or systolic pressure variation).
Monitoring	Standard monitors Art line	If a PA catheter is in place, it may be used or removed based on concerns of catheter-related, right-side

	CVP line UO	endocardial lesions. Rarely is insertion of a PA catheter warranted in these operations. ABG, Hgb/Hct, serum electrolytes, and glucose should be monitored hourly; for operations involving procurement of the lungs or heart-lungs, ABGs should be obtained at least every 30–60 min.
Complications	Hypotension	Most commonly 2° hypovolemia and neurogenic shock (loss of descending vasomotor control). Ensure adequate volume repletion as described previously, then institute or increase inotropic/vasopressor therapy as previously outlined.
	Dysrhythmias	Multiple possible etiologies as described previously. Standard treatment and diagnosis should be employed, with the exception of bradycardia, which is atropine-resistant and should be treated with isoproterenol, dopamine, epinephrine, or transvenous pacing.
	Cardiac arrest	CPR should be instituted in an effort to maintain the viability of the liver, kidneys, and other abdominal viscera intended for transplantation. Procurement of the liver and kidneys should proceed rapidly to aortic cross-clamping at the diaphragm and administration of cold preservation fluid into the aorta and portal vein. This series of events will undoubtedly preclude use of the heart and lungs for transplantation.
	Oliguria	Ensure adequate volume replacement and BP as outlined, then

	add dopamine (2–3 mcg/kg/min), if not previously instituted to promote renal vasodilation and to increase renal blood flow, glomerular filtration rate, and UO. If these measures are ineffective at restoring adequate UO (>1 mL/kg/h), then furosemide or mannitol may be used, after consultation with the transplant team.
Diabetes insipidus (DI)	Fluid and electrolyte therapy as determined by filling pressures and hourly serum electrolyte values. Adjustment of vasopressin or DDAVP infusion to maintain UO < 1.5–3.0 mL/kg/h; initiation of this infusion should be done in consultation with the transplant team. As previously discussed, it may be advisable to D/C vasopressin or DDAVP at least 1 h before aortic cross-clamping.
Coagulopathy	Transfuse Plt, FFP, and cryoprecipitate as necessary for clinical bleeding in the setting of abnormal coagulation studies. Avoid EACA due to risk of microvascular thrombosis in the donor organs.
Hyperglycemia	Avoid dextrose-containing solutions, which may aggravate existing hyperglycemia and contribute to osmotic diuresis and electrolyte abnormalities.
Hypothermia	Early aggressive attempts to minimize intraop heat loss are essential and include warming the OR, use of a forced-air warming blanket, insulating exposed areas,

		warming all fluids, and using heated, humidified inspired gases.
Special considerations	Heart-lung procurement	Division of the mediastinal pleura and tracheal dissection with manipulation of each lung outside the mediastinum may result in ↓↓ BP and may cause problems with oxygenation and ventilation. Adequate intravascular volume is essential, and inotropic therapy may be required during this period. Problems with ventilation and oxygenation must be communicated immediately to the transplant team. Following aortic cross-clamping and infusion of cardioplegia solution, the lung preservation fluid will be infused via the right and left PAs. During this period, the lungs should be ventilated manually with 4 bpm or as otherwise directed by the transplant team. It is prudent early on in the procurement procedure to verify the position of the ETT with the transplant surgeon to ensure that the tube does not contribute to mucosal injury at the site of the anticipated suture line.
	Organ preservation	Therapy aimed at improving organ preservation may require several pharmacologic manipulations, as directed by the transplant team. Agents commonly used during organ procurement include dopamine (2–3 mcg/kg/min), furosemide, mannitol, allopurinol (free-radical scavenger), chlorpromazine and phentolamine (vasodilators), heparin (prevents microvascular thrombosis and

promotes reperfusion), and PGE_1 (vasodilator, membrane stabilizer, antiplatelet effect). Systemic infusion of PGE_1 prior to aortic cross-clamping (commonly used in heart-lung or lung procurement) will lead to predictable and profound ↓ BP; efforts at volume resuscitation toward optimal CVP should continue until the aortic cross-clamp is applied. If heparin is to be administered iv, a catheter should be used after verifying the ability to freely aspirate blood. Methylprednisolone (30 mg/kg) is commonly administered at least 2 h before organ retrieval in an effort to protect the heart and kidneys from ischemic injury. Recent trials suggest that administration of thyroid hormone, cortisol, and insulin may improve cardiovascular status and improved donor viability.

Suggested Readings

1. Anderson TA, Bekker P, Vagefi PA: Anesthetic considerations in organ procurement surgery: a narrative review. Can J Anesth 2015; 62:529–39.
2. Van Norman GA: Another matter of life and death: what every anesthesiologist should know about the ethical, legal and policy implications of the non-heart-beating cadaver organ donor. Anesthesiology 2003; 98:763–73.
3. Xia VW, Braunfeld M: Anesthesia management of organ donors. Anesthesiol Clin 2017; 35:395–406.

CHAPTER 7.13

Trauma Surgery

SURGEONS

Lisa M. Knowlton, MD, MPH
Aussama K. Nassar, MD, MSc, FRCSC, FACS
Timothy Browder, MD, MACM

ANESTHESIOLOGIST

Lindsay Raleigh, MD

INITIAL ASSESSMENT AND AIRWAY MANAGEMENT FOR TRAUMA SURGERY

INITIAL ASSESSMENT

The Advanced Trauma Life-Support (ATLS) Program, developed by the American College of Surgeons Committee on Trauma, provides a safe and reliable method for the immediate treatment of injured patients. The crucial components of ATLS are the rapid and accurate assessment of a patient's condition, the resuscitation, and stabilization of the patient according to a standard sequence of priorities, determining the need for and arranging interhospital transfer, and ensuring optimal care throughout the entire process. The initial assessment and management consist of the primary survey and resuscitation.

During the **primary survey**, life-threatening conditions are identified and treated following the ABCDE sequence: **a**irway, **b**reathing, **c**irculation, **d**isability, and **e**xposure.

In critically injured patients, cervical spine clearance is performed after securing airway. Thus, **airway** patency should be assessed while maintaining strict cervical spine protection. In situations where a patient's airway integrity is unclear or at risk, a

definitive airway should be established. High-flow supplemental oxygen should be delivered and, oxygenation should be monitored with pulse oximetry. **Breathing** and ventilation are assessed, paying attention to any chest injuries that can impair adequate gas exchange. Conditions such as tension pneumothorax, massive hemothorax, flail chest, and open pneumothorax should be identified and treated. **Circulation** is assessed and vascular access established. Shock should be recognized early if present. In trauma, the presence of shock is usually due to hemorrhage, and definitive control of bleeding and replacement of intravascular volume are crucial. **Disability** from neurologic injury should be assessed. Patients with severe neurologic injury may require definitive airway management or urgent neurosurgical evaluation. **Exposure** involves undressing the patient to identify any other life-threatening injuries while keeping the patient warm.

Extended Focused Assessment with Sonography for Trauma (eFAST)

In addition to AP chest x-ray and pelvic x-ray, eFAST (see Fig. 7.13-1) is performed as an adjunct to the primary survey. eFAST is an ultrasound screening examination of the trauma patient. eFAST allows for the rapid detection of pericardial fluid (pericardial tamponade), pneumothorax, hemothorax, and peritoneal free fluid and can speed triage and treatment of trauma patients. It is important to note that many other potentially life-threatening injuries cannot be detected by ultrasound (e.g., retroperitoneal bleeding, bowel perforations, torn diaphragms). eFAST examinations have a low but significant false-negative rate. Ultrasound is not a substitute for more definitive diagnostic procedures.

AIRWAY MANAGEMENT

In trauma, indications for definitive airway can be divided into conditions that require airway protection and conditions that require control of ventilation or oxygenation. Airway patency can be compromised by obtundation, severe facial injuries, bleeding or vomiting, or obstruction from neck or airway injuries. The need for ventilation or oxygenation is indicated by apnea, respiratory distress, severe closed head injury, or hemodynamic instability.

Although airway management in injured patients does not differ fundamentally from airway management in other situations, special attention must be paid to cervical spine protection, high risk of vomiting and aspiration, and recognition of maxillofacial, neck, laryngeal, or head injuries that can cause airway compromise.

Airway maneuvers such as the jaw-thrust maneuver are useful techniques to improve airway patency in unconscious or obtunded patients, although they must be performed without extending the neck and potentially exacerbating a cervical spine injury. Other

maneuvers such as chin lift should ideally be avoided in trauma with suspected cervical spine injuries.

Airway adjuncts such as oropharyngeal airway, nasopharyngeal airway, or laryngeal mask airway are useful for providing temporary ventilation and oxygenation until a definitive airway (oral or nasal endotracheal tube [ETT] or surgical airway) can be established.

Orotracheal intubation, using rapid-sequence intubation and cricoid pressure, is preferred. The approach is rapid, but at least three people are required to perform it safely in the patient with suspected C-spine injury.

In-line stabilization of the neck is performed to minimize neck and spine movements. Because a failed intubation may force operative airway intubation, equipment for cricothyrotomy should be immediately accessible. It is often beneficial to have several types of intubation devices available in addition to traditional laryngoscopes, such as video laryngoscopes, in the case of traumatic airways. Fiberoptic assistance may be used in the stable patient with a difficult airway. Patients in respiratory distress with severe facial or neck trauma or unstable cervical spine injury require a surgical airway. An airway placed in transport should be immediately assessed for position and changed to a definitive airway when appropriate.

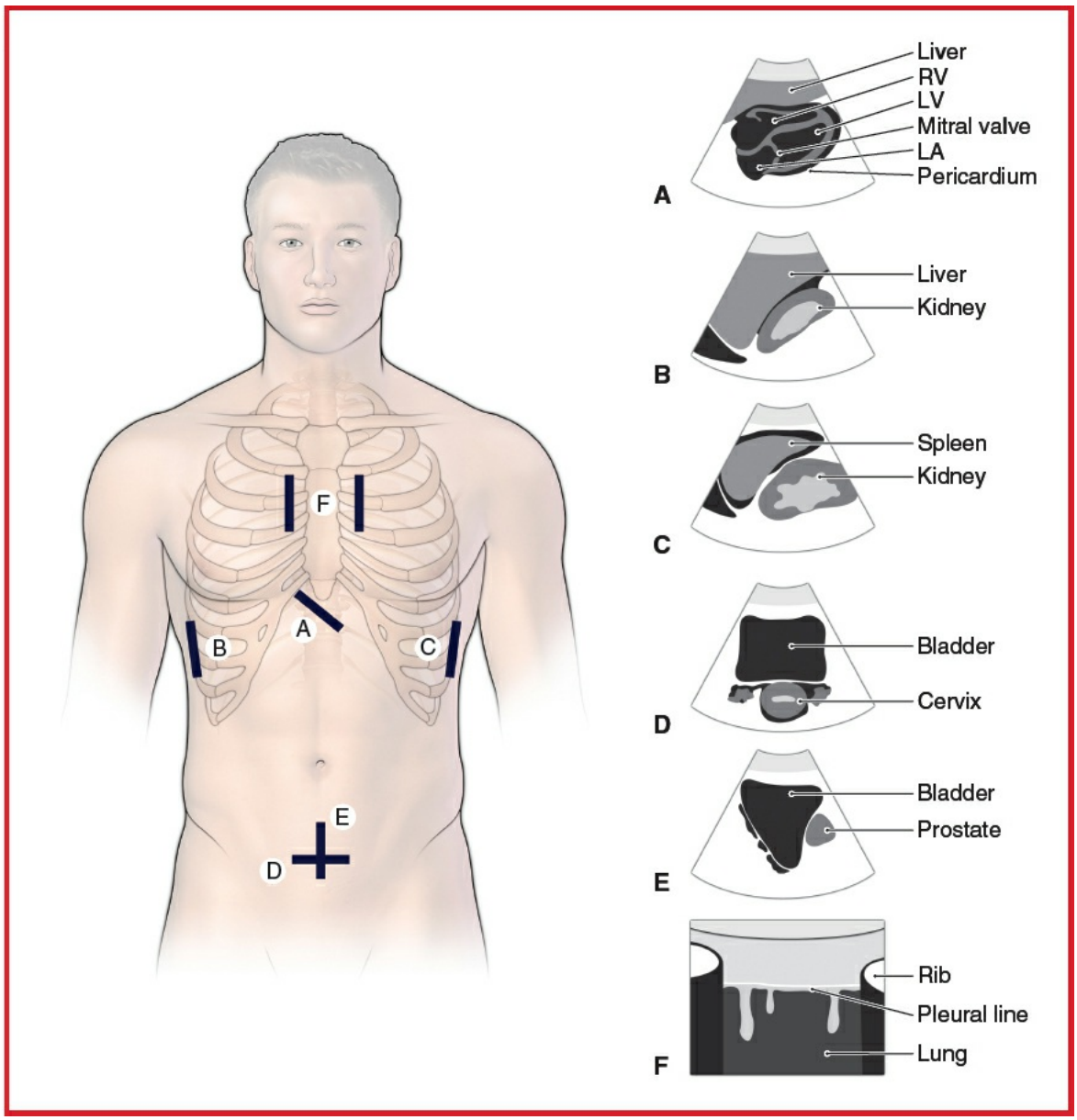

Figure 7.13-1 eFAST transducer placements. A: subxiphoid; B: perihepatic; C: perisplenic; D and E suprapubic; F: thoracic.

Nasotracheal intubation, used only in spontaneously breathing trauma patients, can be performed without the use of pharmacologic agents or special equipment. It is, however, associated with higher incidence of vomiting and aspiration. In the intoxicated patient with a depressed level of consciousness, the success rate may be as low as 65%. Blind nasal intubation is contraindicated in patients with unstable midface fractures, penetrating neck trauma, or significant neck hematomas.

Surgical airway, cricothyrotomy (Fig.7.13-2), is the preferred method in adults who require a surgical airway. The important anatomic landmarks of the superior and inferior borders of the thyroid and cricoid cartilages are palpated. With the nondominant hand, the thyroid cartilage is stabilized, using the index finger to palpate

the cricothyroid membrane. A vertical skin incision is made over that area. With a hemostat or a blade, a transverse incision is made through the cricothyroid membrane, and a size 5–6 ETT or tracheostomy tube is rapidly advanced through the passage. The cricothyroid membrane lies very superficially, covered only by the skin and platysma muscle. In emergency situations, a standard small-caliber ETT is generally easier to insert than a tracheostomy tube (Fig. 7.13-2). Cricothyroidotomies should be converted to tracheotomies within 72 h after the initial injury, provided the patient's condition permits.

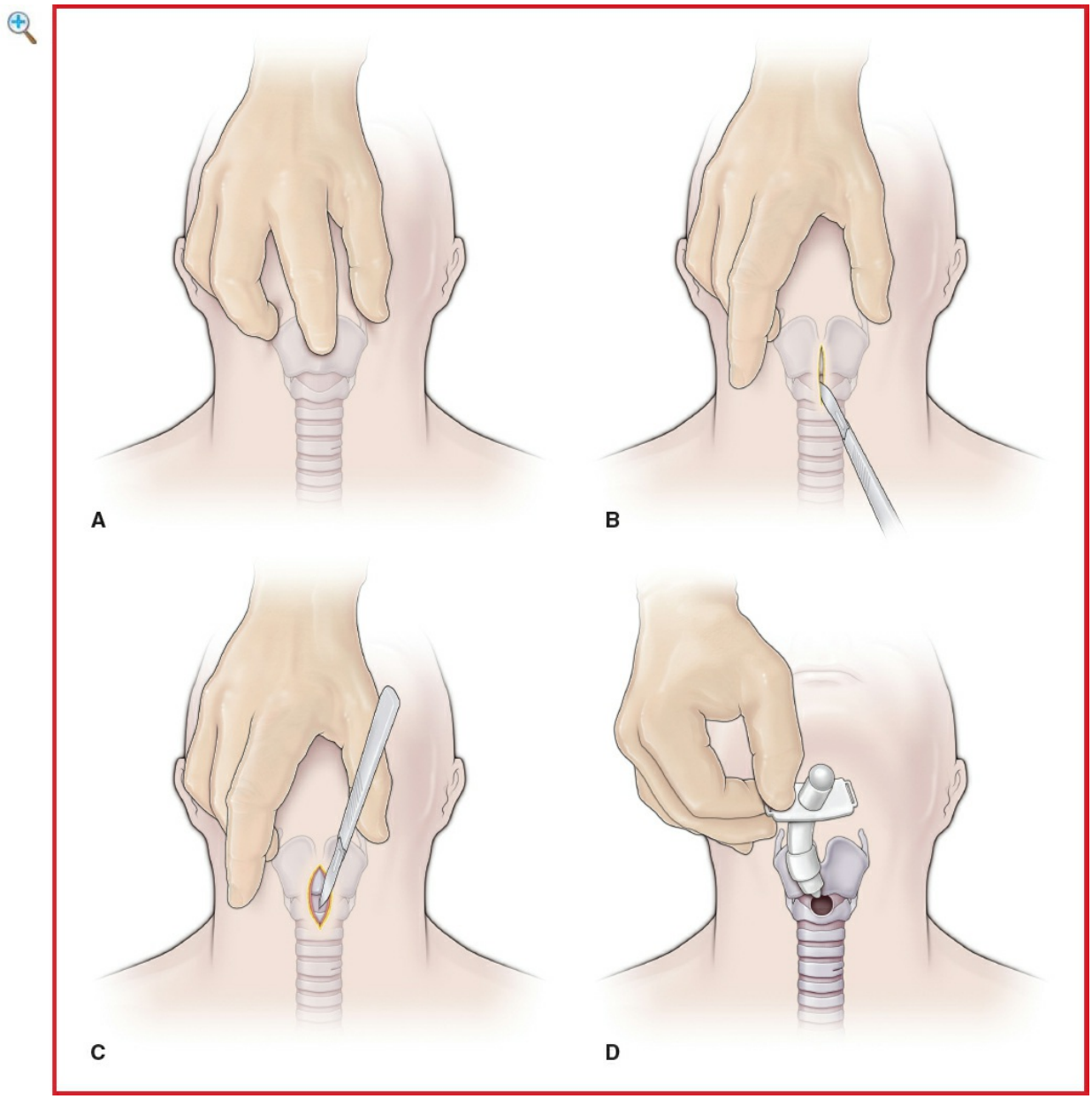

Figure 7.13-2 **A:** Immobilize the larynx and palpate the cricothyroid membrane with the index finger of the nondominant hand. **B:** Make a midline vertical skin incision, 3–5 cm in length. **C:** Incise the cricothyroid membrane transversely. **D:** Insert the tracheostomy tube into the trachea.

Percutaneous cricothyroidotomy is also another alternative to the above technique. There are commercially available kits for that use, with both cuffed and uncuffed cricothyroidotomy tubes. A percutaneous Seldinger technique is employed. If all fails, jet ventilation may be performed through the cricothyroid membrane by using a wide-bore 14- to 16-ga Angiocath and attaching it to high-flow oxygen tubing. A key principle is to incise the side of the oxygen supply tube and periodically cover the slit with a finger using a 1:4 second ratio to help with CO_2 elimination until additional help is available.

A **tracheostomy** is indicated for patients requiring surgical airway in less emergent situations or if a cricothyrotomy cannot be performed due to direct laryngeal injury. A tracheostomy can be accomplished through the same incision, extended caudally if laryngeal injury is found. Rarely, the injury is in the distal cervical or proximal intrathoracic trachea. In such cases, it may be necessary to intubate the distal end of the airway through the wound. A subsequent median sternotomy may be required to expose the injury. Right thoracotomy provides access to the distal intrathoracic trachea (see Chest Trauma).

Usual preop diagnosis

Airway compromise

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Midline 3- to 4-cm longitudinal incision in the neck at the area of the cricothyroid membrane
Unique considerations	The large number of legal claims involving failed intubation suggests that surgical cricothyrotomy remains an underutilized technique.
Antibiotics	Usually not given until clear indications related to the primary injury are apparent.
Surgical time	2–5 min
EBL	Minimal
Postop care	Mechanical ventilation
Mortality	Related to the primary injury

Morbidity	Cricothyrotomy is more likely to result in airway stricture or damage to more proximal structures in the larynx. On this basis, cricothyrotomy is converted to tracheostomy within 48–72 h of admission if patient's general condition permits.
Pain score	3

EMERGENCY TUBE THORACOSTOMY

SURGICAL CONSIDERATIONS

Description

In the United States, trauma is the most common cause of death in young people; 25% of these deaths (~16,000 per yr) are the result of thoracic trauma. Most of these are due to lethal injuries at the scene (e.g., cardiac rupture, free aortic transection). For patients who reach the hospital, proper management is crucial because many deaths can be prevented. Early deaths are due to airway obstruction, tension pneumothorax, massive hemothorax, flail chest, cardiac tamponade, and open pneumothorax. Later deaths are due to respiratory failure, sepsis, and unrecognized injuries.

Eighty percent of blunt thoracic injuries are caused by motor vehicle collisions (MVCs). Penetrating injuries to the chest are almost as common as blunt trauma. The death rate in hospitalized patients with isolated chest injury is 4–8%; this increases to 10–15% when one other organ system is involved and to 35% if multiple additional organs are injured. Eighty-five percent of chest injuries do not require thoracotomy, and the patient can be managed with relatively simple measures, such as airway control, tube thoracostomy, and pain management. Blunt trauma can induce injury by three mechanisms: direct blow, deceleration injury, and compression injury. Rib fracture is the most common sign of blunt thoracic trauma. Fracture of the upper ribs (1st–3rd), clavicle, or scapula implies high-energy impact and is associated with a higher likelihood of major vascular injury.

Life-threatening injuries caused by penetrating trauma are distinctly different from those caused by blunt trauma. In penetrating chest injuries, pneumothorax is almost always present, and hemothorax is present in 80% of cases. Hemodynamic instability in penetrating chest injury generally heralds a major intrathoracic vascular injury.

Tension pneumothorax may be caused by blunt or penetrating trauma. Venous return to

the heart is impaired by the increased intrathoracic pressure and compression of the vena cava → ↓ BP and distended neck veins. Loss of lung volume on the ipsilateral side and subsequent compression of the contralateral side lead to impaired ventilation and hypoxia. The diagnosis of tension pneumothorax is made clinically. The presence of respiratory distress and absent or diminished breath sounds warrant immediate needle decompression (14- to 16-ga catheter through the 2nd intercostal space, midclavicular line), followed by subsequent tube thoracostomy. Treatment should not be delayed for radiographic confirmation. In the hemodynamically stable patient, however, suspicion of a pneumothorax should be confirmed by x-ray. On the CXR, a 20% loss of lung dimension corresponds to ~50% loss of lung volume. A small, simple pneumothorax (<10%) with no respiratory compromise may be observed. These patients require close observation in the hospital and a repeat CXR in 4–6 h. Tube thoracostomy should be performed for a large pneumothorax (>10%), for patients with respiratory compromise or multiple injuries, or when it is not possible to adequately monitor the patient (e.g., during extended transport). Recent developments in emergency ultrasonography have led to the adoption of the "eFAST" examination, which includes ultrasound examination of the anterior chest to detect pneumothoraces. An abnormal eFAST exam may alert the team to the presence of a significant pneumothorax even before a CXR can be obtained. In the presence of an anterior pneumothorax, the eFAST may even be superior in sensitivity to a supine CXR.

As much as 40% of the circulating blood volume can accumulate in a **hemothorax**. The most frequent sources of bleeding are the intercostal and internal mammary vessels. Some degree of hemothorax is present in almost every patient with chest injury. A supine CXR may miss up to 1 L of blood. Although an upright CXR is more sensitive this is generally impractical in a multiple-trauma patient (whose spine often has not been fully evaluated). Following chest tube placement, blood loss >1200–1500 mL or an ongoing loss of 250 mL/h for 4 h suggests the need for surgical intervention.

Simple pneumothorax without associated hemothorax can be treated with a 20- to 22-Fr chest tube placed in the 4th intercostal space in the midaxillary line or in the 5th intercostal space in the anterior axillary line. Hemothorax and tension pneumothorax require a large-bore, 28- to 36-Fr chest tube placed in the midaxillary line through the 5th intercostal space (Fig. 7.13-3). A 20-mL syringe with 1% lidocaine can be used not only to provide local anesthesia but also to locate the upper edge of the rib in the obese patient. A generous 3-cm incision should be made one interspace below the targeted level. The subcutaneous tissues are dissected bluntly, creating a tunnel that is directed upward. The pleural space should be entered just above the upper edge of the rib to avoid injury to the intercostal neurovascular bundle, located just below the lower edge

of the rib. After the pleural space has been entered bluntly, it should be explored with the operator's finger swept around to ensure proper location and to free potential adhesions. The chest tube should be inserted and advanced in the posterior and superior direction. The tube then should be connected to a suction/collection system under 20 cm of negative pressure water, preferably through an autotransfusion device. Repeat chest exam and CXR should immediately follow chest tube placement to evaluate decompression and assess for other injuries. If the pleural space still contains blood, another chest tube could be inserted. Hemothoraces require drainage within the first 24–48 h, to minimize the risk of retained hematoma leading to clotted hemothorax and subsequent empyema.

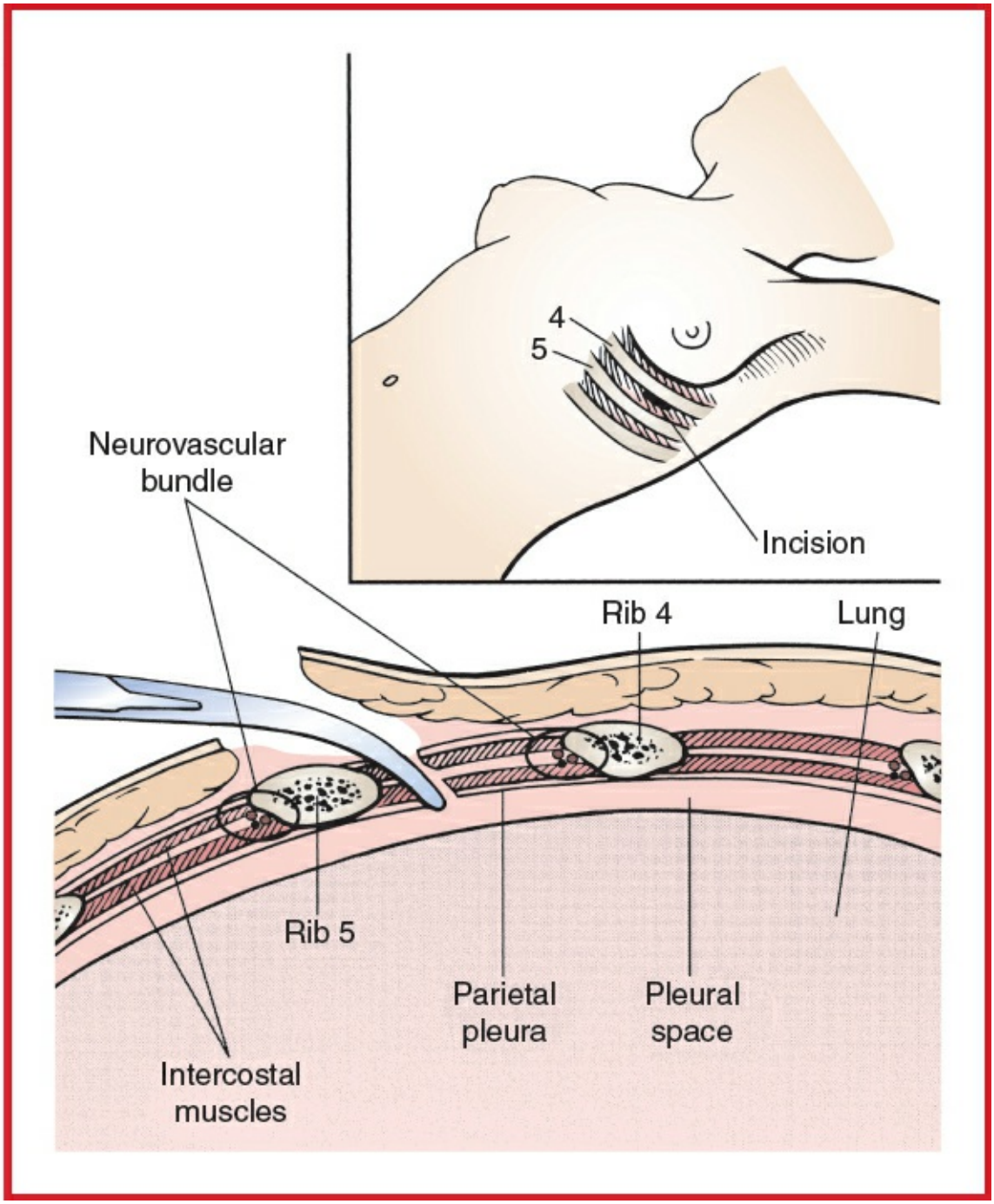

Figure 7.13-3 Tube thoracostomy. Incision through the 4th or 5th interspace at anterior axillary line. Forceps are used to tunnel over the superior edge of the rib and to enter the pleural space bluntly.

Usual preop diagnosis

Tension pneumothorax; pneumothorax; hemothorax

SUMMARY OF PROCEDURE

Position	Supine with arm abducted 90°

Incision	3 cm in interspace below the 5th intercostal space in midaxillary line
Special instrumentation	28- to 36-Fr chest tube should be used in most patients. Small, 20- to 22-Fr tube reserved for simple pneumothorax in stable patients. Autotransfusion device should be available in ED.
Unique considerations	In tension pneumothorax, a large-bore needle inserted in the 2nd intercostal space of the midclavicular line can relieve tension and save a patient's life.
Antibiotics	Cefazolin 2 g iv
Surgical time	5 min
EBL	Minimal from tube placement. Variable amounts drained out, depending on the extent of hemothorax and associated injuries
Postop care	Chest tube may be removed after at least 48 h when there is no air leak from the lung and <100–150 mL of fluid drainage per 24 h.
Mortality	Isolated chest injury: 4–8% When one other organ system is involved: 10–15% When two or more organ systems involved: >35%
Morbidity	Clotted hemothorax Empyema Lung abscess Lung contusion
Pain score	5

EMERGENCY DEPARTMENT THORACOTOMY

SURGICAL CONSIDERATIONS

Description

Rarely, emergency department **thoracotomy** may offer the only chance of survival in some trauma patients. Its use should be restricted largely to patients showing signs of

life in the emergency department (ED) but lose such signs shortly after that. The usual indications are (a) massive exsanguination in the left chest, usually due to cardiac, vascular, or pulmonary injuries, and (b) pericardial tamponade. For patients with penetrating cardiac injuries who show signs of life in the ED, survival may be as high as 15%. For blunt trauma in this setting, survival is <1%, regardless of presentation. With either mechanism, functional survival is almost unprecedented if the patient arrives without vital signs and reactive pupils.

A **left anterolateral thoracotomy** is the preferred approach because pericardiotomy, open cardiac massage, and aortic occlusion are best achieved by this means. This incision can be extended easily across the sternum and into the right chest to improve exposure and to control massive blood loss and from the right lung. The entire chest is prepped liberally, and left anterolateral thoracotomy is performed rapidly in the 5th intercostal space using a large-blade scalpel. Heavy scissors can be used to divide the intercostal muscles quickly and to cut across the sternum. If pericardial tamponade is encountered, the pericardium is opened longitudinally, anterior to the phrenic nerve. Blood and clot are evacuated and bleeding sites controlled with gentle digital pressure. Large, full-thickness lacerations that extend into the chambers may be controlled by inserting a Foley catheter, inflating the balloon, and pulling it snug against the myocardium. The open end of the Foley can be clamped or used as an infusion line for resuscitation. During ED thoracotomy, placement of clamps on the atria or ventricles should be avoided as they may extend the laceration. Attempts to repair cardiac lacerations should be delayed until resuscitative measures have been completed. In the nonbeating heart, suturing is performed before defibrillation. If coronary or systemic air embolism is present, the appropriate hilum is cross-clamped, and air is aspirated from the left ventricle through the elevated apex. Cardiac arrest is an indication for immediate internal massage. The two-hand method is preferred, and internal defibrillation should be instituted. If internal defibrillation does not restore proper cardiac activity, cross-clamping of the aorta will improve coronary perfusion. To cross-clamp the aorta, the left lung is retracted anteriorly and superiorly, and the posterior pleura is dissected under direct vision. An orogastric or nasogastric tube placed in the esophagus aids in the identification of the esophagus by feel, allowing for cross-clamping of the aorta without risking injury to the adjacent esophagus.

Usual preop diagnosis

Penetrating chest trauma with cardiac arrest and recently recorded signs of life

SUMMARY OF PROCEDURE

Position	Supine
Incision	Left anterolateral thoracotomy. Extension of incision across the sternum could be considered for improved exposure.
Special instrumentation	ED thoracotomy tray; internal defibrillator paddles; suction device; Foley catheter; rapid-infusion device; O(−) blood
Unique considerations	Airway should be secured first. OG/NGT tube should be placed if possible. Typically, patients are not anesthetized for this procedure.
Antibiotics	Cefazolin 2 g iv
Surgical time	10 min
EBL	1–2 L
Postop care	ICU
Mortality	Blunt trauma: 98% All penetrating chest injuries requiring ED thoracotomy: 85% Penetrating cardiac injury: 50%
Morbidity	Arrhythmias Acute MI
Pain score	10

EXPLORATORY SURGERY FOR NECK TRAUMA

SURGICAL CONSIDERATIONS

Description

The neck contains vital structures in a relatively unprotected region of the body (Fig. 7.13-4). The cardiovascular, respiratory, digestive, endocrine, and CNS systems are all represented in the neck; injury to any of these can be fatal.

Injuries to the neck may result from blunt or penetrating trauma. In blunt trauma, <5% of cases will have C-spine injuries. Because the consequences are so grave, however, all

patients should be evaluated for C-spine injuries (H&P, x-rays, CT), and full spinal precautions should be maintained until the C-spine is cleared. Blunt airway injuries can be devastating and present significant management difficulties; however, the majority of blunt neck trauma consists of minor soft tissue injuries that can be managed nonoperatively. Blunt cerebrovascular injuries can occur from a direct blow to the carotid or vertebral arteries or from a severe hyperextension or rotation mechanism.

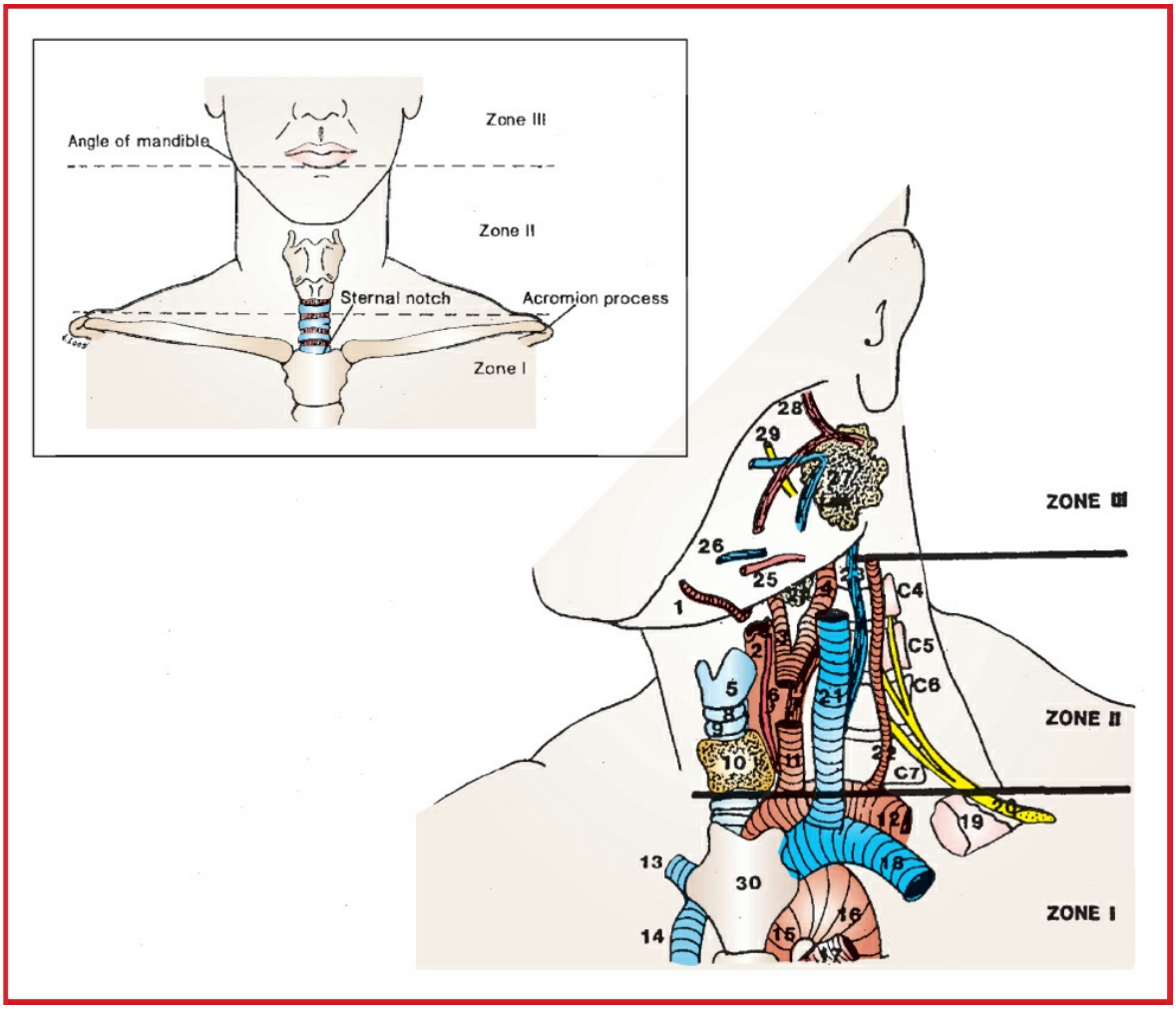

Figure 7.13-4 Cervical structures contained in Zones I, II, and III: (1) facial artery; (2) esophagus; (3) internal carotid artery; (4) external carotid artery; (5) thyroid cartilage; (6) sympathetic trunk; (7) vagus nerve; (8) cricothyroid membrane; (9) cricoid cartilage; (10) thyroid cartilage; (11) common carotid artery; (12) subclavian artery; (13) right innominate vein; (14) SVC; (15) ascending aorta; (16) descending aorta; (17) PA; (18) subclavian vein; (19) clavicle; (20) brachial plexus; (21) IJ vein; (22) vertebral artery; (23) phrenic nerve; (24) submandibular gland; (25) lingual artery; (26) hypoglossal nerve; (27) parotid gland and duct; (28) facial nerve and its branches; (29) maxillary artery; (30) sternal manubrium. The thoracic duct is not shown in this figure. (Adapted with permission from Ordog GJ, Albin D, Wasserberger J, et al: 110 bullet wounds to the neck. J Trauma 1985; 25:238–46). (Inset reproduced with permission from Baker RJ, Fischer JE:Mastery of Surgery, 4th edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Penetrating neck trauma is defined as penetration of the platysma muscle. For these

injuries, the neck is usually divided into three horizontal zones (Fig. 7.13-4, inset). Zone I extends from the sternal notch to the cricoid cartilage. Penetrating injuries in this area are associated with a high mortality. Zone II extends from the cricoid cartilage to the angle of the mandible. Because this is the most exposed region of the neck, injuries can be evaluated and explored using standard operative techniques. Zone III extends from the angle of the mandible to the base of the skull. Because of anatomic constraints, injuries to Zones I and III can be difficult to identify and repair. In patients with a Zone injury, iv access should be established in the contralateral upper extremity because of the possible injury to the ipsilateral internal jugular vein or subclavian vein.

Until recently, evaluation and management of stable patients with neck injuries that penetrated the platysma depended on location of injury. Injuries to Zones I and III were evaluated radiographically, whereas injuries to Zone II were indications for mandatory exploration. With the increased availability of CT and arteriography, however, a selective exploration strategy is now favored. The presence of so-called hard signs, including airway compromise, shock, active bleeding, an expanding hematoma, an evolving stroke, or extensive subcutaneous air, generally mandates operative exploration. "Soft signs," which include hoarseness, hemoptysis, hematemesis, dysphagia, or prominent ecchymosis, can be evaluated with CT and endoscopy.

Management of hemodynamically unstable or symptomatic patients with penetrating neck injuries should be limited to applying direct pressure, protecting the airway, establishing iv access, and obtaining a CXR. Exploration and definitive management of the injury in the OR should follow as soon as possible. In stable patients with penetrating injuries and no indications for exploration, CT is generally the first diagnostic test.

A **median sternotomy incision** may be used for patients with right neck Zone I injuries or if injuries to the mediastinum involving the innominate artery or right subclavian artery are suspected. Exposure of injuries to the proximal left subclavian artery is extremely difficult via median sternotomy. In this case, a left anterior thoracotomy is preferred. The chest and left arm should be prepped and draped to allow arm manipulation.

Usual preop diagnosis

Penetrating neck injury

SUMMARY OF PROCEDURE

Position	Supine with head turned away from side of exploration

	and neck extended. If both sides of neck require exploration, head should be in midposition. It is helpful to clear the C-spine before exploration.
Incision	Sternocleidomastoid anterior border
Unique considerations	Monitor BP and HR carefully during carotid sinus manipulation.
Antibiotics	Cefazolin 2 g iv. If pharyngoesophageal injury, give ampicillin 1 g and gentamicin 80 mg iv.
Surgical time	1 h
Closing considerations	Wound requires drainage, especially in Zone I exploration and if esophagus or airway was violated.
EBL	Variable
Postop care	ICU 12–24 h for neurologic and airway monitoring. After carotid injury repair, angiography should be considered.
Mortality	1%
Morbidity	Hemorrhage: acute from injuries; delayed from pseudoaneurysms Airway injury: acute loss of airway; delayed tracheal stenosis Damage to neural or vascular structures Esophageal fistula
Pain score	4

PATIENT POPULATION CHARACTERISTICS

Age range	Typically young adult
Etiology	Typically male
Incidence	5–10% of all trauma involves neck structures.
Associated conditions	Intrathoracic injuries; spinal cord injuries; recurrent laryngeal nerve injury; phrenic nerve injuries; thoracic duct injury

ANESTHETIC CONSIDERATIONS FOR NECK TRAUMA SURGERY

PREOPERATIVE

Patients with neck injuries often present unique challenges for endotracheal (ET) intubation. Extensive internal damage may be present despite minimal external signs. High-velocity deceleration events, or "seatbelt" sign injuries, are often associated with airway compromise. Vascular injuries, particularly involving the carotid artery, can cause a significant neck hematoma that compresses vital structures and markedly distorts airway anatomy, preventing visualization of laryngeal structures or passage of an ETT. Known or suspected C-spine injuries will restrict optimal positioning of the head and neck for laryngoscopy. Facial or dental injuries may impede access for laryngoscopy because of limited mouth opening or the presence of blood in the oropharynx. The use of alternative methods to secure the airway (e.g., fiberoptic bronchoscopy or video laryngoscopy) or a surgical approach may be the safest option. Equipment for a surgical airway should be available before attempting ET intubation.

Airway and Respiratory	Preop assessment of the airway and neck is of utmost importance. The extent of mouth opening and presence of jaw or dental injuries should be noted. Stridor and hoarseness may be present with laryngeal injury or compression of the trachea; therefore an assessment of the patient's ability to phonate as an important part of the airway evaluation. Damage to the recurrent laryngeal nerve results in changes in voice and ↑ aspiration risk. Presence of C-spine injury (though not common with penetrating neck injuries) should be evaluated by x-ray or CT scan. Additionally, any distortion of internal and external structures due to tissue swelling or hematoma should be determined before intubation. The CXR or CT should be examined carefully for evidence of tracheal deviation, compression, or pneumothorax. Airway injury can be associated with subcutaneous emphysema or pneumothorax. **Tests:** x-ray; CT scan; ABG

Cardiovascular	The patient should be evaluated for the extent of blood loss based on their method and location of injury, hemodynamics (HR, BP), physical exam (capillary refill, peripheral pulse), and imaging results (eFAST results). Notably, facial and dental injuries may result in significant occult blood loss that may accumulate in the stomach. Venous lacerations can allow air embolism.
Neurologic	Physical exam should evaluate for deficits associated with acute compromise of cerebral arterial blood flow. C-spine injuries should be assessed by physical exam (neck pain, neurologic examination) and radiologic studies (lateral C-spine x-rays [including C-7], CT scan, MRI).
Premedication	Premedication may compromise a tenuous airway or lead to respiratory decompensation; use extreme caution when administering anxiolytics or sedatives. Patients are considered to have a full stomach. Sedative premedication should be avoided in patients who are hemodynamically unstable and those with probable head injuries.

INTRAOPERATIVE

Anesthetic technique

GETA.

Induction	The induction technique will depend on the associated injuries and physical exam. If C-spine injury is suspected, in-line stabilization of the patient's head and neck should be provided by an assistant. Patients should be presumed to have a full stomach, and consideration should be given for a rapid-sequence iv induction with the use of cricoid pressure. However, in the presence of an unstable C-spine, cricoid pressure may be associated with further injury. If a difficult intubation is anticipated, the anesthesiologist should consider the risks and

	benefits of an "asleep" vs. an "awake" intubation. A variety of intubation tools (laryngoscope blades, video laryngoscopes, laryngeal mask airways) and a range of ETT sizes (5.9–8.0 mm) should be available. LMA may be useful for providing temporary airway control without C-spine manipulation if direct laryngoscopy is difficult. Fiberoptic intubation or a surgical airway (cricothyrotomy or tracheotomy) should also be considered. In patients with penetrating neck injuries, "blind" intubation techniques should be avoided. The choice of induction medications should take into account the preop hemodynamics and airway concerns. In the hypovolemic patient, induction doses of propofol may be reduced by 50–75% to minimize ↓↓ BP. Consider etomidate (0.2–0.3 mg/kg) or ketamine (0.5–1 mg/kg iv) as alternative induction agents. In the presence of a vascular injury, it is important to avoid rapid ↑BP to prevent expansion of the hematoma. If rocuronium is used to facilitate intubation, sugammadex (e.g., 4–16 mg/kg iv) should be available for rapid reversal of paralytics in case of unanticipated difficult ventilation and intubation.
Maintenance	Standard maintenance is usually appropriate for the normotensive neck trauma patient. In cases of vascular injury, careful control of BP in the low normal range is advantageous. When nerve testing is anticipated, paralytics may need to be avoided.
Emergence	If only minimal distortion of the airway or residual swelling remains, awake extubation at the end of the procedure can be considered. Full reversal of muscle paralytics is of the utmost importance to avoid postop respiratory distress. Postop intubation and mechanical ventilation may be prudent for patients with residual neck or oropharyngeal swelling.
Blood and fluid	IV access: 14–16 ga Resuscitation with balanced

requirements	× 2	crystalloid solutions is recommended (i.e., Normosol®). Blood transfusion may be necessary for vascular injuries. Type and screen should be sent as soon as possible.
Monitoring	ASA standard monitors ± Arterial line	Invasive monitoring may be indicated for patients with major vascular injuries; however, the placement should not necessarily delay the start of emergency surgery.
Positioning	✓ and pad pressure points ✓ eyes	With suspected or known C-spine injuries, stabilization of the head and neck in the neutral position is required. Bed will often be turned 180° for surgical access to the injured site.

POSTOPERATIVE

Complications	Hemorrhage Hematoma Airway compromise	BP control at low normal levels (using SNP/NTG infusion, labetalol) and elevation of the head of the bed (10–20°) will help minimize tissue edema and hematoma formation, which could lead to airway compromise.

Suggested Reading

1. American College of Surgeons Committee on Trauma: Advanced trauma life suppor

for doctors. In: Student Course Manual, 9th edition. American College of Surgeons, Chicago: 2012.

CHEST TRAUMA: PERICARDIAL WINDOW, RELEASE OF TAMPONADE, AND REPAIR OF CARDIAC LACERATION

SURGICAL CONSIDERATIONS

Description

Cardiac contusions may occur in patients with blunt chest trauma. The degree of injury varies from localized contusion to cardiac rupture, but most are clinically insignificant if the patient survives in the hospital. Autopsy studies of victims of immediately fatal accidents show that as many as 65% have rupture of one or more cardiac chambers and 45% have pericardial lacerations. Most of the patients with cardiac rupture die at the scene; however, survivors are reported if vital signs are present during transport. Early clinical findings in cardiac contusion are most commonly dysrhythmias, but occasionally, patients can develop cardiac failure. The initial ECG in the ED is the most sensitive diagnostic test. The most common abnormalities are atrial arrhythmias and RBBB. Serial cardiac monitoring is indicated if the initial ECG is abnormal. Serum enzymes are not helpful. Management is symptomatic. Arrhythmias should be treated in the standard fashion and are not a contraindication to surgery. In the presence of blunt cardiac injury, hemodynamic abnormalities mandate echocardiographic examination to evaluate for structural lesions such as valve or myocardial rupture. Pericardial lacerations from stab wounds tend to seal and cause tamponade, present in 80–90% of patients with stab wounds to the heart. Accumulation of 150 mL of blood in the pericardium may impair preload and cause shock. **Beck triad** of distended neck veins, muffled heart sounds, and ↓ BP is present in only 30% of patients with tamponade. Pulsus paradoxus is even less reliable. The diagnostic test of choice is ultrasound, performed in the ED as part of the focused assessment by sonography for trauma (eFAST) exam.

Treatment of penetrating cardiac injuries has gradually changed from initial management by **pericardiocentesis** to prompt **thoracotomy** and **pericardial decompression**. Pericardiocentesis, with ultrasound guidance, may be used to stabilize a patient until **sternotomy** or thoracotomy can be performed. A **subxiphoid pericardial window** is an option but is best performed in the OR.

Gunshot wounds (GSWs) can produce extensive myocardial damage, multiple perforations, and massive bleeding into the pleural space. Hemothorax, shock, and exsanguination occur in nearly all cases of cardiac GSWs. Pericardial tamponade is often absent. Hemodynamically stable patients with penetrating injuries close to the heart should have ECHO evaluation in the ED only if equipment is immediately available. The presence of pericardial fluid should be evaluated with an eFAST scan. If hemopericardium is confirmed, blood should be evacuated and injury treated in the OR.

Patients who are stable enough to be transported to the OR have an excellent prognosis with reported survival of 97% for stab wounds and 71% for GSWs. In contrast, patients who require ED thoracotomy have only a 15% survival rate for penetrating injuries.

Subxiphoid pericardial window under local or GA: The entire chest is prepped for potential sternotomy. A vertical midline incision is made over the xiphoid process and upper epigastrium. The xiphoid is elevated or excised, allowing access to the pericardiophrenic membrane and anterior mediastinum. The pericardium is opened between two stay sutures and inspected for the presence of blood. With the use of eFAST scanning, this diagnostic test is most useful when the patient is already undergoing an **exploratory laparotomy**, and there is a suspicion for a cardiac injury. If blood is present, a median sternotomy should be performed.

Median sternotomy provides excellent exposure to the heart, great vessels, and pulmonary hila. This approach is ideal for anterior injuries and for the unstable patient but is less well suited for posterior injuries and left subclavian injuries.

Left anterior/anterolateral thoracotomy in the 5th intercostal space can be used in the stable patient or in the newly unstable ED patient with penetrating injury. The pericardium is opened anterior to the phrenic nerve, and tamponade is relieved. The bleeding heart is controlled with digital occlusion, and the laceration is closed with mattress sutures, with care being taken not to occlude coronary flow. Small coronary branches can be ligated, whereas others should be repaired and may even require **CPB**.

Usual preop diagnosis

Cardiac laceration

SUMMARY OF PROCEDURE	
Position	Supine, L arm abducted 90°
Incision	Median sternotomy or left anterior or anterolateral thoracotomy in the 5th intercostal space (see Fig.

	7.13-5). Further exposure may be obtained by transsternal extension into the R chest.
Special instrumentation	Rapid-infusion device; active rewarming system; internal defibrillator
Unique considerations	Massive blood loss is expected on opening pericardium and during repair of laceration. Large-bore peripheral lower extremity iv and central venous access are recommended for monitoring of volume replacement. A Foley catheter can be used to occlude laceration and as access for infusion. Arrhythmias are common.
Antibiotics	Cefazolin 2 g iv
Surgical time	45 min
Closing considerations	Hypothermia and coagulopathy contribute to mortality.
EBL	1–2 L
Postop care	ICU
Mortality	Without tamponade: ~90% With tamponade: ~30%
Morbidity	Overall: 85% Pulmonary complications Acute MI Arrhythmias Intracardiac shunts Ventricular aneurysms Valvular lesions Retained foreign bodies
Pain score	8

PATIENT POPULATION CHARACTERISTICS

Age range	Usually young adult
Etiology	GSWs, stab wounds, blunt trauma
	Hemothorax; pneumothorax; great vessel injury; lung

Associated conditions	contusion

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Chest Trauma.

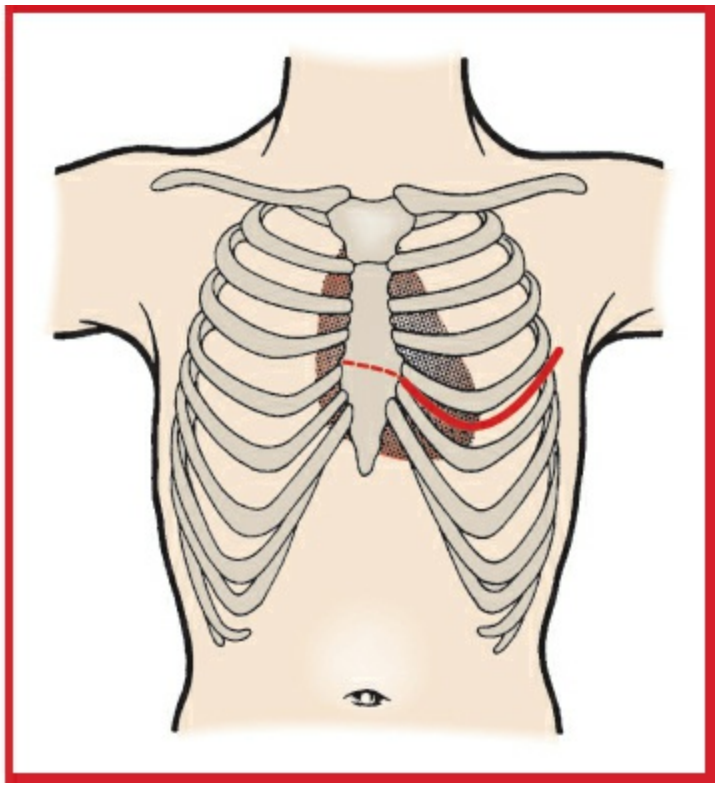

Figure 7.13-5 Incision (dashed/solid line) for ED thoracotomy: made immediately below the nipple, extending from the sternum as far laterally as possible. (Reproduced with permission from Baker RJ, Fischer JE, eds: Mastery of Surgery, 4th edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

CHEST TRAUMA: REPAIR OF GREAT VESSELS

SURGICAL CONSIDERATIONS

Description

Thoracic great vessel injury accounts for 8–9% of all vascular injuries seen in the trauma center. The subclavian artery and descending thoracic aorta are the vessels injured most often (21% of cases), followed by pulmonary artery (16%), subclavian vein (13%), vena cava (11%), and innominate artery and pulmonary veins (9%).

Rupture of the thoracic aorta is the most lethal injury following blunt chest trauma and

causes up to 50% of fatalities in MVCs. Proposed mechanism of injury is a deceleration force causing flexion or torsion of the aortic arch and subsequent disruption of the aortic wall at the ligamentum arteriosum immediately distal to the left subclavian artery. Survival of the patient depends on retention of the hematoma by the adventitial layer of the aorta. The mechanism of injury and the mediastinal silhouette on CXR are the two most sensitive markers for an injured thoracic aorta. Depressed left mainstem bronchus, apical capping, and a deviated trachea or esophagus (OG/NT tube) seen on CXR may be suggestive of aortic injury. CT angiogram of the chest has high sensitivity and is the preferred modality of evaluation in most trauma centers as a screening test. Arteriography is the gold standard for evaluating aortic injuries and may also allow therapeutic intervention. TEE can also aid in the evaluation and diagnosis of aortic injury in intubated patients, with a sensitivity and specificity similar to CT angiography in the hands of a skilled provider.

Smaller dissections in blunt trauma may be managed in the ICU with tight control of heart rate and systolic blood pressure. Injuries requiring operative intervention are traditionally managed with **thoracotomy** and **graft interposition**, but not without significant morbidity. Newer endovascular techniques are increasingly used as an adjunct to surgery or for definitive repair.

Investigation of these techniques is ongoing.

Ascending aorta

Rupture requires median sternotomy, CPB, and repair with a Dacron® graft. Penetrating injury to the anterior aspect of the aorta can be repaired primarily; if there is additional posterior injury, CPB is required for successful repair.

Aortic arch

Complete exposure of the great vessels is required; median sternotomy with extension to the neck and division of the innominate vein may be utilized. Complex injuries may require CPB.

Innominate artery, right carotid artery

Approach is via a median sternotomy with right cervical extension and division of the innominate vein, if necessary. Blunt trauma typically involves the proximal innominate artery, in contrast to penetrating trauma, which usually involves the distal portion of the artery near the carotid or subclavian bifurcation. Injuries are repaired using an interposition graft of Dacron® or Gore-Tex®. Because cerebral perfusion is maintained through the L carotid and subclavian arteries, shunting is not necessary.

Descending thoracic aorta

Ninety-seven percent of patients with great vessel injury who arrive alive at the hospital will have an injury at the isthmus. Clamping and direct reconstruction are required under temporary bypass shunt or pump-assisted shunt. Left posterolateral thoracotomy via the 4th intercostal space is the preferred access. Distal control of the descending aorta is obtained first; then the transverse aortic arch is exposed, and umbilical tape is applied between the L carotid and L subclavian arteries. Vascular clamps are applied at the proximal aorta, distal aorta, and subclavian artery. Graft interposition is utilized in 85% of the cases. An aortic cross-clamp time of <30 min minimizes the incidence of paraplegia.

Subclavian artery or vein

Approach is via a cervical extension of the median sternotomy for right-sided injuries. Exposure of injuries to the proximal, left, subclavian artery via median sternotomy is usually inadequate. In patients with such injuries, a high left thoracotomy, often with either a supraclavicular or trap-door incision, is needed. Graft interposition is often necessary.

Pulmonary artery and veins

In major hilar injury, **pneumonectomy** may be necessary, despite high mortality. Cross-clamping of the hilum prevents air embolus and hemorrhage. Simultaneous cross-clamping of the vessels and bronchus may reduce mortality in those patients requiring pneumonectomy. Fluid administration should be kept to a minimum to prevent right heart failure.

Thoracic vena cava

Intrathoracic IVC injury may cause hemopericardium and tamponade. Repair often is performed through the R atrium. SVC repair often is performed via a lateral venorrhaphy.

Usual preop diagnosis

Thoracic great vessel injury

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Anterolateral thoracotomy is preferred as it provides access to the descending aorta for cross-clamping and good access to heart and may be extended

	across the sternum into the right chest.
Special instrumentation	Intraop blood recovery device; rapid-infusion device; graft materials for any vessels larger than 5 mm. CPB may be necessary.
Unique considerations	Use of vasodilators (e.g., SNP) prevents cardiac strain during cross-clamping of the aorta. Large amount of fluid is required to prevent hypotension after clamp removal.
Antibiotics	Cefazolin 2 g iv
Surgical time	1–3 h
EBL	≥1–2 L
Postop care	ICU. Careful hemodynamic monitoring is critical because underlying pulmonary contusion may be worsened by inappropriate fluid administration. PA catheter may be necessary to optimize hemodynamic parameters, particularly in older patients. Coagulation studies must be carefully monitored and corrected with appropriate blood products.
Mortality	In general, mortality is associated with multisystem trauma and usually 2° concomitant head injury, infection, respiratory insufficiency, and renal failure. Pulmonary artery or vein, suprahepatic IVC, or SVC injury: >70% Ascending thoracic aorta, aortic arch (in patients with stable vital signs on arrival): 50% Blunt injury to the descending thoracic aorta: 5–25% Subclavian artery injury: 5%
Morbidity	Paraplegia: ~8% (with descending aortic injuries)
Pain score	10

PATIENT POPULATION CHARACTERISTICS

Age range	Typically young adult
Incidence	Thoracic great vessel injury accounts for 8–9% of all

	vascular injuries seen in the trauma center.
Etiology	Blunt trauma from MVC; penetrating trauma from stab wounds or GSWs
Associated conditions	Pneumothorax; hemothorax; head injury

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Chest Trauma.

CHEST TRAUMA: PNEUMONECTOMY, LOBECTOMY, AND REPAIR OF TRACHEOBRONCHIAL INJURY

SURGICAL CONSIDERATIONS

Description

Penetrating injuries to the chest can be divided into high- and low-velocity injuries. All stab wounds are classified as low-velocity injuries. GSWs may be considered low- or high-velocity injuries, depending on the energy of the bullet. The majority of GSWs seen in the ED are low velocity; however, higher-velocity injuries are being seen with increased frequency. The extent of tissue destruction in high-velocity injuries is related to blast effect, tumbling, and fragmentation of the missile, as well as secondary missiles, such as bone fragments. Patients with such injuries are more likely to require **thoracotomy** and **pulmonary resection**. In general, pulmonary resection is required in 1% of stab wounds and 2% of GSWs. The indications for early operation are continued shock, prolonged bleeding, a larger air leak with inability to oxygenate or ventilate the patient, and suspected concomitant injuries to the vital intrathoracic structures. In most patients with stab wounds or low-velocity GSWs, bleeding from the lung tissue stops spontaneously after evacuation of the hemothorax and reexpansion of the lung. Only 5–10% of such patients will require thoracotomy to control bleeding as compared to a thoracotomy rate of 70% for high-velocity injuries. Pulmonary contusion is a frequent sequela of GSWs or blunt trauma to the chest. Pulmonary contusion occurs in 75% of patients with flail chest but also can occur following blunt trauma without rib fracture. Alveolar rupture with fluid transudation and extravasation of blood are early findings.

The incidence of tracheobronchial injuries reported in the autopsy series from MVC is 1%. Mechanisms of injury include rapid deceleration, direct blow, or sudden increase of intratracheal pressure against a closed glottis. The most common tracheobronchial injury is transverse rupture, occurring in 74%, followed by longitudinal rupture in 18%, and complex in the remaining 8% of cases. Approximately 80% of cases with tracheal rupture occur within 2.5 cm of the carina. Patients with injury to the airway may present with severe dyspnea and with massive subcutaneous emphysema. About 90% of these patients will have an abnormal CXR, showing pneumothorax, pneumomediastinum, subcutaneous emphysema, or pleural effusion.

Tracheobronchoscopy should be performed in all patients with suspected tracheobronchial injuries to establish the diagnosis and plan operative treatment.

Parenchymal lacerations are repaired by the simplest method available to stop bleeding or air leak. If pulmonary resection is required, formal segmental resection is not necessary. A stapling device should be used to preserve as much lung tissue as possible.

Anatomic pulmonary resections are indicated when bronchial injury repair is not feasible or may lead to complete lobar collapse. **Pneumonectomy** may be required for major hilar injuries but is associated with a mortality rate of 75%. **Primary repair of tracheobronchial injuries** should be performed as soon as possible. Transverse rupture may require the placement of a sterile tracheal tube into the distal trachea through the operative field. After posterior sutures are placed, an orotracheal tube is advanced beyond the area of injury. **Mainstem bronchial repair** is performed under one-lung ventilation. High-frequency jet ventilation may be required to maintain oxygenation. Occasionally, total **CPB** is necessary for repair of complex airway injuries. Before closing, the suture line is pressure-tested and evaluated by **fiberoptic bronchoscopy**.

Usual preop diagnosis

Tracheobronchial injury; penetrating/blunt chest trauma

SUMMARY OF PROCEDURE	
Position	Supine, with neck extended for proximal tracheal injury, or lateral decubitus
Incision	Transverse cervical for almost all proximal tracheal injuries Right posterolateral thoracotomy in the 5th intercostal space for thoracic trachea and right bronchial wounds

	Left posterolateral thoracotomy for L bronchial injury
Special instrumentation	Fiberoptic bronchoscope, intrabronchial tube, jet ventilator/oscillator
Unique considerations	In patients with lobar resection or after pneumonectomy, PEEP may result in bronchopleural fistula.
Antibiotics	Cefazolin 2 g iv
Surgical time	2–3 h
EBL	Variable
Postop care	ICU (typically)
Mortality	Pneumonectomy for trauma: 75% Penetrating tracheobronchial injuries: ~15%
Morbidity	Bronchopleural fistula: 10% Empyema: 5% Hemothorax: 2–5% Pneumothorax ARDS (depends on extent of injuries)
Pain score	Cervical approach: 5–7 Thoracic approach: 8–10

ANESTHETIC CONSIDERATIONS FOR CHEST TRAUMA SURGERY

Blunt and penetrating chest trauma may present as any of the following conditions: hemopericardium, hemo-/pneumothorax, blunt cardiac injury, airway injury, pulmonary contusion with or without associated flail chest syndrome, and diaphragmatic injury. Hemopericardium may rapidly progress to pericardial tamponade, requiring immediate pericardiocentesis or pericardial window, followed by surgical exploration and repair of the cardiac or vascular laceration. These patients typically present with shock (↓↓ BP, ↑↑ HR) with distended neck veins (↑↑ venous pressure) and distant heart sounds (**Beck triad**) without evidence of tension pneumothorax. Blunt cardiac trauma may present with findings ranging from isolated ECG changes to cardiac rupture. The righ ventricle and interventricular septum are most commonly affected. Arrhythmias and ventricular dysfunction are frequently observed. Hemothorax may present as respiratory failure, shock, and absent breath sounds over the affected hemithorax. Pulmonary

contusion often presents with hypoxia and tachypnea; hemoptysis may also be present. Large flail chest defects may require mechanical ventilation. Intrathoracic tracheobronchial injuries are less frequent than upper airway injuries, although they are associated with a high mortality and usually require operative intervention. Video-assisted thoracic surgery (**VATS**) has emerged as the leading diagnostic tool for detection of diaphragmatic injury. Preoperatively, and particularly during the induction of GA, the patient's intravascular volume must be expanded, and myocardial contractility, HR, and SVR maintained. Inotropes and antiarrhythmic drugs may be required if hemodynamic instability occurs and patient does not respond to iv fluid administration. CPB is usually not required.

PREOPERATIVE

Respiratory	Injuries such as hemothorax and pneumothorax may be present, requiring thoracostomy tube placement. Fractures of the 1st or 2nd rib should prompt a detailed search for associated intrathoracic injuries, especially injuries to the great vessels. Injuries to the great vessels may present on imaging with a widened mediastinum or apical pleural capping. Multiple rib fractures are often associated with pulmonary contusions, which may not be apparent on the initial CXR but can progressively impair oxygenation. In cardiac tamponade, spontaneous respiration is preferred over PPV (→ ↓ venous return + ↓ CO). Significant intrathoracic tracheobronchial disruption may require rigid bronchoscopy or a surgical airway. **Tests:** CXR (PA + lateral views)—Upright inspiratory films best delineate chest structures; expiratory films enhance visualization of pneumothorax but are difficult to obtain in multiple-trauma patients; ultrasound can identify the presence of a pneumothorax or pleural effusion. CT of the chest if the patient's condition permits. ABG
Cardiovascular	Intravascular volume should be restored. BP and HR should be followed, and responses to fluid resuscitation noted. Given the risk of myocardial

	contusion, RV failure (due to the substernal location of the RV), and hemopericardium, assessment of cardiac function is also important; cardiac output can be significantly reduced despite normal BP measurements. TTE or TEE is useful for evaluating cardiac function, the presence of pericardial effusion or tamponade, or aortic injuries. In the setting of suspected cardiac dysfunction or tamponade, it may be necessary to support myocardial contractility with inotropes (e.g., epinephrine or dopamine). Myocardial contusion can also be associated with atrial or ventricular arrhythmias, which may require supportive therapy with antiarrhythmic medications (e.g., lidocaine 1–1.5 mg/kg bolus or 1–2 mg/min infusion or amiodarone 150–300 mg bolus or 1 mg/min infusion) or electrical cardioversion/defibrillation. Electrolyte abnormalities should be corrected. Large-bore intravascular access should be obtained, with strong consideration given to the need for invasive monitoring (arterial line, CVP, PAC etc.). **Tests:** ABG, continuous telemetry monitoring or serial ECGs. Ultrasound—eFAST, TTE, TEE
Neurologic	↓ BP and ↓ CO may compromise cerebral perfusion. Associated head injury also can contribute to alterations in mental status. Seek physical evidence of open head or closed head injuries, such as palpable depressions of the skull or scalp lacerations, abrasions, or contusions. Pupil size and reactivity should be noted. Intubation in the ER is necessary for patients who are unable to protect their airway, require hyperventilation, or are combative and unable to cooperate with medical staff for exam and treatment. In general, any patient with a GCS ≤ 8 (no spontaneous eye opening, inappropriate or incomprehensible speech, and only reflexive motor responses) requires intubation. GCS score ≤8 indicates significant brain injury. Motor or sensory

	deficits may reflect spinal cord injury and may be associated with neurogenic ("spinal") shock, particularly with upper thoracic or cervical cord injuries. **Tests:** C-spine x-rays (lateral view, including C7) are good screening exams— ✓ for altered vertical alignment and unequal disc interspaces. CT scan or MRI of the head: ✓ for gross asymmetry, hemorrhage, or midline shift.
Hematologic	Preop T&C appropriate. Depending on estimations of prior, ongoing, and anticipated surgical blood losses, blood products should be available (preferably cross-matched units, but O-neg or type-specific blood if cross-matching not complete). **Tests:** Serial Hct; T&C; ✓ Ca^{++} and K^{+} following massive transfusions
Musculoskeletal	Known or suspected C-spine fractures require intubation precautions, with laryngoscopy performed while an assistant provides in-line stabilization of the patient's head in the neutral position. **Tests:** Lateral C-spine x-rays, including C7; CT; MRI
Premedication	Premedication is rarely useful due to the urgency of the procedures and the need to have an alert, responsive patient for serial evaluations of mental status. Sedative premedication should be avoided in patients who are hemodynamically unstable and those with probable head injuries. Virtually all patients are considered to have full stomachs, and any compromise of the ability to protect the airway is inappropriate.

INTRAOPERATIVE

Anesthetic technique

GETA with full-stomach precautions.

Induction and intubation	Rapid-sequence induction with full-stomach precautions is often preferred. **NB:** In the patient with an unstable C-spine, cricoid pressure (~10 lb) may cause spinal cord injury, and consideration should be given to the establishment of a surgical airway under local anesthesia. Induction medications: • Ketamine (0.5–2.0 mg/kg): associated with ↑ HR, ↑ BP, and ↑ CO. Careful consideration should be given to the catecholamine-depleted trauma patient, in whom the direct myocardial depressant effects of ketamine may be unmasked. • Etomidate (0.2–0.6 mg/kg): useful alternative for patients with head injuries • Agents that tend to decrease SVR, such as inhalational anesthetics and narcotics, should be introduced with caution. • Succinylcholine is attractive due to the quick return of spontaneous ventilation; alternatively, RSI-dose rocuronium (1 mg/kg) can now be immediately reversed with sugammadex (16 mg/kg). • Inotropic agents (ephedrine, dopamine, epinephrine) should be immediately available to treat ↓ BP. GETA is required for exploration through a median sternotomy or left thoracotomy. In the latter case, one-lung ventilation will likely be necessary, with a DLT or bronchial blocker (BB). If a difficult airway is anticipated, a single-lumen ETT may be placed initially with a DLT placed with an airway exchange catheter. Fiberoptic scopes aid in the placement of DLTs and BBs and assist in the confirmation of appropriate positioning. The potential for sudden and substantial blood loss exists, and PRBCs (cross-matched, type-specific or O-neg) should be available in the OR before induction.
Maintenance	Initially, low-dose inhalational agents and low-dose

	narcotics may be used, as tolerated. ↓ BP may require resuscitation with crystalloid, vasoconstrictor, or inotropic agents. Muscle relaxation and PPV are used. N_2O should be avoided if there will be a need for one-lung ventilation or there is associated pulmonary contusion. If the patient is hypotensive and acidotic, scopolamine (0.2–0.4 mg iv) will ↓ risk of recall. As cardiac and vascular injuries are repaired, BP and CO often will improve, permitting increased depth of anesthesia and decreased inotropic support. Indicators of improved tissue perfusion should be followed, such as resolution of lactic acidosis, central or mixed venous oxygen saturation, and improved urine output.	
Emergence	Trauma patients often require prolonged intubation; however, hemodynamically stable patients with limited injuries may be extubated awake. Patients who received significant blood replacement (>50% of blood volume), those requiring inotropic support, intoxicated patients, and those with head injuries should remain intubated and mechanically ventilated postop. Consideration for continued mechanical ventilation should be given to those patients with large pulmonary contusions or flail chest segments.	
Blood and fluid requirements	Be prepared for large blood loss. IV: 14 ga × 2 Fluid warmer Rapid-infusion device	Large blood loss may occur, depending on the severity of the injury. Blood products (pRBC, FFP, platelets) should be available for balanced resuscitation in the setting of hemorrhage. Crystalloid solutions should also be available for resuscitation (e.g., BSS such as Normosol®).
Monitoring	ASA standard monitors	ECG should be observed for changes associated with

	Arterial line CVP ± PA catheter ± TEE	myocardial contusion (atrial/ventricular dysrhythmias, RBBB, ST-T wave changes). Arterial line useful in unstable patients or when frequent lab sampling is anticipated. CVP line or PA catheter may be useful if vasoactive infusions are needed or if ventricular dysfunction is apparent. Placement of additional monitoring should be accomplished without delaying the surgical control of hemorrhage or without interrupting aggressive volume resuscitation. (With release of tamponade, CVP rapidly drops toward normal, and CO and BP will markedly improve.) TEE offers continuous cardiac monitoring of contractility, volume status, and assessment of regional wall motion.
Positioning	✓ and pad pressure points ✓ eyes ± C-spine: neutral position	Axillary roll, if lateral decubitus position; chest roll if median sternotomy
Complications	Hypothermia Awareness Renal failure	Hypothermia → dysrhythmias + ↓ CO → acidosis. Rx: warm OR, warm iv fluids, patient warming devices A concern in unstable patients. Rx: Consider

	Coagulopathy	scopolamine (0.2–0.4 mg iv). Usually 2° ↓ renal perfusion (prerenal). Rx: Restore CO with volume and inotropes. Most commonly 2° dilutional thrombocytopenia or hypothermia. DIC may require replacement therapy with Plts, FFP, and cryoprecipitate. Massive transfusion may benefit from a 1:1 ratio of PRBC to FFP. Maintain nl Ca^{++} (1.05–1.3 mM/L).

POSTOPERATIVE

Complications	Hypotension Cardiogenic shock Arrhythmias Hypothermia Atelectasis, V/Q mismatch, ARDS Coagulopathy, VTE	Cardiogenic shock may be 2° prolonged ↓ BP or cardiac contusion. Neurogenic shock may be seen with associated spinal cord injuries. Hemodynamic instability with atrial/ventricular dysrhythmias may occur. Treatment with inotropic infusions (epinephrine 10–150 ng/kg/min or norepinephrine 1–20 mcg/min or dopamine 5–10 mcg/kg/min) and antiarrhythmic medications Active warming of iv fluids and warming blanket should be continued in ICU or PACU if hypothermia persists. If neurologic injury is present, targeted temperature

		management is recommended (33–36°C, with avoidance of hyperthermia). Pulmonary compliance may decrease with large volumes of fluid replacement. Interstitial and alveolar edema → progressively worsening pulmonary function requiring prolonged mechanical ventilation. Pulmonary contusions may aggravate this problem and severely compromise oxygenation and ventilation, requiring high-inspired O_2 concentration, high PIP, and PEEP. Institution of lung-protective ventilation strategies should be considered. Based on clinical assessment and laboratory data (PT, Plt count, fibrinogen), transfusion of Plts, FFP, or cryoprecipitate may be indicated.
Pain management	PCA or parenteral narcotics Epidural	Epidural infusions of narcotic and/or low-dose local anesthetics can be effective in patients without coagulopathy. Continuous epidural anesthesia may be beneficial in the setting of multiple rib fractures.

ABDOMINAL TRAUMA: DAMAGE CONTROL

SURGICAL CONSIDERATIONS

Description

The incidence of abdominal injuries requiring laparotomy approaches 25% for penetrating and 5–8% for blunt abdominal trauma. In blunt trauma, liver and spleen injuries occur with an incidence of ~50%. In penetrating trauma, the most common injuries are in the small bowel (29%), liver (28%), colon (23%), and stomach (13%). Many preventable deaths in trauma patients are related to shock from unrecognized intra-abdominal hemorrhage caused by solid organ injury.

Victims of severe multisystem trauma are particularly susceptible to the development of a fatal coagulopathic state 2° hypothermia, acidosis, dilution, and consumption. Replacement of two or more blood volumes with BSS and PRBCs will decrease th level of coagulation factors to 15%. Because of delays in obtaining coagulation profile results, coagulation factors should be replaced empirically in the setting of a large transfusion requirement (e.g., 1 U FFP/1.5 U PRBC). Metabolic acidosis affects bot the circulatory system and coagulation, → ↓ CO and triggering DIC. Chances o salvaging a patient with pH < 7.0 approach zero. To stop this self-perpetuating downward cycle, the concept of "damage control" has evolved. This involves **rapid laparotomy** to control hemorrhage and GI spillage, followed by temporary closure of the abdomen and subsequent exploration after the patient has been warmed and stabilized. With the use of this technique, ~40% of critically injured patients can be saved from otherwise fatal injuries.

With the patient on a heated operating table, the patient is prepped from the thighs to the neck and draped, and the abdomen is entered through a midline incision. This critical moment can be associated with significant blood loss and may require rapid blood transfusion. **Four-quadrant packing** with laparotomy pads is performed in the abdominal cavity, and manual compression of the subdiaphragmatic aorta may be instituted if packing alone does not control the hemorrhage. If necessary, the operation is stopped, and blood/fluid resuscitation is performed. After consultation with the anesthesiologist, the surgeon proceeds with the sequential unpacking of each of the four quadrants and identifying injuries. Vascular injuries are controlled with clamping and ligation or shunting, bowel injuries are stapled across, but no attempt is made to restore bowel continuity. Liver and retroperitoneal injuries are controlled with packing alone. When damage control is performed, the abdomen is closed with a running skin suture, if appropriate; otherwise, a temporary vacuum dressing is used. PIP should be monitored during closure, as patients may develop **abdominal compartment syndrome** (↑↑ intra-abdominal pressure → ↑ PIP, ↓ UO, normal filling pressures). The patient is ther

transported to the ICU and actively warmed and resuscitated. Reoperation should be performed at 24–48 h when the patient is rewarmed, and acidosis and coagulopathy have resolved. Definitive repair of the injured organs should be completed.

Usual preop diagnosis

Intra-abdominal trauma and hemorrhage

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Midline abdominal
Special instrumentation	Fluid-warming, rapid-infusion device
Unique considerations	Autotransfusion device (e.g., Cell Saver) may be of use if no contamination of abdominal cavity.
Antibiotics	Cefotetan 1–2 g iv
Surgical time	45–90 min
Closing considerations	Even temporary closure may not be possible because of severe bowel edema. A silo made from a plastic iv bag may be used to cover the bowel. Monitor PIP and UO during abdominal wall closure because abdominal compartment syndrome may develop.
EBL	Average transfusion requirement: 12 L crystalloids, 20 U PRBCs, 10–15 U FFP, 6 U Plts
Postop care	ICU; patient remains intubated. Active rewarming is of primary importance.
Mortality	70%
Morbidity	Intra-abdominal abscess: 30% Fistulas: 10%
Pain score	10

PATIENT POPULATION CHARACTERISTICS	
Age range	Typically young adult

Male:Female	9:1
Incidence	25% for penetrating and 5% for blunt abdominal trauma
Etiology	MVC; penetrating injury (e.g., GSW or stab wound)
Associated conditions	Chest trauma; closed head trauma; pelvic fracture

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Abdominal Trauma Surgery.

ABDOMINAL TRAUMA: HEPATIC AND SPLENIC INJURIES

SURGICAL CONSIDERATIONS

Description

The liver is the most commonly injured organ in patients with blunt trauma and the second most commonly injured organ in penetrating trauma. The management strategy and decision to operate depends upon the hemodynamic status of the patient, grading of the liver injury, and presence of associated injuries. The majority of injuries can be managed nonoperatively if the patient is hemodynamically stable unless other injuries mandate laparotomy. The adjunctive use of angioembolization has significantly increased nonoperative success rates. Thus, most liver injuries that require operation are complex (grades IV–V), with large blood loss and high mortality (up to 30%).

In a patient with massive **intra-abdominal hemorrhage**, sudden cardiovascular collapse is predictable when the abdomen is opened. Laparotomy with manual compression of the aorta at the aortic hiatus is recommended. Access for subsequent aortic clamping is rapidly obtained by blunt finger dissection of the lesser sac. After removing all clots and free blood, four-quadrant packing is used to control bleeding. Significant liver bleeding should be controlled with manual compression, the Pringle maneuver, and perihepatic packing.

Several maneuvers can be used to facilitate **repair of liver injuries: manual compression and packing** temporarily controls bleeding and allows time for volume

resuscitation. The use of topical hemostatic agents and direct suturing of the liver parenchyma provide direct control.

Portal triad occlusion (**Pringle maneuver**; Fig. 7.13-6) decreases blood loss and identifies the patient who might benefit from selective hepatic artery ligation. It also allows for differentiation from hepatic venous or retrohepatic caval bleeding if clamping is unsuccessful in arresting hemorrhage.

In persistently hemodynamically unstable patients, damage control techniques provide time for resuscitation. **Perihepatic packing and planned reexploration** is a lifesaving maneuver and should be used early for patients with severe injuries, before they become hypothermic, coagulopathic, and acidotic. Extensive liver mobilization, parenchymal disruption (i.e., finger fracturing), and atriocaval shunts are rarely indicated. Hepatic angiogram and embolization in the immediate or early postop phase may also be very useful for patients with severe injuries. At reexploration, intrahepatic omental packing may be used for obliterating dead space. Closed suction drains should be used in all patients.

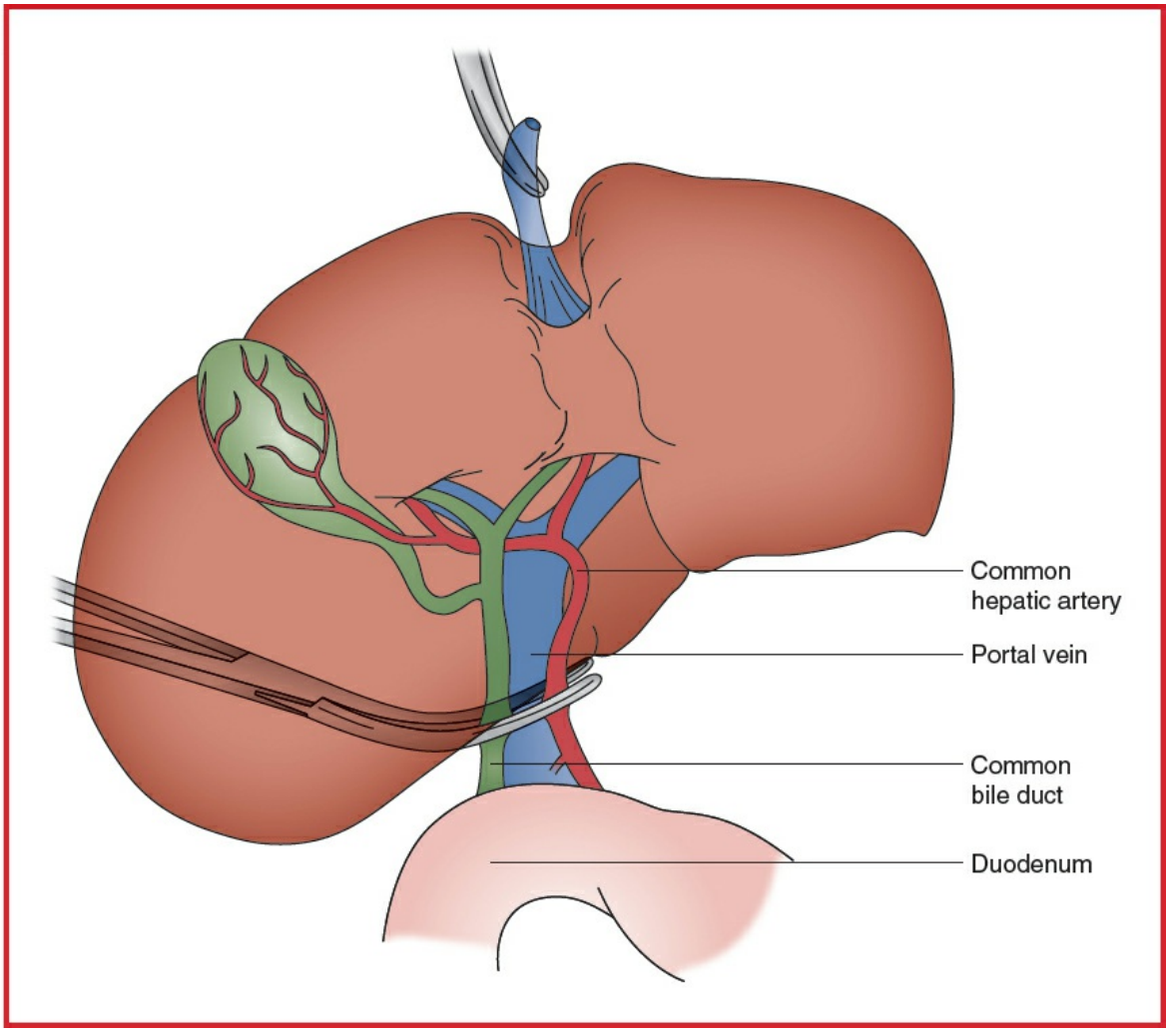

Figure 7.13-6 Pringle maneuver compression of the portal triad structures with a non-crushing vascular clamp for hepatic inflow control. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al, eds: Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Portal triad (portal vein, hepatic artery, common bile duct) injuries, although rare, are associated with extremely high mortality. Simple lacerations to the common bile duct may be repaired using interrupted absorbable sutures. More destructive injuries are best repaired over a T-tube to minimize risk of stricture and facilitate postop contrast studies. Complete transections and tissue defects should be evaluated for reconstruction by a hepatobiliary surgeon. Isolated portal vein injuries are associated with a 70% mortality. The portal vein should be repaired if possible; however, ligation can be tolerated. Careful volume resuscitation should follow portal vein ligation to avoid ↓ BP 2° fluid sequestration in the splanchnic bed. Simple ligation of the hepatic artery, preferably at one of its branches, is recommended for major hepatic artery injuries and patients in extremis. Ligation of the hepatic artery proper carries a significant risk of hepatic necrosis that may necessitate liver resection or transplantation. Shock and transfusion-related coagulopathy occurring in the immediate postop period are responsible for 80% of the deaths in liver injury patients. Control of hemorrhage remains the critical component in the successful management of liver injuries.

More than 90% of splenic injuries are caused by blunt trauma. Approximately 70% of these patients can be managed nonoperatively. Active contrast extravasation or contrast blush on CT scan warrants angioembolization. Hemodynamic instability or failure of nonoperative management (up to 20% failure rate) necessitates **splenectomy**. Grades IV (active intraperitoneal bleeding) and V (shattered/avulsed injuries) are associated with the highest rates of splenectomy. Massive bleeding from the LUQ is probably caused by splenic injury. In trauma, the spleen is delivered into the wound by blunt dissection. The spleen is removed by cross-clamping the hilum and dividing the short gastric vessels. The LUQ is packed and reinspected for hemostasis once better resuscitation is provided. The splenic salvage rate in the pediatric population approaches 90%.

Usual preop diagnosis

Hepatic injury; splenic injury

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Midline abdominal

Special instrumentation	Active rewarming device; cell salvage
Unique considerations	Most emergency laparotomies require close cooperation between anesthesiologist and surgeon. The procedure may need to be interrupted for fluid or blood resuscitation if patient becomes hypotensive. The entire chest and abdomen, including both groins, need to be accessible to the surgeon; ECG electrodes are placed preferably on the patient's back.
Antibiotics	Cefazolin 2 g iv
Surgical time	1–2 h
Closing considerations	After massive fluid resuscitation, concern over compartment syndrome may preclude primary fascial closure. The abdomen may be left open for later closure.
EBL	2–10 L (transfusion requirement 6–20 U)
Postop care	ICU: shock and coagulopathy management; monitoring for possible rebleeding and abdominal compartment syndrome
Mortality	Liver: 10% Spleen: 10% (usually due to associated injuries)
Morbidity	Liver—perihepatic abscess: 10% Spleen—septic complications: 7%
Pain score	8–10

PATIENT POPULATION CHARACTERISTICS

Age range	Any age
Male:Female	3:1
Incidence	Liver: 30% of patients requiring laparotomy for trauma Spleen: 10% of patients requiring laparotomy for trauma
Etiology	Liver: penetrating wound (80%) with gunshot wounds responsible for 60% and stab wounds for 40%

Associated conditions	Spleen: blunt trauma (90%), mostly due to MVC Liver: isolated hepatic injury (30%); injury to one or two other organs (50%), with the diaphragm, major vascular structures, stomach, lung, and colon being most common

ANESTHETIC CONSIDERATIONS

See Anesthetic Conditions for Abdominal Trauma Surgery.

ABDOMINAL TRAUMA: VASCULAR INJURIES

SURGICAL CONSIDERATIONS

Description

The incidence of abdominal vascular injuries in blunt abdominal trauma patients is ~5–10%. Penetrating abdominal trauma results in major abdominal vascular injury for 10% of patients, compared with 20–25% for gunshot injuries. Blunt injuries typically lead to avulsion of vessels, intimal tears with secondary thrombosis, or traumatic false aneurysm. Penetrating abdominal vascular injuries can additionally lead to blast injuries and free hemorrhage or arteriovenous fistula formation.

Initial resuscitation of the patient with abdominal vascular injuries depends on the patient's condition. In blunt trauma, hypotensive patients with a positive eFAST or hypotensive patients with penetrating injury, time in the emergency room should be minimized and transfer to the operating room should be near immediate. Multiple large-bore catheters should be inserted in the upper extremities, or if necessary, central venous access should be obtained. Because of probable intra-abdominal venous injury, lower extremity venous access is not indicated. Blood replacement during resuscitation is done preferably with type-specific blood. It is a good practice to have 2 U of O-neg blood available immediately in the ED in case there is no time for a limited cross-match. Efforts to limit hypothermia should start as soon as the patient arrives (use of warmed fluids and high-flow blood warmers and covering the patient with warm blankets or a forced-air warming blanket). Emergency department resuscitative thoracotomy and descending aorta compression or cross-clamping should be considered in select situations, such as witnessed loss of vital signs and penetrating injury. Even then, survival rates are dismal.

Injuries to the abdominal vessels can be grouped into four regions, which require different surgical approaches:

Midline supramesocolic hemorrhage or hematoma (superior to the transverse mesocolon) is usually 2° injury of the suprarenal aorta, celiac axis, proximal superior mesenteric artery, or proximal renal artery. Proximal aortic control should be obtained at the hiatus by either aortic compression or manually by entering the lesser sac and digitally splitting the muscle fibers of the crura. Once this is done, direct access to the vessels is achieved through medial visceral rotation of all left-sided viscera (**Mattox maneuver**). Injuries to the aorta are then repaired directly or with the appropriate graft. An injured celiac axis probably can be ligated safely if the remaining visceral vessels are intact. Superior mesenteric artery injuries must be repaired, usually with a jump graft. Repair of the superior mesenteric vein is preferred, but the vein may be ligated if complex injuries are present. These patients require substantial fluid resuscitation postop and are at high risk for abdominal compartment syndrome. Injuries to the IVC or right side of the aorta can be exposed by **duodenal mobilization (Kocher maneuver) and right-sided medial visceral rotation (Cattell-Braasch)**.

Midline inframesocolic hemorrhage or hematoma results from infrarenal aorta or IVC injury. Exposure is obtained by incising the posterior peritoneum in the midline after displacement of the small bowel and cephalic retraction of the transverse mesocolon. A proximal aortic clamp is then placed just below the left renal vein, with a distal clamp near the aortic bifurcation. The defect is repaired primarily, using patch aortoplasty, end-to-end anastomosis, or a graft. If the aorta is intact and an inframesocolic hematoma seems to be more extensive on the right side, or if there is active bleeding coming through the base of the mesentery, then injury to the IVC should be suspected. Access to the infrahepatic IVC is preferably obtained by mobilization of the right colon and duodenum. Proximal and distal controls are best obtained by either digital compression or two sponge sticks. The injury is then repaired directly. Blind clamping should be avoided, but occasionally, with good exposure, a **Satinsky clamp** can be placed. In young patients with exsanguinating hemorrhage, the infrarenal IVC can be ligated, providing time for appropriate fluid management. These patients require significant fluid postop, and **leg fasciotomies** should be performed.

Lateral perirenal hematoma or hemorrhage suggests injury to the renal vessels or kidney. In patients with blunt abdominal trauma who have a negative abdominal CT, IVP, or arteriogram, surgery is not required. A penetrating injury usually requires surgical exploration. Vascular control of the ipsilateral renal artery is obtained before the hematoma is entered. If there is active bleeding from the kidney or overlying

retroperitoneum, then the kidney is exposed via a lateral incision, and a vascular clamp is applied to the renal vessel. This usually is followed by **nephrectomy** (after palpation and a one-shot IVP to verify function of a normal contralateral kidney). If the contralateral kidney is missing or nonfunctional, then **back-table salvage surgery and autotransplantation** of the injured kidney should be attempted, despite low salvage rates.

Lateral pelvic hematoma or hemorrhage indicates injury to the iliac vessels. Pelvic hematoma 2° blunt trauma and pelvic fracture should not be explored. The majority of severe bleeding due to pelvic fractures is venous in origin and therefore amenable to a combination of preperitoneal pelvic packing techniques and external fixation of the pelvis. Preperitoneal pelvic packing employs laparotomy sponges in the preperitoneal space to tamponade bleeding and reduce the volume of retroperitoneal space. Primary control of arterial bleeding is by **angiography/embolization**. For penetrating injuries, vascular control is obtained at the aortic bifurcation proximally and close to the inguinal ligament distally. The internal iliac artery is best visualized by elevating common and external iliac arteries on vascular tapes. Unilateral internal iliac artery injuries can be ligated. Common or external iliac artery injuries can be repaired, or a graft can be inserted. Grafts may be used even in the presence of GI contamination, provided the abdomen is thoroughly irrigated, and the retroperitoneum is closed over the graft. A temporary intravascular shunt should be used in patients requiring damage control surgery. Injuries to the iliac veins are treated with lateral venorrhaphy or ligation.

Additional Considerations and Techniques

Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA)

While hemorrhage from extremity trauma is compressible, torso hemorrhage is difficult to control and a leading cause of trauma-related mortality. Significant bleeding from the major vessels can lead to rapid exsanguination. In addition to damage control techniques such as open cross-clamping of the aorta (discussed above), REBOA is a useful and less invasive alternative for temporary hemorrhage control. It acts to reduce the amount of bleeding distal to the site of occlusion to allow time for resuscitation and definitive management.

In the context of available resources, REBOA should be considered for those patients with a pulse whose systolic blood pressure is persistently below 80 mm Hg. The level at which the balloon is placed depends upon the suspected location of hemorrhage (see Fig 7.13-7). Zone 1 level aortic occlusion is useful in circumstances of abdominal exsanguination. Severe pelvic fracture bleeding might warrant infrarenal, or Zone III occlusion. Another advantage of this modality is that femoral access can be obtained

preemptively during trauma resuscitation and subsequently used for balloon catheter access if needed. Placement requires proper endovascular technique and fluoroscopic guidance. Once common femoral arterial access is obtained and the sheath secured, the balloon catheter is inserted and judiciously inflated until operative control of bleeding is obtained. The balloon is then deflated and the sheath removed. Every attempt should be made to minimize occlusion time, as thromboembolic complications and end-organ damage can result.

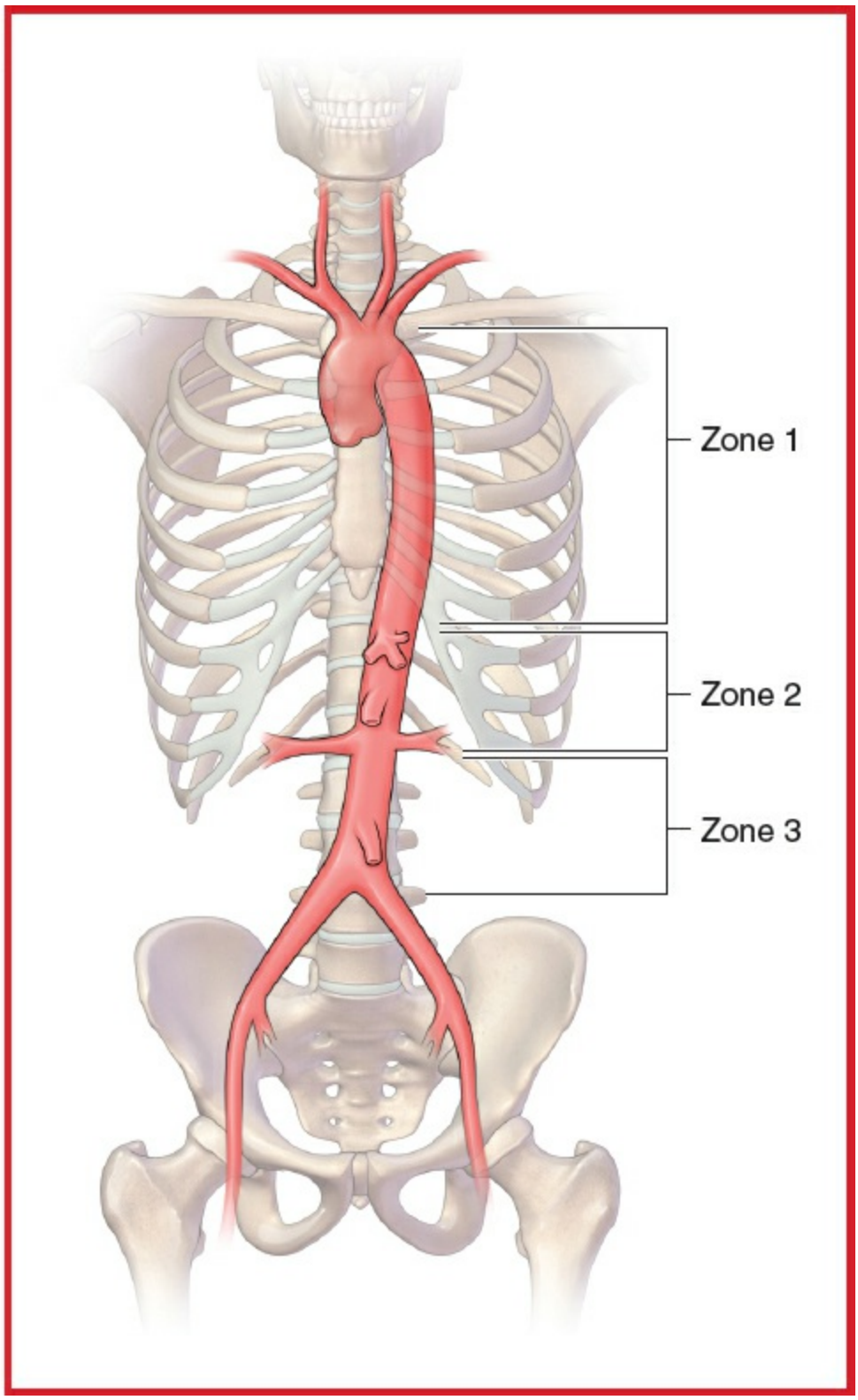

Figure 7.13-7 REBOA zones.

Suggested Reading

1. See p. 839 and end of this chapter.

Usual preop diagnosis

Abdominal vascular injury

SUMMARY OF PROCEDURE	
Position	Supine, with left arm abducted 90°
Incision	Midline abdominal
Special instrumentation	Autotransfusion device (e.g., Cell Saver®); thoracotomy tray; aortic compressor
Unique considerations	Prevent heat loss and warm all infusions and irrigation solutions. Ventilator warming should be used for cold patients. For the patient requiring massive transfusion, ratio of 1 U FFP:1.5 U PRBCs is useful. After prolonged aortic cross-clamp, prophylactic administration of $NaHCO_2$ (1–2 mEq/kg) may be indicated to prevent "washout" acidosis.
Antibiotics	Cefazolin 2 g iv
Surgical time	Variable
Closing considerations	Once vascular injuries are repaired, hepatic injuries are controlled with packing, bowel injuries are closed with staplers, and the abdominal wall is closed temporarily.
EBL	5–10 L
Postop care	ICU; patients after infrarenal vena cava ligation require volume expansion and prevention of lower extremity venous pooling. Elastic wraps and lower extremity elevation should be maintained for at least 1 wk. Similarly, after superior mesenteric vein ligation, splanchnic hypervolemia requires vigorous fluid resuscitation and lasts ~3 d.
Mortality	Combined injury to the suprarenal aorta and IVC: 100% Aorta: 60% Infrarenal abdominal aorta: 50% Superior mesenteric artery: 40–80% Iliac artery: 40%

	Iliac vein: 30% Infrarenal vena cava: 30% Superior mesenteric vein: 20% Renal artery: 15%
Morbidity	Abdominal compartment syndrome (↑↑ abdominal pressure → ↑ PIP + ↓ UO) Acute renal failure Intra-abdominal infection Fistula
Pain score	8–10

PATIENT POPULATION CHARACTERISTICS	
Age range	Typically young adult
Male:Female	Male > female
Incidence	15% of patients with abdominal trauma
Etiology	10% of penetrating stab wounds and 25% of gunshot wounds to the abdomen will cause a major vascular injury.
Associated conditions	Multiple vascular injuries; hollow viscus perforation; fecal contamination

ANESTHETIC CONSIDERATIONS FOR ABDOMINAL TRAUMA SURGERY

Abdominal injuries range from relatively simple penetrating injuries (e.g., a stab wound) to severe blunt trauma (e.g., liver lacerations and pelvic fractures) and are often associated with massive hemorrhage. Head injuries and spinal fractures may complicate management plans. The ability to provide rapid, aggressive volume replacement is often the key to survival. Coagulopathy (DIC) and hypothermia present additional challenges.

PREOPERATIVE

Respiratory	Injuries such as hemothorax and pneumothorax may be present, requiring thoracostomy tube placement. Fractures of the 1st or 2nd rib should prompt a

	detailed search for associated intrathoracic injuries, especially injuries to the great vessels. Injuries to the great vessels may present on imaging with a widened mediastinum or apical pleural capping. Multiple rib fractures are often associated with pulmonary contusions, which may not be apparent on the initial CXR but can progressively impair oxygenation. **Tests:** CXR (PA + lateral views). Ultrasound can identify the presence of a pneumothorax or pleural effusion. CT of the chest if the patient's condition permits. ABG
Cardiovascular	BP and HR should be followed, and responses to fluid resuscitation noted. Tachycardia can maintain an adequate BP with reduced pulse pressure, despite 25–30% loss of blood volume. Attempt to quantify overt blood loss (e.g., scalp lacerations, open fracture sites). Blunt chest trauma (e.g., steering wheel contact) may result in myocardial contusion with various dysrhythmias, most often premature ventricular or atrial complexes. **Tests:** Serial Hct; ABG, continuous telemetry monitoring or serial ECGs. Ultrasound—eFAST, TTE, TEE
Neurologic	↓ BP and ↓ CO may compromise cerebral perfusion. Associated head injury also can contribute to alterations in mental status. Seek physical evidence of open head or closed head injuries, such as palpable depressions of the skull or scalp lacerations, abrasions, or contusions. Pupil size and reactivity should be noted. Intubation in the ER is necessary for patients who are unable to protect their airway, require hyperventilation, or are combative and unable to cooperate with medical staff for exam and treatment. In general, any patient with a GCS ≤ 8 (no spontaneous eye opening, inappropriate or incomprehensible speech, and only reflexive motor responses) requires intubation. GCS ≤ 8 indicates

	significant brain injury. Motor and sensory deficits may reflect spinal cord injury and may be associated with neurogenic ("spinal") shock, particularly with upper thoracic or cervical cord injuries. **Tests:** C-spine x-rays (lateral view, including C7) is a good screening exam—✓ for altered vertical alignment and unequal disk interspaces. CT scan or MRI of the head: ✓ for gross asymmetry, hemorrhage, or midline shift.
Musculoskeletal	Known or suspected C-spine injuries require intubation precautions. In urgent cases, intubation without neck extension is achieved with an assistant providing in-line stabilization of the head in the neutral position. Basilar skull fractures contraindicate nasal ET or NG tubes. Pelvic and femur fractures may represent sources of significant (>1000 mL) occult blood loss. **Tests:** Radiographs of the C-spine (see above), skull, pelvis/extremities
Hematologic	Preop T&C appropriate. Depending on estimations of prior, ongoing, and anticipated surgical blood losses, blood products should be available (preferably cross-matched units, but O-neg or type-specific blood if cross-matching not complete). **Tests:** Serial Hct; T&C; ✓ Ca^{++} and K^{+} following massive transfusions
Laboratory	Other tests as indicated from H&P or suspected injuries, including electrolytes, liver panel, toxicology screen, and blood alcohol level.
Premedication	Premedication is rarely useful due to the urgency of the procedures and the need to have an alert, responsive patient for serial evaluations of mental status or abdominal pain. Sedative premedication should be avoided in hemodynamically unstable patients and those with probable head injuries. Virtually all patients are considered to have full stomachs.

INTRAOPERATIVE

Anesthetic technique

GETA with full-stomach precautions

Induction	Before induction, a variety of laryngoscope blades, ETT tube sizes, and ideally intubating adjuncts including video laryngoscope and FOB in preparation for potential difficult airway should be ready. LMA may be useful for providing temporary airway control without C-spine manipulation, if direct laryngoscopy is difficult. LMA may be used as a conduit for ET intubation (fiberoptic or fast-track LMA). Most often, preoxygenation is followed by a rapid-sequence iv induction with cricoid pressure (Sellick maneuver) using propofol (1–2.5 mg/kg) and succinylcholine (1.0–1.5 mg/kg). If hypotension is present or a concern, alternate induction agents (e.g., ketamine 0.5–2.0 mg/kg iv or etomidate 0.1–0.3 mg/kg iv) may be used. Axial head and neck stabilization are necessary if C-spine injury is present or suspected. Some trauma patients are intubated in the ED. Verify ETT placement by auscultation and $ETCO_2$ monitoring. Very low $ETCO_2$ values may be obtained in patients with ↓↓CO. Ventilation with 100% O_2 and paralysis with muscle relaxant are appropriate. Ongoing fluid resuscitation should be continued during this time. Consider sending lab studies/ABG at this point and ensuring availability of blood products.
Maintenance	Titrate O_2/air, muscle relaxants, narcotics, and volatile agents. Avoid N_2O in the presence of pneumothorax, pneumocephalus, bowel distension, or prolonged procedures. Shorter-acting agents (e.g., volatile agents, remifentanil, rocuronium), carefully titrated, may be preferred in patients with head injuries to facilitate early postop assessment of neurologic status. If ↓ BP precludes use of volatile

	anesthetics and opiates, consider low-dose scopolamine (0.1–0.3 mg iv) or ketamine (0.25 mg/kg/15–30 min) for amnesia. Use forced-air warming blanket(s) and warmed iv fluids, and consider elevated OR temperatures to maintain normothermia.	
Emergence	Before extubation, patient should be awake and able to protect his/her airway and should be hemodynamically stable and spontaneously ventilating with adequate tidal volumes and respiratory rates. Consider postop mechanical ventilation and ICU care for trauma patients with pulmonary compromise/trauma, ongoing acidosis, hemodynamic instability, ongoing or anticipated significant fluid and blood product resuscitation, coagulopathies, intoxication, or neurologic impairment.	
Blood and fluid requirements	Anticipate large blood loss IV: 14–16 ga × 2 or 7–9 Fr × 2 BSS Fluid warmer Rapid-infusion device T&C PRBCs, ± other blood products (FFP, platelets, cryo)	Large blood losses may have already occurred and continue to occur, depending on the mechanism of injury (e.g., liver lacerations, major vascular injury, pelvic fractures). Early determination of availability of blood products advised. BSS, colloid, and blood products should be given to reestablish euvolemia (following BP, HR, CVP, urine output, Hct, ABGs). With massive transfusion, Plts and FFP will be needed. Consider a transfusion ratio of 1 U PRBC:1 U FFP:1 U platelet during massive and ongoing hemorrhage. Vigilant assessment of bleeding, EBL,

		and hemodynamic status is essential during ongoing massive bleeding. Postop hypothermia is best minimized by warming all iv and irrigating fluids, maintaining OR temperature @ 78–80°F, humidifying inspired gases, and using forced-air and circulating water warming blankets.
Monitoring	ASA standard monitors Urinary catheter ± Arterial line ± CVP line ± PA catheter ± TEE	Monitor patient during transport to OR and apply standard monitoring as soon as patient enters the OR. Arterial line useful in unstable patients or when frequent lab sampling is anticipated. CVP line or PA catheter may be useful if vasoactive infusions needed or if ventricular dysfunction apparent. Placement of additional monitoring should be accomplished without delaying the surgical control of hemorrhage or without interrupting aggressive volume resuscitation.
Positioning	✓ and pad pressure points ✓ eyes	If C-spine has not been cleared by both radiographically and clinically, the neck should remain immobilized intraop and postop.
Complications	Hypothermia	Preexisting hypothermia

		common in trauma patient. Measures to manage hypothermia early are key and include warming the OR, use of forced-air warming, and administering warm iv fluids.
	Awareness	May be unavoidable in unstable or hypotensive patients. Rx: Consider scopolamine 0.2–0.4 mg iv or midazolam 1–2 mg iv in such situations.
	Coagulopathy	Causes include dilutional, hypothermia, and brain injury. Assess status and treat early.
	Aspiration	Assume full stomach; aspiration may have occurred before OR.

POSTOPERATIVE

Complications	Hypothermia	Active warming of fluids and blood products and forced-air warming blankets and warm room temperatures should be continued in PACU/ICU if hypothermia persists.
	Atelectasis, V/Q mismatch	Pulmonary compliance may decrease with large volumes of fluid replacement. Pulmonary contusions may aggravate this problem and severely compromise oxygenation and ventilation, requiring high-inspired O_2

		concentration, high PIP, and PEEP. Increased abdominal pressures may also affect ventilation and increase risk of V/Q mismatch.
	Coagulopathy, VTE	Causes of coagulopathy include dilutional, hypothermic, brain injury, and development of SIRS/sepsis. Trauma is a risk factor for VTE.
Pain management	PCA or parenteral narcotics Epidural narcotic	Patients with rib fractures benefit from epidural narcotic and/or low-dose local anesthetic infusions.
Tests	Hgb/Hct Coags/TEG CXR	PT/PTT, Plt counts, TEG if unexplained bleeding postop Fibrinogen, fibrin split products, if DIC suspected

PEDIATRIC TRAUMA

AIRWAY AND VASCULAR ACCESS

Description

Trauma remains the leading cause of death in children and young adults. Children younger than 15 yr are victims in about 25% of all trauma occurring in the United States. The leading causes of injury and death vary by age group. According to the National Pediatric Trauma Registry, the leading cause of pediatric injury/death among children 5–19 yr old is a motor vehicle collision. Falls remain the most common cause of severe nonfatal injury in children under the age of 15. The majority of pediatric injuries that occur are 2° blunt trauma, and infants <2 yr of age are known to have higher mortality rates for the same level of injury compared to older children.

Children have unique differences in physiology and anatomy, which must be acknowledged at the time of resuscitation. Due to their smaller FRC, children tolerate much shorter periods of hypoxia. Confirmation of a patent airway is the essential first

step. The best method for restoring airway patency is the **jaw-thrust maneuver** and removal of any debris from the mouth. In infants, the head is relatively large compared to the body, larger tongue size and a floppy epiglottis impede visualization of the airway, and the subglottic airway is narrower with less developed cartilage. Padding the torso and allowing the occiput to rest on the supporting surface allows for more favorable airway alignment. The Broselow tape measure (relates body length to weight and precalculated medication doses) can be used to estimate endotracheal tube size and facilitate weight-based medication dosing. The most common reason for intubation in the pediatric trauma patient is loss of consciousness or as part of resuscitation from shock. Only 2% of children sustaining trauma will present with complete mechanical obstruction to the airway. In the rare child who presents with acute airway obstruction, **needle cricothyrotomy** is the preferred method of securing the airway until definitive airway control can be achieved. This technique of ventilation uses the principle of jet insufflation. **Surgical cricothyrotomy** in children results in a high incidence of subglottic stenosis, but it is still a viable option in children >10 if needle cricothyrotomy fails to be effective.

Because infants are obligatory nasal and diaphragmatic breathers, fractures and soft tissue injuries that occlude the nostrils may actually obstruct the airway. Because air swallowed by the infant or insufflated into the stomach may cause acute gastric distension and restrict diaphragmatic excursion, the stomach should be decompressed with an OG tube.

Once the airway is secured and breathing is ensured, attention should be given to the circulation. Differences in cardiovascular physiology also exist. Children may compensate for as much as 25–30% of circulating blood volume loss without a change in BP. In the noncrying child, the SBP should be ~80 + their age in years × 2. The most sensitive indicator of shock in children is heart rate. Poor peripheral perfusion, decreased level of consciousness, and ↓ UO are also suggestive of hypovolemia. IV access must be obtained rapidly to begin crystalloid resuscitation in any child with impending signs of shock. If the peripheral iv access is difficult to obtain, saphenous vein cut down at the saphenofemoral junction should be performed. In infants, if iv access cannot be obtained within 2 min, intraosseous access should be attempted (see below and Fig. 7.13-8). After iv access has been obtained, as many as three boluses of crystalloid, using a volume of 20 mL/kg, can be given. If the hypovolemic shock state has not been reversed after the second bolus, and other causes of shock—such as spinal injury, cardiac tamponade, or pneumothorax—are excluded, blood (10 mL/kg) should be administered without delay.

Another important problem in the management of pediatric trauma is related to a high ratio of body surface area to body mass and a lack of substantial subcutaneous tissue. A small infant who is hypothermic may be refractory to therapy; therefore, every attempt should be made to prevent heat loss, and all iv fluids should be warmed.

Needle cricothyrotomy: With the head in neutral position (which may require placement of towels under the shoulders), the neck should be prepped from the jaw to the chest. The neck is protected by in-line immobilization. The cricothyroid membrane should be identified and the thyroid cartilage immobilized with the surgeon's left hand. The cricothyroid membrane is punctured perpendicularly with a 14- to 16-ga iv catheter over a needle. The needle is then redirected caudally, the catheter slid off into the trachea, and jet insufflation initiated. Placement of a permanent airway should follow.

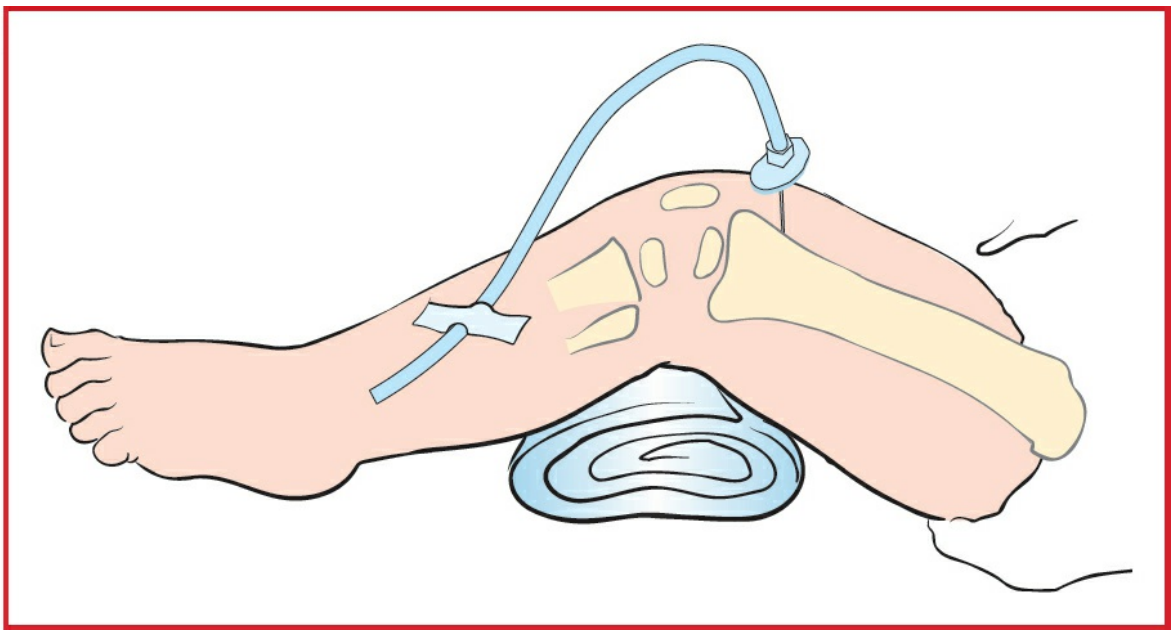

Figure 7.13-8 Intraosseous infusion. (Reproduced with permission from Hodge Dee III: Intraosseous infusion. In: King C, Henretig FM, eds:Textbook of Pediatric Emergency Procedures, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2008.)

Intraosseous infusion: After skin preparation, an incision is made 2 cm distal to the tibial tuberosity on the flattened medial aspect of the tibia. An 18- to 20-ga spinal needle (with obturator) can be used in children <18 mo of age. Older patients may require the use of a 13- to 16-ga bone marrow biopsy needle. Pressure and rotational motion are applied in a direction perpendicular to the bone until a decrease in resistance is felt. The position of the needle can be confirmed by bone marrow or blood aspiration. This route can be used for rapid fluid infusion, and most resuscitation medications can be given this way. Interosseous infusion, however, is only an emergency maneuver and should be used to restore circulating volume to the level that

enables more permanent iv access.

Saphenous cutdown: The groin should be prepped and draped and a curvilinear incision made 1–2 cm below and parallel to the inguinal ligament. The saphenous vein is identified at the saphenofemoral junction medial to the femoral artery. Two ligatures are passed underneath; the distal ligature is tied and used to apply tension to the vein. The vein is punctured with a scalpel blade (No. 11) and cut, creating a small flap. Tension applied to the proximal ligature reduces back bleeding during cannulation. A catheter is then introduced, the proximal ligature is tied, and the distal ligature is used to secure the catheter in place.

Usual preop diagnosis

Airway obstruction; hypovolemic shock; hypovolemic shock with difficult iv access

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SECTION 8.0

OBSTETRIC/GYNECOLOGIC SURGERY

CHAPTER 8.1

Gynecologic Oncology

SURGEONS

Zhenhua Du, MD, PhD

Nelson N. H. Teng, MD, PhD

ANESTHESIOLOGIST

Clifford A. Schmiesing, MD

STAGING LAPAROTOMY FOR OVARIAN, FALLOPIAN TUBE, AND PRIMARY PERITONEAL CANCER

SURGICAL CONSIDERATIONS

Description

Ovarian carcinoma has the highest mortality rate of all gynecologic malignancies because it is usually discovered in advanced stages with a pelvic mass, omental caking, and ascites. Surgery is used for staging as well as therapy. Studies have demonstrated an inverse relationship between postop residual tumor mass and survival; therefore, the goals of surgery are accurate staging and optimal tumor debulking (<1 cm residual disease). The standard open procedure consists of a meticulous exploration of the abdominopelvic cavity, abdominopelvic cytology, multiple random and targeted biopsies, **total abdominal hysterectomy (TAH), bilateral salpingo-oophorectomy (BSO), pelvic** and **paraaortic lymph node dissection, infracolic omentectomy, appendectomy**, and additional cytoreductive procedures. After access to the abdomen is obtained through a midline abdominal incision, cytologic washings of the pelvis, pericolic gutters, lesser sac, and hemidiaphragms are done. The peritoneal cavity is carefully explored. A TAH/BSO is performed by ligating and transecting the round

infundibulopelvic, broad, cardinal, and uterosacral ligaments on both sides. The specimen is cut away from the vagina and the cuff closed. Pelvic and paraaortic lymph node dissections are then performed. Pelvic lymphadenectomy is performed by opening the pelvic peritoneum, developing the paravesical and pararectal space, identifying the ureter, and removing the lymph node tissue adjacent to the common and external iliac vessels and obturator vein and nerve. Paraaortic lymph node dissection is performed by opening the peritoneum over the great vessels followed by removal of the lymph node bundles from the preaortic, lateral aortic, and retroaortic spaces. All residual tumor is removed, using sharp dissection and/or cavitron ultrasonic surgical aspirator (CUSA) and/or argon beam coagulator (ABC), and then an appendectomy is usually performed. The omentum is clamped, transected, and ligated along its attachment to the transverse colon. A **bowel resection** with possible **colostomy** formation may be necessary to achieve optimal cytoreductive surgery (see **Pelvic Exenteration**). Next, the peritoneal cavity is irrigated copiously. Targeted and random biopsies of bladder, cul-de-sac of Douglas, pericolic gutters, hemidiaphragms, small bowel, large bowel, and anterior abdominal wall are performed. A peritoneal port may be placed subcutaneously for use in future intraperitoneal chemotherapy. Approximately 25% of patients undergoing cytoreductive surgery for advanced stages of ovarian carcinoma require bowel resection with either primary reanastomosis or colostomy. A **splenectomy** is not routinely done unless the spleen is involved with tumor. Some patients with unresectable disease and bowel obstruction will require a **gastrostomy tube** placement at this time. A less extensive surgical procedure may be appropriate if a large volume of unresectable tumor is discovered. Surgery in these cases must be individualized. In addition, **laparoscopic surgical staging** has recently become more common for early-stage lesions (see Fig. 8.1-1).

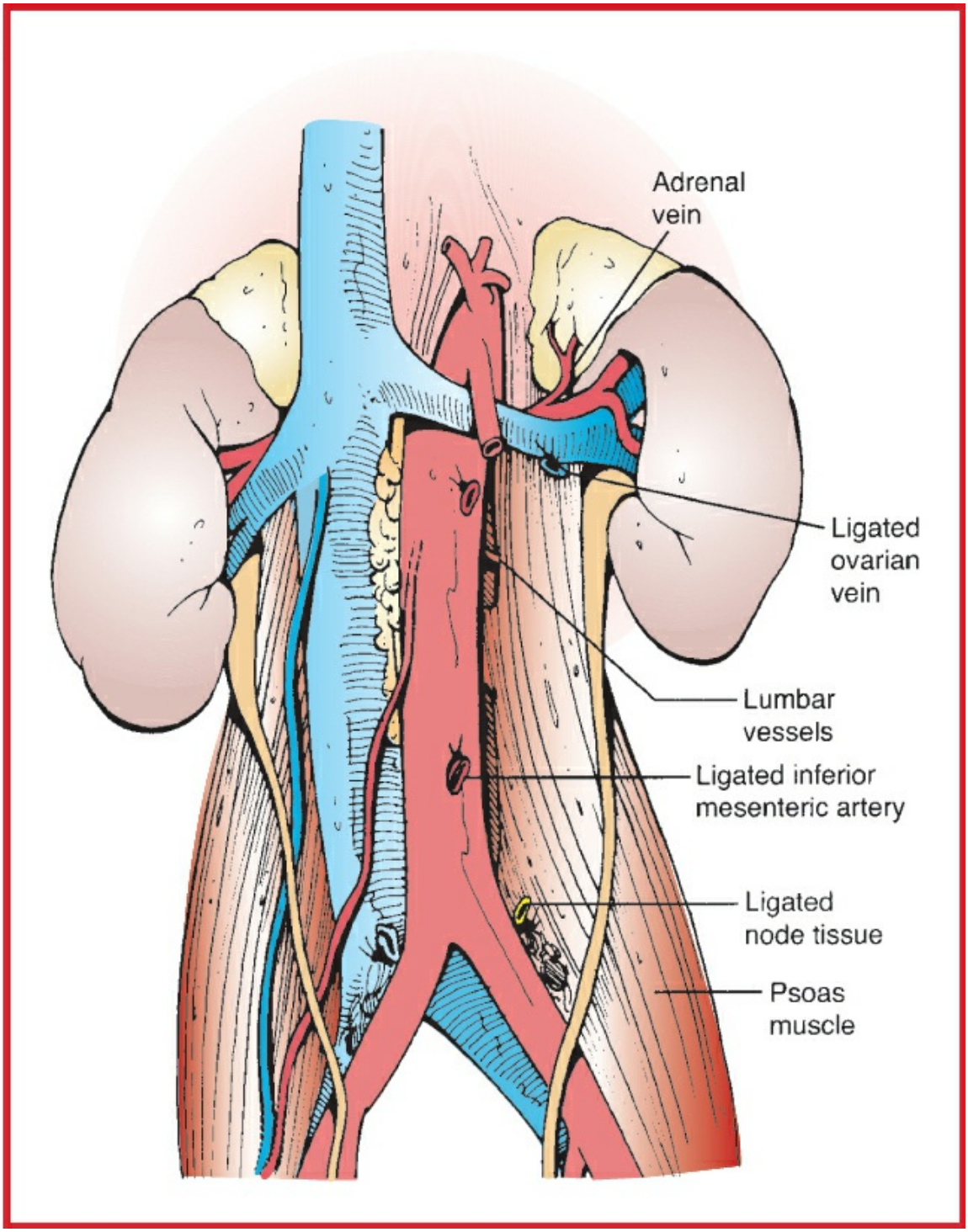

Figure 8.1-1 Aortic node dissection in staging laparotomy for ovarian cancer. In this case, both right and left node dissections have occurred, leaving the kidney, renal hilum, and psoas muscle exposed. Because the dissection is infrarenal and anterior to the lumbar vessels, there is residual fatty and nodal tissue at the posterior limit of the dissection.

In some stage I lesions, a **unilateral salpingo-oophorectomy** (USO) is sufficient therapy. The decision to use this approach depends on cell type, age, reproductive status, and extent of disease. Limited USO staging is usually performed as a fertility-sparing procedure for young women with early-stage tumors. Biopsies, **a**

retroperitoneal lymph node dissection, omentectomy, and **appendectomy** are generally performed as well.

Usual preop diagnosis

Ovarian cancer/pelvic mass

ERAS: Preop counseling by the surgeon/anesthesiologist should include no bowel prep, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading VTE prophylaxis, postop pain management options, postop recovery plan, and possibility of urinary catheter postop. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine, dorsal lithotomy (if anticipating lower bowel resection)
Incision	Midline or paramedian abdominal
Special instrumentation	CUSA, vital view (suction-irrigation device combined with light source) helpful; laparoscopic biopsy forceps (laparoscope, laparoscopic instruments for evaluation of upper abdomen through lower vertical abdominal incision); argon beam coagulator (ABC); TA, GIA, EEA stapling devices
Unique considerations	Removal of large amounts of ascites may → fluid shifts and intravascular volume depletion intraop and postop. Consider preop prophylactic heparin. Some patients will have had bowel prep and may be hypovolemic at the start of surgery. Optimal debulking may require bowel resection, splenectomy, pancreatectomy, or other advanced procedures. During lymphadenectomy, there is a risk of vascular injury that may lead to significant blood loss and need for rapid volume replacement.
Antibiotics	Cefoxitin or cefotetan 2 g iv; redose as indicated by duration and blood loss
Surgical time	1–5 h, including splenectomy and bowel surgery for more advanced stages

Closing considerations	Consider NG tube placement by anesthesiologist (in select cases with extensive bowel involvement or bowel procedures); peritoneal or central venous access for subsequent chemotherapy.
EBL	250–500 mL for stage I lesions; >500–1000 mL for advanced stages
Postop care	Extensive peritoneal raw surfaces → intraperitoneal fluid 3rd-spacing. Patients require aggressive hydration to maintain intravascular volume. Central hemodynamic monitoring and ICU admission are useful in selected patients. Use SCDs and prophylactic heparin for VTE prophylaxis.
Mortality	1–2/1000
Morbidity	Grade 3–4 hemorrhage 7% Postop fever: 14–19% Wound infection: <5% Wound dehiscence: 0.3–3% VTE: 1–2% Ureteral injury: <1% Vaginal vault prolapse: rare
Pain score	5–6

PATIENT POPULATION CHARACTERISTICS

Age range	All age groups; most common, 60–69 yr, mean age 63
Incidence	9.4/100,000 (22,280 new cases/yr); 1.4% lifetime risk of ovarian cancer
Etiology	Unknown
Risk factors	Family Hx of ovarian carcinoma; personal or family Hx of breast cancer (BRCA gene mutations); ↑ age at first pregnancy; nulliparity; advancing age; late menopause; obesity; gonadal dysgenesis; exposure to radiation; environmental factors
Associated	Familial cancer syndromes (e.g., Lynch, BRCA);

conditions	Peutz-Jeghers syndrome, 5% of cases develop gonadal stromal tumor; XY gonadal dysgenesis, gonadoblastomas; multiple nevoid basal cell carcinoma (Gorlin syndrome); ataxia telangiectasia (hereditary, progressive cerebellar lack of muscular coordination associated with recurrent pulmonary infections and ocular and cutaneous telangiectasias)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Ovarian carcinoma may be diagnosed at a late stage, and patients may have developed malignant ascites and pleural effusions, large tumor mass, and omental spread. Surgery is indicated for resection of localized tumor and staging of distant and local metastases. Additional procedures, including bowel resection or lymph node dissection, may be performed at the same time.

Respiratory	Significant ascites and pleural fluid may produce respiratory compromise. The presence of dyspnea, orthopnea, tachypnea, or other chest findings needs to be investigated. Underlying lung diseases, such as asthma, also may be exacerbated by the abdominal distension/ascites. **Tests:** Consider CXR; ± ABG; others as indicated from H&P. Consider preop pleural effusion drainage preop if severe respiratory compromise.
Cardiovascular	An ECHO and N-terminal pro-brain natriuretic peptide (NT-proBNP) may be helpful to evaluate cardiac function. Exercise tolerance should be evaluated in every patient and any preexisting cardiac disease detailed in the preop visit. Irreversible, dose-dependent cardiotoxicity may result from doxorubicin chemotherapy. **Tests:** Consider ECG, NT-proBNP, others as indicated from H&P.
Gastrointestinal	Patient should have adequate preop iv hydration if given a bowel prep overnight. Look for malnutrition (↓ wt and albumin).

Neurologic	Not usually significant. Taxol and cisplatin may → peripheral neuropathy.
Hematologic	Bone marrow suppression common following chemotherapy. Carboplatin, commonly used for ovarian cancer, often induces thrombocytopenia. **Tests:** CBC
Laboratory	CBC, renal function, T&S, consider T&C, and consider hepatic function and PT/PTT. Patients may have had tumor marker studies, including CA 125, CEA, and serum human epididymis protein 4 (HE4).
Premedication	Anxiolysis: consider midazolam 1–2 mg iv. Analgesia: consider acetaminophen 650–1000 mg po, gabapentin 300–600 mg po, and/or celecoxib 400 mg po.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of a TAP or epidural block/analgesia for postop pain management. Consider preop acetaminophen 1000 mg, ± gabapentin 300 mg, ± celecoxib 200 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA ± epidural analgesia. Typically, a balanced anesthetic with inhalational agents and/or propofol infusion (25–150 mcg/kg/min) and opiates. An epidural catheter may be placed for postop pain management and also may be used intraop to ↓ anesthetic requirements.

Induction	Standard induction, though consider full stomach precautions if ascites present.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance. Continue muscle relaxation

	based on nerve stimulator response. Epidural bupivacaine/opiate combination if catheter is placed preop. Consider NG/OG tube. Patients with combined regional/GA may require increased fluids due to vasodilation and ↓ BP. Consider adding ketamine (0.5 mg/kg bolus + 5 mcg/kg/min infusion) for pain management.	
Emergence	The patient may be extubated at the conclusion of surgery, unless hemodynamically unstable and/or requiring continued vigorous fluid resuscitation. Reverse muscle relaxant with neostigmine (0.07 mg/kg with glycopyrrolate 0.01 mg/kg) or sugammadex (2–4 mg/kg). Consider postop ICU bed for unstable patients or those requiring invasive monitoring for fluid management. Discuss with surgeon local wound infiltration or nerve block (e.g., TAP block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Significant blood loss possible IV: 16–18 ga × 2 BSS goal-directed 5% albumin	Blood loss may be >1 L. Order T&S and consider T&C preop. 5% albumin is useful for rapid volume replacement if Hct is acceptable. If large volumes of ascites are removed, significant ↓ BP may develop. Third-space losses may be significant (≥10–15 mL/kg/h). Consider use of BSS with fluid warmer for larger volume infusion. Strive to maintain goal-directed euvolemia based on clinical data: BP, PPV, HR, ABG, UO, EBL, and fluid shift estimates, ±CVP. Goal-Directed Fluid Management

		(see Appendix K, p. K-4).
Monitoring	Standard monitors Foley catheter ± Arterial catheter ± CVP catheter	Arterial and CVP catheters may be helpful for extensive surgery and/or patients with significant comorbidities.
Positioning	✓ and pad pressure points, especially important for longer surgeries ✓ eyes SCD	
Complications	Hypothermia Coagulopathy	Consider warming iv fluids. Heating blanket on bed and/or forced-air warming blanket(s) should be used. Preop malnutrition and/or significant blood loss may → coagulopathy

POSTOPERATIVE

Complications	Hemorrhage VTE Ascites/pleural effusion Respiratory insufficiency PONV	Appendix B, p. B-4 and p. B-6
Multimodal pain management	Multimodal approach ± PCA ± Epidural ± PNB/RA	Consider the following multimodal options: po/iv analgesics: consider acetaminophen 1000 mg po/iv q6h, gabapentin 200 mg po tid, ibuprofen 200–800 mg po/iv q6h, celecoxib 200 mg po q12h, oxycodone 5–10 mg po q6h, or hydromorphone 0.2–0.5 mg iv

		for breakthrough pain. Consider iv ketamine or iv lidocaine for supplemental postop analgesia.
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early (within 24 h) enteral nutrition, Foley catheter removal, and mobilization. Consider VTE prophylaxis. Chewing gum may promote return of bowel function.

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INTERVAL, SECONDARY CYTOREDUCTIVE, AND SECOND-LOOK ASSESSMENT LAPAROTOMY

SURGICAL CONSIDERATIONS

In patients where neoadjuvant chemotherapy was utilized or when optimal debulking could not be performed at initial surgery, an interval (after 3–6 cycles of chemotherapy) or secondary debulking laparotomy is done to achieve optimal cytoreduction. Similar to primary cytoreduction, the surgery involves methodical and meticulous exploration of all of the abdomen and pelvis, multiple cytologies and biopsies, lysis of adhesions, and resection of the residual tumor, as well as the pelvic and periaortic lymph nodes (if not done at time of first surgery). Patients may also be candidates for secondary or tertiary cytoreductive surgical procedures, especially if isolated recurrences are found in the setting of longer disease-free intervals.

Description

Historically, a **"second-look" laparotomy** was undertaken to determine whether a patient was surgically and pathologically free of disease, after an appropriate number of treatment cycles with platinum-based (CDDP or carboplatin) chemotherapy. However, 50% of patients with negative second-look surgeries ultimately recur, and the number of second-look surgeries has decreased significantly in favor of noninvasive evaluation including the use of tumor markers (CA 125) and imaging techniques (CT, MRI, PET) Select patients will benefit from second-look surgery to guide further therapy and to perform **secondary debulking** for select patient. Intra-abdominal assessment may be performed in conjunction with placement of an intraperitoneal port.

Usual preop diagnosis

Ovarian carcinoma

ERAS: Preop counseling by the surgeon/anesthesiologist should include no bowel prep, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading VTE prophylaxis, postop pain management options, postop recovery plan, and possibility of urinary catheter postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE

Position	Supine or dorsal lithotomy

Incision	Midline or paramedian vertical abdominal
Antibiotics	Cefoxitin 2 g or cefotetan 2 g iv; redose as indicated by duration and blood loss
Surgical time	2–3 h
Additional considerations	Placement of permanent central venous or intraperitoneal access; Preop consider VTE mechanical and pharmacologic prophylaxis including pneumatic compression stockings and LMW heparin. (e.g. LMW heparin)
EBL	350–700 mL
Postop care	PACU → ward
Mortality	1–2/1000
Morbidity	Postop fever: 14–19% Wound infection: <5% Wound dehiscence: 0.3–3% PE: 1–2% Incisional hernia: 0.5–1% Ureteral injury: 0.5–1%
Pain score	5–6

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients undergoing interval cytoreductive laparotomy have generally been treated with 3–6 cycles of chemotherapy. Depending on the type of adjunctive treatment given, the patient may come to surgery in poor physical condition from malnutrition or toxicity from chemotherapy (see Table 8.1-1). Peripheral iv access is often preserved due to the use of subcutaneous intravenous access ports (Mediport®, etc.).

Respiratory	Pulmonary function may be impaired by several chemotherapeutic drugs; most commonly bleomycin. Patients often have a Mediport-type catheter, Hickman line, or other central venous access already in place. These ports can be used for induction of anesthesia. Consider preop CXR to assess the

	presence of lung injury if prior chemo given. Consider preop PFTs for patients with dyspnea at rest or with mild exertion. Patients who received bleomycin should not receive O_2 > 39% intraop, but arterial O_2 saturation ideally should be kept ≥93%. The pulmonary toxicity of bleomycin is dose-related with a much higher incidence occurring if >200 mg/m^2 received. Combination chemotherapy with vincristine or cisplatin also increases pulmonary toxicity. **Tests:** Consider CXR; others as indicated from H&P
Cardiovascular	Cardiotoxicity is seen with several antineoplastic agents, especially daunorubicin and doxorubicin. The cardiomyopathy produced by these drugs occurs in two forms: (a) acute, ST–T-wave changes and dysrhythmias, which are transient and usually not a serious problem, and (b) chronic, dose-related toxicity manifested by CHF. Total doses of doxorubicin as low as 250 U can cause myocardial damage but is more common at doses >400 U. Cardiac irradiation, or combination chemotherapy with cyclophosphamide increases the risk of cardiac toxicity. Patients who have received cardiotoxic drugs are usually followed by serial ECHOs, and the results should be reviewed preop. Patients with CHF or ECG changes should have a cardiology consultation preop to optimize their medical condition. **Tests:** ECG, consider echo and NT-proBNP; others as indicated from H&P
Neurologic	Peripheral neuropathies are produced by vincristine, cyclophosphamide, Taxol (paclitaxel), 5-fluorouracil, and several other drugs. Vincristine can also → SIADH. Other CNS effects include N/V, seizure, and cerebellar dysfunction. A preop neurologic exam is useful for patients with evidence of neurotoxicity. Document presence of neurologic deficits preop for subsequent comparisons.

Endocrine	Corticosteroids (e.g., prednisone) are commonly used with chemotherapeutic agents, as treatment for pulmonary fibrosis and other complications of chemotherapy. The use of >10 mg prednisone (or equivalent) per day for >2 wk suppresses the endogenous secretion of the adrenal cortex, which may take up to 6 mo to recover fully. Hydrocortisone 100 mg iv, preop with an additional 2–3 subsequent doses q8h will provide adequate "stress-dose" coverage perioperatively. The dose is tapered rapidly over 2 or 3 d postop. Diabetes and obesity are common. **Tests:** FBS and HbA1c (within 3–6 mo) if diabetic; others as indicated from H&P
Renal	Many chemotherapeutic drugs have renal toxicity; therefore, renal function testing is indicated. Patients with impaired renal function should be given appropriate dosages of medications (e.g., antibiotics), which depend on renal excretion. **Tests:** Renal function
Musculoskeletal	Vincristine produces a neurotoxicity manifested by numbness and tingling in the extremities, weakness, foot drop, loss of reflexes, ataxia, and muscle pains. Muscle weakness in the arms and legs indicates that the drug should be stopped. Muscle weakness may also involve the larynx and extraocular eye muscles. Reduced amounts of NMBs should be used intraop, and a nerve stimulator used to follow twitches.
Gastrointestinal	Consider hydration overnight if given a bowel prep or if there is significant N/V. Look for ascites and malnutrition. **Tests:** Consider electrolytes, LFTs.
Hematologic	Bone marrow suppression is a common side effect of antineoplastic drugs. The toxicity usually produces a reversible drop in leukocytes, erythrocytes, and platelets, with a nadir 10–14 d posttreatment. Patients with a total neutrophil count of <1000 should be kept in isolation until counts improve. A

	low Plt count (<50,000) is an indication for Plt transfusion preop. Regional anesthesia in patients with thrombocytopenia needs to be considered carefully due to ↑ risk of bleeding complications.
Laboratory	Consider CBC, Cr, albumin, lytes, PT/PTT.
Premedication	Anxiolysis: consider midazolam 1–2 mg iv Analgesia: consider acetaminophen 1000 mg po, gabapentin 300 mg po, and/or celecoxib 200 mg po Stress-dose hydrocortisone (100 mg iv) if indicated
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of a TAP or epidural block/analgesia for postop pain management. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA or combined GETA/epidural.

Table 8.1-1 Toxicities of Selected Antineoplastic Chemotherapeutic Agents

Agent	Toxic Effects
Vincristine, vinblastine	Neuropathies, SIADH, myelosuppression
Cyclophosphamide	Prolonged neuromuscular block
Mechlorethamine	Prolonged neuromuscular block
Bleomycin	Pulmonary fibrosis
Doxorubicin, daunorubicin	Cardiotoxicity, GI upset, myelosuppression
Methotrexate	Myelosuppression, GI upset, stomatitis, pulmonary infiltrates

Fluorouracil	Myelosuppression, hepatic and GI alterations, nervous system dysfunction
Mercaptopurine	Myelosuppression
Thioguanine	Myelosuppression
Actinomycin D	Myelosuppression, GI upset, stomatitis
Mitomycin	Myelosuppression, GI upset
Cisplatin	Myelosuppression, GI upset, electrolyte disturbances, nephrotoxicity, peripheral neuropathy
Carboplatin	Myelosuppression, peripheral neuropathy, GI upset, electrolyte disturbances
Paclitaxel	Myelosuppression, peripheral neuropathy, GI upset, arthralgia/myalgias, mucositis, interstitial pneumonitis
Docetaxel	Myelosuppression, peripheral neuropathy, malaise, maculopapular rash, GI upset

General anesthesia

Induction	Standard induction. Consider renal function and surgery duration when deciding on agents.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance: see Anesthetic Considerations for Staging Laparotomy. Consider ketamine (0.5 mg/kg bolus + 5 mcg/kg/min infusion) for supplemental analgesia.
Emergence	Extubate when patient is responsive and neuromuscular block is fully reversed. In patients with borderline pulmonary function, extubation may be delayed until patient is in the PACU or ICU and after ABG is checked while the patient breathes spontaneously. Consider PONV prophylaxis. Discuss with surgeon local wound infiltration or nerve block (e.g., TAP block) placement or reinforcement if

	initially placed >4 h ago. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include ondansetron.

Regional anesthesia

Epidural	2% lidocaine ± epinephrine 1:200,000 (10–20 mL) or 0.25% bupivacaine (10–20 mL) initially; then at ~3–5 mL/h. Opiates, such as morphine (2–4 mg) or hydromorphone (0.3–0.6 mg), may be given in the epidural for postop pain control.	
Blood and fluid requirements	IV: 16–18 ga × 1–2 BSS @ 7–10 mL/kg/h Keep UO >0.5 mL/kg/h	Goal-Directed Fluid Management (see Appendix K, p. K-4) Consider PRBC for Hct < 25%. Goal-Directed Fluid Management (see Appendix K, p. K-4)
	5% albumin	5% albumin may be used as volume replacement, although no proven advantages over crystalloid solutions.
	FFP/Plt	Consider FFP and Plt if evidence of significant coagulopathy (↑ PT, ↑ PTT, ↓ Plt).
Monitoring	Standard monitors Foley catheter ± Arterial line ± CVP catheter	Consider arterial and CVP catheters for patients with compromised cardiac or pulmonary function or patients having extensive surgical procedures.
Positioning	✓ and pad pressure points ✓ eyes	

	Antiembolism stockings and SCD	
Complications	Hypothermia	Warm fluids; keep heating pad on bed; use forced-air warmer.
	Bleeding	✓ PT; PTT, Plts periodically if large blood loss

POSTOPERATIVE

Complications	Bleeding Infection PONV Respiratory insufficiency VTE	
Multimodal pain management	Multimodal approach ± PCA ± epidural ± PNB/RA	Consider the following multimodal options: po/iv analgesics: consider acetaminophen 650–1000 mg po/iv q6h, gabapentin 100–600 mg po tid, ibuprofen 200–800 mg po/iv q6h, celecoxib 200 mg po q12h, oxycodone 5–10 mg po q6h, or hydromorphone 0.2–0.5 mg iv for breakthrough pain. Consider iv ketamine or iv lidocaine for supplemental analgesia.
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early (within 24 h) enteral nutrition, Foley catheter removal, and mobilization. Consider VTE prophylaxis. Chewing gum may promote return of bowel function.

Tests	Consider CXR ABG	As indicated by postop clinical findings

Suggested Reading

1. See suggested reading for Anesthetic Consideration for Staging Laparotomy for Ovarian, Fallopian Tube, and Primary Peritoneal Cancer above (p. 848).

RADICAL VULVECTOMY

SURGICAL CONSIDERATIONS

Description

Historically, invasive vulvar carcinoma has been treated with en bloc dissection of the inguinal-femoral region and the vulva. The surgery involves bilateral excision of lymphatic and areolar tissue in the inguinal and femoral regions, combined with removal of the entire vulva between the labia-crural folds, from the perineal body to the upper margin of mons pubis (Fig. 8.1-2). A large surgical wound is created and, if 1° closure without tension is not possible, a skin or myocutaneous graft may be necessary. Deep pelvic nodes are rarely involved with metastases when the superficial and deep groin nodes are free of disease; therefore, a **pelvic lymphadenectomy** is no longer routinely performed. If presence of tumor is documented in the groin nodes, particularly in Cloquet sentinel nodes (the most cephalad, deep inguinal nodes), a **deep pelvic lymphadenectomy** may be performed. **Postop radiation therapy**, however, is widely used instead of a pelvic lymph node dissection to minimize operative morbidity and confer a survival advantage.

A skin incision in the shape of a bull's head (Fig. 8.1-2) allows access to the inguinal-femoral region. (The incision ideally should extend 2+ cm beyond the tumor margin.) The inguinal ligament and rectus fascia should be cleared bilaterally of all nodal tissues and the fossae ovalis on both sides identified. The lateral aspect of the femoral sheath is incised along the sartorius muscle, with care being taken not to injure the femoral nerve or vessels, and the cribriform fascia is cleaned off the femoral artery. The external pudendal artery, which marks the entrance of the saphenous vein into the fossa ovalis, should be identified and ligated. The proximal and distal segments of the saphenous vein should be ligated and excised as the fibrofatty, lymph-bearing tissue of the femoral sheath is resected. Cloquet nodes at the femoral ring beneath the inguinal ligaments on both sides should be resected and submitted for frozen section pathology evaluation. The deep inguinal lymphatic chain is removed on both sides by opening the inguinal

canal from the external inguinal ring. The vulvar incision is carried down through the labia-crural folds. The internal pudendal vessels at the posterior lateral margin of the vulvar incision are identified as they emerge from Alcock canal, and then they are ligated and incised.

Use of electrocautery in this portion of the procedure usually tends to decrease operative blood loss. The dissection is continued along the periosteum of the symphysis at the level of the fascia of the deep muscles of the urogenital diaphragm. The bulbocavernosus, ischiocavernosus, and superficial transverse perinei muscles are removed. A circumferential vaginal incision, excluding the urethral meatus, is then performed and the vulva is removed. The incisions overlying the groin node dissections should be closed with minimal tension after placement of closed-suction Jackson-Pratt drains. The vulvar surgical wound is closed by slightly undermining the skin of the edges of the incision and suturing them to the vaginal mucosa. A **vulvar reconstruction**, using myocutaneous flaps, also can be performed at this time (see **Pelvic Exenteration**).

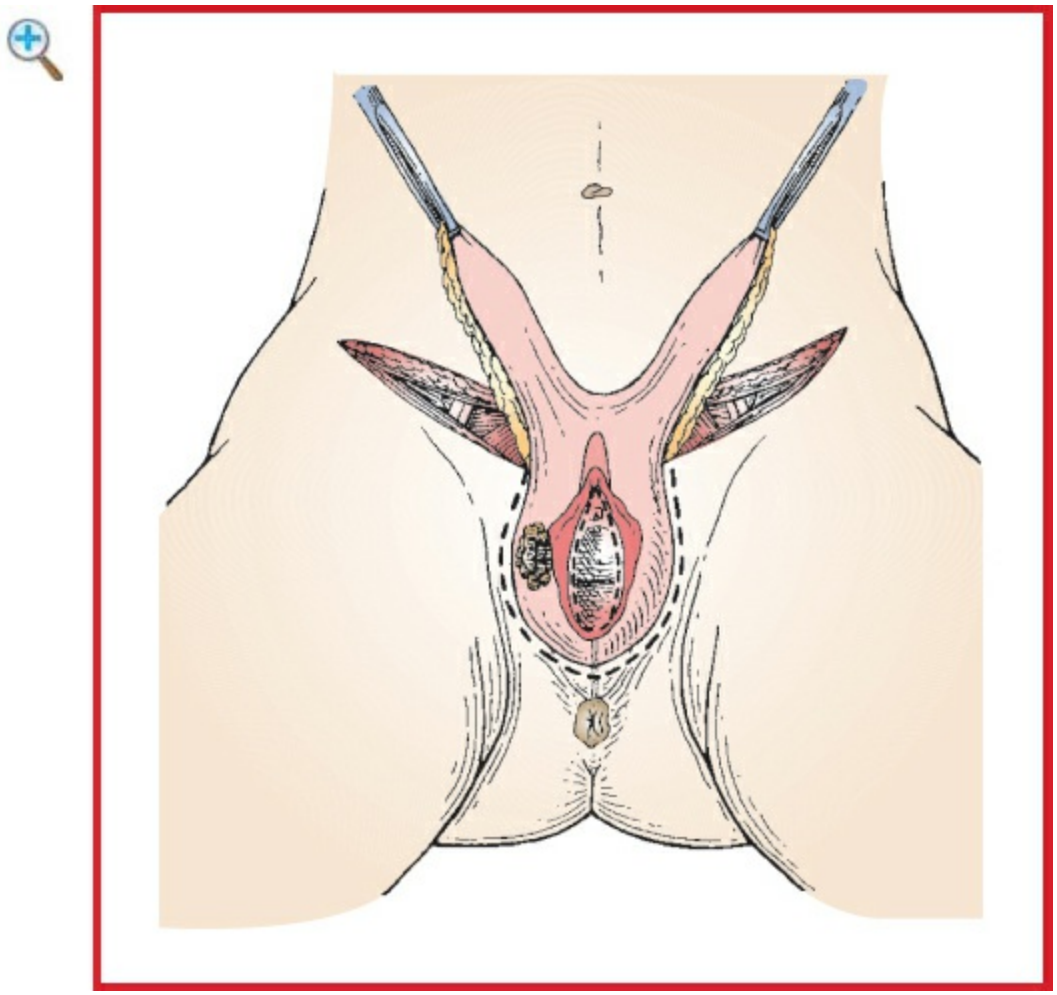

Figure 8.1-2 En bloc radical vulvectomy incisions shown; bilateral inguinal lymphadenectomy is

complete. (Reproduced with permission from Rock JA, Thompson JD:TeLinde's Operative Gynecology, 8th edition. Lippincott-Raven, Philadelphia: 1997.)

Variant procedure or approaches

In 1962, Byran and associates popularized a **three-incision technique** first described by Kehrer in 1918. This three-incision technique, with separate vulva and groin incisions, is the most common approach (Fig. 8.1-3). This operative approach has led to a significant decrease in wound infection and breakdown, apparently without increasing tumor recurrence in the inguinal dermal bridge above the symphysis pubis. Another variant is the **hemivulvectomy** (Fig. 8.1-4), in which unilateral radical hemivulvectomy and groin node dissection are performed in selected stage I, non midline, unifocal vulvar cancer patients. This procedure will minimize morbidity, disfigurement, and sexual dysfunction. The observation that almost no contralateral groin metastases occur in the absence of positive ipsilateral groin nodes allows the surgeon to perform only a **unilateral groin node dissection**. Recent trials have shown sentinel lymph node mapping may be an alternative to groin lymphadenectomy in select patients with early-stage disease. For this approach, a radioactive tracer is injected intradermally 20–30 min before groin incision. Blue dye is also injected to improve visualization. This is done after the patient is prepped due to the rapid movement of the dye to lymphoid tissue. Using both radioactivity and direct visualization allows identification of the sentinel lymph node. If a sentinel lymph node(s) is not found, full lymphadenectomy is performed. Benefits of this approach include less dissection of tissue and lower rates of postoperative complications.

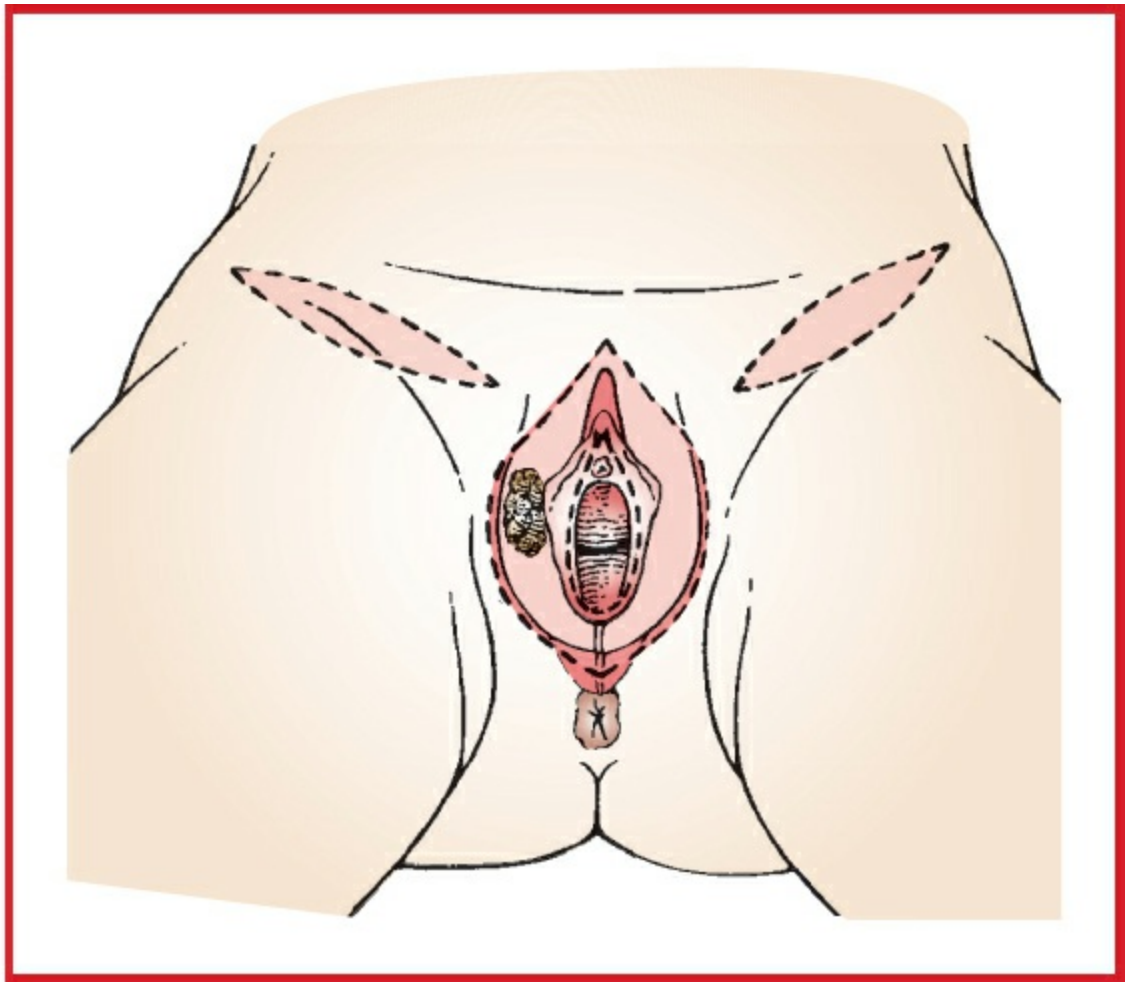

Figure 8.1-3 Three-incision radical vulvectomy and bilateral inguinofemoral lymphadenectomy. (Reproduced with permission from Rock JA, Thompson JD:TeLinde's Operative Gynecology, 8th edition. Lippincott-Raven, Philadelphia: 1997.)

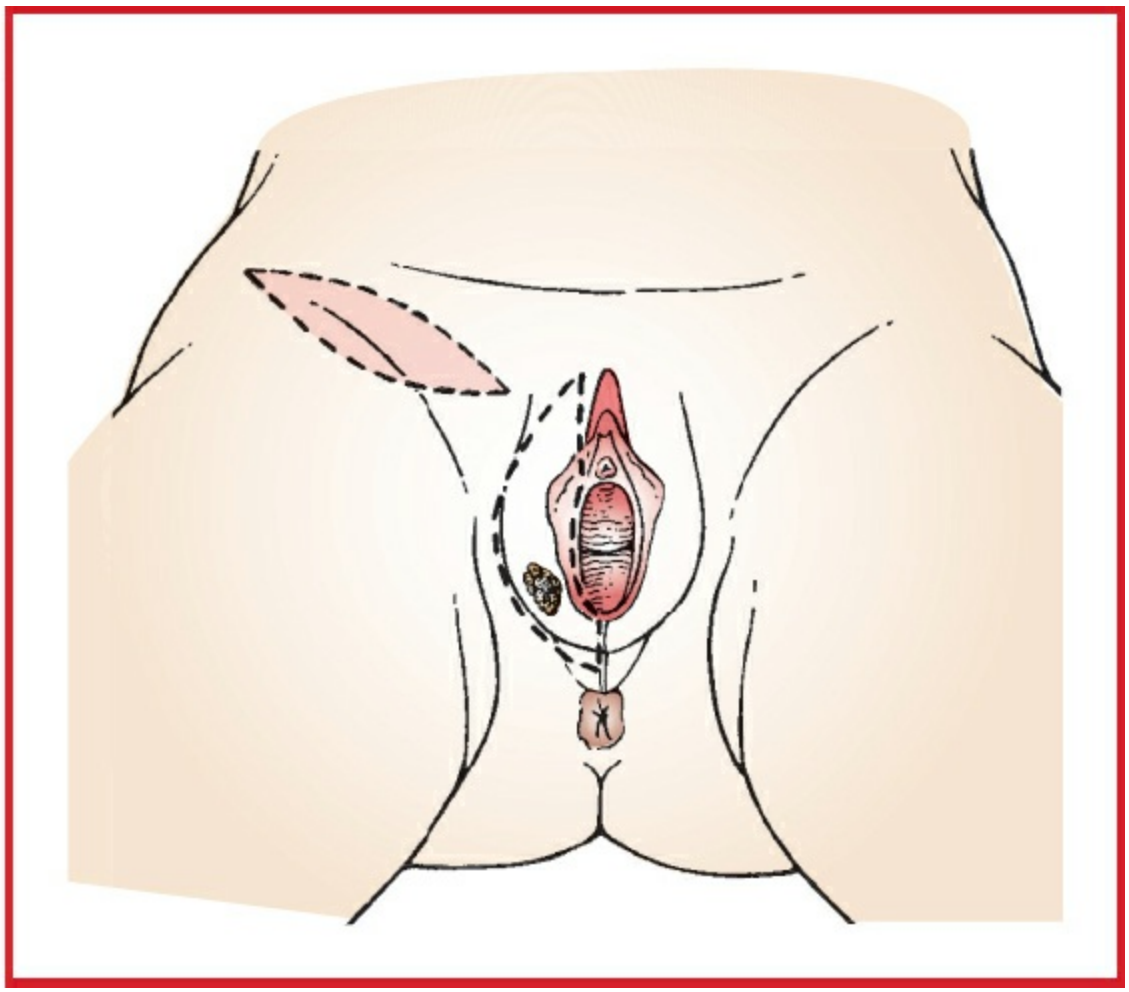

Figure 8.1-4 Unilateral lymphadenectomy for a well-lateralized lesion. (Reproduced with permission from Rock JA, Thompson JD:TeLinde's Operative Gynecology, 8th edition. Lippincott-Raven, Philadelphia: 1997.)

Usual preop diagnosis

Invasive vulvar cancer

ERAS: Preop counseling by the surgeon/anesthesiologist should include: no bowel prep, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading VTE prophylaxis, postop pain management options, postop recovery plan, and possibility of urinary catheter postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	En Bloc Dissection	Three-Incision	Hemivulvectomy
Position	Modified	⇐	⇐

	dorsolithotomy in Allen universal stirrups		
Incision	Bull's head, from iliac crest to iliac crest and along labia-crural folds (Fig. 8.1-2)	2 separate groin incisions from iliac crest to pubic tubercle; 1 vulvar incision (Fig. 8.1-3)	1 or 2 separate groin incisions from iliac crest to pubic tubercle; vulvar incision (Fig. 8.1-4)
Special instrumentation	Argon beam coagulator	⇐	⇐
Unique considerations	Two-team approach to minimize surgical time. Consider constipating medications (e.g., Lomotil) to ↓ postop bowel movements. Consider preoperative prophylactic heparin	⇐	⇐
Antibiotics	Cefoxitin 2 g or cefotetan 2 g iv; redose as indicated by duration and blood loss	⇐	⇐
Surgical time	3–4 h	⇐	2–3 h
Closing considerations	Possible skin graft; vulvar and groin suction drains	⇐	⇐
EBL	500–1000 mL	⇐	250–500 mL

Postop care	PACU or ICU, if necessary; aggressive local wound care. VTE prophylaxis (see Appendix B, p. B-7). **NB:** trauma to femoral vessels at time of groin lymph node dissection increases risk of VTE and PE	⇐	⇐
Mortality	1–2%	⇐	⇐
Morbidity	Wound infection and breakdown: 40–80%	15%	<15%
	Introital stenosis and dyspareunia: 50%	⇐	⇐
	Lymphedema of lower extremities: 25–30%	⇐	<25% (if deep groin nodes not dissected)
	Lymphocysts: 10%	⇐	⇐
	Genital prolapse: 7%	⇐	1–2%
	Stress incontinence: 5%	⇐	1–2%
	Thrombophlebitis: 3–5%	⇐	1–2%
	Hernia: 1–2%	⇐	⇐
	PE: 1–2%	⇐	⇐
Pain score	5–6	5–6	4–5

PATIENT POPULATION CHARACTERISTICS

Age range	Median = 70 yr

Incidence	2.2/100,000; 4% of female genital malignancies
Etiology	Two pathways of vulvar cancer are thought to exist, one related to HPV infection and the second related to chronic inflammation or an autoimmune process.
Risk factors	HPV infection, vulvar dystrophies, tobacco use, immunosuppression, HIV
Associated conditions	Bowen disease, condyloma acuminata, diabetes, obesity, HTN, arteriosclerosis, cervical malignancy

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients with vulvar carcinoma are often elderly. Consider and evaluate coexisting medical conditions thoroughly. Radical vulvectomy is performed for invasive tumor that has not metastasized to distant sites.

Respiratory	The presence of lung disease and smoking Hx should be discussed with the patient preop. Consider CXR and PFTs or reviewing preexisting studies for patients with significant respiratory disease and symptoms. **Tests:** Others as indicated from H&P
Cardiovascular	There is an increased incidence of HTN and atherosclerosis in these patients. A cardiology consultation is indicated for angina, recent MI, CHF, or heart murmurs. **Tests:** ECG; consider NT-proBNP; others as indicated from H&P
Renal	With age, creatinine clearance decreases 2° ↓ renal mass, but serum creatinine remains unchanged because of decreased muscle mass. **Tests:** Serum creatinine; others as indicated from H&P
Gastrointestinal	Patients should have iv hydration preop if given bowel prep overnight.

Neurologic	Document a neurologic exam if Hx of stroke, seizure, or other neurologic diseases. Hx of peripheral neuropathy or autonomic dysfunction should be assessed in diabetic patients. **Tests:** As indicated from H&P
Endocrine	Diabetes and obesity are common. **Tests:** FBS and HbA1c (within 3–6 mo) if diabetic; others as indicated from H&P
Hematologic	Chronic anemia may be present. **Tests:** Hgb/Hct; Plt count
Laboratory	Cr, if age > 65
Premedication	Anxiolysis: consider midazolam 1–2 mg iv Analgesia: consider acetaminophen 1000 mg po, gabapentin 300–600 mg po, and/or celecoxib 400 mg po
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of a TAP or epidural block/analgesia for postop pain management. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA or regional anesthesia, alone or in combination.

General anesthesia

Induction	Standard induction
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance. Consider ketamine (0.5 mg/kg bolus + 5 mcg/kg/min infusion) for supplemental analgesia.
Emergence	No special considerations. Discuss with surgeon local

	wound infiltration or nerve block (e.g., TAP block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.

Regional anesthesia

Epidural	2% lidocaine ± epinephrine 1:200,000 (10–20 mL) or 0.25% bupivacaine (10–20 mL) are used; then at ~3–5 mL/h. Opiates such as morphine (2–4 mg) in the epidural for postop pain control	
CSE	Hyperbaric bupivacaine (10–12 mg), ± preservative-free morphine (0.1–0.2 mg) → T10 sensory level	
Blood and fluid requirements	IV: 16–18 ga × 2 BSS @ 6–8 mL/kg/h Warm iv fluids UO > 0.5 mL/kg/h	Goal-Directed Fluid Management (see Appendix K, p. K-4). Occasionally, femoral vessels may be injured, requiring rapid blood replacement. Consider PRBCs for Hct < 21% in healthy patients and <25% in patients with cardiac or pulmonary disease. Goal-Directed Fluid Management (see Appendix K, p. K-4)
Monitoring	Standard monitors ± Arterial line ± CVP line Foley catheter	Invasive monitors indicated for patients in poor condition or with cardiovascular or respiratory disease. An arterial catheter is useful for drawing labs in surgery to check Hct, coags, glucose, or ABGs.
Positioning	✓ and pad pressure points ✓ eyes SCD	

POSTOPERATIVE

Complications	Hypothermia Bleeding PONV VTE	
Multimodal pain management	Multimodal approach ± PCA ± epidural ± PNB/RA	Consider the following multimodal options: po/iv analgesics: consider acetaminophen 650–1000 mg po/iv q6h, gabapentin 100–600 mg po tid, ibuprofen 200–800 mg po/iv q6h, celecoxib 200 mg po q12h, oxycodone 5–10 mg po q6h, or hydromorphone 0.2–0.5 mg iv for breakthrough pain. Consider iv ketamine or iv lidocaine for supplemental analgesia.
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early (within 24 h) enteral nutrition, Foley catheter removal, and mobilization. Consider VTE prophylaxis. Chewing gum may promote return of bowel function.
Tests	Tests as indicated from postop clinical findings	

Suggested Readings

1. Hoffman MS: Malignancies of the vulva. In: Rock JA, Jones HW, edsTeLinde's Operative Gynecology. Lippincott Williams & Wilkins, Philadelphia: 2015, 1293–350.
2. Huang TJ: Invasive cancer of the vulva. In: DiSaia PJ, Creasman WT, edsClinical Gynecologic Oncology, 9th edition. C.V. Mosby, St. Louis: 2018, 217–30.
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5. Moroney JW, Kunos C, Wikinson EJ et al: Vulva. In: Barakat RR, Perelman RC Markman M, et al, eds. Principles and Practice of Gynecologic Oncology, 6th edition. Lippincott Williams, & Wilkins, Philadelphia: 2013, 757–848.

CONIZATION OF THE CERVIX

SURGICAL CONSIDERATIONS

Description

Conization of the cervix can be used for both diagnostic and therapeutic purposes. It is performed in cases of biopsy-proven dysplasia with unsatisfactory colposcopy (inadequate visualization of the endocervical canal) or following endocervical curettage showing dysplasia or atypical glandular epithelial cells (Fig. 8.1-5). Persistent abnormal cytology associated with normal colposcopy, colposcopic suspicion of invasion, and/or cervical biopsy showing microinvasive cancer is also an indication for this procedure. The surgery consists of the annular removal of a cone-shaped wedge of tissue from the cervix with a scalpel. With the advent of the loop electrosurgical excision procedure (LEEP), most cone biopsies are done under local paracervical/intracervical block in an office setting and do not require the services of an anesthesiologist.

Variant procedure or approaches

In selected patients, a **laser** is used in place of the scalpel. This procedure can be performed under local anesthesia with less blood loss, but operative time is usually longer. The thermal effect of the laser at the cone margins, although usually minimal, may interfere with pathologic interpretation. In pregnant patients, a **shallower cone** is done to minimize complications. Approximately 1% of women with cervical carcinoma are pregnant at the time of diagnosis, and 1/1240 pregnancies is complicated by cervical cancer. Recognition and therapy of preinvasive cervical lesions during pregnancy, therefore, are of paramount importance. Because of the increased vascularity of the pregnant uterus and cervix, conization is usually associated with increased blood loss and morbidity.

Usual preop diagnosis

Cervical dysplasia

ERAS: Preop counseling by the surgeon/anesthesiologist should include no bowel prep, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading VTE prophylaxis, postop pain management options, and postop recovery plan. **See Appendix K, p. K-1.**

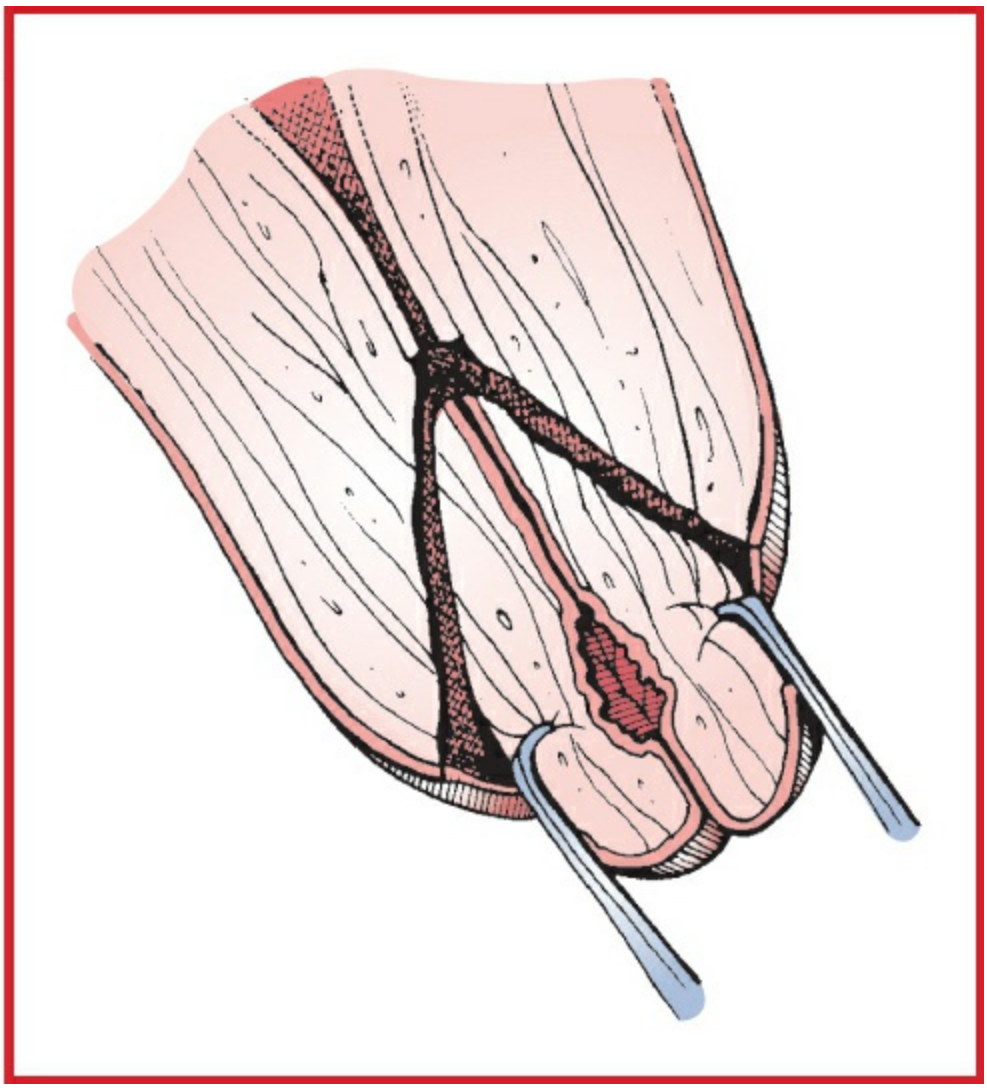

Figure 8.1-5 Cut across endocervix to complete cone excision.

SUMMARY OF PROCEDURES

	Conization	Laser Conization	Shallow Cone In Pregnancy
Position	Lithotomy	⇐	Lithotomy; with left lateral tilt in 3rd trimester
Incision	Cervical	⇐	⇐
Special instrumentation	Colposcope	CO_2 laser; protective eye wear; colposcope	Colposcope

Unique considerations	Infiltration of the cervix with dilute vasopressin or phenylephrine solution. A 1:200,000 epinephrine solution also can be used. Vaginal pack necessary in selected patients	⇐	Phenylephrine, vasopressin, or epinephrine should not be used during pregnancy. Liberal use of hemostatic sutures should be made.
Antibiotics	None	⇐	⇐
Surgical time	30–60 min	30–90 min	⇐
EBL	50–200 mL	50 mL	100–350 mL
Postop care	Monitor for postop bleeding	⇐	⇐
Mortality	<0.01%	⇐	⇐
Morbidity	Hemorrhage: 5–10%	⇐	10–15%
	Preterm delivery: 16%	⇐	⇐
	Cervical stenosis: 2–3%	⇐	⇐
	Dysmenorrhea: rare	⇐	⇐
	Infertility: rare	⇐	⇐
	Injury to rectum and bladder: rare	⇐	⇐
	Pelvic cellulitis: rare	⇐	⇐
	Uterine perforation: rare	⇐	⇐
			Fetal loss: 10–15% (up to 30% in 1st trimester)*

			Premature labor: 5–10% (controversial) Rupture of membrane: 2–5%
Pain score	3	3	3

*The naturally higher incidence of spontaneous miscarriages in the 1st trimester contributes to this figure.

PATIENT POPULATION CHARACTERISTICS

Age range	Reproductive and postreproductive years
Incidence	~5% of Pap smears (+ for dysplasia); 10–17% of patients who undergo colposcopic exams
Etiology	Majority of cervical dysplasia is caused by persistent HPV infections
Risk factors	Smoking; human papillomavirus (HPV); herpes simplex virus (HSV); multiple sexual partners; early age of onset of coitus; multiparity; lower socioeconomic status; HIV; immunocompromised hosts

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Conization is done for diagnosis and treatment of cervical lesions. Occasionally, it is necessary to perform the procedure during pregnancy, which increases the risk of bleeding complications. The effect of anesthetic agents on the fetus (especially 1st trimester) also needs to be considered when choosing anesthetic technique.

Respiratory	Not significant unless underlying lung disease
Cardiovascular	These patients are generally young and, therefore, less likely to have significant heart disease.
Neurologic	Usually not significant unless there is Hx of seizure disorder or other neurologic illness
Hematologic	Consider hemogram.
Laboratory	Consider pregnancy test.

Premedication	Anxiolysis: consider midazolam 1–2 mg iv (though generally held if pregnant). Analgesia: consider acetaminophen 650–1000 mg po, gabapentin 300–600 mg po, and/or celecoxib 400 mg po.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg, po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Usually a local or MAC anesthetic; occasionally, GETA or spinal. Pregnancy makes i desirable to perform the procedure under local or regional anesthesia if appropriate (1% of cases).

General anesthesia

Induction	Standard induction. If pregnant patient >20 wk of gestation, consider rapid-sequence induction with cricoid pressure.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance
Emergence	No special issues. PONV prophylaxis may include dexamethasone and ondansetron.

Regional anesthesia

Both spinal and epidural techniques are acceptable and may be preferred for pregnant patients who cannot tolerate local anesthesia. Prehydration with 1000 mL BSS before block is recommended. Treat ↓ BP with ephedrine 5–10 mg iv, or phenylephrine 50–100 mcg, titrated to effect.

Blood and fluid	Minimal blood loss	Zero Balance Fluid

requirements	IV: 18–20 ga × 1 BSS @ 2–4 mL/kg/h	Management (see Appendix K, p. K-2)
Monitoring	Standard monitors Fetal monitoring may be indicated for viable pregnancies.	
Positioning	✓ and pad pressure points ✓ eyes Left uterine displacement Antiembolic stockings + SCD	**NB** peroneal nerve compression at lateral fibular head → foot drop Left uterine displacement with a wedge under mattress should be used for pregnant patients (after ~20 wk) or earlier gestation if cardiovascular compromise when supine.
Complications	Laser eye damage Fire Premature labor (if pregnant)	If a laser is used, eye protection is required for the patient and all OR personnel; be alert for fire hazards when using a laser.

POSTOPERATIVE

Complications	Peroneal nerve injury (2° lithotomy position) PONV Premature labor Bleeding	Nerve injury manifested as foot drop and loss of sensation over dorsum of foot
Multimodal pain management	po/iv analgesics	Consider the following multimodal options: po/iv analgesics: for example, acetaminophen 1000 mg po/iv q6h, ± celecoxib 200 mg po q12h.
ERAS	PONV protocol (see	Encourage early (within 24 h)

	Appendix B, p. B-1)	enteral nutrition and mobilization.

Suggested Readings

1. Copeland LJ, Landon MB: Malignant disease in pregnancy. In: Gabbe SG, Niebyl JR Simpson JL, eds. Obstetrics: Normal and Problem Pregnancies, 7th edition. Churchill Livingstone, New York: 2016, 1255–81.
2. Meyer LA, Lasala J, Iniesta MD, et al: Effect of an enhanced recovery after surger program on opioid use and patient-reported outcomes. Obstet Gynecol 2018; 132(2):281–90.
3. Modesitt SC, Sarosiek BM, Trowbridge ER, et al: Enhanced recover implementation in major gynecologic surgeries: effect of care standardization. Obstet Gynecol 2016; 128(3):457–66.
4. Simeoens C, Goffin F, Simon P, et al: Adverse obstetrical outcomes after treatment of precancerous cervical lesions: a Belgian multicentre study. BJOG 2012; 119:1247–55.
5. Tewari KS: Cancer in pregnancy. In: DiSaia PJ, Creasman WT, eds.Clinical Gynecologic Oncology, 9th edition. C.V. Mosby, St. Louis: 2018, 353–419.

ANESTHETIC CONSIDERATIONS FOR LASER THERAPY TO THE VULVA, VAGINA, AND CERVIX

PREOPERATIVE

Laser therapy is indicated for preinvasive lesions of the vulva, vagina, or cervix. It destroys tissues by the selective application of light energy focused into a beam. Vaporized tissues tend to heal without scarring, and blood loss is minimal due to the cauterizing effect of the laser. Many gynecologic laser procedures are done with local anesthesia in the clinic setting and do not require the services of an anesthesiologist.

Respiratory	Not significant unless there is underlying lung disease
Cardiovascular	In elderly patients, exercise tolerance should be assessed. **Tests:** ECG if >60 yr
Hematologic	**Tests:** Hct
Laboratory	Consider pregnancy test in young women.

Premedication	Anxiolysis: consider midazolam 1–2 mg iv Analgesia: consider acetaminophen 650–1000 mg po, gabapentin 300–600 mg po, and/or celecoxib 400 mg po
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of an epidural block/analgesia for postop pain management. Consider preop acetaminophen 1000 mg, ± celecoxib 200 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Usually MAC; GETA/LMA or regional technique may be used. Sedation with propofol midazolam, and fentanyl in small doses usually is effective.

General anesthesia

Induction	Standard induction
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance. Muscle relaxation not necessary. A technique with relatively rapid emergence (e.g., propofol and/or sevoflurane/desflurane/N_2O combinations) is useful for outpatient surgery.
Emergence	Limit opiates. Discuss with surgeon local wound infiltration or nerve block placement. PONV prophylaxis should include ondansetron.

Regional anesthesia

Spinal or epidural anesthesia or CSE may be used with a sensory level to T10. Provide supplemental O_2 if iv sedation given.

Spinal	A T10 sensory level is desirable; hyperbaric bupivacaine 10–12 mg can be used. Small-diameter spinal needles (e.g., 25-ga Sprotte needles) minimize chance of postdural puncture headache (PDPH).	
Epidural	2% lidocaine, ± epinephrine 1:200,000 (10–15 mL), or 0.25% bupivacaine (10–15 mL) is used; redose as needed with 3–5 mL. Opiates, such as morphine (2–4 mg) or hydromorphone (0.3–0.6 mg), may be given in the epidural for postop pain control.	
Blood and fluid requirements	Minimal blood loss IV: 18 ga × 1 BSS @ 2–4 mL/kg/h	Consider prehydrating patient (e.g., 500 mL BSS) if using neuraxial block, especially if NPO period was prolonged. Zero Balance Fluid Management (see Appendix K, p. K-2)
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes Antiembolic stockings + SCDs	
Complications	Eye injury OR fires Aerosolization of viral particles	Goggles should be worn by the patient and all OR personnel during laser use to prevent injury to eyes. Whenever laser is in use, be prepared for fires: Keep FiO_2 ≤0.3, know where fire extinguisher is located, and watch for improper handling of lasers.

POSTOPERATIVE

Complications	PONV	PDPH may require epidural

	PDPH	blood patch for treatment.
Multimodal pain management	Multimodal approach ± epidural	
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early (within 24 h) enteral nutrition and mobilization.

Suggested Readings

1. Meyer LA, Lasala J, Iniesta MD, et al: Effect of an enhanced recovery after surger program on opioid use and patient-reported outcomes. Obstet Gynecol 2018; 132(2):281–90.
2. Modesitt SC, Sarosiek BM, Trowbridge ER, et al: Enhanced recover implementation in major gynecologic surgeries: effect of care standardization. Obstet Gynecol 2016; 128(3):457–66.

SUCTION CURETTAGE FOR GESTATIONAL TROPHOBLASTIC DISEASE

SURGICAL CONSIDERATIONS

Description

Suction curettage is the most efficient method of evacuating a gestational trophoblastic neoplasm (mole). The procedure involves dilation of the cervix by instruments or by laminaria tents, followed by insertion of suction cannula of appropriate diameter into the uterine cavity. Standard negative pressures used are in the range of 30–70 mm Hg. Intravenous oxytocin—to maintain uterine contraction and minimize blood loss—is started after a moderate amount of tissue has been removed. Suction curettage is followed by gentle, sharp curettage of the uterus to ensure adequate evacuation. Curettage may be performed under ultrasound guidance to decrease the risk of uterine perforation and to ensure adequate evacuation. Paracervical injection of dilute vasopressin solution or 1% lidocaine with 1:200,000 epinephrine may decrease operative blood loss (in cases not complicated by thyrotoxicosis or HTN) (Fig. 8.1-6).

Variant procedure or approaches

Evacuation of a mole >16 wk gestation size is associated with a significant risk of trophoblastic embolization and cardiorespiratory compromise (2° pulmonary

HTN/edema, cyanosis, ↓ CO, ↓ BP, right heart failure). Consider hemodynamic monitoring with TEE or a CVP catheter to manage cardiovascular changes associated with trophoblastic embolization and to prevent inadvertent fluid overload. In general, earlier diagnosis of molar pregnancies has decreased the incidence of complications such as HTN and thyrotoxicosis.

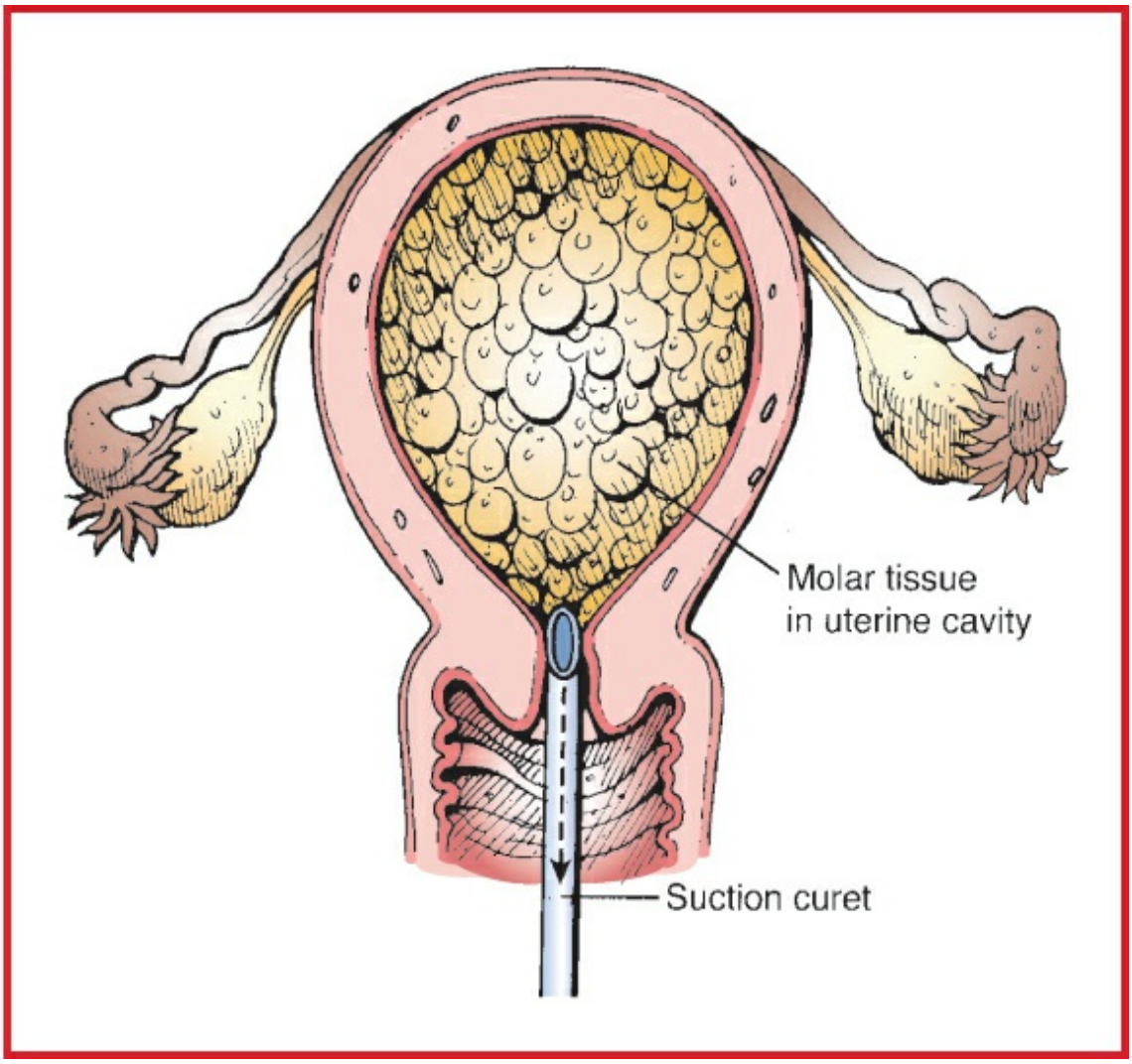

Figure 8.1-6 Suction curettage of a molar pregnancy.

Usual preop diagnosis

Gestational trophoblastic disease (GTD)

ERAS: Preop counseling by the surgeon/anesthesiologist should include no bowel prep, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading VTE prophylaxis, postop pain management options, and postop recovery plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Small Mole <16 Wk Size	Large Mole >16 Wk Size
Position	Lithotomy	⇐
Incision	None	⇐
Special instrumentation	Suction evacuation kit	⇐
Unique considerations	If mole >12 wk size, laparotomy setup should be readily available. Oxytocin drip, anesthesia, or surgery may precipitate thyroid storm. If hyperthyroidism is suspected before induction of anesthesia, beta-blockers should used. In PACU, monitor for signs of trophoblastic embolization or amniotic fluid embolus. If patient is Rh negative, give RhoGAM.	⇐ ± central hemodynamic monitoring with TEE or CVP catheter; avoid overzealous use of fluids.
Antibiotics	Cefotetan 2 g iv or doxycycline 200 mg po before procedure and 100 mg po after procedure	⇐
Surgical time	30–60 min	⇐
EBL	200–400 mL	⇐
Postop care	Outpatient (usually)	Consider inpatient observation or ICU admission.
Mortality	Rare	⇐
Morbidity	Trophoblastic embolization: rare	11–27% 10%

	Excessive bleeding: 2% Infection: <2% Uterine perforation: <1%	⇐ 1–2% Acute pulmonary edema: 2–11%
Pain score	3	3

PATIENT POPULATION CHARACTERISTICS	
Age range	Reproductive age group
Incidence	1/1000 deliveries in the United States
Etiology	Genetics, androgenous (all chromosomes in true moles are paternal in origin); nutritional deficiency, protein, folic acid, carotene (vitamin A)
Risk factors	Extremes of reproductive age, prior GTD (incidence 0.6–2.0%), Asian, Hispanic populations
Associated conditions	Hyperemesis gravidarum (2° ↑ levels of HCG); preeclampsia in 1st trimester; thyrotoxicosis (because of its analogy to TSH molecule, ↑ levels of HCG can bind TSH receptors and cause thyrotoxicosis)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Some 80% of cases are diagnosed at 12–18 wk of development. Most patients have an unusually large uterus for the length of the pregnancy, and vaginal bleeding is common. Trophoblastic disease is classified by the degree of invasiveness; **retained mole** is the most common type and the least invasive; **invasive mole** involves the wall of the uterus, and **metastatic mole** involves more distant sites. Chemotherapy with methotrexate and actinomycin D usually is given postop for invasive or metastatic disease. (See Table 8.1-1 for toxicities of chemotherapeutic agents.)

Respiratory	Pulmonary edema may complicate preeclampsia, which occurs in 25% of patients with GTD. If respiratory distress is present, it also may be 2° embolization of tumor to lungs. Avoid overhydration → pulmonary complications in patients with large moles.

	Tests: Consider preop ABG if pulmonary function impaired and in patients at high risk of developing trophoblastic embolization. Others as indicated by H&P
Cardiovascular	Dehydration and/or ↓ blood volume may exist due to hyperemesis and vaginal bleeding. Adequate hydration should be given preop if patient shows Sx of hypovolemia (e.g., tachycardia, orthostatic ↓ BP, low UO). Preeclampsia also may complicate this disease and can be diagnosed by HTN, proteinuria, ± edema. If the patient has severe preeclampsia, invasive monitoring of BP may be advisable. Also, if patient is receiving Mg^{++} therapy, a serum level should be ✓'d preop. Mg^{++} therapy may inhibit myocardial contractility in high doses. Ca^{++} is the preferred antidote for myocardial depression. $MgSO_4$ → uterine atony → ↑ blood loss.
Neurologic	Seizure prophylaxis with Mg^{++} is indicated for women with preeclampsia. Magnesium 4–6 mg loading dose iv over 20 min and then 1–2 g/h maintenance infusion. A 2nd bolus of 2 g over 5 min can be administered if the initial bolus dose is complete. If seizure occurs, a small dose of propofol (20–40) mg or midazolam (1–2 mg) should be given iv and respiration assisted with supplemental O_2 by mask. The trachea should be intubated for airway protection in patients with full stomachs and in those who are difficult to ventilate by mask.
Musculoskeletal	✓ reflexes if patient has received Mg^{++}. Reduce amount of muscle relaxant to compensate for the effects of Mg^{++} on muscle strength.
Hematologic	Anemia may be masked by hypovolemia. Rh– patients with Rh+ partners should receive 300 mcg of Rh immune globulin (RhoGAM) within 72 h postop to ↓ possibility of Rh isoimmunization in future pregnancies. **Tests:** CBC; ✓ Plt in preeclamptics. If patient has

	received chemotherapy recently, ✓ HCT; complete blood count (WBC, Plt).
Endocrine	Hyperthyroidism occurs in 5% of women with hydatidiform moles and is 2° the thyroid-stimulating effects of HCG. **Tests:** Thyroid function tests should be ✓'d preop in women with Sx of hyperthyroidism and managed before surgery. FBS and HbA1c (within 3–6 mo) if diabetic; others as indicated from H&P
Laboratory	Serum HCG level; consider thyroid function tests; LFTs; PT; PTT; Plt count; Mg^{++} level; UA—as indicated from H&P, T&S or T&C
Premedication	Anxiolysis: consider midazolam 1–2 mg iv Analgesia: consider acetaminophen 650–1000 mg po, gabapentin 300–600 mg po, and/or celecoxib 400 mg po
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Usually GETA, although may be carried out under spinal or epidural anesthesia.

General anesthesia

Induction	A rapid-sequence induction with cricoid pressure should be used. For RSI, consider supplementation with labetalol, hydralazine, esmolol, or remifentanil to obtund exaggerated laryngoscopic hypertensive response in preeclampsia.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and

	normothermia.
Maintenance	Standard maintenance. Control BP, if preeclamptic, with labetalol, hydralazine, or SNP. Try to keep DBP at 90–100 mm Hg. NDMR potentiated by magnesium
Emergence	Extubate when fully awake and protective airway reflexes have returned. Consider PONV prophylaxis. Discuss with surgeon local wound infiltration for analgesia. PONV prophylaxis should include ondansetron.

Regional anesthesia

Spinal	A T10 sensory level is desirable; hyperbaric bupivacaine (10–12 mg) may be used.	
Epidural	Use 2% lidocaine ± epinephrine 1:200,000 (10–20 mL) or 0.25% bupivacaine (10–15 mL).	
Blood and fluid requirements	Possible large blood loss IV: 16–18 ga × 1 BSS @ 2–4 mL/kg/h	Goal-Directed Fluid Management. One large-volume iv line should be placed and blood readily available. The usual causes of bleeding are uterine perforation, cervical laceration, or uterine atony. Cautious use of fluids if on magnesium infusion due to risk of pulmonary edema. Zero Balance Fluid Management (see Appendix K, p. K-2)
Control of bleeding	Oxytocin (30–40 U/L) infusion ↑ % volatile anesthetic may ↓ uterine tone Methylergonovine maleate 0.2 mg im	Oxytocin is begun about halfway through procedure at 250 mL/h (consult obstetrician). Large oxytocin boluses may → ↓ BP. Try to keep anesthetic <1 MAC to prevent uterine relaxation. Methylergonovine may be given for severe bleeding. Because this drug can cause HTN, it is contraindicated in any hypertensive etiology (e.g.,

		preeclampsia).
Monitoring	Standard monitors ± Arterial catheter ± CVP/PA catheter Foley catheter	An arterial catheter ± CVP are indicated in cases of thyrotoxicosis, preeclampsia, or significant hemorrhage. The use of vasodilators, such as SNP, is also an indication for invasive monitoring.
Positioning	✓ and pad pressure points ✓ eyes SCDs	* **NB:** peroneal nerve compression at lateral fibular head → foot drop
Complications	Embolization of trophoblastic material	Embolization may occur, especially if >16 wk gestation. Significant respiratory and cardiac compromise may occur, requiring postop ventilation and PEEP, hemodynamic support, and ICU admission.

POSTOPERATIVE

Complications	Bleeding PONV HTN ↓ BP Peroneal nerve injury (2° to lithotomy position)	Continue oxytocin infusion. Significant hemorrhage should be evaluated by surgeons for possible perforation, laceration, or atony. Consider PONV prophylaxis with ondansetron 4 mg. BP should be monitored closely in preeclamptics. Consider ICU admission if unstable. Consider trophoblastic embolization and manage aggressively. Nerve injury manifested as foot drop and loss of

		sensation over dorsum of foot
Multimodal pain management	Multimodal approach	Consider the following multimodal options: po/iv analgesics: for example, acetaminophen 650–1000 mg po/iv q6h, ibuprofen 200–800 mg po/iv q6h, or celecoxib 200 mg po q12h.
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early (within 24 h) enteral nutrition.

Suggested Readings

1. Brown J, Naumann RW, Seckl MJ, et al: 15 years of progress in gestational trophoblastic disease: scoring, standardization, and salvage. Gynecol Oncol 2017; 144(1):200–07.
2. Heller DS: Update on the pathology of gestational trophoblastic disease. APMIS 2018; 126(7):647–54.
3. Meyer LA, Lasala J, Iniesta MD, et al: Effect of an enhanced recovery after surgery program on opioid use and patient-reported outcomes. Obstet Gynecol 2018; 132(2):281–90.
4. Modesitt SC, Sarosiek BM, Trowbridge ER, et al: Enhanced recovery implementation in major gynecologic surgeries: effect of care standardization. Obstet Gynecol 2016; 128(3):457–66.

PELVIC EXENTERATION

SURGICAL CONSIDERATIONS

Description

Pelvic exenteration was introduced by Brunschwig as an ultraradical surgical approach for advanced and radioresistant cervical cancer. Although advanced vaginal and vulvar carcinomas occasionally have been treated with this procedure, its most important role is in the management of centrally recurrent, surgically resectable, radioresistant cervical carcinoma. **Total pelvic exenteration** involves **en bloc resection** of all pelvic tissues, including the uterus, cervix, vagina, bladder, and rectum. Involvement of the distal vagina may require resection of the vulva and groin nodes. The goal of this procedure is curative with removal of all cancer tissue and reconstruction of

appropriate diversions for the urine and stool, if the colon cannot be reanastomosed to the rectum. It is rare for cervical and vaginal cancer to involve the lower 5 cm of the rectum and anus. It is, therefore, often possible to mobilize the descending colon and anastomose it primarily to the distal rectum. Otherwise, an **end colostomy** is created. A **continent or incontinent urinary diversion, omental pelvic carpet** or **sling,** and **gracilis myocutaneous flaps** for vaginal and perineal reconstruction are performed. A **rectus abdominis muscle flap** also can be used for vaginal reconstruction. This type of flap yields excellent aesthetic and functional results. In cases where an omental sling (shown in Fig. 8.1-7) cannot be developed, an absorbable synthetic mesh is sutured to the pelvic peritoneum to create a pelvic lid (like a hammock) to keep the small bowel off the denuded pelvic peritoneum, thus decreasing the possibility of small bowel obstruction. In general, an additional 2–3 h of surgical time and an additional 300 mL of EBL are expected when a vaginal reconstruction is undertaken. An **exploratory laparotomy** is needed before initiation of the exenterative procedure to exclude spread of disease outside the pelvis and/or extension to pelvic sidewalls and pelvic lymph nodes, all of which are absolute contraindications to this procedure.

Resectability is evaluated by examination of pelvic and paraaortic lymph nodes, liver, hemidiaphragms, and peritoneal surfaces of the upper abdomen and pelvic wall. Washings are obtained for cytology. Evaluation of lymph nodes is then performed, and all suspicious nodes are submitted for frozen section pathologic examination. The pararectal, paravesical, and presacral spaces are then developed. If the patient is found to be inoperable, CUSA can be used to decrease the tumor burden. Consideration also should be given to **intraoperative radiation therapy**, which may provide an adjunctive treatment to radical surgery in the setting of (a) recurrent disease close to the pelvic sidewalls and (b) microscopically positive surgical margins or “close” resection margins. If the patient is deemed operable, the space of Retzius is developed. The round ligaments are then transected close to the pelvic sidewall bilaterally, and the infundibulopelvic ligaments also are ligated and transected. The ureters are divided as close to the bladder as possible. The superior hemorrhoidal vessel is ligated and transected, and the colon is transected at the appropriate level. The anterior divisions of the internal iliac artery on both sides are ligated and divided, and the web of tissue is clamped close to the pelvic sidewall, transected, and suture ligated. Following this, sharp dissection can be done to free up the specimen from the low attachments to the levator muscles. In larger tumors, the levator muscle is partially removed with the specimen to provide adequate margins. From a combined perineal and abdominal approach, the distal vagina, urethra, and perineum (± rectum) can be resected. The specimen is handed off the field, hemostasis is achieved, and the bladder is reconstructed with a continent urinary diversion using an ileocolonic segment, ileal

loop, or transverse colon conduit. An ileal loop or other urinary conduit is performed, a colostomy or low rectal anastomosis is done, vaginal reconstruction is undertaken, and the pelvic floor is covered. (Figs. 8.1-7 and 8.1-8 show the completed exenteration.)

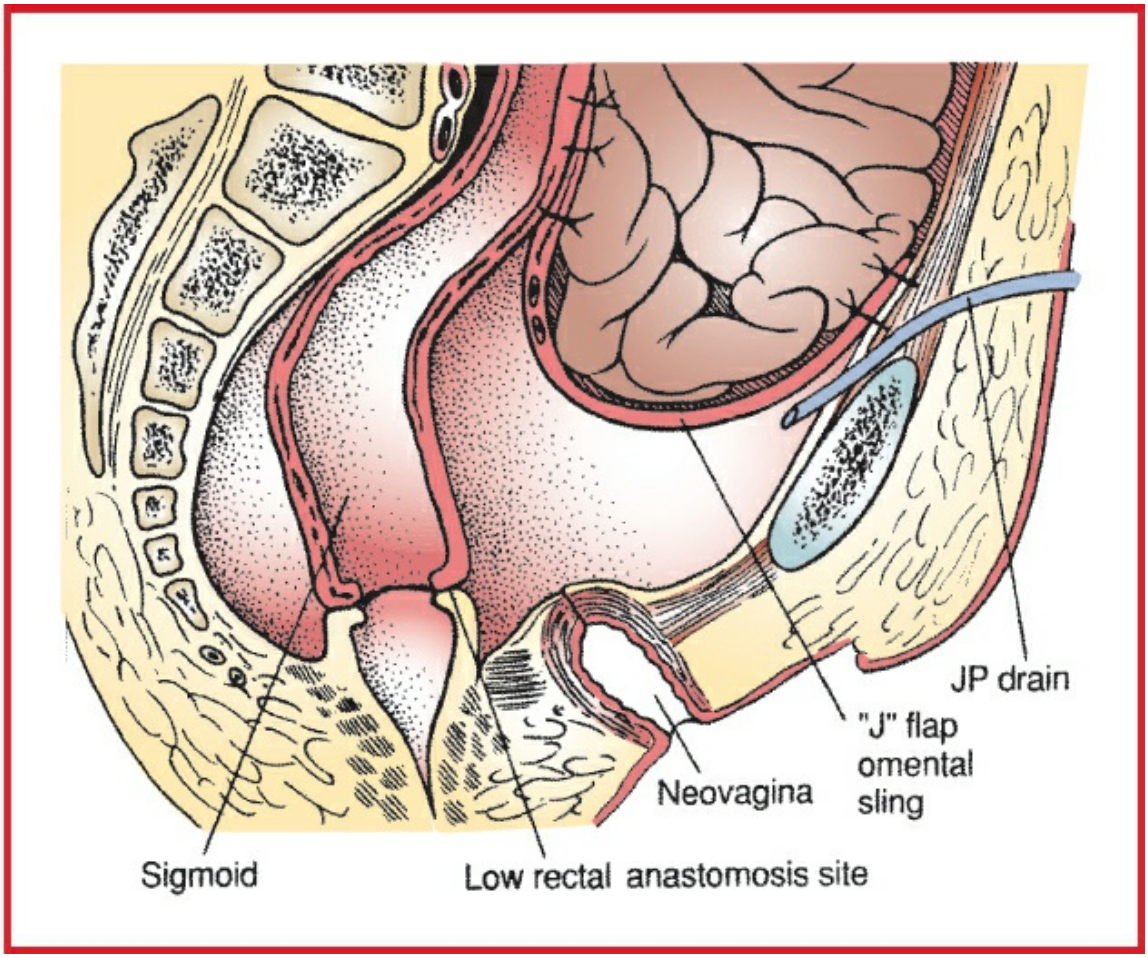

Figure 8.1-7 Sagittal section of the pelvis after a total pelvic exenteration. Note that all the reproductive organs, along with their supporting structures, the rectum and the bladder, have been resected. Drains can be placed through separate stab incisions in the abdomen. The small bowel is kept away from the operative site by a pelvic lid. The urinary and fecal diversions are not diagrammed. (Reproduced with permission from Wheeless CR: Atlas of Pelvic Surgery, 2nd edition. Lea & Febiger, Philadelphia: 1988.)

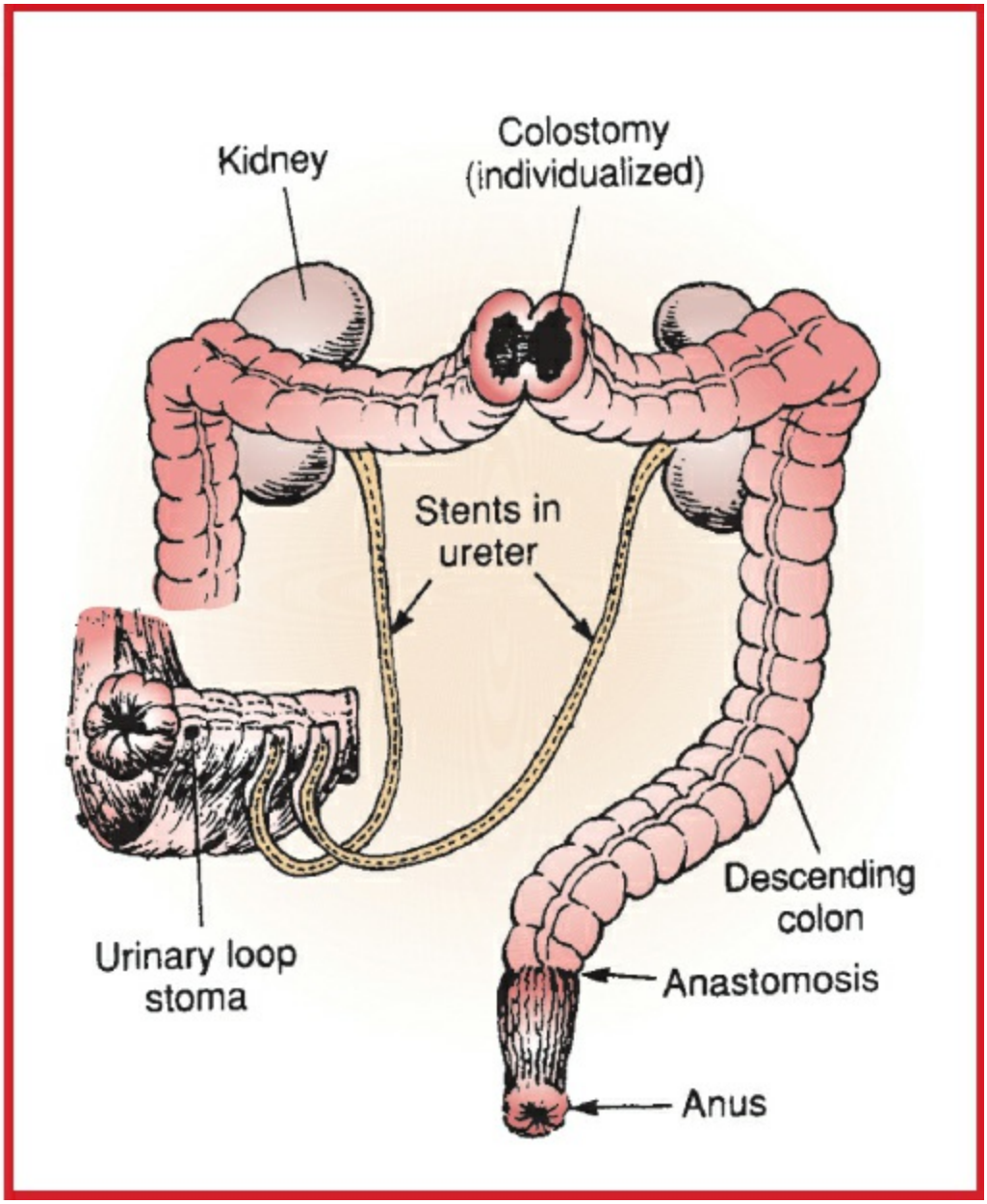

Figure 8.1-8 Conceptual drawing shows the urinary and fecal diversions after a total pelvic exenteration. (Reproduced with permission from Wheeless CR:Atlas of Pelvic Surgery, 3rd edition. Williams & Wilkins, Baltimore: 1997.)

Variant procedure or approaches

Anterior pelvic exenteration is technically similar to a total pelvic exenteration, except the rectum is left intact. **Posterior pelvic exenteration** involves preservation of the bladder. Posterior exenteration has proved more useful in cancer of the vulva or vagina than in cervical cancer. Anterior and posterior exenterations are used in selective cases because of the increased risk of an incomplete tumor resection and multiple complications and malfunctioning of the preserved organ.

Usual preop diagnosis

Recurrent cervical carcinoma following radiotherapy

ERAS: Preop counseling by the surgeon/anesthesiologist should include no bowel prep, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading VTE prophylaxis, postop pain management options, postop recovery plan, possibility of urinary catheter postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE

Position	Modified dorsolithotomy with Allen stirrups
Incision	Midline longitudinal, perineal
Special instrumentation	Vital view, ABC may be helpful; EEA, GIA, TA staplers; robo retractor or similar devices
Unique considerations	NG tube placement intraop. VTE prevention with preop SCDs and prophylactic heparin. Consider preop Greenfield IVC filter placement to avoid PE for high-risk patients. Consider intraop radiation of tumor bed and/or of resection margins. Abort case for positive lymph nodes, extrapelvic metastases and/or tumor extension to pelvic sidewalls noted.
Antibiotics	Cefoxitin 2 g or cefotetan 2 g iv; redose as indicated by duration and blood loss. Alternatively, ertapenem 1 mg iv or a combination of ampicillin (1 g), gentamicin (80 mg), and metronidazole (500 mg) may be given.
Surgical time	8–12 h (2-team approach); 5–10 h (for anterior and posterior exenteration)
Closing considerations	Abdominal drains; colostomy; ureteral stents; urostomy; intraop radiation therapy. Triple-lumen central line placement. Copious irrigation of the operative sites.
EBL	1200–4000 mL
Postop care	ICU: 2–3 d. Correction of electrolyte imbalance. Extensive peritoneal raw surfaces → intraperitoneal fluid 3rd-spacing. Patients require good hydration to

	maintain intravascular volume. SCDs and heparin VTE prophylaxis. Early and aggressive use of TPN is important. Remove ureteral stents 1–2 wk postop, when the edema at the ureterointestinal site has subsided.
Mortality	<5%
Morbidity	Intraop hemorrhage requiring a median of 5 U PRBC Infectious: Wound breakdown: 20–30% Nonspecific: 25% Flap necrosis: 1–15% Pelvic abscess: 9–17% Pyelonephritis: 14–27% Wound infection: 35% Sepsis: 5–27% Psychiatric: Confusion: 24% Intestinal: Ileus: 2–20% GI fistula: 10–32% Stoma breakdown: 3% Small bowel obstruction: 4–9% Renal: Ureteral stricture: 8% Ureteral fistulae: 4–8% Failure: 1–5% Cardiovascular: Venous thrombosis: 7–11% DIC: 3% Dysrhythmia: 3% MI: 3% Pulmonary: Pneumonia: 9% PE: 2% Neurologic: CVA: 2%
Pain score	5–6

PATIENT POPULATION CHARACTERISTICS	
Age range	All age groups
Incidence	1.5–17% of cervical cancers treated with radiation therapy (depending on stage and cell type)
Associated conditions	Advanced or recurrent gynecologic malignancies; radiation injury

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

This procedure is performed for recurrent rectal, cervical, or other gynecologic cancers and involves removal of all pelvic organs. Occasionally, the bladder or rectum is preserved, if not involved with tumor. Most patients have undergone preop radiation or chemotherapy.

Respiratory	Usually not significant unless there is Hx of smoking or lung disease. Consider prior chemotherapy. (See Anesthetic Considerations for Second-Look/Reassessment Laparotomy for Ovarian Cancer.) **Tests:** Consider CXR; others as indicated from H&P
Cardiovascular	Exercise tolerance should be assessed. Underlying CAD or CHF should be medically optimized preop. Any exposure to cardiotoxic chemotherapy should be investigated; consider ECHO. **Tests:** Consider ECG and NT-proBNP; others as indicated from H&P
Neurologic	Any Hx of stroke, seizure, carotid artery disease, or other neurologic disease should be evaluated.
Endocrine	Any endocrine disease, such as diabetes, should be optimized in consultation with the patient's primary care physician or

	endocrinologist. Ask about recent corticosteroid use. **Tests:** FBS and HbA1c (within 3–6 mo) if diabetic; others as indicated from H&P
Gastrointestinal	Consider ascites and malnutrition.
Hematologic	Look for anemia from chronic disease, chemotherapy, or malnutrition. Consider T&S/T&C. **Tests:** CBC, PT, PTT
Laboratory	Additional testing as indicated from preop H&P
Premedication	Anxiolysis: consider midazolam 1–2 mg iv Analgesia: consider acetaminophen 1000 mg po, gabapentin 300 mg, and/or celecoxib 400 mg po Detailed explanation about the procedure and the potential for postop events including intubation and mechanical ventilation is worthwhile
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of a TAP or epidural block/analgesia for postop pain management. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA ± supplemental epidural anesthesia.

General anesthesia

Induction	Standard induction, unless otherwise indicated by patient condition. Keep in mind that possible surgery could be

	significantly shortened if patient deemed inoperable during initial exploration.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Balanced anesthetic technique based on comorbidities, use of concomitant epidural anesthesia, and likelihood of needing ICU admission postop. Epidural anesthetic and opiates (morphine or hydromorphone) can be given to reduce anesthetic requirements. Consider ketamine (0.5 mg/kg bolus + 5 mcg/kg/min infusion).	
Emergence	If patient is hemodynamically stable, with favorable oxygenation and pulmonary function, normothermic, and responsive at the end of surgery, extubation may be appropriate. Any patient who is unstable and hypothermic, has high-oxygen requirements and significant edema of the face or airway, and is acidotic or who has ongoing fluid requirements should be admitted to the ICU and remain intubated. Due to the large fluid shifts and significant complication rates, postop monitoring in the ICU is appropriate. Discuss with surgeon local wound infiltration or nerve block (e.g., TAP block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Epidural	Consider epidural for intraop and/or postop use: 2% lidocaine (10–15 mL), or 0.25% bupivacaine (10–20 mL), with or without hydromorphone (0.3–0.8 mg), may be given in the epidural for postop pain control. Intraop use may ↑ hemodynamic instability in setting of ↑ bleeding and fluid shifts.	
Ventilation	5–7 cm H_2O PEEP may help prevent atelectasis	✓ ABGs during surgery. Adjust ventilation to keep normocarbic. Correct the underlying cause of any metabolic acidosis.
Blood and fluid	Potential large blood loss	Consider access to rapid

requirements	IV: 14–16 ga × 2 BSS @ 10–15 mL/kg/h Consider PRBCs when Hct < 25–27%. Maintain UO of 0.5–1 mL/kg/h. Ionized Ca^{++} FFP/Plt	infuser. Strive to maintain euvolemia based on BP, PPV, HR, UO, ABG, invasive monitoring (CVP, CO, art line tracing), and estimates of ongoing EBL and fluid shifts. Goal-Directed Fluid Management (see Appendix K, p. K-4 p. K-4) Measure ionized Ca^{++} and K^{+} after rapid administration of blood products; replace Ca^{++} as necessary. Plt or FFP for coagulation abnormalities. Monitor values at regular intervals based on PT stability and events.
Monitoring	Standard monitors ± Arterial line ± CVP Foley catheter ± TEE	Invasive hemodynamic monitoring with arterial and CVP catheters usually helpful in these cases, which are of very long, and associated with major bleeding, fluid shifts, ICU admission postop, and potential need for vasoactive infusions. TEE allows intraop assessment of myocardial function and may be appropriate in selected patients.
Positioning	✓ and pad pressure points ✓ eyes	**NB:** peroneal nerve compression at lateral fibular head → foot drop

	SCD	
Complications	Hypothermia VTE Coagulopathy Trauma to kidney ± Ureters Bleeding Metabolic acidosis Peripheral nerve injury	Use forced-air and fluid warmers and monitor temperature. See Appendix B, p. B-7. Watch for hematuria or ↓ UO. Monitor hemoglobin and coagulation status periodically during long surgery. Keep adequate reserve blood products available. Prolonged surgery: carefully pad, secure, and monitor all extremities

POSTOPERATIVE

Complications	Bleeding Fluid overload Hypothermia PONV VTE Peripheral nerve injury	✓ Hct and coags periodically. Be prepared for continued increased fluid requirements for 24 h postop. Maintain euvolemia, if significant fluid gain occurs; consider ICU postop ventilation. If extubated For prolonged surgery, carefully pad, secure, and monitor all extremities.
Multimodal pain management	Use multimodal analgesia ± PCA	po/iv analgesics: for example, acetaminophen 1000 mg

	± epidural ± TAP block	po/iv q6h, gabapentin 200 mg po tid, ibuprofen 200–800 mg po/iv q6h, celecoxib 200 mg po q12h, oxycodone 5–10 mg po q6h, or hydromorphone 0.2–0.5 mg iv for breakthrough pain.
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early (within 24 h) enteral nutrition, Foley catheter removal, and mobilization. Consider VTE prophylaxis.
Tests	Follow CBC, chemistry panel, coags, and ABG as indicated by postop course	Others as indicated from postoperative course. Patient will likely need ongoing critical care/ICU management.

Suggested Readings

1. Meyer LA, Lasala J, Iniesta MD, et al: Effect of an enhanced recovery after surger program on opioid use and patient-reported outcomes. Obstet Gynecol 2018; 132(2):281–90.
2. Modesitt SC, Sarosiek BM, Trowbridge ER, et al: Enhanced recover implementation in major gynecologic surgeries: effect of care standardization. Obstet Gynecol 2016; 128(3):457–66.
3. Nelson G, Altman AD, Nick A, et al: Guidelines for pre- and intra-operative care i gynecologic/oncology surgery: Enhanced recovery after surgery (ERAS®) Society recommendations—Part I. Gynecol Oncol 2016; 140(2):313–22.
4. Nelson G, Altman AD, Nick A, et al: Guidelines for postoperative care i gynecologic/oncology surgery: Enhanced recovery after surgery (ERAS®) Society recommendations—Part II. Gynecol Oncol 2016; 140(2):323–32.
5. Nelson G, Dowdy SC, Lasala J, et al: Enhanced recovery after surgery (ERAS®) in gynecologic oncology—Practical considerations for program development. Gynecol Oncol 2017; 147(3):617–20.
6. Oh TK, Lim MC, Lee Y, et al: Improved postoperative pain control for cytoreductive surgery in women with ovarian cancer using patient-controlled epidural analgesia. Int J Gynecol Cancer 2016; 26(3):588–93.
7. Types of Urostomies and Pouching Systems. American Cancer Society [Internet]. [cited 2018 Aug 13]. Available from: https://www.cancer.org/treatment/treatments-

and-side-effects/physical-side-effects/ostomies/urostomy/types.html

EXPLORATORY LAPAROTOMY OR LAPAROSCOPY AND HYSTERECTOMY/BSO FOR UTERINE CANCER

SURGICAL CONSIDERATIONS

Description

Currently, endometrial cancer is the most common gynecologic malignancy in the United States. The first step in the management of this cancer is surgical staging via laparotomy or laparoscopy. The objective, aside from 1° therapy, is to obtain as much surgical and pathologic staging data as feasible for determination of adjuvant postop therapy. Traditionally, surgery for uterine cancer was performed via laparotomy; however, laparoscopy has become a preferred approach for early-stage uterine cancers after recent trials have shown decreased operative morbidity and similar survival outcomes compared to laparotomy. In laparoscopy, or an open approach, the first step is careful exploration, which is carried out for evidence of omental, liver, peritoneal, and adnexal metastases. Aortic and pelvic areas are evaluated for metastases, and suspicious nodes are removed. In patients with low-grade histology and no or minimal suspected invasion, complete lymph node dissection remains an area of controversy, and treatment is generally individualized based on clinicopathologic factors. In patients with more extensive disease, a pelvic and periaortic lymph nodes dissection is performed. The lymph node sampling may be omitted in the treatment of some uterine sarcomas. A **total hysterectomy** with **BSO** is then performed in the usual manner (see discussion of TAH/BSO in Staging Laparotomy for Ovarian Cancer).

As a result of recent clinical trials, minimally invasive surgery via laparoscopy or robotic-assisted laparoscopy has become the first approach for uterine cancer staging. The GOG conducted a randomized prospective study evaluating exploratory laparotomy with open staging versus laparoscopic staging (GOG LAP2) to compare outcomes and safety. In 2009, the GOG published the data regarding perioperative morbidity and showed that the laparoscopic approach was associated with a shorter hospital stay and fewer moderate-to-severe postoperative complications. In 2012, the GOG published the survival data, which did not show statistical equivalence between two approaches relative to survival; however, a recent Cochrane meta-analysis has shown equivalent recurrence-free and overall survival with laparoscopy compared to laparotomy. When proceeding with a laparoscopic approach, it is important to note that adhesions of

variable severity may be present from prior surgery or radiation. Care should be taken to avoid possible bowel injury at time of trocar insertion. Patient needs to be in steep Trendelenburg position for duration of the procedure, and both arms should be tucked in at the patient's sides. Because argon is a heavy gas, prolonged use of the endoscopic ABC in a patient in steep Trendelenburg can → significant facial and neck subcutaneous emphysema. As with the open technique, the lymph nodes being removed are in the immediate proximity of the great pelvic vessels. The surgeon and anesthesiologist should be mindful of the potential for severe hemorrhage if these vessels are injured.

Usual preop diagnosis

Endometrial carcinoma

ERAS: Preop counseling by the surgeon/anesthesiologist should include no bowel prep, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading VTE prophylaxis, postop pain management options, postop recovery plan, possibility of urinary catheter postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Open Technique	Laparoscopic and Robotic Technique
Position	Supine	Modified dorsolithotomy in Allen stirrups
Incision	Midline longitudinal abdominal/transverse	Vertical infraumbilical and multiple small transverse incisions. For robotic surgery, midline incision is supraumbilical.
Special instrumentation	None	Uterine manipulator, videolaparoscopy equipment. Endoscopic GIA staplers, endoscopic ABC, endoscopic vascular clips, and CO_2 laser. For robotic surgery, bean bag positioner, additional padding for shoulders, neck, and arms
Unique	None	Mechanical bowel preop; steep

considerations		Trendelenburg
Antibiotics	Cefoxitin 2 g or cefotetan 2 g iv; redose as indicated by duration and blood loss	⇐
Surgical time	2–4 h	2–3 h
Closing considerations	± NG tube placement	Release the pneumoperitoneum completely. Closure of fascia at trocar sites ≥10 mm diameter
EBL	400–750 mL	100–500 mL
Postop care	Consider SCDs and heparin for VTE prophylaxis.	Begin early ambulation and feeding. Patients generally can be discharged on POD 1 or 2.
Mortality	0.1%	⇐
Morbidity	Hemorrhage requiring transfusion: 15%	4–7%
	Thrombophlebitis: 7%	⇐
	UTI: 7%	⇐
	Paralytic ileus: 2–5%	1–2%
	Wound infection: 3–7%	Rare
	VTE: 1–3%	⇐
	Pelvic infection: 1–2%	⇐
	Wound dehiscence: 1%	N/A
	Bowel injuries: <1%	1%
	Urinary tract injuries: <1%	1–5% Trocar site herniation: 0.5–2% Trocar site tumor: <1%
Pain score	7	2–3

PATIENT POPULATION CHARACTERISTICS	
Age range	Reproductive and postreproductive ages (average = 61 yr)
Incidence	24/100,000; 47,130 new cases in 2012, lifetime risk 2.6%
Etiology	Exposure to unopposed endogenous or exogenous estrogen; ↑ extraglandular conversion of androstenedione to estrone; sequential oral contraceptive pills; exposure to radiation (sarcomas)
Risk factors	Nulliparity, late menopause, early menarche, family hx, chronic anovulation, PCOS, tamoxifen use
Associated conditions	Obesity; diabetes; HTN; nulliparity; late menopause; early menarche; family Hx; Stein-Leventhal syndrome; chronic anovulation; ovarian and colon cancer; granulosa cell ovarian tumors; arthritis; hypothyroidism; HNPCC (Lynch) syndrome

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Endometrial cancer usually is diagnosed in postmenopausal women who present with vaginal bleeding. Exploratory laparotomy or laparoscopy and TAH/BSO are commonly performed for removal of the primary tumor as well as staging of metastatic disease. Occasionally, preop radiation therapy may be in progress, with consequent systemic effects.

Respiratory	✓ or Hx of lung disease or smoking **Tests:** Others as indicated from H&P
Cardiovascular	Hx of CAD, HTN, or CHF Sx (e.g., angina, dyspnea, or peripheral edema) should be investigated. Assess patient's exercise tolerance and current medications. **Tests:** Consider ECG within 6–12 mo for age >65. Consider NT-proBNP, if significant CHF or cardiomyopathy present.
Neurologic	Screen during preop eval. Evaluation as indicated by

	H&P
Endocrine	✓ for diabetes and hypothyroidism, which have been associated with this tumor. If the patient has received corticosteroids within the previous 6 m → consider supplemental dose of hydrocortisone (100 mg iv q12h × 2 d). **Tests:** FBS and HbA1c (within 3–6 mo) if diabetic; others as indicated from H&P
Hematologic	If vaginal bleeding has been profuse or of long duration, significant anemia may occur. Consider preop iron supplements or iv iron therapy. **Tests:** CBC or hemogram; consider T&S and T&C.
Laboratory	Additional testing based on preop H&P
Premedication	Anxiolysis: consider midazolam 1–2 mg iv Analgesia: consider acetaminophen 1000 mg po, gabapentin 300 mg po, and/or celecoxib 200 mg po
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of a transversus abdominis plane or epidural block/analgesia for postop pain management. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA ± epidural or spinal analgesia/anesthesia.

General anesthesia

Induction	Standard induction
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance. Consider ketamine (0.5

	mg/kg bolus + 5 mcg/kg/min infusion).
Emergence	Reverse muscle relaxant with neostigmine (0.07 mg/kg with glycopyrrolate 0.01 mg/kg) or sugammadex (2–4 mg/kg). Provide PONV prophylaxis. (See Appendix B, p. B-4 and p. B-6) Discuss with surgeon local wound infiltration or nerve block (e.g., TAP block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.

Regional anesthesia

Epidural (open procedures)	2% lidocaine (10–20 mL), ± epinephrine 1:200,000, or 0.25% bupivacaine (15–20 mL) is used; then at ~3–5 mL/h. Opiates, such as morphine (2–4 mg) or hydromorphone (0.3–0.6 mg), may be given in the epidural for postop pain control.	
Blood and fluid requirements	IV: 16–18 ga × 1 BSS @ 4–6 mL/kg/h Consider PRBC for Hct < 25%.	Goal-Directed Fluid Management (see Appendix K, p. K-4). Crystalloid is used for volume replacement. If anemia is present preop, it may be necessary to give PRBCs to keep Hct > 25%. Goal-Directed Fluid Management (see Appendix K, p. K-4)
Monitoring	Standard monitors Foley catheter	Direct monitoring of arterial pressure is indicated in patients with CAD, severe HTN, or lung disease.
	± Arterial line, CVP OGT/NGT for laparoscopic/robotic procedures	Consider art line and/or CVP if significant comorbidities exist.

Positioning	✓ and pad pressure points ✓ eyes SCD	
Complications	Hypothermia Trauma or obstruction of ureter	Warm iv fluids; use forced-air warmer. Heating pad on OR table. Watch for hematuria or ↓ UO.

POSTOPERATIVE

Complications	PONV VTE Hypothermia Bleeding	See Appendix B, p. B-4 and p. B-6. See Appendix B, p. B-7. Use forced-air warming in recovery.
Multimodal pain management	Multimodal approach ± PCA ± epidural ± PNB/RA	Consider the following multimodal options: po/iv analgesics: consider acetaminophen 650–1000 mg po/iv q6h, gabapentin 200 mg po tid, ibuprofen 200–800 mg po/iv q6h, celecoxib 200 mg po q12h, oxycodone 5–10 mg po q6h, or hydromorphone 0.2–0.5 mg iv for breakthrough pain.
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early (within 24 h) enteral nutrition, Foley catheter removal, and mobilization. Consider VTE prophylaxis. Chewing gum may promote return of bowel function.

Suggested Readings

1. Coronado PJ, Herrai MA, Magrina JF, et al: Comparison of perioperative outcome and cost of robotic-assisted laparoscopy, laparoscopy, and laparotomy for endometrial cancer. Eur J Obstet Gynecol Repro Biol 2012; 165(2):289–94. doi: 10.1016/j.ejogrb.2012.07.00.
2. Galaal K, Bryant A, Fisher AD, et al: Laparoscopy versus laparotomy for the management of early stage endometrial cancer. Cochrane Database Syst Rev 2012; (9):CD006655.
3. Meyer LA, Lasala J, Iniesta MD, et al: Effect of an enhanced recovery after surger program on opioid use and patient-reported outcomes. Obstet Gynecol 2018; 132(2):281–90.
4. Modesitt SC, Sarosiek BM, Trowbridge ER, et al: Enhanced recover implementation in major gynecologic surgeries: effect of care standardization. Obstet Gynecol 2016; 128(3):457–66.
5. Walker JL, Piedmonte MR, Spirtos NM, et al: Recurrence and survival after randor assignment to laparoscopy versus laparotomy for comprehensive surgical staging of uterine cancer: Gynecologic Oncology Group LAP2 Study.J Clin Oncol 2012; 30:695–700.
6. Zakhari A, Czuzoj-Shulman N, et al: Laparoscopic and robot-assisted hysterectomy for uterine cancer: a comparison of costs and complications. Am J Obstet Gynecol 2015; 213(5):665.e1–7.

RADICAL HYSTERECTOMY

SURGICAL CONSIDERATIONS

Description

Radical hysterectomy is the preferred mode of therapy for young women with Stage IA, IB, or non bulky IIA cervical carcinoma, who want to preserve ovarian function. I is also appropriate with Stage II endometrial and Stage I vaginal carcinoma. The operation involves the removal of the uterus, along with the upper vagina and all the parametrial tissues to the pelvic sidewall. A pelvic and paraaortic **lymph node dissection** usually is performed at the beginning of the procedure. Suspicious nodes are submitted for pathologic frozen section evaluation. The paravesical and pararectal spaces are then developed, with the "web" of tissue between these two spaces being palpated carefully (Fig. 8.1-9). In cases of cervical or vaginal cancer, if parametrial tumor extension is noted and/or the lymph nodes are positive on frozen section, the hysterectomy may be aborted. The radical hysterectomy is performed after the

pararectal, and paravesical spaces have been developed. The uterine arteries are divided at their origin from the anterior division of the internal iliac artery. The ureters are dissected free of the parametrial tissues, which are then transected close to the pelvic sidewall. Next, the rectovaginal space is developed (Fig. 8.1-10). The uterosacral ligaments are transected between their uterine and sacral attachments. The upper third of the vagina is cross-clamped and divided in such a manner as to provide a 3-cm margin, and the specimen is delivered en bloc. Note that during this procedure the ureters and bladder are dissected free and left intact. With the increasing use of minimally invasive surgery in gynecologic oncology, radical hysterectomy is frequently performed laparoscopically or robotically. Similar to laparoscopic surgery for endometrial cancer, steep Trendelenburg is required during the procedure, and special care is taken to support the head, shoulders, and arms.

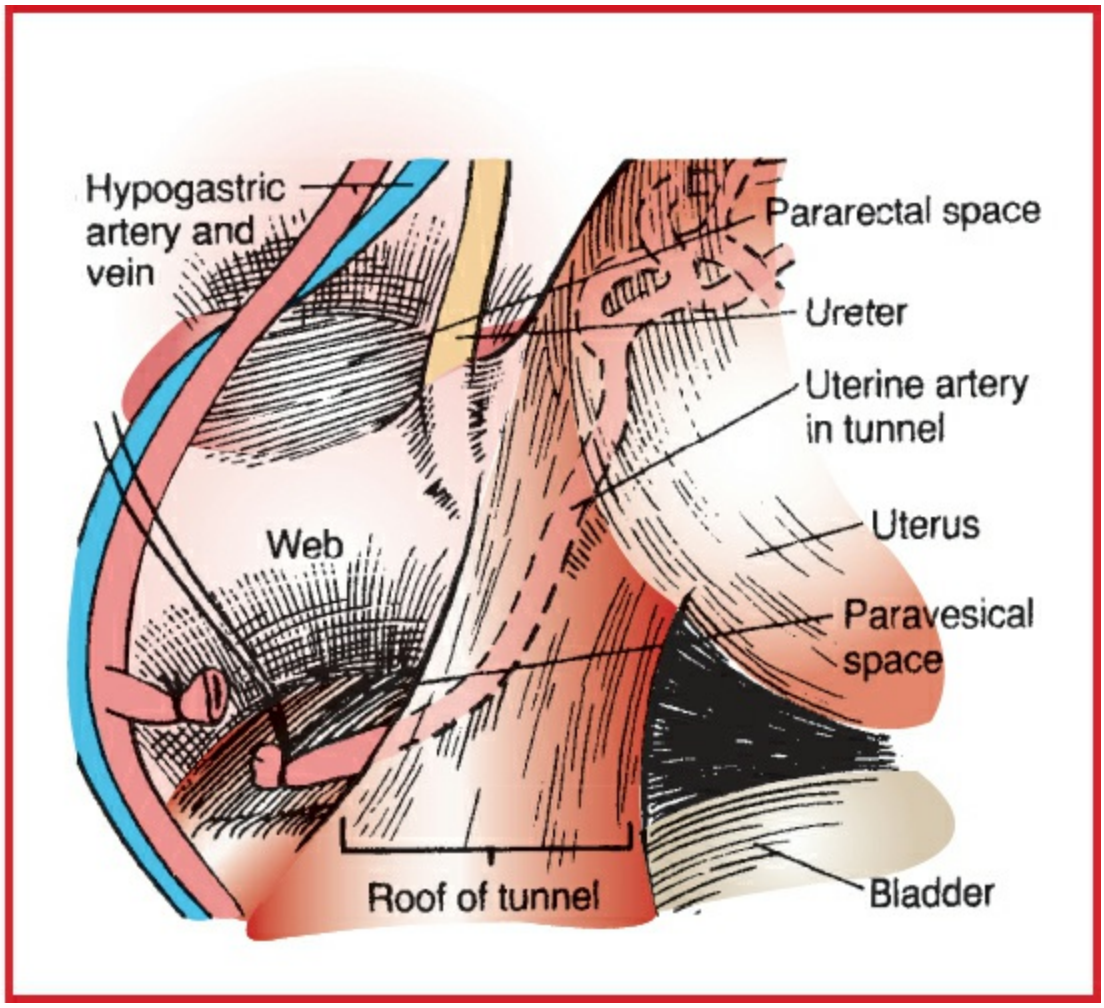

Figure 8.1-9 View of parametrial area, showing positions of ureter and uterine artery to web, hypergastric vessels, paravesical, and pararectal spaces. (Reproduced with permission from Wheeless CR: Atlas of Pelvic Surgery, 3rd edition. Williams & Wilkins, Baltimore: 1997.)

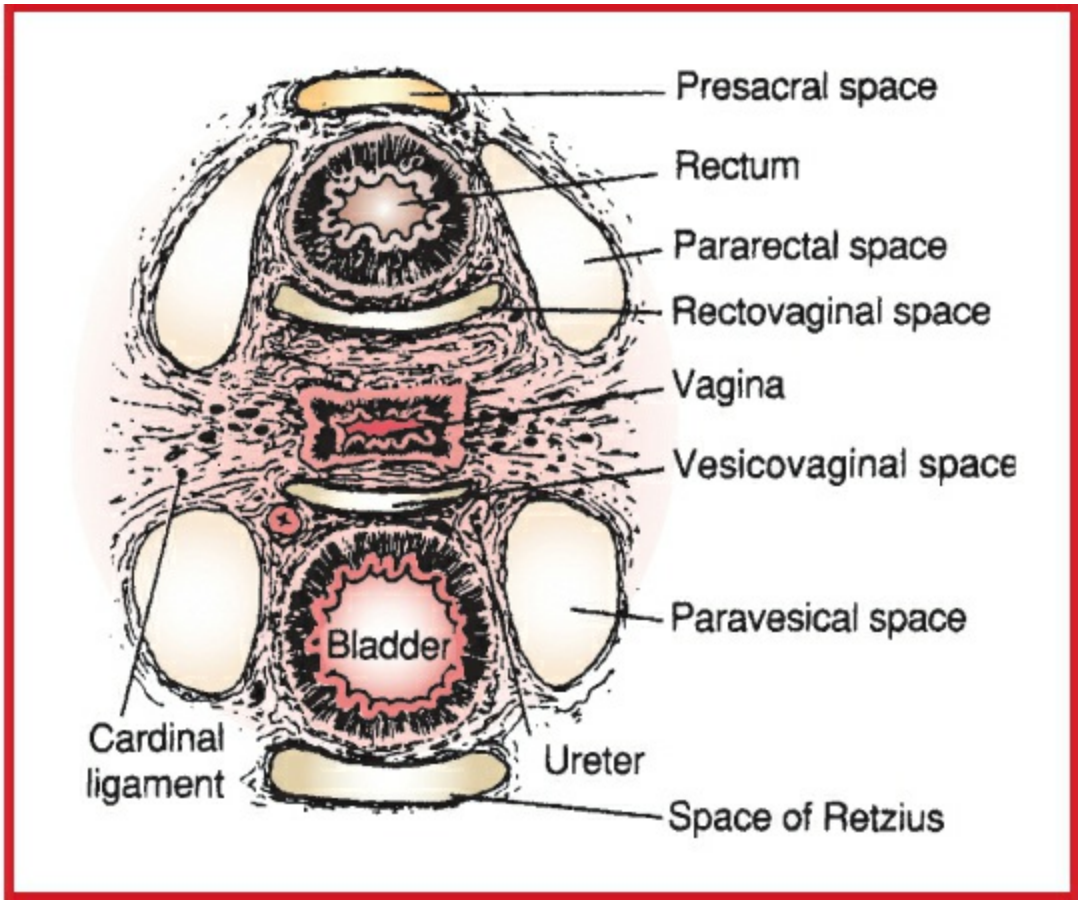

Figure 8.1-10 Schematic diagram of a cut in the anterior/posterior plane with positions of all spaces in relation to pelvic organs. (Reproduced with permission from Wheeless CR:Atlas of Pelvic Surgery, 3rd edition. Williams & Wilkins, Baltimore: 1997.)

In reproductive age women, who may require postop radiotherapy, ovarian function is preserved by performing an **oophoropexy**. This is accomplished by severing the utero-ovarian ligament and mobilizing the ovarian vessels as they course through the infundibulopelvic ligament. The ovaries are then sutured outside the radiation therapy field and marked with metal clips for future identification.

Variant procedure or approaches

Stallworthy, Dolstad, Novak, Rutledge, Wertheim, and other surgeons have proposed several modifications in an effort to reduce the incidence of ureteral and bladder fistulae. These approaches include preservation of blood supply to the terminal 2 cm of the pelvic ureter by widely displacing ureters (not dissecting them from their fascial beds) and limiting parametrial dissection to the proximal 1/3 or 1/2.

Usual preop diagnosis

Stage IA, IB, or nonbulky IIA cervical carcinoma; Stage II endometrial or Stage vaginal carcinoma (less common)

ERAS: **Preop counseling by the surgeon/anesthesiologist should include no bowel prep, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading VTE prophylaxis, postop pain management options, recovery plan, possibility of urinary catheter postop.** **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Laparotomy	Laparoscopy or Robotic-Assisted Laparoscopy
Position	Supine/modified lithotomy	Modified dorsal lithotomy
Incision	Midline longitudinal or low transverse abdominal (Maylard/Cherney)	Supra- or infraumbilical midline incision and multiple small transverse incisions
Special instrumentation	ABC, vital view (suction, irrigation, and light source combined in 1 instrument) helpful	
Unique considerations	Abort case if positive paraaortic lymph nodes found on frozen section or if obvious parametrial involvement noted. Consider intraop radiation therapy (investigational), if patient is inoperable.	⇐ ± Mechanical bowel prep, steep Trendelenburg
Antibiotics	Cefoxitin 2 g or cefotetan 2 g iv; redose as indicated by duration and blood loss	⇐
Surgical time	3–6 h	2–4 h
Closing considerations	Vaginal and abdominal drains; ± NG tube placement; suprapubic bladder catheter placement; oophoropexy; copious irrigation	Release the pneumoperitoneum completely. Closure of fascia at trocar sites >10 mm diameter

EBL	500–1500 mL	100–500 mL
Postop care	Transient ileus very common. Advance diet slowly. Transient bladder dysfunction very common; therefore, continued bladder drainage for 1+ wk may be necessary. Consider using SCDs and heparin for VTE prophylaxis.	Early ambulation and feeding. Patients can be discharged POD#1 or 2. Transient bladder dysfunction common; urinary catheter kept in place 5–7 d. Consider preoperative prophylactic heparin.
Mortality	0.3–2.0%	0.1–0.2%
Morbidity	Paralytic ileus: 3–11%	Ileus: 1–2%
	Pelvic lymphocyst: 2–3%	Lymphocyst: 2–6%
	Intraop hemorrhage: 3–5%	Intraop hemorrhage: 1–3%
	Thrombophlebitis: 7%	Thrombophlebitis: 7%
	Pneumonia: 1.5–4%	Pneumonia: 1.5–4%
	Wound infection: 3.5%	Wound infection: rare
	Vesical injury: 2–3%	Vesical injury: 2–3%
	Pelvic infection: 1–2%	Ureteral injury: 1–3%
	PE: 1–2%	Pelvic infection: 1–2%
	Vesical fistulae: 1–2%	PE: 1–3%
	Small bowel obstruction: 1–2%	Small bowel obstruction: rare
	Ureteral fistulae: 1–2%	Wound dehiscence: rare
	Uretral injury: 1–2%	Postop lymphedema: rare
	Wound dehiscence: 1%	Conversion to laparotomy: 1–2%
	Postop lymphedema: <1%	Cuff dehiscence: 5–8%

	Rectal injury: <1% Pelvic urinoma: rare	Trocar site herniation: 0.5–2% Bladder dysfunction: 10–20%
Pain score	8	5–6

PATIENT POPULATION CHARACTERISTICS

Age range	Reproductive and postreproductive years
Incidence	10/100,000
Etiology	Human papillomavirus (HPV), subtypes 16, 18 (most common), and others
Associated conditions	Smoking; venereal warts; genital herpes; multiple sexual partners; early-age onset of coitus; multiparity; lower socioeconomic status; HIV infection

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

This surgery usually is performed for cervical carcinoma in young women who wish to preserve ovarian function and whose tumor has not spread beyond local invasion. Lymph nodes are removed to confer a therapeutic advantage and to plan postop adjuvant therapy, if any.

Respiratory	These tumors have been associated with cigarette smoking. ✓ for preexisting lung disease. **Tests:** As indicated from H&P
Cardiovascular	**Tests:** Consider ECG within 6–12 mo for age >65. Consider NT-proBNP if significant CHF or cardiomyopathy present. Others as indicated by H&P
Hematologic	✓ for preop anemia **Tests:** Hemogram or CBC; consider T&S and T&C.
Laboratory	Renal panel if age ≥ 65 yr, HTN, renal disease, DM
Premedication	Anxiolysis: consider midazolam 1–2 mg iv Analgesia: consider acetaminophen 1000 mg po, gabapentin 300 mg po, and/or celecoxib 200 mg po

ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of TAP or epidural block/analgesia for postop pain management. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA ± epidural or spinal analgesia for postop pain control.

	Laparotomy	Laparoscopic or Robotic Assist
Induction	Standard induction	⇐
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	⇐
Maintenance	Standard maintenance. Consider ketamine (0.5 mg/kg bolus + 5 mcg/kg/min infusion).	Standard maintenance
Emergence	Discuss with surgeon local wound infiltration or nerve block (e.g., TAP block) placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >4–6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	Reverse muscle relaxant with neostigmine (0.07 mg/kg with glycopyrrolate 0.01 mg/kg) or sugammadex (2–4 mg/kg). Provide PONV prophylaxis. (See Appendix B, p. B-4 and p. B-6)

Blood and fluid requirements	500–1500 mL (laparotomy) 100–500 mL (laparoscopic) IV: 16–18 ga × 1–2 BSS @ up to 6–8 mL/kg/h Maintain UO > 0.5 mL/kg/h Warm iv fluids Goal-Directed Fluid Management (see Appendix K, p. K-4)	⇐
Monitoring	Standard monitors Foley catheter ± Arterial catheter ± CVP catheter	Consider invasive monitoring for patients with underlying cardiopulmonary disease, advanced age, or in cases of large anticipated or unanticipated blood loss.
Positioning	✓ and pad pressure points ✓ eyes SCD	Steep Trendelenburg may be necessary for laparoscopic and robotic-assisted procedures.
Complications	Injury to ureters Hypothermia	Watch for hematuria or ↓ UO. Warm iv fluids; use forced-air warmer.

POSTOPERATIVE

Complications	Atelectasis Hypothermia Bleeding VTE PONV	 VTE prophylaxis See Appendix B, p. B-4 and p. B-6.
Multimodal pain management	Multimodal approach ± PCA ± Epidural ± PNB/TAP	Consider the following multimodal options as appropriate: po/iv analgesics:

		acetaminophen 1000 mg po/iv q6h, gabapentin 300 mg po tid, ibuprofen 200–800 mg po/iv q6h, celecoxib 200 mg po q12h, oxycodone 5–10 mg po q6h, or hydromorphone 0.2–0.5 mg iv for breakthrough pain.
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early (within 24 h) enteral nutrition, Foley catheter removal, and mobilization. Consider VTE prophylaxis. Chewing gum may promote return of bowel function.

Suggested Readings

1. Meyer LA, Lasala J, Iniesta MD, et al: Effect of an enhanced recovery after surger program on opioid use and patient-reported outcomes. Obstet Gynecol 2018; 132(2):281–90.
2. Modesitt SC, Sarosiek BM, Trowbridge ER, et al: Enhanced recover implementation in major gynecologic surgeries: effect of care standardization. Obstet Gynecol 2016; 128(3):457–66.
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ROBOTIC-ASSISTED LAPAROSCOPY AND SURGERY IN GYNECOLOGIC ONCOLOGY

SURGICAL CONSIDERATIONS

Description

Laparoscopy and robotic-assisted laparoscopy are both widely used to treat gynecologic cancers. As reviewed previously, a recent Cochrane review has shown equivalent disease-free and overall survival when comparing laparoscopy to an open approach for the treatment of endometrial cancer. In addition, other advantages of a

laparoscopic approach include a shorter hospital stay, better pain control, faster recovery time, ↓ morbidity, and cosmetically appealing smaller incisions. Increasingly, more studies are being published to better answer questions regarding the safety of use in malignant diseases, differences in operative time, and cost, as well as survival and morbidity differences based on cancer type. The authors believe that there is a role for laparoscopy in select situations, such as:

- Assessment of adnexal masses and diagnosis of ovarian cancer
- Laparoscopic lymphadenectomy with laparoscopically assisted vaginal hysterectomy or laparoscopic hysterectomy in staging of endometrial cancer
- Laparoscopically assisted radical vaginal hysterectomy or laparoscopic radical hysterectomy with lymphadenectomy in early-stage cervical cancer
- Laparoscopically assisted application of interstitial brachytherapy implants
- Interval or secondary cytoreductive surgery for ovarian cancer

Details of each of these procedures are beyond the scope of this section; however, common principles of laparoscopic techniques (e.g., adhesiolysis, biopsies, oophorectomy, omentectomy) apply (see discussion in Laparoscopic Procedures for Gynecologic Surgery). The patient is placed in the dorsal lithotomy position, with the buttocks extended over the edge of the table to allow for instrument manipulation, and may need to be placed in steep Trendelenburg position during surgery. Various techniques are used for entry into the abdominal cavity, but the open laparoscopic technique is favored by many and may ↓ risk of vascular or visceral injuries. Other incision-related complications include dehiscence and hernia.

Usual preop diagnosis

Ovarian tumor and other gynecologic cancers/tumors

ERAS: Preop counseling by the surgeon/anesthesiologist should include no bowel prep, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading VTE prophylaxis, postop pain management options, recovery plan, possibility of urinary catheter postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Dorsal lithotomy; legs in Allen universal stirrups; steep Trendelenburg
Incisions	Intraumbilical; bilateral suprapubic; midline suprapubic

Special instrumentation	CO_2 laser; bipolar LigaSure® or other device; suction irrigator; may require Harmonic Scalpel®; various laparoscopic stapling instruments; beanbag or other support for robotic surgery
Unique considerations	Extended operative time and period of abdominal insufflation for radical procedures. Possible rapid need for laparotomy. Extensive use of electrocautery, ABC, CO_2 laser
Antibiotics	Cefoxitin or cefotetan 2 g iv; redose as indicated by duration and blood loss
Surgical time	1.5–5 h
Closing considerations	Quicker than with laparotomy; but fascia of all 10- to 12-mm ports need to be closed. 5-mm trocar sites can be closed in a subcuticular fashion.
EBL	50–1500 mL, depending on extent of procedure
Postop care	Advance diet as tolerated, ambulate POD 0, and discharge POD 1–2.
Mortality	0.1%
Morbidity	Overall complication rate: 0.2–10.3% Conversion to laparotomy: 2.1–7% Port-site metastasis: <1% Subcutaneous emphysema: 0.3–2% Pneumomediastinum: 0.26% Brachial plexus neuropathy: 0.16% Incisional hernia: 0.5–2% Bowel injury: 1% Major vascular injury: <1% Bladder/ureteral injury: 1–3% Gas embolism: rare Wound infection: uncommon
Pain score	3–4

PATIENT POPULATION CHARACTERISTICS

Age range	Reproductive and postreproductive year

Incidence	Depends on primary disease
Etiology	Numerous, depending on primary disease (see appropriate sections earlier in this chapter)
Associated conditions	See specific procedures in this chapter.

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Laparoscopic Hysterectomy.

Suggested Readings

1. Coronado PJ, Herrai MA, Magrina JF, et al: Comparison of perioperative outcome and cost of robotic-assisted laparoscopy, laparoscopy, and laparotomy for endometrial cancer. Eur J Obstet Gynecol Reprod Biol2012; 165(2):289–94. doi: 10.1016/j.ejorgb.2012.07.006.
2. Walker JL, Piedmonte MR, Spirtos NM, et al: Recurrence and survival after randor assignment to laparoscopy versus laparotomy for comprehensive surgical staging of uterine cancer: Gynecologic Oncology Group LAP2 Study.J Clin Oncol 2012; 30:695–700.
3. Wright JD, Herzog TJ, Neugut AI, et al: Comparative effectiveness of minimall invasive and abdominal radical hysterectomy for cervical cancer. Gynecol Oncol 2012; 127:11–7.
4. Zakhari A, Czuzoj-Shulman N, Spence AR, et al: Laparoscopic and robot-assiste hysterectomy for uterine cancer: a comparison of costs and complications. Am J Obstet Gynecol 2015; 213(5):665.e1-7.

INTERSTITIAL PERINEAL IMPLANTS

SURGICAL CONSIDERATIONS

Description

Radiotherapy is the treatment of choice for International Federation of Gynecology and Obstetrics (FIGO) Stage IIB-IVA carcinoma of the cervix; Stage I, II, III, and IV vaginal cancers; selected vulvar cancers; and pelvic recurrences of gynecologic cancers. In addition, radiotherapy is also commonly used as an adjuvant treatment with chemotherapy and surgery for advanced endometrial cancer. Often, **external beam therapy** is combined with **brachytherapy**, either in the form of intracavitary insertion

or as an interstitial perineal template implant. Intracavitary radiotherapy utilizes devices such as Fletcher-Suit tandem and ovoid applicators (Fig. 8.1-11) or cylinders that are fitted into the vagina and provide a therapeutic boost to the vaginal apex region after external beam irradiation. In general, these devices do not require a laparotomy or laparoscopy for guidance. For selected patients with distorted anatomy and/or bulky tumors, interstitial implants provide superior dose distribution and better local tumor control. The two most widely used systems are the **Martinez Universal Perineal Interstitial Template (MUPIT)** and the **Syed-Neblett applicator**. These systems have similar efficacy, and both are performed in the OR with the patient under MAC or GA. A **laparoscopy** or **laparotomy** is frequently performed at the time of interstitial implant placement to accurately guide the needles into their target tissues and to avoid radiation injury to bowel and/or other pelvic organs not involved with tumor. To minimize postop patient discomfort, some centers use laparoscopy instead of laparotomy for needle guidance. A two-team approach is used: a gynecologic oncology team performs the laparotomy or laparoscopy and guides the needles from above; a radiation oncology team inserts the implants from below. The implants are afterloaded with the appropriate radiation sources when the patient has returned to her shielded room. If a **hysterectomy** has been done previously, an **omental pelvic carpet,** or a **pelvic lid** made of delayed, absorbable mesh, is performed to provide additional space between the radiation source and bowel.

One important and recent advance in radiation therapy is the technique, intensity-modulated radiation therapy (IMRT). IMRT is a form of external beam radiation and allows creation of a gradient of radiation dose over a specified treatment area, in contrast to the previous method of delivering a constant dose to all tissues. As more IMRT is being used, fewer patients are needing an operative procedure to assist with delivery of the appropriate radiation dose.

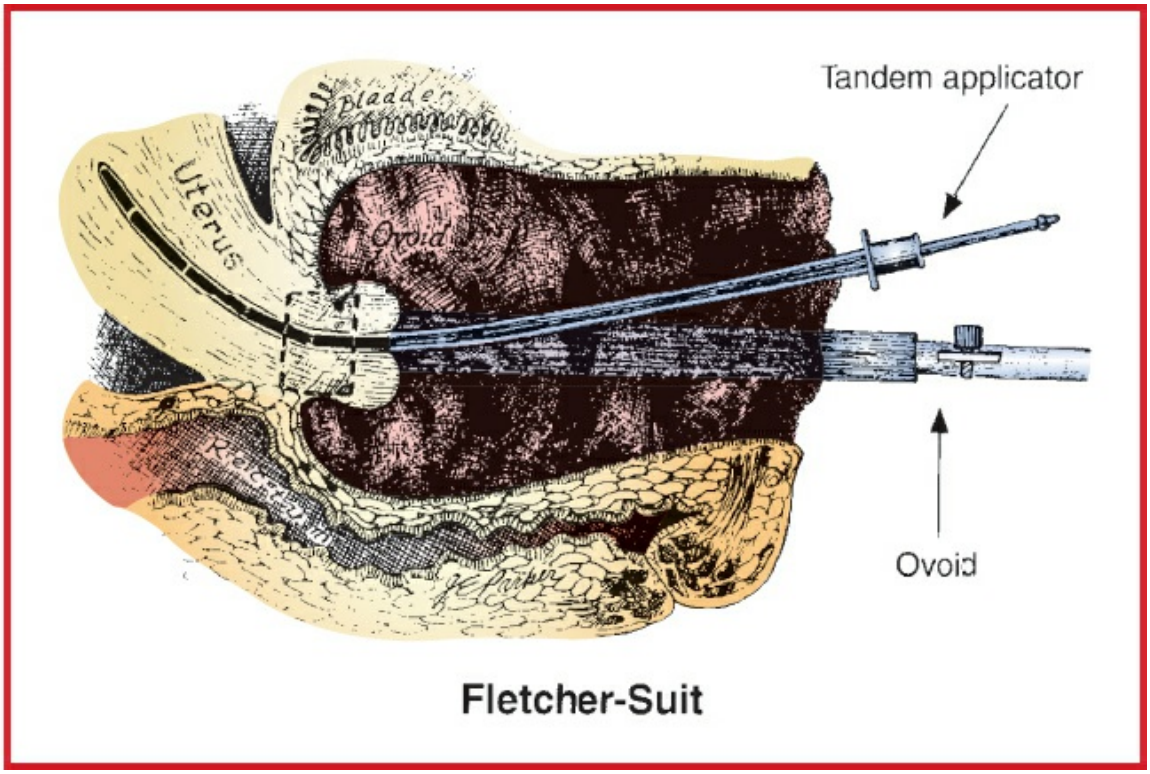

Figure 8.1-11 "Fletcher-Suit." The tandem and ovoid applicators are packed into the vagina, leaving the maximum distance between the bladder and radium sources. (Reproduced with permission from Wheeless CR: Atlas of Pelvic Surgery, 3rd edition. Williams & Wilkins, Baltimore: 1997.)

Usual preop diagnosis

Cervical, vaginal, vulvar carcinomas; pelvic recurrence of gynecologic malignancies

ERAS: Preop counseling by the surgeon/anesthesiologist should include no bowel prep, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading VTE prophylaxis, postop pain management options, recovery plan, possibility of urinary catheter postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Laparotomy Guided	Laparoscopy Guided
Position	Modified dorsolithotomy; Allen stirrups	⇐
Incision	Midline longitudinal abdominal	Vertical infraumbilical and multiple small transverse incisions at the pubic hairline

Special instrumentation	Syed-Neblett or MUPIT systems or modifications thereof	⇐ + Videolaparoscopy equipment, preferably with a 3-chip camera
Unique considerations	MRI and/or CT scans + information from physical exam are used to preplan implant with a computer dosimetry program. Patients require thorough preop mechanical and antibiotic bowel prep. Preop epidural placement or postop PCA may prove helpful for pain control. Foley catheter needs to be inserted through an opening at the top of the clear plastic template before implant positioning.	⇐ + Adhesions of variable severity may be present from prior surgery or radiation. Care should be taken to avoid possible bowel injury at time of trocar insertion. Patient needs to be in steep Trendelenburg position for duration of procedure.
Antibiotics	Cefoxitin 2 g or cefotetan 2 g iv; then q12h × 3 doses	⇐
Surgical time	1.5–3 h	⇐
EBL	150–350 mL	Minimal
Closing considerations	Suture template to perineum. Perform rectal exam and adjust any needles that are too close to, or have protruded through, the rectal mucosa. Pack any space between template and perineum with Vaseline gauze. Obtain A-P and lateral orthogonal localization films with the patient in the supine bed	⇐ + Release the pneumoperitoneum completely. Consider insertion of 1 L heparinized LR to cause the bowel to float and remain mobile, thus minimizing the risk of radiation injury.

	rest position. Insert Hypaque dye into Foley catheter balloon before localization films. Consider insertion of a large Foley into the rectum, and attach to a drainage bag.	
Postop care	Patient is confined to bed while interstitial implants are in place. SCDs and minidose heparin for VTE prophylaxis. Vigorous use of incentive spirometry. Consider constipating medications (e.g., Lomotil). Patient must be placed in a shielded room. Visitors and medical personnel should interact with patient from behind a lead shield until radiation sources have been removed.	⇐
Mortality	0.1–0.3%	⇐
Morbidity	Hemorrhagic proctitis with diarrhea and tenesmus: 7–18%	⇐
	Radiation cystitis: 7–10%	⇐
	Cervical necrosis: 5–6%	⇐
	Rectovaginal fistula: <5%	⇐
	Vesicovaginal fistula: <5%	⇐
	Vaginal vault necrosis: 3–5%	⇐

	Rectal fibrosis: 2–5% Pelvic infection: 2–3%	⇐ ⇐
Pain score	8–9	8–9

PATIENT POPULATION CHARACTERISTICS

Age range	Reproductive and postreproductive age; childhood—rare
Etiology	Cervical, vaginal, or vulvar carcinomas; pelvic recurrence of gynecologic malignancies

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Radiation implants are used for palliation or cure in cervical, endometrial, and ovarian cancer. The implants concentrate the radiation close to the site of the tumor and may be supplemented by external beam radiation. The unique tolerance of the uterus and vagina to radiation permits large doses and accounts for the success in treating cervical lesions. The sigmoid, rectum, and large bowel are much more sensitive to radiation injury, limiting the dose of radiation that may be given to the pelvis. There is a trend toward the use of sophisticated external beam radiation (intensity modulated), resulting in fewer cases requiring radiation implants.

Respiratory	Usually not significant unless underlying lung disease is present
Cardiovascular	Many patients with pelvic tumors are elderly and prone to cardiovascular disease. **Tests:** ECG if age ≥ 65; others as indicated from H&P
Hematologic	**Tests:** CBC; consider PT/PTT if at risk for coagulopathy.
Laboratory	Renal panel
Premedication	Anxiolysis: consider midazolam 1–2 mg iv Analgesia: consider acetaminophen 1000 mg po, gabapentin 300 mg po, and/or celecoxib 200 mg po
ERAS	Check compliance with presurgical ERAS

	recommendations (see above) including NPO status. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Regional or GA, depending on site involved. A postop epidural is useful for pain management.

Induction	Standard induction	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance. Consider ketamine (0.5 mg/kg bolus + 5 mcg/kg/min infusion).	
Emergence	Consider PONV prophylaxis. See Appendix B, p. B-4 and p. B-6. PONV prophylaxis may include dexamethasone and ondansetron.	
Blood and fluid requirements	Small blood loss IV: 18–20 ga × 1 BSS @ 2–4 mL/kg/h	Goal-Directed Fluid Management (see Appendix K, p. K-4)
Monitoring	Standard monitors	
Positioning	May be necessary to keep patient motionless during implant insertion. ✓ and pad pressure points ✓ eyes SCD	

POSTOPERATIVE

Multimodal pain management	Multimodal approach ± PCA ± epidural ± PNB/RA	Consider the following multimodal options: po/iv analgesics: acetaminophen 1000 mg

		po/iv q6–8h, gabapentin 200 mg po tid, ibuprofen 200–800 mg po/iv q6h, celecoxib 200 mg po q12h, oxycodone 5–10 mg po q6h, or hydromorphone 0.2–0.5 mg iv for breakthrough pain.
ERAS	PONV protocol (see Appendix B, p. B-1)	Encourage early (within 24 h) enteral nutrition, Foley catheter removal, and mobilization. Consider VTE prophylaxis. Chewing gum may promote return of bowel function.

Suggested Readings

1. Koh WJ, Sales LR: Principles of radiation therapy. In: Karlan BY, Bristow RE, I AJ, eds. Gynecologic Oncology Clinical Practice and Surgical Atlas, 1st edition. McGraw-Hill Co., San Francisco: 2012.
2. Meyer LA, Lasala J, Iniesta MD, et al: Effect of an enhanced recovery after surger program on opioid use and patient-reported outcomes. Obstet Gynecol 2018; 132(2):281–90.
3. Modesitt SC, Sarosiek BM, Trowbridge ER, et al: Enhanced recover implementation in major gynecologic surgeries: effect of care standardization. Obstet Gynecol 2016; 128(3):457–66.
4. Syed AM, Puthawala AA, Abdelaziz NN, et al: Long-term results of low-dose-rat interstitial-intracavitary brachytherapy in the treatment of carcinoma of the cervix. Int J Radiat Oncol Biol Phys 2002; 54(1):67–78.

CHAPTER 8.2

Gynecology/Infertility Surgery

SURGEONS

Deirdre Lum, MD
Amin A. Milki, MD
Jonathan Kort, MD
Lynn M. Westphal, MD

ANESTHESIOLOGIST

Clifford A. Schmiesing, MD

DILATATION AND CURETTAGE (D&C)

SURGICAL CONSIDERATIONS

Description

During **dilatation and curettage (D&C)**, the endometrial lining of the uterus and coexisting lesions (myoma, polyp) are sampled or removed. This procedure is performed to diagnose and treat bleeding from uterine and cervical lesions, to treat cervical stenosis, to complete an incomplete or missed spontaneous abortion, or as a method for pregnancy termination. An office endometrial biopsy and medical management are usually initially performed for bleeding problems.

With the patient in the dorsal lithotomy position, the surgeon initially performs a bimanual examination under anesthesia to obtain information about both the presence of adnexal pathology and anatomic detail of the uterus. A speculum is inserted into the vagina, and the cervix is grasped with a single-tooth tenaculum for manipulation. The cervix is pulled gently toward the operator, who then uses a uterine probe to delineate the length of the uterus and the angulation between the cervical canal and uterus. The uterine cavity is reached by dilating the cervical canal with progressively larger

dilators (Hegar or Pratt) to the desired diameter for the procedure. A polyp forceps may be used at this stage to remove existing polyps, and a sharp curette is used to remove the endometrial lining (Fig. 8.2-1). A suction curette is often used for abortion procedures.

Usual preop diagnosis

Uncontrolled uterine bleeding refractory to hormonal treatment; abnormal uterine bleeding; incomplete, missed, or induced abortion; pregnancy termination; cervical stenosis causing dysmenorrhea or obstruction of menstrual flow

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol, and smoking cessation, carb-loading and postop pain management options. See Appendix K: Enhanced Recovery After Surgery, p. K-1.

SUMMARY OF PROCEDURE	
Position	Dorsal lithotomy with stirrups
Incision	None
Special instrumentation	To prevent a peroneal nerve injury, the area of the leg leaning against the stirrup (lateral knee) should be well cushioned. To prevent a femoral nerve injury, prolonged hyperflexion of the hips should be avoided.
Unique considerations	Following induction, the perineum is positioned at the very end of the table to ensure optimal exposure. During the cervical dilatation, a vasovagal response can occur, with subsequent bradycardia and ↓ BP. Uterine perforations will often manifest as severe postop pain.
Antibiotics	None or doxycycline 100 mg orally or iv before the procedure
Surgical time	5–15 min
EBL	0–50 mL
Mortality	Minimal
Morbidity	Postop fever: 1.7% Uterine perforation: 0.63% Severe immediate postop bleeding (caused by either uterine artery perforation or cervical injury): <1%

Pain score	3–5

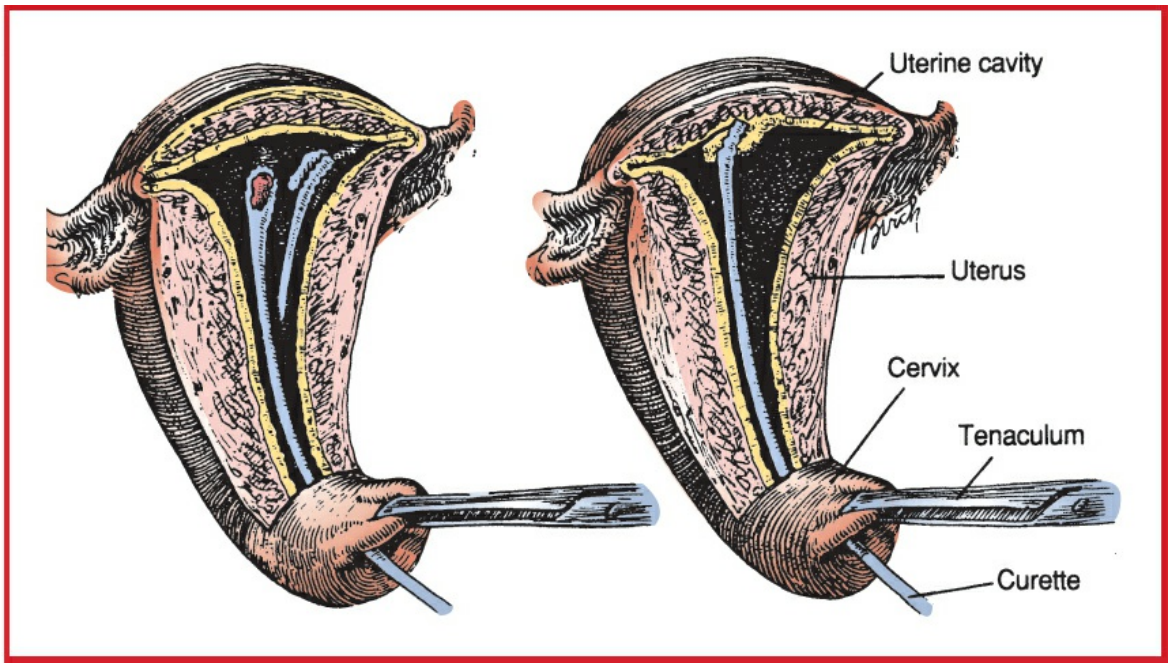

Figure 8.2-1 Curettage of endometrial lining. (Reproduced with permission from Rock JA, Jones HW, eds: TeLinde's Operative Gynecology, 10th edition. Wolters Kluwer Health/Lippincott Williams & Wilkins, Philadelphia: 2008.)

PATIENT POPULATION CHARACTERISTICS

Age range	20–80 yr
Incidence	>1/50 females
Etiology	Dysfunctional uterine bleeding, endometrial pathology, pregnancy issues
Associated conditions	Obesity, HTN

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Therapeutic Abortion, Dilatation, and Evacuation.

Suggested Reading

1. Tangsiriwatthana T, Sangkomkamhang US, Lumbiganon P, et al: Paracervical local anaesthesia for cervical dilatation and uterine intervention. Cochrane Database Syst Rev 2013; (9):CD005056.

THERAPEUTIC ABORTION, DILATATION, AND EVACUATION (D&E)

SURGICAL CONSIDERATIONS

Description

Therapeutic abortion (TAB) is the elective termination of a pregnancy before viability (usually considered to be 24 wk). In 2017, 879,000 abortions were reported in the United States, a rate of 14.6 abortions per 1000 women aged 14–44. **Suction curettage** is the most efficient method to terminate pregnancies during the 1st trimester (<12 wk), and the great majority of abortions are performed in this manner. Few (<5%) 1st trimester abortions in the United States are performed with a sharp curette due to increased operative time and blood loss, and also the risk of intrauterine adhesions potentially resulting in infertility. Very early termination can be performed without anesthesia via medical termination.

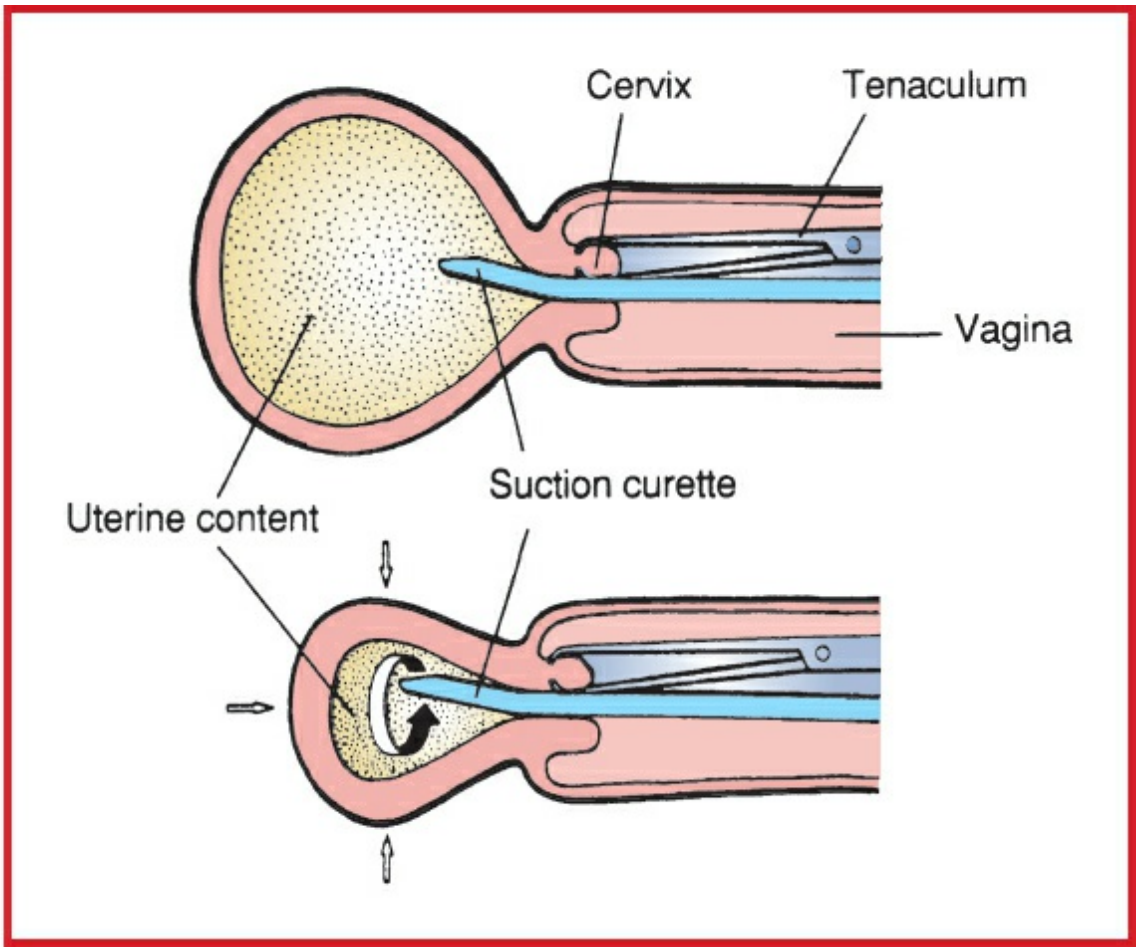

Figure 8.2-2 Uterine aspiration. Top, uterus at beginning of procedure; bottom, at conclusion of procedure. (Reproduced with permission from Rock JA, Thompson JD, eds: TeLinde's Operative

Gynecology, 8th edition. Lippincott-Raven, Philadelphia: 1997.)

The TAB procedure consists of a standard cervical dilatation (required for gestations >6 wk), followed by vacuum aspiration of the uterine contents using a plastic suction curette (Fig. 8.2-2). Alternatively, the cervical canal can be dilated >6 h before the operation with laminaria or synthetic osmotic dilators, which, after insertion, swell to provide dilatation. A sharp curette is sometimes gently used at the very end to verify the emptiness of the cavity. Due to the risk of misdiagnosis and incorrect dating, physicians should confirm and date the intrauterine pregnancy via ultrasound before performing a TAB. Ergonovine maleate (0.2 mg im) and oxytocin (Pitocin) 20–30 U/1000 mL iv can be administered during the procedure to reduce bleeding, although the efficacy of oxytocin has been questioned. The uterus becomes increasingly responsive to oxytocin after 20 wk of gestation. The procedure is performed under local with or without iv sedation or GA; it is generally felt that local is safer. Regardless of the method used, the obtained products of conception (POC) are sent for histologic examination to exclude the presence of trophoblastic neoplasm or ectopic pregnancy.

Variant procedure

Dilatation and evacuation (D&E) remains the safest method for 2nd trimester pregnancy termination. It is performed similarly to 1st trimester suction curettage with the addition of using large-ring forceps to grasp and remove fetal parts intermittently. This procedure is often performed under GA.

Usual preop diagnosis

Pregnancy (viable or nonviable): 52% within 8-wk estimated gestational age; 90% within 12-wk estimated gestational age

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol, and smoking cessation, carb-loading and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE

	1st Trimester Suction Curettage or 2nd Trimester D&E			
Position	Dorsal lithotomy with patient in Allen stirrups. Following induction, the perineum is positioned at end of the table to ensure optimal exposure.			
Incision	None			
Special instrumentation	Suction; + large-ring forceps for 2nd trimester D&E			
Unique considerations	To prevent a peroneal nerve injury, the area of the leg leaning against the stirrup (lateral knee) should be well cushioned. To prevent a femoral nerve injury, prolonged hyperflexion of the hips should be avoided. During cervical dilatation, a vasovagal reaction can occur → ↓ HR + ↓ BP. During injection of lidocaine for paracervical block, seizure may occur. Uterine perforations often will result in excessive postop pain.			
Antibiotics	Doxycycline 100 mg iv			
Surgical time	5–15 min; 15–45 min (2nd trimester D&E)			
EBL	Number week gestation 1–4: 10 mL 5–8: 10–30 mL 9–10: 30–80 mL 11–12: 80–200 mL 13–14: 200–400 mL 300–500 mL (2nd trimester D&E)			
Postop care	PACU			
Mortality	0–3.1/100,000; 13/100,000 (2nd trimester D&E)			
Morbidity	Mild infection Resuctioned day of surgery Resuctioned subsequently Cervical stenosis causing amenorrhea Cervical incompetence Underestimation of gestational age Seizure (after local anesthesia)	1/216 1/553 1/596 1/6071 1/9444 1/15,454 1/25,086	For 2nd trimester D&E T > 38° for >l d Cervical injury Cervical tear Retained POC Hemorrhage UTI	 13.4/1000 11.6/1000 10/1000 9/1000 7.1/1000 1.8/1000
Complications requiring hospitalization	Incomplete abortion Sepsis Uterine perforation Vaginal bleeding Inability to complete Coexisting tubal pregnancy Total	1/3617 1/4722 1/10,625 1/14,166 1/28,333 1/42,500 1/1405	For 2nd trimester D&E Endometritis Uterine perforation Need for laparotomy Need for blood transfusion	 8.5/1000 3.2/1000 2.1/1000 1.9/1000
Pain score	5			

PATIENT POPULATION CHARACTERISTICS	
Age range	15–45 yr
Incidence	Abortions: 14.6/1000 women age 14–44 yr in the United States (2014)
Etiology	Desire for pregnancy termination

ANESTHETIC CONSIDERATIONS FOR D&C, TAB, D&E

PREOPERATIVE

These are among the most common procedures performed in gynecology. Patients presenting for these procedures are generally healthy; however, bleeding and sepsis may alter ASA status.

Cardiovascular	Hemodynamic status may be impaired 2° preop uterine bleeding, and patient may be septic from retained uterine products. **Tests:** As indicated from H&P
Laboratory	Hgb/Hct; consider T&S/T&C; other tests, as indicated from H&P.
Premedication	Consider midazolam 1–2 mg iv.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po. Consider aprepitant 40 mg po for GA patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Local/MAC, regional, and GA all may be appropriate. In the younger patien population, spinal anesthesia may be less desirable because of increased incidence of post dural puncture headache (PDPH).

Local anesthesia

Some obstetricians/gynecologists perform these procedures under local anesthesia. Paracervical block has the potential for inadvertent intravascular administration, with

consequent local anesthetic toxicity.

Regional anesthesia

A T10 sensory level is sufficient to provide anesthesia for procedures on the uterus.

Spinal	0.75% bupivacaine 7.5–12 mg in 8.25% dextrose ± 10–20 mcg fentanyl (IT). (See Anesthetic Considerations for Cesarean Section) If spinal anesthesia is indicated, a pencil-point spinal needle (e.g., Whitacre or Sprotte) should be used to decrease the incidence of PDPH.
Epidural	1.5–2.0% lidocaine with epinephrine 5 mcg/mL (1:200,000), 15–20 mL. Supplemental iv sedation. (See Anesthetic Considerations for Cesarean Section.)
CSE	**Combined spinal/epidural (CSE):** An alternative technique combining the rapid onset and density of spinal anesthesia with the flexibility of continuous epidural anesthesia. Apply monitors, administer fluid, and position patient as for spinal or epidural. The most common technique is the needle-through-needle. After the epidural space is located with a standard 17-ga Tuohy needle, insert a 4-inch 26- to 27-ga pencil-point spinal needle through it to administer 7.5–12 mg of spinal bupivacaine (0.75%) ± fentanyl 10–20 mcg and ± morphine sulfate 0.1–0.2 mg. Secure the epidural catheter and use if needed (a test dose is advisable).

General anesthesia

Induction	Consider full stomach precautions (see p. B-5 for RSI) at 20 wk gestation and beyond. First trimester and early 2nd trimester generally TAB low risk for aspiration based on pregnancy-related changes. Supraglottic airway often appropriate
ERAS	Verify preprocedure antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and

	normothermia.	
Maintenance	Standard maintenance. Consider keeping MAC < 1 to lower the risk of uterine atony + bleeding.	
Emergence	Be ready with suction in the event of vomiting on emergence. Consider NSAIDs iv. Consider ketorolac (15–30 mg) after bleeding is controlled. PONV prophylaxis may include dexamethasone and ondansetron.	
Blood and fluid requirements	Minimal blood loss IV: 18–20 ga × 1 (unless hypovolemic)	Usual replacement of maintenance fluids and overnight deficit with BSS to restore euvolemia. Blood transfusion rarely indicated. See Restricted Fluid Management, Appendix K, p. K-4.
Control of blood loss	Oxytocin 20–30 U/L iv Methylergonovine maleate 0.2 mg im	Oxytocin causes uterine contraction, with a consequent decrease in blood loss. Rapid iv bolus may lead to hypotension. 20–30 U of oxytocin is usually diluted in 1 L of crystalloid and then infused. Methylergonovine maleate also causes uterine contraction. Dose is usually 0.2 mg im. Side effects include HTN, myocardial ischemia, and dysrhythmias. Do not give iv.
Monitoring	Standard monitors	
Positioning	✓ hip, leg, hand position ✓ and pad pressure points ✓ eyes Shoulder abducted	Lithotomy position may worsen pulmonary function. Consider L uterine displacement if >20 wk.

	<90°	
Vagal stimulation	Bradycardia	When the cervix is grasped and dilated, the patient may have excessive vagal stimulation, which can be treated by prompt cessation of stimulation and glycopyrrolate 0.1–0.2 mg iv or, if preferred, atropine 0.2–0.4 mg.
Complications	Nerve injury	Common peroneal nerve palsy (e.g., foot drop) is possible if pressure on the nerve over the fibula is not prevented by adequate padding or positioning. Hyperflexion of the hip joint can cause femoral and lateral femoral cutaneous nerve palsy. Obturator and saphenous nerve injuries are also complications of the lithotomy position.
	Finger trauma	Take care to ensure safety of patient's fingers when manipulating foot of the bed. Avoid finger injury by placing patient's arms on arm boards or by wrapping her hands.
	Laryngospasm	Avoid light anesthesia.

POSTOPERATIVE

Complications	PONV Uterine perforation (rare) Severe hemorrhage,	→ Severe abdominal pain Severe postop bleeding may be caused by uterine atony,

	necessitating blood transfusion (rare)	retained POCs, uterine perforation, or cervical injury.
Multimodal pain management	Oral analgesia IV opiates	Acetaminophen ± opiates, NSAIDs IV fentanyl. With extreme pain, consider uterine perforation.
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition and mobilization.
Tests	Hgb/Hct, if hemorrhage	

Suggested Readings

1. Chapman JS, Roddy E, Ueda S, et al: Enhanced recovery pathways for improvin outcomes after minimally invasive gynecologic oncology surgery. Obstet Gynecol 2016; 128(1):138–44.
2. van den Berg MMJ, Dancet EAF, et al: Patient-centered early pregnancy care: systematic review of quantitative and qualitative studies on the perspectives of women and their partners. Hum Reprod Update 2018; 24(1):106–18.

HYSTEROSCOPY

SURGICAL CONSIDERATIONS

Description

Hysteroscopy is a procedure in which the endometrial cavity is directly visualized via the hysteroscope. The procedure is used primarily to investigate abnormal uterine bleeding, often caused by intrauterine submucous myomata and polyps. After the diagnosis, these lesions can be removed through the operative hysteroscope using a variety of techniques.

Variant procedure or approaches

Diagnostic and operative hysteroscopies can be performed under either GA or local anesthesia with iv sedation. An examination under anesthesia is performed, followed by the insertion of an open-sided speculum and the placement of a tenaculum on the cervix. The cervical canal is dilated until the hysteroscope can be introduced with its sheath

(Fig. 8.2-3). A distension medium—usually a low-viscosity fluid—is then used to provide visualization of the uterine cavity. The most commonly used low-viscosity fluids are NS, sorbitol 3%, mannitol 0.5%, and mannitol 5% solutions. NS is mos commonly used for diagnostic hysteroscopies, whereas the other nonconductive fluids are used for operative hysteroscopies. Certain bipolar operative hysteroscopies also allow the use of NS.

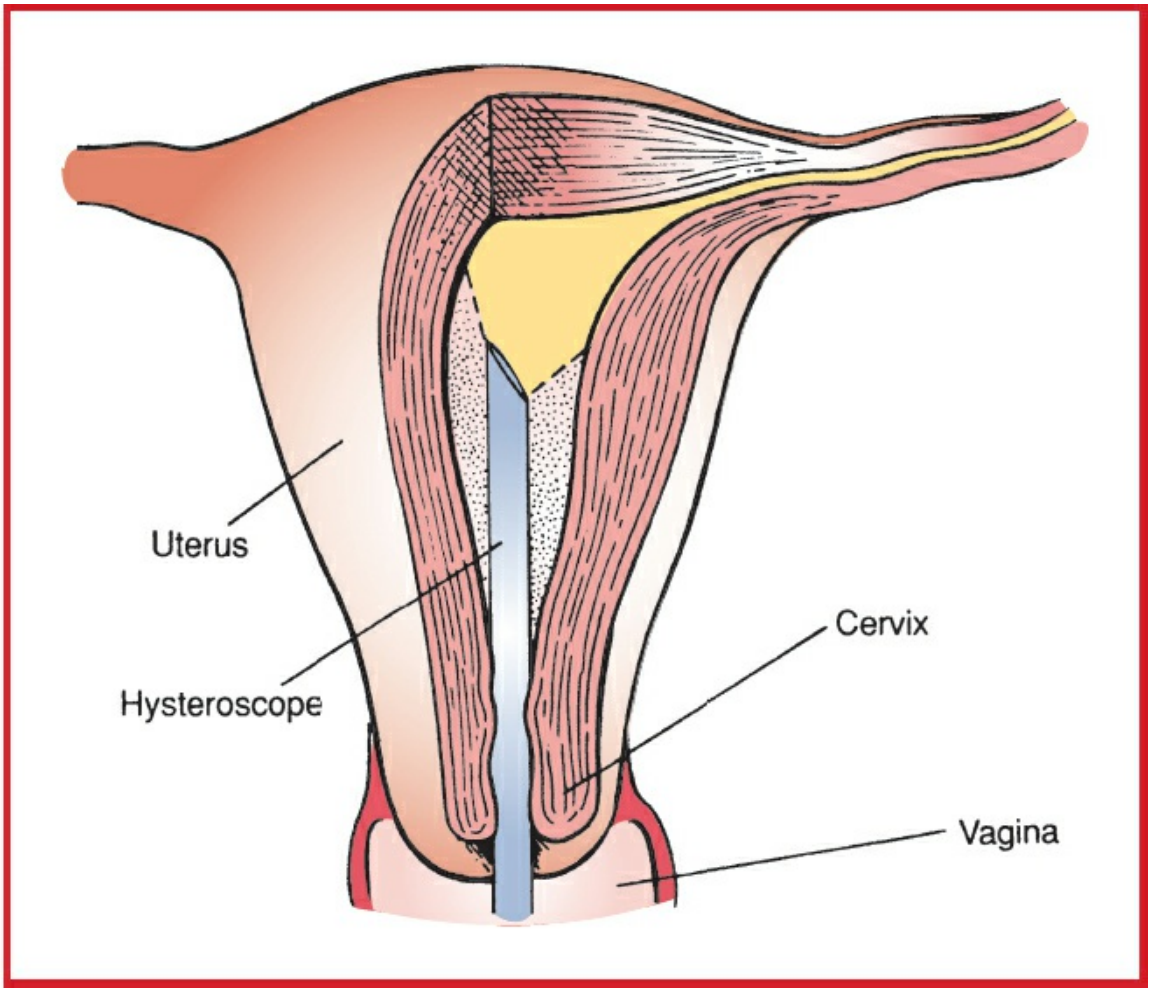

Figure 8.2-3 Hysteroscopy. (Reprinted from Baggish MS, Barbot S, Valle RFDiagnostic & Operative Hysteroscopy, 1st edition. Year Book Medical Publishers, Chicago: 1989. Copyright © 1989 Elsevier. With permission.)

It is important for the surgeon to be vigilant regarding the fluid uptake by closely monitoring the infused volume and the collected volume. Intracervical injection of a dilute vasopressin solution before the procedure reduces media absorption. At a fluid uptake of 500 mL of a hypo-osmolar solution (e.g., sorbitol/mannitol) or 1000 mL of an iso-osmolar solution (e.g., NS), consideration should be given to stopping the procedure given concerns for fluid overload. The maximum fluid deficit of 1000 mL is suggested when using hypotonic solutions and 2500 mL when using isotonic solutions. However,

decisions regarding when to terminate the procedure based on fluid deficit should be individualized based on the patient's condition and comorbidities. Ongoing communication between the surgeon and anesthesiologist is essential, as iv fluids can add to increased circulatory volume and potential fluid overload. Fluid overload can lead to complications such as pulmonary edema and hyponatremia. A rapid increase in fluid deficit can also be a sign of an occult uterine perforation.

The distension medium is delivered to the hysteroscope by means of gravity or by a pump. Most systems use gravity, whereby the fluid is delivered via a wide-bore tubing, and the maximum intrauterine pressure (IUP) is determined by the height of the fluid container above the uterus. The maximum IUP is thus limited by gravity, making this system relatively safe. The lowest IUP necessary to provide adequate visualization should be used to decrease the rate of absorption of the distension medium. If using a pump, the pressure should be set at or just above the patient's mean arterial pressure (MAP). A video camera is usually attached to the hysteroscope to allow for easier visualization. During operative cases, an accompanying laparoscope is sometimes inserted into the abdomen to evaluate the progress of the hysteroscopy and to safeguard against uterine perforation and potential bowel injury. GA is required if a laparoscopy is to be performed concurrently.

Usual preop diagnosis

Abnormal uterine bleeding; infertility; recurrent pregnancy loss

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol, and smoking cessation, carb-loading and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Dorsal lithotomy (Allen stirrups)
Incision	None
Special instrumentation	Fluid pump; laser; electrocautery equipment
Unique considerations	Accelerated fluid absorption with lengthy procedures or with resections may → pulmonary edema. Laparoscopy may accompany this procedure.
Surgical time	15 min–2 h

Antibiotics	None
EBL	0–100 mL
Postop care	Excessive postop bleeding can be controlled by using a 5-mL Foley balloon catheter in the uterus for several hours.
Mortality	Minimal
Morbidity	Pleural effusion can be seen with use of low-viscosity medium.
Pain score	3–5

PATIENT POPULATION CHARACTERISTICS

Age range	20–80 yr
Incidence	>1/50
Etiology	Unexplained uterine bleeding; infertility
Associated conditions	Obesity

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Hysteroscopy may be performed for diagnosis or treatment of intrauterine pathology.

Cardiovascular	As patient may be undergoing hysteroscopy for uterine bleeding, consider hypovolemia and anemia. **Tests:** As indicated from H&P
Laboratory	Hgb/Hct if bleeding Hx. Other tests, as indicated from H&P; consider pregnancy testing.
Premedication	Consider midazolam 1–2 mg iv.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po. Consider aprepitant 40 mg po for GA patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Local, regional, or GA may be used. If spinal anesthesia is indicated, pencil-poin spinal needles (e.g., Sprotte or Whitacre) should be used to decrease the incidence o PDPH.

Local anesthesia

Some procedures may be done under local, usually with supplemental iv sedation, especially if they are diagnostic. Paracervical block has the potential for an inadvertent intravenous administration and local anesthetic toxicity.

Regional anesthesia

A T10 sensory level is sufficient to provide anesthesia for these procedures.

Spinal	0.75% bupivacaine 7.5–10 mg in 8.25% dextrose ± 10–20 mcg fentanyl (See Anesthetic Considerations for Cesarean Section.)
Epidural	1.5–2.0% lidocaine with epinephrine 5 mcg/mL (1:200,000), 15–20 mL; supplemental iv sedation (See Anesthetic Considerations for Cesarean Section.)
CSE	**Combined spinal/epidural (CSE):** An alternative technique combining the rapid onset and density of spinal anesthesia with the flexibility of continuous epidural anesthesia. Apply monitors, administer fluid, and position patient as for spinal or epidural. The most common technique is the needle-through-needle. After the epidural space is located with a standard 17-ga Tuohy needle, insert a 4-inch 26- to 27-ga pencil-point spinal needle through it to administer 7.5–12 mg of spinal bupivacaine (0.75%) ± fentanyl 10–20 mcg and ± morphine sulfate 0.1–0.2 mg. Secure the epidural catheter and use if needed (a test dose is advisable).

General anesthesia

Induction	Standard induction. Supraglottic airway may be appropriate.	
ERAS	Verify preprocedure antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance	
Emergence	Standard emergence. PONV prophylaxis may include dexamethasone and ondansetron.	
Blood and fluid requirements	IV: 18–20 ga × 1 BSS @ 2–4 mL/kg/h	Minimal blood loss. See Restricted Fluid Management, Appendix K, p. K-4.
Positioning	✓ hip, leg, and hand positions ✓ and pad pressure points ✓ eyes Shoulder abduction <90°	Lithotomy position can be deleterious to pulmonary function, as it may impair respiratory mechanics. Common peroneal nerve palsy is possible if pressure on the nerve over the fibula is not prevented by adequate padding or positioning. Hyperflexion of hip joint can cause femoral and lateral femoral cutaneous nerve palsy. Obturator and saphenous nerve injuries are also complications of the lithotomy position.
Monitoring	Standard monitors	
Surgical stimulation	When cervix is grasped and dilated, patient may have excessive vagal nerve stimulation.	Rx: prompt cessation of stimulation by surgeons and treatment with glycopyrrolate (0.1–0.2 mg) or atropine (0.2–0.4 mg)
Complications	Air embolism Pulmonary and cerebral edema	Air embolism can occur with the use of gas distension media; thus, most institutions

	(2° hypotonic fluid overload) Coagulopathy Anaphylactoid reactions	currently use low-viscosity fluids for distension. Low-viscosity media can be grouped as follows, based on their tonicity and electrolyte content: (a) hypotonic, electrolyte-free media that may cause hypotonic fluid overload, and (b) isotonic, electrolyte-containing media that may cause isotonic fluid overload. It is not uncommon to use 10–20 L of distension fluid during an operative hysteroscopy. Monitor for fluid balance. Adjust iv fluid to maintain euvolemia.
	Finger injury (2° positioning)	When manipulating the foot of the bed, avoid finger injury by placing patient's arms on arm boards or by wrapping her hands.

POSTOPERATIVE

Complications	PONV Fluid overload/pulmonary edema from excessive fluid absorption	
Multimodal pain management	Oral analgesics Acetaminophen ± NSAIDs	Patients usually do not require opiate medications.
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6	Encourage early enteral nutrition and mobilization.
Tests	Consider CXR and	For patient with respiratory

	ABG. Serum electrolytes	compromise (rare)

Suggested Readings

1. AAGL Advancing Minimally Invasive Gynecology Worldwide; Munro MG, Storz K et al: AAGL practice report: practice guidelines for the management of hysteroscopic distending media: (Replaces Hysteroscopic Fluid Monitoring Guidelines. J An Assoc Gynecol Laparosc. 2000;7:167-168.). J Minim Invasive Gynecol 2013; 20(2):37–48.
2. Chapman JS, Roddy E, Ueda S, et al: Enhanced recovery pathways for improvin outcomes after minimally invasive gynecologic oncology surgery. Obstet Gynecol 2016; 128(1):138–44.
3. Cooper JM, Brady RM: Intraoperative and early postoperative complications o operative hysteroscopy. Obstet Gynecol Clin North Am 2000; 27(2):247–66.

PELVIC LAPAROTOMY

SURGICAL CONSIDERATIONS

Description

Laparotomy and its variants are all common gynecologic procedures. Laparotomy for benign gynecologic procedures is most frequently performed via a Pfannenstiel incision, which is often used for a cesarean section, thus is familiar for the gynecologic surgeon. A vertical incision is used in oncologic surgery or in the presence of a large uterus or mass. A knife or electrocautery (Bovie) is used to cut through the skin and underlying tissue until the rectus fascia is reached. The fascia is incised and then sharply extended bilaterally 2–4 inches with scissors or Bovie. The rectus muscle is separated sharply in the midline down to the pubis, and the peritoneum is entered. The peritoneal incision is then extended vertically and/or transversely. The pelvis and entire abdominal cavity are explored first by palpation. Then the bowels are usually packed in a cephalad direction with surgical laparotomy sponges (laps) to prevent them from falling back into the pelvis. Good muscle relaxation is important during this stage to ensure optimal packing. A self-retaining retractor is frequently used to keep the lap pads in place and to enhance exposure. After the desired operation has been performed, the retractor and packs are removed. During the peritoneal closure, abdominal muscle relaxation is again important to minimize tension on this layer and risk of bowel injury with the needle. The rectus fascia, the subcutaneous tissue, and the skin are closed in succession.

Variant procedures

Myomectomies are performed to remove myomata that are causing abnormal bleeding, bulk symptoms, infertility, and sometimes pain. Myomata are heavily vascularized at the base, and the surgeon has several ways to minimize this bleeding. A tourniquet can be placed across the uterine vasculature to minimize blood flow to the uterus. A common alternative is the use of a vasoconstrictor, such as a diluted epinephrine (1:200,000) or vasopressin (1–5 U/10 mL NS) solution. The solution (2–10 mL) is injected around the myoma before incising the uterus, which invariably →↑ HR (epi) or ↓ HR (vasopressin) and ↑ BP. Gonadotropin-releasing hormone (GnRH) agonists may be used for a few months before the operation to render the patient hypoestrogenic and, thus, decrease the vascularity of the myomata. After the myomata have been removed, the uterine defects within the myometrium are closed with several layers of suture, and the uterine serosa is then closed.

Ovarian cystectomies are performed to alleviate related pain and associated bulk, also to provide a diagnosis of asymptomatic cysts. Small, single-functional ovarian cysts are found at different stages in a woman's menstrual cycle. At times, these cysts can increase in size and quantity, which may cause severe pain. The ovary can also contain various nonfunctional cysts (e.g., tumors), which should be removed, even if asymptomatic, to exclude malignancy and prevent ovarian torsion or rupture, which may require more urgent surgical intervention. After the pelvic structures are well visualized, the cystic ovary is stabilized with instruments or surgical laps. Sharp or blunt dissection is used to shell out the cyst intact. If there is any suspicion about the nature of the cyst, an intraoperative frozen section is obtained. The ovary is then reapproximated, and the abdomen closed. If the cyst is large and little healthy ovarian stroma remains, or if there is uncontrollable bleeding, an **oophorectomy** is performed.

Ectopic pregnancies are usually surgical emergencies. Laparoscopy is the most common approach, although a laparotomy may be utilized if the patient is unstable from internal hemorrhage. The abdomen is entered, and the pregnancy located quickly. An attempt is made to control the bleeding with the surgeon's hand, clamp, or suture. Frequently, large amounts of blood in the pelvis are suctioned, and the ectopic pregnancy can be removed via a **partial tubal resection**, **salpingostomy**, or **salpingectomy**; then the abdomen is closed. A **D&C** may be performed at the end to prevent late bleeding from the pregnancy-induced endometrial proliferation.

An **abdominal**, **laparoscopic**, **or robotic colpopexy** (fixation of vagina) is utilized to repair vaginal vault prolapse after hysterectomy. The patient is placed in the lithotomy position, usually with Allen stirrups, to perform an examination under anesthesia. A

urethral catheter is initially inserted. Typically, a synthetic graft is used. The bowel is packed, and the defect is examined from the abdominal perspective. Frequently, there is an accompanying enterocele that must be closed initially (see **Moschcowitz procedure**, below). The peritoneum over the vaginal apex is then entered, and the neighboring rectum and bladder are dissected a distance away from the vaginal apex. The peritoneum over the sacrum is incised, and the cephalad end of the graft is sutured to the anterior sacral ligament of the third vertebrae. Severe bleeding can occur if there is injury to the middle sacral artery. The caudal end of the graft is attached to the vaginal apex. The peritoneum and abdomen are closed, and the patient's legs are elevated to the dorsal lithotomy position for a high-posterior **colporrhaphy** (repair of vagina).

The **Moschcowitz procedure** is used to reduce enteroceles via an abdominal approach. The abdomen is entered in the usual fashion, the uterus held up with a traction suture, the bowel packed, and the patient placed in the Trendelenburg position. Multiple concentric purse-string sutures are used to close the defect in the pouch of Douglas, and the abdomen is closed. A McCall procedure can also be performed to prevent enterocele formation. Here, the uterosacral ligaments are plicated and sutured together in the midline, at the level of the pouch of Douglas, to obliterate that space.

A **presacral neurectomy** is an operation performed for women with severe dysmenorrhea and chronic midline pelvic pain. Many patients have had previous surgery and have a diagnosis of endometriosis. The procedure is usually performed laparoscopically. The rectosigmoid is brought over to the left to make a vertical, posterior peritoneal incision over the sacral area. The anatomy is examined closely, and the superior hypogastric plexus is dissected out and obliterated or excised; then the peritoneum and abdomen are closed. Severe bleeding can be seen intraop from the hemorrhoidal and sacral veins but can usually be controlled with pressure.

Usual preop diagnosis

Myomata (pelvic pain, menorrhagia, pelvic pressure symptoms, infertility); ovarian cysts and pelvic pain with undiagnosed ovarian mass; ectopic pregnancy; vaginal vault prolapse; enterocele; presacral neurectomy (chronic pelvic pain)

ERAS: Preop counseling by the surgeon/anesthesiologist should include no bowel prep, limiting NPO duration, alcohol, and smoking cessation, review of nutritional status, discussion of carb-loading DVT prophylaxis, postop pain management options, physiotherapy plan, and possibility of urinary catheter postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine or lithotomy
Incision	Pfannenstiel or low midline abdominal laparoscopic or robotic incisions
Unique considerations	Muscle relaxation is important during bowel packing and abdominal closure. Vasoconstrictor solutions for controlling myomata bleeding (1:200,000 epinephrine and 1–5 U vasopressin/10 mL NS) are often used and can alter BP and HR.
Antibiotics	Cefoxitin 1–2 g iv
Surgical time	45 min–4 h Abdominal colpopexy: 4–5 h
EBL	50–1000 mL (maximum related to procedure)
Postop care	PACU
Mortality	Minimal
Morbidity	Gastric dilatation: 3% Thrombophlebitis: 3% PE: 2% Ureteral stenosis: 1%
Pain score	8

PATIENT POPULATION CHARACTERISTICS

	Myomectomy	Ovarian Cystectomy, Oophorectomy	Ectopic Pregnancy	Abdominal Colpopexy, Moschcowitz	Presacral Neurectomy
Age range	20–45 yr	20–85 yr	15–45 yr	40–80 yr	20–50 yr
Incidence	>1/5 females	⇐	1/100 females	1/500 females	⇐
Etiology	Congenital	Endometriosis Anovulation Adenoma	Preexisting tubal disease	Multiparous Obesity Chronic cough Older age group	Endometriosis
Associated conditions	Menorrhagia and pelvic symptoms associated with bulk	Endometriosis	Pelvic adhesions	Pelvic relaxation	Endometriosis

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Infertility Operations.

Suggested Readings

1. Allen RH, Micks E, Edelman A: Pain relief for obstetric and gynecologic ambulatory procedures. Obstet Gynecol Clin North Am 2013; 40(4):625–45.
2. Nelson G, Dowdy SC, Lasala J, et al: Enhanced recovery after surgery (ERAS) in gynecologic oncology—practical considerations for program development. Gynecol Oncol 2017; 147(3):617–20.
3. Verheijen R, Zweemer R: Robotic surgery for gynaecologic cancer: an overview. Curr Oncol Rep 2012; 14(6):544–9.

TRANSVAGINAL OOCYTE RETRIEVAL

SURGICAL CONSIDERATIONS

Description

Transvaginal oocyte retrieval (TVOR) is performed on patients who have undergone ovarian stimulation using ovulation-inducing agents. This procedure is performed 35–36 h after the patient has been injected with human chorionic gonadotropin (HCG) and/or leuprolide acetate to induce oocyte maturation. It is crucial for the success of the procedure that the retrieval is performed within this time period. If a retrieval is

performed too late, ovulation will have occurred, and oocyte retrieval will no longer be possible.

The patient should empty her bladder just before the procedure to facilitate visualization with transvaginal ultrasound. In the procedure room, the patient is placed in the dorsal lithotomy position, and moderate to heavy iv sedation is started. A sterile speculum is inserted into the vagina, and a vaginal prep is performed with sterile saline irrigation as other bactericidal preparations may also be harmful to the oocytes. Next, an ultrasound probe with a 16- to 17-ga needle on a needle guide is placed into the patient's vagina. One of the ovaries is identified and entered by inserting the needle through the vaginal fornix. Patients may experience a combination of pain and pressure at this point in the procedure. After the needle is in the ovary, the surgeon will then proceed with sequential aspiration of the ovarian follicles. It is important that the patient remain relaxed and motionless as movement may prevent aspiration of oocytes and increase the risk of injury to the surrounding organs and vessels. After retrieval is completed in the first ovary, the needle is withdrawn; the other ovary is identified, and a second puncture is made through the vaginal fornix. Procedure duration is 10–30 min, depending on the number of follicles present. After all of the follicles have been aspirated, the needle and ultrasound probe are removed. A sterile speculum is then reintroduced into the vagina, and the vaginal wall and cervix are inspected for hemostasis. Pressure is applied for 3–5 min if bleeding is noted. The patient is then recovered for 30–60 min before going home. If the patient is undergoing an embryo transfer within the same menstrual cycle (fresh embryo transfer), NSAIDs are contraindicated intra- or postoperatively.If the patient is planning to cryopreserve oocytes or embryos for later use, and hemostasis is adequate, NSAIDs are appropriate.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol, and smoking cessation, carb-loading and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Dorsal lithotomy
Incision	Vaginal punctures (usually 2)
Special instrumentation	Ultrasound probe with needle guide, 16- to 17-ga needle
Unique considerations	Requires complete relaxation/sedation to prevent injury and loss of oocyte during follicle aspiration

Antibiotics	Cefotetan or cefazolin 2 g iv before incision
Procedure time	Setup: 5–10 min Procedure: 10–30 min (depending on number of follicles)
Postop care	PACU→home
Morbidity	Bleeding: rare Infection: rare
Pain score	1–3 (abdominal cramping)

PATIENT POPULATION CHARACTERISTICS	
Age range	18–50 yr (rare after age 43)
Incidence	It is estimated that at least 10–15% of American couples of reproductive age who desire pregnancy are unable to conceive within 1 yr.
Etiology	A male factor is responsible for 1/3 of cases and female factor 1/3, and 1/3 are a combination or unexplained.
Associated conditions	Thyroid disorders; polycystic ovarian syndrome; endometriosis; tubal disease; depression

Suggested Reading

1. Rose BI: Approaches to oocyte retrieval for advanced reproductive technology cycles planning to utilize in vitro maturation: a review of the many choices to be made. J Assist Reprod Genet 2014; 31(11):1409–19.

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

This is generally a healthy patient population. Little is required beyond routine tests unless otherwise indicated.

Laboratory	Tests as indicated from H&P
Premedication	Consider midazolam 1–2 mg iv.
ERAS	Check compliance with presurgical ERAS

	recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg. Consider aprepitant 40 mg po for patients with h/o severe PONV.	

INTRAOPERATIVE

Anesthetic technique

Moderate to heavy IV sedation with propofol effective and most commonly used technique for IVF. Local anesthetic and mild to moderate sedation with midazolam +/- fentanyl an alternative if propofol sedation contraindicated. The most stimulating parts of the procedure occur when the vaginal fornix is pierced on each side and when the ovarian follicles are entered for aspiration of the eggs.

MAC	Propofol infusion (50–200 mcg/kg/min), ± midazolam (1–2 mg iv), and ± fentanyl titrated to achieve the desired combination of moderate to heavy sedation and analgesia.	
Blood and fluid requirements	Minimal blood loss IV: 20–22 ga × 1	See Restricted Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	
Positioning	✓ hip, leg, and hand positions ✓ and pad pressure points	

POSTOPERATIVE

Complications	PONV Bleeding: rare	PONV rare with propofol-based TIVA. Minimal postop pain → limit intraop opiates.
Multimodal pain management	Pain: usually minimal	Oral analgesics (e.g., acetaminophen, NSAIDs) are usually sufficient occasionally supplemented with fentanyl (25–50 mcg iv).
ERAS	PONV protocol (see	Encourage early enteral

Appendix B, p. B-4 and p. B-6) nutrition and mobilization.

Suggested Readings

1. Chapman JS, Roddy E, Ueda S, et al: Enhanced recovery pathways for improvin outcomes after minimally invasive gynecologic oncology surgery. Obstet Gynecol 2016; 128(1):138–44.
2. Hadimioglu N, Titiz TA, Dosemeci L, et al: Comparison of various sedatio regimens for transvaginal oocyte retrieval. Fertil Steril 2002; 78(3):648–9.
3. Matsota P, Kaminioti E, Kostopanagiotou G: Anesthesia related toxic effects on i vitro fertilization outcome: burden of proof. Biomed Res Int 2015; 2015:475362.
4. Van de Velde M: Anesthesia for in-vitro fertilization. Curr Opin Anaesthesiol 2005; 18(4):428–30.

INFERTILITY OPERATIONS/ASSISTED REPRODUCTIVE TECHNOLOGIES

SURGICAL CONSIDERATIONS

Description

These operations all deal with reproductive problems. The general trend is to avoid laparotomies and to perform operations using outpatient laparoscopy and hysteroscopy techniques whenever possible.

Fimbrioplasty is used to repair distal fallopian tubal occlusion—a common cause for infertility—which is usually a consequence of pelvic inflammatory disease (PID). The operation may be performed by **pelvic laparotomy** or **laparoscopy**. A urethral catheter is inserted to empty the bladder, followed by the insertion of a transcervical uterine catheter for chromopertubation (dye injection). The abdomen is opened, and the pelvic structures are exposed. During the operation, microsurgical techniques are followed closely to minimize trauma. Meticulous hemostasis is important. A wound protector is often used instead of self-retaining retractors. The peritoneum and pelvic structures are kept moist with intermittent irrigation. **Salpingolysis** and **ovariolysis** may be performed microsurgically. After the adnexae have been freed, they are elevated by loosely packing the pouch of Douglas with insulated pads (plastic sheathed covered laps). **Chromopertubation** is then performed, and if occlusion is present, a new stoma is created using microsurgical instruments and sutures. The abdomen is then closed.

Tubal reanastomosis, performed to restore fertility, is very similar to fimbrioplasty, with microsurgical techniques followed diligently. After the tubal segments have been freed slightly from their underlying mesosalpinx, the occluded ends are cut, and chromopertubation is performed to ensure patency. After patency has been established, anastomosis is performed in two layers. The mesosalpinx is reapproximated to the tubal serosa and the abdomen closed.

The uterus is embryologically formed by the fusion of two paramesonephric tubes. At times, the fusion is incomplete, and a septated uterus or bicornuate uterus is formed. The malformed uterus is associated with an increased risk for miscarriages and preterm labor. **Metroplasty** is used to correct this condition. The **Strassman procedure** (extremely rare) for bicornuate uteri uses a standard pelvic laparotomy. Following uterine exposure, an incision is made on the medial side of each hemicorpus and carried down until the uterine cavity is entered. The edges are reapproximated to form a single uterus. Septated uteri are usually repaired via a hysteroscopic approach (see Hysteroscopy) with scissors or laser.

Proximal tubal cannulation is a procedure in which proximal tubal occlusion can be repaired through either fluoroscopic or hysteroscopic approach. The hysteroscopic approach, usually performed under GA, allows the surgeon to insert a small cannula to restore tube patency. This procedure is often done with laparoscopy to follow the progress of the cannulization and to visualize the chromopertubation (see Hysteroscopy and Laparoscopy).

Gamete intrafallopian transfer (GIFT),**zygote intrafallopian transfer** (ZIFT), and **tubal embryo transfer** (TET) are methods of**assisted reproductive technology (ART) but are seldom used**. Couples who have undergone extensive infertility workups and treatment without success may become candidates for GIFT, ZIFT, or TET procedures. Ovarian follicles are stimulated to grow with the help of gonadotropins. These follicles are then punctured with a needle transvaginally to "harvest" the eggs. These eggs can be mixed with semen and placed directly into the distal end of the fallopian tube (GIFT) using laparoscopic techniques and a small tubal catheter (see Laparoscopy). In the ZIFT and TET procedures, the semen and eggs are allowed to incubate 1–2 d in vitro; embryos form and are transferred to the fallopian tubes like GIFT procedure. Most patients undergoing ART procedures utilize conventional in vitro fertilization (IVF) and do not need laparoscopy.

Usual preop diagnosis

Infertility; history of recurrent pregnancy loss and preterm labor

ERAS: **For elective procedures, preop counseling by the surgeon/anesthesiologist should include no bowel prep, limiting NPO duration, alcohol, and smoking cessation, discussion of carb-loading DVT prophylaxis, postop pain management options, physiotherapy plan, and possibility of urinary catheter postop.** **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE

(For summaries of specific procedures, see Laparoscopy; Hysteroscopy; or Pelvic Laparotomy.)

PATIENT POPULATION CHARACTERISTICS

Age range	18–50 yr
Incidence	1/20 women
Etiology	PID; endometriosis; idiopathic
Associated conditions	Obesity

ANESTHETIC CONSIDERATIONS

(Procedures covered: pelvic laparotomy for myomectomy; ovarian cystectomy; oophorectomy; ectopic pregnancy removal; abdominal colpopexy; Moschcowitz enterocele repair; presacral neurectomy; infertility operations.)

PREOPERATIVE

This is generally a healthy patient population; however, this procedure can be performed for a wide variety of pathologic conditions.

Cardiovascular	Patients undergoing myomectomy and, especially, ectopic pregnancy removal may have had a significant amount of preop bleeding; therefore, assess for hypovolemia. Preexisting comorbidities and preop status will vary considerably. Assess as appropriate. **Tests:** As indicated from H&P
Laboratory	Hgb/Hct. Consider T&S/T&C. Patients with ectopic

	pregnancy may have urine/serum pregnancy tests as well as pelvic ultrasound.
Premedication	Patients with ruptured ectopic pregnancies may come to the OR urgently and should be treated with full stomach precautions.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of a transversus abdominis plane or epidural block/analgesia for postop pain management. Consider preop acetaminophen 1000 mg, ± gabapentin 300 mg, ± celecoxib 200 mg po. Consider aprepitant 40 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA is indicated for patients undergoing laparoscopic surgery and in patients presenting for emergency surgery. Neuraxial anesthesia is best avoided in hemodynamically unstable patients (i.e., ectopic pregnancies) and for laparoscopy where breathing difficulty may develop 2° to pneumoperitoneum and Trendelenburg position. Regional anesthesia may be suitable for simple pelvic laparotomies. In the younger patient population, spinal anesthesia is less desirable because of an increased incidence of postdural puncture headache (PDPH). If spinal anesthesia is indicated, a pencil-point needle (e.g., Whitacre, Sprotte) should be used to decrease the incidence of PDPH.

General anesthesia

Induction	Standard induction: In a patient with a ruptured ectopic pregnancy, bleeding, and hemodynamic instability, consider ketamine 1–2 mg/kg or etomidate 0.1–0.4 mg/kg. These patients are generally considered unfasted and would require rapid-sequence induction. Use OGT/NGT to decompress the stomach after induction for laparoscopic surgery.
ERAS	Verify preincision antibiotics. Assess volume status

	(see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance. Consider PONV prophylaxis.
Emergence	Standard emergence. Discuss with surgeon local wound infiltration. Consider iv acetaminophen if po dose given >6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.

Regional anesthesia

A T4-T6 sensory level is recommended for pelvic/lower abdominal surgery.

Spinal	0.75% bupivacaine 12–14 mg in 8.25% dextrose (see Anesthetic Considerations for Cesarean Section) + 10–20 fentanyl ± 0.1–0.2 mg morphine	
Epidural + narcotic	1.5–2.0% lidocaine with epinephrine 5 mcg/mL, 15–20 mL; redose with 3–5 mL as needed. Provide supplemental iv sedation. (See Anesthetic Considerations for Cesarean Section)	
CSE	**Combined spinal/epidural (CSE):** An alternative technique combining the rapid onset and density of spinal anesthesia with the flexibility of continuous epidural anesthesia. Apply monitors, administer fluid, and position patient as for spinal or epidural. The most common technique is the needle-through-needle. After the epidural space is located with a standard 17-ga Tuohy needle, insert a 4-inch 26- to 27-ga pencil-point spinal needle through it to administer 12–14 mL of spinal bupivacaine (0.75%) ± fentanyl 10–20 mcg ± morphine sulfate 0.1–0.2 mg. Secure the epidural catheter and use if needed (a test dose is advisable).	
Blood and fluid requirements	Blood loss variable IV: 16–18 ga × 1–2 BSS @ 4–7 mL/kg/h	Blood loss will vary by procedure. Generally limited unless ruptured ectopic pregnancy or vascular complication of laparoscopy.

		See Goal-Directed Fluid Management, p. K-4.
Control of blood loss	Epinephrine Vasopressin	During myomectomies, surgeons may inject vasopressors into the area surrounding myomata before excision. This may cause HTN, ↑ HR (epic), or ↓ HR (vasopressin).
Monitoring	Standard monitors ± Foley catheter ± Arterial catheter	Patients with ectopic pregnancies may need intra-arterial monitoring if major hemorrhage occurs.
Positioning	✓and pad pressure points ✓eyes	During abdominal colpopexy, patient is placed intermittently in both the lithotomy and supine positions. (See p. 895 and p. 899 for concerns regarding the lithotomy position.)
Complications	Pneumoperitoneum ↑ $PaCO_2$, ↓ PaO_2 ETT migration	Pneumoperitoneum with CO_2 insufflation and steep Trendelenburg position cause cephalad displacement of diaphragm with ↓ FRC, ↓ pulmonary compliance, and ↑ airway closure/atelectasis. Hypercarbia and hypoxia, due to respiratory compromise, can result unless ventilation is controlled during GA. Check for endobronchial migration of ETT upon assumption of Trendelenburg position.
	Pneumothorax	Pneumothorax due to retroperitoneal dissection of

		insufflated gas into the mediastinum can cause hypoxemia, ↑ airway pressure, subcutaneous emphysema, and ↓ BP.
	↓BP	↓ BP can result from ↓ venous return caused by pneumoperitoneum.
	Hemorrhage Dysrhythmias Peripheral nerve injury	Hypotension may result from hemorrhage or rapid reversal of head-down position.
	Venous CO_2 embolism	Unintended intravascular injection of CO_2 gas can → ↓ BP and dysrhythmias.

POSTOPERATIVE

Complications	PONV Anemia Shoulder pain	
Multimodal pain management	Regional analgesia PCA	Emphasize multimodal approach combining nonopioid ± bolus/PCA opioid analgesics with epidural analgesia and/or TAP blocks (see Appendix K, p. K-2).
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early (within 24 h) enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum may promote return of bowel function.
Tests	Hgb/Hct	If hemorrhage occurs

ANESTHETIC CONSIDERATIONS FOR ASSISTED

REPRODUCTIVE TECHNOLOGIES (ART)

PREOPERATIVE

This is generally a fit, healthy patient population. Little is required beyond routine tests unless otherwise indicated.

Laboratory	Tests as indicated from H&P
Premedication	Standard premedication
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider aprepitant 40 mg po for GA patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Conscious sedation, local anesthesia, and regional (e.g., spinal and epidural) and GA all have been employed for ART. The standard IVF technique consists of transvaginal egg retrieval and embryo transfer (not laparoscopic technique), and one study suggests higher pregnancy and delivery rates if iv sedation or epidural anesthesia is used as opposed to GA. Laparoscopy is only performed for GIFT, ZIFT, or TET, but not fo IVF. For TVOR, use moderate → heavy iv sedation. For laparoscopic procedures breathing difficulty can develop due to pneumoperitoneum and Trendelenburg position. Therefore, GETA with controlled ventilation is most commonly used. No difference ir pregnancy rates with the use of isoflurane, propofol, N_2O, or midazolam has been demonstrated.

Induction	Standard induction. Avoidance of succinylcholine may decrease postop myalgia.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance. N_2O does not appear to adversely affect success of fertilization.
Emergence	No special considerations. PONV prophylaxis should include dexamethasone and ondansetron.

Blood and fluid requirements	Minimal blood loss IV: 18 ga × 1 BSS @ 2 mL/kg/h	Blood loss minimal, unless trauma to vasculature. Rarely, trauma to blood vessels or organs following laparoscopy may necessitate laparotomy. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	
Positioning	✓and pad pressure points ✓eyes	
Complications	Ventilatory	Pneumoperitoneum with CO_2 and steep Trendelenburg position cause cephalad displacement of the diaphragm with ↓ FRC, ↓ pulmonary compliance, and ↑ airway closure/atelectasis. Hypercarbia and hypoxia, due to respiratory compromise, can result unless ventilation is controlled during GA. Check for endobronchial migration of ETT upon assumption of Trendelenburg position.
	Pneumothorax	Pneumothorax due to retroperitoneal dissection of insufflated gas into the mediastinum can cause hypoxemia, ↑ airway pressure, subcutaneous emphysema, and ↓ BP.
	Cardiovascular	↓ BP may result from ↓ venous return 2° pneumoperitoneum.
	Hemorrhage	Hemorrhage may result from

		blood vessel injury or rapid reversal of head-down position.
	Venous CO_2 embolism Dysrhythmias Nerve injury Bowel injury	Unintended intravascular injection of CO_2 gas → ↓ BP and dysrhythmias. Use of Trendelenburg position incurs risk of nerve injury. Hyperextension of the arm may result in brachial plexus injury, and careful padding of vulnerable points is necessary.

POSTOPERATIVE

Complications	Shoulder pain	Postop pain may be referred to the shoulder, due to irritation of the diaphragm by residual pneumoperitoneum or bleeding.
Multimodal pain management	Oral analgesics are usually sufficient.	NSAIDs or acetaminophen
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early (within 24 h) enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis.

Suggested Readings

1. Allen RH, Micks E, Edelman A: Pain relief for obstetric and gynecologic ambulatory procedures. Obstet Gynecol Clin North Am 2013; 40(4):625–45.
2. Beilin Y, Bodian C, Eisenkraft J, et al: The use of propofol, nitrous oxide, or isoflurane does not affect the reproductive success rate following gamete intrafallopian transfer (GIFT). Anesthesiology 1999; 90:36–41.
3. Meyer LA, Lasala J, Iniesta MD, et al: Effect of an enhanced recovery after surgery program on opioid use and patient-reported outcomes. Obstet Gynecol 2018;

132(2):281–90.
4. Modesitt SC, Sarosiek BM, Trowbridge ER, et al: Enhanced recover implementation in major gynecologic surgeries: effect of care standardization. Obstet Gynecol 2016; 128(3):457–66.
5. Nelson G, Altman AD, Nick A, et al: Guidelines for pre- and intra-operative care in gynecologic/oncology surgery: enhanced recovery after surgery (ERAS®) Society recommendations—Part I. Gynecol Oncol 2016; 140(2):313–22.
6. Nelson G, Altman AD, Nick A, et al: Guidelines for postoperative care in gynecologic/oncology surgery: enhanced recovery after surgery (ERAS®) Society recommendations—Part II. Gynecol Oncol 2016; 140(2):323–32.
7. Nelson G, Dowdy SC, Lasala J, et al: Enhanced recovery after surgery (ERAS®) in gynecologic oncology—practical considerations for program development. Gynecol Oncol 2017; 147(3):617–20.

HYSTERECTOMY—VAGINAL, ABDOMINAL, LAPAROSCOPIC, OR ROBOTIC

SURGICAL CONSIDERATIONS

Description

Hysterectomy is one of the most commonly performed operations in the United States (650,000/yr). Several approaches are possible: vaginal, abdominal, laparoscopic, and robotic. The **vaginal approach**, performed with the patient in a dorsal lithotomy position, is preferred because it offers significantly less morbidity and mortality. Use of the vaginal approach may be limited by such factors as the pelvic bony architecture, excessive uterine size, pelvic adhesions, or the presence of gynecologic cancers, thus requiring an **abdominal or laparoscopic/robotic approach.** The approach may be changed in the OR, where a pelvic examination under anesthesia will determine the actual uterine size, degree of prolapse, and the presence of pelvic pathology. More recently, minimally invasive approaches with laparoscopy and robotic surgery have allowed for decreased morbidity and recovery time when compared to an abdominal approach. For a **total laparoscopic**, **laparoscopic-assisted**, **or robotic-assisted hysterectomy**, patients are placed in a low lithotomy position, and abdominal entry is confirmed with the laparoscope once the abdomen has been insufflated. The procedural steps are identical to the abdominal approach. For a laparoscopic or robotic-assisted hysterectomy, the patient is placed in a Trendelenburg position. Pelvic organ prolapse (POP) is the most frequent preoperative diagnosis in patients having a vaginal

hysterectomy. POP includes one or more of the following: prolapse of the uterus, intestine into the pouch of Douglas (enterocele), bladder into the anterior vaginal wall (cystocele), urethra into the anterior vaginal wall (urethrocele), and rectum into the posterior vaginal wall (rectocele). In these cases, the hysterectomy is often accompanied by an anterior/posterior **colporrhaphy**, **vault suspension**, and **perineoplasty**.

Variant approaches

Abdominal hysterectomy is performed through a Pfannenstiel or vertical midline incision, depending on the uterine size and the need to perform a **lymph node dissection** for cancer. A Pfannenstiel incision often can be extended with two types of muscle-splitting steps: the **Maylard**, in which the rectus muscles are cut, or a **Cherney rectus muscle detachment** performed at the pubic insertion. After entering the abdomen, a self-retaining retractor is placed, and the round, ovarian, and broad ligaments are clamped, cut, and tied, in that order. The uterine vessels are identified and ligated, then ligation of the uterosacral and cardinal ligaments is performed. The vagina is entered and the cervix removed. Then, the vaginal cuff is closed in a way that should incorporate the uterosacral ligaments for pelvic support. The visceral peritoneum is reapproximated, the retractors are removed, and the abdominal layers are closed. During a **supracervical hysterectomy**, the uterine corpus is detached from the cervix, and the vagina is not entered.

In a **vaginal hysterectomy**, the cervix is retracted, a paracervical incision is made, and the anterior and posterior cul-de-sacs are entered (Fig. 8.2-4). The uterosacral and cardinal ligaments and the uterine vessels are cut and ligated. With steady downward traction, the broad ligament is ligated in a stepwise manner until either the ovarian or infundibulopelvic ligament is reached, and one of the two is ligated, depending on whether the ovaries are to be removed or not. After the uterus has been removed, closure of the vaginal cuff follows, which often includes the uterosacral and cardinal ligaments for support. A vaginal pack often is left in place. **Laparoscopic-assisted vaginal hysterectomy (LAVH)** is sometimes performed to facilitate a unilateral or bilateral salpingo-oophorectomy (USO or BSO) or perform any adnexal surgery by ensuring good visualization of the infundibulopelvic and utero-ovarian ligaments as well as ovarian vessels. Once the abdomen is entered, the ureters are identified as they cross the iliac vessels at the level of the pelvic brim. The infundibulopelvic or utero-ovarian ligaments are then coagulated and cut. The remainder of the procedure is performed vaginally, including entry into the peritoneum, ligation of the ovarian vessels, and suturing of the vaginal cuff. Once the vaginal cuff is closed, and pneumoperitoneum achieved, the surgeon can look into the abdomen through the laparoscope to ensure

hemostasis at the end of the case.

For a **total laparoscopic hysterectomy (TLH)**, with or without robotic assistance, the entire procedure is performed laparoscopically. Some surgeons may prefer to suture the cuff vaginally. The uterine specimen is removed vaginally, either intact or after morcellation.

Usual preop diagnosis

Uterine myoma; pelvic organ prolapse; pelvic pain 2° endometriosis or adhesions; uncontrolled uterine bleeding/dysmenorrhea; endometrial hyperplasia; gynecologic cancers; pelvic masses

ERAS: Preop counseling by the surgeon/anesthesiologist should include no bowel prep, limiting NPO duration, alcohol, and smoking cessation, review of nutritional status, discussion of carb-loading DVT prophylaxis, postop pain management options, physiotherapy plan, and possibility of urinary catheter postop. **See Appendix K, p. K-1.**

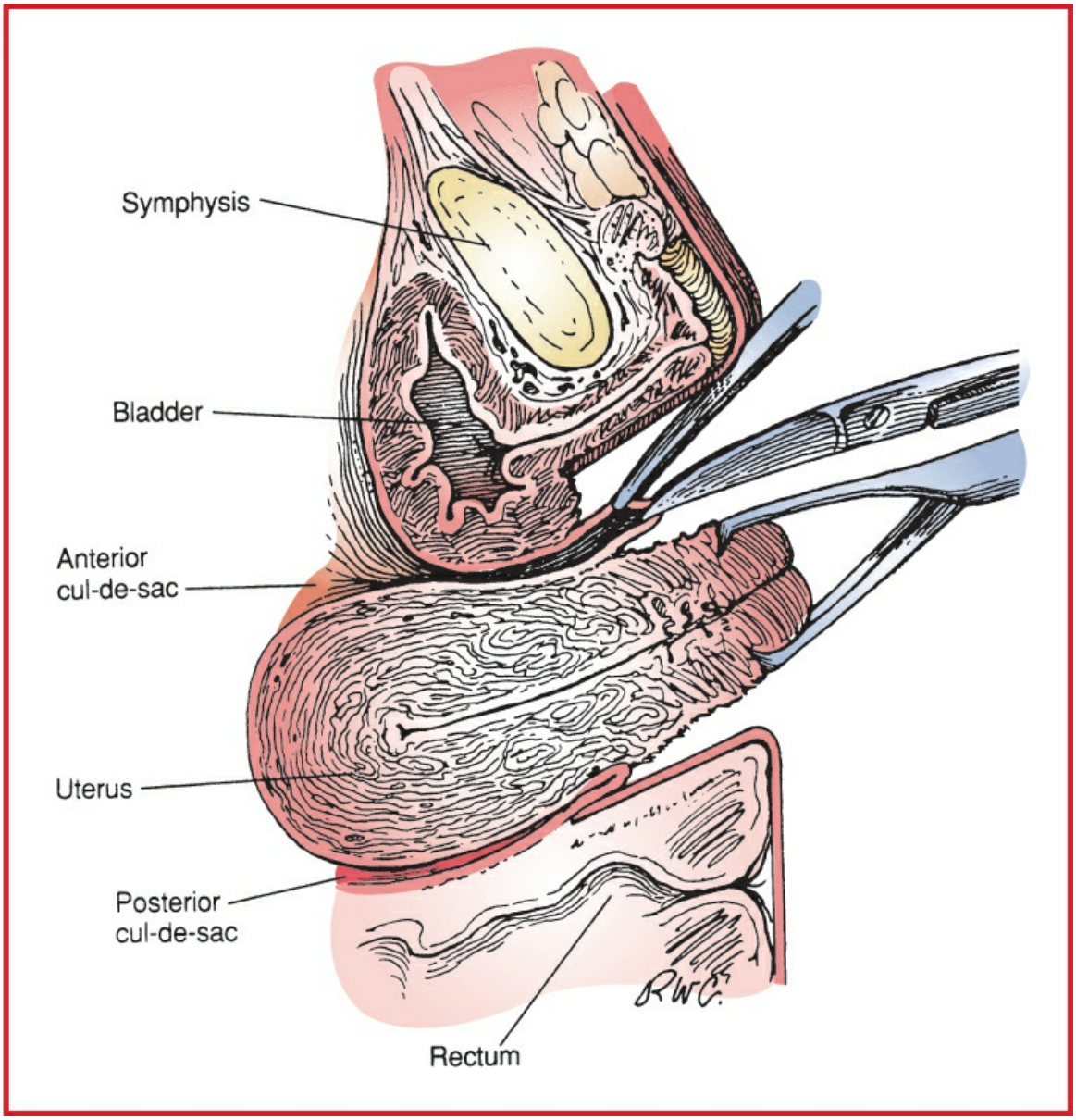

Figure 8.2-4 Surgical anatomy for vaginal hysterectomy. (Reproduced with permission from Rock JA, Thompson JD, eds: TeLinde's Operative Gynecology, 8th edition. Lippincott-Raven, Philadelphia: 1997.)

Summary of Procedures

	Abdominal Approach	Vaginal Approach
Position	Supine	Lithotomy. Following induction, position patient so that the perineum is at the end of the operating table to ensure optimal surgical exposure.
Incision	Pfannenstiel, low vertical midline, or	Pericervical, vaginal

	laparoscopic. The Pfannenstiel incision can be extended with a Maylard muscle-splitting procedure or a Cherney rectus muscle detachment at pubic insertion.	
Special instrumentation	None	Stirrups
Unique considerations	None	To prevent peroneal nerve injury, the area of leg leaning against stirrup should be well cushioned. Often, vasoconstriction agents (1:200,000 epinephrine and vasopressin) are used to cut down perioperative vaginal cuff bleeding.
Antibiotics	Cefoxitin or cefotetan 2 g iv + clindamycin 600 mg iv	⇐
Surgical time	1–2 h	45 min–1.5 h
EBL	200–300 mL	100–200 mL
Postop care	PACU	⇐
Mortality	Overall (10,000 patients): 14.6	20
	<25 yr: 8.9	0
	25–34 yr: 4.7	0.9
	35–44 yr: 3.8	0.5
	45–54 yr: 6.5	2.7
	55–64 yr: 41.3	1.9
	65–74 yr: 93.0	18.3

	>75 yr: 255.8	56.8
Morbidity	Infection	⇐
	Unexplained fever: 10–20%	5–8%
	Pelvic infection: 3.2–10%	3.9–10%
	Wound infection: 4–8%	–
	Urinary tract infection: 1.1–5%	1.7–5%
	Femoral nerve injury: 11.6%	–
	Hemorrhage	⇐
	Intraop: 1–2%	0.7–2–5%
	Requiring transfusion: 2–12%	2–8.3%
	Unintended major procedures: 1.7%	5.1%
	Injury	⇐
	Bladder: 1–2%	0.5–1.5%
	Bowel: 0.1–0.5%	0.1–0.8%
	Ureter: 0.1–0.5%	0.05–0.1%
	Vesicovaginal fistula: 0.1–0.2%	⇐
	Thromboembolic events: 0.4–1.3%	0.62–1.7%
Pain score	5–8	4–6

PATIENT POPULATION CHARACTERISTICS

Age range	30–80 yr
Incidence	>1/5 females; 650,000/yr in the United States
Etiology	Uterine myomata; endometriosis; uterine prolapse; uterine cancer; pelvic mass
Associated conditions	Stress urinary incontinence; obesity

Suggested Reading

1. Moen M: Hysterectomy for benign conditions of the uterus: total abdominal hysterectomy. Obstet Gynecol Clin North Am 2016; 43(3):431–40.

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Although many patients presenting for this procedure are otherwise healthy, others may have advanced cancer.

Respiratory	CXR may be indicated to r/o pleural effusion or other lung pathology in cancer patients. Also, ABG, ± PFTs, may be indicated preop in patients with significant pulmonary involvement. **Tests:** As indicated from H&P
Cardiovascular	Patient may have blood loss from the primary problem. Bowel prep may cause dehydration and electrolyte abnormalities. **Tests:** As indicated from H&P
Hematologic	Hgb/Hct. Consider T&S/T&C.
Laboratory	Consider pregnancy testing. Other tests, as indicated from H&P
Premedication	Consider midazolam 1–2 mg iv.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of a transversus abdominis plane or epidural block/analgesia for postop pain management. Consider preop

	acetaminophen 1000 mg, ± gabapentin 600 mg, ± celecoxib 200 mg po. Consider aprepitant 40 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Increasingly, these procedures are done laparoscopically or robotically. Thus, GA would be the preferred anesthetic technique. Spinal, epidural, or combined spinal-epidural (CSE) anesthesia may be appropriate for normovolemic patients undergoing simple hysterectomy through a Pfannenstiel incision or vaginal hysterectomy. If spinal anesthetic is indicated, a pencil-point needle (e.g., Sprotte or Whitacre) should be used to decrease the incidence of PDPH.

General anesthesia

Induction	Standard induction
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance. Muscle relaxation is necessary if the procedure is performed abdominally. These patients have a high incidence of PONV; consider ketamine (0.5 mg/kg bolus + 5 mcg/kg/min infusion).
Emergence	Standard emergence. PONV prophylaxis should include dexamethasone and ondansetron.

Regional anesthesia

A T4-T6 sensory level is sufficient to provide anesthesia for procedures on the uterus.

Spinal	0.75% bupivacaine 10–15 mg in 8.25% dextrose ± fentanyl 10–20 mcg; ± morphine 0.1–0.2 mcg. (See Anesthetic Considerations for Cesarean Section.) Supplement with iv sedation.
Epidural	1.5–2.0% lidocaine with epinephrine 5 mcg/mL (1:200,000), 15–20 mL; supplement with 3–5 mL as

	needed. Supplemental iv sedation. (See Anesthetic Considerations for Cesarean Section.) Supplement with iv sedation.
CSE	**Combined spinal/epidural (CSE):** An alternative technique combining the rapid onset and density of spinal anesthesia with the flexibility of continuous epidural anesthesia. Apply monitors, administer fluid, and position patient as for spinal or epidural. The most common technique is the needle-through-needle. After the epidural space is located with a standard 17-ga Tuohy needle, insert a 4-inch 26- to 27-ga pencil-point spinal needle through it to administer 0.6 mL of spinal bupivacaine (0.75%) ± fentanyl 10 mcg ± morphine sulfate 0.1–0.2 mg. Secure the epidural catheter and use if needed (a test dose is advisable).

General considerations

Blood and fluid requirements	IV: 18 ga × 1–2 BSS; warm fluids T&S/T&C patients at ↑ risk of bleeding	Consider ↑ blood loss in cancer patients, prior XRT, and prior abdominal surgery. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Control of blood loss	**Vaginal, laparoscopic, and robotic hysterectomy:** Minimal blood loss **Abdominal hysterectomy:** Moderate to heavy blood loss	See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	**Vaginal hysterectomy:** Standard monitors	

	± Foley catheter **Abdominal hysterectomy:** Standard monitors Foley catheter ± Arterial line ± CVP line	Consider in patients with anticipated ↑ blood loss or major medical comorbidities.
Positioning	✓ and pad pressure points Shoulder abduction <90°	The lithotomy position has several considerations for safety. (See p. 895 and p. 899 for details.)
Complications	**Vaginal hysterectomy:** Cervical stimulation Epinephrine/vasopressin injection **Abdominal hysterectomy:** Blood loss Epinephrine/vasopressin injection	Vagal stimulation and ↓↓ HR may occur with cervical/peritoneal manipulation. Surgeon may inject epinephrine or vasopressin to decrease local bleeding → HTN and brady- or tachydysrhythmias.

POSTOPERATIVE

Complications	PONV VTE Anemia	
Multimodal pain management	Regional analgesia PCA	Emphasize nonopiate analgesia. Epidural opiates if catheter to be used postop
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early (within 24 h) enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum may promote return of bowel function.

Tests	Hct CXR (if CVP catheter placed intraop)	CXR to evaluate central line placement and rule out pneumothorax

Suggested Readings

1. Bauchat JR, Habib AS: Evidence-based anesthesia for major gynecologic surgery Anesthesiol Clin 2015; 33(1):173–207.
2. Meyer LA, Lasala J, Iniesta MD, et al: Effect of an enhanced recovery after surger program on opioid use and patient-reported outcomes. Obstet Gynecol 2018; 132(2):281–90.
3. Modesitt SC, Sarosiek BM, Trowbridge ER, et al: Enhanced recover implementation in major gynecologic surgeries: effect of care standardization. Obstet Gynecol 2016; 128(3):457–66.
4. Nelson G, Altman AD, Nick A, et al: Guidelines for pre- and intra-operative care ir gynecologic/oncology surgery: enhanced recovery after surgery (ERAS®) Society recommendations—Part I. Gynecol Oncol 2016; 140(2):313–22.
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6. Nelson G, Dowdy SC, Lasala J, et al: Enhanced recovery after surgery (ERAS®) in gynecologic oncology—practical considerations for program development. Gynecol Oncol 2017; 147(3):617–20.

OPERATIONS FOR PELVIC ORGAN PROLAPSE: ANTERIOR AND POSTERIOR COLPORRHAPHY, ENTEROCELE REPAIR, SACROSPINOUS LIGAMENT VAGINAL VAULT SUSPENSION, UTEROSACRAL LIGAMENT VAGINAL VAULT SUSPENSION, AND SACROCOLPOPEXY

SURGICAL CONSIDERATIONS

Description

Pelvic organ prolapse often includes coexisting anatomical hernias that can be reported

as symptomatic vaginal pressure or bulges (e.g., enterocele [Fig. 8.2-5C] and uterine prolapse). Cystocele (Fig. 8.2-5A) and rectocele (Fig. 8.2-5B) are prolapses (relaxations) of the anterior and posterior vaginal wall, respectively. Cystoceles are often symptomatic due to bladder protrusion past the introitus during straining. Often, this relaxation will allow the bladder neck to lose its important anatomical relationship to the urethra and the rest of the bladder. The result can be bothersome stress urinary incontinence and/or incomplete emptying for the patient (see Operations for Stress Urinary Incontinence). The rectocele often is experienced as a vaginal bulge during straining and tends to cause incomplete evacuation of stool. The goal of the colporrhaphy is to restore the original anatomy. Due to the frequent coexisting relaxations, a **posterior colporrhaphy** (vaginal repair), **enterocele repair**, and **vaginal hysterectomy** are frequently performed at the same time.

In an **anterior colporrhaphy**, the patient is placed in a high dorsal lithotomy position with the perineum at the end of the operating table for surgical access. The bladder is emptied, and a weighted speculum is inserted into the vagina. A **vaginal hysterectomy** is performed at this point if indicated (see Vaginal Hysterectomy). The extent of the urethrocystocele is determined manually, and the vaginal mucosa is grasped at its cephalic border with two clamps. From this point to the external urethral meatus, the mucosa is undermined with a vasoconstrictive solution epinephrine (5–10 mL, 1:200,000), phenylephrine (1:200,000), or vasopressin (1–5 U/10 mL NS). This decreases blood loss significantly and helps to determine the depth of the vaginal mucosa. The mucosa is cut over this undermined area, and, with the help of sharp and blunt dissection, the mucosa is dissected laterally from its underlying fascia. A series of fascial plication sutures are placed to reduce the cystourethrocele. The redundant mucosa is excised, and the edges are reapproximated.

Paravaginal repair is another procedure for repair of cystocele and can be performed via the abdomen or the vagina. The space between the bladder and pubic bone is entered, and the bladder is dissected off the pelvic sidewall, taking care to avoid injury to the obturator nerve and vessels. The arcus tendineus fascia pelvis is visualized, running from the inferior margin of the pubic symphysis posteriorly to the ischial spine. The surgeon places a hand in the vagina to elevate the lateral vaginal sulcus to the arcus tendineus fascia. Multiple fine sutures are placed to secure the paravaginal tissues to the arcus tendineus fascia pelvis. The same is done for the opposite pelvic sidewall if bilateral defects are present.

If necessary, a **posterior colporrhaphy** may be performed. A small portion of the perineum posterior to the introitus is removed initially. The vaginal mucosa over the

rectocele is undermined with vasoconstrictor fluid before incision, followed by dissection of the overlying mucosa in a manner nearly identical to anterior colporrhaphy. One or several layers of stitches are placed to plicate the pararectal fascia, allowing for reduction of the rectocele. Redundant mucosa is excised, and the edges are reapproximated. A vaginal pack is usually placed to minimize bleeding.

An **enterocele** often is first noticed during a posterior colporrhaphy procedure and is repaired during the posterior repair. The enterocele is well identified and dissected away from the surrounding tissue. Two or more parallel purse-string stitches are used to close the enterocele. The enterocele tissue distal to the purse-string closure is excised. To reduce the enterocele in an optimal fashion the intra-abdominal pressure has to be at a minimum.

Abdominal approach: An **abdominal sacrocolpopexy** or **sacrocervicopexy** can be performed for vaginal vault or cervical stump prolapse. This procedure can be performed through a Pfannenstiel or midline incision or via the laparoscopic/robotic approach. After entering the abdomen, a self-retaining retractor is used to retract the bowels. The peritoneum over the sacral promontory is carefully incised longitudinally, and the sacral promontory is exposed. The peritoneum is opened along the right pararectal space down to the right uterosacral ligament and the vaginal cuff or cervical stump **(cervicopexy)**. Careful attention is paid to visualization of the right ureter. An EEA sizer is introduced into the vagina, and the peritoneum is dissected off the anterior and posterior vagina. The bladder and rectum are also dissected from the vaginal vault. A “Y”-shaped polypropylene mesh graft is then introduced into the abdomen. One end of the mesh is attached to the vaginal cuff (cervix) and the opposite end attached to the sacral promontory, thereby elevating the vaginal apex. The peritoneum is then closed over the mesh.

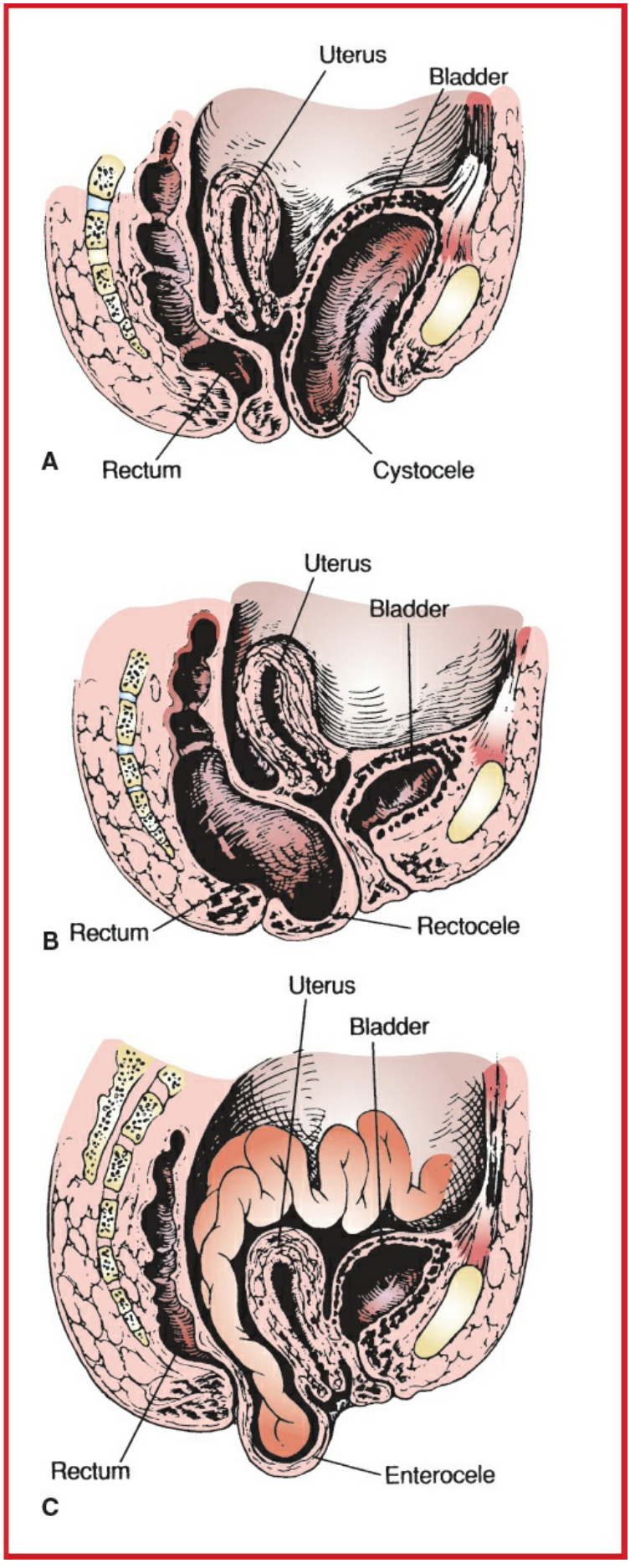
Uterus
Bladder
A
Rectum
Cystocele
Uterus
Bladder
B
Rectum
Rectocele
Uterus
Bladder
Rectum
Enterocele
C

Figure 8.2-5 **A:** Anatomy of cystocele. **B:** Anatomy of rectocele. **C:** Anatomy of enterocele. (Republished with permission of McGraw-Hill Education from Pernoll ML, ed. Current Obstetrics and Gynecological Diagnosis and Treatment, 7th edition. Appleton & Lange, Norwalk, Connecticut: 1991; permission conveyed through Copyright Clearance Center, Inc.)

During laparoscopy or a robotic-assisted abdominal sacrocolpopexy or cervicopexy, the patient is placed in steep Trendelenburg to aid in bowel retraction. The procedure is performed in the same fashion as an abdominal sacrocolpopexy. **Cystourethroscopy** is performed after the procedure to ensure ureteral and bladder integrity. A **midurethral urinary incontinence sling** is often performed after completion of the sacrocolpopexy to prevent stress urinary incontinence.

Variant procedure or approaches

Vaginal sacrospinous ligament suspension is an alternative to sacrocolpopexy. The patient is placed in a dorsal lithotomy position, and an examination under anesthesia is performed. A vasoconstrictive solution is injected (usually epinephrine 3–5 mL, 1:200,000) in the posterior vaginal wall. A vertical incision is made, and the mucosa is bluntly dissected off the rectum in an anterolateral direction. An enterocele, if found, is repaired at this time. The pararectal tissue is then bluntly pierced to enter the pararectal space. The anatomy surrounding the sacrospinous ligament is well palpated and, with the help of the special Miya hook, a large suture (see Operations for Pelvic Organ Prolapse) is placed into the sacrospinous ligament. The other end of the suture is placed at the apex of the vagina, which, after tying, is pulled in a lateral cephalad direction. The mucosa is finally closed.

Uterosacral ligament suspension, or **high McCall culdoplasty**, is an alternate procedure for vaginal apex support. After the uterus is removed by a **vaginal hysterectomy**, the uterosacral ligaments are identified. Two separate permanent sutures are placed along the uterosacral ligament as far cephalad (toward the sacrum) as possible. The same is done on the opposite side. An additional stitch of absorbable suture is placed at the vaginal corners bilaterally and carried through the uterosacral ligaments as well. A cystoscopy is then carried out with all four stitches placed on tension to r/o ureteral obstruction due to ligation or kinking of the ureters. The stitches are replaced if obstruction is observed. After ureteral patency has been confirmed, these stitches are sutured to the fibromuscular layer of the vaginal cuff and tied to bring the apex as cephalad as possible. The vaginal cuff is closed with absorbable sutures.

The **LeFort procedures**, **colpectomy**, and **colpocleisis**, are highly efficacious, minimally invasive operations performed in women with complete prolapse of the uterus and/or vagina, respectively, who do not desire to remain sexually active. With

the patient in a dorsal lithotomy position, the anterior and posterior vaginal mucosae are dissected from the underlying fascia, and then the anterior and posterior vaginal fasciae are plicated together, resulting in near-complete closure of the vagina. Advantages of these techniques are that they can be performed rapidly, they do not require general anesthesia, and most patients can be discharged from the hospital the following day. Closure procedures are ideal for patients who are elderly and/or have multiple medical conditions that make more invasive surgery risky.

Use of vaginal mesh: In 2008 and 2011, the U.S. Food and Drug Administration (FDA issued safety communications warning doctors and consumers about an increase in adverse event reports related to mesh used for urogynecologic procedures. In 2016, the U.S. FDA reclassified surgical mesh for transvaginal POP repair as a class III (i.e high-risk) device. While transvaginal synthetic mesh slings have become the standard of care for surgical treatment of stress urinary incontinence, concerns about the safety of synthetic mesh in treating POP have led to an overall decline in use of vaginal mesh.

Cystourethroscopy is performed after the procedure to ensure ureteral and bladder integrity.

Usual preop diagnosis

Symptomatic cystocele; symptomatic uterine prolapse; enterocele; rectocele

ERAS: Preop counseling by the surgeon/anesthesiologist should include no bowel prep, limiting NPO duration, alcohol, and smoking cessation, discussion of carb-loading DVT prophylaxis, postop pain management options, physiotherapy plan, and possibility of urinary catheter postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Dorsal lithotomy
Incision	Vaginal mucosal; peritoneum for enterocele repair
Unique considerations	To prevent peroneal nerve injury, the area of the leg leaning against the stirrup should be well cushioned. Putting the legs in a high position increases venous return to the heart. Infiltration with epinephrine and vasopressin often is used to reduce intraop bleeding. This causes changes in CO, HR, and BP. Low intra-abdominal pressure (good muscle relaxation) is needed during the enterocele reduction.

Antibiotics	Cefoxitin or cefotetan 2 g iv	
Surgical time	45 min (anterior colporrhaphy) 30 min (posterior colporrhaphy/enterocele repair) 45 min (uterosacral ligament suspension) 1 h (paravaginal repair)	
Closing considerations	Suprapubic catheter (anterior colporrhaphy); vaginal pack (enterocele repair)	
EBL	20–500 mL	
Postop care	PACU	
Mortality	1%	
Morbidity	**Anterior colporrhaphy** Delayed voiding 1–7 d: 30% Foul vaginal discharge: 14% Bacteriuria: 13% Pyrexia (>100.4° F): 11% Atelectasis: 3% Delayed voiding >7 d: 0.6% Need for blood transfusion: 0.6% Urethrovaginal fistula: 0.4% Acute gastric dilatation: 0.2% **Uterosacral ligament suspension** Ureteral obstruction Perirectal abscess due to stitch in the	**Vaginal sacrospinous suspension (Miya hook)** Bleeding in gluteal and pudendal vessels Pararectal burning pain × 2 mo Sciatic pain (indicating misplaced sutures, which must be removed) Peritoneal tear (during Miya hook insertion) **Paravaginal repair** Obturator vessel laceration Obturator nerve injury Ureteral obstruction Bladder laceration

	rectum
Pain score	5–8

PATIENT POPULATION CHARACTERISTICS	
Age range	40–80 yr
Incidence	>1/5 women
Etiology	Multiparous state; obesity; chronic cough; previous pelvic surgery
Associated conditions	Pelvic relaxation syndrome

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Operations for Stress Urinary Incontinence.

Suggested Readings

1. Iglesia CB, Smithling KR: Pelvic organ prolapse.Am Fam Physician 2017; 96(3):179–85.
2. Mowat A, Maher D, Baessler K, et al: Surgery for women with posterio compartment prolapse. Cochrane Database Syst Rev 2018; (3):CD012975.
3. Zwain O, Aoun J, Eisenstein D: Minimally invasive surgery in pelvic floor repair Curr Opin Obstet Gynecol 2017; 29(4):276–81.

OPERATIONS FOR STRESS URINARY INCONTINENCE

SURGICAL CONSIDERATIONS

Description

Stress urinary incontinence is a common condition affecting mostly older and multiparous women. It is a disorder of the musculofascial support to the bladder neck, urethra, and pelvic floor. Many of these patients have had extensive preop workup to exclude urge or other types of urinary incontinence, and many have been treated with pelvic floor exercises (Kegel) before surgery. Many surgical approaches exist: **abdominal suspension** procedures, **suburethral slings**, and **transurethral injections of**

bulking agents. Evidence suggests that **midurethral slings** are the most successful procedures. Given that they can be performed with regional or even local anesthesia as outpatient procedures, midurethral slings are the most commonly used procedures to treat stress urinary incontinence. **Bladder neck slings** and injection of urethral bulking agents can also be used for those with contraindication to a midurethral sling. Patient positioning is crucial for all vaginal surgery.

Vaginal approaches

The **Kelly urethral plication** was historically used as the primary surgical treatment, especially when other vaginal surgeries are to be performed. The patient initially is placed in a high dorsal lithotomy position with the perineum at the end of the operating table for surgical exposure. The bladder is emptied, and a weighted speculum is inserted into the vagina. The extent of the cystourethrocele is determined and the vaginal mucosa is grasped at its cephalad border with two clamps. From this point to the external urethral meatus, the mucosa usually is undermined with 5–10 mL of a vasoconstrictive solution (epinephrine 1:200,000, phenylephrine 1:200,000, or vasopressin 1–5 U/10 mL NS). This decreases blood loss significantly and helps to determine the depth of the mucosa. With the help of sharp and blunt dissection, the mucosa is freed laterally from its underlying adherent fascia. Series of vertical mattress sutures are placed in the mobilized paraurethral and paravesical fascia to reduce the cystourethrocele and elevate the posterior urethra to a high retropubic position. The redundant mucosa is excised, and the edges are reapproximated. A suprapubic catheter is often inserted at the end of the surgery to prevent bladder overdistension. The Kelley urethral plication is rarely performed in modern practice and has been supplanted by the midurethral sling.

Two anterior bladder neck suspension techniques—Stamey and **modified Pereyra**—are very similar procedures wherein the vaginal mucosa is incised and dissected off the underlying paraurethral fascia, much the same way as in the Kelly plication. Instead of using a layer of mattress sutures, both suspension methods use two lateral sutures that suspend the vesical neck on each side (see Fig. 9-22). The ends of the sutures are tied over the rectus fascia to provide support. The Stamey method uses a small Dacron cuff to prevent the suture from tearing through the paravesical fascia, whereas in the modified Pereyra method, the posterior loop is attached firmly to the pubourethral ligament. One or two small suprapubic abdominal incisions must be made to allow for the tying of the sutures. Specialized long needles are used to help the placement of these sutures, and a cystoscope often is used to verify their placement. Perforation of the bladder is a common complication found upon cystoscopy. Finally, a suprapubic catheter is placed at the end of the operation. Stamey and Pereyra

suspensions are rarely performed and are mostly of historical significance as they have been replaced by midurethral urinary incontinence slings.

Abdominal approaches

Burch (urethropexy) and the **Marshall-Marchetti-Krantz (MMK)** are both abdominal suspension procedures, though most clinicians have abandoned the MMK procedure due to higher complication rates. The patient is placed in Allen stirrups in the frog-leg position with a urethral catheter in place. A Pfannenstiel incision is used to enter the space of Retzius, which lies between the parietal peritoneum and the rectus fascia under the pubic bone. Blunt dissection is used to open and extend this space. The surgeon then inserts two fingers into the vagina to raise the anterior vagina and bladder neck. This enables the surgeon to place two or more sutures in the tissue just lateral to the urethra and attach them to Cooper ligament (Burch) or to the periosteum of the pubic symphysis (MMK).

The **pubovaginal sling** and highlight sling are often reserved for women in whom other incontinence operations have failed. It can also be used as primary treatment for stress urinary incontinence, though it is more invasive than a midurethral sling. The goal of the sling procedure is to produce extrinsic compression of the urethrovesical junction with the help of a strip anchored to the rectus fascia or pubic bone (see Fig. 9-22). With the patient in the dorsal lithotomy position, a urethral catheter is placed and the vaginal mucosa incised and dissected off the underlying paravesical and paraurethral fascia, similar to the Kelly plication. The retropubic space is entered through a Pfannenstiel incision, and a strip of rectus fascia is obtained. The strip is then brought through the vagina, around the urethra, and back to the abdomen, where it is fastened to the rectus fascia, creating a sling under the urethra at the junction of the bladder neck. The vaginal and abdominal incisions are closed, and a suprapubic catheter is often placed. If donor fascia lata or synthetic material is used, a small (~2 inches) horizontal incision is made above the pubic bone for attachment of the sling. The patient's own fascia lata (from the lateral thigh) can also be used.

Midurethral sling placement may be performed under local, regional, or general anesthesia. Local anesthesia may be combined with conscious sedation. If local anesthesia is used, it will also be administered to the vaginal incision site as well as the groin areas or suprapubic areas where the trocar and mesh will exit.

Tension-free vaginal tape (TVT) sling is a newer sling procedure for the treatment of stress urinary incontinence. A polypropylene mesh sling is used to support the urethra, although it is not attached to the fascia. The mesh is woven in such a way that the sling does slide out over time. Fibroblasts grow into the sling to anchor it throughout the

endopelvic fascia and around the dependent surface of the urethra. The patient is placed in a high dorsal lithotomy position with the perineum at the end of the operating table for surgical exposure. The bladder is emptied and a weighted speculum or retractor is inserted into the vagina. The vaginal mucosa is grasped near the middle of the urethra with two clamps. The vaginal mucosa is hydrodissected with a small amount of vasoconstrictive solution (epinephrine 1:200,000, phenylephrine 1:200,000, vasopressin 1–5 U/10 mL NS). This decreases blood loss significantly and helps to determine the depth of the mucosa. With the help of sharp and blunt dissection, the mucosa is freed laterally from its underlying adherent fascia, and two midurethral submucosal tunnels are made toward the underside of the pubic symphysis. The TVT curved needle is introduced from the vagina through the space of Retzius on each side of the urethra and is brought out to the abdomen above the pubic bone. The sling mesh is attached to the ends of each needle; thus, when both needles are pulled through the abdominal sites, the mesh will rest under the urethra. A cystoscopy is done before pulling the mesh through to verify that neither needle is in the bladder or the urethra. The mesh is then adjusted so that the urethra is resting on the sling, under no tension. The **transobturator tape (TOT) sling** is a commonly used alternative to the TVT sling that does not enter the retropubic space. The sling is inserted under the midurethra and exits through the obturator membrane, inferior to the adductor longus tendon, through a poke incision lateral to the vagina in the groin. There are two variations: **inside-out**, where the trocars are passed from a midurethral vaginal incision to exit through bilateral groin incisions, and **outside-in**, where the trocars are passed from bilateral groin incisions to exit through a midurethral vaginal incision.

Usual preop diagnosis

Stress urinary incontinence; intrinsic sphincter deficiency

ERAS: Preop counseling by the surgeon/anesthesiologist should include no bowel prep, limiting NPO duration, alcohol, and smoking cessation, discussion of carb-loading DVT prophylaxis, postop pain management options, postop recovery plan, and possibility of urinary catheter postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Kelly Plication	Midurethral Sling	MMK/Burch	Pubovaginal Sling
Position	Dorsal lithotomy	Lithotomy	Frog-leg	⇐
Incision	Vaginal mucosa	2 suprapubic and a vaginal incision	Pfannenstiel	Vaginal and suprapubic incision
Unique considerations	Cushion area of leg against stirrup to prevent peroneal injury. Epinephrine (1:200,000) or vasopressin is often infiltrated to reduce intraop bleeding for vaginal approaches. Injections may cause ↑ BP and tachydysrhythmias (epi) or bradydysrhythmias (vasopressin). The urethral catheter is frequently removed and reinserted during surgery.	⇐	⇐	⇐
Antibiotics	Cefoxitin 1–2 g iv	⇐	⇐	⇐
Surgical time	1 h	⇐	⇐	⇐
Closing considerations	Suprapubic catheter	⇐	⇐	⇐
EBL	50 mL	Roughly 50 mL	100–200 mL	50–100 mL
Postop care	Inpatient	Outpatient	⇐	± Outpatient
Mortality	Minimal	Minimal	⇐	⇐
Morbidity	Detrusor instability: Rare (due to vaginal approach) Enterocele: Rare Incisional hernia: Rare Osteitis pubis: Rare Voiding difficulties: Rare Wound infection: Rare	<7% Rare ⇐ Rare <2% Rare	14% 15% 0.09% ⇐ 2% 8.7%	⇐ N/A Rare ⇐ ~40% Rare Prolonged catheter time: >50% Outlet obstruction: 10–20% Urethral perforation: 7% Bladder perforation: 1%
Pain score	4–6	1–3	6–8	4–6

PATIENT POPULATION CHARACTERISTICS	
Age range	40–80 yr
Incidence	>1/5 women
Etiology	Multiparous state; obesity; chronic cough
Associated conditions	Other components of pelvic relaxation syndrome (rectocele, uterine prolapse, enterocele)

Suggested Reading

1. Lukacz ES, Santiago-Lastra Y, Albo ME, et al: Urinary Incontinence in women: a review. JAMA 2017; 318(16):1592–604.

ANESTHETIC CONSIDERATIONS

(Procedures covered: anterior and posterior colporrhaphy; enterocele repair; vaginal sacrospinous suspension; operations for stress urinary incontinence.)

PREOPERATIVE

This is usually an older patient population, past childbearing age. Assess for medical comorbidities.

Laboratory	Hgb/Hct, as indicated from H&P
Premedication	Consider midazolam 1–2 mg iv.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of spinal or epidural block/analgesia for postop pain management. Consider preop acetaminophen 1000 mg. Consider aprepitant 40 mg po for GA patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Regional or GA may be used.

Regional anesthesia

A T10 sensory level is sufficient to provide anesthesia for procedures using a perineal approach, but a T4 level is recommended for abdominal/combined approaches.

Spinal	0.75% bupivacaine 10–15 mg in 8.25% dextrose (see Anesthetic Considerations for Cesarean Section) ± 10–20 mg fentanyl ± 0.1–0.2 mg morphine
Epidural	1.5–2.0% lidocaine with epinephrine 5 mcg/mL, 15–20 mL; supplement with 3–5 mL as needed. Supplemental iv sedation. (See Anesthetic Considerations for Cesarean Section) Spinal may provide better perineal block.
CSE	**Combined spinal/epidural (CSE):** An alternative technique combining the rapid onset and density of spinal anesthesia with the flexibility of continuous epidural anesthesia. Apply monitors, administer fluid, and position patient as for spinal or epidural. The most common technique is the needle-through-needle. After the epidural space is located with a standard 17-ga Tuohy needle, insert a 4-inch 26- to 27-ga pencil-point spinal needle through it to administer 0.6 mL of spinal bupivacaine (0.75%) ± fentanyl 10 mcg ± morphine sulfate 0.1–0.2 mg. Secure the epidural catheter and use if needed (a test dose is advisable).

General anesthesia

Induction	Standard induction
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance
Emergence	No special considerations. PONV prophylaxis should include dexamethasone and ondansetron.
Blood and fluid	IV: 18–20 ga × 1 Normally minimal blood loss.

requirements	BSS @ 2–4 mL/kg/h	See Goal-Directed Fluid Management, Appendix K, p. K-4.
Control of blood loss	Epinephrine, vasopressin, phenylephrine used by surgeons	Surgeons may inject vasopressors into the submucosa to minimize blood loss, which may cause ↑ BP and tachydysrhythmias (epi) or bradydysrhythmias (phenylephrine/vasopressin).
Monitoring	Standard monitors	Although bladder catheterization before incision is normal, the catheter is not left in place throughout surgery in those patients undergoing anterior and posterior colporrhaphy, enterocele repair, and Kelly urethral plication. Suprapubic bladder catheters are placed toward the end of surgery in these procedures, as well as in the Stamey, Pereyra, and urethral sling procedures.
Positioning	✓ and pad pressure points ✓ eyes	See p. 895 and p. 899 for concerns regarding the lithotomy position.

POSTOPERATIVE

Complications	PONV	
Multimodal pain management	Regional analgesia, IV opiates, ketorolac	Usually rapid conversion to po pain medications
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early (within 24 h) enteral nutrition, Foley catheter removal, and

	mobilization. Consider DVT prophylaxis. Chewing gum may promote return of bowel function.
Tests	None indicated

Suggested Readings

1. Allen RH, Micks E, Edelman A: Pain relief for obstetric and gynecologic ambulatory procedures. Obstet Gynecol Clin North Am 2013; 40(4):625–45.
2. Bauchat JR, Habib AS: Evidence-based anesthesia for major gynecologic surgery. Anesthesiol Clin 2015; 33(1):173–207.
3. Meyer LA, Lasala J, Iniesta MD, et al: Effect of an enhanced recovery after surgery program on opioid use and patient-reported outcomes. Obstet Gynecol 2018; 132(2):281–90.
4. Modesitt SC, Sarosiek BM, Trowbridge ER, et al: Enhanced recovery implementation in major gynecologic surgeries: effect of care standardization. Obstet Gynecol 2016; 128(3):457–66.
5. Nelson G, Altman AD, Nick A, et al: Guidelines for pre- and intra-operative care in gynecologic/oncology surgery: Enhanced Recovery After Surgery (ERAS®) Society recommendations—Part I. Gynecol Oncol 2016; 140(2):313–22.
6. Nelson G, Altman AD, Nick A, et al: Guidelines for postoperative care in gynecologic/oncology surgery: Enhanced Recovery After Surgery (ERAS®) Society recommendations—Part II. Gynecol Oncol 2016; 140(2):323–32.
7. Nelson G, Dowdy SC, Lasala J, et al: Enhanced recovery after surgery (ERAS®) in gynecologic oncology—practical considerations for program development. Gynecol Oncol 2017; 147(3):617–20.

CHAPTER 8.3

Obstetric Surgery

SURGEONS

Samantha Corey Do, MD
Yasser Y. El-Sayed, MD

ANESTHESIOLOGISTS

Brendan Carvalho, MBBCh, FRCA, MDCH
Lee Coleman, MD

We gratefully acknowledge the past contributions of surgeon, M. Mark Taslimi, MD.

CESAREAN SECTION—LOWER SEGMENT AND CLASSIC

SURGICAL CONSIDERATIONS

Description

Cesarean section (C-section) is the delivery of the fetus through a horizontal or, less commonly, through a vertical incision in the lower uterine segment. The skin incision is made either as a Pfannenstiel's (transverse in the crease above the pubis), a Maylard (in extremely obese patients), or vertical midline from umbilicus to pubis. The peritoneal cavity is entered as in any laparotomy. A retractor is placed inferiorly, and the reflection of visceral peritoneum from the bladder dome to the anterior lower segment of the uterus (bladder flap) is incised and may be displaced inferiorly, along with the bladder. The uterus is entered sharply and the incision extended with digital pressure

and/or bandage scissors. The fetal head is elevated out of the pelvis and delivered through the uterine incision. In cases of nonvertex lie, the infant's breech or foot is grasped and brought out of the incision. After the delivery of the fetus, the cord is double-clamped and cut, and cord blood is obtained for analysis. The placenta is removed manually and the uterine cavity cleared of all debris and clots. The uterine incision is closed with a running, interlocking stitch, followed by a second imbricating layer. The bladder flap and parietal peritoneum do not require closure, and the rectus muscles do not routinely require reapproximation. Finally, the fascia is closed and the skin reapproximated with staples. **Classic C-section** usually involves a fundal vertical uterine incision (Fig. 8.3-1). Patients with a history of prior classical C-section should be delivered abdominally via a repeat C-section because their risk of uterine rupture with labor and vaginal delivery is ~12%.

Usual preop diagnosis

Failure to progress in labor; elective repeat C-section; fetal distress; malpresentation

ERAS: For elective procedures, preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, carb loading, DVT prophylaxis, postop pain management options, and postdelivery plan. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

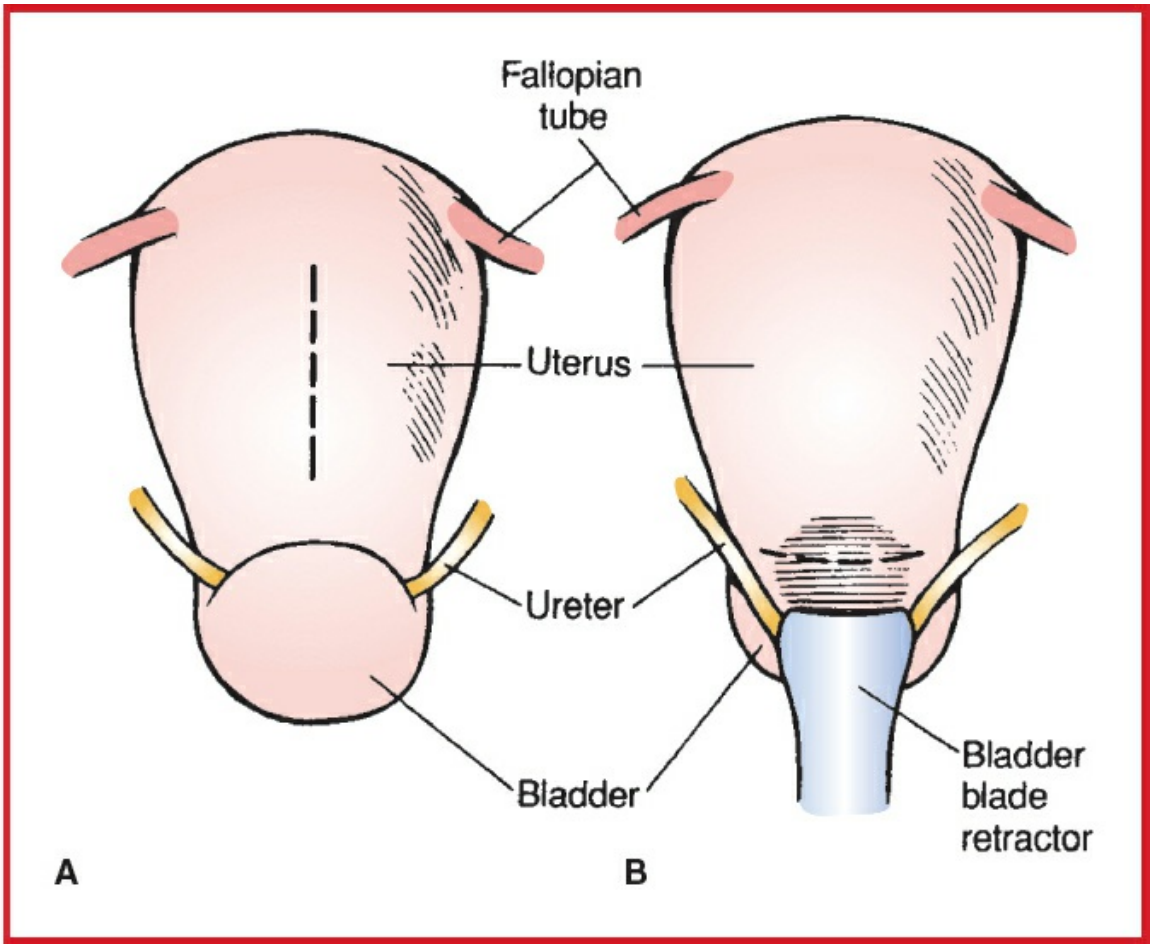

Figure 8.3-1 Typical C-section incisions. **A:** Classic incision, in the upper uterine segment. **B:** Low transverse incision.

SUMMARY OF PROCEDURES

	Lower-Segment C-Section	Classic C-Section
Position	Supine with left lateral tilt. (In obese patients, the pannus may be lifted superiorly by tape or towel clips or inferiorly for a supraumbilical incision.)	⇐
Incision	Skin: transverse low abdominal (Pfannenstiel's) or repeat vertical. Uterus: transverse (Kerr) or low vertical (for premature infants or nonvertex lie)	Skin: Pfannenstiel's or, more commonly, vertical midline Uterus: vertical fundal

Special instrumentation	Bladder blade retractor; small ring forceps; bandage scissors; suction bulb; DeLee suction trap (if meconium)	⇐
Unique considerations	✓ fetal heart tones before the procedure. If for CPD: vaginal exam within the last 15 min before the procedure. If for fetal distress: continuous monitoring until skin incision	⇐
Antibiotics	If in labor or membranes ruptured: continue prophylactic antibiotics or cefazolin 2 g iv (before incision).	⇐
Surgical time	20–90 min	40–90 min
Closing considerations	Low transverse: closed in two layers. Low vertical: two layers; may require additional operative time for control of incision bleeding or repair of incision extension into the cervix	Three-layer closure requires additional time.
EBL	750–1000 mL	1000–2000 mL
Postop care	Observation for bleeding and ↓ BP	Special attention to VS is needed due to additional blood loss.
Mortality	<0.1%	⇐
Morbidity	Infection: Not in labor: <5% In labor/ruptured membranes: 50% (antibiotics reduce incidence to 15%) Small bowel obstruction (SBO): rare	⇐ ⇐ ⇐
Pain score	1–5 (treated) 6–10 (untreated)	

PATIENT POPULATION CHARACTERISTICS	
Age range	14–45 yr
Incidence	10–30%
Etiology	Failure to progress (30%); repeat C-section (30%); fetal anomaly/other (20%); abnormal presentation (10%); fetal distress (10%)
Associated conditions	Preeclampsia/eclampsia; DIC; hemolysis, elevated liver enzymes, low Plt count (HELLP) syndrome; obstetrical hemorrhage/shock; chorioamnionitis

ANESTHETIC CONSIDERATIONS

(Procedures covered: C-section; emergent obstetrical hysterectomy; repair of uterine rupture.)

PREOPERATIVE

In general, patients are young and healthy, although the pregnant patient has undergone profound physiologic changes that affect the administration of anesthesia. Women present for C-section for a multitude of reasons, including failure to progress in labor, repeat cesarean delivery, fetal indications including breech presentation, and certain medical indications, and for emergency cesarean delivery for nonreassuring fetal heart rate tracing and/or hemorrhage (placenta previa, abruptio placenta, and, rarely, uterine rupture).

Respiratory	The pregnant patient has a compensated respiratory alkalosis ($PaCO_2$ = 32–34), ↑ minute ventilation (MV; ↑ 50%), and ↓ FRC (↓ 20%). ↑ O_2 consumption (↑ 20%) with ↓ FRC results in rapid onset of hypoxemia if ventilation is compromised. Small airway closure due to elevation of the diaphragm (exaggerated by obesity and supine position) can → VQ mismatch and ↓ PaO_2. ↑ MV and ↓ FRC enhance uptake of inhalational anesthetics. Mucosal capillary engorgement in the upper airways may necessitate a smaller ETT and mandates careful airway suctioning

	to avoid bleeding. Avoid any nasal airways. Airway changes can occur in labor and necessitate an airway evaluation just before administration of anesthesia. **Tests:** As indicated from H&P
Cardiovascular	Typically, there is a ↓ SVR (↓ 15%), ↓ diastolic pressure, and ↓ MAP (↓ 15%) with ↑ HR (↑ 20%) and ↑ CO (↑ 40%, higher in multifetal pregnancy, higher in labor). Use left uterine tilt (15°) to minimize aortocaval compression and supine hypotension. Immediately postpartum, 600–800 mL blood enters the central circulation, due to placental autotransfusion, with further ↑ in CO. **Tests:** As indicated from H&P
Hematologic	These patients have ↑ red cell mass (↑ 300–400 mL), ↑ plasma volume (↑ 1200–1300 mL), ↑ blood volume (↑ 1500–1600 mL), ↑ more with multifetal pregnancy. WBC count may ↑ to 15,000/mm^3. Iron deficiency anemia often is superimposed on the dilutional anemia of pregnancy (Hct 33%). The typical blood loss of 700–1000 mL is usually well tolerated. Excessive blood loss is possible with uterine atony, placenta previa, and abruptio placenta. Repeat C-section associated with placenta previa poses high risk for hemorrhage because of increased risk for associated abnormal placental implantation. **Tests:** Hgb/Hct
Gastrointestinal	Abnormalities, including ↑ intragastric pressure, ↓ esophageal sphincter tone, and ↓ gastric motility (after onset of labor), predispose to aspiration pneumonitis. All parturients should be considered to have full stomachs and should receive nonparticulate antacid (e.g., 0.3 M Na citrate 30 mL) iv metoclopramide 10 mg and ranitidine 150 mg or famotidine 20 mg before general anesthesia.
Hepatic	Liver enzymes can be mildly elevated, alkaline phosphatase is elevated from placental source, and

	plasma protein concentration is diminished (↑ unbound drug levels). **Tests:** As indicated from H&P
Renal	These patients have ↑ renal blood flow (↑ 50%), ↑ GFR, and ↑ creatinine clearance and ↓ serum creatinine and ↓ BUN. Dependent edema results from increased water and Na^+ retention 2° resetting of the osmotic threshold for thirst and vasopressin secretions. **Tests:** As indicated from H&P
Laboratory	T&S maternal blood if risk factors for blood loss are present. Routine cross-match unnecessary unless significant blood loss is anticipated. Routine autologous blood donation is not recommended. Coagulation studies and Plt count are recommended with PIH, abnormal placentation, and heavy maternal bleeding. BUN, Cr, UA, and fasting blood glucose as indicated from H&P.
Premedication	Agents to decrease risk of aspiration pneumonitis include a nonparticulate antacid (e.g., 0.3 M Na citrate 30 mL po), ranitidine 150 mg iv, and metoclopramide 10 mg iv. Sedatives are not routinely administered. In extremely anxious patients, however, 0.5–1.0 mg midazolam iv is an excellent anxiolytic, without apparent effect on maternal memory, alertness, or neonatal condition.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of an epidural block for anesthesia and postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

SPECIAL CONSIDERATIONS

Pregnancy-induced	PIH is characterized by generalized vasoconstriction

hypertension (PIH)	with relative intravascular volume depletion and, occasionally, diffuse capillary leak. Cautious hydration before regional anesthesia is necessary to prevent hypotension or pulmonary edema. Hepatic dysfunction may be present (HELLP syndrome). Epidural, spinal, and combined spinal-epidural (CSE) are all considered safe techniques in PIH assuming normal Plt count. Cardiovascular stability is better with regional than GA, provided intravascular volume is adequate. Abnormal coagulation (↓ Plt count or dysfunctional Plt) contraindicates regional anesthesia. If GA is necessary, it is vital that precautions are taken to ↓ laryngoscopic hypertensive response. Use supplementation along with RSI technique; esmolol (1.5 mg/kg), NTG (2 mcg/kg), lidocaine (1.5 mg/kg), and/or remifentanil (0.5–1 mg/kg). Labetalol (20 mg) or hydralazine (5–10 mg) can be used, but beware of onset times (<5 min and 5–15 min, respectively) and longer duration of action, so choose drugs appropriate to urgency. There is a potential for difficult intubation in PIH due to airway edema; therefore, a small ETT (6.0 mm) should be available. $MgSO_4$ potentiates neuromuscular blocking agents; avoid defasciculating dose of muscle relaxant before induction, use smaller than normal doses of nondepolarizing agents, and monitor neuromuscular function. $MgSO_4$ may potentiate hypotension and increase vasopressor requirements. **Tests:** PT; PTT; Plt; TEG or bleeding time; LFTs
Eclampsia	Treat eclamptic Sz with adequate oxygenation and a small dose of either midazolam (1–2 mg) or propofol (20–40 mg). Intubate if necessary to protect airway. Initiate $MgSO_4$ therapy (loading dose: 4–6 g iv over 20 min; then, infuse at 1–2 g/h). If 2nd seizure occurs during maintenance dose (rare): administer 2nd bolus dose of 2 g over 5 min.

Massive maternal hemorrhage: • Placenta previa • Abruptio placenta • Ruptured uterus	Activate massive transfusion protocol (MTP) if available at institution. Insert two large-bore iv catheters (14–16 ga) and consider sending Hg/HCT and coagulation studies. Ensure immediate availability of cross-matched blood and if unavailable consider uncross-matched or O-negative blood. Rapidly restore intravascular volume with crystalloid, colloid, or both until blood is available. If bleeding continues, administer MTP, consisting of a transfusion of PRBC, plasma, and platelets. Induction with either ketamine (1–1.5 mg/kg) or etomidate (0.2–0.6 mg/kg) is preferred in hypovolemic or unstable patients. DIC and dilutional coagulopathy may follow abruptio placenta, amniotic fluid embolism, massive blood loss, and resuscitation. A ratio of RBC:FFP:PLT of 6:4:1 or RBC:FFP of 1:1 is currently recommended during massive transfusion. Consider tranexamic acid (e.g., 10 mg/kg) if EBL > 1000 mL. Fibrinogen concentrate or cryoprecipitate empirically or as directed by PT, PTT, fibrinogen levels, and TEG. Uterine atony is treated with oxytocin 30 U/L in NS at a rate sufficient to control atony (250–500 mL/h). Small boluses 1–2 U are appropriate, but avoid larger doses (risk of ↓ BP); alternatively, methylergonovine, 0.2 mg im (risk of HTN); carboprost tromethamine (Hemabate®; a synthetic analog of $PGF_{2\alpha}$), 0.25 mg im or intramyometrially (risk of pulmonary HTN, bronchospasm); or misoprostol (600 mg buccal or 1000 mg PR). Bakri balloon, B-Lynch sutures or uterine artery embolization may be effective in controlling continued postpartum bleeding and may be considered before surgical artery ligation or hysterectomy. Emergency hysterectomy, however, may be the only solution to continued bleeding. Conversion to GA may be necessary if massive bleeding occurs during regional anesthesia.
Diabetes	Diabetic patients may have an increased propensity to ↓ BP following regional anesthesia. Determine

	blood glucose hourly and maintain at 80–100 mg/dL. Insulin requirements decrease drastically after delivery, and insulin dosage must be reduced to prevent maternal hypoglycemia. **Tests:** Fasting blood glucose; UA
Response to anesthetic drugs	In pregnant patients, MAC is ↓ 30% for inhaled agents; combined with more rapid uptake, this predisposes to anesthetic overdose. Sensitivity to local anesthetics also is increased. Epidural space capacity is decreased 2° engorgement of epidural veins; this decreases requirements for local anesthetics and increases possibility of intravascular injection of drugs. Increased sensitivity to nondepolarizing muscle relaxants (especially in patients receiving $MgSO_4$) mandates careful TOF monitoring and use of reduced doses. Decreased protein binding may increase toxicity of highly protein-bound drugs such as bupivacaine.

INTRAOPERATIVE

Anesthetic technique

Regional (neuraxial) anesthesia has many maternofetal advantages (↓ maternal mortality, ↓ risks of aspiration, participation in childbirth, better pain control) over GA. Anesthetic choice in specific circumstances depends on maternal and fetal conditions and degree of urgency.

Spinal anesthesia is preferred for elective or unplanned C-section (unless patient has an existing epidural) when no contraindications to regional anesthesia exist (e.g., patient refusal, coagulopathy, active neurologic disease, elevated ICP, hypovolemia, infection at site of insertion). With the use of small-gauge (e.g., 25–27 ga), pencil-point needles (e.g., Sprotte, Whitacre), the risk of headache is low (0.5–1%). Advantages of spinal over epidural anesthesia include rapid onset of block and more reliable anesthesia. ↓ BP, however, is more common with spinal anesthesia. Fluid (1–1.5 L crystalloid or 500 mL colloid) preloading or co-loading (at the time of the spinal), leg wrapping (e.g., compression stockings), and vasopressors infusions (phenylephrine 25–50 mcg/min) reduce the incidence and severity of ↓ BP, but do not eliminate it. Additional boluses of vasopressors (e.g., phenylephrine [50–100 mcg] or ephedrine [5–10 mg]) should be

used as appropriate to treat ↓ BP. Phenylephrine should be considered the vasopressor of choice due to its rapid onset, efficacy in treating ↓ SVR, and limited placental transfer. Ephedrine may be associated with ↑ fetal acidosis. Atropine (0.4 mg iv) should be used to treat ↓ HR. Consider using epinephrine (50–100 mcg iv) if other vasopressors are unsuccessful in reversing severe ↓ BP or profound ↓ HR.

General anesthesia is used when regional anesthesia is contraindicated or when there is inadequate time to institute regional blockade. Obstetric emergencies for which rapid induction of GA may be indicated include severe maternal hemorrhage, prolapsed umbilical cord, severe fetal bradycardia, severe persistent fetal decelerations, or the need for intrauterine manipulation. Less dire situations often permit the performance of a quickly placed spinal or extension of a functioning epidural block with an agent having a rapid onset (e.g., 15–20 mL 3% 2-chloroprocaine or 2% lidocaine with epinephrine 1:200,000 and bicarbonate). Continuous monitoring of the fetal heart rate (FHR) in the OR may allow use of regional anesthesia if the FHR tracing is reassuring. Constant communication with the obstetrician regarding maternal and fetal condition is essential. Although situations exist in which a GA is preferable to regional, the risks must be weighed against the benefits for patients with greater potential for complications. If difficult intubation is anticipated, rapid-sequence induction of GA with cricoid pressure should not be undertaken. Alternative approaches include awake intubation, regional anesthesia, or local infiltration by the obstetrician. Sometimes, a nonreassuring FHR pattern is diagnosed as "fetal distress." Fetal distress is an imprecise and nonspecific term with little positive predictive value. The duration and severity of any FHR abnormality should be considered when the type of anesthesia is determined. C-section performed for a nonreassuring FHR pattern does not necessarily preclude the use of regional anesthesia.

Regional anesthesia

Epidural	Apply monitors, fluid load, and place the patient in the sitting or lateral decubitus position. Locate the epidural space with a 17–18-ga Tuohy needle and LOR to saline (preferable) or air technique. A 3-mL test dose of 1.5–2% lidocaine (45–60 mg) with 1:200,000 epinephrine (15–20 mcg) is given through the epidural catheter to exclude intravascular injection (Sx: tachycardia, palpitations, dizziness, tinnitus, new taste in the mouth) or subarachnoid placement (motor/sensory block in lower extremities,

rapid onset of pain relief). After 3–5 min, inject 15–20 mL 2% (300–400 mg) lidocaine with 1:200,000 epinephrine (75–100 mcg) incrementally over 5–10 min. Sodium bicarbonate, 1-mEq/10-mL lidocaine, hastens onset of block and improves the block quality, but increases risk of ↓ BP. Fentanyl (50–100 mcg) can improve block quality and decrease intraoperative nausea and vomiting. 2-Chloroprocaine (450–600 mg) or 2% lidocaine with epinephrine should produce adequate surgical anesthesia within 5–10 min. Bupivacaine, levobupivacaine, and ropivacaine 0.5%, 15–20 mL (75–100 mg), with or without epinephrine 1:200,000 and/or fentanyl (50–100 mcg) are alternative options but with slower onset of blockade.

Left uterine displacement is best achieved by elevating the right hip with a wedge or towel. Administer O_2 by mask or nasal cannula if needed, and continue to monitor FHR before abdominal prep. Monitor BP every min until stable and then every 3–5 min. Treat ↓ in BP with further uterine displacement, additional fluids, and vasopressors as outlined earlier. Maintain BP at baseline levels to optimize placental perfusion and minimize maternal nausea. For inadequate anesthesia, give additional epidural local anesthetic, 50–100 mcg fentanyl iv or epidurally, 50% N_2O/O_2, ketamine 10–20 mg iv, midazolam 1–2 mg iv, and/or infiltrate with local anesthetic. The patient must remain conscious to avoid risk of aspiration. If anesthesia is still inadequate, induce GA (see below).

After delivery of infant and placenta, bolus (1–2 U) and infuse (30 U in 1 L at 250–500 mL/h) oxytocin. Monitor for excessive blood loss, recognizing that significant blood loss can occur quickly and outside of direct observation and is often underestimated. Chest pain, mild oxyhemoglobin desaturation, and SOB after delivery may be due to irritation of the

	diaphragm by blood or packs, too high or inadequate level of anesthesia, or venous air or amniotic fluid embolization. Transient ST-segment changes on ECG may occur, but do not usually signify myocardial ischemia.
Spinal	Apply monitors, administer fluid, and position as for epidural anesthesia. Insert 25- to 27-ga pencil-point needle and verify free flow of CSF. If technical difficulties or urgent situations are encountered, a larger pencil-point needle (e.g., 22-ga Sprotte) may be considered. Inject hyperbaric 0.75% spinal bupivacaine 11–12 mg (1.5–1.6 mL) ± fentanyl 10–20 mcg and preservative-free morphine 0.1–0.15 mg, and position the patient with left uterine displacement. Monitor and treat ↓ BP as for epidural. Adjust operating table position to insure a T4 level of anesthesia. If anesthesia is inadequate and time permits, consider repeating block with CSE (reduced intrathecal dose) or epidural. Incrementally dose the epidural catheter as needed. Treat persistent inadequate anesthesia as for epidural. Induce GA if these measures fail.
Combined spinal-epidural (CSE)	An alternative technique combining the rapid onset and density of spinal anesthesia with the flexibility of continuous epidural anesthesia (e.g., if necessary to extend the duration or intensity of the block). Apply monitors, administer fluid, and position as for spinal/epidural. The recommended technique is the needle-through-needle. When the epidural space is located with a standard 17–18-ga Tuohy needle, insert a 25- to 27-ga pencil-point spinal needle through it, and administer either a standard C-section spinal dose of bupivacaine and narcotics as described for spinal or reduced dose if indicated (e.g., maternal cardiac disease or short stature). Secure the epidural catheter and use if needed. Appreciate that the epidural catheter is untested and an epidural test dose is advisable before dosing.

General anesthesia

Induction	Elevate the right hip (wedge or towel) to provide left uterine displacement. Preoxygenation for 3–5 min is optimal; however, 4–8 maximal inspiratory breaths in 30 sec is a satisfactory substitute in an emergency. Head up and CPAP may improve oxygenation in obese parturients. Place patient in maximal "sniff" position (ramp patient if necessary), to optimize position for intubation. After patient is prepped and draped and obstetric team is ready to begin, perform rapid-sequence induction with cricoid pressure. Administer propofol 2–3 mg/kg (or ketamine 1–1.5 mg/kg or etomidate 0.2–0.6 mg/kg in hypovolemic or cardiovascularly unstable patients) and succinylcholine 1–1.5 mg/kg to induce GA and facilitate intubation. Inflate cuff of ETT and verify tracheal placement by $ETCO_2$ waveform and auscultation of bilateral breath sounds.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Failed intubation	If tracheal intubation is unsuccessful, oxygenation and mask ventilation must become a priority, and numerous attempts to intubate should be avoided. Summon experienced help and quickly decide whether surgery must proceed. The risks of continuing with mask GA and cricoid pressure must be weighed against the risk of allowing the mother to awaken. If mask ventilation is impossible, quickly attempt ventilation with an LMA. If this succeeds, either continue to use throughout the case or place an ETT (6 mm ID) through LMA blindly or with a fiberoptic scope; alternatively, use an intubating LMA. A ProSeal LMA has been used successfully as a rescue supraglottic airway device in this situation

	and may negate the necessity for ET intubation. Cricoid pressure may interfere with mask ventilation or LMA placement and should be released if necessary. If LMA fails to allow ventilation, attempt emergency transtracheal ventilation using a 12–14-ga iv catheter (or specific cricothyroid airway device) and appropriate tubing to connect to a high-pressure O_2 source (e.g., jet ventilator). If these measures are unsuccessful, an emergency cricothyrotomy or tracheostomy should be performed by experienced personnel. **Planning for a failed intubation must occur before it happens**. A difficult-intubation tray, including video laryngoscopes, supraglottic airways, and equipment for emergency jet ventilation, must be immediately accessible in or very near the delivery room.
Maintenance	50% N_2O/O_2 with isoflurane, sevoflurane, or desflurane (limit MAC < 1.5 to reduce uterine atony). Propofol infusion for maintenance negates the uterine relaxant effect of the halogenated agents but may lead to more neonatal depression. Avoid hypocapnia ($ETCO_2$ 32–36 mm Hg) during controlled ventilation, which may ↓ umbilical blood flow. After delivery, NDMR is rarely required; give additional opioid (e.g., fentanyl 150–250 mcg) and increase N_2O concentrations if necessary, or consider converting to TIVA (with propofol and remifentanil infusions). Administer small doses of muscle relaxants (e.g., vecuronium 2–3 mg or rocuronium 10–20 mg) if needed. Reverse with neostigmine 0.05 mg/kg and glycopyrrolate 0.01 mg/kg or atropine 0.02 mg/kg or sugammadex 2–4 mg/kg. Consider titrating longer-acting opioids (e.g., hydromorphone 1–2 mg) for postpartum analgesia. Midazolam (1–2 mg), given after delivery, helps avoid maternal awareness, which occasionally occurs with this anesthetic technique. Consider TAP (transversus abdominis plane) block pre-emergence if consented.

Emergence	Delay extubation until patient is fully awake and muscle strength has returned to normal. Discuss with surgeon local wound infiltration or nerve block. Consider iv acetaminophen if po dose is not given. PONV prophylaxis should include ondansetron.	
Blood and fluid requirements	Moderate blood loss IV: 16–18 ga × 1 (additional larger iv access if hemorrhage) BSS: 1–3 L typical replacement	Infuse 1–2 L BSS (± colloid 500 mL) immediately before (preload) or after (coload) regional anesthesia. Typical blood loss = 700–1000 mL. A rapid-fluid infuser and blood warmer should be available in the event that large-volume blood transfusion is required. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors FHR monitor ±arterial line ±CVP ±TTE/TEE	Arterial BP monitoring via automated BP device or arterial line (e.g., severe or labile HTN, hemorrhage). TTE (awake) or TEE (asleep) should be considered to evaluate volume status and cardiac function. Occasionally, a CVP is needed (e.g., pulmonary edema, vasopressor requirements, unresponsive oliguria).
Positioning	Left uterine displacement (blanket under the right hip and/or table tilt)	Minimizes aortocaval compression
Complications	Amniotic fluid embolism	Rare cause of hemodynamic collapse hypoxemia and DIC. Often fatal. Rx: supportive,

		100% O_2, PEEP, and vasopressors. Correct Plt, clotting factors, and metabolic disturbances. CPB has been used successfully.

POSTOPERATIVE

Complications	VTE	Pregnancy and C-section increase risk of venous thromboembolism. DX: pleuritic chest pain, cough, hypoxemia, ↑ RR, ↑ HR, ↑ A-a gradient. Rx: supportive, 100% O_2, volume expansion, vasopressors, or thrombectomy
	Postpartum hemorrhage	See Anesthetic Considerations for Removal of Retained Placenta.
Multimodal pain management	**Epidural:** 3–4 mg (preservative-free) morphine after delivery **Intrathecal:** Morphine (preservative-free) 0.1–0.15 mg given with spinal local anesthetic	Common side effects include pruritus (70%), nausea (30%), and, rarely, respiratory depression. Nalbuphine (2.5–5 mg) and naloxone (0.1–0.4 mg) are used for reversal of these side effects. Metoclopramide (10 mg iv) and/or ondansetron (4 mg iv) may be needed for persistent nausea. Risk of delayed respiratory depression in healthy patients is small; however, adequately trained nursing staff and a protocol for treatment of complications are mandatory

		if neuraxial opioids are used. These patients should not routinely receive sedatives or other systemic opioids for 12 h, and close monitoring of RR and level of consciousness every hour is necessary for 12 h and then every 2 h for the next 12 h. Pulse oximetry and monitors of ventilation (e.g., $ETCO_2$) should be considered in high-risk patients, including those with obstructive sleep apnea, those with super-morbid obesity, and patients receiving additional sedatives.
	Parenteral opioids: iv opioids (e.g., fentanyl 25–50 mcg, hydromorphone 0.2–0.4 mg) boluses prn or PCA instituted in recovery room.	NSAIDs (e.g., ketorolac): iv either in OR at the end of case or in PACU or if unable to take orally after surgery. Acetaminophen: iv 1000 mg in OR or PACU TAP block is a beneficial rescue analgesic option in select patients.
	Oral analgesics: NSAIDs (e.g., ibuprofen) and acetaminophen around-the-clock for 48–72 postcesarean. Oxycodone (or equivalent oral opioid), for breakthrough pain management.	

ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6.)	Encourage early enteral nutrition and mobilization. Consider DVT prophylaxis.
Tests	As indicated	

Suggested Readings

1. Abir G, Mhyre J: Maternal mortality and the role of the obstetric anesthesiologist Best Pract Res Clin Anaesthesiol 2017; 31:91–105.
2. American Society of Anesthesiologists Task Force on Obstetric Anesthesia: Practice guidelines for obstetric anesthesia: an updated report by the ASA Task Force on Obstetric Anesthesia and Perinatology. Anesthesiology 2016; 124(2):270–300.
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4. Corso E, Hind D, Beever D, et al: Enhanced recovery after elective caesarean: a rapid review of clinical protocols, and an umbrella review of systematic reviews. BMC Pregnancy Childbirth 2017; 17(1):91.
5. Kinsella S, et al: International consensus statement on the management of hypotension with vasopressors during caesarean section under spinal anaesthesia. Anaesthesia 2018; 73(1):71–92.
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MEDICAL AND SURGICAL MANAGEMENT OF POSTPARTUM HEMORRHAGE

SURGICAL CONSIDERATIONS

Description

The most common indication for **postpartum uterine devascularization and hysterectomy** is **intractable postpartum hemorrhage** (**PPH**). PPH is clinically defined as any uncompensated postpartum blood loss → tissue hypoperfusion. There are four major causes of PPH: uterine atony, retained products of conception (POC) laceration of the genital tract, and coagulopathies. Inherited coagulopathies include von Willebrand disease, hemophilia, and factor XI deficiency. Acquired coagulopathies are most often related to thrombocytopenia 2° preeclampsia/eclampsia, hypofibrinogenemia 2° long-standing fetal demise, placental abruption, and DIC related to massive blood loss.

Postpartum blood loss can be reduced by prophylactic use of oxytocin, methylergonovine, or prostaglandins, and these same agents are used as the first line of treatment for PPH. Methylergonovine should be given im only (0.2 mg q2–4 h up to 1 mg) because iv infusion has been reported to cause acute HTN, stroke, and seizure. Ergot derivatives are contraindicated in patients with Hx of HTN, asthma, Raynaud syndrome, or migraine. $PGF_{2\alpha}$ (Hemabate®) may be injected im (intramyometrial) at a dose of 0.25 mg, up to a total of 2 mg. Misoprostol, a PGE, may be given rectally (up to 1000 mcg).

Simultaneously, the surgeon should explore the cause of PPH and apply a specific treatment. If PPH is not controlled with treatment of uterine atony, and after volume replacement and correction of any coagulopathy, temporizing measures should be applied while preparing the patient for definitive invasive treatments. Temporizing measures include packing of uterine cavity with a long gauze, use of balloon tamponade (Bakri balloon), or B-Lynch suture. Nonpneumatic antishock garment (ASG) or nonpregnant patients is applied to postpartum patients with some success in temporizing hypovolemic shock from abdominal and pelvic bleeding. ASG can be applied quickly and results in an immediate 1500–2000 mL autotransfusion. ASG should not be used with fetus in situ or thoracic site of hemorrhage. After stabilization, patient should be transferred to radiology for uterine artery embolization under fluoroscopic control where uterine arteries are selected, and absorbable Gelfoam pledgets are introduced. Treatment may be repeated until bleeding is stopped. In known cases of placenta accreta, in anticipation of PPH, catheters have been placed in uterine arteries before C-section.

If selective embolization is not available or fails to stop hemorrhage, more invasive surgical intervention should be employed, including uterine compression sutures, iliac artery ligation, **uterine devascularization**, and **hysterectomy**. The decision for surgical intervention is made when other options (i.e., medical, interventional radiology) have not been successful in decreasing the hemorrhage. PRBC, Plt, FFP, and cryoprecipitate replacement should continue while proceeding with surgery. Tranexamic acid and fibrinogen concentrates should be considered.

The technique for an **emergent obstetrical hysterectomy** is largely similar to a hysterectomy for other indications. Of note is the engorged and prominent nature of the vessels supplying the gravid uterus. The edematous tissues surrounding the uterus are very friable and may bleed profusely if improperly manipulated. A **supracervical** or **total hysterectomy** may be performed. Through a midline or Pfannenstiel incision, the uterus is elevated out of the abdominal cavity. The round ligaments are clamped,

transected, and ligated, and the anterior leaf of the broad ligament is incised bilaterally from the transected round ligaments to the vesicouterine reflection. The posterior leaf of the broad ligament adjacent to the uterus is entered at a level just below that of the fallopian tubes and utero-ovarian ligaments. These are then clamped, transected, and ligated. Next, incision of the posterior leaf of the broad ligament toward the cardinal ligaments is performed. With gentle blunt dissection, the bladder and attached vesicouterine peritoneal flap are dissected off the lower uterine segment. The ascending uterine arteries and veins are identified bilaterally, then clamped, transected, and ligated. If a **subtotal hysterectomy** is planned, the body of the uterus is amputated at this level, and the cervical stump is closed with interrupted sutures. If a total hysterectomy is planned, dissection of the bladder off the cervix is continued until the cervicovaginal margin is identified. The cardinal and uterosacral ligaments are clamped, transected, and ligated, with clamps placed as close to the cervix as possible without including cervical tissue. After the level of the lateral vaginal fornix is reached, a clamp is swung below the cervix, across the lateral vaginal fornix. The cervix is then amputated off the vaginal cuff. Throughout the procedure, it is vital to clamp and ligate any bleeding vessels and to take extra care to avoid damage to the ureter or bladder. Following removal of the uterus and cervix, the vaginal cuff angles are sutured to the ipsilateral cardinal ligament stumps and the vaginal cuff is closed with a running locked stitch. The abdominal wall is closed in layers.

Usual preop diagnosis

Intractable postpartum bleeding; rupture of gravid uterus

ERAS: Preop enhanced recovery options are limited by the emergent nature of this surgery.

SUMMARY OF PROCEDURE	
Position	Supine, with left lateral tilt
Incision	Pfannenstiel's or midline longitudinal
Unique considerations	Monitoring of coagulation parameters and correction of DIC. Consider central venous hemodynamic monitoring. Pediatrics team present, if indicated.
Antibiotics	Cefazolin 2 g iv q8h; total 3 doses
Surgical time	2–3 h
Closing	Subcutaneous intraperitoneal drains, if indicated

considerations	
EBL	3000–4000 mL
Postop care	ICU if blood loss severe; patient may require continued intubation and mechanical ventilatory support. Monitor for infectious morbidity and acute renal failure.
Mortality	<1%
Morbidity	Hemorrhage Postop febrile morbidity DIC Wound infection Sheehan syndrome Bladder injury Intraperitoneal bleeding requiring reoperation Vesicovaginal fistula Ureterovaginal fistula Transfusion-related complications
Pain score	5–10 (untreated) 0–5 (treated)

PATIENT POPULATION CHARACTERISTICS

Age range	Reproductive age
Incidence	0.11% of obstetric patients
Etiology	Unknown
Associated conditions	Placenta accreta; uterine atony nonresponsive to medical or other surgical intervention; extension of cervical tear to lower uterine segment; placenta previa; uterine rupture; uterine inversion

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Cesarean Section.

Suggested Readings

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3. Crespo A, et al: Postpartum hemorrhage with pelvic arterial embolization, study of 33 cases. J Matern Fetal Neonatal Med 2017; 16:1–6.
4. El-Refaeey A, Gibreel A, Fawzy M: Novel modification of B-Lynch uterine compression sutures for management of atonic postpartum hemorrhage: VV uterine compression sutures. J Obstet Gynaecol Res 2014; 40(2):387–91.
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REPAIR OF UTERINE RUPTURE

SURGICAL CONSIDERATIONS

Description

Rupture of the gravid uterus is considered a true obstetric emergency and can be catastrophic, with significant maternal and fetal mortality. The classic symptoms are "shearing" pain, cessation of uterine contractions, loss of fetal heart tones, and the onset of vaginal bleeding. Unfortunately, these warning symptoms occur only in a minority of uterine rupture cases. Extrusion of the placenta through the uterine rupture may result in late decelerations due to uteroplacental insufficiency. Extrusion of the umbilical cord may be manifested by recurrent variable decelerations. Suprapubic pain as the only symptom has not been associated with uterine rupture. Causes of uterine rupture include breakdown of a previous uterine scar, obstructed labor, or uterine trauma. In cases where the uterine rupture occurs at the site of a prior uterine scar, the clinical course is usually less severe and the blood loss less than in cases of primary rupture of an intact uterus. The incidence of uterine rupture at the site of the old scar is 0.5% for lower-uterine transverse C-sections and 12% for classic C-sections.

Total abdominal hysterectomy, or **supracervical hysterectomy**, is the definitive therapy; however, depending on the clinical situation and the patient's wishes for future fertility, a **uterine repair** may be undertaken. This consists of a two- to three-layered closure of the defect, using synthetic absorbable sutures. A transverse abdominal incision is made ~3 cm above the symphysis pubis and carried to the anterior rectus fascia. The fascia is incised, and the muscles of the anterior abdominal wall are separated sharply and bluntly from the midline. The peritoneum is elevated and entered

sharply. Because of the emergent nature of this condition and the possible massive blood loss associated with rupture of a gravid uterus, the anesthesiologist must act quickly. Prompt O_2 administration, together with aggressive iv fluid resuscitation, followed by transfusion of PRBC, Plt, and FFP. Cryoprecipitate, fibrinogen concentrate, and/or tranexamic acid should be considered. The use of unmatched O(−) or type-specific blood until cross-matched blood becomes available. Intraop **hypogastric or uterine artery ligation** may help minimize blood loss. Patient's coagulation parameters must be monitored because hypoxia and massive blood loss are associated with DIC.

Usual preop diagnosis

Uterine rupture

ERAS: Preop enhanced recovery options are limited by the emergent nature of this surgery.

SUMMARY OF PROCEDURE	
Position	Supine with left-lateral tilt
Incision	Pfannenstiel's (low, transverse abdominal) or midline longitudinal
Unique considerations	Pediatrics team present for infant resuscitation, if necessary. Thorough surgical exploration of the urinary tract (bladder and ureters), because ~10% of cases are associated with bladder lacerations. Cell-Saver may be helpful.
Antibiotics	Cefazolin 2 g iv q8h × 3 doses
Surgical time	1–2 h
EBL	500–3000 mL
Postop care	ICU if blood loss severe; MTP for continued hemorrhage; intubation and mechanical ventilatory support if aggressive fluid resuscitation results in pulmonary edema. Acute renal failure may occur 2° hypoxic and hypovolemic renal injury at time of acute uterine rupture with massive bleeding; monitor UO and serial renal function tests.
Mortality	Fetal: 35–45%

	Maternal: 5%
Morbidity	Blood transfusion >5 U: 58% Postop wound infection: 33% Pelvic abscess: 8% Repeat uterine rupture with subsequent pregnancies: 5%
Pain score	6–10 (untreated) 0–5 (treated)

PATIENT POPULATION CHARACTERISTICS

Age range	Reproductive age
Incidence	1/1400 deliveries
Etiology	Prior uterine surgery; grand multiparity; obesity; manual removal of the placenta; injury from tools of abortion; direct or indirect violence; oxytocin use; intra-amniotic or vaginal prostaglandins; breech extractions; internal or external version; forceps rotation; shoulder dystocia; fundal pressure; neglect (cephalopelvic disproportion, etc.); congenital uterine anomaly; cornual pregnancy; gestational trophoblastic neoplasia; placenta percreta; abruptio placenta

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Cesarean Section.

Suggested Readings

1. Al-Zirqi I, et al: Risk factors for complete uterine rupture. Am J Obstet Gynecol 2017; 216:165e1–8.
2. Markou G, Muray J, Poncelet C: Risk factors and symptoms associated with materna and neonatal complications in women with uterine rupture: a 16 years multicentric experience. Eur J Obstet Gynecol Reprod Biol 2017; 217:126–30.
3. Stattmiller S, et al: Trial of labor after cesarean in the low-risk obstetric population: a retrospective nationwide cohort study. J Perinatol 2016; 36:808–13.
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5. Yang Y, Ye X, Sun X: Maternal and neonatal morbidity: repeat cesarean versus a trial of labour after previous cesarean delivery. Clin Invest Med 2017; 40:e135–45.

POSTPARTUM TUBAL LIGATION

SURGICAL CONSIDERATIONS

Description

Postpartum tubal ligation (PPTL) is female surgical sterilization performed at the time of **cesarean section** (C-section) after delivery of the infant and repair of the uterine incision or within the first several days after a vaginal delivery. Although PPTL can be performed immediately postpartum, problems in the neonate may not be immediately evident, and a delay in surgery may be appropriate. If performed after a vaginal delivery, a small infraumbilical incision is made in the skin and carried down through the parietal peritoneum. The fallopian tubes are identified and brought out of the incision. It is important to identify the fimbriated end of the tube to ensure that the structure ligated is not the round ligament. A midsegment portion of the tube over an avascular portion of the mesosalpinx is selected, and tubal patency is disrupted by a variety of methods (**Pomeroy, Parkland, Irving, Uchida**, etc.). The Pomeroy, or a modification of it, is the most common technique used. The segment of tube grasped is ligated with absorbable suture, and the knuckle of tube formed is excised. The cut ends of the tubes should be hemostatic before replacing the tubes into the abdomen. The wound is closed in layers in the usual fashion.

The consent for sterilization requires special consideration. The procedure is strictly elective and voluntary and must be considered permanent, even though reversal may be possible. Some patients will eventually regret the decision to undergo permanent sterilization. The risk of sterilization failure and an increased risk of ectopic pregnancy in case of failure must be reviewed. The full range of alternatives to PPTL, including an interval sterilization procedure (sterilization performed remote from pregnancy), must also be considered.

Usual preop diagnosis

Desire for permanent sterilization

ERAS: For elective procedures, preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, carb loading, DVT prophylaxis, postop pain management options, and recovery plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE

Position	Supine; steep Trendelenburg often required to allow the bowel to fall away for exposure
Incision	Infraumbilical
Special instrumentation	Small Richardson and Army/Navy retractors; Babcock clamps; vein retractor
Unique considerations	A special consent form for sterilization must be signed by the patient in advance of the surgery. The bladder must be drained before the procedure.
Antibiotics	None recommended
Surgical time	15–25 min (Uchida technique may ↑ operative time)
EBL	10 mL
Postop care	Routine postpartum care after recovery from anesthesia
Mortality	3/100,000
Morbidity	Hemorrhage Infection Incidental damage to bowel or bladder
Pain score	3–5 (untreated) 0–3 (treated)

PATIENT POPULATION CHARACTERISTICS	
Age range	Reproductive age
Incidence	The most common contraceptive procedure in the United States

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Optimal timing of **tubal ligation** remains controversial. Often, it is more convenient for both the surgeon and the parturient with a functioning epidural catheter to have surgery immediately after delivery. Some obstetricians, however, favor waiting 8–24 h, when adequate assessment of the neonate should be complete and risk of postpartum complications, including maternal hemorrhage, is lessened. Alternatively, the patient's existing labor epidural catheter can be left in place and reinjected at a later time

(successful epidural reactivation within 12–24 h is possible in the majority of patients and drops significantly after 24 h). Because pulmonary aspiration remains a theoretical risk, initiation of GA or spinal anesthesia often is delayed 8–24 h until the acute GI changes of pregnancy have regressed and the patient is NPO for 8 h. Shorter hospital stays after vaginal delivery are encouraging more tubal ligations during the first 12 h after delivery, and it is unknown whether this affects morbidity or mortality.

Respiratory	FRC returns to normal almost immediately after delivery. Laryngeal edema may persist in postpartum patients after protracted expulsive efforts during labor and in the pre-eclamptic → requirement for a small ETT. Laryngeal edema can also turn an expected easy airway into a difficult intubation. **Tests:** As indicated from H&P
Cardiovascular	The physiologic changes of pregnancy return to normal at varying intervals after delivery. For example, risk of aortocaval compression disappears immediately. Blood volume and hemodynamic changes return to prepregnant values over several days to weeks. Postpartum hemorrhage can occur without warning. **Tests:** As indicated from H&P
Gastrointestinal	Postpartum patients continue to be at risk for acid aspiration, although it is not known exactly when normal GI function returns. If elective PPTL is planned within 8 h of delivery, patient should have no oral intake of solid foods during labor and the postpartum period. Precautions for prevention of acid aspiration should be followed as discussed in Cesarean Section.
Neurologic	Local anesthetic requirements for spinal and epidural anesthesia remain decreased compared to nonpregnant patients for 36–48 h after delivery.
Laboratory	Hct; other tests as indicated from H&P
Premedication	Precautions should be taken to ↓ risk of aspiration pneumonitis, as discussed in Cesarean Section.
ERAS	Check compliance with presurgical ERAS

	recommendations (see above) including NPO status. Discuss the possibility of spinal or epidural block for anesthesia and postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients undergoing GA with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Spinal anesthesia is preferred if a functioning labor epidural catheter is not in place. Epidural catheters frequently become dislodged after a patient becomes ambulatory. GA is acceptable if patient has a strong preference or failed regional anesthesia or if contraindications to regional anesthesia exist. These patients may be at risk for aspiration of gastric contents at least 8–24 h postdelivery.

Regional anesthesia

Spinal	For technique and monitoring for spinal anesthesia, see Cesarean Section. Hyperbaric bupivacaine (7.5–10 mg) ± fentanyl (10–20 mcg), with goal of obtaining a T6 level of anesthesia. Sedate patient as necessary with small doses of iv midazolam 0.5–1.0 mg.
Epidural	A 3-mL epidural test dose, followed after 3–5 min by 15–20 mL of either 2% lidocaine with 1:200,000 epinephrine or 3% chloroprocaine injected incrementally. Titrate local anesthetic as needed to ensure adequate level of anesthesia. Consider adding fentanyl 100 mcg epidurally to reduce local anesthetic requirements and extend the duration of analgesia for several hours postoperatively.

General anesthesia

Induction	Rapid-sequence induction with propofol (2–3 mg/kg) and succinylcholine (1–1.5 mg/kg) for ET intubation. In selected patients >24 h after delivery, supraglottic

	airway devices (e.g., ProSeal LMA) may be appropriate.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance	
Emergence	Extubation should be delayed until patient is fully awake and protective airway reflexes have returned. Consider iv acetaminophen if po dose is given >4–6 h ago. PONV prophylaxis should include ondansetron.	
Blood and fluid requirements	Minimal blood loss IV: 18–20 ga × 1	1–1.5-L BSS. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes	
Complications	None specific	

POSTOPERATIVE

Complications	Minimal bleeding	
Multimodal pain management	**Neuraxial opioids:** Fentanyl intrathecally 10–20 mcg or epidurally 50–100 mcg. Some authors propose small doses of intrathecal or epidural morphine to improve duration of analgesia, but patients then require 24-h monitoring. **Oral or parenteral opioids:** Oral opioids	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with spinal or epidural analgesia (see Appendix K, p. K-6).

	(e.g., oxycodone 5–10 mg), iv opioids (e.g., morphine 2–4 mg iv, up to 20 mg), or hydromorphone 0.2–0.4 mg iv instituted in the recovery room **NSAIDs:** Intravenous (e.g., ketorolac 15–30 mg) or oral (e.g., ibuprofen 600 mg) as necessary may be effective for pain of a cramping nature. Acetaminophen iv or oral as needed	
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6.)	Encourage early enteral nutrition and mobilization. Consider DVT prophylaxis.
Tests	None routinely indicated	

Suggested Readings

1. American College of Obstetricians and Gynecologists: ACOG Committee Opinion Committee on Ethics: Sterilization of women, including those with mental disabilities. No 371, 2007 (replaces No 63, 1988, No 73, 1989, and No 216 1999) Obstet Gynecol 2007; 110(1): 217–20.
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5. McKenzie C, Seden A, Gillian A, et al: Postpartum tubal ligation: a retrospective review of anesthetic management at a single institution and a practice survey of academic institutions. J Clin Anesth 2017; 43:39–46.
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postpartum tubal ligation: a prospective, observational study. J Clin Anesth 2016; 35:221–24.

REPAIR OF VAGINAL/CERVICAL LACERATIONS

SURGICAL CONSIDERATIONS

Description

Vaginal and cervical lacerations may occur 2° trauma of spontaneous and operative vaginal delivery. Adequate repair requires optimal surgical assistance, exposure, and patient comfort. Repair may be performed in a birthing bed or may require patient positioning, lighting, anesthesia, or monitoring capabilities available only in an OR. Vaginal and cervical lacerations can extend into the perineum, rectum, urethra, bladder, lower uterine segment, broad ligament, or peritoneal cavity.

Lacerations of the lower vagina generally are easy to identify and repair. Small, superficial lacerations that do not bleed usually do not need repair, whereas larger ones should be approximated. Deep lacerations may cause profuse bleeding; if it persists despite placement of multiple stitches, brief tamponade may be adequate to achieve hemostasis or vaginal packing may be required. Lacerations involving the perineum are classified as follows: first-degree—involves break in the mucosa and skin; second-degree—involves deeper tissue (bulbocavernosus and levator ani fascia and muscle); third-degree—involves anal sphincter; and fourth-degree—extends into the rectal mucosa. First- and second-degree lacerations are repaired in layers with continuous or interrupted stitches. The skin usually is closed with a subcuticular stitch. When the anal sphincter is lacerated, it often retracts. The ends are grasped with Allis clamps and approximated with multiple stitches. When the laceration extends into the rectum, the rectal mucosa usually is closed in two layers, with the second layer imbricating the first. With periurethral lacerations, a catheter may need to be placed in the urethra to prevent passing a stitch through it. A laceration involving the urethra or bladder should be closed in multiple layers, followed by bladder drainage for several days.

Lacerations of the upper vagina are often difficult to visualize. Uterine bleeding and the umbilical cord of an undelivered placenta can obscure the field, and it can be difficult to determine if bleeding is vaginal or uterine. It is helpful to deliver the placenta and control uterine bleeding before proceeding. After visualization is adequate, it is important to place the first stitch above the apex of the laceration to control bleeding from vessels that may have retracted. Again, vaginal packing may be

required if oozing of blood persists.

Superficial **lacerations of the cervix** occur with most deliveries but usually do not require treatment. Deep lacerations can cause significant blood loss, especially when they involve larger branches from the uterine artery or extend into the lower uterine segment. Again, the first stitch must be placed above the apex of the laceration to control bleeding from vessels that may have retracted. A **laparotomy** may be necessary if a laceration extends into the lower uterine segment or broad ligament and is causing significant bleeding that cannot be controlled otherwise. Alternatively, uterine artery embolization may be considered.

Usual preop diagnosis

Vaginal or cervical laceration

ERAS: Preop enhanced recovery options are limited by the urgent nature of this surgery.

SUMMARY OF PROCEDURE	
Position	Dorsal lithotomy
Incision	None (unless exploratory laparotomy is performed)
Special instrumentation	Right-angle retractors; ring forceps; Allis clamps; Gelpi retractor; vaginal packing
Antibiotics	May be used for lacerations involving entry into the peritoneal cavity or the rectal mucosa
Surgical time	10–45 min (possibly longer if exploratory laparotomy is performed)
EBL	Variable. Possible need for transfusion. Areas that persistently ooze after repeated placement of suture may be managed with vaginal packing.
Postop care	PACU → ward
Mortality	Rare
Morbidity	Hemorrhage Hematoma Infection Rectovaginal fistula

	Vesicovaginal fistula
Pain score	3–5 (untreated) 0–3 (treated)

PATIENT POPULATION CHARACTERISTICS

Age range	Reproductive age
Incidence	Not uncommon
Etiology	Trauma 2° spontaneous or operative vaginal delivery (98%); other vaginal/pelvic trauma (2%)
Associated conditions	Major blood loss possible; with nonobstetric etiology, the possibility of sexual assault needs to be explored.

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Vaginal and cervical lacerations are reported in up to 11% of women during vaginal delivery. These lacerations may be associated with severe postpartum hemorrhage and can extend into the lower uterine segment leading to considerable blood loss that may go undetected. Patients should be examined carefully for Sx of hypovolemia with appropriate volume resuscitation before anesthesia. Evaluation and exploration of all but the most superficial of lacerations need to be done in the operating room to optimize anesthesia options, hemodynamic monitoring, and surgical exposure.

Respiratory	FRC returns to normal soon after delivery. **Tests:** As indicated from H&P
Cardiovascular	The physiologic changes of pregnancy return to normal at varying intervals after delivery. For example, risk of aortocaval compression disappears immediately. Blood volume and hemodynamic changes return to prepregnant values over several days to weeks. Postpartum hemorrhage can occur without warning. Ensure adequate fluid resuscitation before induction of GA or regional anesthesia. **Tests:** As indicated from H&P
Gastrointestinal	Postpartum patients continue to be at risk for acid aspiration, although it is not known exactly when

	normal GI function returns. Precautions for prevention of acid aspiration should be followed as discussed in Cesarean Section.
Neurologic	Local anesthetic requirements for spinal and epidural anesthesia remain decreased compared to nonpregnant patients for 36–48 h after delivery.
Laboratory	Hct; consider coagulation studies with excessive blood loss; other tests as indicated from H&P
Premedication	Precautions should be taken to ↓ risk of aspiration pneumonitis, as discussed in Cesarean Section.
ERAS	Discuss with surgeon the possibility of a nerve block for anesthesia and postop pain management.

INTRAOPERATIVE

Anesthetic technique

In many patients, a functioning epidural catheter will be in place, and supplemental doses of anesthetic may be given to provide adequate analgesia for the surgery. If no epidural is in place and the patient is hemodynamically stable, a spinal anesthetic may be satisfactory. GA may be required when regional is contraindicated.

Regional anesthesia

Epidural	Supplemental doses of local anesthetic (1.5–2% lidocaine 10–15 mL) with or without fentanyl (50–100 mcg) injected incrementally with patient in sitting position (if tolerated) to promote perineal anesthesia
Spinal	Hyperbaric bupivacaine 0.75% 7.5 mg combined with fentanyl 10–20 mcg with patient in sitting position, if tolerated. 25- to 27-ga pencil-point needle to ↓ incidence of spinal headache. Anesthesia to T10 is usually adequate. Repair of more extensive lacerations may require a higher anesthetic dermatomal level and, consequently, a higher dose of hyperbaric bupivacaine (e.g., 10 mg).
Combined spinal-	An alternative technique combining the rapid onset

epidural (CSE)	and density of spinal anesthesia with the flexibility of continuous epidural anesthesia (e.g., if necessary to extend the duration or intensity of the block). Position and prepare patient as for any neuraxial anesthetic. The recommended technique is the needle-through-needle, which entails after locating the epidural space with a 17-ga Tuohy needle, a 25- to 27-ga pencil-point needle is then inserted through the Tuohy needle into the intrathecal space. An intrathecal dose of 7.5 mg of bupivacaine is administered, and after removal of the spinal needle, the epidural catheter is threaded through the Tuohy needle. Secure the epidural catheter and use if needed. (An epidural test dose is advisable.)

General anesthesia

Induction	Rapid-sequence induction with propofol (2–3 mg/kg) and succinylcholine (1–1.5 mg/kg) for ET intubation. If significant blood loss, ketamine 1.5 mg/kg or etomidate 0.3 mg/kg is preferred for induction.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.	
Maintenance	Standard maintenance	
Emergence	Extubation should be delayed until patient is fully awake and protective airway reflexes have returned. Discuss with surgeon local wound infiltration or nerve block.	
Blood and fluid requirements	Potential large blood loss IV: 16–18 ga × 1	1–1.5 L BSS ± PRBC as per blood loss. Blood loss may be extensive until laceration is repaired. See Goal-Directed Fluid Management, Appendix K, p. K-4.

Monitoring	Standard monitors	
Complications	Bleeding	
Positioning	✓ pad pressure points ✓ eyes	To avoid peroneal nerve compression at lateral fibular head → foot drop

POSTOPERATIVE

Complications	Bleeding Peroneal nerve injury (2° lithotomy position)	Nerve injury manifests as foot drop and loss of sensation over the dorsum of the foot
Multimodal pain management	**Neuraxial opioids:** 10–20 mcg fentanyl intrathecally or 50–100 mg fentanyl epidurally enhances intraop anesthesia and provides 3–4 h postop analgesia.	Emphasize multimodal approach combining nonopioid and epidural analgesia.
	Oral or parenteral opioids: Oral opioids (e.g., oxycodone 5–10 mg) or iv opioids (e.g., morphine 2–4 mg iv up to 20 mg or hydromorphone 0.2–0.4 mg iv) instituted in the recovery room	Avoid NSAIDs if significant bleeding.
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6.)	Encourage early enteral nutrition and mobilization. Consider DVT prophylaxis.
Tests	Hct	

Suggested Readings

1. American College of Obstetricians and Gynecologists' Committee on Practice

Bulletins—Obstetrics: Practice Bulletin No. 165: prevention and management o obstetric lacerations at vaginal delivery. Obstet Gynecol 2016; 128(1):e1–15.
2. Corso E, Hind D, Beever D, et al: Enhanced recovery after elective caesarean: a rapid review of clinical protocols, and an umbrella review of systematic reviews. BMC Pregnancy Childbirth 2017; 17(1):91.
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CERVICAL CERCLAGE—ELECTIVE AND EMERGENT

SURGICAL CONSIDERATIONS

Description

Cervical cerclage is the reinforcement of the cervix to prevent premature cervical dilation in a patient with an incompetent cervix. With cervical incompetence, there is painless dilation of the cervix in the midtrimester of pregnancy. The membranes bulge through the cervix and rupture, followed by delivery of a severely premature infant.

An elective cerclage is performed prophylactically before pregnancy or usually after the first trimester of pregnancy on a patient with a Hx of cervical incompetence. If cerclage is performed before pregnancy, it may need to be removed because of spontaneous abortion or fetal anomalies. It generally is performed between 14- and 16-wk gestation but may be performed as early as 10-wk gestation. An **emergent (rescue) cerclage** is performed in a patient who presents in the second trimester with painless cervical dilation and/or effacement. Ultrasound is performed before the procedure to confirm viability and to r/o major congenital anomalies. An emergent cerclage should not be performed if there is advanced cervical dilation or any evidence of infection, contractions, or uterine bleeding.

There are two types of cerclage procedures generally performed: the McDonald and the Shirodkar. The **McDonald cerclage** is technically easier, and the one most commonly performed. A purse-string stitch with nonabsorbable monofilament suture is placed high

around the cervix near the level of the internal os and tied at the 12-o'clock position. The end of the suture is cut long to facilitate removal. The cerclage is removed electively at term or earlier if there is rupture of membranes, persistent contractions, bleeding, or evidence of infection. The **Shirodkar cerclage** involves incising the cervix transversely, anteriorly, and posteriorly and advancing the bladder off the cervix. A nonabsorbable monofilament suture is placed submucosally between the incisions, and the mucosa is closed, burying the stitch. A Shirodkar cerclage may be left for future pregnancies if abdominal delivery is performed. If the cervix cannot be adequately accessed through the vagina, cerclage may be attempted through laparotomy or laparoscopy.

Usual preop diagnosis

Cervical incompetence

ERAS: For elective procedures, preop counseling by the surgeon and anesthesiologist should include limiting NPO duration and carb loading. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Dorsal lithotomy, with the use of cane stirrups. Left lateral pelvic tilt (if performed during pregnancy); Trendelenburg
Incision	None with McDonald cerclage; transverse cervical with Shirodkar cerclage
Special instrumentation	Right-angle retractors; monofilament, nonabsorbable stitch
Unique considerations	For emergent cerclage, when prolapsing membranes are present, they may be reduced by filling the bladder and/or possibly removing amniotic fluid transabdominally.
Antibiotics	None recommended
Surgical time	30 min to 1 h (may be longer for Shirodkar cerclage)
EBL	25–50 mL (may be higher with the Shirodkar cerclage)
Postop care	PACU → ward; tocolysis with indomethacin or other agent may be considered.

Mortality	Rare
Morbidity	Morbidity is increased for emergent cerclage, especially when performed later in the 2nd trimester. The McDonald cerclage is associated with less trauma and bleeding than the Shirodkar cerclage. Cervical trauma Rupture of membranes Chorioamnionitis Preterm labor Spontaneous abortion
Pain score	McDonald, 0–3; Shirodkar, 0–4

PATIENT POPULATION CHARACTERISTICS

Age range	Reproductive age
Incidence	Not uncommon
Etiology	Cervical trauma from previous vaginal delivery; cervical trauma at time of previous D&C; previous treatment for cervical dysplasia (laser therapy, cryotherapy, loop electrosurgical excision procedure [LEEP]/large loop excision of the transformation zone [LLETZ], cone biopsy); congenital anomalies; idiopathic

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Cervical insufficiency affects ~1% of pregnant women, and ~40,000 cerclage placement procedures are performed annually in the United States. This patient population is generally healthy, and little workup is needed unless otherwise indicated. Cerclage is usually performed between 14 and 24 wk of pregnancy. When performed after 20 wk, relevant physiologic changes are as discussed under Cesarean Section. Women requiring a cerclage may also have uterine irritability and potentially receive drugs such as β-sympathomimetics (e.g., terbutaline), nifedipine, or indomethacin.

Laboratory	Hct; other tests as indicated from H&P

Premedication	None usually, but the significantly anxious patient may benefit from midazolam (0.5–2 mg). If >18-wk gestation and GA required, precautions should be taken to decrease risk of aspiration pneumonitis, as discussed in Cesarean Section.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status.

INTRAOPERATIVE

Anesthetic technique

Drug exposure during the critical period of organogenesis (15–56 d) should be minimized, although no particular anesthetic techniques or agents have proven teratogenic in humans. Although N_2O is teratogenic in rodents, there is no evidence of human teratogenicity when used for cervical cerclage or other operations. Ensure adequate uteroplacental perfusion and fetal oxygenation by maintaining normal maternal BP and oxyhemoglobin saturation. Use left uterine displacement after 20-wk gestation. Maternal hyperventilation and IPPV may diminish uteroplacental and umbilical blood flow. Monitoring FHR may permit optimization of fetal well-being by adjustment of maternal blood pressure, oxygenation, or position. Spinal anesthesia is ideal as it minimizes fetal drug exposure and provides good operating conditions. Risk of headache is low with the use of 25- to 27-ga pencil-point needles (e.g., Sprotte, Whitacre). Epidural anesthesia is an appropriate alternative for this procedure. GA may be required if regional anesthesia is contraindicated or if uterine relaxation is desired to facilitate cerclage placement (e.g., increased uterine tone with bulging fetal membranes).

Regional anesthesia

Spinal	Hyperbaric bupivacaine 7.5–10 mg ± fentanyl 10–20 mcg. Position patient to obtain T8-T10 block. Monitor BP every min until stable and then every 3–5 min. Treat ↓ in BP below baseline with fluids and a vasopressor (e.g., phenylephrine 50–100 mcg or ephedrine 5–10 mg iv).

General anesthesia

Induction	Standard induction. If >16- to 18-wk gestation, rapid-sequence induction is indicated.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance. If <16- to 18-wk gestation, use of LMA or mask anesthesia with either O_2/N_2O/volatile agent/opioid or propofol infusion is appropriate. If >16- to 18-wk gestation, ET intubation will be necessary.	
Emergence	If >16- to 18-wk gestation, extubate patient when fully awake and protective airway reflexes have returned.	
Blood and fluid requirements	Minimal blood loss IV: 18 ga × 1	Fluid preloading (before regional anesthesia) or coloading (at the time of spinal) with 1- to 1.5-L BSS or 500 mL of colloid may be beneficial in decreasing spinal hypotension. See Restrictive Fluid Management, Appendix K, p. K-2 and p. K-4.
Monitoring	Standard monitors ±FHR monitor	Consider FHR monitoring for viable fetuses and in earlier gestation, as the FHR may indicate inadequate placental perfusion and can guide BP management.
Positioning	Left uterine displacement, if >20-wk gestation ✓ and pad pressure points ✓ eyes	Lithotomy positioning: **NB:** peroneal nerve compression at lateral fibular head → foot drop.

POSTOPERATIVE

Complications	Preterm labor Hypotension	Observe for preterm labor in recovery area. Tocolytic agents (beta-adrenergic agents) given to inhibit uterine contractions can cause maternal dysrhythmias or ↓ BP.
	Peroneal nerve injury	Manifests as foot drop and loss of sensation over the dorsum of the foot
Multimodal pain management	**Intraspinal opioids:** 10 - to 20-mcg fentanyl **Parenteral opioids:** iv opioids (e.g., fentanyl 25–50 mcg iv, morphine 2–4 mg iv, or hydromorphone 0.2–0.4 mg) instituted in the recovery room **Oral analgesics:** NSAIDs (e.g., ibuprofen) should not be prescribed for analgesia during pregnancy (cardiopulmonary and renal effects in developing fetus). Acetaminophen ± oxycodone (or equivalent oral narcotics), once patient can tolerate oral medication.	Intrathecal fentanyl given with spinal improves intraop analgesia and provides several hours of postop analgesia. Emphasize multimodal approach combining nonopioid analgesics with spinal/epidural analgesia.
ERAS	PONV protocol (see Appendix B, p. B-4	Encourage early enteral nutrition and mobilization.

and p. B-6.) Consider DVT prophylaxis.

Suggested Readings

1. American College of Obstetricians and Gynecologists: ACOG Practice Bulletin No 142: Cerclage for the management of cervical insufficiency. Obstet Gynecol 2014; 123:372–9.
2. American College of Obstetricians and Gynecologists: Nonobstetric surgery during pregnancy. Committee Opinion No. 696. Obstet Gynecol 2017; 129:777–8.
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REMOVAL OF RETAINED PLACENTA

SURGICAL CONSIDERATIONS

Description

In most deliveries, the placenta is easily removed with gentle cord traction and uterine massage. If, after 30 min, the placenta remains undelivered, **manual removal**, following either parenteral analgesia, sedation, or GA, must be initiated. NTG (100–200 mcg iv or 0.4–0.8 mg sublingually) may induce uterine relaxation during manual removal. A possible alternative to manual removal involves injection of 10 mL of oxytocin (10 U/mL) into the umbilical vein; however, the success of this procedure is unpredictable. A retained placental fragment may cause immediate or late postpartum hemorrhage. An ultrasound evaluation of the uterus may help in the detection of a retained fragment. If retained products are found, **curettage** is recommended. Frequently, the retained product will already have been flushed out of the uterus by brisk bleeding. In such

cases, iv oxytocin, rectal misoprostol, IM prostaglandins, or methylergonovine may be administered to contract the uterus before curettage.

Bleeding from a retained placenta or fragment is frequently brisk, so the anesthesiologist must be ready to administer iv fluids or blood, provide supplemental O_2, and correct any coagulopathy. Cross-matched blood must be available. Placenta accreta, if extensive, can cause profuse bleeding at delivery, and a hysterectomy is often necessary.

Oxytocin boluses (1–2 U) and infusion of 30 U in 1000 mL of LR at 250–500 mL/l should be administered at a rate sufficient to maintain uterine tone after manual removal of the placenta or after sharp/suction curettage of a retained placental fragment.

Usual preop diagnosis

Retained placenta

ERAS: Preop enhanced recovery options are limited by the urgent nature of this surgery.

SUMMARY OF PROCEDURE	
Position	Dorsal lithotomy
Incision	None
Special instrumentation	Banjo curette/suction cannula
Unique considerations	IV fluids; PRBC and blood products, as needed; monitoring of VS
Antibiotics	Cefazolin 2 g iv q8h; 3 total doses
Surgical time	30 min
EBL	300–900 mL
Postop care	PACU → ward. Monitor for infection and further bleeding.
Mortality	Rare
Morbidity	Hemorrhage Endometritis Uterine perforation 2° curettage

	Asherman syndrome Transfusion-related morbidity (hepatitis, HIV, transfusion reactions)
Pain score	0–4

PATIENT POPULATION CHARACTERISTICS

Age range	Reproductive age
Incidence	0.25–0.8% of vaginal deliveries
Etiology	Unknown
Associated conditions	Placenta accreta; avulsed cotyledon; succenturiate lobe

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

The incidence of retained placenta is about 1–4%. The degree of urgency associated with these patients may vary dramatically. Some patients may be hemodynamically unstable as a result of heavy and/or persistent bleeding in the postpartum period; others may have a retained placenta with minimal bleeding. Delays in delivery of the placenta increase the risk of significant postpartum hemorrhage. Evaluation of the patient in the OR to optimize monitoring, anesthetic options, and surgical exposure is essential.

Respiratory	Laryngeal edema may persist in postpartum patients after protracted expulsive efforts during labor and increases the likelihood of difficult intubation. **Tests:** As indicated from H&P
Cardiovascular	Volume status should be carefully assessed, and resuscitation started early. Restore intravascular volume before institution of analgesia or anesthesia. Neuraxial anesthesia (either spinal or extension of existing lumbar epidural blockade) may aggravate hypovolemia. Consider possibility of placenta accreta (placental villi are attached to the myometrium), especially if the placenta is difficult to remove, and expect greater blood loss.

Gastrointestinal	Postpartum patients continue to be at risk for acid aspiration, although it is not known exactly when normal GI function returns. Precautions for prevention of acid aspiration should be followed as discussed in Cesarean Section.
Neurologic	Local anesthetic requirements for neuraxial anesthesia remain decreased compared to nonpregnant patients for 36–48 h after delivery.
Hematologic	Coagulopathy can develop rapidly with retained placenta, especially if bleeding is severe and persistent. **Tests:** Hct, PT, PTT, Plt, fibrinogen, as indicated
Laboratory	Other tests as indicated from H&P. T&C for 2–4 U+ if time permits. Emergency transfusion with type O(−) or type-specific blood may be necessary. If available, consider activation of MTP if severe hemorrhage, significant coagulopathy, unstable hemodynamics, and/or if there are significant delays in receiving cross-matched blood. Consider tranexamic acid if >1000-mL blood loss. PRBC, Plt, FFP, cryoprecipitate/fibrinogen concentrates as needed.
Premedication	Precaution should be taken to decrease risk of aspiration, as discussed in Cesarean Section. Anxiolysis (e.g., midazolam 0.5–2 mg iv) may be indicated.
ERAS	Discuss with surgeon the possibility of an epidural/spinal block for anesthesia (if MAC is not an option) and postop pain management. Consider preop acetaminophen 1000 mg po with sip of water.

INTRAOPERATIVE

Anesthetic technique

There are several anesthesia options (MAC/GA/neuraxial technique) for the removal o a retained placenta depending on the urgency and severity. Sedation (MAC) may be

sufficient to enable the obstetrician to manually extract the placenta. If better analgesia and additional uterine relaxation are needed, however, then GA may be required. If intravascular volume has been restored and an existing labor epidural catheter is in place, the sensory block can be extended to provide adequate anesthesia. Initiating spinal anesthesia is also an option if intravascular volume status is adequate, there is no significant active bleeding, and time permits. Small doses of iv opioids, midazolam, and/or ketamine sometimes provide sufficient analgesia and sedation to allow removal of a retained placenta without compromising maternal safety. If this proves inadequate or hemorrhage is severe, however, GA with ET intubation is required. NTG in 100-mcg iv boluses or sublingual NTG 400 mcg provides uterine relaxation and may aid delivery of a retained placenta in normovolemic patients.

Regional anesthesia

Spinal	For technique and monitoring of spinal anesthesia, see Cesarean Section. Hyperbaric bupivacaine 7.5–10 mg, with or without fentanyl 10–20 mg, to obtain T8 level of anesthesia.
Epidural	For technique and monitoring, see Cesarean Section. Administer increments of 2% lidocaine (with 1:200,000 epinephrine and bicarbonate) or 3% 2-chloroprocaine until block level is adequate. Additional local anesthetic and fentanyl 50–100 mcg can be administered epidurally as needed to ensure adequate level of anesthesia.
MAC	Titrate small doses of opioids (e.g., fentanyl 25–50 mcg) and midazolam 0.5–2.0 mg or ketamine 0.1–0.2 mg/kg. Sedation and analgesia should be titrated carefully, due to the potential risk of pulmonary aspiration in the parturient with an unprotected airway. Ensure patient is awake and responsive throughout. Consider NTG 100 mcg iv for uterine relaxation, repeated as necessary to obtain the desired effect. Transient ↓ BP may follow vasodilation due to NTG and should be treated with volume and vasopressors if necessary.

General anesthesia

Induction	Preoxygenation, rapid-sequence induction with cricoid pressure, and hydration, as discussed in Cesarean Section. Ketamine (1 mg/kg) is preferred for induction of hypotensive patient, but, in larger doses (>1.5 mg/kg), it theoretically may increase uterine tone and make removal of the placenta more difficult. Etomidate 0.2–0.4 mg/kg is also a suitable induction agent in this setting.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Anesthesia with N_2O/O_2 + volatile + opioid often permits delivery of placenta. If uterine relaxation is necessary, administer volatile agent (>1.5 MAC) or NTG (see above) until uterine tone decreases.	
Emergence	Extubation should be delayed until patient is fully awake and protective airway reflexes have returned.	
Blood and fluid requirements	Anticipate large blood loss IV: 16–18 ga × 1–2	1–1.5 L BSS or colloid 500 mL or greater volumes ± PRBC based on blood loss. Treat ↓ BP with fluids and vasopressors and by decreasing concentration of volatile agent. Surgery is usually brief; additional muscle relaxation is not usually necessary. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	
Complications	Bleeding Uterine atony	Oxytocin is the first-line uterotonic agent. Consider small boluses 1–2 U in addition to an infusion (e.g., 30 U in 1000 mL NS at 250–500 mL/h). Second-line

		uterotonics include methylergonovine 0.2 mg im (may →↑ BP), $PGF_{2\alpha}$ (Hemabate) 250 mcg im/intrauterine (may → cardiovascular collapse/bronchospasm), and/or misoprostol (Cytotec) 600–1200 mg rectal/sublingual.
Positioning		**NB:** peroneal nerve compression at lateral fibular head → foot drop.

POSTOPERATIVE

Complications	Peroneal nerve injury (2° lithotomy position)	Nerve injury manifested as footdrop and loss of sensation over the dorsum of the foot.
	Bleeding	See uterine atony, above.
Multimodal pain management	Parenteral: Opioids (e.g., fentanyl 25–50 mcg iv; titrated to effect) instituted in recovery room. Avoid NSAIDs in patients with persistent or significant bleeding. Administer acetaminophen and oral opioids (e.g., oxycodone 5–10 mg) for postoperative pain management.	Emphasize multimodal approach combining nonopioid analgesics with epidural/spinal analgesia blocks.
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6.)	Encourage early enteral nutrition and mobilization. Consider DVT prophylaxis.

Tests	Hct, coagulation profile

Suggested Readings

1. Anteby M, et al: Risk factors and complications of manual placental removal after vaginal delivery-how common are additional invasive procedures? J Matern Fetal Neonatal Med 2017; 19:1–5.
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MANAGEMENT OF UTERINE INVERSION

SURGICAL CONSIDERATIONS

Description

Uterine inversion is associated with fundal implantation of the placenta whereby a thinning of the uterine wall, together with placental separation, causes an invagination of the myometrium, resulting in inversion. Vigorous fundal pressure or cord traction also can contribute to uterine inversion, which can be complete or incomplete. **Complete inversion** results in the inverted fundus extending beyond the cervix and appearing at the vaginal introitus, whereas in an **incompletely inverted uterus,** the fundus does not extend beyond the external cervical os. Uterine inversion can cause hemorrhage and shock out of proportion to observed bleeding and must be managed as an obstetrical emergency. An anesthesiologist must be called to the delivery room as soon as a diagnosis of uterine inversion is made. The ready availability of GA is paramount. Large-bore iv access with rapid infusion systems and appropriate fluid resuscitation must be initiated emergently. Blood and blood products should be available for administration as indicated.

Frequently, **uterine replacement** can be accomplished with iv tocolytics, such as terbutaline, $MgSO_4$, and, more recently, NTG; however, GA with a volatile agent may be necessary. Delay in treatment of uterine inversion is associated with increased blood loss. Initiate iv resuscitation and iv tocolytics (or anesthesia). Three primary methods for uterine replacement are the Johnson, Huntington, and Haultain procedures. Usually the **Johnson method** is attempted first. Leave the placenta attached. Cup the inverted fundus in the palm of the hand, and elevate the inverted prolapsed fundus. Apply persistent upward pressure to the ring of inversion with the tip of the operator's fingers. Once the fundus is replaced, keep a fist inside the uterus and apply external fundal massage. Continue uterotonic treatments. Attempt manual removal of the placenta at this stage. Watch for reinversion. Laparotomy must be performed if uterine replacement with the Johnson method is unsuccessful. The **Huntington procedure** involves grasping the round ligaments and applying upward traction on them while an assistant exerts upward pressure on the uterus via a hand in the vagina. If the inverted uterus is trapped below the cervical ring, the **Haultain procedure** is used. This procedure involves making a longitudinal fundal incision posteriorly to allow easier reinversion of the fundus. Hydrostatic and laparoscopic reduction of uterine inversion has also been described.

Usual preop diagnosis

Uterine inversion

ERAS: Preop enhanced recovery options are limited by the emergent nature of this surgery.

SUMMARY OF PROCEDURES

	Manual Reinversion	Huntington/Haultain
Position	Dorsal lithotomy	Supine
Incision	None	Pfannenstiel's or midline longitudinal
Unique considerations	Prompt O_2 and iv fluid resuscitation; use of blood and blood products as necessary.	⇐
Antibiotics	Cefazolin 2 g iv q8h; total 3 doses	⇐
Surgical time	30 min	1–2 h

EBL	250–3000 mL	⇐
Postop care	±ICU. ARDS may necessitate mechanical ventilation. Monitor for acute renal failure 2° hypoxia and hypovolemia.	⇐
Mortality	Rare	⇐
Morbidity	Febrile morbidity Clinical shock Infectious morbidity from blood transfusion	⇐ ⇐ ⇐
Pain score	2–5	3–7

PATIENT POPULATION CHARACTERISTICS

Age range	Reproductive age
Incidence	1/2000–6000 deliveries
Etiology	Unknown
Associated conditions	Fundal implantation of the placenta; primiparity; intrapartum oxytocin; placenta accreta; therapy of preeclampsia with $MgSO_4$; macrosomic fetus

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Uterine inversion is an obstetric emergency as it usually is accompanied by hemorrhage and shock. Management requires prompt recognition and action. These patients often present in shock out of proportion to blood loss because of the parasympathetic effect of traction on the ligaments supporting the uterus. Immediate resuscitation almost always is necessary. Blood loss varies from 250 to 3000 mL and is easily underestimated. Patient condition will improve as soon as the uterus is replaced, and therefore, surgical treatment should not be delayed. Consider activation of MTP if available.

Respiratory	FRC returns to normal almost immediately after delivery. **Tests:** As indicated from H&P

Cardiovascular	Massive hemorrhage and pain usually present with complete inversion. Before induction, insert large-bore iv, and rapidly begin fluid resuscitation to treat ↓ BP. Blood transfusion may be necessary, although is seldom available until after surgery.
Gastrointestinal	Postpartum patients continue to be at risk for acid aspiration, although it is not known exactly when normal GI function returns. Precautions for prevention of acid aspiration should be followed as discussed in Cesarean Section.
Neurologic	Local anesthetic requirements for neuraxial anesthesia remain decreased compared to nonpregnant patients for 36–48 h after delivery.
Laboratory	Hct; Plt; consider coagulation studies and other tests as indicated from H&P. T&C for 2–4 U PRBC; keep 2 U ahead. MTP with O-negative PRBC if necessary.
Premedication	Na citrate 30 mL po within 30 min of GA induction. If time permits, other agents to decrease risk of aspiration pneumonitis, as discussed in Cesarean Section
ERAS	Enhanced recovery options are limited by the emergent nature of this surgery.

INTRAOPERATIVE

Anesthetic technique

Attempted uterine replacement and induction of anesthesia should not await intravascular volume replacement. Bleeding usually stops when the uterus is replaced. Uterotonic therapy should be discontinued, and iv NTG (50–200 mcg) will often provide uterine relaxation to facilitate replacement and can be administered in the labor suite. Other tocolytics, such as terbutaline or Mg^{++}, also may assist in restoration of the uterine fundus. **Do not give oxytocin before uterine replacement**. If regional anesthesia (e.g., epidural or spinal) was used for delivery, replacement of the uterus may be accomplished with little further anesthetic intervention, with or without NTG. If regional anesthesia was not used for delivery, iv analgesia and sedation with small doses of fentanyl (25–50 mcg iv), ketamine (10–20 mg iv), or midazolam (0.5–1 mg iv)

may allow reduction. Sometimes, however, GA is required, often with increasing concentrations of volatile agents to facilitate uterine replacement. GA also provides the opportunity for a laparotomy to correct the inversion if other measures fail.

Induction	Rapid-sequence induction with ketamine (1.0 mg/kg) or etomidate (0.3 mg/kg) preferred. Higher dose of ketamine may adversely increase uterine tone.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Attempt to maintain normovolemia and normothermia.	
Maintenance	Sevoflurane and desflurane are effective uterine relaxants. ↓ BP should be treated with fluids + vasopressors and transfusion ± blood and blood products as necessary.	
Emergence	Extubation should be delayed until patient is fully awake and protective airway reflexes have returned. Consider iv acetaminophen. PONV prophylaxis should include ondansetron.	
Blood and fluid requirements	Significant blood loss IV: 16–18 ga × 2	Possible continued blood loss after reduction of the uterus due to uterine atony. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	Arterial line may be useful, if time allows.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Uterine atony Massive blood loss	Rx: ↓volatile anesthetic concentrations. Oxytocin infusion, uterine massage, ± methylergonovine 0.2 mg im (may ↑ BP), $PGF_{2\alpha}$ (Hemabate) 250 mcg/im/intrauterine (may →

		cardiovascular collapse/bronchospasm); Cytotec (misoprostol) 600–1200 mg rectal/sublingual

POSTOPERATIVE

Complications	Bleeding	
Multimodal pain management	**Oral or parenteral opioids:** oral opioids (e.g., oxycodone 5–10 mg) or iv opioids (e.g., morphine 2–4 mg iv, up to 20 mg; hydromorphone 0.2–0.4 mg iv) instituted in the recovery room. Avoid NSAIDs if significant bleeding. Use acetaminophen for opioid-sparing analgesia.	Emphasize multimodal approach combining nonopioid and bolus/PCA opioids (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6.)	Encourage early enteral nutrition and mobilization.
Tests	Hct, coagulation profile	

Suggested Readings

1. Coad S, et al: Risks and consequences of puerperal uterine inversion in the United States, 2004 through 2013. Am J Obstet Gynecol 2017; 217:377.e1–6.
2. Corso E, Hind D, Beever D, et al: Enhanced recovery after elective caesarean: a rapid review of clinical protocols, and an umbrella review of systematic reviews. BMC Pregnancy Childbirth 2017; 17(1):91.
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CHAPTER 8.4

Laparoscopic Procedures with and Without Robotic Assistance for Gynecologic Surgery

SURGEONS

Camran R. Nezhat, MD, FACOG, FACS
Stacy Young, MD
Megan Kennedy Burns, MD, MA
Lucia DiFrancesco, MD
Azadeh A. Nezhat, MD, FACOG

ANESTHESIOLOGIST

Clifford A. Schmiesing, MD

We gratefully acknowledge the past contributions of anesthesiologist, Amy Lu, MD, MPH

LAPAROSCOPIC SURGERY FOR ENDOMETRIOSIS

SURGICAL CONSIDERATIONS

Description

Endometriosis is defined as the presence of endometrial glands and stroma in ectopic locations. Intervention usually is indicated for intractable pain, infertility, or impaired function of the gastrointestinal (GI) or genitourinary (GU) tracts or involvement of the thoracic cavity. GU endometriosis may range from superficial involvement of

peritoneum overlying the ureters (known as extrinsic disease) and bladder to deep infiltrating endometriosis (DIE) penetrating through ureteral and bladder mucosa. Scarring and fibrosis can cause ureteral obstruction and hydronephrosis with consequent renal insufficiency and eventual failure. Patients with GI endometriosis may have thickening of the rectovaginal septum, suggesting obliteration of the posterior cul-de-sac or rectosigmoid involvement. Adhesions may make rectovaginal examination difficult or painful. Pelvic structures may be immobile (known as the "frozen pelvis"), suggesting adhesions are fixing bowel or bladder to the uterus. In severe cases of GI endometriosis, sigmoidoscopy should be performed to rule out malignancy and to determine whether endometriosis has penetrated through the bowel mucosa, in which case bowel resection may be required.

Laparoscopy (Fig. 8.4-1) is the most appropriate surgical technique for the diagnosis and treatment of endometriosis. Data from animal and clinical studies suggest that laparoscopic surgery is more effective for adhesiolysis, reduces blood loss, and causes fewer de novo adhesions compared to laparotomy. Special consideration must be given to the patient's history of abdominal or pelvic surgery, pelvic inflammatory disease (PID), and endometriosis. These factors will affect the choice of surgical approach as there may be extensive adhesive disease. Alternative port entry sites, such as Palmer point (midclavicular line, 4–5 cm below left costal margin), may be chosen to avoid adhesions at the umbilicus from prior surgeries. Conservative surgical management with excision of endometriosis is indicated for women who desire future fertility and whose disease is responsible for their symptoms of pain or infertility. Surgery improves fertility and pregnancy outcomes (preterm birth, placenta previa, small for gestational age, cesarean section, and miscarriage rates) and offers at least a temporary pain relief. **Bilateral oophorectomy** might be necessary to decrease estrogen levels that sustains and stimulates the ectopic endometrium to prevent future recurrence of disease. **Hysterectomy** with **bilateral salpingo-oophorectomy (BSO)** may be indicated for patients with severe symptoms who have not responded to medical or conservative surgical treatment and who do not desire fertility (see **Laparoscopic hysterectomy**). It is important to weigh these benefits against the risks of premature iatrogenic surgical menopause in women.

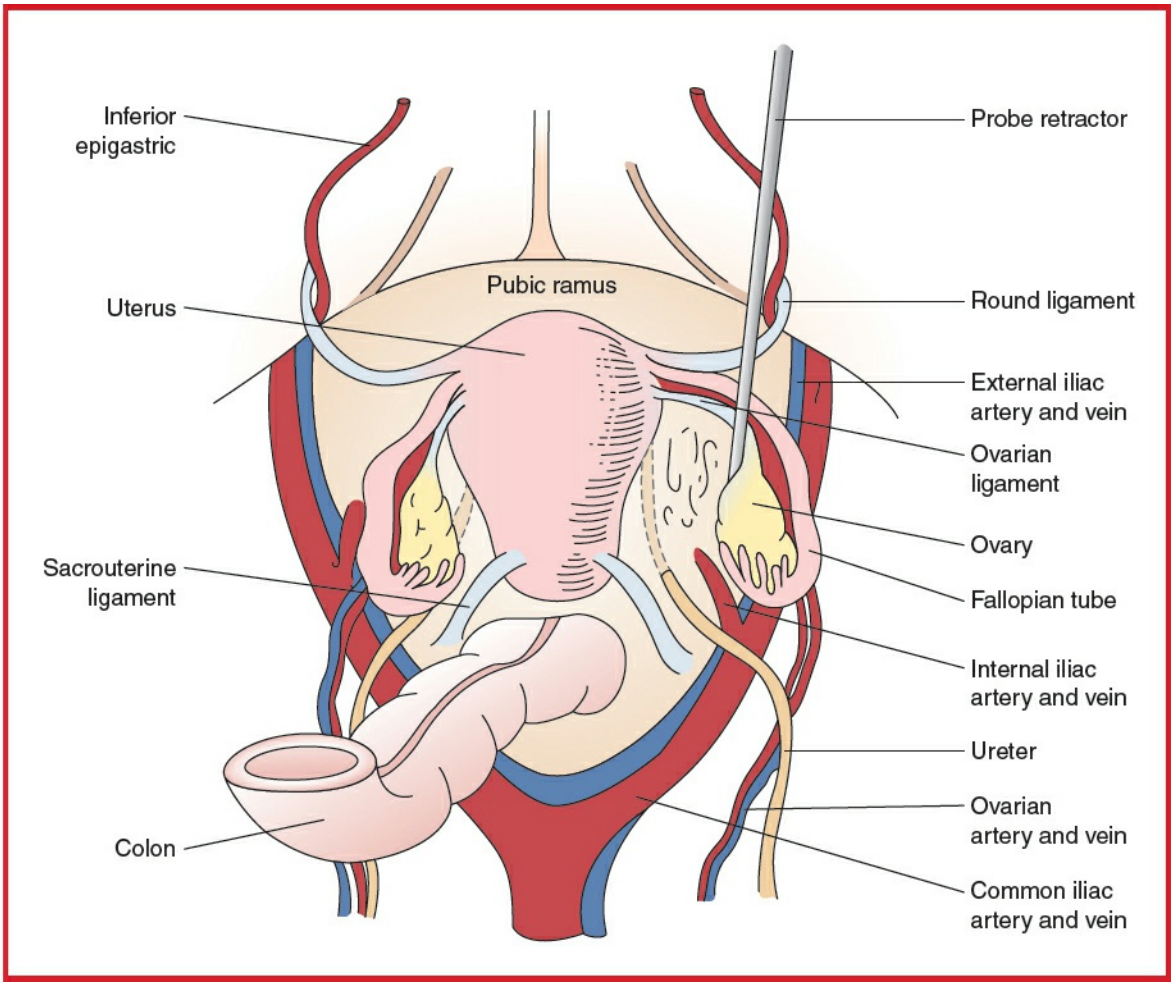

Figure 8.4-1 Laparoscopic view of the female pelvis.

Initial steps of laparoscopy

Entry into the abdomen, particularly placement of the initial port, has the potential of being the most hazardous maneuver in laparoscopic surgery, with over 50% of injuries to bowel and major vessels occurring during initial port placement. Although rare, both visceral and vascular injuries can lead to significant morbidity and potential mortality. The risk of any entry-related complications, including extraperitoneal insufflation or vascular and visceral injury, has been reported to increase with the number of attempts, ranging from 0.8% to 16.3% on entries requiring a single attempt, 16–37% with two attempts, and 44–64% with three or more attempts.

A Foley catheter should be placed before the beginning of the procedure to allow continuous drainage of the bladder, thereby reducing the likelihood of trocar injury to the bladder. The patient should be completely relaxed and supine on the operating table. An OG/NG tube should be placed to decompress the stomach to avoid trocar injury to the stomach. In a patient with no history of pelvic surgery, the direct trocar method with or without Optiview® may be used with an infraumbilical incision because this is the

anatomical area closest to the fascia and peritoneum and involves the least risk of injury to retroperitoneal structures. This area has the least amount of subcutaneous fat, both layers of fascia are fused, and there is no rectus muscle. Once the incision is made, towel clips on either side of the umbilicus are placed, the abdominal wall is lifted and the trocar is placed through the skin incision. Using an infraumbilical incision and inserting the trocar at 90° facilitate access to the abdominal cavity and decrease the risk of injury to the major pelvic vessels. This technique of direct trocar insertion may not be suitable for patients who have had prior laparotomy or laparoscopy due to risk of adhesions at the umbilicus. Another method of entry uses the Veress needle to obtain pneumoperitoneum before trocar placement. The majority (96.3%) of gynecologic laparoscopies are initiated using the Veress needle to achieve pneumoperitoneum. An infraumbilical incision is made, the abdominal wall is lifted, and the Veress needle is inserted through the skin incision at a 90° angle while connected to a low-flow CO_2 insufflation. This method allows for the abdomen to be insufflated before trocar placement, thereby facilitating ease of primary trocar placement. A mapping technique can be used after establishing pneumoperitoneum with the Veress needle to check for periumbilical adhesions. With this technique, a spinal needle attached to a water-filled 10 cc syringe is inserted adjacent to the primary port placement site. Aspiration of air indicates the site is clear of adhesions. Aspiration of bowel contents would indicate the presence of bowel adhesions to the anterior abdominal wall. The patient is then placed in steep Trendelenburg position. Two lateral 5-mm accessory ports are placed 2 cm cephalad and 2 cm medial to the anterior superior iliac spine under direct visualization, taking care to avoid the inferior epigastric vessels. A third 5-mm port is placed 2–4 cm above the pubic symphysis, again under direct visualization. Filmy adhesions of the bowel or omentum to the anterior abdominal wall or uterus can be lysed using CO_2 laser, bipolar cautery, monopolar scissors, or sharp dissection.

Pelvic endometriosis

Treatment of peritoneal endometriosis ranges from laser ablation of superficial peritoneal implants to excision and dissection of deeply embedded, fibrotic areas, known as DIE. Scarring from endometriosis that has penetrated the peritoneum to involve deeper structures destroys normal surgical planes and distorts anatomical relationships, and patients are at risk for ureteral or vascular injury at the time of surgery. Identification of ureters and blood vessels is critical before treatment of the pelvic sidewall disease. Although different modalities have been used, hydrodissection in combination with high-power superpulse or ultrapulse CO_2 lasers is the best option for endometriosis treatment. Carbon dioxide laser is much more precise, with less thermal spread and risk of unintentional injury compared to electrocautery (1.5 mm vs.

7.5 mm). Because the CO_2 laser does not penetrate water, hydrodissection of the retroperitoneal space increases the distance between the peritoneum and underlying vital structures such as blood vessels, ureter, or intestine. A 0.5-cm peritoneal incision is made in an unaffected area adjacent to the endometriotic lesion. The tip of the suction irrigator is inserted into the peritoneal opening, and LR or NS solution is injected into the retroperitoneal space. The entire endometriotic lesion is excised with a 1–2 cm margin.

Ovarian endometriosis

Type 1 endometriomas <2 cm are difficult to remove and can be resected using laser or bipolar electrocautery. Larger Type I endometriomas may require excision using a combination of blunt and sharp dissection with laparoscopic graspers and scissors. For Type II endometriomas, the procedure begins with lysis of periovarian adhesions using CO_2 laser or monopolar scissors. Suspicious areas are biopsied and sent to pathology. A plane is developed between the cyst wall and ovary by grasping the wall and separating it from ovarian stroma. Difficult areas where endometriosis has embedded through the cyst wall, and disrupted planes, require hydrodissection with vasopressin solution and bipolar cautery to control bleeding in the ovarian stroma. In some cases, it is necessary to remove a portion of the ovary attached to the cyst wall until a plane can be found. Redundant or bleeding ovarian tissue is reapproximated with suturing to close the defect.

Bladder endometriosis

If the lesions are superficial, hydrodissection and vaporization are adequate for treatment. Using hydrodissection, the areolar tissue between the bladder serosa and muscularis beneath the implants is dissected. The lesion is grasped and excised using the laser, ensuring complete excision with a 1–2 cm margin. Traction allows the small blood vessels supplying the surrounding tissue to be coagulated as the lesion is resected. Frequent irrigation is necessary to remove char, ascertain the depth of vaporization, and ensure that the lesion does not involve the muscularis or mucosa. Endometriosis extending to the muscularis but without mucosal involvement can be treated laparoscopically, and any residual or deeper lesions may be treated successfully with hormonal therapy. When endometriosis involves full bladder wall thickness, segmental bladder resection may be required. Cystoscopy is performed simultaneously, and bilateral ureteral stents may be inserted for ureteral identification, especially if the lesion is near the trigone or <2 cm from the ureteral orifice. The lesion is excised by first holding the bladder dome near the midline with laparoscopic graspers. An incision is made 5 mm beyond the lesion with the CO_2 laser. The specimen is completely

excised and removed from the abdominal cavity. After again identifying the ureters and examining the bladder mucosa, a watertight one- or two-layer closure using barbed suture is performed. Cystoscopy is performed to identify any leaks.

Patients may be discharged the same day and instructed to take prophylactic antibiotics while an indwelling catheter is present. The catheter is removed 7–14 d later, after a voiding cystourethrogram or computed tomography urogram with iv contrast is performed prior to Foley catheter removal.

Appendectomy

The appendix (a common site for endometriosis, found in 8% of women with gastrointestinal endometriosis) is identified, mobilized, and examined laparoscopically. Adhesions may be lysed using either the CO_2 laser or laparoscopic scissors. The mesoappendix is then coagulated using laparoscopic bipolar cautery and scissors or a vessel-sealing device. At this time, a laparoscopic GI stapler is introduced through a 10- to 12-mm port and placed across the mesoappendix and appendix. It is imperitive to closely examine the placement of the stapler and its proximity to the rectum. After adequate placement is observed, the entire appendix and mesoappendix are stapled and cut in a single motion. The specimen is removed, and the staple line is inspected for hemostasis. Copious amounts of irrigation fluid is used to minimize bacterial contamination. Additional broad-spectrum prophylactic antibiotics to cover gastrointestinal flora (i.e., metronidazole) are given.

Thoracic endometriosis

Diaphragmatic endometriosis is more common than realized and has been shown to co-occur in 50–80% of cases with pelvic endometriosis. Thoracic endometriosis can be detected on the diaphragm, chest wall, pleura, and lung parenchyma. It is more commonly found on the right side and on the thoracic diaphragm. Patients may present with catamenial (menses-related) chest pain, shortness of breath, hemoptysis, pneumothorax or hemothorax, and pulmonary nodules, known as thoracic endometriosis syndrome. The diaphragm should be routinely inspected for endometriosis in all patients. Placing the patient in a steep reverse Trendelenburg position, the use of an atraumatic liver retractor or grasping forceps to retract the liver and cutting the falciform ligament near the liver may also assist with visualization of the diaphragm. Medical management is the first-line approach, but patients frequently require surgical excision if medical management fails. Treatment is not advised in asymptomatic patients with incidentally discovered thoracic endometriosis, due to the risk of injury to the diaphragm, phrenic nerve, lungs, or heart. A DLT or bronchial blocker may be used for single-lung ventilation of the unaffected side. In addition to the usual accessory trocars

in the right and lower quadrants, additional trocars are placed in the upper quadrant (right or left depending on location of endometriotic lesions), similar to the arrangement for a laparoscopic cholecystectomy. Laparoscopically identified endometrial lesions on the diaphragm can be visualized and treated with hydrodissection and CO_2 laser fulguration or excision, but this requires an experienced gynecologist and thoracic surgeon. If large lesions are visualized, then pulmonary wedge resection of deep parenchymal nodules or diaphragm resection with concurrent VATS is the preferred method of treatment. Lesions found during VATS are treated either by bipolar diathermy, CO_2 laser, or sharp dissection. Treatment with CO_2 laser is preferred as it is much more precise and has a smaller depth of penetration with less thermal spread and risk of unintentional injury. Electrocautery of lesions near the heart may induce arrhythmias, while tissue necrosis due to electrocautery may cause diaphragmatic fenestrations. Postop, a chest tube to decompress the pneumothorax or hemothorax may be used.

Robotic assistance

The available evidence demonstrates the feasibility and safety of robotic-assisted laparoscopic surgery in benign and malignant gynecologic diseases, with equivalent outcomes compared with standard laparoscopy. The robot does require additional costs, as well as longer surgical and anesthesia time, but may be particularly useful in cases of extensive endometriosis involving the ureters, bladder, or bowel. The robotic arm is another tool that can enable a surgeon to perform complex laparoscopic procedures. With the advent of robotic-assisted laparoscopic surgery, the previously described procedures can be performed with three-dimensional visualization, improved magnification, and greater operative flexibility and comfort. The difference is location and sometimes size of the trocars used for the robotic arms as well as possible increased operative time. Additionally, patients are placed in steep Trendelenburg for the entirety of procedure.

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, discussion of carb-loading DVT prophylaxis, postop pain management options, and the possibility of urinary drain postop. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

SUMMARY OF PROCEDURES

	Ovarian Endometriosis	Pelvic/GI/GU Endometriosis

Position	Dorsal lithotomy, legs in Allen stirrups ± steep Trendelenburg	⇐
Incision	Infraumbilical; lateral; midline suprapubic	⇐
Special instrumentation	CO_2 laser or another cutting instrument; bipolar Kleppinger forceps; LigaSure; harmonic scalpel; monopolar scissors or hook; suction irrigator; uterine manipulator	± Ureteral stenting, cystoscope, proctoscope, sigmoidoscope
Antibiotics	Cefoxitin or cefazolin 2 g iv before incision	⇐
Surgical time	45 min–3 h, depending on extent of disease	1–4 h
Closing considerations	Close fascia of all 10- to 12-mm ports; subcuticular closure for 5-mm trocar sites	⇐
EBL	Minimal	⇐
Postoperative care	Mild disease: PACU →home; otherwise discharge on POD1-2	⇐
Mortality	0.08–0.2/1000	⇐
Morbidity	Overall complication rate: 2.5% Conversion to laparotomy: 0.42% Venous gas embolism Peroneal nerve injury Vascular injury: 0.2–0.4/1000	⇐ ⇐ ⇐ ⇐ ⇐ ⇐

	Bowel injury: 0.4/1000 Urinary tract injury: rare	
Pain score	4–8	4–8

PATIENT POPULATION CHARACTERISTICS		
Age range	Reproductive-age women	20s–40s
Incidence	10–15% of all reproductive age women 25% of all gynecologic laparotomies	1–11% of women with known endometriosis
Etiology	Numerous theories (see above)	Extensive disseminated endometriosis
Associated conditions	Infertility; pelvic pain; bladder or bowel symptoms; dysmenorrhea; dyspareunia	Pelvic pain; GI or GU symptoms

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Laparoscopic Hysterectomy.

Suggested Readings

1. Nezhat C, Falik R, McKinney S, et al: Pathophysiology and management of urinar tract endometriosis. Nat Rev Urol 2017; 14:359–72.
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LAPAROSCOPIC SURGERY FOR ECTOPIC PREGNANCY OR ADNEXAL MASS

SURGICAL CONSIDERATIONS

Description

Ectopic pregnancy is defined as a pregnancy occurring outside the uterus and affects 1–2% of pregnancies. The majority of ectopic pregnancies occur in the ampullary region of fallopian tubes (95–97%); the remainder occurs in the cornua (2–4%), ovary (0.1%), cervix (0.1%), or abdomen (0.03%). Ectopic pregnancy remains a leading cause of maternal morbidity and mortality and is responsible for 9% of pregnancy-related deaths in the United States. Predisposing factors include history of tubal ligation or other tubal surgery, pelvic inflammatory disease (PID), smoking, prior ectopic pregnancy, IUD in situ, and history of in vitro fertilization (IVF) or other treatments for infertility.

Patients typically present with lower quadrant pain, vaginal bleeding, and an ↑ β-hCG or positive pregnancy test. The imaging of choice is a transvaginal ultrasound. A complex adnexal mass with a sonolucent center may be seen on ultrasound. The presence of an intra-uterine gestational sac (double decidual sign) when β-hCG >1500–2000 (known as the discriminatory zone) effectively rules out an ectopic pregnancy as the incidence of heterotopic pregnancy (pregnancy simultaneous in the uterine cavity and fallopian tube) is extremely rare. Treatment options for an ectopic gestation include expectant management, operative laparoscopy, or a trial of medical management with intramuscular methotrexate. A 2007 Cochrane review found no difference in success rates, tubal patency, and fertility rates between **laparoscopic salpingostomy** and medical treatment with methotrexate. In cases where the size of the ectopic pregnancy is too large for conservative medical management (>3.5 cm, β-hCG >5000, or embryonic cardiac motion) and the patient is hemodynamically stable, operative management is reasonable.

Expectant management is possible for patients with low (<200) and falling β-hCG levels, with no evidence of adnexal mass on ultrasound, and who are asymptomatic. β-hCG levels should be checked every 48 h until they decrease and then weekly until they reach zero. The patient must be counseled on the risk of tubal rupture and the need for immediate surgical intervention in that case. Methotrexate or surgical management should be considered if that patient experiences increasing pain or rising β-hCG levels.

Access to the abdomen is obtained in the usual fashion (e.g., through a Veress needle or direct trocar insertion, as described in previous section). **Ruptured tubal pregnancies**

can be treated endoscopically if the bleeding has ceased or can be controlled, and the surgeon is proficient in laparoscopic techniques. Actively bleeding vessels are identified and cauterized, and forced irrigation is used to dislodge clots and trophoblastic tissue. A large-bore suction irrigator can be used to clear large amounts of clot and hemoperitoneum. Depending on their size, the products of conception (POCs) are removed through either a 5- or 10-mm trocar sleeve or placed into an endoscopic bag for removal; for larger POCs a minilaparotomy can be performed. Copious irrigation should follow to ensure hemostasis and identify and remove any remaining trophoblastic tissue. Trophoblast is invasive, and residual tissue may implant into bowel, bladder, peritoneum, or other abdominal structures and cause significant future morbidity.

For an unruptured ectopic pregnancy, the tube is identified and stabilized using laparoscopic forceps. To minimize bleeding, 5–7 mL of a solution of 50 IU **vasopressin** in 100 mL NS is injected into the mesosalpinx just below the ectopic pregnancy and over the antimesenteric surface of the tubal segment containing the gestation. Intravascular injection of vasopressin solution can precipitate acute arterial HTN bradycardia, or even death; therefore, care must be taken to avoid intravascular injection. A linear incision is made with the monopolar needle over the thinnest portion of the tube. Trophoblastic tissue usually protrudes through the incision. The suction irrigator tip is inserted into the incision, and forceful irrigation dislodges POCs from its implantation site.

In a ruptured tubal or isthmic pregnancy, **resection of the tubal segment (salpingectomy)** containing the gestation is preferable to **salpingostomy**. A salpingostomy should be performed in patients who desire future fertility unless the affected tube is severely damaged and the contralateral tube is normal. If a salpingostomy is performed, serial β-hCG levels should be checked until they reach zero to ensure complete evacuation of products of conception. **Total salpingectomy** can be performed by progressive coagulation and cutting the mesosalpinx, which is separated from the uterus using bipolar coagulation and scissors, LigaSure, or laser. The isolated tube segment containing the ectopic pregnancy is removed intact in an endoscopic bag or in sectioned parts through the 10-mm trocar sleeve. At the completion of the procedure, the abdomen is irrigated and inspected, and incisions are closed in the usual fashion.

Hydrosalpinx

A hydrosalpinx is a fluid-filled fallopian tube, which occurs after an inflammatory process (e.g., PID, tubo-ovarian abscess [TOA], or endometriosis) damages the serosa

and mucosa of the tube. This results in occlusion at the fimbriated end and accumulation of tubular fluid and can occur unilaterally or bilaterally. Currently, for women with hydrosalpinges who are to undergo IVF, the recommendation is laparoscopic salpingectomy before IVF treatment. Bilateral salpingectomy has been shown to improve IVF success rates. It is theorized that the fluid in the fallopian tube causes inflammation and is toxic to embryos. The mechanical force from back flow of fluid may also prevent implantation of the embryo. The procedure is performed as described earlier for resection of a tubal segment.

Tuboovarian abscess

TOA is a severe complication of pelvic inflammatory disease (PID). PID results from an ascending infection from the vagina or cervix, leading to salpingitis. If this is not recognized early and adequately treated with antibiotics, this infection can then spread to the ovaries, resulting in unilateral or bilateral TOAs. The treatment of choice for TOA is medical management with antibiotics or percutaneous drainage if medical management fails or the TOA is very large. If percutaneous drainage is not possible, laparoscopic drainage may be performed. Laparoscopic access to the abdomen is performed with an umbilical port and two lateral ports. Using a suction irrigator and laparoscopic forceps, the entire abdominal cavity is examined for purulent material. Once the abscess is localized, it is drained with the suction irrigator. Care is taken to lyse adhesions as needed using blunt dissection and hydrodissection. Adhesions encountered in this situation are usually filmy and can be disrupted without the need for sharp dissection. Meticulous dissection of the abscess and surrounding adhesions is vital for the success of this procedure. Once the ovary is freed, a small incision is made to allow for copious irrigation. The laparoscopic forceps can be used to separate any adhesions at the fimbriated end of the fallopian tubes. The procedure is completed with copious irrigation of the abdominal cavity. In cases where the TOA is chronic, laparoscopy will show that the walls of the abscess are denser, and surrounding adhesions may cause structures to be matted together. In this case, sharp dissection with laparoscopic scissors may be needed, but care should be taken as planes of dissection can be difficult to define.

Usual preoperative diagnosis

Ectopic pregnancy; adnexal mass

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, discussion of carb-loading DVT prophylaxis, postop pain management options, recovery plan, and possibility of urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE

Position	Dorsal lithotomy, legs in Allen stirrups, steep Trendelenburg
Incision	Infraumbilical, lateral suprapubic, midline suprapubic
Special instrumentation	CO_2 laser, laparoscopic instrumentation, uterine manipulator
Unique considerations	Intraperitoneal hemorrhage and hemodynamic instability are potential risks. Patient should be cross-matched for 2 units of PRBCs.
Antibiotics	Cefoxitin 1–2 g iv before incision
Surgical time	45 min to 2 h
Closing considerations	Fascia of 10- to 12-mm trocar sites should be closed in layers. Smaller 5-mm ports closed in a subcuticular fashion.
EBL	100 mL, severe hemorrhage if ruptured
Postoperative care	The patient may be admitted overnight for observation. Quantitative β-hCG should be followed until undetectable to rule out the possibility of retained trophoblastic tissue.
Mortality	5/1000. For any laparoscopy, 0.08–0.2/1000
Morbidity	Overall complication rate: 2.5% hemorrhage and need for transfusion Conversion to laparotomy: 4.2/1000 Air embolism: rare Unintended puncture of viscera: rare Puncture of a major vessel: rare Insufflation of incorrect site: rare
Pain score	3–5

PATIENT POPULATION CHARACTERISTICS

Age range	Reproductive-age females
Incidence	1/100 pregnancies

Etiology	Distorted tubal or uterine anatomy
Associated conditions	History of pelvic inflammatory disease, endometriosis, tubal damage, IUD, and IVF

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Laparoscopic Hysterectomy.

Suggested Readings

1. Nezhat C, Cho J, King LP, et al: Laparoscopic management of adnexal masses.Obstet Gynecol Clin N Am 2011; 38(4):663–76.
2. Nezhat C, Nezhat F, eds: Nezhat's Video-Assisted and Robotic-Assisted Laparoscopy and Hysterectomy. Cambridge University Press, New York: 2013.

LAPAROSCOPIC MYOMECTOMY

SURGICAL CONSIDERATIONS

Description

Uterine myomata, or fibroids, are the most common uterine neoplasm, affecting ~20–25% of women of reproductive age. Their growth is influenced by many factors, such as estrogen and progesterone or synergistically with growth hormone and human placental lactogen in pregnancy. The severity of symptoms depends on the number, size, and location of the tumors. Symptoms may include constipation, pelvic or abdominal pressure, dysmenorrhea, dyspareunia, infertility, pregnancy complications, urinary frequency, and most commonly, menorrhagia. Patients often present with profound anemia from menorrhagia or menometrorrhagia, the usual indications for surgery. Other indications include rapidly changing size, ureteral compression, hydro-ureter, or hydronephrosis. Size, number, and location are the primary factors that will determine surgical approach to myomata.

For women who have completed childbearing, the vast majorities are offered a **hysterectomy**. It is associated with a high degree of patient satisfaction but is not free from complications. Anatomic distortions from a myomatous uterus pose an increased risk of injury to surrounding structures. For women wanting to maintain their fertility, a **myomectomy** is offered. The simplest approach is a combination of **laparoscopy** and **minilaparotomy** for removal of myomas. This approach limits operative time. The three

goals of **laparoscopic myomectomy** are (a) minimizing blood loss, which can be severe, (b) minimizing postop adhesion formation, and (c) maintaining uterine wall integrity. Preop treatment with GnRH analogues to shrink fibroids has been shown tc decrease the size of the myoma and reduce the need for transfusion but can cause fibroid degeneration and disrupt surgical planes. For a large myomatous uterus, in which a pure laparoscopic procedure may be tedious and difficult, a **laparoscopically assisted myomectomy (LAM)** is an alternative. Although myomectomy may be performed to preserve fertility, postop adhesion formation often jeopardizes this goal. Adhesion formation can be minimized by using a single, vertical, anterior midline uterine incision. Patients who have had myomectomies that enter the endometrial cavity will require cesarean sections with future pregnancies.

The abdomen is entered in the usual fashion for laparoscopy (e.g., through Veress needle or direct trocar insertion, followed by insufflation and insertion of accessory trocars). To reduce blood loss in pedunculated myomas, diluted **vasopressin** (3–5 mL) is injected into the base of the stalk where it joins the uterine wall. Intravenous vasopressin can cause ↑ BP, myocardial ischemia, dysrhythmias, or cardiac arrest and should be avoided. The pedicle is coagulated and cut with bipolar electrocautery. For subserosal or intramural myomas, diluted vasopressin is injected between the myometrium and the myoma pseudocapsule, and an incision is made on the serosa overlying the myoma using the CO_2 laser or monopolar needle or hook. As the incision is made, the myometrium is retracted away with graspers to expose the tumor. Vessels are coagulated before cutting. After the myoma is removed, the myoma bed is copiously irrigated, and bleeding points are coagulated again. The myometrial defect is closed in multiple layers to ensure all the dead space is eliminated. After closure, the serosa is irrigated. Uteroperitoneal fistulae may follow laparoscopic myomectomy because complete laparoscopic approximation of all layers of the myometrium is impossible, and the use of electrocoagulation for hemostasis inside the uterine defect also may increase the risk of fistula formation. Failure to close the dead space can also cause postop hematoma, infection, and pregnancy complications.

Removal of the specimen is frequently the most challenging aspect of the operation. The myoma can be removed either by morcellation of the specimen manually with a scalpel or by extending the suprapubic incision via a minilaparotomy. Alternatively, a **posterior culdotomy** may be performed and the myoma removed via the vagina. After the myoma is removed, the incision can be closed using laparoscopic suturing. **Minilaparotomy** or **culdotomy** facilitate removal but increase postop wound complication risks, such as infection or hernia formation. After myoma removal, the abdomen and pelvis are irrigated, the patient is taken out of the Trendelenburg position, and any fluid that might

have tracked into the upper abdomen is suctioned. The ports are closed in the usual fashion.

Usual preoperative diagnosis

Uterine myoma, fibroids

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, discussion of carb-loading DVT prophylaxis, postop pain management options, recovery plan, and possibility of urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Dorsal lithotomy; steep Trendelenburg to move bowel out of the operative field
Incision	Infraumbilical; 5 mm later and 5–12 mm midline suprapubic; minilaparotomy via extension of suprapubic incision or posterior culdotomy for removal of large myomata
Special instrumentation	CO_2 laser; laparoscopic instrumentation
Unique considerations	For large myomata: pretreatment with GnRH analogues (3–6 mo), intraoperative injection of dilute vasopressin (1 IU in 100 mL LR) into myometrium to decrease bleeding
Antibiotics	Cefoxitin 1–2 g iv before incision
Surgical time	1–4 h
Closing considerations	Close fascia of all 10- to 12-mm ports; 5-mm ports are closed in a subcuticular fashion. Fascial closure essential in minilaparotomy. Posterior culdotomy requires laparoscopic suturing or vaginal closure.
EBL	100–600 mL
Postoperative care	Usually PACU → home. Occasionally 24-h hospital stay; early ambulation; clear liquids POD #0; gradually advance diet after discharge home

Mortality	0.08–0.2/1000
Morbidity	Rates 1.3–5.9/100 Peroneal nerve damage from positioning Severe bleeding with possible need for transfusion Uteroperitoneal fistulae Infertility GI/GU injury Air embolism Puncture of a major vessel Insufflation in the wrong place Need for emergent laparotomy Uterine rupture in pregnancy: 2% Adhesion formation
Pain score	4–6

PATIENT POPULATION CHARACTERISTICS

Age range	Reproductive-age females; myomas shrink in postmenopausal women and are less symptomatic.
Incidence	20–25% of all women
Etiology	Benign transformation and proliferation of a single smooth muscle cell
Associated conditions	Menorrhagia; anemia; ureteral obstruction; pelvic pain or pressure

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Laparoscopic Hysterectomy.

Suggested Readings

1. AAGL Advancing Minimally Invasive Gynecology Worldwide: AAGL practice report: morcellation during uterine tissue extraction. J Minim Invasive Gynecol 2014; 21:517–30.
2. Kho KA, Anderson TL, Nezhat CH: Intracorporeal electromechanical tissue morcellation: a critical review and recommendations for clinical practice. Obstet Gynecol 2014; 124:787–93.
3. Kho KA, Brown DN: Surgical treatment of uterine fibroids within a containment system and without power morcellation. Clin Obstet Gynecol 2015; 59:85–92.

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5. Nezhat C, Nezhat F, eds: Nezhat's Video-Assisted and Robotic-Assisted Laparoscopy and Hysterectomy. Cambridge University Press, New York: 2013.

LAPAROSCOPIC HYSTERECTOMY

SURGICAL CONSIDERATIONS

Description

Hysterectomy is the second most common gynecologic operation, after **cesarean section**. The indications for **hysterectomy** ± **salpingo-oophorectomy** include leiomyomata (38%), malignancy (15%), ovarian tumors (10%), abnormal bleeding (13%), adenomyosis (9%), pelvic pain or adhesions (5%), endometriosis (3%), and uterine prolapse (1%). Other less common indications include parametrial disease, pelvic infection, and complications of pregnancy and delivery. Selection of surgical approach for hysterectomy requires consideration of the patient's age, medical history, history of prior pelvic surgery, the presence or possibility of adhesions or endometriosis, uterine size, adnexal pathology, and the presence or amount of uterine prolapse.

Laparoscopic hysterectomy offers many advantages, including shorter recovery time, rapid return of bowel function, less pain, less bleeding and adhesion formation, and a lower wound complication rate. The disadvantages are higher cost and the surgical expertise required. The most commonly performed procedure is the **laparoscopically assisted vaginal hysterectomy** (LAVH), in which hysterectomy is begun by laparoscopy, but four or more steps are performed vaginally. Variants include **total laparoscopic hysterectomy** (TLH), in which all steps are performed laparoscopically; **supracervical hysterectomy**, where the cervix is not removed; and **vaginally assisted laparoscopic hysterectomy** (VALH), in which four steps are performed laparoscopically and the procedure is completed vaginally. Combinations are usually performed, depending on surgical findings. Mechanical bowel preparation is not advised. Consultation with a urologist, colorectal surgeon, and oncologist are sought as necessary.

Access to the abdomen is obtained in the usual fashion (e.g., through a Veress needle or direct trocar insertion or through special assist device, followed by insufflation and insertion of accessory trocars). **Diagnostic laparoscopy** is performed, adhesions lysed,

and endometriotic lesions treated. The course of the ureters is noted through the peritoneum from the pelvic brim medial to the external iliac arteries and followed inferiorly until they are no longer visible at the level of the cardinal ligaments. When ureters cannot be identified clearly because of severe scarring or endometriosis, they are dissected retroperitoneally, and the dissection proceeds as for a radical hysterectomy. At the cardinal ligaments, the peritoneum is opened above or below the ureter, and hydrodissection is performed to lift the peritoneum off the ureter without damaging it. Routine hysterectomy using hydrodissection to identify tissue planes and limit blood loss can be performed following identification of the ureters.

If the ovaries are to be spared, the utero-ovarian ligament, proximal tube, and mesosalpinx are cauterized and cut progressively, and the posterior leaf of the broad ligament is opened with blunt dissection or hydrodissection. The bladder is dissected free from the cervix and lower uterine segment. Next, the uterine vessels are identified, noted to be free of the ureters, desiccated, and cut. At the level of the cardinal ligaments, the ureters and descending branches of the uterine artery are close to one another and the cervix; therefore, cardinal ligament dissection and cautery must be precise to prevent bleeding and ureteral injury. A small uterus can be removed easily through the vagina. The use of **intracorporeal power morcellation** to remove a large uterus is no longer advised because morcellated particles may contain neoplastic tissue (known or occult) and disseminate throughout the abdominal cavity. Additionally, spread of morcellated benign tissue can cause disseminated peritoneal leiomyomatosis. A large uterus, instead, can be removed by extracorporeal **hand morcellation** in a bag and removed through the vagina or minilaparotomy incision. Pneumoperitoneum will be lost during this procedure, and care must be taken to keep instruments free of bowel or other abdominal structures.

If the procedure is to be completed entirely laparoscopically, pneumoperitoneum can be maintained by placing a glove containing two 4″ × 4″ sponges in the vagina. The vaginal wall is cut circumferentially, and the uterus is pulled to mid vagina, but not removed, to preserve the pneumoperitoneum. Alternatively, the uterus may be placed in a laparoscopic specimen bag. The suprapubic incision may be extended into a minilaparotomy incision for specimen removal. The vaginal cuff is closed transversely using laparoscopic sutures, and any coexisting cystocele or enterocele is repaired. After the uterus is removed and the vaginal cuff closed, the pelvic and abdominal cavities are reevaluated, irrigated, and cleared of blood and debris. The skin and fascia are closed in the usual fashion. **Cystoscopy** is performed at the end of the procedure to verify ureter function and bladder integrity.

Variant procedure

In patients with severe rectovaginal and vesical endometriosis, the retroperitoneal space is first entered using hydrodissection, and the external iliac vessels, hypogastric artery, and ureters are identified. In cases where extensive dissection and resultant blood loss are anticipated, coagulation or ligation of the hypogastric artery with laparoscopic clips may be performed. Endometriosis of the rectum, rectovaginal septum, and uterosacral ligaments is treated by vaporization, excision, or a combination of both. **Sigmoidoscopy or proctoscopy** with concurrent laparoscopic visualization of the pelvis may be necessary to rule out the presence of incidental enterotomy. **Cystoscopy with ureteral stenting** also may be helpful to identify anatomy and ureteral injury if it occurs.

After the ureter is identified along its course and entry into the bladder, the uterine vessels are retracted medially and separated from the ureter using a CO_2 laser. The uterus is retracted medially, and the ureter laterally as the cardinal and uterosacral ligaments are cauterized and cut, maintaining the ureter under direct visualization. After these vascular pedicles have been ligated and all endometriosis treated, the hysterectomy and specimen removal proceed as described earlier. In patients with a history of prior cesarean section, endometriosis, or anterior myomectomy, adhesions can distort anatomy and increase the risk of inadvertent cystotomy. In this case, it may be useful to perform a "reverse" inferior to superior vesicouterine fold dissection technique to mobilize the bladder. This technique utilizes blunt dissection within the broad ligament to visualize a new anatomical plane, lateral to the vesicocervical ligaments. By extending from this "new space" inferomedially across the anterior aspect of the cervix, a connection is developed inferior to the vesicouterine adhesions. Then, using an inferior to superior sweeping motion, the bladder can be easily dissected off of the vagina, cervix, and uterus from an unscarred plane, and the cervical cuff can be exposed for **colpotomy**.

After or at the time of closure of the vaginal cuff, some gynecologic surgeons perform a **culdoplasty** to close the posterior cul-de-sac. This is recommended to decrease the risk of enterocele formation and the potential development of vaginal vault prolapse. There are different types of culdoplasty, and they can be done vaginally or laparoscopically. The most common vaginal culdoplasty is the **McCall culdoplasty** where the uterosacral-cardinal complex is plicated and attached to the peritoneal surface of the posterior cul-de-sac to elevate the posterior vaginal cuff. After the uterus is removed, the patient is placed in a dorsal lithotomy position to allow for vaginal access. Before closure of the cuff, an absorbable suture is placed through the full-thickness of the posterior vaginal wall from outside to in and then passed through the left uterosacral ligament pedicle, the posterior peritoneum, the right uterosacral ligament pedicle, and back through the full

thickness of the posterior vaginal cuff from inside out. The two ends of the suture are then tied, bringing the uterosacral ligaments together in a procedure called a **Moschcowitz culdoplasty**. After the vaginal cuff is closed, a separate absorbable suture is used to close the posterior cul-de-sac. Suture is passed through one of the uterosacral ligaments, through the posterior peritoneum, through the other uterosacral ligament, and then through another portion of the posterior peritoneum and tied to form a purse string.

Another type of laparoscopic culdoplasty is the **Halban culdoplasty**: after the vaginal cuff is closed, interrupted sutures are placed vertically across the posterior cul-de-sac starting with the posterior peritoneum over the rectum and taking small portions of the peritoneum up to and including the vaginal cuff apex. Usually, three to four interrupted sutures are used. The most common complications of culdoplasty are injuries to the ureter. As a result of suturing of the uterosacral ligaments, which are very close to the ureters, the ureters are at risk for being obstructed by the culdoplasty stitch. Pyridium (phenazopyridine) should be given before the procedure to help better identify the ureter. **Cystoscopy** should also be performed after the culdoplasty to ensure bilateral ureteral patency. Another complication, although uncommon, is rectal injury. The rectum is directly under the posterior peritoneum and can occasionally get sutured into the culdoplasty. If this is suspected, then proctoscopy should be performed to evaluate the rectum.

Usual preoperative diagnosis

Leiomyomata; malignancy; ovarian tumors; abnormal bleeding; adenomyosis; pelvic pain or adhesions; endometriosis; uterine prolapse; parametrial disease; pelvic infection; complications of pregnancy and delivery

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading DVT prophylaxis, postop pain management options, recovery plan, and possibility of urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Dorsal lithotomy; legs in Allen stirrups; steep Trendelenburg
Incision	Infraumbilical; lateral suprapubic; midline suprapubic (5 or 10 mm)
Special	CO_2 laser; laparoscopic instruments; uterine

instrumentation	manipulator
Unique considerations	Extensive ureterolysis and treatment of endometriosis may require addition of cystoscopy, ureteral stent placement, and/or sigmoidoscopy.
Antibiotics	Cefoxitin 2 g iv before incision
Surgical time	2–6 h. Operative time is increased in cases of extensive adhesiolysis or endometriosis.
Closing considerations	Close fascia of all 10- to 12-mm ports; 5-mm ports are closed in a subcuticular fashion. Fascial closure essential in minilaparotomy.
EBL	100–800 mL, depending on anatomy and difficulty of dissection
Postoperative care	PACU → home. Occasionally 24-h hospital stay
Mortality	0.08–0.2/1000
Morbidity	Overall complication rate: 2.5% Conversion to laparotomy: 4.2/1000 Air embolism: rare Peroneal nerve damage from positioning: rare Unintended puncture of viscera: rare Puncture of a major vessel: rare Insufflation of incorrect site: rare Urinary and ureteral trauma, including fistulae: 1.6%
Pain score	4–9

PATIENT POPULATION CHARACTERISTICS	
Age range	30s–90s
Incidence	20% of women <40 yr; 37% of women < age 65
Etiology	see Associated Conditions
Associated conditions	Myomata; abnormal uterine bleeding; adenomyosis; malignancy; pelvic pain; endometriosis

Suggested Readings

1. Nezhat C, et al: Reverse vesicouterine fold dissection for laparoscopic hysterectomy after prior cesarean deliveries. Obstet Gynecol 2016; 128(3):629–33.
2. Nezhat C, Li A, Falik R, et al: Bowel endometriosis: diagnosis and management.Am J Obstet Gynecol 2018; 218(6):549–62.
3. Nezhat C, Nezhat F, eds: Nezhat's Video-Assisted and Robotic-Assisted Laparoscopy and Hysterectomy. Cambridge University Press, New York: 2013.
4. Nezhat C, Falik R, McKinney S. et al: Pathophysiology and management of urinary tract endometriosis. Nat Rev Urol 2017; 14:359–72.

LAPAROSCOPIC SURGERY FOR VAGINAL VAULT SUSPENSION

SURGICAL CONSIDERATIONS

Description

Pelvic organ prolapse (POP) is a more common finding in older women, and there are both nonsurgical and surgical approaches to treatment. Nonsurgical options include pessaries and pelvic floor training and are often used for women who are not surgical candidates or who would instead not undergo surgery. A surgical approach to treating POP is more definitive and can be performed abdominally, vaginally, laparoscopically, or robotically. When being performed laparoscopically or robotically, the patient benefits from a shorter hospital stay, less postop pain, and faster recovery.

Sacrocolpopexy is considered the surgical standard for treatment of POP. It is suitable for patients with uterine prolapse or Stages II–IV vaginal vault prolapse and recurrence after previous operation, particularly for younger patients who are sexually active. This procedure aims to provide apical support for defects in the cardinal-uterosacral ligament complex and has the highest success rate. This procedure is not without unique complications. They include mesh and suture erosion, dyspareunia, and alterations to bowel or bladder function.

The abdomen is entered in the usual fashion for laparoscopy through a Veress needle or direct trocar insertion followed by insufflation and insertion of accessory trocars. If the patient has not had a hysterectomy, a supracervical hysterectomy is performed instead of a total hysterectomy, to reduce the risk of mesh erosion. The bowel is elevated from the pelvis for visualization. There are two main areas of dissection: pelvic and presacral. The bladder is mobilized and dissected away from the anterior surface of the cervix and vagina. In a similar fashion, the rectum is dissected and mobilized away from the

posterior surface of the vagina. It is important in this dissection to identify tissue planes and avascular spaces. Vasopressin injection may be used during the dissection to control bleeding and allow for better visualization. Attention is then turned to the presacral area. The peritoneum over the sacrum is tented up with laparoscopic graspers and incised. Frequently, hydrodissection in this area is beneficial for identification of the correct tissue planes. The dissection is carried down to and through the presacral adipose to the level of the anterior longitudinal ligament. Particular attention must be taken to avoid injury to the middle sacral vessels, the right ureter, and sigmoid colon. At this time, the peritoneum between the presacral dissection and the posterior vaginal dissection is opened. This will be closed later over mesh, making it retroperitoneal. A "Y"-shaped mesh is inserted through a trocar into the abdomen. The mesh is then secured to the posterior and anterior side of the vagina, taking full thickness bites and using laparoscopic suturing technique. The tail of the mesh is then secured to the anterior longitudinal ligament in a similar fashion, suspending the vaginal apex. The peritoneum is then closed over the mesh to help prevent bowel adhesions. The pelvis is then irrigated, and hemostasis confirmed. The ports are closed in the usual fashion. If a concurrent **hysterectomy** was performed, a **cystoscopy** is done at the end of the procedure to ensure bilateral ureteral patency.

Variant procedure

The vaginal posterior and anterior dissection, as well as the type of graft material used for the suspension are the two main areas that may vary during this procedure. Both of these factors are highly dependent on the surgeon.

ERAS: Preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb-loading DVT prophylaxis, postop pain management options, recovery plan, and possibility of urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Dorsal lithotomy; legs in Allen stirrups; steep Trendelenburg
Incision	Infraumbilical; 5 mm lateral and 5–12 mm midline suprapubic
Special instrumentation	CO_2 laser; laparoscopic instrumentation; uterine manipulator, bipolar Kleppinger forceps, suction irrigator

Unique considerations	Extensive ureterolysis and enterolysis may require addition of cystoscopy, ureteral stent placement, and/or sigmoidoscopy.
Antibiotics	Cefoxitin 1–2 g iv before incision
Surgical time	2–6 h, depending on anatomy and difficulty of dissection
Closing considerations	Close fascia of all 10- to 12-mm ports; 5-mm ports are closed in a subcuticular fashion. Fascial closure essential in minilaparotomy.
EBL	100–800 mL
Postoperative care	Usually PACU → home. Occasionally 24-h hospital stay; early ambulation
Mortality	Rare
Morbidity	Unintentional puncture of viscera: rare Puncture of a major vessel: rare Insufflation of incorrect site: rare Urinary and ureteral trauma, including fistulae: 1.6%
Pain score	4–9

PATIENT POPULATION CHARACTERISTICS	
Age range	39s–90s
Incidence	20% of women >40 yo; 37% of women >65 yo
Etiology	See associated conditions
Associated conditions	Cystocele, rectocele, enterocele

Suggested Readings

1. Callewaert G, Bosteels J, Housmans S, et al. Laparoscopic versus robotic-assisted sacrocolpopexy for pelvic organ prolapse: a systematic review. Gynecol Surg 2016; 13:115–23.
2. Nezhat C, Nezhat F, eds: Nezhat's Video-Assisted and Robotic-Assisted-Laparoscopy and Hysterectomy. Cambridge University Press, New York: 2013.

ANESTHETIC CONSIDERATIONS

(Procedures covered: laparoscopic surgery for endometriosis, ectopic pregnancy, myomectomy, hysterectomy.)

PREOPERATIVE

Respiratory	There can be intraop respiratory compromise from ↑ intra-abdominal pressure 2° CO_2 insufflation; however, patients without significant respiratory disease tolerate the insufflation quite well. Look for diaphragmatic hernia or advanced pulmonary disease, which → ↑ risk of laparoscopic approach. **Tests:** As indicated from H&P
Cardiovascular	Insufflation of the abdomen (typically with pressures of 14–22 mm Hg) → ↑ SVR and ↓ venous return. ↑ $PaCO_2$ → ↑ dysrhythmias. These are usually well-tolerated in the otherwise healthy patient. **Tests:** As indicated from H&P
Gastrointestinal	Consider NPO status for emergent ectopic pregnancy patients. High BMI complicates steep Trendelenburg positioning during laparoscopic pelvic surgery. Prior pelvic and abdominal surgery and intra-abdominal disease including, endometriosis and pelvic inflammatory disease will complicate laparoscopic surgery and may force conversion to open procedure. The combination of ↑ intra-abdominal pressure + Trendelenburg position → ↑ aspiration risk. Note: mechanical bowel preparation no longer recommended. Normal NPO restrictions should apply. **Test:** Electrolytes
Hematologic	These patients often are having surgery for abnormal uterine bleeding → consider anemia, which may be severe. **Tests:** Hgb/Hct; consider T&S/T&C, especially if patient anemic preop

Laboratory	Other tests as indicated from H&P
Premedication	Anxiolysis: consider midazolam 1–2 mg iv Analgesia: consider acetaminophen 650–1000 mg po, gabapentin 300–600 mg po, and/or celecoxib 400 mg po (see Appendix C: Multimodal Perioperative Pain Management, p. C-1)
ERAS	Routine mechanical bowel prep not recommended. Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg, ± gabapentin 300 mg po. Consider aprepitant 40 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA

Induction	Standard induction (see p. B-2). Rapid sequence induction usually is indicated for patients with an ectopic pregnancy. OGT/NGT to decompress stomach before laparoscopic trocar insertion.
ERAS	Goals include opiate-sparing techniques and multimodal analgesia (Appendix K, p. K-2 and p. K-5), measures to achieve normothermia, euvolemia w/ balanced salt solutions, and PONV prophylaxis. Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance (see p. B-3). Muscle relaxation helpful for initial trocar insertions and may be helpful throughout procedure. Consider ketamine for chronic pain patients (0.5 mg/kg bolus + 5 mcg/kg/min infusion).
Emergence	Standard emergence. PONV prophylaxis may include dexamethasone and ondansetron.

Blood and fluid requirements	Usually minimal blood loss though may be significant during some procedures. Discuss with surgeon ahead of time. IV: 18–16 ga × 1–2 BSS @ 2–6 mL/kg/h	Consider preop hypovolemia in setting of acute bleeding (ectopic pregnancy with rupture). Establish iv access accordingly. During surgery, large volumes of fluid are sometimes given intra-abdominally for irrigation and hydrodissection → fluid overload; therefore, carefully account for all fluids, and titrate iv fluids to maintain euvolemia. See Restricted Fluid Management, p. K-2.
Monitoring	Standard monitors (see p. B-1) Foley catheter	
Positioning	✓ and pad pressure points ✓ eyes	Sciatic and femoral nerve injuries may occur in the lithotomy position. Check to minimize hip abduction and external rotation. Carefully pad and secure knees and heels. Watch hands and finger carefully when arms tucked at patient's side.
Complications	Abdominal access injuries	Most complications occur during abdominal access. These include injuries to major and minor blood vessels and may lead to catastrophic and even fatal bleeding. Bowel and bladder injuries may occur and go undiagnosed until the postop period.
	Pneumoperitoneum effects	Effects may include subcutaneous emphysema,

		mediastinal emphysema, pneumothorax, shoulder pain, CO_2 retention, air embolism following venous injury, and dysrhythmias. Physiologic changes induced by pneumoperitoneum including ↑HR, MAP, PVR, and SVR, and ↓VC, venous return, preload, and CO may be poorly tolerated in patients with advanced pulmonary and/or cardiac disease.
	Bradydysrhythmias	May be profound. Halt surgery, consider deflating pneumoperitoneum, and treat with atropine (0.5 mg) or glycopyrrolate (0.2–0.4 mg) if persistent or severe.
	Abdominal wall hematoma	
	Nerve injury	
	Hypothermia	See positioning.
	Neuropathies	These can be long cases, with the patient in lithotomy position. Make sure the pressure points are padded well, and, if the arms are out, relieve stress on the brachial plexus.
	Fluid overload	✓ fluid volume entering and exiting the abdomen. Fluid absorption → fluid overload → CHF, edema

POSTOPERATIVE

Complications	PONV	↑↑ Risk for PONV. See p. B-6.
	VTE	See p. B-7.
	Hypothermia	

Multimodal pain management	Consider ketorolac 15–30 mg iv at closing ± LA into surgical wounds	Patients may complain of shoulder pain due to diaphragmatic irritation. Consider acetaminophen 1000 mg po/iv q8h, ±gabapentin 100–200 mg po tid, ibuprofen 200–800 mg po/iv q6h, or hydromorphone 0.2–0.5 mg iv for breakthrough pain.
ERAS	Goals include opiate-sparing and multimodal postop analgesia	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum may promote return of bowel function.

Suggested Readings

1. Børglum J, Gögenür I, Bendtsen TF: Abdominal wall blocks in adults.Curr Opin Anaesthesiol 2016; 29(5):638–43.
2. Chapman JS, Roddy E, Ueda S, et al: Enhanced recovery pathways for improving outcomes after minimally invasive gynecologic oncology surgery. Obstet Gynecol 2016; 128(1):138–44.
3. Gerges FJ, Kanazi GE, Jabbour-Khoury SI: Anesthesia for laparoscopy: a reviewJ Clin Anesth 2006; 18(1):67–78.
4. Nelson G, Altman AD, Nick A, et al: Guidelines for postoperative care in gynecologic/oncology surgery: enhanced recovery after surgery (ERAS®) Society recommendations—Part II. Gynecol Oncol 2016; 140(2):323–32.
5. Nelson G, Altman AD, Nick A, et al: Guidelines for pre- and intra-operative care in gynecologic/oncology surgery: enhanced recovery after surgery (ERAS®) Society recommendations—Part I. Gynecol Oncol 2016; 140(2):313–22.

SECTION **9.0**

UROLOGY

SURGEON
Harcharan S. Gill, MD, FRCS, FACS

ANESTHESIOLOGISTS
Periklis Panousis, MD, PhD
Roya Saffary, MD

DIAGNOSTIC TRANSURETHRAL (ENDOSCOPIC) PROCEDURES

SURGICAL CONSIDERATIONS

Description

Many urologic diseases are diagnosed and evaluated endoscopically through the urethra with the use of specialized instruments, such as cystoscopes and resectoscopes. With the patient in a lithotomy position, the cystoscope is introduced into the urethra and advanced under direct vision all the way into the bladder (Figs. 9.1 and 9.2), allowing inspection of the urethra (**urethroscopy**) and bladder (**cystoscopy**). If pathology is noted, a biopsy can be obtained easily through the cystoscope. It is also possible to introduce a small catheter into the ureteral orifice and advance it up to the kidney for radiologic evaluation (**retrograde pyelography**), to collect a urine specimen, or to bypass areas of obstruction. If the upper urinary tract needs to be visualized, a ureteroscope is introduced through the urethra into the bladder and through the ureteral orifice into the ureter and advanced up to the kidney, allowing inspection of the ureter (**ureteroscopy**) and intrarenal collecting system (**nephroscopy**). These procedures often precede a major surgical operation.

Usual preop diagnosis

Hematuria; hydronephrosis; benign prostatic hypertrophy; cancer of the urethra, prostate, bladder, ureter, and renal pelvis; urinary tract stones; strictures; ureteropelvic junction obstruction; hemorrhagic or interstitial cystitis

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, postop pain management options, and possibility of urinary drain postop. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

SUMMARY OF PROCEDURES

	Urethroscopy/Cystoscopy	Ureteroscopy/Nephroscopy
Position	Lithotomy	⇐
Incision	None	⇐
Special instrumentation	Cystoscope	Ureteroscope

Unique considerations	Use of x-ray and fluoroscopy	⇐
Antibiotics	Cefazolin 2 g iv	⇐
Surgical time	15 min	45 min
EBL	None	⇐
Postop care	PACU → home	⇐
Mortality	Minimal	⇐
Morbidity	Infection: 5%	⇐ Ureteral perforation: <5%
Pain score	1	1

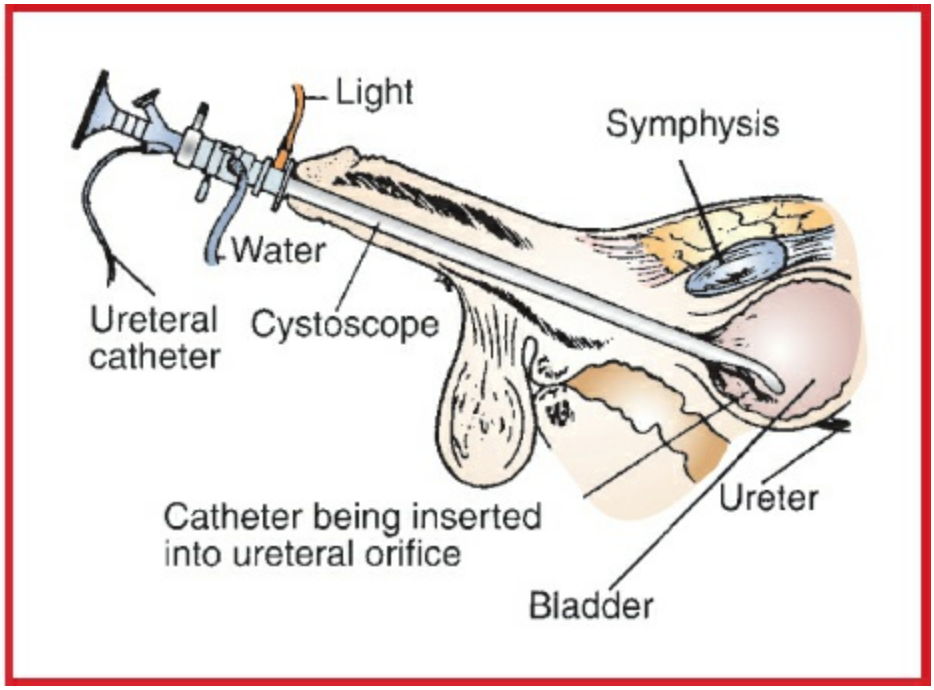

Figure 9.1 Cystoscope introduced into the bladder via the urethra (male anatomy). (Reproduced with permission from Hardy JD: Textbook of Surgery, 2nd edition. JB Lippincott, Philadelphia: 1988.)

PATIENT POPULATION CHARACTERISTICS

Age range	All ages	⇐
Male:Female	1:1	⇐
Incidence	30% of all urologic procedures	⇐

Etiology	Hematuria	⇐
	Urethral and bladder	⇐
	tumors	⇐
	Stones	⇐
	Urethral strictures	Ureteropelvic junction obstruction
Associated conditions	Prostatic hypertrophy	Hydronephrosis
	Cystitis	⇐

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Therapeutic Transurethral Procedures (Excep TURP).

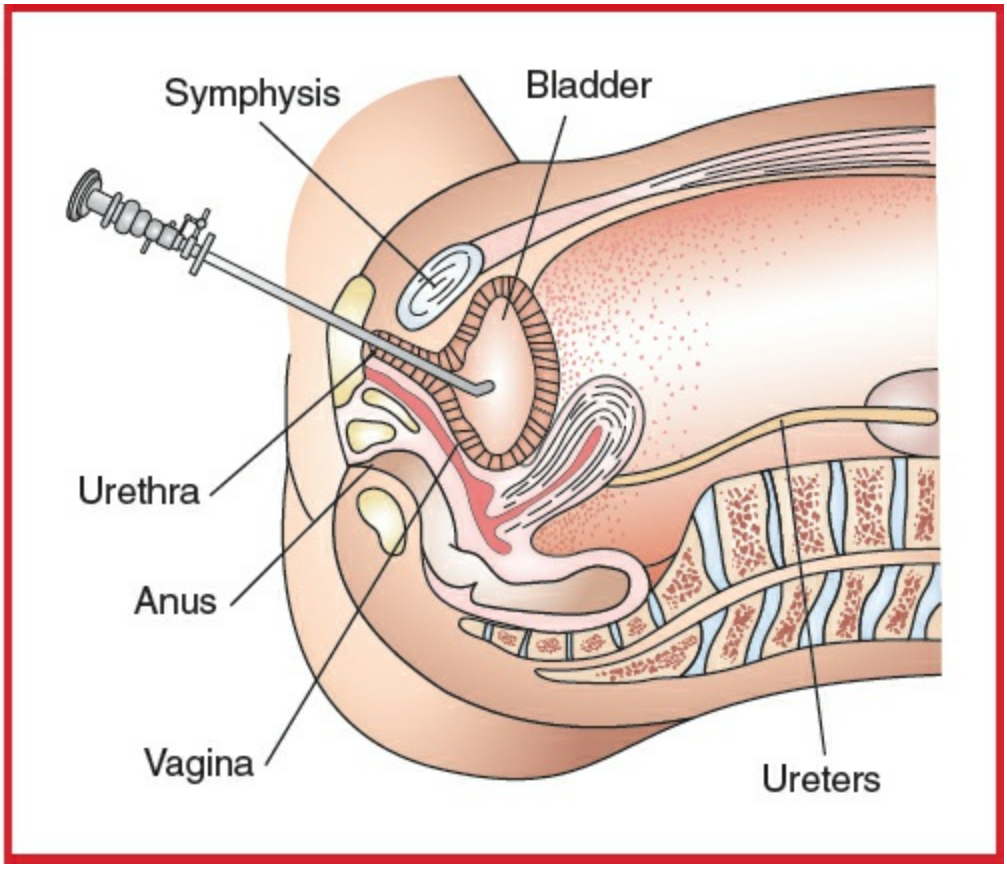

Figure 9.2 Cystoscope introduced into the bladder (female anatomy). (Reproduced with permission from Govan DE: Roche Manual of Urologic Procedures. Hoffmann-La Roche: 1976.)

THERAPEUTIC TRANSURETHRAL PROCEDURES (EXCEPT TURP)

SURGICAL CONSIDERATIONS

Description

Therapeutic transurethral procedures, the most common urologic operations, require the use of specialized instruments, such as cystoscopes and resectoscopes. Because of continuously improving instrumentation and fiberoptics, the range and complexity of these operations are widening, and more operations are being done transurethrally now than ever before. These operations are **transurethral resection (TUR)** of any urethral, prostatic, or bladder pathology; **fulguration** of bleeding vessels; **instillation of chemicals**, such as oxychlorosene (Clorpactin) and formalin, into the bladder; **extraction** of stones; and **incision and dilation** of strictures.

With the patient in the lithotomy position, the cystoscope or resectoscope is introduced into the urethra and advanced under direct vision into the bladder, allowing inspection of the urethra and bladder (Figs. 9.1 and 9.2). The pathology is identified. If it is a tumor, it is resected piecemeal with the electrode of the resectoscope, using the cutting current and cauterizing the base of the tumor with the coagulating current. If the pathology is a stone, it is extracted with special forceps or a stone basket. Large stones have to be fragmented, prior to extraction, with a mechanical lithotrite, electrohydraulic probe, ultrasound lithotrite, or laser (holmium or pulsed dye). Chemicals can be instilled through the cystoscope to control interstitial and hemorrhagic cystitis. Bleeding vessels can be coagulated with the electrode. Strictures of the urethra can be dilated or incised with an endoscopic knife. Strictures of the ureter also can be treated endoscopically by dilatation with a balloon catheter or by incision with electrocautery. Balloon catheters with attached cutting electrowires (Acucise) often are used. A temporary ureteral stent is placed at the end of most endoscopic ureteral surgeries.

Variant procedure or approaches

Occasionally, access to the intrarenal collecting system (renal pelvis and calyces) and upper ureter is easier and more appropriately done by a **percutaneous nephrostomy** than by a transurethral procedure. The patient is placed in a prone or flank position, a percutaneous stab wound is made at the costovertebral angle, and a tube is introduced into the kidney under fluoroscopic control.

Usual preop diagnosis

Tumors of the urinary tract; stones; interstitial or hemorrhagic cystitis; strictures

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, postop

pain management options, and possibility of urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Transurethral	Percutaneous
Position	Lithotomy	Flank or prone
Incision	None	Stab wound
Special instrumentation	Cystoscope; resectoscope; catheters; stents	Percutaneous nephrostomy kit; nephroscope; urethroscope; catheters; stents
Unique considerations	Use of x-rays, fluoroscopy, and electrocautery	⇐
Antibiotics	Cefazolin 2 g iv	⇐
Surgical time	1 h	2–3 h
EBL	100 mL	500 mL
Postop care	Irrigation of tubes and catheters to clear clots and prevent obstruction	⇐
Mortality	<1%	⇐
Morbidity	Bleeding: 10% Infection: 5% Perforation: 2% Retained stones: 2%	⇐ ⇐ ⇐ ⇐
Pain score	1	3

PATIENT POPULATION CHARACTERISTICS

Age range	All ages	⇐
Male:Female	1:1	⇐
Incidence	10% of urologic diseases	⇐

	involve these procedures	
Etiology	Urethral and bladder tumors; bladder and ureteral stones; interstitial cystitis; hemorrhagic cystitis; urethral stricture	Kidney stones; upper ureteral stones; ureteropelvic junction obstruction

ANESTHETIC CONSIDERATIONS FOR TRANSURETHRAL PROCEDURES (EXCEPT TURP)

PREOPERATIVE

Patients of all ages may present for ureteral stone extraction. Paraplegics and quadriplegics have a predilection for nephrolithiasis and may present for repeated cystoscopies. Bladder tumors usually are seen in older patients, who may present for cystoscopy or TUR. These patients may have preexisting medical problems, including CAD, CHF, PVD, cerebrovascular diseases, COPD, and/or renal impairment. Preo evaluation should be directed toward the detection and treatment of these conditions prior to anesthesia.

Neurologic	Paraplegics and quadriplegics may present for repeated cystoscopies and stone extractions. Note Hx of autonomic hyperreflexia; Sx may include flushing, headache, and nasal stuffiness, associated with voiding or noxious stimuli below the level of spinal cord injury (see below).
Musculoskeletal	Contractures and pressure sores may make positioning difficult in paraplegics or quadriplegics.
Laboratory	Tests as indicated from H&P
Premedication	Sedation prn anxiety (e.g., lorazepam 1–2 mg po 1–2 h before surgery; midazolam 1–2 mg iv in preop area)
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status.

INTRAOPERATIVE

Anesthetic technique

Spinal, continuous lumbar epidural, and GA are acceptable, with the choice dependent on type and length of procedure, age, coexisting disease, and patient preference. Simpler transurethral procedures (e.g., cystoscopy) are amenable to topical anesthesia, whereas longer and more complex procedures (e.g., ureteral stone extraction) will require regional or GA (see discussion below regarding autonomic hyperreflexia). Note that many of these procedures are done on an outpatient basis, and the anesthetic should be planned accordingly. For regional anesthesia, a sacral block is required for urethral procedures (T9-T10 level for procedures involving the bladder and as high as T8 for procedures involving the ureters).

Regional anesthesia

Topical	2% lidocaine jelly
Spinal	0.75% bupivacaine 10–12 mg. For shorter procedures (<1 h), consider low-dose bupivacaine (0.75%, 7.5 mg), mepivacaine (1.5%, 45 mg), or procaine (10%, 100–150 mg). Lidocaine may be used, but the incidence of transient neurologic symptoms may be as high as 30% for procedures performed in the lithotomy position.
Lumbar epidural	1.5–2.0% lidocaine with epinephrine 5 mcg/mL, 15–25 mL; supplement with 5–10 mL boluses as needed. Supplemental iv sedation

General anesthesia

Induction	Standard induction. ET intubation may not be necessary for shorter procedures; consider LMA. Succinylcholine should be avoided in paralyzed (e.g., paraplegic, quadriplegic) patients 2° ↑ K^+ → VF or asystole.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Pure inhalation anesthetic (e.g., N_2O, sevoflurane/desflurane) for short cases. IV technique

	(e.g., propofol 100–200 mcg/kg/min; supplement with N_2O ± volatile anesthetic ± remifentanil). Muscle relaxation is not essential. Long-acting narcotics are unnecessary because postop pain is usually minimal.	
Emergence	No specific considerations	
Blood and fluid requirements	Usually minimal blood loss IV: 18 ga × 1 BSS @ 1–3 mL/kg/h	See Zero Balance Fluid Management, Appendix K, p. K-2 and p. K-4.
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes	**NB:** In lithotomy position, peroneal nerve compression at lateral fibular head → foot drop.
Complications	Anticipate ↓ BP upon returning from lithotomy position. Autonomic hyperreflexia (**AH**): • Severe HTN • Bradycardia • Dysrhythmias • Cardiac arrest	Rx: volume (200–500 mL BSS) or ephedrine (5 mg iv) may be necessary. Patients with spinal cord injury level above T10 are at risk for **AH** associated with stimulation below the level of transection. Transection levels below T5 may be associated with less severe manifestations. AH can be prevented by GA, spinal, or epidural anesthesia. If AH occurs intraop, it should be treated by deepening the level of anesthesia and iv antihypertensive agents (e.g., SNP 0.5–5 mcg/kg/min; labetalol 5–10 mg iv; phentolamine

		2–5 mg iv), if necessary.

POSTOPERATIVE

Complications	Peroneal nerve injury 2° lithotomy position Bladder perforation Fever/bacteremia	Peroneal nerve injury manifested as foot drop with loss of sensation over the dorsum of the foot. Seek neurology consultation. Bladder perforation may present as shoulder pain in the awake patient but may go unnoticed in a patient under GA. Sx include unexplained HTN, tachycardia, ↓ BP (rare).
Multimodal pain management	Pain usually mild	Rx: acetaminophen 1000 mg, fentanyl 25–50 mcg iv, ketorolac 15–30 mg im or iv
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Cockcroft JO, Berry CB, McGrath JS, et al: Anesthesia for major urologic surgery Anesthesiol Clin 2015; 33(1):165–72.
2. Liu N, Zhou M, Biering-Sørensen F, et al: Iatrogenic urological triggers of autonomic dysreflexia: a systematic review. Spinal Cord 2015; 53(7):500–9.
3. Vukovic N, Dinic L: Enhanced recovery after surgery protocols in major urologic surgery. Front Med (Lausanne) 2018; 5:93.

TRANSURETHRAL RESECTION OF THE PROSTATE (TURP)

SURGICAL CONSIDERATIONS

Description

TURP is one of the most common urologic operations, performed to relieve bladder outlet obstruction by an enlarging prostate gland. It is often preceded by **cystoscopy**, which is used to evaluate the size of the prostate gland and to rule out any other pathology, such as bladder tumor or stone. The operation is performed with the resectoscope, a specialized instrument having an electrode capable of transmitting both cutting and coagulating currents. Resectoscopes are either single inflow only or continuous flow with an inflow and outflow system. The latter allows the surgeon to maintain low pressure in the bladder and prostatic fossa and thus limit fluid absorption. Two different electrical options are available. The traditional resectoscope is a monopolar system, and this requires a grounding pad and possible interference with electric devices, such as pacemakers. Bipolar resectoscopes have both the active and return electrode fitted in the resectoscope and do not cause any electrical interference with cardiac electrical devices. In addition, the use of bipolar cautery allows saline to be used as an irrigant during surgery.

The resectoscope is introduced into the bladder (Fig. 9.3), and the tissue protruding into the prostatic urethra is resected in small pieces called "chips." Bleeding vessels are coagulated with the coagulating current. The resection is performed with continuous irrigation using an isotonic solution, such as sorbitol 2.7% with mannitol 0.54% in monopolar resectoscopes and normal saline in bipolar resectoscopes. After the obstructing prostatic tissues are completely resected and bleeding vessels coagulated, the chips are irrigated from the bladder and the resectoscope is removed. An indwelling Foley catheter is introduced into the bladder. The time of transurethral resection should not exceed 2 h because excessive absorption of the irrigating fluid may → dilutional hyponatremia, confusion, seizures, and heart failure. However, this is less of an issue with a continuous flow bipolar resectoscope where saline is used as an irrigant. Although fluid absorption can occur, hyponatremia does not occur with the use of saline. The size of the enlarged prostate or adenoma, therefore, needs to be carefully assessed preop to determine if it is possible to complete the resection within 2 h. If not, an **open prostatectomy** is performed. This variant approach is discussed under Open Prostate Operations.

Variant procedure or approaches

A number of techniques have been developed to avoid the morbidity of TURP. These are either **vaporization** (electrocautery or laser) or **thermocoagulation** of the prostate (laser, microwave, radiofrequency). The following techniques are available and approved:

TUVP

Transurethral vaporization of the prostate with a standard resectoscope using a roller ball electrode at 275–300 watts setting

Laser ablation (PVP)

Laser coagulation of the prostate was done with Nd:YAG or Ho:YAG laser through a standard cystoscope. This procedure has been largely replaced by photoselective vaporization of the prostate (PVP) with an 80-w KTP laser, 120- to 180-w GreenLigh laser, or diode laser. These green spectrum laser wavelengths allow 1–2 mm deep vaporization of prostate tissue with minimal blood loss. This is currently the most popular minimally invasive technique used for treatment of BPH. It can also be done on patients while on anticoagulation or with bleeding disorders. All personnel in the OR, including the patient, must wear protective glasses to protect the eyes from inadvertent exposure from a break in the laser fiber.

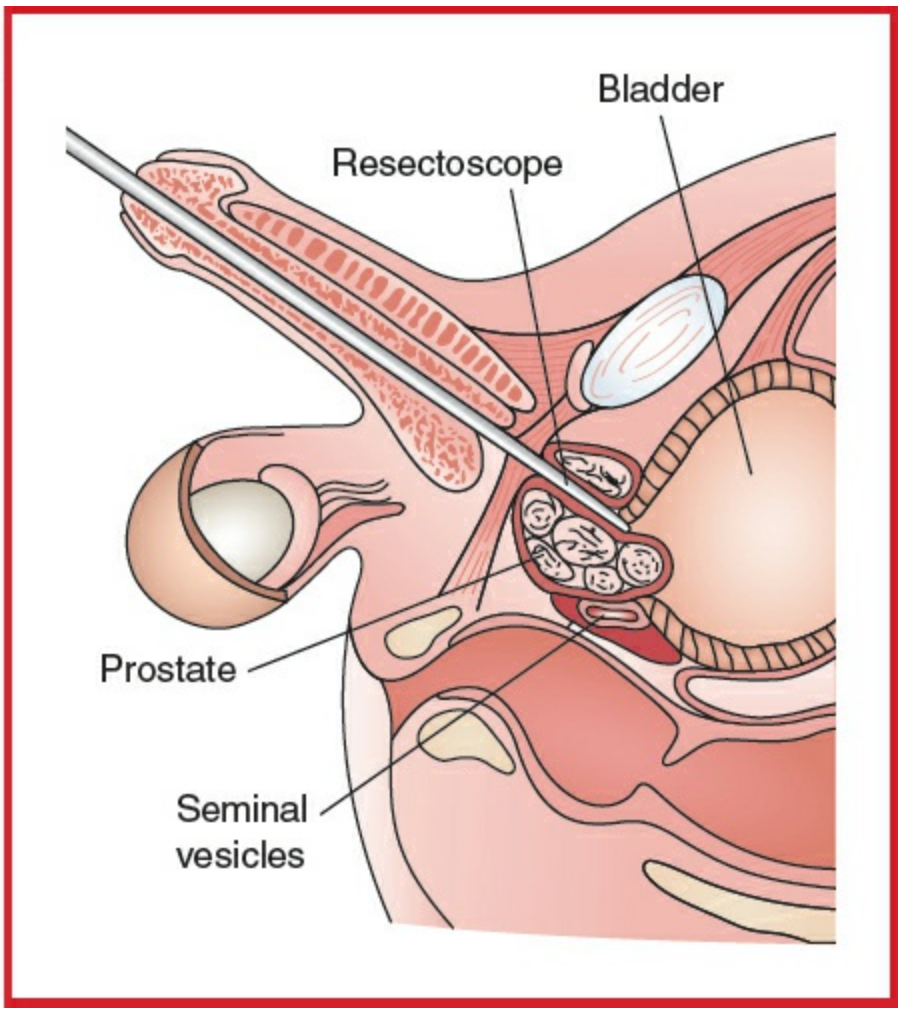

Figure 9.3 Transurethral resection of the prostate using a resectoscope. (Reproduced with permission from Govan DE: Roche Manual of Urologic Procedures. Hoffmann-La Roche: 1976.)

TUNA

Transurethral needle ablation of the prostate is done with a special disposable device connected to a radiofrequency generator.

TUMT

Transurethral microwave thermotherapy is done with a catheter that has a microwave antenna attached to it. A microwave generator is needed for this procedure.

UroLift™

Prostatic urethral lift (UroLift) implants are transmural tethers (see Fig. 9.4) used to enlarge the urethral lumen. They are placed using a rigid cystoscope, usually with local anesthesia ± sedation.

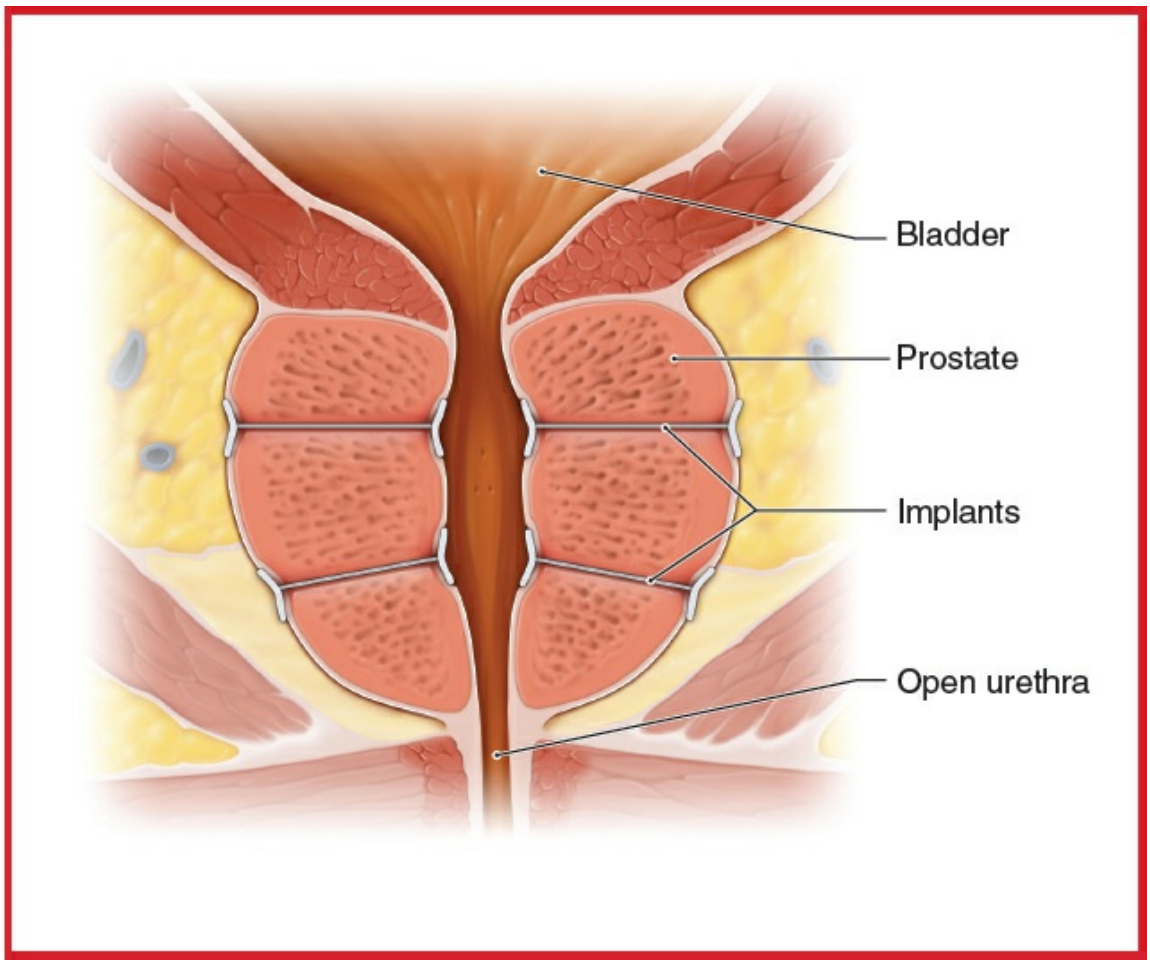

Figure 9.4 Dilated urethra following transurethral placement of UroLift® implants.

All of the above have several advantages over TURP, including shorter surgical time, no blood loss, and reduced risk of fluid absorption and all can be done as outpatient procedures.

Usual preop diagnosis

Benign prostatic hypertrophy; prostate cancer

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, and possibility of urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES		
	TURP	**Thermotherapy**
Position	Lithotomy	⇐

Incision	None	⇐
Special instrumentation	Cystoscope; resectoscope; catheters; electrocautery	Cystoscope; resectoscope; catheters; electrocautery (standby); laser equipment
Unique considerations	During resection, the patient should be absolutely still because any movement may lead to perforation or injury to the external sphincter, → postop incontinence.	During laser resection, the patient and all personnel should wear protective eyeglasses.
Antibiotics	Cefazolin 2 g iv	⇐
Surgical time	1–2 h (not to exceed 2 h)	1 h
EBL	500 mL	None
Postop care	Irrigation of the Foley catheter to clear it of clots and keep it from being blocked. Determination of serum Na^+	⇐
Mortality	<1%	⇐
Morbidity	Significant intraop bleeding: 10% Intraop perforation and fluid extravasation, which may require placement of retropubic drain: <0.5% Postop bleeding, which may necessitate a return to OR for fulguration of bleeding vessels: <5% Absorption of irrigating fluid, which may → dilutional hyponatremia, mental confusion, and	Prolonged catheterization: 10% Postop bleeding: 1%

	heart failure: 2–5%	
Pain score	1	1

PATIENT POPULATION CHARACTERISTICS

Age range	49–90 yr; typically, 70s and 80s
Incidence	Very common; 90% of men will develop benign hypertrophy; 20% may need surgical intervention.
Etiology	Aging; benign prostatic hypertrophy; prostate cancer
Associated conditions	COPD (10%); heart disease (10%); HTN (10%); diabetes mellitus (DM) (5%); DIC (1–2% of patients with prostate cancer may also have a low-grade, subclinical DIC, which becomes clinically manifest postop)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients presenting for prostate surgery are generally older and may have preexisting medical problems, including CAD, CHF, PVD, cerebrovascular disease, COPD, an renal impairment. Preop evaluation should be directed toward the detection and treatment of these conditions before anesthesia.

Respiratory	COPD common in this age group. Patients with >50 pack-year smoking Hx, or with any respiratory Sx, may need PFTs. For dyspnea with moderate exercise, ✓ VC, FEV_1, and MMEF. If VC < 80%, FEV_1 < 60%, or MMEF < 40% is predicted, ✓ ABG. If ABG and PFT are markedly abnormal, consider postponing surgery until patient's respiratory condition has been optimized. **Tests:** PFT; CXR; ABG, as indicated from H&P
Cardiovascular	HTN, CAD common in this age group. Assess exercise tolerance by H&P (e.g., should be able to climb a flight of stairs without difficulty or SOB). **Tests:** ECG; others as indicated from H&P

Neurologic	Cerebrovascular disease, Alzheimer's, and other neurologic problems may be present in this age group. Assess mental status to guide evaluation of any intraop or postop changes.
Renal	Anticipate renal impairment 2° chronic obstruction. **Tests:** BUN; Cr; electrolytes. If ↑ BUN and ↑ Cr, ✓ creatinine clearance (nl = 95–140 mL/min).
Musculoskeletal	Various arthritides in this age group may cause problems with positioning for regional anesthesia and surgery.
Endocrine	Increased incidence of DM
Hematologic	Moderate blood loss expected with larger glands. If the gland <80 g, no T&C is necessary. **Test:** Hct
Laboratory	Other tests as indicated from H&P
Premedication	Continue commonly used drugs (e.g., digitalis, β-blockers, NTG) to prevent cardiovascular problems. Sedation prn anxiety (e.g., midazolam 1–2 mg iv before surgery)
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for GA patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Regional or GA. Choice of technique depends on the coexisting disease and the patient's preference. Regional anesthesia may hold some advantage over GA for TURP in that it allows evaluation of mental status and, thus, earlier detection of TURP syndrome. The incidence of postdural puncture headache is very low in this age group (<1%). A T9 level is optimal. Continuous lumbar epidural anesthesia has no advantage over (and may be less reliable than) spinal anesthesia for TURP. Since the procedure is relatively short, supplemental doses are usually not necessary.

Regional anesthesia

Spinal	0.75% bupivacaine, 12 mg in 7.5% dextrose solution (1.6 mL)

General anesthesia

Induction	Standard induction	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance. Muscle relaxation is not mandatory, although patient movement during the procedure must be avoided.	
Emergence	Postop pain is usually not significant. Anticipate ↓ BP when legs are repositioned from lithotomy. Avoid stress on the lumbar spine by slowly and simultaneously bringing legs together and returning to supine position. PONV prophylaxis should include ondansetron.	
Blood and fluid requirements	Moderate blood loss (TURP) Minimal blood loss (thermotherapy) IV: 16–18 ga × 1 BSS @ 1–3 mL/kg/h	Blood loss can be large (TURP) if venous sinuses are entered and difficult to quantify because of irrigant. To flush away blood and tissue and to promote visibility during TURP (or thermotherapy), continuous irrigation is used. For monopolar procedures, irrigating fluid must be nonelectrolytic to prevent dispersion of current but near iso-osmotic to prevent hemolysis. For these reasons, sorbitol

		(2.7%) with mannitol (0.54%) or glycine (1.5%) is added to distilled water to produce solutions that are nearly isotonic. A zero balance fluid management strategy is recommended (see p. K-3). See Zero Balance Fluid Management, p. K-2.
Monitoring	Standard monitors	Regional anesthesia allows monitoring of mental status. Invasive monitoring, if indicated from H&P
TURP syndrome	Intravascular volume overload Hyponatremia +Hypotonicity 2° absorption of irrigant Symptoms include: • N/V • Visual disturbances • Mental status changes • Coma • Sz • HTN • Angina • Cardiovascular collapse	Factors that influence the absorption of irrigant include surgical technique (TURP or thermotherapy), hydrostatic pressure of irrigant (height of bag), number of venous sinuses opened, peripheral venous pressure, duration of surgery, and experience of the surgeon. Resections should optimally be limited to 1 h or less. Some CNS manifestations (e.g., visual disturbances, nausea, confusion) are 2° glycine and its metabolites. Rx may include observation, diuresis (e.g., furosemide 5–20 mg iv), and

		administration of hypertonic saline (e.g., 100 mL of 3% saline over 1–2 h). Serum sodium <120 is associated with more severe symptoms, and the goal of therapy is to restore sodium to >120. In milder cases, observation and water restriction may be sufficient.
Positioning	✓ and pad pressure points ✓ eyes	**NB:** In lithotomy position, peroneal nerve compression at the lateral fibular head → foot drop
Complications	Bladder perforation TURP syndrome	Bladder perforation may produce shoulder pain in the awake patient. Bladder perforation (and TURP syndrome) may go unnoticed under GA; Sx: ↑ BP, ↑ HR (occasionally ↓ BP).

POSTOPERATIVE

Complications	TURP syndrome Bladder perforation Fever/bacteremia/sepsis Hypothermia	See discussion of TURP syndrome above.
Multimodal pain management	Minimal postop pain	Rx: acetaminophen 1 g is often sufficient.
ERAS	PONV protocol (see Appendix B, p. B-4 and p.	Encourage early enteral nutrition, Foley catheter

	B-6)	removal, and mobilization.
Tests	Hct; electrolytes Blood cultures if febrile	Consider serum osmolarity, CXR, ECG in TURP syndrome.

Suggested Readings

1. Cornu JN: Bipolar, monopolar, photovaporization of the prostate, or Holmium Laser enucleation of the prostate: how to choose what's best? Urol Clin North Am 2016; 43(3):377–84.
2. Hawary A, Mukhtar K, Sinclair A, et al: Transurethral resection of the prostate syndrome: almost gone but not forgotten. J Endourol 2009; 23(12):2013–20.
3. Longo MA, Cavalheiro BT, de Oliveira Filho GR: Systematic review and meta analyses of tranexamic acid use for bleeding reduction in prostate surgery. J Clin Anesth 2018; 48:32–8.
4. Magistro G, Stief CG, Gratzke C: Prostatic urethral lift versus transurethral resection of the prostate (TURP). Curr Urol Rep 2017; 18(10):82.
5. Smith RD, Patel A: Transurethral resection of the prostate revisited and updated Curr Opin Urol 2011; 21(1):36–41.
6. Teng J, Zhang D, Li Y, et al: Photoselective vaporization with the green light laser vs transurethral resection of the prostate for treating benign prostate hyperplasia: a systematic review and meta-analysis. BJU Int 2013; 111(2):312–23.
7. Vukovic N, Dinic L: Enhanced recovery after surgery protocols in major urologic surgery. Front Med (Lausanne) 2018; 5:93.
8. Wang J, Zhang C, Tan G, et al: Risk of bleeding complications after preoperative antiplatelet withdrawal versus continuing antiplatelet drugs during transurethral resection of the prostate and prostate puncture biopsy: a systematic review and meta-analysis. Urol Int 2012; 89(4):433–8.

OPEN PROSTATE OPERATIONS

SURGICAL CONSIDERATIONS

Description

Open (in contrast to transurethral or endoscopic) operations on the prostate gland are less common. They include **simple prostatectomy and radical prostatectomy** and are done through either a midline extraperitoneal incision, which extends from the umbilicus

to the symphysis pubis, or through a Pfannenstiel incision (Fig. 9.5, inset).

Simple prostatectomy

When the benign prostatic hypertrophy or adenoma is too large to be resected transurethrally, it is removed by a simple prostatectomy. The prostate gland is exposed through a retropubic approach (Fig. 9.5A), and the anterior capsule is incised, exposing the adenoma—the central part of the prostate—which is excised, "shelled" out by blunt dissection (Fig. 9.5B), leaving behind the peripheral prostate and all the associated structures. A Foley catheter is left indwelling in the urethra, and the incision in the prostate capsule is closed. In a **suprapubic prostatectomy**, the incision is made in the bladder and the adenoma shelled from within the bladder.

Radical prostatectomy

The term **radical prostatectomy** is used because the entire prostate, both seminal vesicles and pelvic nodes, is removed. It is used to differentiate this cancer operation from a simple prostatectomy (used for benign prostatic hypertrophy). Radical prostatectomy can be achieved through a **retropubic approach**. In radical prostatectomy, all of the prostate gland is removed, together with the bladder neck, the seminal vesicles, and the ampullae of the vas deferens. A **limited pelvic lymphadenectomy** (Fig. 9.6) also is performed. After the prostate gland and its associated structures are removed, the bladder neck is reduced to 1 cm diameter and anastomosed to the membranous urethra over an indwelling Foley catheter. Most of the blood loss occurs during control of the dorsal vein complex. In early-stage cancers, which nowadays comprise 90% of patients, a nerve sparing procedure is done. This involves preserving potency by preserving the nerves to the corpora cavernosa. More recently, radical prostatectomy is being done by laparoscopy. This procedure has been popularized with the use of robots. Please see section of robotic urologic surgery.

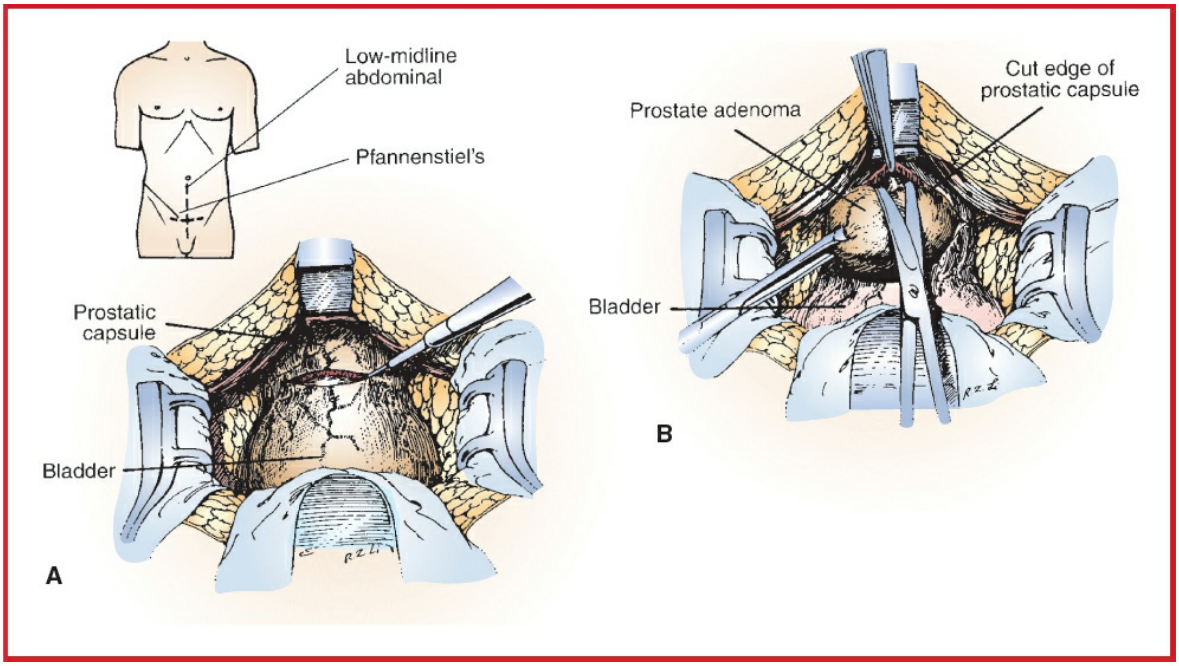

Figure 9.5 Retropubic prostatectomy. **A:** A transverse capsulotomy is made between heavy hemostatic stay sutures. **B:** The cleavage plane between the adenoma and the surgical capsule is developed with scissors. (Reproduced with permission from Fowler JE:Manual of Urologic Surgery. Little, Brown, Boston: 1990.)

Variant approach

Minimally invasive prostate cancer surgery has expanded with the use of the **da Vinci robotic system**. Most laparoscopic radical prostatectomies are done with the assistance of the robot. With the robotic system, the surgeon sits at a console away from the patient and has a three-dimensional view with 10× magnification. A bedside assistant is necessary for instrument change and retraction. See page 1022 for special Anesthetic Considerations for Robotic-Assisted Laparoscopic Surgery.

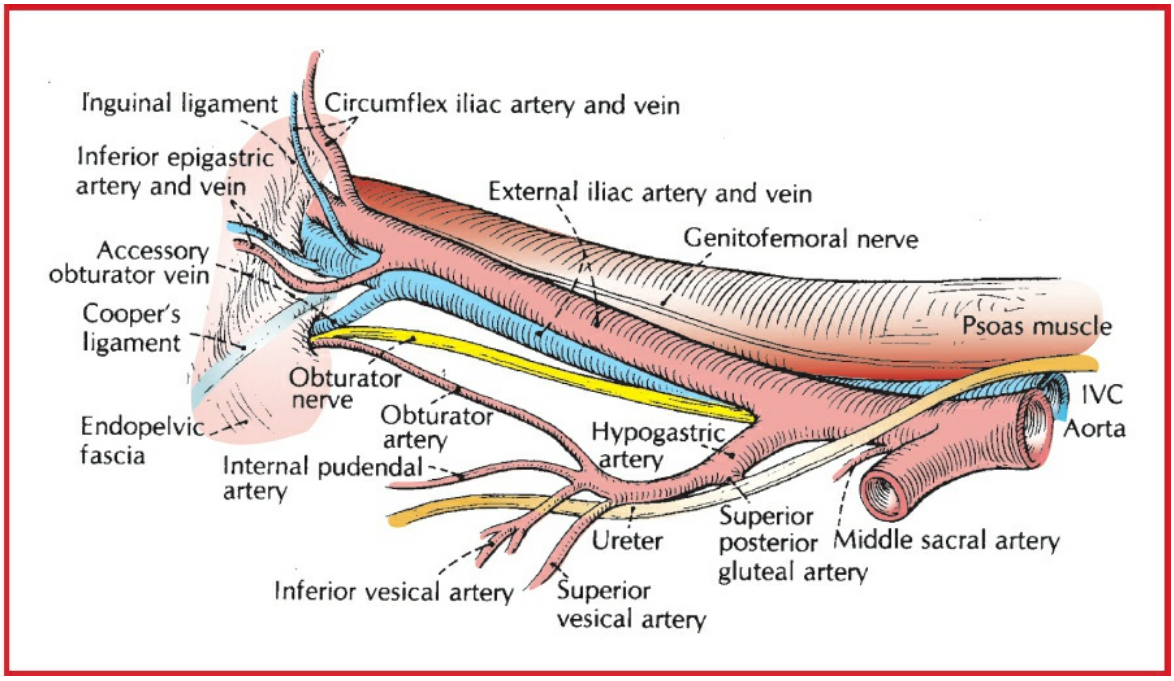

Figure 9.6 Right lateral pelvic wall. Anatomy of pelvic blood vessels and nerves encountered in a pelvic lymph node dissection. (Reproduced with permission from Graham SD Jr:Glenn's Urologic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1998.)

Usual preop diagnosis

Benign prostatic hypertrophy; prostate cancer

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, postop recovery plan, and urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Simple Prostatectomy	Radical-Retropubic
Position	Supine	⇐; lithotomy → steep Trendelenburg (robotic)
Incision	Extraperitoneal, low midline (Fig. 9.7), or Pfannenstiel's (Fig. 9.5A, inset)	⇐; multiple port sites (robotic)
Unique considerations	None	⇐; da Vinci robotic system is used increasingly (>80%); abdominal

		insufflation.
Antibiotics	Cefazolin 2 g iv	Cefazolin 2 g iv
Surgical time	1 h	2–3 h (experienced surgeon)
EBL	500 mL	1500 mL (less with robotic assist)
Postop care	Irrigate catheter to clear blood clots and prevent obstruction, frequently, if urine is bloody.	⇐
Mortality	<1%	⇐
Morbidity	Bleeding: 2% DVT: 2% Infection: 2% PE: 1%	⇐ ⇐ ⇐ ⇐ Impotence: Non–nerve-sparing:100% Nerve-sparing: 20–50% Lymphocele: 4%
Pain score	8	8

PATIENT POPULATION CHARACTERISTICS

Age range	40–80 yr
Incidence	20% of men will develop symptomatic benign prostatic hypertrophy; 9% will develop clinically evident prostate cancer.
Etiology	Aging
Associated conditions	COPD (10%); CAD (10%); HTN (10%); diabetes mellitus (5%); renal failure (1%)

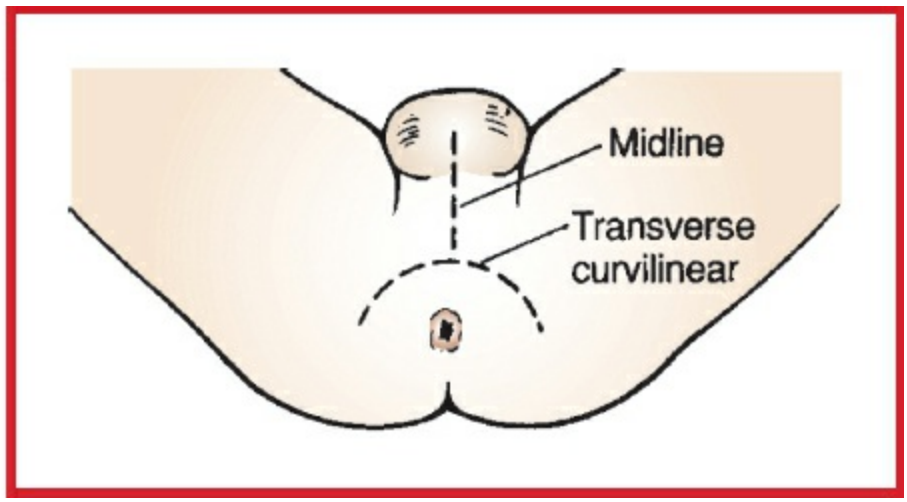

Figure 9.7 Perineal incisions.

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients presenting for prostate surgery are generally elderly and may have preexisting medical problems, including CAD, CHF, PVD, cerebrovascular disease, COPD, an renal impairment. Preop evaluation should be directed toward the detection and treatment of these conditions prior to anesthesia. A bowel prep may have been completed before surgery.

Respiratory	COPD common in this age group. Patients with Hx of >50 pack-year smoking, or with respiratory Sx, may require PFTs. For dyspnea with moderate exercise, check VC, FEV_1, and MMEF. If VC < 80%, FEV_1 < 60%, or MMEF < 40% is predicted, ✓ ABG. If ABG and PFT are markedly abnormal, consider postponing surgery until patient's respiratory condition has been optimized. In robotic surgery, steep Trendelenburg position will compromise pulmonary function. **Tests:** PFT; CXR; ABG, as indicated from H&P
Cardiovascular	HTN, CAD common in this age group. Assess exercise tolerance by H&P (e.g., should be able to climb a flight of stairs without difficulty or SOB). Transition plans for patients on anticoagulants for coronary stents should be discussed with both the cardiologist and surgeon before surgery.

	Tests: ECG; others as indicated from H&P
Neurologic	Cerebrovascular disease, Alzheimer's, and other neurologic problems may be present in this age group. Assess mental status to guide evaluation of any intraop or postop changes. In robotic cases, steep Trendelenburg position and CO_2 insufflation → ↑ ICP and ↑ intraocular pressure. A preop neurosurgical consult is recommended for patients with intracranial lesions or VP shunts. Blindness has been reported following robotic prostatectomy.
Renal	Anticipate renal impairment 2° chronic obstruction. Pneumoperitoneum during robotic surgery may ↓ renal blood flow and oliguria postop. **Test:** Cr
Musculoskeletal	Various arthritides may cause problems with positioning for regional anesthesia and surgery.
Endocrine	Increased incidence of diabetes mellitus
Hematologic	Moderate blood loss expected with larger glands. For glands <30 g, no T&C is necessary; for glands 30–80 g, T&C 2 U PRBCs; for glands >80 g, T&C 4 U PRBCs. **Test:** Hct
Laboratory	Other tests as indicated from H&P
Premedication	Continue commonly used drugs (e.g., digitalis, β-blockers, diuretics, NTG) to prevent cardiovascular complications. Sedation prn anxiety (e.g., midazolam 1–2 mg iv on call to OR) If ERAS protocol is followed, consider preoperative acetaminophen 1000 mg po and/or gabapentin 600–1200 mg po or pregabalin 150–300 mg po 30–60 min prior to induction.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of a rectus sheath catheter or epidural block for postop pain management. Consider preop acetaminophen 1000 mg po with sip of water. Consider aprepitant 40 mg

	po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Regional (spinal, continuous spinal, continuous lumbar epidural), GA, or combined techniques are acceptable for open procedures. Robotic procedure typically requires GA. If regional anesthesia is used, optimal block level is T8-T10 (depending on the incision site). Advantages of regional anesthesia include potential for lower intraop blood loss, possible lower incidence of DVT postop, and faster return of bowel function. Disadvantages include positioning considerations (see below).

Regional anesthesia

Spinal	Bupivacaine (0.75%) 12 mg in 7.5% dextrose solution (1.6 mL)
Epidural	1.5–2% lidocaine with epinephrine 5 mcg/mL, 15–25 mL, supplemental iv sedation as necessary. Additional epidural lidocaine (5–10 mL boluses) may be needed, depending on the length of procedure. Alternatively, smaller volumes of bupivacaine (0.25–0.5%) or ropivacaine (0.5–1%) may be used. The addition of opiates has been associated with ↑ urinary retention in noncatheterized patients.

General anesthesia

Induction	Standard induction
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Standard maintenance. In robotic cases, recheck ETT position after the patient has been positioned and the abdomen insufflated to avoid mainstem intubation. Patient movement is not well tolerated by the robot → visceral/vascular injury. Consider

	ketamine 0.5 mg/kg bolus + 0.25 mg/kg/h infusion during surgery (especially in opioid-dependent patients).	
Emergence	No special considerations. Airway edema may occur after prolonged steep Trendelenburg position. Discuss with surgeon local wound infiltration or nerve block placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose is given >6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Moderate-to-large blood loss IV: 14–16 ga × 1–2 BSS @ 1–3 mL/kg/h	Additional requirements dependent on the type of anesthesia. Regional techniques may require the use of vasopressors or volume (if indicated) to offset sympathectomy and systemic vasodilation; RA also may be associated with lower blood loss than GA. A zero balance fluid management strategy may be beneficial (see Appendix K, p. K-2 and p. K-4.). See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors Depending on underlying disease: ± CVP ± Arterial line	Arterial line is often useful for continuous BP and PPV monitoring. Patients at particularly high risk (e.g., Hx of preexisting cardiopulmonary disease) may benefit from both ART and CVP lines.

Positioning	Anticipate ↓ BP on return from lithotomy position. ✓ and pad pressure points ✓ eyes	Rx: ephedrine (5–10 mg iv) or volume (250 mL BSS) may be necessary. Elderly patients with arthritis or respiratory impairment may not tolerate the extreme positioning associated with robotic prostatectomy. **NB:** In lithotomy position, peroneal nerve compression at the lateral fibular head → foot drop.
Complications	Indigo carmine reaction Hemorrhage Hypothermia	Indigo carmine → false ↓ O_2 sat ± ↑ BP; rare allergic reaction → rash + bronchoconstriction + ↓ BP
	VAE Robot malfunction	Insufflation pressure may exceed venous pressure → VAE.
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum promotes return of bowel function.

POSTOPERATIVE

Complications	Peroneal nerve injury 2° lithotomy position DVT Airway edema → obstruction	Manifested by foot drop with loss of sensation on the dorsum of the foot. Seek neurology consultation.

		Incidence of DVT less with regional than GA Sx: variable, with pain and tenderness over involved area
Multimodal pain management	Significant postop pain. Rx: hydromorphone 0.01–0.02 mg/kg iv in incremental doses (e.g., 10–15 min prn) or PCA	Emphasize multimodal approach including regional analgesia, acetaminophen, ± celecoxib, and ± gabapentin. Consider epidural infusion of dilute local anesthetics/opiates or PCA. Robotic procedure patients have lower postop pain.
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum promotes return of bowel function.
Tests	Hct	

Suggested Readings

1. Basiri A, de la Rosette JJ, Tabatabaei S, et al: Comparison of retropubic laparoscopic and robotic radical prostatectomy: who is the winner? World J Urol 2018; 36(4):609–21.
2. Cockcroft JO, Berry CB, McGrath JS, et al: Anesthesia for major urologic surgery Anesthesiol Clin 2015; 33(1):165–72.
3. Kalmar AF, Dewaele F, Foubert L, et al: Cerebral haemodynamic physiology during steep Trendelenburg position and CO_2 pneumoperitoneum. Br J Anaesth 2012; 108(3):478–84.
4. Vukovic N, Dinic L: Enhanced recovery after surgery protocols in major urologic surgery. Front Med (Lausanne) 2018; 5:93.
5. Whalley DG, Berrigan MJ: Anesthesia for radical prostatectomy, cystectomy nephrectomy, pheochromocytoma, and laparoscopic procedures. Anesthesiol Clin

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NEPHRECTOMY

SURGICAL CONSIDERATIONS

Description

Nephrectomies fall into three basic groups: simple, partial, and radical. (Surgical anatomy is shown in Fig. 9.8.)

Simple nephrectomy, performed for benign conditions, is the surgical excision of the kidney and a small segment of proximal ureter. The dorsal approach is well suited for this operation and begins with an incision extending from the 12th rib to the iliac crest along the lateral edge of the sacrospinalis muscle and quadratus lumborum muscle. The dorsolumbar fascia is opened, exposing Gerota fascia and the perinephric fat (Fig. 9.9). The kidney is mobilized until the hilum is exposed. The artery and vein are tied, suture-ligated, and transected. The ureter is followed distally as far as possible, tied, and transected. The kidney is delivered out of the incision, which is then closed by approximating the dorsolumbar fascia and the fascia of the sacrospinalis muscle.

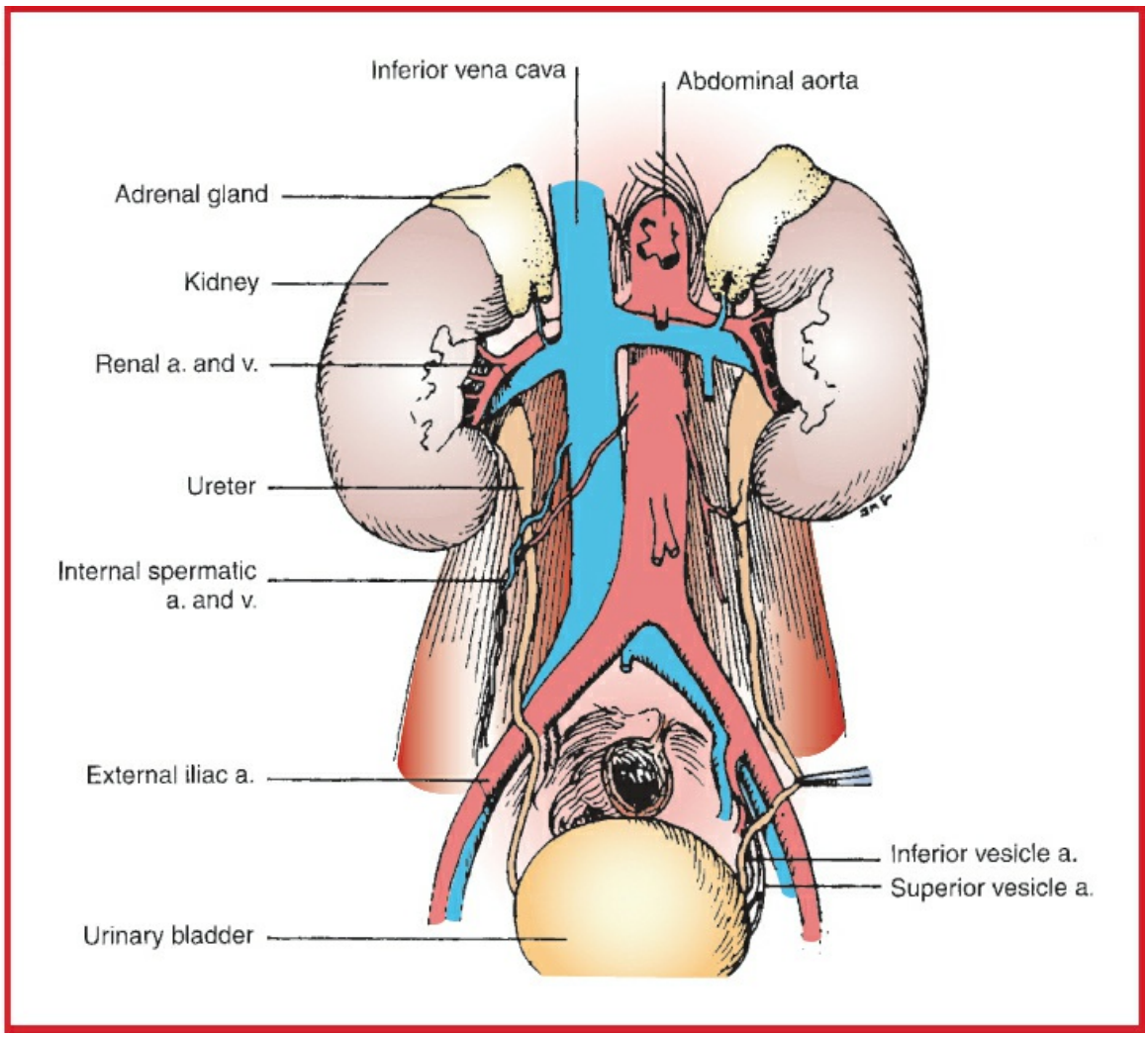

Figure 9.8 Surgical anatomy of the urinary tract. (Reproduced with permission from Hardy JD: Hardy's Textbook of Surgery, 2nd edition. JB Lippincott, Philadelphia: 1988.)

Usual preop diagnosis

Chronic hydronephrosis; hypoplastic kidney; renovascular HTN; double collecting system

Partial nephrectomy is the surgical excision of the segment of the kidney harboring the pathology. It is performed for small renal cell carcinomas and benign tumors of the kidney, such as angiomyolipomas, and for duplicated collecting systems with a diseased moiety. If the partial nephrectomy is being done for renal cell carcinoma, it may be accompanied with a **regional lymphadenectomy**. The flank approach (Fig. 9.10A) is well suited for this operation and begins with an incision over the 12th or 11th rib, or in between, and extends anteriorly over the external and internal oblique muscles, which are transected. The transversalis muscle and fascia are opened, exposing Gerota fascia. The renal capsule is exposed at the planned site of resection. Control of the renal vessels and local hypothermia with ice slush is advised for control of bleeding, if

excessive. Incision in the renal parenchyma is made by sharp and blunt dissection, suture-ligating all bleeders. If the collecting system is opened, it should be closed with absorbable sutures. After complete hemostasis, Gelfoam, thrombin, Floseal, or perinephric fat is used to cover the raw surface of the kidney. More recently, robotic-assisted partial nephrectomy has been shown to provide at least equivalent outcomes compared to laparoscopic or open surgery.

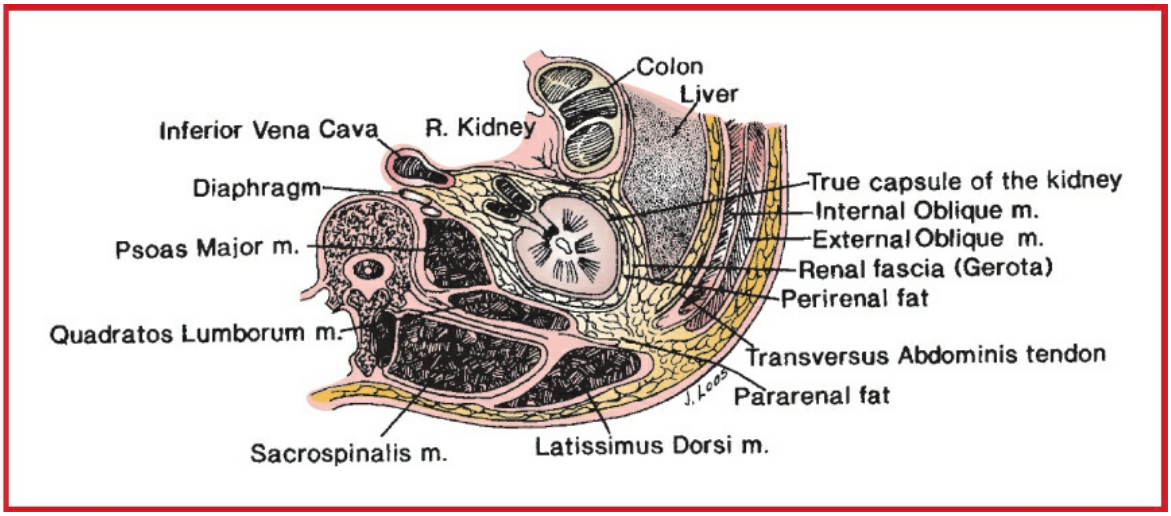

Figure 9.9 Transverse section showing the relation of the renal fascias to the right kidney. (Reproduced with permission from Baker RJ, Fischer JE:Mastery of Surgery, 4th edition. Lippincott Williams & Wilkins: 2001.)

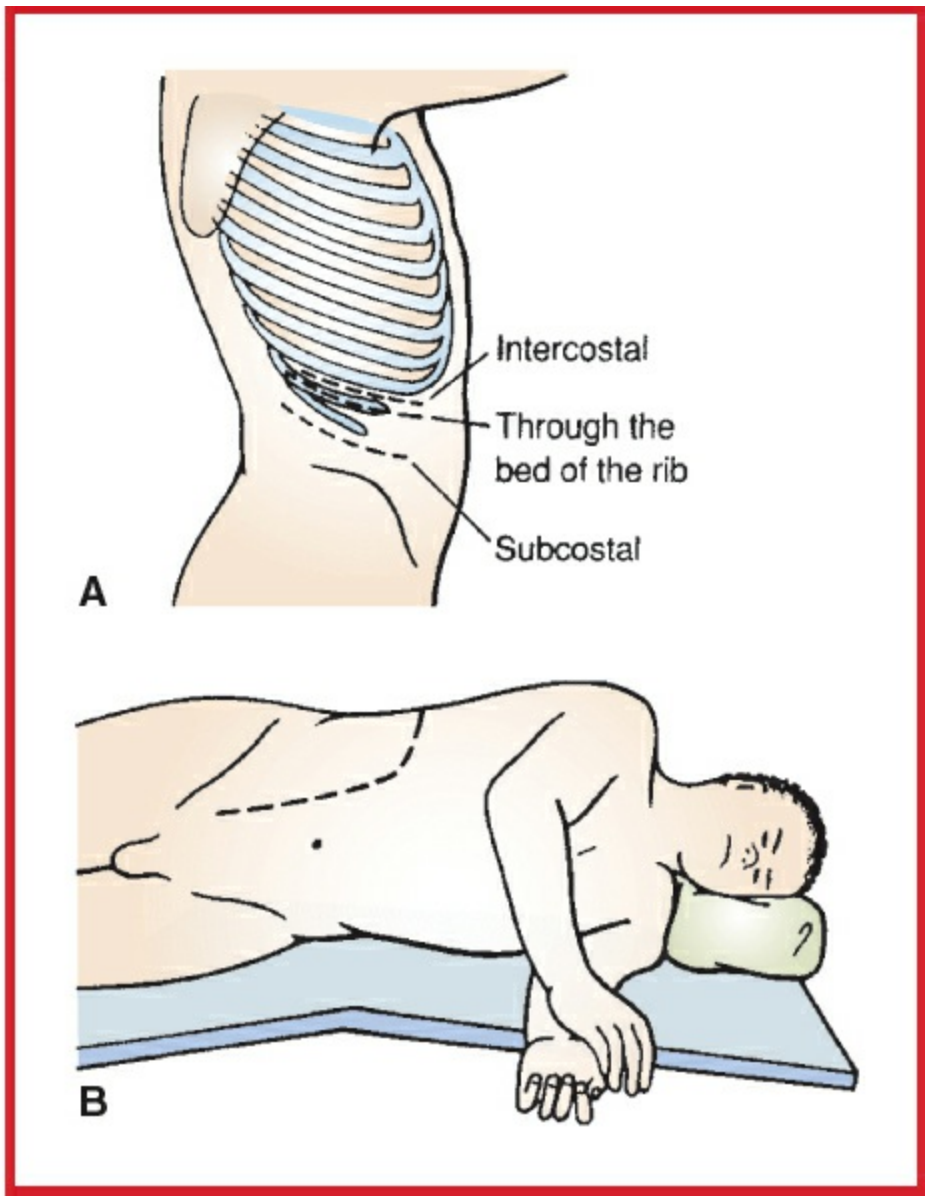

Figure 9.10 **A:** Flank incisions. **B:** Subcostal transabdominal incision.

Usual preop diagnosis

Renal cell carcinoma; double collecting system

Radical nephrectomy is the surgical excision of the kidney with its surrounding perinephric fat and Gerota fascia and the proximal 2/3 of the ureter, accompanied by paracaval or paraaortic **lymphadenectomy**. It is performed for renal cell carcinoma. Early control of renal vessels is advised before excessive manipulation of the tumor to minimize blood loss and hematogenous spread. Transabdominal or flank approaches (Fig. 9.10A, B) are best suited for this operation. Surgery in patients with renal vein or inferior vena cava involvement is more complex and prone to more intraoperative complications, including blood loss. When the tumor thrombus involves a large segment

of the vena cava or is in the right atrium, a team approach with cardiac surgeons is used. Often patients have to be put on cardiopulmonary bypass under hypothermia.

Laparoscopic simple or radical nephrectomy: A pneumoperitoneum is created by insufflating CO_2 to a pressure of 14–16 mm Hg. Three to four trocars are inserted as necessary (Fig. 9.11). Typically, the patient is placed in a flank position as in an open radical nephrectomy. This procedure can be either **transperitoneal** or **retroperitoneal**, depending on the surgeon's preference or experience. The transperitoneal approach may be modified by using a hand-assistance device through one of the ports (**hand-assisted laparoscopic nephrectomy**). Most radical nephrectomies can be done by an experienced laparoscopic surgeon.

Usual preop diagnosis

Renal cell carcinoma, nonfunctioning kidney 2° infection or obstruction; kidney donation for transplant

Nephroureterectomy is a radical nephrectomy with ureter resection, including the ureteral orifice and a cuff of bladder wall around it. It is accompanied by a regional lymphadenectomy because it is performed for a cancerous condition. The approach is either **transabdominal** or **extraperitoneal** through an extended flank incision, starting at the tip of the 11th rib and curving caudally along the lateral edge of the rectus abdominis muscle down to the pubic bone (Fig. 9.10B). Some surgeons prefer two separate incisions: a flank incision for the radical nephrectomy part and a lower abdominal incision for the ureterectomy. This procedure can be done by laparoscopy with a lower midline incision made to remove the specimen. It is often done as a combined laparoscopic and open procedure. The kidney is removed laparoscopically, while the distal ureter is excised by open surgery. The specimen is removed through the infraumbilical incision. This technique involves positioning, prepping, and draping the patient twice during the case.

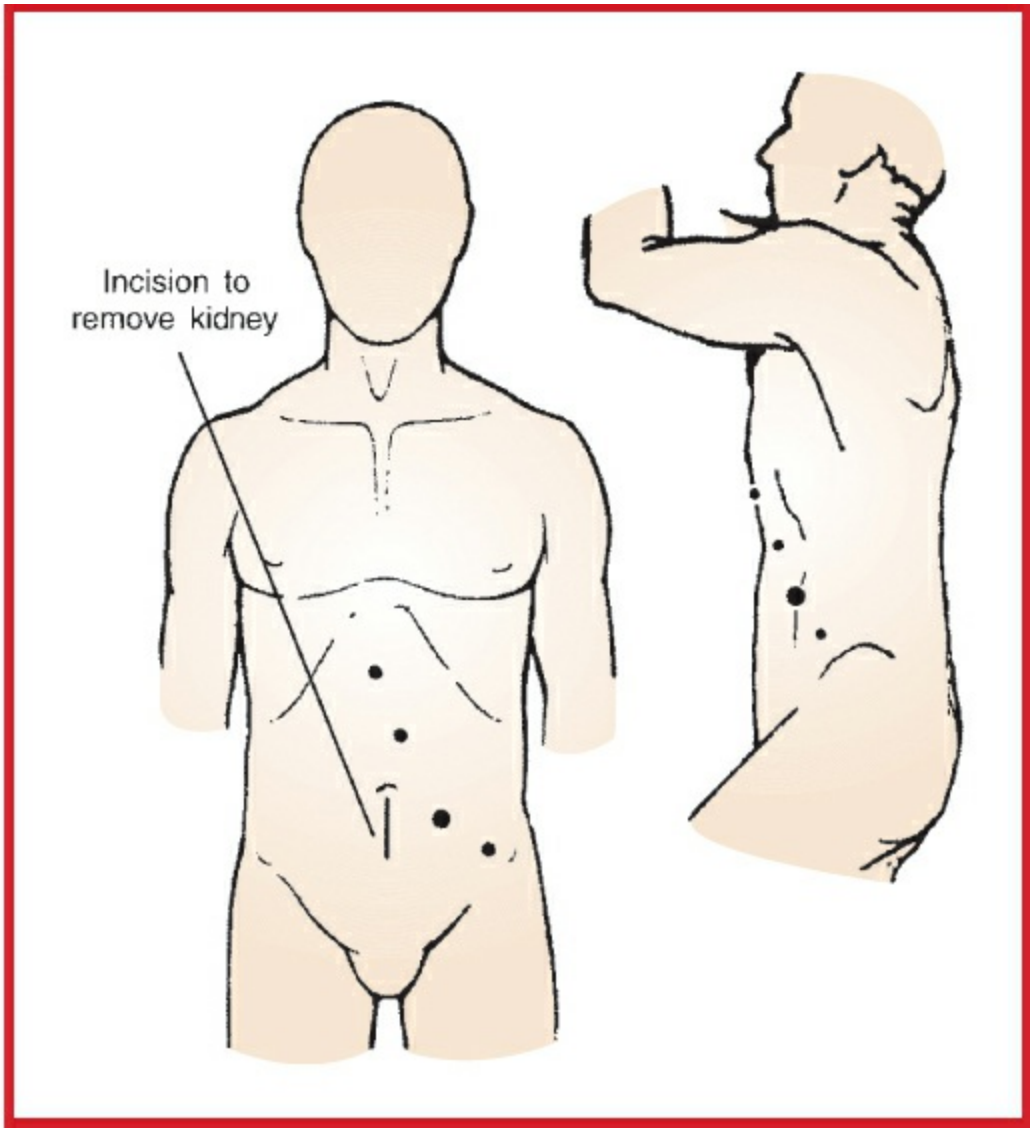

Figure 9.11 Incision and placement of trocars in laparoscopic nephrectomy. (Reproduced with permission from Scott-Conner CEH, Dawson DLOperative Anatomy, 2nd edition. Lippincott Williams & Wilkins: 2003.)

Usual preop diagnosis

Transitional cell carcinoma of the renal collecting system or ureter

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, postop recovery plan, possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Simple Nephrectomy	Partial Nephrectomy	Radical Nephrectomy	Laparoscopic Nephrectomy or Nephroureterectomy
Position	Flank or prone	Flank	Supine or flank	Flank
Incision	Flank (Fig. 9.10A) or dorsal along paraspinous muscles	Flank (Fig. 9.10A)	Midline or subcostal transabdominal (Fig. 9.10B) or flank; subcostal or intercostal or through bed of 11th or 12th rib (Fig. 9.10A)	3–4 ports (Fig. 9.11)
Unique considerations	None	⇐	If tumor involves renal vein and/or IVC, clamp IVC.	Risk of emergent conversion to open case
Antibiotics	Cefazolin 2 g iv	⇐	⇐	⇐
Surgical time	2–3 h	3–4 h	⇐	⇐
Closing considerations	Chest tube may be required if pleura opened with flank incision.	⇐	⇐	A small incision is made at the end of the case to remove the specimen.
EBL	500 mL	1200 mL	500 mL	300 mL
Mortality	<1%	⇐	1%	⇐
Morbidity	Prolonged ileus: 5% Pneumothorax 2° unrecognized pleural perforation: 2%	⇐	⇐	Vascular injury requiring conversion to open case
Pain score	10	10	10	4

PATIENT POPULATION CHARACTERISTICS

Age range	All ages	⇐	⇐	⇐
Male:Female	1:1	⇐	⇐	⇐
Incidence	<1%	⇐	⇐	⇐
Etiology	Double collecting system; chronic hydronephrosis; hypoplastic kidney; renovascular HTN	Localized renal cell carcinoma	Wilms tumor (8% of all childhood malignancies); transitional cell carcinoma (7% of all kidney tumors); renal cell carcinoma (3% of adult malignancies)	
Associated conditions	HTN (if nephrectomy was used to treat renovascular HTN)			

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Operations on the Renal Pelvis and Upper Ureter.

Suggested Readings

1. Cacciamani GE, Medina LG, Gill T, et al: Impact of surgical factors on robotic partial nephrectomy outcomes: comprehensive systematic review and meta-analysis. J Urol 2018; 200(2):258–74.
2. Conacher ID, Soomro NA, Rix D: Anaesthesia for laparoscopic urological surgery Br J Anaesth 2004; 93(6):859–64.
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OPERATIONS ON THE RENAL PELVIS AND UPPER URETER

SURGICAL CONSIDERATIONS

Description

Operations on the renal pelvis and upper ureter are becoming less common because of the increasing use of endoscopic and percutaneous procedures. The basic surgical approach is the same as that for nephrectomy. Specific procedures include the following:

Pyeloplasty is the surgical correction of congenital ureteropelvic junction stenosis to relieve obstruction. The most commonly used is the **dismembered pyeloplasty**, or **Anderson-Heinz pyeloplasty**, wherein the diseased ureteropelvic junction is excised, the redundant renal pelvis is reduced, and an anastomosis is established between the renal pelvis and ureter (Fig. 9.12).

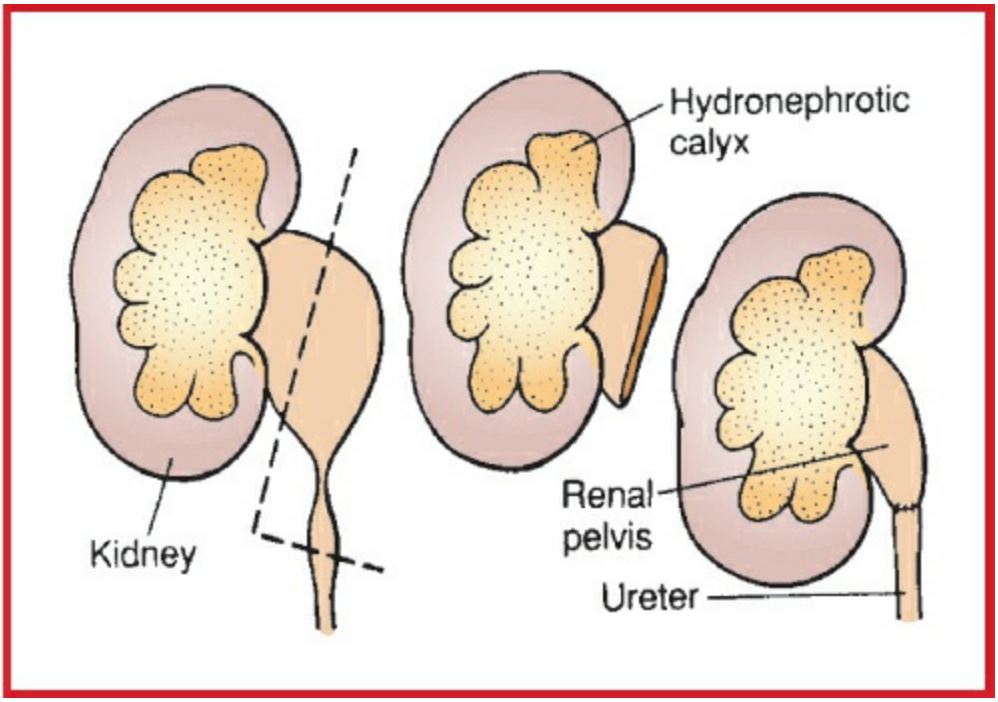

Figure 9.12 Dismembered pyeloplasty.

Usual preop diagnosis

Ureteropelvic junction obstruction

Pyelolithotomy and ureterolithotomy are used to remove calculi from the renal pelvis or ureter. The upper ureter and renal pelvis are exposed, usually through a flank approach, the calculus is palpated, and an incision is made in the ureter or renal pelvis over the calculus, which is then delivered. The incision is closed with fine, absorbable sutures.

Usual preop diagnosis

Renal pelvic or ureteral stone

Transureteroureterostomy is the transposition of one ureter across the midline and anastomosing it to the other ureter (Fig. 9.13). This operation is performed whenever the distal ureter is traumatized or diseased, and the proximal ureter is not long enough to reimplant into the bladder. The recipient ureter should be normal.

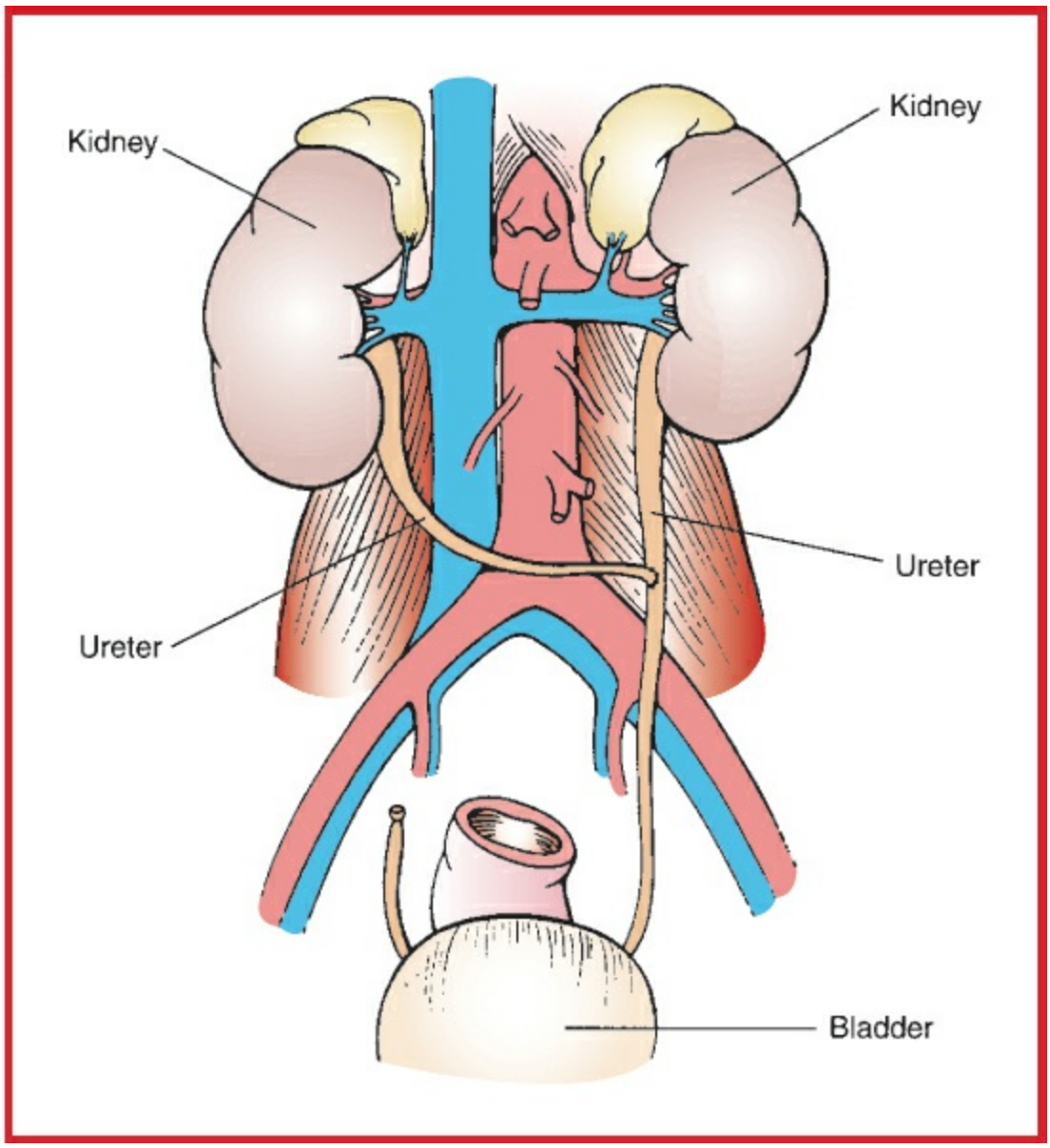

Figure 9.13 Transureteroureterostomy.

Usual preop diagnosis

Traumatic loss of distal ureter; distal ureteral tumor requiring distal ureterectomy

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, postop recovery plan, possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Pyeloplasty	Pyelolithotomy/Ureterolithotomy	Transureterour
Position	Flank or prone	⇐	Supine
Incision	Flank (Fig. 9.10A) or dorsal	⇐	Midline abdomina 9.10A, inset)
Antibiotics	Cefazolin 2 g iv	⇐	⇐
Surgical time	3 h	1–2 h	3 h
EBL	Minimal	⇐	⇐
Mortality	<1%	⇐	⇐
Morbidity	Urinary leakage: 5% Infection: 2%	⇐ ⇐	⇐ ⇐
Pain score	10	10	10

PATIENT POPULATION CHARACTERISTICS			
Age range	All ages	⇐	⇐
Male:Female	1:1	⇐	⇐
Incidence	Rare	Extremely rare	⇐
Etiology	Ureteropelvic junction obstruction: 80% of causes of dilated collecting system in the newborn	Renal pelvic and upper ureteral stone	Traumatic loss of lower ureter; lower ureteral tumor
Associated conditions	Renal failure: 1%		

ANESTHETIC CONSIDERATIONS

(Procedures covered: nephrectomy and operations on the renal pelvis and upper ureter.)

PREOPERATIVE

Patients presenting for nephrectomy and operations on the renal pelvis and upper ureter may be of any age, depending on the etiology of the abnormality. Many patients may have renal insufficiency 2° the underlying problem or from renovascular HTN. Elderly patients frequently have preexisting medical problems, including CAD, CHF, PVD cerebrovascular disease, COPD, and renal impairment. Preop evaluation should be directed toward the detection and treatment of these conditions prior to anesthesia.

Respiratory	Increased postop pulmonary complications because of location of incision (nonlaparoscopic). If Hx of pulmonary disease (e.g., asthma, COPD), consider postop respiratory therapy. **Tests:** As indicated from H&P
Cardiovascular	Consider possibility of renal HTN.
Hematologic	Polycythemia may be seen in association with polycystic kidney disease, renal cell carcinoma. Consider preop blood donation for autologous transfusion. **Tests:** Hct
Laboratory	Electrolytes; BUN; Cr; other tests as indicated from H&P
Premedication	Standard premedication
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of a rectus sheath catheter or thoracic epidural block for postop pain management. Consider preop acetaminophen 1000 mg, ± celecoxib 200 mg, and ±gabapentin 300 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA is recommended for these procedures; technique depends on underlying disease. Regional techniques (spinal or epidural) may be alternatives for some open procedures but are less than optimal because of awkward positioning that may → patient discomfort and pain, resulting from diaphragmatic stimulation. Consider combined technique with regional opiates.

Induction	Standard induction	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.	
Maintenance	Standard maintenance. If intraperitoneal or laparoscopic approach is used, surgeon may request limiting N_2O to avoid distension of bowel and interference with operative field.	
Emergence	No specific considerations. Discuss with surgeon local wound infiltration or nerve block placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose is given >6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Mild-to-moderate blood loss IV: 14–16 ga × 1 BSS @ 2–5 mL/kg/h Warm all fluids.	Intraperitoneal approach associated with higher vasopressor use and fluid requirements. When renal vessels are to be cross-clamped, mannitol (0.5 g/kg) is often given prior to occlusion (20 min maximum). See Goal-Directed Fluid Management, Appendix K, p. K-4.

Monitoring	Standard monitors Urinary catheter Arterial line (partial nephrectomy) ± CVP line	Invasive monitoring if indicated from H&P. CVP line may be useful for partial nephrectomy in patients with solitary kidneys.
Positioning	Use axillary roll if lateral. Avoid stretching brachial plexus—limit abduction to 90° If prone, repeatedly ✓ eyes and pressure points. Assure free excursion of the abdomen	The lateral position with kidney rest and table flexion may → ↓ BP, possibly 2° vena cava obstruction. Vasopressors and moderate iv volume administration with gradual assumption of the position are recommended to avoid this complication.
Complications	Pneumothorax ↓ BP with positioning (see above). Indigo carmine → ↑ BP and ↑ SVR Methylene blue → ↓ BP	Sx of pneumothorax include ↑ RR, ↑ PIP, hypoxemia, and hypercarbia. If in doubt, ✓ CXR.

POSTOPERATIVE

Complications	Postnephrectomy syndrome Eye injury (if prone) Brachial plexus injury (if lateral) Pneumothorax Atelectasis Pneumonia	Postnephrectomy syndrome 2° retractor injury: L1 nerve root damage with resulting pain, dysesthesia, and sensory loss in L1 dermatome distribution

Multimodal pain management	Hydromorphone Acetaminophen Celecoxib PCA Consider epidural opiate.	Postop analgesia critical to minimize pulmonary complications. Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with epidural analgesia, rectus sheath, and/or TAP blocks (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum promotes return of bowel function.
Tests	Hct CXR	Others dependent on operative course, coexisting disease

Suggested Reading

1. Vukovic N, Dinic L: Enhanced recovery after surgery protocols in major urologic surgery. Front Med (Lausanne) 2018; 5:93.

CYSTECTOMY

SURGICAL CONSIDERATIONS

Description

Open (in contrast to transurethral or endoscopic) bladder operations (cystectomies) account for 15–20% of all urologic procedures. They are grouped as simple, partial, and radical procedures.

Simple cystectomy is performed for benign conditions of the bladder, such as severe hemorrhagic cystitis, radiation cystitis, and contracted bladder. It involves the removal of the bladder only. The operation is performed through a lower abdominal incision.

The peritoneal reflections are incised down to the pouch of Douglas; the vasa deferentia and superior vesical arteries are identified, cross-clamped, transected, and tied. The ureters are identified, separated from the surrounding tissues, cross-clamped near the bladder, transected, and tied. The bladder is bluntly separated from the anterior rectal wall all the way to the apex of the prostate. The lateral pedicles of the bladder are cross-clamped, cut, and tied. The endopelvic fascia is incised, separating the prostate from the lateral pelvic wall. The puboprostatic ligaments are transected, and the dorsal vein of the penis is suture-ligated. The tied dorsal vein and urethra are incised just distal to the apex of the prostate. The specimen is delivered out of the incision and hemostasis secured with electrocautery. An ileal conduit is then performed (see below).

Partial cystectomy is the excision of only the part of the bladder containing the pathology. This is not a commonly performed operation and is reserved for tumors located in the dome of the bladder of older patients who are poor surgical risks for major operations, such as radical cystectomy. The operation is preceded by a cystoscopy to identify the site of pathology. Beginning with a lower abdominal incision, the dome and lateral walls of the bladder are separated from the surrounding tissues, which are covered by wet packs to minimize contamination. An incision is made in the dome of the bladder at least 2 cm away from the pathology. The inside of the bladder is inspected and the pathology identified. The incision in the bladder is continued around, and at least 2 cm away from, the pathology, until the latter is completely excised. Bleeders in the wall of the bladder are electrocoagulated. The bladder wall is then closed in two layers—a through-and-through layer and an inverting layer—using absorbable material. Wet packs are removed, a drain is left in the region, and the abdominal incision is closed.

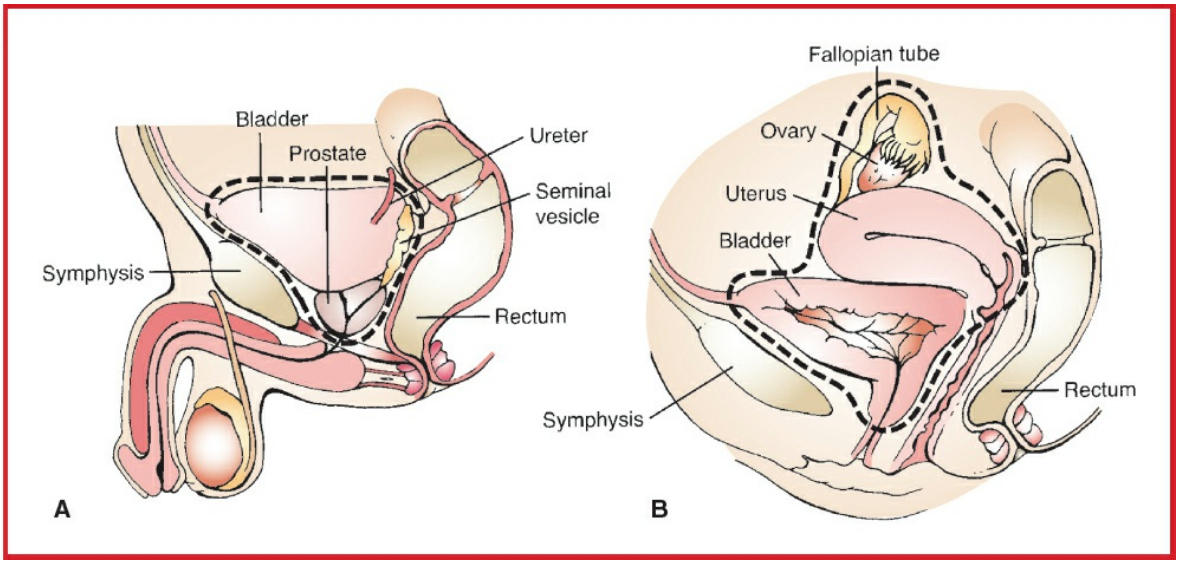

Figure 9.14 Anatomy of the pelvis with tissue to be excised outlined by dashed line. **A:** Male. **B:**

Female.

Radical cystectomy (or **radical cystoprostatectomy**) is performed for treatment of invasive bladder cancer. It encompasses the removal of the bladder and the lower ureters, the prostate gland, and seminal vesicles in men (Fig. 9.14A) and the uterus, ovaries, and the anterior vaginal wall in women (Fig. 9.14B). Accompanied by a **pelvic lymphadenectomy**, it is performed in the supine position, except when a concomitant **urethrectomy** is required, wherein a lithotomy position is used.

Following cystectomy, whether radical or simple, some form of **urinary diversion** is required. This can be accomplished with either a standard ileal conduit or a bladder substitution. The **ileal conduit** is constructed from 6 to 8 inches of the terminal ileum isolated, with its blood supply, from the small intestine. The continuity of the small intestine is accomplished by a simple anastomosis. The ureters are implanted into the proximal end of the conduit, and the distal end is brought through the abdominal wall as a stoma (Fig. 9.15). **Bladder substitution** is a more complex operation wherein a longer segment of bowel is isolated, with its blood supply, and fashioned into a pouch. The ureters are implanted in the pouch, and the most dependent part of the pouch is connected to the membranous urethra, avoiding a stoma (Fig. 9.16). Not all patients undergoing cystectomies are candidates for bladder substitution. For example, patients who require a urethrectomy are not candidates because of the need to remove the urethra.

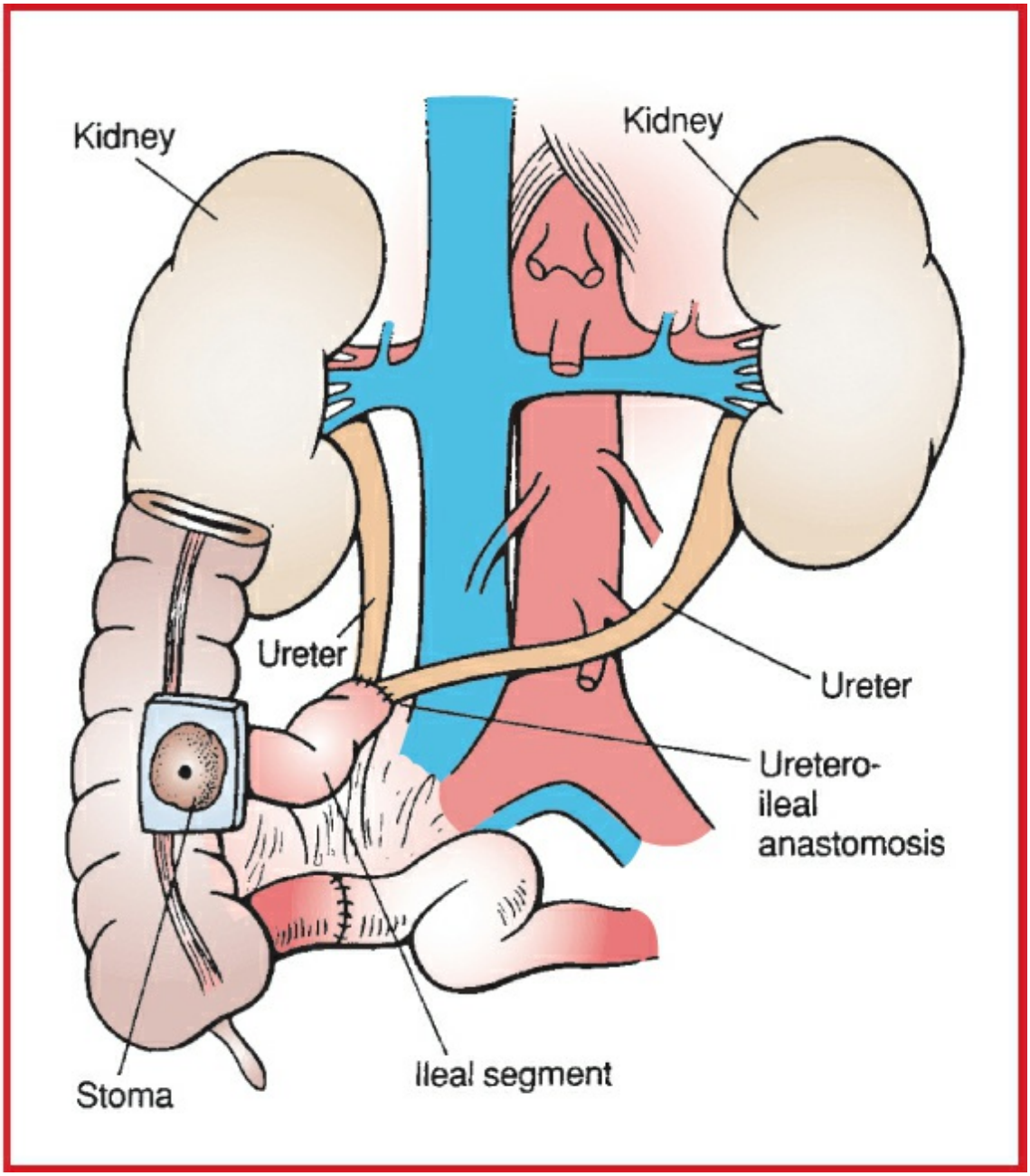

Figure 9.15 Ileal conduit: A segment of the ileum is isolated from the terminal ileum, and continuity of the bowel is reestablished with an end-to-end anastomosis. Ureters are joined to the proximal end of the ileal segment, and the distal end is brought out to the skin as a stoma.

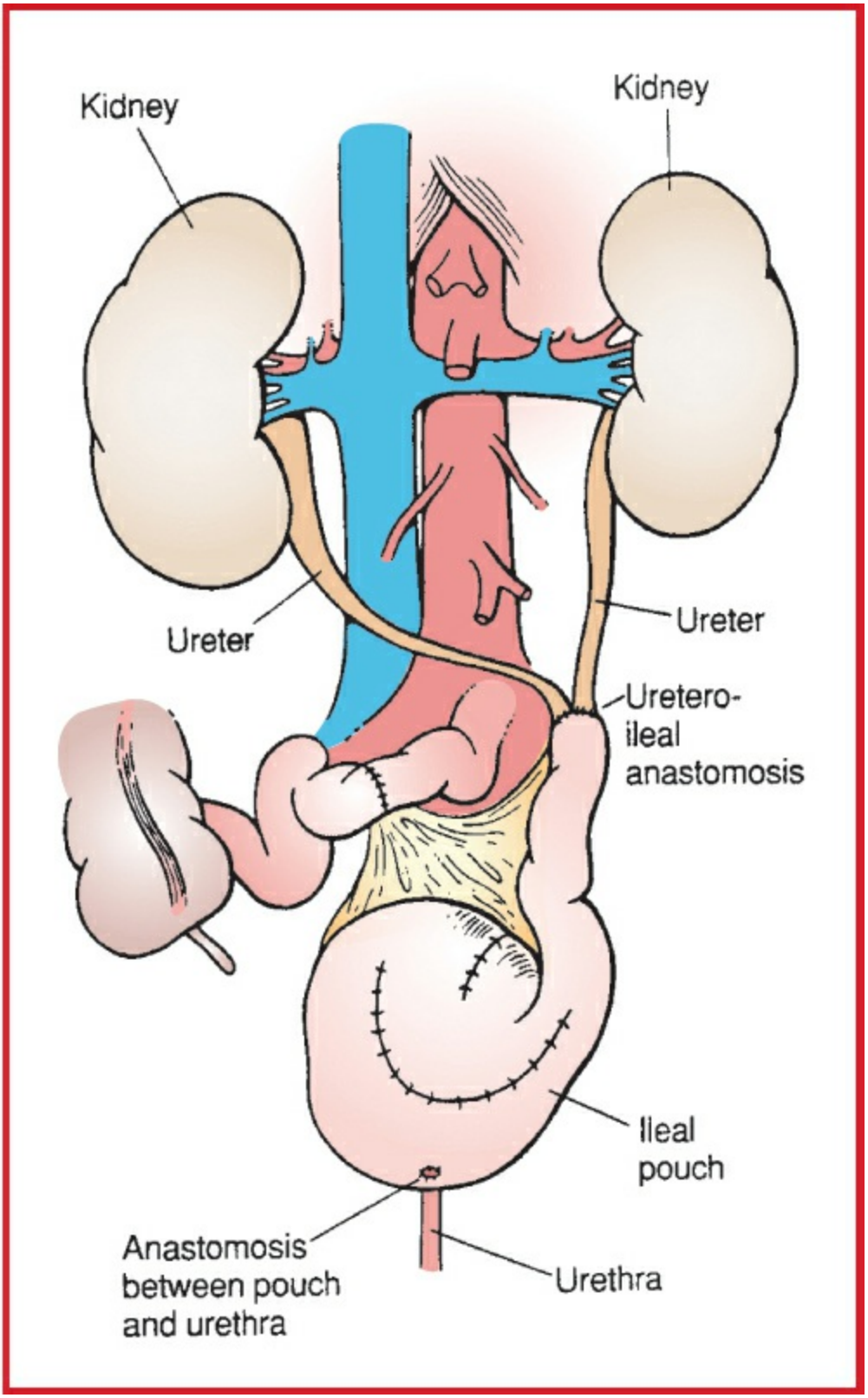

Figure 9.16 Bladder substitution: A segment of the ileum is fashioned into a pouch and anastomosed to the urethra. The ureters are joined to the proximal, nondetubularized segment.

Usual preop diagnosis

Bladder cancer; contracted bladder; hemorrhagic cystitis; radiation cystitis; bladder

diverticulum

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, DVT prophylaxis, postop pain management options, postop recovery plan, possibility of NG tube, and urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Simple Cystectomy	Partial Cystectomy	Radical Cystectomy
Position	Supine	⇐	Supine or lithotomy
Incision	Transperitoneal, midline	⇐	⇐
Antibiotics	Cefotetan or ceftriaxone 1 g	⇐	⇐
Surgical time	4 h	2 h	6 h
EBL	1000 mL	Minimal	1500 mL
Postop care	Care of the stoma	Catheter care	Care of the stoma
Mortality	1%	<1%	2%
Morbidity	Prolonged ileus: 5% Infection: 2%	— — Hematuria: 5%	5% 2%
Pain score	10	10	10

PATIENT POPULATION CHARACTERISTICS

	Simple Cystectomy	Partial Cystectomy	Radical Cystectomy
Age range	40–80 yr	⇐	⇐
	3:1	⇐	⇐

Male:Female			
Incidence	60,000 new cases of bladder cancer diagnosed/yr; 20% treated with cystectomy	⇐	⇐
Etiology	Contracted bladder; hemorrhagic and radiation cystitis	Bladder cancer; bladder diverticulum	⇐
Associated conditions	Heart disease (10%); HTN (10%); COPD (5%); diabetes mellitus (5%)	Heart disease (10%)	⇐

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients presenting for cystectomy are frequently elderly and may have preexisting medical problems, including CAD, CHF, PVD, cerebrovascular disease, COPD, an renal impairment. Preop evaluation should be directed toward the detection and treatment of these conditions prior to anesthesia.

Respiratory	✓ for pulmonary disease in older patients **Test:** As indicated from H&P
Cardiovascular	✓ for cardiac disease, HTN in older patients **Tests:** Consider ECG; others as indicated from H&P
Gastrointestinal	Bowel prep is likely and may cause dehydration and electrolyte disturbances. **Tests:** Electrolytes, if indicated
Hematologic	T&C for 2–4 U PRBC **Test:** Hct
Laboratory	Other tests as indicated from H&P
Premedication	Sedation prn anxiety in adults (e.g., lorazepam 1–2 mg po 1–2 h preop; midazolam 1–2 mg iv in preop

	area)
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of a rectus sheath catheter or thoracic epidural block for postop pain management. Consider preop acetaminophen 1000 mg, ± celecoxib 200 mg, and ±gabapentin 300 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Spinal, continuous lumbar epidural, or GA is acceptable, with choice dependent on the length of procedure, coexisting disease, and patient preference. A combined technique using GA and regional anesthesia may be preferable. A T4 sensory level is recommended, because peritoneal stimulation is likely during this procedure.

Regional anesthesia

Spinal	0.75% bupivacaine 12–15 mg in 7.5% dextrose; hyperbaric tetracaine 10–15 mg with 200 mcg epinephrine for procedures >3 h
Epidural	1.5–2% lidocaine with epinephrine 5 mcg/mL, 15–25 mL; supplement with 5–10 mL as needed. Supplemental iv sedation (e.g., midazolam 1 mg iv prn; fentanyl 50 mcg iv prn). Bupivacaine (0.25–0.5%), levobupivacaine (0.25–0.5%), or ropivacaine (0.5–0.75%), with or without sufentanil or fentanyl, may also be used. The addition of opiates has been associated with ↑ urinary retention in noncatheterized patients.

General anesthesia

Induction	Standard induction

ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.	
Maintenance	Standard maintenance. Consider ketamine 0.5 mg/kg bolus + 0.25 mg/kg/h infusion during surgery iv (especially in opioid-dependent patients).	
Emergence	No specific considerations. Discuss with surgeon local wound infiltration or nerve block placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose is given >6 h ago. PONV prophylaxis should include dexamethasone and ondansetron.	
Blood and fluid requirements	Significant blood loss possible IV: 16 ga × 1 BSS @ 6–10 mL/kg/h Warm fluids Humidify gases	Blood loss may be less with regional than GA. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors Arterial line CVP line	Consider PA catheter or TEE in patients with cardiopulmonary disease. UO as measure of volume status may be unavailable during procedure.
Complications	Major blood loss 3rd-space losses Hypothermia	
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum promotes return of bowel function.

POSTOPERATIVE

Complications	Hypothermia	
Multimodal pain management	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with epidural analgesia, rectus sheath, and/or TAP blocks (see Appendix K, p. K-6).	Regional analgesia. Acetaminophen, fentanyl 100–250 mcg, or Dilaudid 0.5–1 mg, ± celecoxib 200 mg Pain is considerably less after robotic cases, and pain management should be adjusted accordingly.
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum promotes return of bowel function.
Test	Hct	Others as indicated by intraop course

Suggested Readings

1. Azzouni F: Current status of robot-assisted radical cystectomy for bladder cancer. Net Rev Urol 2012; 9(10):573–82.
2. Cheung G, Dasgupta P, Guru KA, et al: Minimally invasive cystectomy approaches in the treatment of bladder cancer. Expert Rev Anticancer Ther 2012; 12(6):733–41.
3. El-Galley R, Hammontree L, Urban D, et al: Anesthesia for laparoscopic donor nephrectomy: is nitrous oxide contraindicated? J Urol 2007; 178(1):225–7.
4. Poch MA, Raza J, Nyquist J, et al: Tips and tricks to robot-assisted radical cystectomy and intracorporeal diversion. Curr Opin Urol 2013; 23(1):65–71.
5. Vukovic N, Dinic L: Enhanced recovery after surgery protocols in major urologic surgery. Front Med (Lausanne) 2018; 5:93.

OPEN BLADDER OPERATIONS (OTHER THAN CYSTECTOMY)

SURGICAL CONSIDERATIONS

Description

Open bladder operations include the following:

Augmentation cystoplasty (or **enterocystoplasty**): Small, contracted bladders can be enlarged and their size and capacity augmented with a segment of the intestine. The bladder is opened widely, anterior/posteriorly, or from side to side or with a cruciate incision. A segment of the intestine—small bowel, cecum, or colon—is isolated from the intestinal tract, detubularized, and added onto the bladder.

Variant procedure

The antrum of the stomach can also be used (**gastrocystoplasty**).

Usual preop diagnosis

Contracted bladder from chronic cystitis or neurogenic bladder

Repair of vesicovaginal or enterovesical fistulas

The communication between the vagina and bladder or bladder and bowel is identified and excised, and the edges are freshened until normal, noninflamed tissues are exposed. The openings in the bladder and in the vagina or bowel are closed, and omentum is interposed in between to promote healing and prevent recurrence. With enterovesical fistulas, often the diseased segment of the intestine is excised, and an **end-to-end anastomosis** of the intestine is performed.

Variant procedure

Transvaginal repair of vesicovaginal fistula (see Vaginal Operations).

Usual preop diagnosis

Vesicovaginal or enterovesical fistula

Ureteral reimplantation, performed to correct vesicoureteral reflux, is more commonly used in the pediatric group than in adults. In adults, it is performed mainly for lower ureteral injuries, iatrogenic or traumatic. The lower ureter is identified and dissected proximally until adequate length is obtained. The bladder is opened and a 2- to 3-cm submucosal tunnel is created in or near the trigone, and the ureter is brought into the

tunnel and fixed with sutures. If there is a large gap between the ureter and the bladder, a **psoas hitch procedure** is necessary. The bladder is mobilized and stitched to the psoas muscle to reach the ureter. In children, if the ureter is dilated, its diameter is reduced by imbrication before reimplantation. In adults, a nonrefluxing implantation is usually not necessary if the operation is being performed for ureteral injury.

Usual preop diagnosis

Vesicoureteral reflux; lower ureteral injuries

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, DVT prophylaxis, postop pain management options, and possibility of urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Augmentation Cystoplasty	Repair of Fistulas	Ureteral Reimplantation
Position	Supine	Supine or lithotomy	Supine
Incision	Low abdominal	⇐	⇐
Antibiotics	Gentamicin 80 mg iv, slowly	⇐	⇐
Surgical time	4 h	3 h	⇐
EBL	Minimal	⇐	⇐
Postop care	Care of catheters and stents	⇐	⇐
Mortality	<1%	⇐	⇐
Morbidity	Infections: 5% Urinary leakage: 1%	⇐ ⇐	⇐ ⇐
Pain score	10	10	10

PATIENT POPULATION CHARACTERISTICS

Age range	All ages	⇐	⇐

Male:Female	1:4	⇐	⇐
Incidence	Rare	⇐	⇐
Etiology	Contracted bladders from chronic cystitis	Traumatic fistulas; vesicovaginal; regional enteritis; diverticulitis; colon cancer	Vesicoureteral reflux; injury to lower ureters

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients presenting for open bladder operations may be of any age, depending on the etiology of the abnormality. Elderly patients frequently have preexisting medical problems, including CAD, CHF, PVD, cerebrovascular disease, COPD, and rena impairment. Preop evaluation should be directed toward the detection and treatment of these conditions prior to anesthesia.

Respiratory	✓ for pulmonary disease in elderly patients **Tests:** As indicated from H&P
Cardiovascular	✓ for cardiac disease in elderly patients **Tests:** Consider ECG; others, if indicated from H&P.
Neurologic	Paraplegics and quadriplegics may present for operations on the bladder and urinary tract. Obtain Hx of autonomic hyperreflexia (AH). Sx are flushing, HA, nasal stuffiness, and HTN associated with voiding or noxious stimuli below the level of transection.
Laboratory	Other tests as indicated from H&P
Premedication	Midazolam 1–2 mg iv
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Spinal, continuous lumbar epidural, or GA is acceptable, with choice dependent on the length of procedure, coexisting disease, and patient preference. A combined technique using light GA with regional anesthesia is also acceptable. A T10 sensory level is sufficient to provide anesthesia for procedures on the bladder, but a T4 level is recommended if the peritoneum is opened. (See Anesthetic Considerations for Transurethral Procedures [except TURP], for patients with AH.)

Regional anesthesia

Spinal	0.75% bupivacaine 10–12 mg. For shorter procedures (<1 h), consider low-dose bupivacaine (0.75%, 7.5 mg), mepivacaine (1.5%, 45 mg), or procaine (10%, 100–150 mg). Lidocaine may be used, but the incidence of transient neurologic symptoms is significant (30%).
Epidural	1.5–2% lidocaine with epinephrine 5 mcg/mL, 15–25 mL; supplement with 5–10 mL as needed. Supplemental iv sedation. Bupivacaine (0.25%), levobupivacaine (0.25–0.5%), or ropivacaine (0.5–0.75%), with or without sufentanil or fentanyl, may also be used. The addition of opiates has been associated with ↑ urinary retention in noncatheterized patients.

General anesthesia

Induction	Standard induction
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance. Consider limiting N_2O for long intraperitoneal procedures to minimize bowel distension.
Emergence	No specific considerations. Consider iv acetaminophen if po dose is given >4–6 h ago. PONV

	prophylaxis should include ondansetron.	
Blood and fluid requirements	Minimal-to-moderate blood loss IV: 16–18 ga × 1 BSS @ 2–4 mL/kg/h Warm fluids Humidify gases for lengthy procedures	See Zero Balance Fluid Management, Appendix K, p. K-2 and p. K-4. Intraperitoneal procedures have higher volume requirements. If possible, use Goal-Directed Fluid Management (see p. K-4).
Monitoring	Standard monitors for simpler procedures ± Arterial/CVP lines	UO as a measure of volume status may be unreliable and often unavailable during the procedure. Consider arterial line, CVP for longer, more complex procedures.
Positioning	✓ and pad pressure points ✓ eyes	**NB:** In lithotomy position, peroneal nerve compression at the lateral fibular head → foot drop
Complications	AH in spinal cord–injured patients	See discussion in Anesthetic Considerations for Transurethral Procedures.

POSTOPERATIVE

Complications	Hypothermia Fever, bacteremia	
Multimodal pain	Consider epidural	Emphasize multimodal

management	narcotics or PCA.	approach combining nonopioid (e.g., acetaminophen, celecoxib) and bolus opioid analgesics (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum promotes return of bowel function.
Tests	Hct Blood cultures if febrile	Others as indicated by intraop course

Suggested Reading

1. Vukovic N, Dinic L: Enhanced recovery after surgery protocols in major urologic surgery. Front Med (Lausanne) 2018; 5:93.

INGUINAL OPERATIONS

SURGICAL CONSIDERATIONS

Description

Inguinal operations are very common and are usually performed on an outpatient basis. Groin dissection, however, may necessitate inpatient care.

Inguinal herniorrhaphy: A 3″ inguinal incision is made, starting 1″ medial to the anterior-superior iliac spine and ending at the pubic tubercle. The external oblique aponeurosis is excised, opening the external inguinal ring. The spermatic cord and the hernial sac are freed off the inguinal canal; then, the hernial sac is dissected off the spermatic cord and followed proximally into the internal inguinal ring, where it is suture-ligated and excised. The floor of the inguinal canal is strengthened by approximating the conjoined tendon to the reflected part of the inguinal ligament. Modifications include laparoscopic repair and use of surgical mesh. Please see Section 7.9 for details.

Usual preop diagnosis

Inguinal hernia (See Figs. 9.17 and 9.18 for details of anatomic relationships.)

Orchiopexy is performed through the same incision as used in herniorrhaphy. After the inguinal canal is exposed, a search for the undescended testis begins. The testis and cord are dissected free from all surrounding tissue until adequate length is obtained to bring the testis down to the scrotum. Next, a pouch is created in the wall of the scrotum by incising the scrotal skin and dissecting it off the dartos fascia. The testis is brought down into the pouch and fixed to the dartos fascia with sutures, and the incisions are closed. Often a **herniorrhaphy** is performed at the same time.

Unusual preop diagnosis

Undescended testis

Radical orchiectomy is performed through a herniorrhaphy incision (described above). The spermatic cord is freed and cross-clamped at the internal inguinal ring, transected, and suture-ligated. The testis, with its tunica vaginalis, is then delivered through the incision by blunt and sharp dissection, and the inguinal incision is closed. Sometimes, a testicular prosthesis is inserted and fixed in the scrotum before the inguinal incision is closed.

Usual preop diagnosis

Testicular cancer

Ligation of spermatic vein is performed through a small, transverse incision 1–2″ above the internal inguinal ring. Muscles are split and the peritoneum is reflected medially to expose the spermatic vessels; the vein is identified and ligated. This operation can also be done through a scrotal incision.

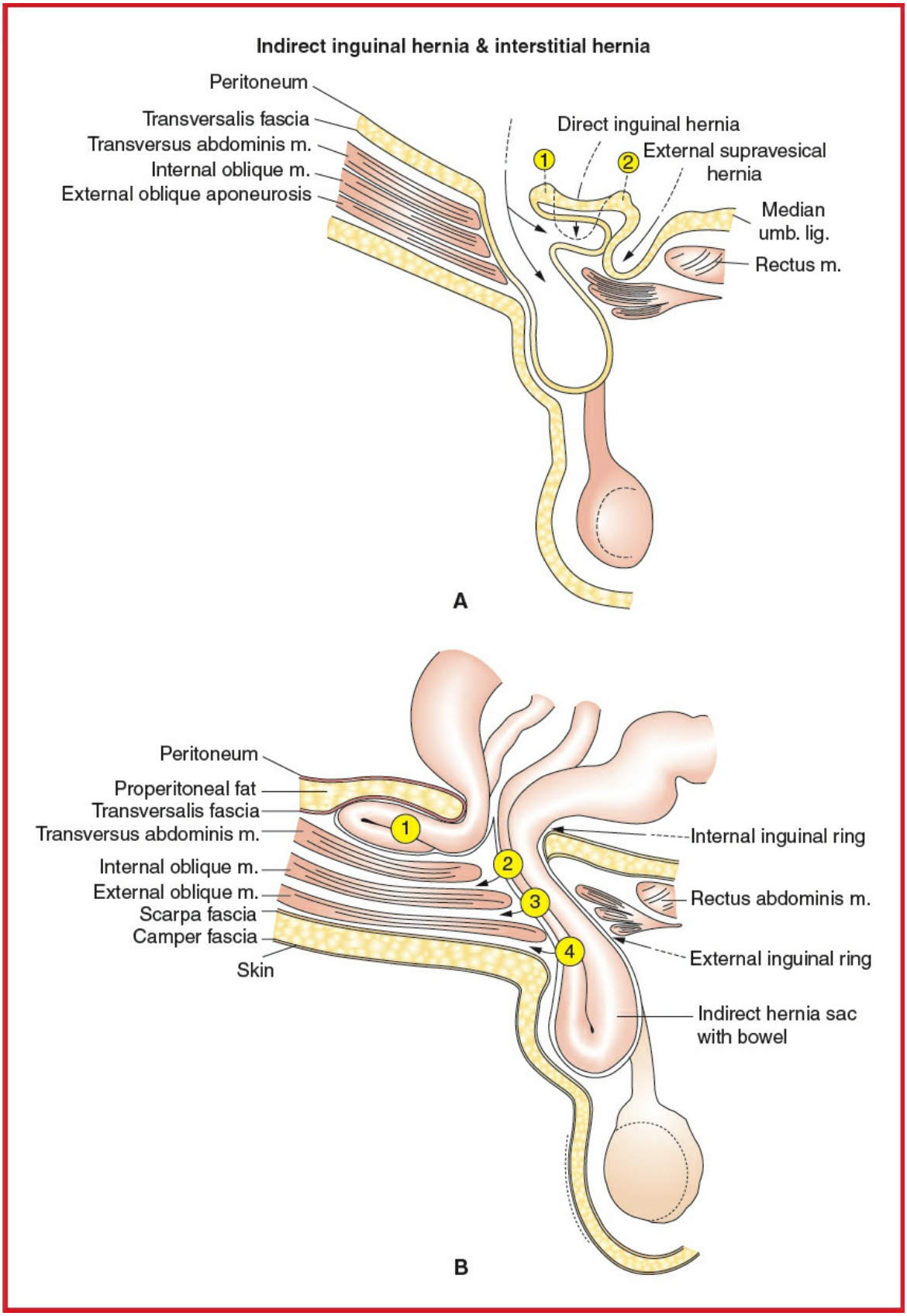

Figure 9.17 **A:** Relationships of four groin hernias in one patient. Indirect inguinal hernia with intraparietal diverticulum, direct hernia, and external supravesical hernia. 1, lateral umbilical ligament; 2, medial umbilical ligament. Arrows indicate different sites of origin of each hernia. (Reproduced with permission from Skandalakis JE, Gray SW, Burns WB, et al: Internal and external supravesical hernia.

Am Surg 1976; 42(2):142–6.) **B:** Diagram of intraparietal hernia. The sac, entering at the internal ring, may pass into any one or more spaces between layers of the abdominal wall. 1, properitoneal; 2 and 3, interstitial; 4, superficial. An indirect hernia also may be present. (Reprinted from Skandalakis JE, Gray SW, Akin JT Jr: The surgical anatomy of hernial rings. Surg Clin North Am 1974; 54(6):1227–46. Copyright © 1974 Elsevier. With permission.)

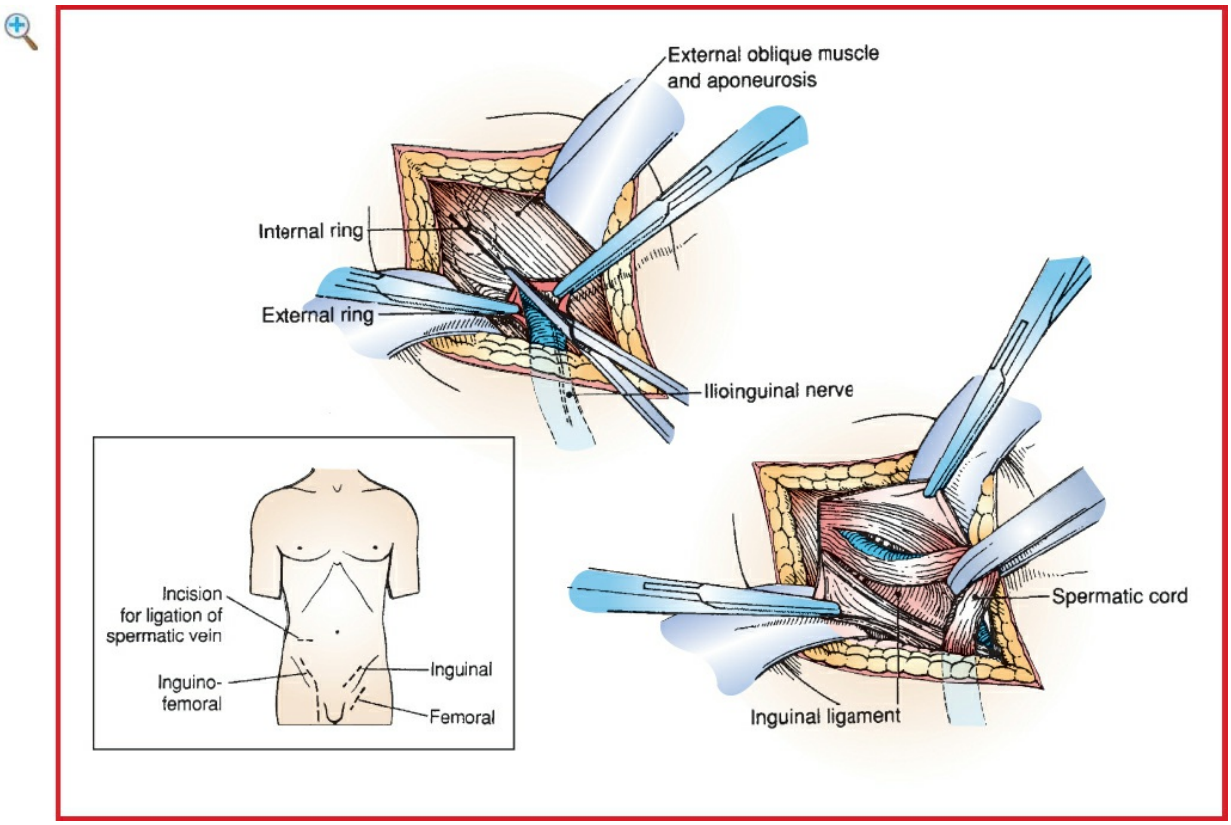

Figure 9.18 Incisions and exposure of the spermatic cord for inguinal hernia repair. (Reproduced with permission from Scott-Conner CEH, Dawson DLOperative Anatomy, 2nd edition. Lippincott Williams & Wilkins: 2003.)

Usual preop diagnosis

Varicocele causing infertility

Groin dissection, or **inguinofemoral lymphadenectomy** (lymph node dissection), is the most critical of the inguinal operations. It is performed either through an inguinal incision (Fig. 9.18, inset) curved distally over the femoral vessels or through two incisions, inguinal and upper thigh (Fig. 9.18, inset), over the femoral triangle. A complete inguinal and femoral lymphadenectomy is performed.

Usual preop diagnosis

Penile cancer

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting

NPO duration, alcohol and smoking cessation, discussion of carb loading, postop pain management options, and possibility of urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Herniorrhaphy, Orchiopexy, Orchiectomy	Ligation of Spermatic Vein	Groin Dissection
Position	Supine	⇐	⇐
Incision	Inguinal (Fig. 9.18, inset)	Transverse groin (Fig. 9.18, inset)	Inguinal and upper thigh (Fig. 9.18, inset)
Antibiotics	None	⇐	⇐
Surgical time	1 h	⇐	3 h
EBL	Minimal	⇐	200 mL
Postop care	PACU → home	⇐	PACU → ward; leg elevation
Mortality	<1%	⇐	⇐
Morbidity	Wound infection: 2%	⇐	⇐
Pain score	7	5	7

PATIENT POPULATION CHARACTERISTICS

Age range	All ages	Young adults	Middle age
Incidence	Hernia: 5% of population Undescended testis: 0.8% of male children Testis cancer: 6/100,000	1% of young men	Extremely rare, <1% of all males
Etiology	Unknown; congenital	Varicocele	Penile cancer

	(very rare)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Typically, patients presenting for inguinal operations are healthy, with most returning home on the day of surgery. The most common inguinal operation is herniorrhaphy. In these patients, consider causes of increased intra-abdominal pressure during H&P. A hernia may strangulate → acute abdomen.

Respiratory	Chronic cough is a common precipitating factor.
Gastrointestinal	Constipation may be a precipitating factor.
Laboratory	Tests as indicated from H&P
Premedication	Midazolam 1–2 mg iv in preop area
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Local anesthesia (with sedation), spinal, epidural, and GA are acceptable techniques with the choice dependent on patient age and coexisting disease, type and length of procedure, and patient preference. Local anesthesia is acceptable for simple herniorrhaphy, although discomfort may be elicited if the peritoneum is manipulated. If a spinal or epidural anesthetic is chosen, a T6 level should be sought. Most inguinal procedures are done on an outpatient basis, and the anesthetic should be planned appropriately.

Regional anesthesia

Spinal	0.75% bupivacaine 10–12 mg. For shorter procedures (<1 h), consider low-dose bupivacaine (0.75%, 7.5 mg), mepivacaine (1.5%, 45 mg), or procaine (10%, 100–150 mg). Lidocaine may be

	used, but the incidence of transient neurologic symptoms is significant.
Epidural	1.5–2.0% lidocaine with epinephrine 5 mcg/mL, 15–25 mL; supplement with 5–10 mL as needed. Supplemental iv sedation with local or regional technique in adults, e.g., midazolam (1–2 mg iv), fentanyl (25–50 mcg iv prn anxiety or discomfort), or propofol infusion (25–50 mcg/kg/min).

General anesthesia

Induction	Standard induction. ET intubation and/or controlled ventilation may not be needed for shorter cases; consider LMA.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance; consider propofol infusion (100–200 mcg/kg/min). Muscle relaxation is usually not required.	
Emergence	No specific considerations. PONV prophylaxis should include ondansetron.	
Blood and fluid requirements	Usually minimal blood loss IV: 18 ga × 1 BSS@ 1–2 mL/kg/h	Minimize BSS to avoid postop urinary retention after herniorrhaphy. See Zero Balance Fluid Management, Appendix K, p. K-2 and p. K-4.
Monitoring	Standard monitors	

POSTOPERATIVE

Complications	PONV Failure to void	May delay discharge from PACU → home
Multimodal pain management	Local anesthesia Ketorolac 30 mg iv in	Instillation (2 min) or infiltration of wound with

	adults ± Fentanyl 25–50 mcg iv	0.25% bupivacaine or ilioinguinal nerve block provides prolonged postop analgesia and decreases need for narcotics in outpatients. This can be used in both adult and pediatric patients.
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Castorina S, Luca T, Privitera G, et al: An evidence-based approach for laparoscopic inguinal hernia repair: lessons learned from over 1,000 repairs. Clin Anat 2012; 25(6):687–96.
2. Joshi GP, Rawal N, Kehlet H, et al: Evidence-based management of postoperative pain in adults undergoing open inguinal hernia surgery. Br J Surg 2012; 99(2):168–85.
3. Vukovic N, Dinic L: Enhanced recovery after surgery protocols in major urologic surgery. Front Med (Lausanne) 2018; 5:93.

PENILE OPERATIONS

SURGICAL CONSIDERATIONS

Penectomy is the total or partial resection of the penis for squamous cell carcinoma of the penile skin. If the tumor can be resected with a safe margin of at least 2 cm, partial penectomy is usually enough. A tourniquet is placed at the base of the penis, which is amputated at least 2 cm proximal to the tumor. The corpora cavernosa are sutured, and the tourniquet is released, followed by inspection for bleeding. The edges of the urethra are sutured to the ventral skin, and the lateral and dorsal skin edges are approximated over the ends of the corpora cavernosa. Often, an **inguinal lymph node biopsy** follows the penectomy.

Usual preop diagnosis

Squamous cell carcinoma of the penile skin

Insertion of penile prosthesis is performed for impotence. The prosthesis is inserted into the corpora cavernosa (Fig. 9.19) through a penile or suprapubic incision. Penile prostheses are either malleable or inflatable. The latter have a reservoir in the retropubic space and a pump in the scrotum.

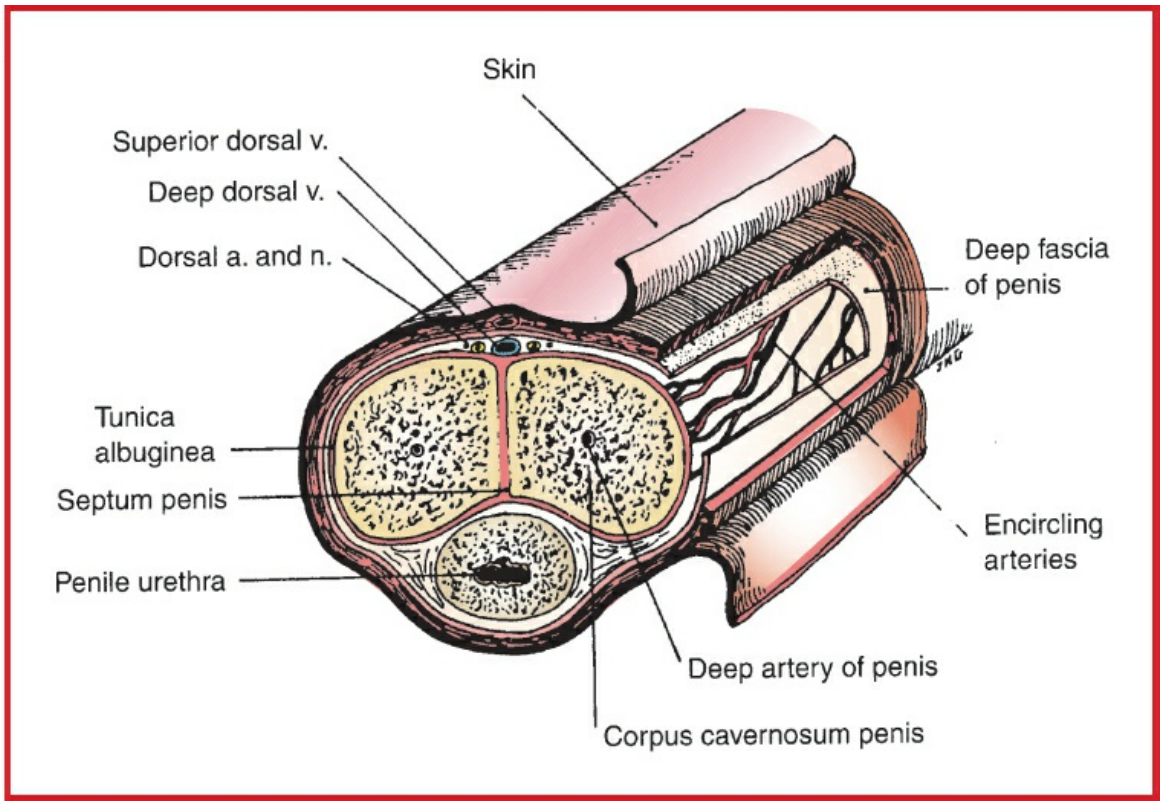

Figure 9.19 Anatomy of the penis. (Reproduced with permission from Hardy JD:Hardy's Textbook of Surgery, 2nd edition. JB Lippincott, Philadelphia: 1988.)

Usual preop diagnosis

Impotence

Hypospadias repair is performed primarily on children <5 yr.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, discussion of carb loading, postop pain management options, and possibility of urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

Insertion of Penile

	Penectomy	Prosthesis
Position	Supine	⇐
Incision	Circumferential penile	Bilateral incisions at the base of the penis
Special instrumentation	None	⇐
Unique considerations	None	⇐
Antibiotics	Cefazolin 2 g iv	Gentamicin 80 mg iv, slowly; ampicillin 2 g iv
Surgical time	2 h	⇐
Closing considerations	None	⇐
EBL	200 mL	⇐
Postop care	PACU → home	⇐
Mortality	<1%	⇐
Morbidity	Penile hematoma: 5%	Malfunction: 10% Edema: 5% Infection: 2% Extrusion of the prosthesis: 1%
Pain score	5	5

PATIENT POPULATION CHARACTERISTICS		
Age range	Adults	⇐
Incidence	<1% of all males	1–2% of all males
Etiology	Poor hygiene	Organic impotence

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients presenting for insertion of a penile prosthesis are frequently elderly and often have preexisting medical problems, including CAD, CHF, PVD, cerebrovascula disease, COPD, and renal impairment. Preop evaluation should be directed toward the detection and treatment of these conditions prior to anesthesia.

Neurologic	Patients presenting for insertion of a penile prosthesis often have Hx of diabetes or spinal cord injury. Note the presence of neuropathy or Hx of autonomic hyperreflexia (AH) (see Anesthetic Considerations for Transurethral Procedures [except TURP]). Sx suggestive of AH include HA, flushing, nasal stuffiness, and HTN associated with voiding or noxious stimuli below the level of transection. It is important to document neurologic deficits prior to regional anesthesia.
Hematologic	Coagulation defects may be present in patients with priapism. There is a high incidence of priapism in patients with sickle cell anemia. **Test:** Hct, if indicated from H&P
Laboratory	Other tests as indicated from H&P
Premedication	Midazolam 1–2 mg iv in preop area
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po. Consider aprepitant 40 mg po with sip of water for GA patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Spinal, caudal, or lumbar epidural and GA are acceptable, with choice dependent on the length of procedure, patient age, coexisting disease, and patient preference. Sacral anesthesia (saddle block) is sufficient; lumbar epidural anesthesia may be less reliable than spinal or caudal at blocking sacral fibers.

Regional anesthesia

Spinal	5% lidocaine 50 mg (controversial); 0.75% bupivacaine 10 mg in 7.5% dextrose; hyperbaric tetracaine 10 mg with epinephrine for longer procedures
Caudal	0.5% bupivacaine with epinephrine 5 mcg/mL 15–20 mL
Epidural	1.5% lidocaine with epinephrine 5 mcg/mL 15–25 mL; supplement with 5–10 mL as needed. Supplemental iv sedation

General anesthesia

Induction	Standard induction. ET intubation may not be necessary for shorter procedures; consider LMA.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance. Deeper levels of anesthesia usually are required to obtund autonomic reflexes (e.g., HTN, laryngospasm), resulting from intense surgical stimulation that may occur during these procedures.	
Emergence	No specific considerations. Consider iv acetaminophen if po dose is given >6 h ago. PONV prophylaxis should include ondansetron.	
Blood and fluid requirements	Minimal blood loss IV: 18 ga × 1 BSS @ 1–3 mL/kg/h	See Zero Balance Fluid Management, Appendix K, p. K-2 and p. K-4.
Monitoring	Standard monitors	
Complications	AH	See Anesthetic Considerations for Transurethral Procedures.

POSTOPERATIVE

Complications	Urinary retention	
Multimodal pain management	Hydromorphone 0.2–1 mg iv or fentanyl 25–50 mcg iv prn; ketorolac 30 mg im or iv	
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Reading

1. Vukovic N, Dinic L: Enhanced recovery after surgery protocols in major urologic surgery. Front Med (Lausanne) 2018; 5:93.

SCROTAL OPERATIONS

SURGICAL CONSIDERATIONS

Description

Scrotal operations are minor, common urologic procedures, performed on an outpatient basis.

Simple orchiectomy is performed as an alternative to medical castration (which uses either estrogens or LH-RH agonists on men with metastatic prostate cancer for androgen ablation). Orchiectomy is always bilateral. A small scrotal incision is made, and the testis delivered. The spermatic cord is cross-clamped, transected, and suture-ligated.

Usual preop diagnosis

Metastatic prostate cancer

Vasovasostomy is the reestablishment of the continuity of the vas deferens and restoration of fertility following a previously performed vasectomy. Through a small scrotal incision, the testis and spermatic cord are delivered. The site of previous vasectomy is identified and excised and the two ends of the vas deferens are anastomosed. It is bilateral and requires the use of either the operating microscope or magnifying loupes.

Usual preop diagnosis

Infertility 2° vasectomy

Hydrocelectomy: The testis, with the surrounding hydrocele (Fig. 9.20), is delivered through a scrotal incision. The wall of the hydrocele is excised and the edges are sutured around the epididymis to prevent recurrence.

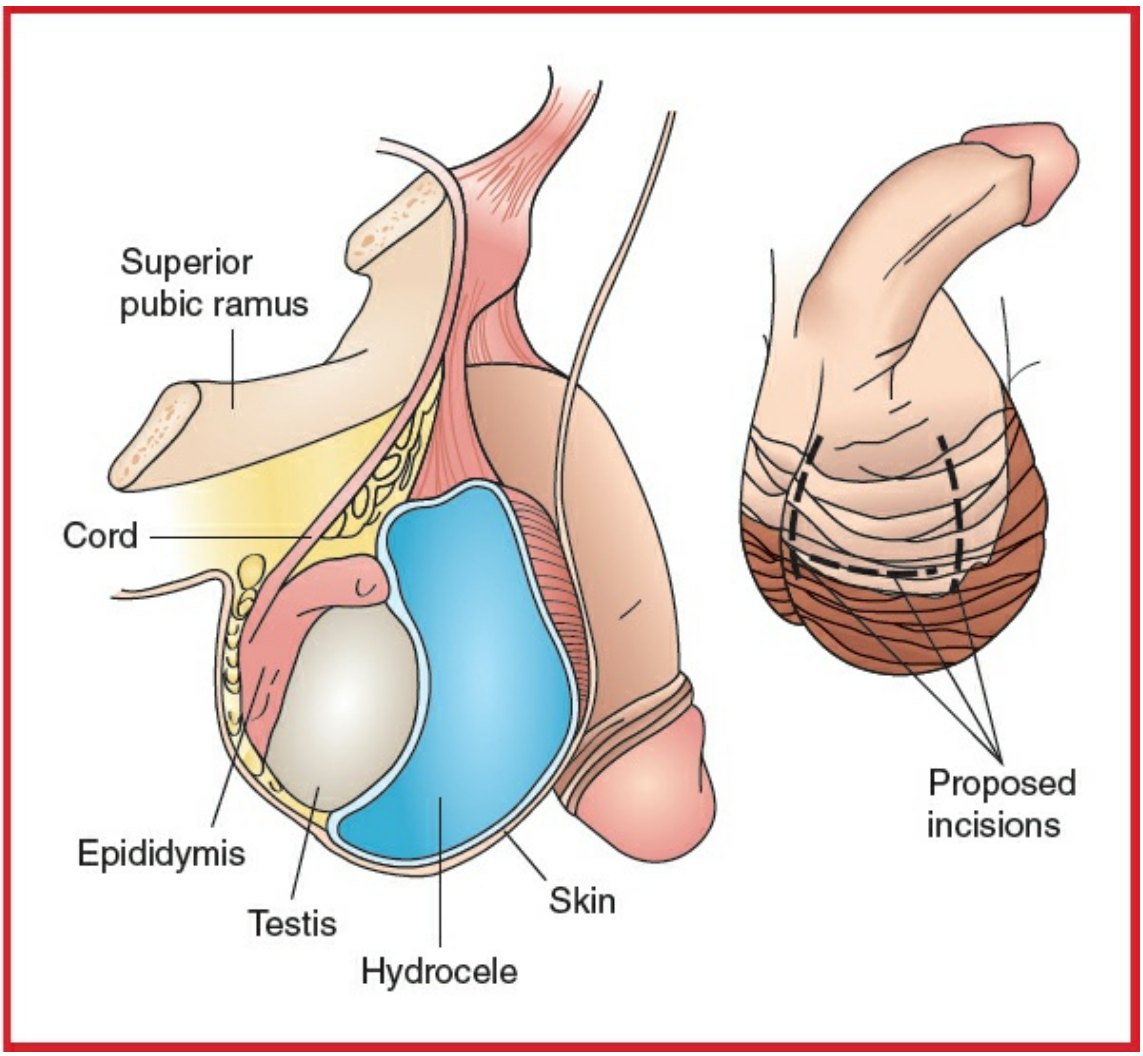

Figure 9.20 Scrotal hydrocele: scrotal incision.

Variant procedure or approach

Aspiration is used as a temporizing approach because recurrence is almost 100%.

Usual preop diagnosis

Hydrocele

Spermatocelectomy: A spermatocele is a cyst of the epididymis, usually excised with the part of the epididymis from which it arises.

Variant procedure

Aspiration as a temporizing maneuver until the operation can be performed.

Usual preop diagnosis

Spermatocele or epididymal cyst

Insertion of testicular prosthesis: A small incision is made in the scrotal skin, and a pouch is created by blunt dissection in the dartos fascia. The prosthesis is placed in the pouch and fixed to the dartos fascia to prevent prosthesis migration.

Usual preop diagnosis

Absent testis, either congenital or following orchiectomy

Reduction of testicular torsion is an emergency operation that must be performed within 6 h of occurrence to prevent irreversible ischemic damage to the testis. Through a small scrotal incision, the testis is reduced and fixed to the dartos fascia to prevent retortion.

Usual preop diagnosis

Acute testicular torsion

ERAS: For elective procedures, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, postop pain management options, and possibility of urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Scrotal (Fig. 9.20, inset)
Special instrumentation	Operating microscope: magnifying loupe for vasovasostomy
Antibiotics	Cefazolin 2 g iv
Surgical time	1 h
EBL	Negligible
Postop care	PACU → home
Mortality	<1%
Morbidity	Scrotal hematoma: 2% Wound infection: 2%

Pain score	4

PATIENT POPULATION CHARACTERISTICS

Age range	All ages
Incidence	Common
Etiology	See preop diagnosis for each procedure above.

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients presenting for scrotal operations typically fall into two groups: young, otherwise healthy patients, and an older population who may present with metastatic prostate cancer accompanied by other medical conditions. The latter group is the focus of this preop evaluation.

Respiratory	Pulmonary disease may be present in elderly patients requiring orchiectomy. **Tests:** As indicated from H&P
Cardiovascular	Cardiac disease may be present in elderly patients requiring orchiectomy. **Tests:** Consider ECG; others, if indicated from H&P.
Neurologic	Document neurologic exam before regional anesthesia in patients with metastatic prostate carcinoma (spinal cord or nerve root compression may be present preop).
Musculoskeletal	✓ for the presence of spinal metastases if orchiectomy is done for palliation of prostate carcinoma. Extensive lumbar metastases may preclude the use of spinal or epidural anesthesia (relative contraindication). **Tests:** L-spine films if Hx is suggestive of spinal metastases.
Laboratory	Other tests as indicated from H&P
Premedication	Midazolam 1–2 mg iv in preop area

ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po. Consider aprepitant 40 mg po with sip of water for GA patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Local anesthesia (with sedation) is acceptable for simpler operations (vasectomy, orchiectomy). Procedures that are longer or more complex may require spinal, epidural, or GA. A sensory level of T10 is required to block pain 2° testicular manipulation. Many of these procedures are done on an outpatient basis, and the anesthetic should be appropriately planned to facilitate early discharge.

Regional anesthesia

Spinal	0.75% bupivacaine 10–12 mg. For shorter procedures (<1 h), consider low-dose bupivacaine (0.75%, 7.5 mg) or mepivacaine (1.5%, 45 mg). Lidocaine may be used, but the incidence of transient neurologic symptoms is significant.
Epidural	1.5–2% lidocaine with epinephrine 5 mcg/mL, 15–20 mL; supplement with 5–10 mL as needed. Supplemental iv sedation with local or regional techniques (e.g., midazolam 1–2 mg, fentanyl 25–50 mcg iv prn anxiety or discomfort).

General anesthesia

Induction	Standard induction. Consider the use of LMA.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance. Muscle relaxation is usually not imperative. Deeper levels of anesthesia are usually required to obtund autonomic reflexes (e.g., HTN, laryngospasm), resulting from intense surgical

	stimulation that may occur during these procedures.	
Emergence	No specific considerations. PONV prophylaxis should include ondansetron.	
Blood and fluid requirements	Minimal blood loss IV: 18 ga × 1 BSS @ 1–3 mL/kg/h	See Zero Balance Fluid Management, Appendix K, p. K-2 and p. K-4.
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes	**NB:** Peroneal nerve compression at the lateral fibular head → foot drop

POSTOPERATIVE

Complications	Peroneal nerve injury 2° lithotomy position	Peroneal nerve injury manifested by foot drop and loss of sensation on the dorsum of the foot. Seek neurology consultation.
Multimodal pain management	Acetaminophen 1 g ketorolac 30 mg im or iv in adults ± hydromorphone 0.2–1 mg iv or fentanyl 25–50 mcg iv prn	Following orchiopexy, high incidence of postop pain, which may be reduced by ilioinguinal/iliohypogastric nerve blocks
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum promotes return of bowel function.

Suggested Reading

1. Vukovic N, Dinic L: Enhanced recovery after surgery protocols in major urologic surgery. Front Med (Lausanne) 2018; 5:93.

PERINEAL OPERATIONS

SURGICAL CONSIDERATIONS

Urethroplasty: Urethral strictures that do not respond to transurethral dilation and incision are corrected with urethroplasty. A transverse or longitudinal perineal incision is made and carried down to the urethra, which is dissected free from surrounding tissues. The strictured area is excised and end-to-end anastomosis is performed over a catheter. Repair of a long urethral stricture may require placement of a patch from the scrotum, foreskin, or buccal mucosa.

Variant procedure

Transurethral incision and dilation, which is associated with a 30–50% recurrence rate.

Usual preop diagnosis

Urethral stricture, usually posttraumatic

Urethrectomy: Partial or total urethrectomy is done through a longitudinal perineal incision. The urethra is dissected free of surrounding tissues and followed proximally and distally from the membranous urethra to the external urethral meatus. In total urethrectomy, a tubularized skin graft is interposed between the membranous urethra and perineal skin.

Usual preop diagnosis

Urethral carcinoma

Insertion of artificial urinary sphincter, performed for incontinence, consists of a perineal incision, through which a cuff is inserted around the bulbar urethra. A suprapubic incision is made to place the reservoir and pump, which inflates and deflates the cuff.

Usual preop diagnosis

Urinary incontinence

Transperineal prostate seed implantation (brachytherapy)

High doses of radiation can be delivered to the prostate by implanting radioactive seeds directly into the prostate gland. Using a transrectal ultrasound probe, radioactive seeds (iodine 125 or palladium 103) are implanted into the prostate (Fig. 9.21). The patient is placed in lithotomy position, and a rectal ultrasound probe, with a perineal grid

attached, is introduced to image the prostate. Radioactive seeds are then placed transperineally using preloaded needles. Preop dosing calculations determine the number and location of the seeds. This procedure is done by a combined team of radiation oncologists and urologists. No special radiation precautions are necessary for the OR team.

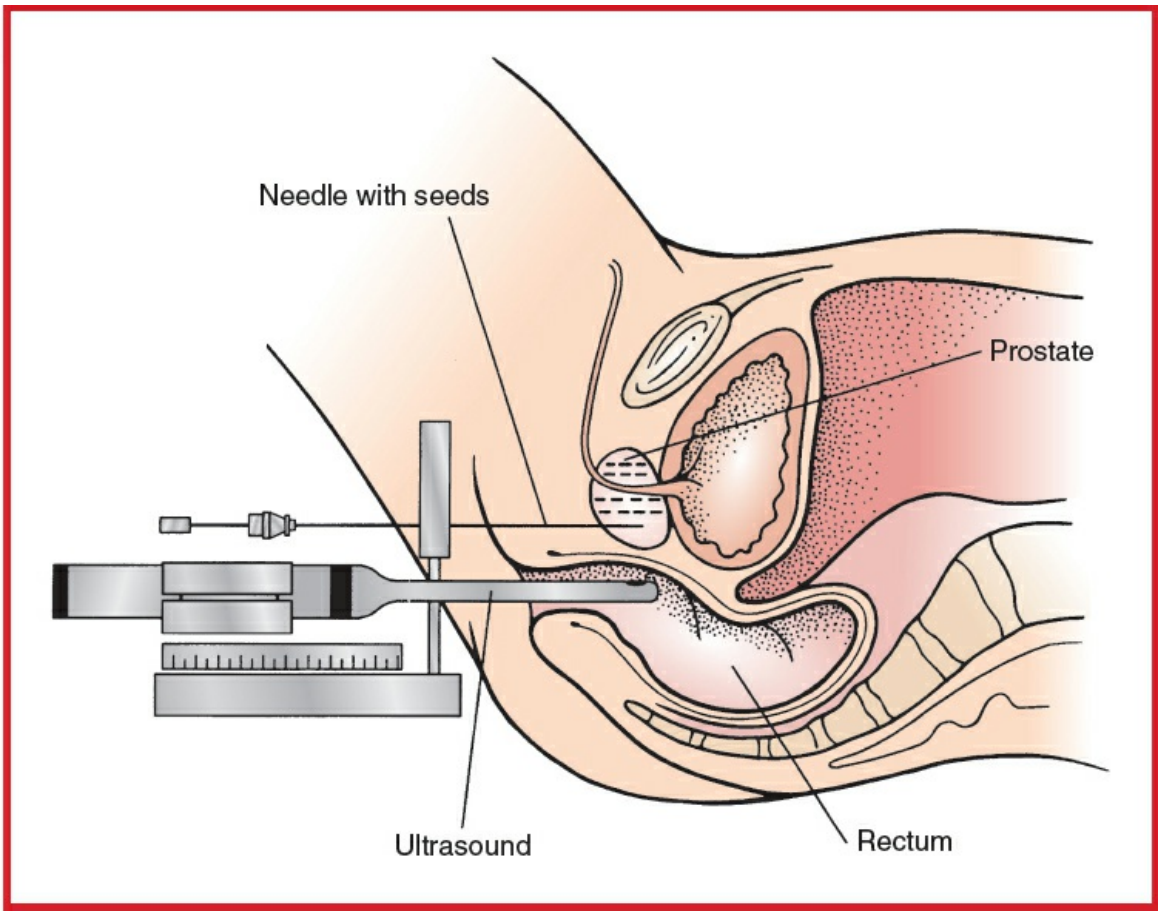

Figure 9.21 Transperineal brachytherapy of the prostate gland.

Usual preop diagnosis

Prostate cancer

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, DVT prophylaxis, postop pain management options, and possibility of urinary drain postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Urethroplasty	Urethrectomy	Insertion of Sphincter	Brachytherapy
Position	Lithotomy	⇐	⇐	⇐
Incision	Perineal (Fig. 9.7)	⇐	⇐ and scrotal (Fig. 9.20, inset)	None
Antibiotics	Gentamicin 80 mg im/iv	⇐	⇐	⇐
Surgical time	3 h	2 h	3 h	2 h
EBL	100 mL	300 mL	Minimal	⇐
Postop care	PACU → home	⇐	⇐	PACU, outpatient
Mortality	<1%	⇐	⇐	⇐
Morbidity	Wound infection: 2%	⇐	⇐ Erosion of the urethra: 10% Extrusion of sphincter: 2%	Urinary retention
Pain score	3	3	4	3

PATIENT POPULATION CHARACTERISTICS

Age range	All ages	Adults	Older adults	50–80 yr
Incidence	<1% of urologic procedures	⇐	2% of radical prostatectomy	10% of prostate cancer
Etiology	Traumatic strictures	Unknown	Radical prostatectomy (2%); incontinence	Aging

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

This is a generally healthy patient population; preop considerations should be based on H&P.

Laboratory	Tests as indicated from H&P
Premedication	Sedation prn anxiety in adults (e.g., lorazepam 1–2 mg po 1–2 h prior to surgery; midazolam 1–2 mg iv in preop area)
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg. Consider aprepitant 40 mg po with sip of water for GA patients

	with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Spinal or GA is acceptable, with choice dependent on the length of procedure, position, patient age, coexisting disease, and patient preference. A sacral sensory level (saddle block) is usually sufficient. Lumbar epidural anesthesia may be less reliable at providing sacral anesthesia and offers no advantages over the above techniques for shorter procedures, although caudal anesthesia may be an acceptable alternative.

Regional anesthesia

Spinal	0.75% bupivacaine 10 mg in 7.5% dextrose: hyperbaric tetracaine 10 mg (with epinephrine [200 mcg] for longer procedures)
Caudal	0.5% bupivacaine with epinephrine 5 mcg/mL 15–20 mL. Supplemental iv sedation

General anesthesia

Induction	Standard induction. Consider the use of LMA.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance; muscle relaxation is usually not required. Deeper levels of anesthesia are usually required to obtund autonomic reflexes (e.g., HTN, laryngospasm), resulting from intense surgical stimulation that may occur during these procedures.	
Emergence	No specific considerations. PONV prophylaxis should include ondansetron.	
Blood and fluid requirements	Minimal blood loss IV: 20–18 ga × 1 BSS @ 1–3 mL/kg/h	See Zero Balance Fluid Management, Appendix K, p. K-2 and p. K-4.
Monitoring	Standard monitors	

Positioning	✓ and pad pressure points ✓ eyes	Patients with arthritis or other musculoskeletal disorders may not tolerate the exaggerated lithotomy position, thus precluding the use of a regional technique. **NB:** In lithotomy position, peroneal nerve compression at the lateral fibular head → foot drop.
Complications	Anticipate ↓ BP on return from lithotomy position.	Rx: volume (200–500 mL NS/LR) or ephedrine (5 mg iv) may be necessary.

POSTOPERATIVE

Complications	Peroneal nerve injury 2° lithotomy position	Peroneal nerve injury manifested as foot drop with loss of sensation over the dorsum of the foot. Seek neurology consultation.
Multimodal pain management	Emphasize multimodal approach combining nonopioid and bolus opioid analgesics (see Appendix K, p. K-6).	Acetaminophen 1 g po or iv ± Hydromorphone 0.2–1 mg iv prn ± Ketorolac or celecoxib
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Reading

1. Vukovic N, Dinic L: Enhanced recovery after surgery protocols in major urologic surgery. Front Med (Lausanne) 2018; 5:93.

VAGINAL OPERATIONS

SURGICAL CONSIDERATIONS

Description

Vaginal operations are performed by both urologists and gynecologists. They include the following:

Repair of vesicovaginal fistulas: The vaginal approach is usually recommended for small and distally located vesicovaginal fistulas; otherwise, a transabdominal repair is performed (see Open Bladder Operations, p. 1002). An incision is made in the anterior vaginal wall around the fistula, which is excised. Bladder and vaginal walls are separated and closed with interposition of tissues or flaps to separate the incisions and prevent recurrence. A Foley catheter is left indwelling.

Variant approach

Transabdominal repair of vesicovaginal fistula (see Open Bladder Operations, p. 1002).

Usual preop diagnosis

Vesicovaginal fistula

Operations to correct stress urinary incontinence: Many procedures have been designed to correct female urinary incontinence. They fall into two basic groups: (a) operations to correct hypermobility of the urethra and (b) operations to correct the nonfunctioning urethra. The operation most commonly used by urologists to correct hypermobility is the **Stamey procedure** (Fig. 9.22) or **vesical neck suspension**. The operation is performed through two small suprapubic incisions, one on each side of the midline, and an anterior vaginal incision. A nylon suture is placed in a loop from either side of the bladder neck and not around it. Cystoscopy is used to ensure proper placement and to prevent the suture from transversing the bladder. When the sutures are pulled up and tied over the anterior rectus sheath, they pull the bladder neck up to its original position behind the symphysis pubis and restore the acute posterior ureterovesical angle. A variant of this procedure is the **Raz bladder neck suspension**, where bolsters are not used.

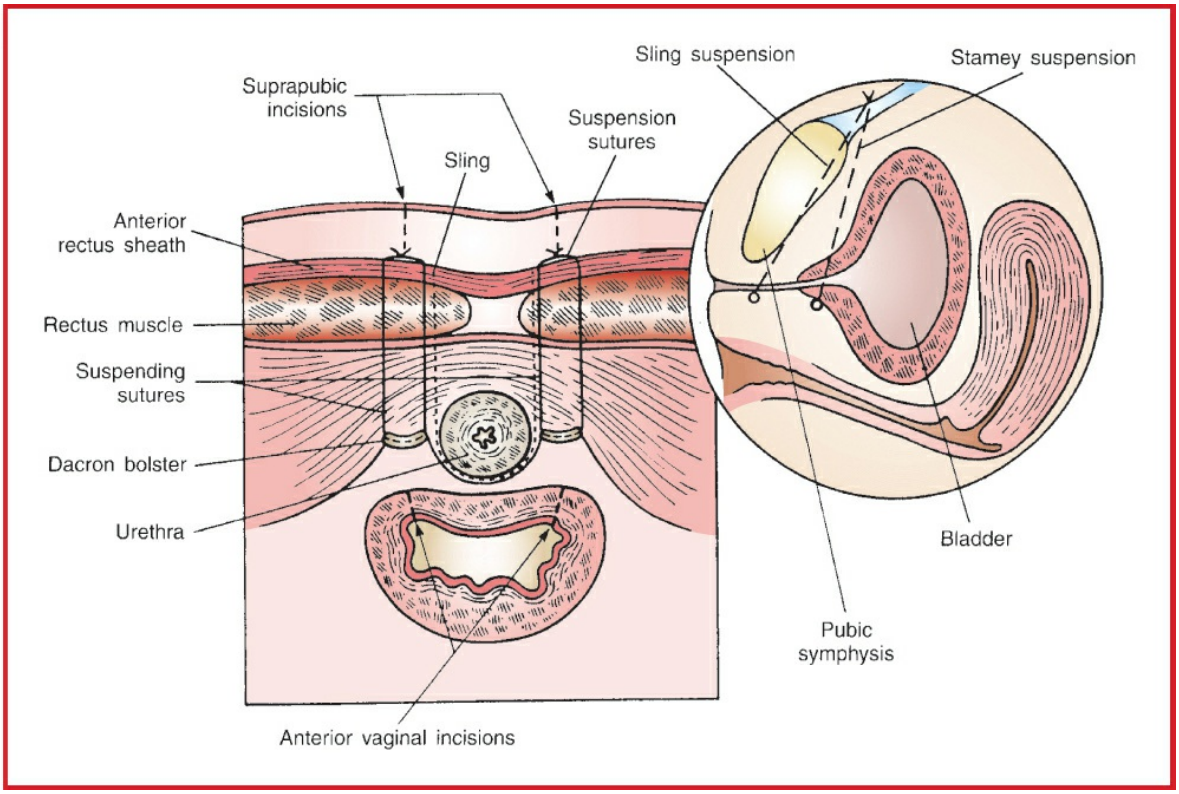

Figure 9.22 Stamey and sling procedures, sectional view; **inset** shows lateral view.

Operations to correct a nonfunctioning urethra include **submucosal collagen injection** at the bladder neck or construction of a **sling**. The rectus fascia, the fascia lata of the thigh, or the vaginal wall can be used to construct a sling around the urethra. All these techniques involve a combined suprapubic and vaginal approach.

Sling operations are the most common procedures done for correction of stress incontinence. These procedures can be done vaginally or open via a suprapubic incision. A variety of materials, both natural and synthetic, have been used. Many modifications have been made with reference to the placement of anchorage of the sling; therefore, there are a large number of procedures with different names utilizing the same principle. Most slings are placed midurethra.

Variant approach

T h e **Marshall-Marchetti-Krantz operation**, which is performed retropubically, sutures the anterior portion of the urethra, bladder neck, and bladder to the pubic bone. Other modifications include laparoscopic suspensions and ligament surgery. Some patients have cystoceles and rectoceles, which can be repaired at the same time as the vaginal sling surgery.

Usual preop diagnosis

Stress urinary incontinence

Excision of urethral diverticulum: Urethral diverticula are extremely rare and need excision only if they are the cause of recurrent UTIs. An incision is made in the anterior vaginal wall over the urethral diverticulum, which is dissected all around until it is attached only by its neck. It is excised and the neck closed. A Foley catheter is left indwelling, and the vaginal incision is closed.

Usual preop diagnosis

Recurrent UTI 2° infected urethral diverticulum

Repair of cystocele and rectocele: Some patients with urinary incontinence also present with prolapse of the bladder or rectum into the vagina. These can be repaired at the same time as incontinence surgery. A vaginal incision (anterior for cystocele, posterior for rectocele) is made and dissected laterally to free the bladder or rectum from the vagina. The defect is repaired and the redundant vaginal wall excised.

Usual preop diagnosis

Incontinence with pelvic prolapse, cystocele, or rectocele

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, DVT prophylaxis, postop pain management options, and possibility of urinary drain postop. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Repair of Vesicovaginal Fistula	Correction of Stress Incontinence	Excision of Urethral Diverticulum
Position	Lithotomy	⇐	⇐
Incision	Anterior vaginal	Anterior vaginal; suprapubic	Anterior vaginal
Special instrumentation	None	Cystoscope	None
Antibiotics	Gentamicin 80 mg iv, slowly	⇐	⇐
Surgical time	2 h	1 h	⇐

EBL	200 mL	500 mL	200 mL
Postop care	PACU → room	⇐	⇐
Mortality	<1%	⇐	⇐
Morbidity	Infection: 2% Recurrence: 2%	⇐ 10% Urinary retention: 20%	⇐ ⇐
Pain score	3	5	3

PATIENT POPULATION CHARACTERISTICS			
Age range	20–80 yr	⇐	⇐
Incidence	<1% of urologic procedures	5% of urologic procedures	<1% of urologic procedures
Etiology	Traumatic delivery; iatrogenic following hysterectomy (<1%)	Childbirth	Congenital (extremely rare)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

This is a generally healthy patient population. Preop considerations should be based on H&P.

Laboratory	Tests as indicated from H&P
Premedication	Standard premedication
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po. Consider aprepitant 40 mg po with sip of water for GA patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Spinal, continuous lumbar epidural, or GA are acceptable, with choice dependent on age, coexisting disease, and patient preference. A block level of T9-T10 is recommended for operations involving the bladder, whereas somewhat higher levels of anesthesia may be necessary if a suprapubic incision is made. Epidural anesthesia may be less reliable than spinal in providing sacral anesthesia.

Regional anesthesia

Spinal	0.75% bupivacaine 10–12 mg (1.6 mL)
Epidural	2% lidocaine with epinephrine 5 mcg/mL, 15–20 mL. Supplemental iv sedation

General anesthesia

Induction	Standard induction	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance. Muscle relaxation is not imperative.	
Emergence	No specific considerations. PONV prophylaxis should include ondansetron.	
Blood and fluid requirements	Minimal blood loss IV: 18 ga × 1 BSS @ 1–3 mL/kg/h	See Zero Balance Fluid Management, Appendix K, p. K-2 and p. K-4.
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes	**NB:** In lithotomy position, peroneal nerve compression at the lateral fibular head → foot drop
Complications	Anticipate ↓ BP when returning from lithotomy position. Bladder perforation	Rx: volume (200–500 mL NS/LR) or ephedrine (5 mg iv) may be necessary. Bladder perforation may present as shoulder pain

		in the awake patient but may go unnoticed in the patient under GA. Sx include unexplained HTN, tachycardia, and ↓ BP (rare).

POSTOPERATIVE

Complications	Peroneal nerve injury 2° lithotomy position Bladder perforation (see above)	Peroneal nerve injury is manifested as foot drop with loss of sensation on the dorsum of the foot. Seek neurology consultation.
Multimodal pain management	Regional analgesia when possible Acetaminophen 1 g po or iv	Consider ketorolac 30 mg iv in adults; supplement with hydromorphone 0.2–1 mg iv prn.
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis.

Suggested Readings

1. Ashok K, Petri E: Failures and complications in pelvic floor surgery. World J Urol 2012; 30(4):487–94.
2. Vukovic N, Dinic L: Enhanced recovery after surgery protocols in major urologic surgery. Front Med (Lausanne) 2018; 5:93.

SPECIAL CONSIDERATIONS FOR ROBOTIC-ASSISTED LAPAROSCOPIC PROCEDURES

ANESTHETIC CONSIDERATIONS

The anesthetic considerations for the majority of laparoscopic and robotic procedures on the urologic system are similar and are thus summarized in this section rather than repeated for each individual procedure.

INTRAOPERATIVE

Anesthetic technique

In general, because laparoscopic surgery involves insufflation of the abdomen with CO_2 and may also require steep Trendelenburg position, GA with tracheal intubation and controlled ventilation is the technique of choice.

General anesthesia

Induction	Standard induction	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance. Muscle relaxation is advised.	
Emergence	Ensure airway patency (subcutaneous emphysema → airway compromise). Consider iv acetaminophen if po dose given >6 h ago. PONV prophylaxis should include ondansetron.	
Blood and fluid requirements	IV: 16–18 ga × 1 BSS @ 1–3 mL/kg/h Warm fluid and humidify gases	Blood loss may be difficult to estimate. In general, less than for open procedures. See Zero Balance Fluid Management, Appendix K, p. K-2 and p. K-4.
Monitoring	Standard monitors ± Arterial line ± CVP	Consider invasive monitors for nephrectomy and prostatectomy.
Positioning	✓ and pad pressure points ✓eyes	Prolonged duration of robotic procedures in lithotomy position of special concern (peroneal nerve injury)

Complications	CO_2 insufflation	→ ↑ intra-abdominal pressure → ↓ venous return, ↓ BP; also ↑ airway pressure, ↑ PCO_2/$ETCO_2$ **NB:** Right mainstem intubation can occur because of shift of diaphragm cephalad.
	Retroperitoneal gas insufflation VAE	→ subcutaneous emphysema (can track to the head and neck → airway compromise), pneumothorax Gas embolism via prostatic venous sinuses reported

POSTOPERATIVE

Complications	Peroneal nerve injury (foot drop) Upper airway obstruction	Other pressure point injuries may occur 2° subcutaneous emphysema tracking up to the head and neck.
Multimodal pain management	Consider acetaminophen ± Ketorolac 30 mg iv/im in adults	Pain less than for open procedures. Supplement with hydromorphone 0.2–1 mg iv prn followed by PCA (see Appendix K, p. K-6).
ERAS		Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing

		gum promotes return of bowel function.
Test	Hct	If excessive blood loss

Suggested Readings

1. Conacher ID, Soomro NA, Rix D: Anaesthesia for laparoscopic urological surgery Br J Anaesth 2004; 93(6):859–64.
2. Nelson JB: Debate: open radical prostatectomy vs. laparoscopic vs. robotic.Urol Oncol 2007; 25(6):490–3.
3. Zorn KC, Gofrit ON, Orvieto MA, et al: Da Vinci robot error and failure rates: single institution experience on a single three-arm robot unit of more than 700 consecutive robot-assisted laparoscopic radical prostatectomies. J Endourol 2007; 21(11):1341–4.

Suggested Viewing

Links are available online to the following videos:

TURP: https://www.youtube.com/watch?v=WNCsunVC4Rs

KTP Laser TURP (green light laser prostatectomy): https://www.youtube.com/watch?v=TKtMMao5vpY

Weill Cornell Robotic Prostatectomy: 3-D Animation (2/6): https://www.youtube.com/watch?v=5Exd86dbT68

Nephrectomy (laparoscopic, hand-assisted): https://www.youtube.com/watch?v=JJK5n6RGC_s

Robotic / DaVinci™ Partial Nephrectomy; Kurt Strom MD, Joshua Holyoak MI https://www.youtube.com/watch?v=w5zfOsyz1wQ

Minimally Invasive, Open Robotic Cystectomy for Bladder Cancer Removal https://www.youtube.com/watch?v=fJ7JjDqrr-g

SECTION 10.0

ORTHOPEDIC SURGERY

CHAPTER 10.1

Hand Surgery

SURGEONS

Paige M. Fox, MD, PhD
Catherine Curtin, MD
Vincent R. Hentz, MD

ANESTHESIOLOGIST

Lindsey Vokach-Brodsky, MB, ChB, FFARCSI

DARRACH PROCEDURE

SURGICAL CONSIDERATIONS

Description

The **Darrach procedure** (Fig. 10.1-1) is a resection of the distal ulna. The distal 2 cm of the ulna is resected subperiosteally, and local soft tissues are used to stabilize and cover the remaining ulna. It is commonly performed in patients who have had a disruption of the distal radioulnar joint with subluxation of the ulna. It also is indicated for patients who have had a malunion of a distal radius fracture such that the radius has shortened relative to the ulna or is abnormally angulated, resulting in dorsal subluxation of the ulna and impingement of the ulnar head upon the carpus. This malposition causes painful motion of the wrist and forearm and posttraumatic degenerative arthritis of the ulnar head, carpus, and sigmoid notch of the distal radius. Disorders of the distal radioulnar joint and degeneration of the ulnar head, which may lead to attrition rupture of the overlying extensor tendons, are common in rheumatoid arthritis. This dorsal prominence of the ulnar head is treated by **Darrach resection,** combined with a soft tissue procedure to stabilize the remaining ulna. Osteoarthritic degeneration of the distal radioulnar joint, either 2° trauma (see above) or due to idiopathic osteoarthritis, responds well to this procedure.

Variant procedure or approaches

The **Sauvé-Kapandji procedure** retains the articular portion of the distal ulna and fuses it to the sigmoid notch. The area of distal ulna that is resected is proximal to the joint; instability of the proximal stump may become problematic. Hemiresection with tendon interposition and distal ulnar arthroplasty are less common techniques for managing distal radioulnar arthritis.

Usual preop diagnosis

Arthritis or derangement of the distal radioulnar joint; rheumatoid arthritis; ulnar impingement syndrome; malunion of Colles fracture or other fracture of the distal radius

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K: Enhanced Recovery After Surgery, p. K-1.

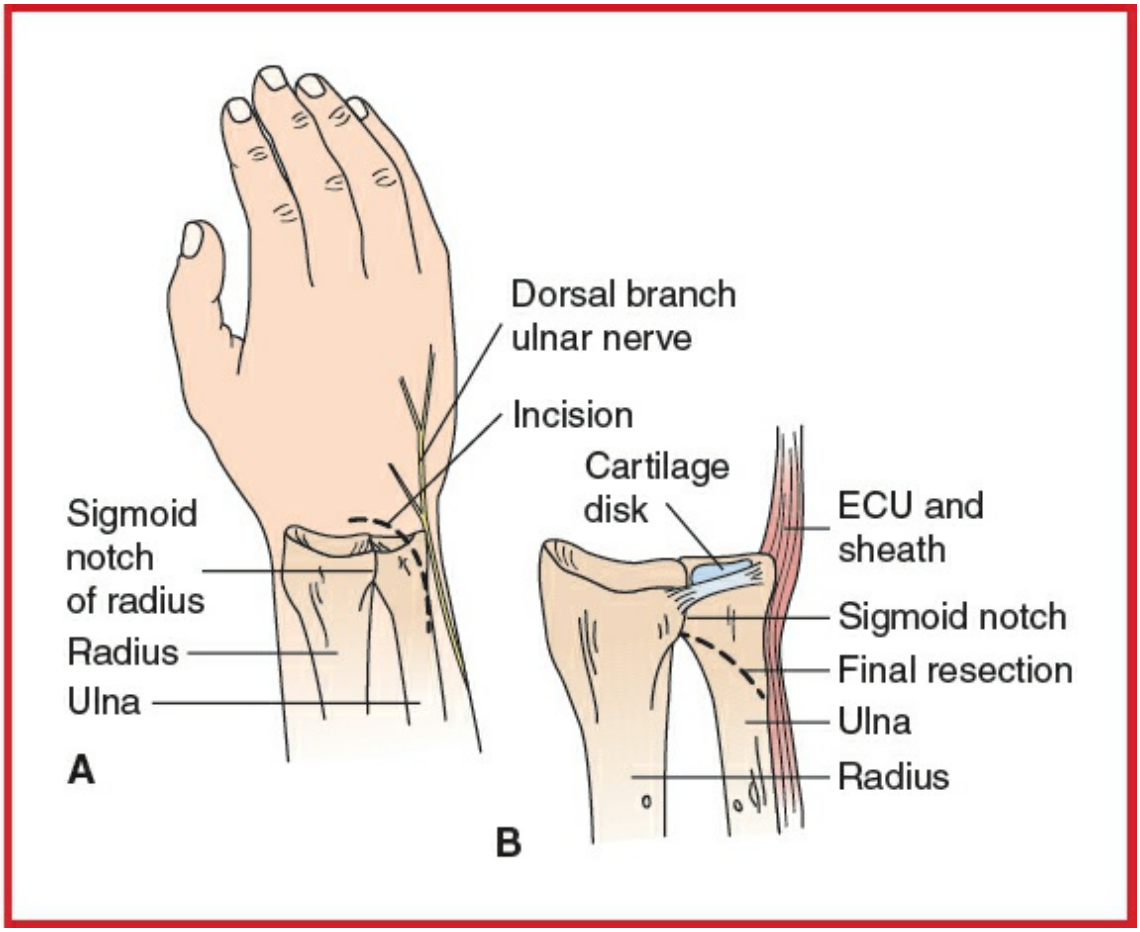

Figure 10.1-1 The Darrach procedure. **A:** Skin incision. Avoid dorsal cutaneous branch of the ulnar nerve. **B:** The distal ulna is resected at the radioulnar articulation just proximal to the sigmoid notch. ECU, extensor carpi ulnaris. (Reproduced with permission from Chapman MWChapman's Orthopaedic

Surgery, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

SUMMARY OF PROCEDURES

Position	Supine, with arm extended on hand surgery table
Incision	Dorsal-ulnar, over distal ulna
Special instrumentation	Pneumatic tourniquet
Antibiotics	Cefazolin 2 g iv
Surgical time	1–2.5 h, depending on associated procedures
Tourniquet	150 mm Hg above SBP; max time = 120 min
Closing considerations	Routine skin closure; postop splint placed at conclusion of procedure
EBL	Minimal; performed under tourniquet control
Postop care	PACU → home
Mortality	None associated with procedure
Morbidity	Ulnar nerve injury: rare Postop swelling (rarely requires specific treatment)
Pain score	5–7

PATIENT POPULATION CHARACTERISTICS

Age range	Adult population
Male:Female	Slight predominance of females, due to incidence of malunion of Colles fractures in women with senile osteoporosis as well as incidence of inflammatory arthropathies in women
Incidence	Not uncommon
Etiology	See Usual preop diagnosis above.
Associated conditions	Rheumatoid arthritis

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Wrist Procedures, p. 1037.

Suggested Reading

1. Grawe B, Heincelman C, Stern P: Functional results of the Darrach procedure: a long-term outcome study. J Hand Surg Am 2012; 37(12):2475–80.

DORSAL STABILIZATION AND EXTENSOR SYNOVECTOMY OF THE RHEUMATOID WRIST

SURGICAL CONSIDERATIONS

Description

This procedure is indicated for patients with rheumatoid arthritis and extensor tenosynovitis refractory to medical treatment, as well as extensor tendon ruptures and/or intercarpal synovitis. The procedure is performed under tourniquet control through a straight dorsal incision over the wrist. A **radical tenosynovectomy** of the extensor tendons in all six extensor compartments is carried out. Tendon ruptures or impending ruptures are repaired with tendon grafts or side-to-side anastomoses. Bone spurs are removed, and a synovectomy of the distal radioulnar joint is carried out. A **modified Darrach procedure,** with resection or osteoplasty of the distal ulna, is usually performed. If there is evidence of synovitis within the wrist joint, a synovectomy is performed through a dorsal arthrotomy. A flap of the extensor retinaculum is transposed beneath the extensor tendons to reinforce the dorsal wrist ligaments and, thus, stabilize the wrist to prevent volar subluxation of the carpus. A posterior interosseous neurectomy is carried out at the same time. The remaining extensor retinaculum is divided into two transverse strips, and one is used to stabilize the distal ulna. The second strip is placed dorsal to the extensor tendons, so they will not bowstring during wrist extension.

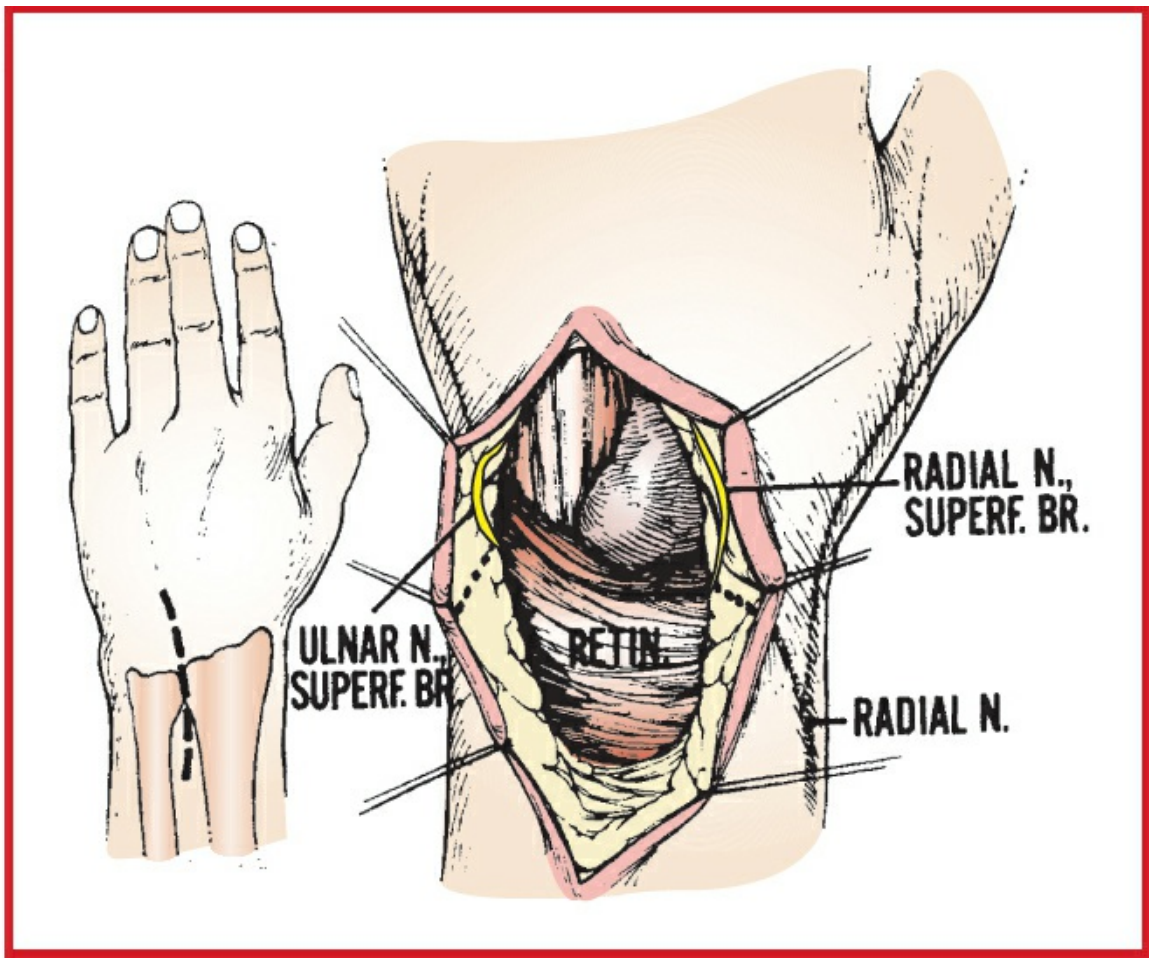

Figure 10.1-2 Incision and exposure for dorsal tenosynovectomy. Note superficial branches of radial and ulnar nerves protected in skin flaps. (Illustration by Elizabeth Roselius, 1988. Reprinted from Green DP, Hotchkiss RN, Pederson WC, eds:Operative Hand Surgery, 2nd edition. Churchill Livingstone, London: 1988. Copyright © 1988 Elsevier. With permission.)

Usual preop diagnosis

Rheumatoid arthritis with extensor tendon tenosynovitis; extensor tendon rupture; distal radioulnar joint synovitis and/or subluxation

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES	
Position	Supine, with arm extended on hand surgery table
Incision	Dorsal wrist (Fig. 10.1-2)

Special instrumentation	Pneumatic tourniquet
Antibiotics	Cefazolin 2 g iv
Surgical time	2 h
Tourniquet	150 mm Hg above SBP; max time = 120 min
Closing considerations	Postop splint
EBL	Minimal; tourniquet used until dressing in place
Postop care	PACU → home
Mortality	None associated with procedure
Morbidity	Extremity swelling (typically does not require treatment) Delayed healing 2° immunosuppression and steroid use Wound infection: rare (unless patient is immunosuppressed)
Pain score	3–5

PATIENT POPULATION CHARACTERISTICS

Age range	Procedure uncommon before 4th decade
Male:Female	As in all patients with rheumatoid arthritis, females more common
Incidence	Not uncommon
Etiology	Connective tissue disorder; rheumatoid arthritis or variant
Associated conditions	All conditions associated with connective tissue disorders, including active rheumatoid arthritis, steroid dependency, immunosuppressive therapy, and/or skin fragility

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Wrist Procedures p. 1037.

Suggested Reading

1. Chim HW, Reese SK, Toomey SN, et al: Update on the surgical treatment fo rheumatoid arthritis of the wrist and hand. J Hand Ther 2014; 27:134–41.

METACARPOPHALANGEAL AND INTERPHALANGEAL JOINT ARTHROPLASTY AND ARTHRODESIS

SURGICAL CONSIDERATIONS

Description

Joint replacement (arthroplasty) in the hand is most commonly indicated in patients with rheumatoid arthritis with severe joint destruction → pain and dysfunction. Another option in these patients is arthrodesis or joint fusion, which involves removing the degenerative cartilaginous surfaces and using implanted metal to secure two opposing bone surfaces. Joint arthroplasty is rarely indicated in patients with osteoarthritis. The most common prostheses, made of silicone rubber and popularized by Swanson, differ from total joint replacement in the hip or knee in that they do not function as true joints but rather as spacers in a **resection arthroplasty.** Most of the stability and motion of these joints depend on meticulous soft tissue reconstructions involving tendon and ligament transfers, as well as intensive postop physical therapy. To obtain good results, patients must be well motivated and understand their disease process and what will be asked of them during the recovery period. The results for **metacarpophalangeal (MP) arthroplasty** are far better than those obtained in the proximal interphalangeal joints. **Proximal interphalangeal joint arthroplasty** is sometimes complicated by soft tissue deformities in rheumatoid arthritis such as swan-neck and boutonniere deformities. A swan-neck deformity consists of hyperextension of the PIP joint and flexion of the DIP joint. Conversely, a boutonniere deformity involves flexion at the PIP joint and hyperextension of the DIP joint. Arthroplasty is generally not indicated for the index finger due to the high stresses associated with pinch that may compromise the longevity or stability of an arthroplasty. **Distal interphalangeal (DIP) arthroplasty** is rarely performed because these patients do well with fusions. The procedure for the MP joints is performed through a dorsal transverse incision under tourniquet control. The metacarpal heads are removed with an oscillating saw and the intramedullary canals reamed to accept the stems of the prostheses. After they have been placed with a no-touch technique, the capsule is closed, and the supporting ligaments are reconstructed with centralization of extensor tendons. Technique for PIP joints is similar, although

some surgeons will use a longitudinal or volar approach. A splint with support for each finger is placed at the conclusion of surgery. Reconstructive procedures of the wrist and fingers can be combined with arthroplasty.

Variant procedure or approaches

Some surgeons favor longitudinal incisions rather than a transverse incision for the approach to the MP joints.

Usual preop diagnosis

Osteoarthritis or rheumatoid arthritis or other connective tissue disorder

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES	
Position	Supine, with arm extended on hand surgery table
Incision	Dorsal hand, transverse, or longitudinal
Special instrumentation	MP or PIP joint prostheses and associated instruments for preparing the medullary canal; power for bone cuts; K-wires, plates, or wire loop for fusion; pneumatic tourniquet
Antibiotics	Cefazolin 2 g iv
Surgical time	2.5 h
Tourniquet	150 mm Hg above SBP; max time = 120 min
Closing considerations	Critical postop splinting
EBL	Minimal; tourniquet used throughout procedure
Postop care	PACU → home
Mortality	None associated with procedure
Morbidity	Swelling (may require early splitting of dressing) Wound infection: rare (if it occurs, requires removal of prosthesis)

	Prosthesis infection: rare
Pain score	3–6

PATIENT POPULATION CHARACTERISTICS	
Age range	>50 yr
Male:Female	As in rheumatoid arthritis, females predominate.
Incidence	Uncommon
Etiology	Rheumatoid arthritis or other connective tissue disorder
Associated conditions	As in rheumatoid arthritis (e.g., skin fragility, steroid dependency, immunosuppression)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Wrist Procedures, p. 1037.

ARTHRODESIS OF THE WRIST

SURGICAL CONSIDERATIONS

Description

A variety of arthrodeses can be performed about the wrist. These include **radiopancarpal arthrodesis (total wrist fusion)** and radiolunate, radioscapholunate, and intercarpal arthrodeses (partial wrist fusions). Radiopancarpal arthrodesis is generally performed as a salvage procedure for wrist pathology that cannot be treated with a procedure that preserves wrist motion. These indications include posttraumatic degenerative arthritis following fractures, dislocations and ligamentous injuries, idiopathic osteoarthritis, and/or rheumatoid arthritis. Predictable patterns of arthritis occur as a result of both scapholunate interosseous ligament injury (scapholunate advanced collapse) and scaphoid nonunion (scaphoid nonunion advanced collapse). As arthritic changes progress, patients are no longer candidates for either reconstruction of the ligaments or fixation of the scaphoid. Another alternative to fusion is a proximal row carpectomy, which is a motion-preserving procedure that may be used in patients without advanced capitolunate arthritis. In the nonrheumatoid patient, an effective procedure is an arthrodesis using an iliac crest bone graft fixed with plate and screws. More recent techniques with improved plate designs may not require iliac crest bone

graft. As another option, local bone from the distal radius may be utilized. It has been shown that a position of fusion in 10–15° of dorsiflexion provides the greatest grip strength. In the rheumatoid patient, a technique using intramedullary fixation with a large-diameter Steinmann pin is preferred. Rheumatoid bone is osteoporotic 2° disuse and chronic steroid administration. Screw fixation is not ideal in this soft bone. Bone graft is obtained locally in these patients, usually from the resected ulnar head. **Radiolunate fusion** also is indicated in rheumatoid patients who have progressive ulnar translation of the carpus. The lunate acts to block this translation of the carpus. **Radioscapholunate fusion** is indicated in patients with radiocarpal arthritis. This procedure preserves about 50% of wrist motion that occurs at the midcarpal joint. Bone graft is necessary and is easily obtained from the distal radius through the same incision. There are a variety of **intercarpal arthrodeses,** including **triscaphe** (scaphotrapezial trapezoid), **scaphocapitate, lunotriquetral,** and **four corner** (capitate-hamate-triquetral-lunate). These procedures are indicated for the treatment of intercarpal arthritis, carpal instabilities due to intercarpal ligament tears, and Kienböck disease (aseptic necrosis of the lunate). Special instrumentation (e.g., **Cloward cervical spine instrumentation**) is useful for obtaining a bicortical plug of bone from the iliac crest with minimal dissection. Local bone graft from the distal radius may be obtained using curettes or larger core needles.

Usual preop diagnosis

Posttraumatic arthritis; osteoarthritis or rheumatoid arthritis; Kienböck disease; carpal instability

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

Position	Supine, with arm extended on hand surgery table. The iliac crest may be prepped and elevated with a sandbag beneath the ipsilateral buttock.
Incision	Dorsal wrist, transverse or longitudinal
Special instrumentation	Pneumatic tourniquet; possibly power for preparation of opposing bone surfaces; K-wires, screws, or special instrumentation for fusion

Unique considerations	Bone-graft donor site
Antibiotics	Cefazolin 2 g iv
Surgical time	2 h
Tourniquet	150 mm Hg above SBP; max time = 120 min
Closing considerations	Immobilization with splints
EBL	Minimal; procedure is performed under tourniquet control. If iliac crest bone graft is used, there may be increased blood loss.
Postop care	PACU → home, sometimes admission for pain control and elevation
Mortality	None associated with procedure
Morbidity	Nonunion of fusion: ≤20%
Pain score	5–7, if no iliac graft; 6–9, if iliac graft used

PATIENT POPULATION CHARACTERISTICS

Age range	>40 yr
Male:Female	Females predominate in rheumatoid arthritis and males in posttraumatic arthritis.
Incidence	Common
Etiology	Trauma (common); rheumatoid arthritis (common)
Associated conditions	Typical for rheumatoid arthritis (e.g., skin fragility, steroid dependency, immunosuppression)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Wrist Procedures, p. 1037.

Suggested Readings

1. Wei DH, Feldon P: Total wrist arthrodesis: indications and clinical outcomes. J Am Acad Orthop Surg 2017; 25(1):3–11.

2. Wysocki RW, Cohen MS: Complications of limited and total wrist arthrodesis. Hand Clin 2010; 26(2):221–8.

TOTAL WRIST REPLACEMENT

SURGICAL CONSIDERATIONS

Description

The major indication for this procedure is rheumatoid arthritis of the wrist. **Total wrist replacement (TWR)** is often recommended in patients with bilateral wrist disease. An arthrodesis will be carried out on the nondominant helping hand and a TWR on the dominant hand to preserve dexterity. Many surgeons prefer to avoid **bilateral wrist arthrodesis,** although some patients with bilateral fusions have been able to function relatively well. Currently available prostheses are suitable only for low-demand patients and are not indicated for high-demand patients with posttraumatic arthritis, especially younger patients. High-demand patients will do better with wrist arthrodesis. Silastic wrist prostheses are associated with a high failure rate and silicone synovitis, and their use has been abandoned by many surgeons. The most commonly used prostheses today are metal on ultrahigh-molecular-weight polyethylene articulations that are fixed with methyl methacrylate cement or bone ingrowth into porous stems. The distal radius articular surface is resected to accept the implant, the proximal carpal row is resected, and the distal carpus is prepared to accept the distal implant. All of these prostheses depend on intact, normally functioning wrist extensor tendons, especially the extensor carpi radialis brevis, for balance and function. Absence of this tendon is felt by many to be an absolute contraindication to this procedure. Because these tendons are so commonly affected by rheumatoid arthritis, the patient population for this procedure is limited. In addition to functioning tendons, meticulously accurate placement of the components in relation to the centers of rotation of the wrist is critical for success. If the centers of rotation of the prosthesis do not duplicate those of the normal wrist, early component loosening and failure are likely. Intraop radiographs are useful in verifying component position. These patients frequently have other upper extremity deformities that will require reconstruction. Because of the complexity of TWR, other reconstructive procedures are not carried out at the same time.

Usual preop diagnosis

Rheumatoid arthritis

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist

should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

Position	Supine, with arm extended on hand surgery table
Incision	Dorsal wrist
Special instrumentation	TWR instrumentation; power for bone cuts; pneumatic tourniquet
Antibiotics	Cefazolin 2 g iv
Surgical time	2 h
Tourniquet	150 mm Hg above SBP; max time = 120 min
Closing considerations	Postop splint
EBL	Minimal; procedure performed under tourniquet control
Postop care	PACU → home vs admission for pain control and elevation
Mortality	None associated with procedure
Morbidity	Infection: rare (but requires removal of prosthesis and methyl methacrylate cement, if used) Poor wound healing
Pain score	4–8

PATIENT POPULATION CHARACTERISTICS

Age range	Rare before 4th decade; most in 6th and 7th decades
Male:Female	Females outnumber males, as in rheumatoid arthritis.
Incidence	Rare
Etiology	Rheumatoid arthritis
Associated conditions	Rheumatoid arthritis

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Wrist Procedures, p. 1037.

Suggested Reading

1. Halim A, Weiss AC: Total wrist arthroplasty. J Hand Surg Am 2017; 42(3):198–209.

THUMB CARPOMETACARPAL JOINT FUSION/ARTHROPLASTY/STABILIZATION

SURGICAL CONSIDERATIONS

Description

Patients with degenerative arthritis of the carpometacarpal (CMC) joint of the thumb present with subluxation, pain, and synovitis of the joint. A **synovectomy and ligament reconstruction** to restore stability will treat pain and may delay further degeneration. This procedure is performed through a curvilinear incision over the joint. A distally attached graft of the radial 1/2 of the flexor carpi radialis tendon is passed through a drill hole in the base of the metacarpal and woven into the joint capsule. In the later stages of degeneration, patients must be treated with either an arthroplasty or an arthrodesis. For more progressive arthritis, a variety of **arthroplasty techniques** are available to the surgeon; most involve removal of degenerated articular surfaces, soft tissue interposition, and often K-wire fixation to suspend the metacarpal which is used. Cemented arthroplasty techniques were initially associated with a high loosening rate and fell out of favor. Newer designs and techniques do not have long-term follow-up yet. The status of the MCP joint of the thumb must be considered prior to CMC intervention. Hyperextension at the MCP joint will increase forces across any CMC procedure.

Variant procedure or approaches

Some surgeons choose to address CMC arthritis arthroscopically with joint debridement and sometimes material interposition.

Usual preop diagnosis

Osteoarthritis of CMC joint; basal joint arthritis; synovitis of CMC joint; CMC joint dislocation; trauma

ERAS: **For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options.** **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

Position	Supine, with arm extended on hand surgery table
Incision	Curvilinear over joint at base of thumb. If soft tissue interposition is used, additional incisions may be required.
Special instrumentation	Pneumatic tourniquet; power if K-wire suspension is to be used
Antibiotics	Cefazolin 2 g iv
Surgical time	1.5–2 h
Tourniquet	150 mm Hg above SBP; max time = 120 min
EBL	Minimal; procedures performed under tourniquet control
Postop care	PACU → home
Mortality	None associated with procedure
Morbidity	Nonunion of arthrodesis: ≤20% Particulate synovitis (silicone rubber prostheses) Dislocation (newer prostheses)
Pain score	8–9

PATIENT POPULATION CHARACTERISTICS

Age range	Joint stabilization in 3rd–5th decades; arthroplasty and arthrodesis in 5th–8th decades
Male:Female	Basal joint instability and arthritis much more prevalent in women
Incidence	Common
Etiology	Trauma may play a role in producing instability. Intra-articular fracture of the base of the first metacarpal with a nonanatomic reduction → incongruence of the joint → posttraumatic arthritis.

	Rheumatoid arthritis → instability and degeneration of the joint. Congenital ligamentous laxity → unstable basal joints and arthritis in many patients
Associated conditions	Rheumatoid arthritis; osteoarthritis; carpal tunnel syndrome (CTS)

ANESTHETIC CONSIDERATIONS FOR WRIST PROCEDURES

(Procedures covered: Darrach procedure; dorsal stabilization and extensor synovectomy of the rheumatoid wrist; metacarpophalangeal and interphalangeal joint arthroplasty; arthrodesis of the wrist; total wrist replacement; thumb carpometacarpal joint fusion/arthroscopy/stabilization)

PREOPERATIVE

Airway	Rheumatoid involvement of the C-spine, TMJ, and cricoarytenoid joint (CAJ) are common in this patient population. Erosion of cervical vertebrae → unstable C-spine (e.g., atlantoaxial subluxation) necessitates extreme care in head and neck manipulation. C-spine fusion (↓ neck ROM), TMJ arthritis (↓ mouth opening), and CAJ arthritis (laryngeal narrowing, hoarseness, DOE, stridor) portend difficult intubation and may necessitate awake fiberoptic intubation. In the case of CAJ arthritis, the use of a smaller ETT may be required.
Respiratory	Rheumatoid patients may exhibit Sx of pleural effusion (✓ CXR) or pulmonary fibrosis (dyspnea, diffuse rales, ↓ diffusing capacity, honeycomb appearance in CXR). **Tests:** Consider CXR, PFTs, and ABGs in affected patients.
Cardiovascular	Rheumatoid patients may suffer from pericarditis, myocarditis, valvular disease, and cardiac conduction defects. Because of the physical limitations imposed by the disease process, it may prove difficult to evaluate these patients' cardiovascular status;

	hence, cardiology consultation, ECG, and ECHO may be useful in preparing for surgery. **Tests:** Consider ECG and ECHO, especially in patients with severe rheumatoid arthritis.
Neurologic	Rheumatoid patients may have cervical or lumbar radiculopathies that should be documented carefully preop. In addition, peripheral neuropathy with consequent sensory/motor defects may be present. **Tests:** Consider C-spine radiographs to r/o occult subluxations in rheumatoid patients with neck pain or upper extremity radiculopathy.
Musculoskeletal	Bony deformities or muscle contractures may necessitate special attention to positioning.
Hematologic	Anemia, eosinophilia, and thrombocytosis may be present. Venous access may be difficult 2° vasculitis and ↑ skin fragility (steroid-induced). Virtually all of these patients will be on some type of anti-inflammatory medication that may result in anemia or Plt inhibition. Ideally, patients should discontinue NSAIDs at least 5 d preop and aspirin, 7 d preop.
Endocrine	Rheumatoid patients may be on oral corticosteroids and require supplemental periop steroids (e.g., 100 mg hydrocortisone q8h iv) to treat adrenal suppression, although the routine use of "stress-dose steroids" has been questioned.
Laboratory	Hb/Hct serves as a minimum in otherwise healthy rheumatoid patients. Severe rheumatoid patients may require more extensive testing to screen for drug effects, etc. (e.g., serum electrolytes; glucose; kidney function tests; LFTs).
Premedication	Mild-to-moderate premedication (e.g., in adults, midazolam 1–2 mg iv, fentanyl 50–100 mcg iv, titrated to effect) is often desirable before placement of a regional block.
ERAS	Check compliance with presurgical ERAS

	recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po, ± celecoxib 200 mg po, with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Regional anesthesia, GA, or a combination of the two can be used. A brachial plexus block via the supraclavicular, axillary, or infraclavicular approach is excellent for this procedure; it is a means of avoiding tracheal intubation for GA if airway difficulty is anticipated. Furthermore, it decreases admission rate, speeds discharge from PACU ir day surgery setting, and increases patient satisfaction. Intravenous regional anesthesia (Bier block) is most useful for short procedures (<1 h). If regional anesthesia is contraindicated, rheumatoid patients may require awake fiberoptic intubation.

Regional anesthesia

1.5% mepivacaine, 30 mL for routine, superficial cases; 0.5% bupivacaine, or 0.5% ropivacaine, 30 mL for procedures >2.5 h or if extended analgesia is desired.

Ultrasound-guided brachial plexus block	Ultrasound-guided brachial plexus using supraclavicular, infraclavicular, or axillary approaches are all suitable for surgery below the shoulder. The infraclavicular approach is the most effective for placement of peripheral nerve catheters. The supraclavicular approach is associated with phrenic nerve blockade in 50% of patients and should be avoided in patients with respiratory compromise.
Bier block	The Bier block (intravenous regional anesthesia) is a technique for short (<60 min) wrist and hand surgeries. 40–50 mL of 0.5% lidocaine is commonly used. For short procedures (<30 min), consider reducing the dose of iv anesthetic (e.g., 25 mL of 0.5% lidocaine) and using a forearm tourniquet instead of an upper arm tourniquet. The OR staff should be alerted that iv regional anesthesia is being used, so that all are ready to proceed after the tourniquet is inflated. Tourniquet pain and postop

	pain are reduced by adding ketorolac (20 mg) or clonidine (1 mcg/kg) to the lidocaine solution.

General anesthesia

Induction	Standard induction in patients with normal airways	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance	
Emergence	Skin closure frequently is followed by application of a splint, and the patient should remain anesthetized during the splinting procedure. Cases with difficult airways require awake extubation. PONV prophylaxis should include ondansetron.	
Blood and fluid requirements	Minimal blood loss IV: 18 ga × 1 BSS @ 1.5–3 mL/kg/h	IV placed in the contralateral upper extremity. See Restrictive Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	
Positioning	Special handling required ✓ and pad pressure points ✓ eyes ✓ C-spine instability	As with nearly all orthopedic cases, positioning is a subtle yet crucial aspect of anesthetic management. Rheumatoid patients may have contractures that require special attention. Steroid-dependent patients require special handling because of fragile skin.
Brachial plexus block complications	Local anesthetic systemic toxicity Inadequate block Pneumothorax Nerve injury	Pneumothorax is very rare. Transient nerve injury <1% Permanent nerve injury risk ~1:2500
Bier block	Local anesthetic toxicity	Proper exsanguination and

complications	Inadequate block Thrombophlebitis	tourniquet function are critical. Upper arm tourniquet should remain inflated a minimum of 25 min. Systemic toxic reaction to the local anesthetic may occur as a result of tourniquet leak or inadvertent premature (<20 min) upper arm tourniquet release. Treatment is supportive. Sz are controlled with midazolam, with appropriate airway protection. Rx severe toxicity with Intralipid® 20% 1.5 mL/kg iv. Even with a functioning tourniquet, it is possible to overcome tourniquet pressure by injecting anesthetic too vigorously. Care must be taken when switching from proximal to distal upper arm tourniquet; never deflate proximal tourniquet until verifying that distal tourniquet is working.

POSTOPERATIVE

Multimodal pain management	Multimodal therapy in combination with regional block. Continuous peripheral nerve block should be considered.	Regional or combined regional-general anesthetic techniques are excellent for wrist procedures, especially with respect to postop pain management (see p. 1037).
ERAS	PONV protocol (see Appendix B, p. B-4 and p.	Encourage early enteral nutrition and mobilization.

	B-6)
Tests	None routinely indicated

Suggested Readings

1. Arslanian B, Mehrzad R, Kramer T, et al: Forearm Bier block: a new regiona anesthetic technique for upper extremity surgery. Ann Plast Surg 2014; 73(2):156–7.
2. Chandrasoma J, Harrison TK, Ching H, et al: Peripheral nerve blocks for hand procedures. N Engl J Med 2018; 379(10):e15.
3. Falcão LF, Perez MV, de Castro I, et al: Minimum effective volume of 0.5% bupivacaine with epinephrine in ultrasound-guided interscalene brachial plexus block. Br J Anaesth 2013; 110(3):450–5.
4. Mian A, Chaudhry I, Huang R, et al: Brachial plexus anesthesia: a review of the relevant anatomy, complications, and anatomical variations. Clin Anat 2014; 27(2):210–21.
5. Seyoum D, Khan W: Perioperative considerations in rheumatoid arthritis patients Curr Rheumatol Rev 2016; 12(3):185–9.
6. Steiner MM, Calandruccio JH: Use of wide-awake local anesthesia no tourniquet in hand and wrist surgery. Orthop Clin North Am 2018; 49(1):63–8.
7. Ustuner E, Yilmaz A, Ozgencil E, et al: Ultrasound anatomy of the brachial plexus nerves in the neurovascular bundle at the axilla in patients undergoing upper-extremity block anesthesia. Skeletal Radiol 2013; 42(5):707–13.

EXCISION OF GANGLION OF THE WRIST

SURGICAL CONSIDERATIONS

Description

Ganglion cysts about the wrist most commonly occur dorsally, originating from the scapholunate joint. The second most common site is volar to the scaphotrapezial joint. To prevent recurrence, these synovial fluid-filled outpouchings of the joint capsule must be excised completely. This requires isolating the stalk of the cyst to its origin and excising a small cuff of normal joint capsule with the cyst. The joint, therefore, must be entered for a complete excision. For patients with dorsal ganglia who have considerable preoperative pain, a posterior interosseous neurectomy may be done at the same time as the excision. Older studies found that the recurrence rate was decreased by the use of GA, as opposed to local or regional anesthetics. This was due to the fact that a more complete excision was performed when the patient was under GA. Hand

specialists today feel that regional anesthetics are quite acceptable for this procedure, as long as the surgeon performs a meticulous excision. More recently, hand surgeons are using lidocaine with epinephrine which eliminates the need for a tourniquet. This field block works well for simple cases such as a dorsal ganglion excision. Volar wrist ganglions commonly are near the radial artery, which is at risk during excision. A preop Allen test should be performed to ensure that, if the radial artery is interrupted, there will not be ischemia in the hand. Primary small dorsal ganglions may be approached arthroscopically.

Usual preop diagnosis

Ganglion cyst, primary or recurrent

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES	
Position	Supine, with arm extended on hand surgery table
Incision	Longitudinal or transverse directly over cyst
Special instrumentation	Pneumatic tourniquet—unnecessary if the surgeon plans to use a field block with lidocaine and epinephrine
Antibiotics	Cefazolin 2 g iv
Surgical time	0.5–1.5 h
Tourniquet	150 mm Hg above SBP; max time = 120 min
Closing considerations	Routine skin closure. Large recurrent cysts may require a repair of the wrist capsule. Splint applied in OR
EBL	Minimal; performed under tourniquet control or with an epinephrine-containing field block
Postop care	PACU → home
Mortality	None associated with procedure
Morbidity	Injury to radial artery: rare (Because of the vascular interconnections between radial and ulnar arteries, loss of

	radial artery flow rarely → complications.)
Pain score	2–4

PATIENT POPULATION CHARACTERISTICS	
Age range	Adults
Male:Female	1:1
Incidence	Very common
Etiology	Unknown. Trauma has been associated with ~50% of ganglion cysts. Underlying carpal instabilities, such as scapholunate instability, have been implicated.
Associated conditions	Carpal instability; trauma (wrist sprains and strains)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Repair of Flexor Tendon Laceration, p. 1044.

PALMAR AND DIGITAL FASCIECTOMY

SURGICAL CONSIDERATIONS

Description

This procedure is indicated for the treatment of Dupuytren contractures of the digits, which produces a neoplastic thickening of the palmar and digital fascia. These pathologic cords (whose active cell is the myofibroblast) contract and, through their connections with the skin, tendon sheath, and phalangeal bone, cause flexion contractures of the MP, proximal interphalangeal, and DIP joints. The disease is progressive, and the common treatment is surgical excision of the fascia. Surgical options for treatment include **needle aponeurectomy**, which incises the diseased fascia but does not remove it, and collagenase (Xiaflex®), which dissolves away the abnormal fascia. In addition to the pathologic changes in the fascia of the hands, many patients also have thickening of the plantar fascia of the foot (Ledderhose disease) and the dorsal fascia of the penis (Peyronie disease). Patients with severe contractures that have been neglected may require amputation. Because the pathologic fascia is so intimately connected to the skin, it is sometimes necessary to excise the skin and replace it with

full-thickness skin grafts. The groin is an excellent donor site for these grafts.

Usual preop diagnosis

Dupuytren contracture

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES	
Position	Supine, with arm extended on hand surgery table
Incision	Transverse or longitudinal palmar. Groin may be used as a full-thickness skin graft donor site.
Antibiotics	Cefazolin 2 g iv
Surgical time	1–3 h
Tourniquet	150 mm Hg above SBP; max time = 120 min. Because of the need to deflate tourniquet so that hemostasis can be obtained, Bier block is not suitable.
Closing considerations	Must obtain meticulous hemostasis. Z-plasties and skin grafts used frequently
EBL	Minimal; dissection done under tourniquet control. A small amount of blood loss occurs when tourniquet is released and hemostasis is obtained.
Postop care	PACU → home
Mortality	None associated with procedure
Morbidity	Hematoma (usually requires operative intervention) Skin necrosis (may require secondary skin grafting) Digital nerve and artery injury (Vascular injuries typically recognized immediately. An operating microscope may be needed, and the procedure will be prolonged.) Reflex-sympathetic dystrophy (so-called sympathetic flare reaction; requires prompt treatment, including stellate ganglion blockade)

	Recurrence rate: 40–80%
Pain score	4–5

PATIENT POPULATION CHARACTERISTICS	
Age range	Typically, 40–60 yr
Male:Female	More common in males (1.7:1)
Incidence	Common (U.S.: 21% @ 65 yo); R ring finger most frequently involved
Etiology	Definite heritance—associated with strong family Hx. More common in Scandinavians. Almost never seen in Blacks. Experimental studies suggest that microhematomas 2° repetitive trauma may be important in the disease process.
Associated conditions	Alcoholism; epilepsy; occupational hand trauma; diabetes

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Repair of Flexor Tendon Laceration, p. 1044.

REPAIR OF LACERATED TENDONS/NERVES

SURGICAL CONSIDERATIONS

Description

The prognosis and difficulty of a flexor tendon repair depend on the anatomic site of the laceration. There are five zones of injury in the upper extremity (Fig. 10.1-3). Zone I is distal to the flexor digitorum superficialis (FDS) tendon insertion and involves only the flexor digitorum profundus (FDP) tendon. Zone II extends from the entrance to the fibro osseous sheath at the metacarpal head to the FDS insertion. Lacerations usually involve both the FDS and FDP. These are the most difficult to repair and have the wors prognosis, as the tendons are apt to become scarred to each other and limit gliding. Zone III is the palm; zone IV is at the level of the carpal canal; and zone V is in the forearm Lacerations in these areas are easier to repair and have good prognoses for restoration of tendon gliding and, thus, digit motion. Associated injuries to the neural structures are common. Digital nerve lacerations are seen in zone II and median or ulnar nerve injuries

in zone IV and proximal. Lacerations to the dorsal side of the hand involving the extensor tendons may be repaired in the emergency room as they often do not involve neurovascular structures, and the extensor digitorum communis tendon as well as the junctura tendinum may prevent retraction of the proximal tendon into the forearm. The exception to this is the thumb and radial dorsal hand, where the extensor and abductor tendons may retract, and the dorsal sensory branch of the radial nerve is at risk.

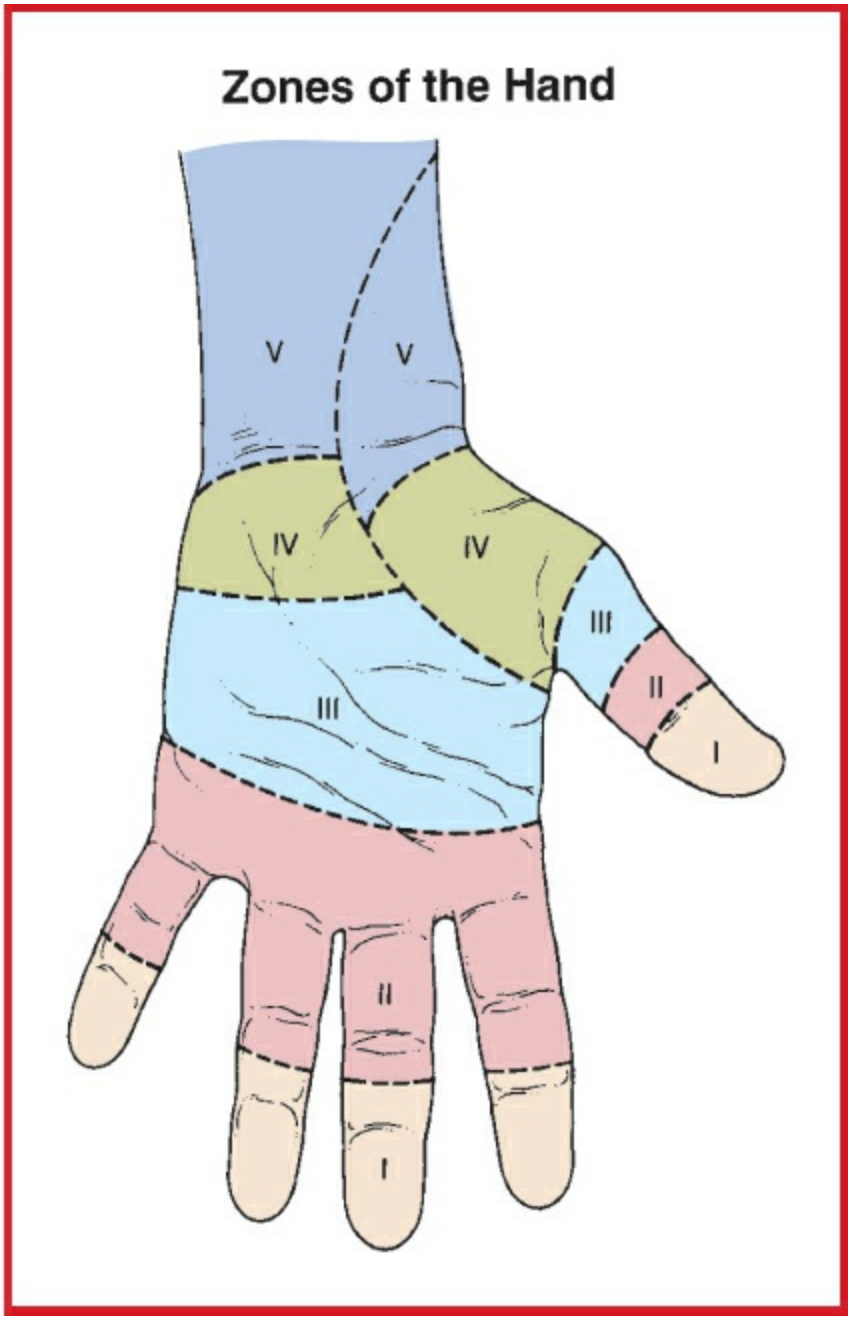

Figure 10.1-3 Zone classification of flexor tendon injuries. (Reproduced with permission from Scott-Conner CEH, Dawson DLOperative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

In general, nerve injuries are repaired at the time of the tendon repair. Depending on the surgeon, an operating microscope or loupe magnification may be used. Some surgeons will use a field block with local anesthetic and epinephrine to allow the patient to test the repair and ensure smooth gliding of the tendon intraop.

Tendons lacerated in the finger are often pulled back into the palm by muscular contraction. A palmar incision is required to retrieve the tendon, which must then be threaded carefully through the pulleys in the digit. Suture techniques for tendon repair create a juncture that is far weaker than an intact tendon. For this reason, the juncture must be protected from mechanical stress for a period of 8 wk or more. This is done by splinting the hand with the wrist and digits flexed so that the pull on the tendon by its muscle is limited. It is important that the patient emerges gently from anesthesia to limit the stress on the repair. The best results are obtained when repair is carried out within 7 d of the injury, although primary repair can be performed up to 3 wk. After 7 d, the muscle begins to undergo irreversible contracture. If the flexor tendon is advanced after this has occurred, a flexion contracture results. If a flexor tendon laceration is neglected, a palm-to-fingertip tendon graft should be performed. If the tendon bed is suitable for gliding, the graft can be accomplished in one stage. If not, a Silastic tendon spacer (rubber rod) must be placed at the first stage; 6–8 wk later, a palm-to-fingertip graft is placed in the bed prepared with the Silastic rod. Tendon graft donor sites include the palmaris longus tendon and toe extensors.

A variant of the sharp flexor tendon laceration is the FDP avulsion from its insertion in zone I. This is the so-called jersey finger—initially named for the classic mechanism of someone grasping the jersey of a ball carrier. This injury occurs during forceful grasp and most commonly affects the ring finger. The FDP tendon retracts to various predictable levels per the classification system of Leddy. Type I retracts in to the palm; this injury is most likely to disrupt the blood supply to the tendon via the vincula. Type II retracts to the level of the PIP joint, and type III retracts to the level of the DIP join In general, these injuries should be explored and repaired within 7 d. Repair may require minisuture anchors or a button/pullout suture through the nail/distal phalanx because there is no sufficient tendon distally for a primary repair. If neglected, these patients should be treated with a **distal interphalangeal (DIP) arthrodesis.** A flexor tendon graft through an intact FDS tendon usually is not indicated because tendon adhesions will commonly interfere with the function of the FDS, leading to decreased overall active motion of the digit. The most common complication is the development of tendon adhesions, which limit tendon gliding and digit motion. If these patients fail to improve within a 3- to 6-mo course of physical therapy, they require an operative tendolysis to lyse the adhesions.

Usual preop diagnosis

Flexor tendon laceration; FDP avulsion ("jersey finger"); digital nerve laceration; median nerve laceration

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES	
Position	Supine, with arm extended on hand surgery table. The foot may be prepped for a graft.
Incision	Zig-zag (Brunner) within the digits, extensile approach hand or wrist
Special instrumentation	Pneumatic tourniquet (unnecessary if using a local anesthetic field block containing epinephrine), ± operating microscope for nerve injuries
Antibiotics	Cefazolin 2 g iv
Surgical time	1–2 h; may be extended for nerve repair and treatment of associated injuries
Closing considerations	Tendon and nerve repairs must be protected with splints before emergence from GA. Smooth extubation (see Emergence, below)
EBL	Minimal; procedure performed under tourniquet control
Postop care	PACU → home
Mortality	None associated with procedure
Morbidity	Tendon adhesions: 25% Rupture of tendon repair: <5% Infection: rare
Pain score	2–4

PATIENT POPULATION CHARACTERISTICS	
Age range	Adult population, rarely children

Male:Female	Slight male predominance, due to occupational injuries
Incidence	Not uncommon
Etiology	Trauma

ANESTHETIC CONSIDERATIONS

(Procedures covered: excision of ganglion of the wrist; palmar and digital fasciectomy; repair of flexor tendon laceration)

PREOPERATIVE

The majority of patients presenting for these procedures are usually otherwise healthy. Many of them present for elective surgery as a result of progressive functional impairment and pain, and preop workup is routine.

Neurologic	If regional anesthesia is contemplated, preexisting sensory or motor defects should be documented carefully.
Laboratory	Hb/Hct (healthy patients); otherwise, as indicated from H&P
Premedication	Mild-to-moderate premedication (e.g., in adults, midazolam 1–2 mg iv, fentanyl 50–100 mcg iv, titrated to effect) is often desirable before placement of a regional block.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po, ± celecoxib 200 mg po with sip of water. Consider aprepitant 40 mg po for GA patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Regional anesthesia (most common), GA, or a combination of the two may be used. Intravenous regional anesthesia (Bier block) is most useful for short procedures that last

for <1 h (see Anesthetic Considerations). Some surgeons prefer to place a local anesthetic field block so that the patient is able to participate and move their finger during surgery. Sedation should be titrated so that the patient can participate in testing.

A brachial plexus block via the axillary, infraclavicular, or supraclavicular approach is another good choice for this procedure. Because most of these procedures are done on an outpatient basis, brachial plexus block without GA is usually preferred to promote early "street-readiness."

Regional anesthesia

1.5% mepivacaine 30cc for routine, superficial cases; 0.5% bupivacaine or 0.5% ropivacaine 30 mL for procedures >2.5 h or if extended analgesia is desired.

Ultrasound-guided brachial plexus block	Ultrasound-guided brachial plexus using supraclavicular, infraclavicular, or axillary approaches are all suitable for surgery below the shoulder. The infraclavicular approach is the most effective for placement of peripheral nerve catheters. The supraclavicular approach is associated with phrenic nerve blockade in 50% of patients and should be avoided in patients with respiratory compromise.
Bier block	The Bier block (intravenous regional anesthesia) is useful for short (<60 min), wrist and hand surgeries. 40–50 mL of 0.5% lidocaine is commonly used. For short procedures (<30 min), consider reducing the dose of iv anesthetic (e.g., 25 mL 0.5% lidocaine) and using a forearm tourniquet instead of an upper arm tourniquet. The OR staff should be alerted that iv regional anesthesia is being used, so that all are ready to proceed after the tourniquet is inflated. Tourniquet pain and postop pain are reduced by adding ketorolac (20 mg) or clonidine (1 mcg/kg) to the lidocaine solution.

General anesthesia

Induction	Standard induction
ERAS	Verify preincision antibiotics. Assess volume status (see

	Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance	
Emergence	Standard emergence. Skin closure is frequently followed by application of a splint; patient should remain anesthetized during splinting procedure. PONV prophylaxis should include ondansetron.	
Blood and fluid requirements	Minimal blood loss IV: 18 ga × 1 BSS @ 1.5–3 mL/kg/h	An 18-ga iv catheter placed in the contralateral upper extremity should be adequate. See Restrictive Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes	
Supraclavicular block complications	Inadequate block Intravascular injection Persistent paresthesia Local anesthetic toxicity Horner syndrome Pneumothorax Phrenic nerve block	Ulnar nerve sparing—may require separate block Rx severe LA toxicity with Intralipid® 20% 1.5 mL/kg iv initially Sx: cough, pleuritic pain, SOB Respiratory impairment possible
Infraclavicular block complications	Inadequate block Intravascular injection Pneumothorax Phrenic nerve block Persistent paresthesia Local anesthetic toxicity	Pneumothorax is very rare. Usually asymptomatic. Incidence ≤50%
Field block complications	Local anesthetic toxicity Inadequate block	An accidental intravascular injection, although unlikely, can cause CNS toxicity. Sz should be treated with midazolam titrated to effect,

		accompanied by airway control. Rx severe toxicity with Intralipid® 20% 1.5 mL/kg iv, initially. If there is any question of a full stomach, intubation should be accomplished rapidly.
Bier block complications	Local anesthetic toxicity Inadequate block Thrombophlebitis	Proper exsanguination and tourniquet function are critical. Upper arm tourniquet should remain inflated a minimum of 25 min. Systemic toxic reaction to the local anesthetic may occur as a result of upper arm tourniquet leak or inadvertent premature (<20 min) upper arm tourniquet release. Treatment is supportive. Sz are controlled with midazolam, with appropriate airway protection. Even with a functioning tourniquet, it is possible to overcome tourniquet pressure by injecting too vigorously. Care must be taken when switching from proximal to distal upper arm tourniquet; never deflate proximal tourniquet until verifying that distal tourniquet is working.

POSTOPERATIVE

Multimodal pain management	Oral analgesics are usually sufficient.	The lingering analgesia of the brachial plexus block is often

		sufficient for pain relief in the recovery room; oral analgesic therapy can be instituted prior to discharging patient to home.
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition and mobilization.
Tests	None routinely indicated	

Suggested Readings

1. Arslanian B, Mehrzad R, Kramer T, et al: Forearm Bier block: a new regiona anesthetic technique for upper extremity surgery. Ann Plast Surg 2014; 73(2):156–7.
2. Chandrasoma J, Harrison TK, Ching H, et al: Peripheral nerve blocks for han procedures. N Engl J Med 2018; 379(10):e15.
3. Mian A, Chaudhry I, Huang R, et al: Brachial plexus anesthesia: a review of th relevant anatomy, complications, and anatomical variations. Clin Anat 2014; 27(2):210–21.
4. Steiner MM, Calandruccio JH: Use of wide-awake local anesthesia no tourniquet i hand and wrist surgery. Orthop Clin North Am 2018; 49(1):63–8.
5. Ustener E, Yilmaz A, Ozgencil E, et al: Ultrasound anatomy of the brachial plexus nerves in the neurovascular bundle at the axilla in patients undergoing upper-extremity block anesthesia. Skeletal Radiol 2013; 42(5):707–13.

WRIST ARTHROSCOPY/REPAIR OF TRIANGULAR FIBROCARTILAGE COMPLEX TEARS

SURGICAL CONSIDERATIONS

Description

Wrist arthroscopy may be performed for either diagnostic or therapeutic indications. A smaller diameter version of the standard arthroscope is used for visualizing the wrist joint. The primary entry portals are on the dorsum of the wrist and course between the extensor compartments. Irrigation is used during the procedure. Unlike the knee joint, where visualization is obtained by distention of the joint, in-the-wrist visualization is obtained by distraction. The digits are placed in finger traps, and up to 10 lb of traction

can be placed on the wrist. Specialized instrumentation is available to resect and débride intra-articular structures and to place sutures to repair torn ligaments. The **triangular fibrocartilage complex** is a source of ulnar-sided wrist pain. It is a term given to the soft tissues spanning the distal radioulnar joint. It is composed of the articular disk, radioulnar ligaments, ulnocarpal ligaments, extensor carpi ulnaris tendon sheath, and meniscus homologue. Advances in both imaging and arthroscopic techniques in the recent past have led to our ability to better treat patients with injuries to the triangular fibrocartilage complex (**TFCC**). The classification of these injuries credited to Palmer involves both traumatic and degenerative tears, which are associated with ulnar-positive variance and ulnar impaction or impingement syndrome. If an open procedure, such as repair of an intercarpal ligament or an ulnar shortening procedure, is contemplated following diagnostic arthroscopy, either GA or regional block is preferred.

Variant procedure or approaches

The standard approach is to suspend the forearm vertically in traction. The forearm also can be placed horizontally on the hand table in traction.

Usual preop diagnosis

Internal derangement of the wrist of unknown etiology; tears of the TFCC; intercarpal instability due to intercarpal ligament tears; scapholunate dissociation; lunotriquetral dissociation; fracture of distal radius; ulnar impingement syndrome

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES	
Position	Supine, with arm extended on hand surgery table
Incision	Small incisions are made on the dorsum of the wrist for instrument insertion.
Special instrumentation	2.7-mm-diameter arthroscope, 0 or 30° field of view; light source and video camera; television monitor; surgical power shaver; joint irrigation system; traction device for forearm; pneumatic tourniquet
Unique	Patient is often awake and observes surgery on monitor.

considerations	
Antibiotics	Cefazolin 2 g iv
Surgical time	30 min to 2 h
Tourniquet	150 mm Hg above SBP; max time = 120 min
Closing considerations	Arthroscopic portals are each closed with a single skin suture.
EBL	Minimal; procedure performed with tourniquet control
Postop care	PACU → home
Mortality	None associated with procedure
Morbidity	Infection: <1% Swelling (2° to irrigation fluid): Common Nerve and artery damage: Uncommon
Pain score	1–3

PATIENT POPULATION CHARACTERISTICS

Age range	Adults
Male:Female	1:1
Incidence	Least common form of arthroscopy
Etiology	See Usual preop diagnosis above.
Associated conditions	Antecedent trauma

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Carpal Tunnel Release.

Suggested Readings

1. Ahsan ZS, Yao J: Complications of wrist and hand arthroscopy. Hand Clin 2017; 33(4):832–8.
2. Wolf JM, Dukas A, Pensak M: Advances in wrist arthroscopy. J Am Acad Orthop Surg 2012; 20(11):725–34.

CARPAL TUNNEL RELEASE

SURGICAL CONSIDERATIONS

Description

This is the most commonly performed procedure in hand surgery. It consists of the transection of the transverse carpal ligament through either an open-palmar or an endoscopic approach (Fig. 10.1-4). In patients with severe synovitis, as in rheumatoid arthritis, a synovectomy should be performed at the same time. If there is advanced thenar atrophy and weakness of thumb opposition, a tendon transfer may be done at that time. The most common transfer is the **Camitz opponensplasty,** in which the palmaris longus tendon is prolonged with palmar fascia and transferred to the thumb. Transfers of the extensor indicis proprius and superficial flexor tendons also can be performed. Surgeons differ in their approach to anesthesia for this procedure: some prefer local infiltration, whereas others prefer regional as there is less fluid edema.

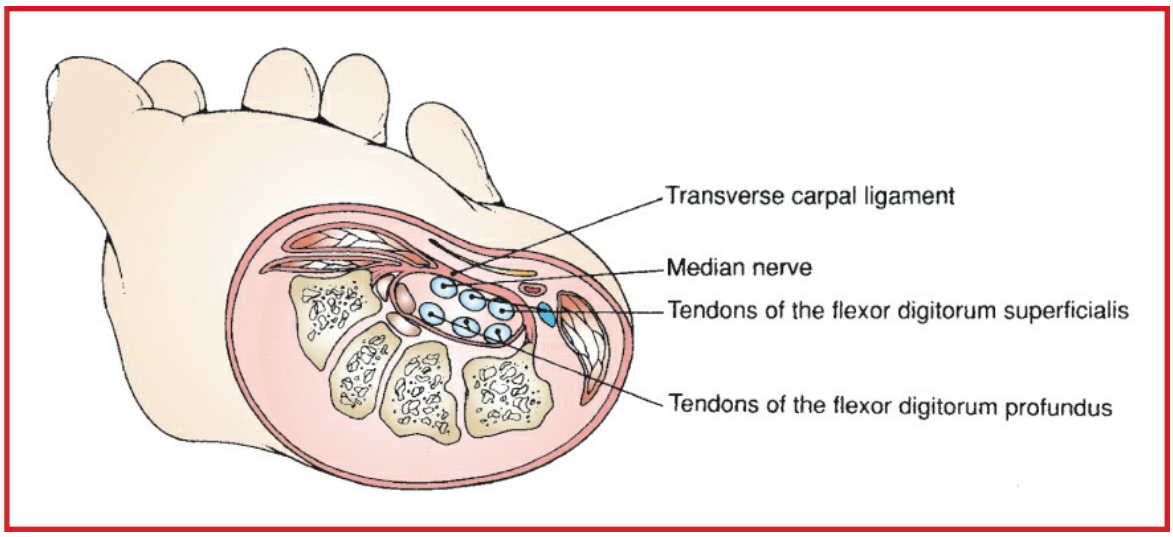

Figure 10.1-4 Exposure of the carpal tunnel. (Reproduced with permission from Scott-Conner CEH, Dawson DL: Operative Anatomy, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2003.)

Usual preop diagnosis

Carpal tunnel syndrome (CTS); median nerve compression at the wrist

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Open Carpal	Endoscopic Carpal Tunnel

	Tunnel Release	Release
Position	Supine	⇐
Incision	Longitudinal incision in palm; may extend to forearm	2 cm transverse at proximal flexion crease of wrist; some use a distal palmar incision also.
Special instrumentation	Pneumatic tourniquet	Endoscopic carpal tunnel release system: endoscope, sheath and trocar, special cutting tools
Unique considerations	Although rare, damage to neurovascular structures	Danger of intraop injury to digital nerves, median nerve, tendons, superficial vascular arch
Antibiotics	±Cefazolin 2 g iv	⇐
Surgical time	30 min	30 min
Tourniquet	150 mm Hg above SBP; max time = 120 min	⇐
Closing considerations	Simple skin closure; some surgeons will splint	⇐
EBL	Minimal; performed under tourniquet control	Minimal
Postop care	PACU → home	⇐
Mortality	None associated with procedure	⇐
Morbidity	Overall complication rate: 4%	⇐
	Complex regional pain syndrome (CRPS): <5%	Rare

	Hematoma: rare Infection: uncommon	Complications of ulnar nerve palsy <5% Tendon and nerve laceration: rare (<1%) Vascular injury: less common than nerve injury
Pain score	1–2	1–2

PATIENT POPULATION CHARACTERISTICS

Age range	20–80 yr; 50% are 40–60 yr
Male:Female	1:2
Incidence	Common
Etiology	Compression of the median nerve within the carpal tunnel by synovitis; mass effect 2° tumor or fracture fragments, peripheral neuropathy, gout, anomalous structures, thrombosis of a persistent median artery, and idiopathic; repetitive trauma (e.g., computer use)
Associated conditions	Rheumatoid arthritis; thyroid imbalance; diabetes; amyloidosis; multiple myeloma; alcoholism; hemophilia; pregnancy; menopause; gout; fractures of the distal radius; Kienböck disease

ANESTHETIC CONSIDERATIONS

(Procedures covered: tendolysis of flexor or extensor tendon; wrist arthroscopy; carpal tunnel release)

PREOPERATIVE

In general, there are two patient populations involved: (a) healthy patients with Hx of wrist trauma and (b) rheumatoid patients. (See Anesthetic Considerations for Wrist Procedures, for discussion of preop concerns in the rheumatoid patient.)

Laboratory	None; otherwise, as indicated from H&P
Premedication	Mild-to-moderate premedication (e.g., in adults,

	midazolam 1–2 mg iv, fentanyl 50–100 mcg iv, titrated to effect) is often desirable before placement of a regional block.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po, ± celecoxib 200 mg po, with sip of water. Consider aprepitant 40 mg po with sip of water for GA patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Intravenous regional anesthesia is suitable only for procedures that are <1 h. For longer procedures, supraclavicular and infraclavicular brachial plexus blocks are good alternatives. Regional techniques are especially appropriate for outpatients. Some of these procedures can be performed with local infiltration of anesthetic.

Intravenous regional block	The Bier block (intravenous regional anesthesia) is for short (<60 min), superficial wrist and hand surgeries. 40–50 mL of 0.5% lidocaine is commonly used. A very brief operative procedure may be an indication to reduce the dose of iv anesthetic agent by, for example, having the surgeon use a forearm tourniquet instead of an upper arm tourniquet. The OR staff should be alerted that iv regional anesthesia is being used, so that all are ready to proceed after the tourniquet is inflated. Tourniquet pain and postop pain are reduced by adding ketorolac (20 mg) or clonidine (1 mcg/kg) to the lidocaine solution.	
Blood and fluid requirements	Minimal blood loss IV: 20 ga × 1 BSS @ 1.5–2 mL/kg/h	A 20-ga iv catheter placed in the nonoperative upper extremity should be adequate. See Restrictive Fluid Management, Appendix K, p. K-4.

Monitoring **Positioning**	Standard monitors ✓ and pad pressure points ✓ eyes	
Intravenous regional block complications	Local anesthetic toxicity Inadequate block Thrombophlebitis	Proper exsanguination and tourniquet function are critical. A tourniquet should remain inflated a minimum of 25 min. Systemic toxic reaction to the local anesthetic may occur as a result of tourniquet leak or inadvertent premature (<20 min) tourniquet release. Treatment is supportive. Sz are controlled with midazolam, with appropriate airway protection. Even with a functioning tourniquet, it is possible to overcome tourniquet pressure by injecting too vigorously. Care must be taken when switching from proximal to distal tourniquet; never deflate proximal tourniquet until verifying that distal tourniquet is working.

POSTOPERATIVE

Multimodal pain management	Oral analgesics are usually sufficient.	Residual analgesia with iv regional anesthesia is minimal unless ketorolac or clonidine is used.
ERAS	PONV protocol (see Appendix B, p. B-4 and p.	Encourage early enteral nutrition and mobilization.

	B-6)
Tests	None routinely indicated

Suggested Readings

1. Chandrasoma J, Harrison TK, Ching H, et al: Peripheral nerve blocks for hand procedures. N Engl J Med 2018; 379(10):e15.
2. Maga JM, Cooper L, Gebhard RE: Outpatient regional anesthesia for upper extremity surgery update (2005 to present) distal to shoulder. Int Anesthesiol Clin 2012; 50(1):47–55.
3. Steiner MM, Calandruccio JH: Use of wide-awake local anesthesia no tourniquet in hand and wrist surgery. Orthop Clin North Am 2018; 49(1):63–8.

FIXATION OF FRACTURES AND DISLOCATIONS OF THE WRIST AND HAND

SURGICAL CONSIDERATIONS

Description

Patients with fractures of the distal radius, distal ulna, carpus, metacarpals, and phalanges that cannot be treated adequately with closed methods require fixation. Difficult fractures may require a combination of techniques such as percutaneous pinning or external fixation in addition to **open reduction and internal fixation** (ORIF) The criteria for adequate treatment include anatomic reduction of the fracture fragments with focus on articular congruity and stable fixation for maintenance of this reduction. Cast/splint treatment or fixation of any kind is an effort to decrease motion at the fracture site and allow the body to produce a bony union with acceptable length, alignment, and rotation. Patients with carpal/wrist fractures or dislocations may have signs of neurologic compromise, specifically the median nerve. Often a closed reduction will improve these symptoms, but if not, urgent operative treatment is indicated. Most dislocations within the hand are reducible in the emergency room setting with adequate anesthesia; there are irreducible varieties that warrant immediate operative treatment. Vascular compromise of the hand associated with these injuries is rare, usually occurring in patients with severe crush or high-energy injuries. The devascularized hand is a surgical emergency, and revascularization must be carried out as soon as possible. High-energy injuries such as gunshot wounds may have significant soft tissue components that must be treated. The possibility of a coexisting compartment

syndrome should be considered, and a fasciotomy may be needed at the time of surgery. Open fractures are, by definition, contaminated and should be irrigated and débrided within 8 h of the injury. Surgical approaches depend on the nature and location of the fracture but typically are longitudinal. Some fractures of the articular surface of the distal radius are amenable to percutaneous pin fixation using fluoroscopy and possibly arthroscopic assistance. Screw fixation of the scaphoid also can be accomplished via percutaneous methods using image guidance. This injury may be associated with a picture of perilunar instability. Damage to intercarpal ligaments may require open repair or reduction and percutaneous pinning. Intraoperative fluoroscopy often is utilized, as are standard portable radiographs to monitor and assess the quality of the reduction of the fracture.

Soft tissue coverage of these injuries may be problematic, and **local flaps** or **free microvascular tissue transfers** may be indicated. Rarely are these procedures done with the initial operative debridement; an antibiotic bead pouch or wound VAC may be used to temporize open wounds. Free transfers can come from the same limb (radial forearm flap, based on the radial artery; lateral upper arm flap, based on the posterior radial collateral artery) or a remote site (latissimus dorsi muscle, based on the thoracodorsal artery; or scapular skin flap, based on the circumflex scapular artery). Remote flaps require special patient positioning and draping. Microsurgical tissue transfers also may need special pharmacologic considerations, including the administration of heparin or dextran to prevent thrombosis of the anastomosis, and avoidance of vasoconstrictors. These procedures also significantly increase operative time and equipment needs.

Usual preop diagnosis

Fractures of the distal radius (Colles', Barton's, Smith's are common eponyms); wrist dislocations (perilunate, lunate); fractures of the carpus, metacarpals, or phalanges; GSW; crush injuries; blast injuries

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES	
Position	Supine, with arm extended on hand surgery table
Incision	Usually volar, longitudinal for distal radius; longitudinal

	either midaxial, midlateral or dorsal for phalanges; dorsal for metacarpals and carpal fractures; a volar incision is used if symptoms of acute carpal tunnel syndrome are present.
Special instrumentation	Fluoroscopy; internal and external fixation devices and power tools; pneumatic tourniquet
Unique considerations	Associated injuries and soft tissue problems in high-energy fractures
Antibiotics	Cephalosporin prophylaxis (e.g., cefazolin 2 g) is indicated for the treatment of closed fractures. Open fractures may require the addition of an aminoglycoside or penicillin depending on the amount and type of contamination.
Surgical time	30 min to 3 h (longer if free tissue transfer is required)
Tourniquet	150 mm Hg above SBP; max time = 120 min
Closing considerations	Some injuries require local flaps or free microsurgical tissue transfers for closure. Fasciotomy wounds may be left open. Splint applied at surgery
EBL	Minimal for fracture treatment, as tourniquet control is used
Postop care	PACU → home unless significant soft tissue injuries requiring additional procedures
Mortality	Usually 2° associated injuries
Morbidity	Loss of reduction, requiring repair Nonunion (requires additional surgical procedure) Infection
Pain score	3–9 (Great variation, probably depending on degree of median, ulnar, or dorsal radial sensory nerve involvement. Postop pain management is often problematic. Early use of stellate ganglion blocks may be beneficial in preventing the development of sympathetic mediated pain syndromes.)

PATIENT POPULATION CHARACTERISTICS	
Age range	All ages. More conservative approaches are used with elderly patients.
Male:Female	1:1
Incidence	Very common
Etiology	Trauma
Associated conditions	Traumatic injuries

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

The majority of patients presenting for these procedures are relatively young and healthy. Most present for elective repair of a traumatic injury, and preop workup is routine. Reimplantation and some injuries, such as irreducible dislocations or open fracture, require immediate attention and necessitate emergency surgery and full-stomach considerations.

Neurologic	If regional anesthesia is contemplated, preexisting sensory or motor defects should be documented carefully preop.
Laboratory	As indicated from H&P
Premedication	Mild-to-moderate premedication (e.g., in adults, midazolam 1–2 mg iv, fentanyl 50–100 mcg iv, titrated to effect) is often desirable before placement of a regional block.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po, ±celecoxib 200 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for GA patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique: GETA, regional anesthesia, or a combination is commonly used. A brachial plexus block is excellent for short (1–2 h) procedures on the wrist and hand. Ultrasound-guided block may be performed with a supraclavicular infraclavicular or axillary approach. Regional anesthesia alone is a means of avoiding the risk of aspiration pneumonitis associated with GA in the patient with a full stomach whose operation must be done emergently. A combination of regional and general anesthesia is appropriate for prolonged cases and those that require the use of bone grafts harvested from the iliac crest or a free-tissue transfer.

General anesthesia

Induction	Standard induction
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance
Emergence	Skin closure is frequently followed by application of a splint; patient should remain anesthetized during splinting procedure. Consider iv acetaminophen if po dose not given. PONV prophylaxis should include ondansetron.

Regional anesthesia

1.5% mepivacaine (30 mL) for routine superficial cases; 0.5% bupivacaine or 0.5% ropivacaine, 30 mL for procedures >2.5 h or if extended analgesia is desired.

Ultrasound-guided brachial plexus block	Ultrasound-guided brachial plexus using supraclavicular, infraclavicular, or axillary approaches are all suitable for surgery below the shoulder. The infraclavicular approach is the most reliable for placement of peripheral nerve catheters. The supraclavicular approach is associated with phrenic nerve blockade in 50% of patients and should be avoided in patients with respiratory compromise.	
Blood and fluid requirements	Minimal-to-moderate blood loss IV: 18 ga × 1	An 18-ga iv catheter placed in the nonoperative upper extremity should be

	BSS @ 1.5–3 mL/kg/h	adequate. See Restrictive Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes	
brachial plexus block complications	Local anesthetic toxicity Inadequate block Pneumothorax Persistent paresthesia Phrenic nerve block Horner syndrome	Rx severe LA toxicity with Intralipid® 20% 1.5 mL/kg iv initially Usually asymptomatic. Incidence ≤50%

POSTOPERATIVE

Multimodal pain management	Continuous nerve block can be considered in appropriate cases. Multimodal therapy in combination with regional block	Regional or combined regional-general anesthetic techniques are excellent for wrist procedures, especially with respect to postop pain management.
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition and mobilization.
Tests	None routinely indicated	

Suggested Readings

1. Coleman AC: Perioperative pain management for upper extremity surgery. Orthop Clin North Am 2017; 48(4):487–94.
2. Jones NF, Jupiter JB, Lalonde DH: Common fractures and dislocations of the hand Plast Reconstr Surg 2012; 130(5):722e–36e.
3. Madison SJ, Humsl J, Loland VJ, et al: Ultrasound-guided root/trunk (interscalene block for hand and forearm anesthesia. Reg Anesth Pain Med 2013; 38(3):226–32.
4. Park SK, Lee SY, Kim WH, et al: Comparison of supraclavicular and infraclavicula

brachial plexus block: a systemic review of randomized controlled trials. Anesth Analg 2017; 124(2):636–44.
5. Ustuner E, Yilmaz A, Özgencil E, et al: Ultrasound anatomy of the brachial plexus nerves in the neurovascular bundle at the axilla in patients undergoing upper-extremity block anesthesia. Skeletal Radiol 2013; 42(5):707–13.

DIGIT AND HAND REPLANTATION

SURGICAL CONSIDERATIONS

Description

Patients with traumatic amputations of digits and the hand are candidates for emergency microsurgical replantation of these parts. In children, replantation is attempted for essentially all amputations. In the adult, replantation is carried out for amputations of the thumb, multiple digits, and amputations through the palm or proximal. In general, amputations of a single digit are not candidates for replantation because of the minimal loss of function in relation to the long rehabilitation period and expected outcome. Certainly, a single digit amputated proximal to the insertion of the FDS tendon (zone II Fig. 10.1-3) should not be replanted. The condition of the amputated part plays an important role in the decision to proceed with replantation. A severely crushed, contaminated, or burned part cannot be expected to survive and function. In addition to the condition of the amputated part, the method of preservation and the time from initial injury play a role in deciding on whether or not replantation is attempted. The patients also may have associated traumatic injuries (i.e., intra-abdominal bleeding with a positive peritoneal lavage, chest injuries), which will take precedence over replantation. The patient's overall health status must be assessed and may play a role in deciding whether or not to proceed with replantation.

There are a variety of reasons that people suffer amputations. Some studies of these patients have shown an increased incidence of psychopathology, such as alcohol or substance abuse. More often than not, these injuries occur in industrial accidents or in a population of people using power tools at home. Rarely children will gain access to dangerous objects, and self-inflicted injuries can occur. Because these procedures are emergent, patients often arrive at the hospital with full stomachs. Although regional anesthesia techniques provide peripheral vasodilation through their sympatholytic effect, surgeons prefer GA because of the unpredictable length of the procedures. While the patient is being readied for induction, the surgeon prepares the amputated part in the OR. At this time, the structures to be repaired are tagged, which saves a great deal of

anesthetic time. When the patient is prepped and draped, the hand is irrigated and débrided, and the corresponding structures are tagged in similar manner. The amputated part is brought to the field, and the actual replantation is performed. Once arterial blood flow is reestablished, the patient must be kept warm to prevent vasospasm. As with other microsurgical procedures, pharmacologic intervention is indicated to prevent thrombosis; iv heparin and dextran are normally administered. Skin grafts for soft tissue coverage and vein grafts to replace segmental vascular defects are commonly used. Vein grafts can be obtained from the ipsilateral upper extremity or from the lower extremity, especially the dorsum of the foot. Either the lateral thigh or abdomen is an excellent donor site for split-thickness skin grafts. Rarely is an immediate microsurgical free tissue transfer indicated for soft tissue coverage.

Usual preop diagnosis

Traumatic amputation of the digits or hand

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES	
Position	Supine, with arm extended on hand surgery table
Incision	Incisions extend both proximal and distal to traumatic amputation to explore neurovascular structures as well as define the zone of injury. Lower extremity prepped and draped as donor site for vein grafts from dorsum of foot, split-thickness skin graft from the thigh
Special instrumentation	Operating microscope; microsurgical instrumentation
Unique considerations	Emergency procedure
Antibiotics	Cefazolin 2 g iv
Surgical time	3–12 h
Tourniquet	150 mm Hg above SBP; max time = 120 min
Closing	Routine volar hand splint

considerations	
EBL	<500 mL
Postop care	ICU → requires monitoring in intensive nursing environment. Should be kept pain-free for extended period postop to minimize vessel spasm. Patients will benefit from postop sedation.
Mortality	Minimal for digit and hand. Mortality becomes an important issue when large amounts of muscle are part of the reattachment.
Morbidity	Loss of replanted part (vessel thrombosis): 10% Infection: rare
Pain score	3–5

PATIENT POPULATION CHARACTERISTICS

Age range	All ages, typically adults of working age
Male:Female	1:1
Incidence	Uncommon
Etiology	Trauma
Associated conditions	Substance abuse; alcoholism

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

In general, there are two patient populations for hand replantation: (a) isolated hand injury patients (common) and (b) multiple trauma victims (rare).

Respiratory	As suggested by coexisting disease or acute trauma injuries. Evidence of occult chest injury, including pneumothorax and pulmonary contusion, should be sought. **Tests:** Consider CXR; ABGs in victims of significant trauma.
Cardiovascular	As suggested by coexisting disease or acute trauma injuries. ✓ for evidence of occult cardiac or

	mediastinal injuries, such as myocardial contusion or great vessel rupture. **Tests:** Consider CXR (with NG tube in place to assess mediastinal widening) and ECG in victims of significant trauma.
Neurologic	As suggested by coexisting disease or acute trauma injuries. The possibility of closed head injury should be addressed in multiple trauma victims. Verify integrity of C-spine. **Tests:** Consider head CT prior to beginning a long procedure under GA in a patient with evidence of head trauma; C-spine x-ray.
Gastrointestinal	All patients should be considered to have a full stomach and to be at risk for aspiration pneumonitis. In general, they should receive preop medication to reduce stomach volume and acidity (e.g., metoclopramide 10 mg iv and ranitidine 50 mg iv).
Hematologic	Multiple trauma victims are likely to suffer from acute blood loss. Although blood loss from these procedures is generally modest, a preop T&C for several U PRBCs is wise for trauma patients. **Tests:** CBC
Metabolic	~50% of trauma victims are intoxicated. Anesthesia-related implications of ethanol intoxication include decreased anesthetic requirements, diuresis, vasodilation, and hypothermia.
Laboratory	As suggested by coexisting disease or acute trauma injuries. In general, most victims of significant trauma are best served by obtaining a wide variety of baseline lab studies to screen for unrecognized injury. These studies normally include ABGs, UA, renal function tests, LFTs, serum amylase, and tox screen.
Premedication	Full-stomach precautions: consider Na citrate 0.3 M 30 mL po, metoclopramide 10–20 mg iv; H_2-blocker
ERAS	Check compliance with presurgical ERAS

	recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po, ±celecoxib 200 mg po, ±gabapentin 300 mg po with sip of water. Consider aprepitant 40 mg po with sip of water for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA, after rapid sequence induction. Because of the unpredictable length of these procedures and the possible need for bone and/or vessel grafts, regional anesthesia is not feasible as the primary technique. A concurrent, continuing brachial plexus block, however, will provide sympathetic blockade, as well as postop analgesia, and catheter placement should be considered before inducing GA. The hand injury repair may be done concurrently with other procedures in multiple trauma victims.

Induction	Rapid sequence induction is mandatory in emergency cases, unless awake intubation is performed. C-spine fracture patients and those with facial injuries may require awake fiberoptic intubation. Hemodynamically unstable, acute trauma patients may be induced more safely with etomidate or ketamine.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance for stable patients. Hemodynamically unstable, acute trauma victims undergoing emergency surgery may be better served by using a combination of medications designed to have minimal hemodynamic consequences (e.g., fentanyl for analgesia, rocuronium for muscle relaxation, and scopolamine or midazolam for amnesia). N_2O is best avoided in the trauma patient.
Emergence	Difficult airway or full-stomach cases require awake extubation. Trauma victims who have undergone a prolonged procedure or who have significant associated cardiopulmonary injuries should remain intubated for postop mechanical ventilation. Consider iv

	acetaminophen if po dose given >6 h ago. PONV prophylaxis may include ondansetron and dexamethasone.	
Blood and fluid requirements	Significant blood loss IV: 16 ga × 1 BSS @ 1.5–3 mL/kg/h + replacement of blood loss Fluid/blood warmers, heating blanket, warmed circuit humidifier	A 16-ga iv catheter in nonoperative upper extremity should be adequate in hemodynamically stable patients. Acute trauma victims who are unstable require a minimum of two large-bore iv catheters or large-bore central lines. Keeping the patient well hydrated will ↓incidence of small vessel thrombosis. See Restrictive Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	Invasive hemodynamic monitoring and TEE should be considered in acute, multiple trauma victims.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Hemodynamic instability	Previously unrecognized injuries (e.g., pneumothorax, cardiac tamponade, intracranial bleeding) should be considered as a cause of unexplained intraop hemodynamic instability in all acute trauma victims.

POSTOPERATIVE

Complications	Sepsis ARDS	
Multimodal pain management	PCA. Regional analgesia	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6)	Encourage early enteral nutrition and mobilization.
Tests	None routinely indicated	

Suggested Readings

1. Barbary S, Dap F, Dautel G: Finger replantation: surgical technique and indications Chir Main 2013; 32(6):363–72.
2. MacKay BJ, Nacke E, Posner M: Hand transplantation—a review.Bull Hosp Jt Dis 2014; 72(1):76–88.
3. Scheker LR, Becker, GW: Distal finger replantation.J Hand Surg Am 2011; 36(3):521–8.

Suggested Viewing

Links are available online to the following videos:

Hand Ganglion Cyst Excision (Dorsal) with Bier Block: https://www.youtube.com/watch?v=_7ihlyW7LxQ

Wrist Arthroscopy Surgery: https://www.youtube.com/watch?v=Wg1GwRBMiZ4

Carpal Tunnel Surgery: Inside the Operating Room: https://www.youtube.com/watch?v=JdHrRf7JinA

Trigger Finger Surgery: Inside the Operating Room: https://www.youtube.com/watch?v=DISCFr0YeiM

Dupuytren's Contracture Release: https://www.youtube.com/watch?v=yjYRlo_Zupw

CHAPTER 10.2

Shoulder/Arm Surgery

SURGEONS

Amy L. Ladd, MD
Emilie V. Cheung, MD

ANESTHESIOLOGIST

Lindsey Vokach-Brodsky, MB, ChB, FFARCSI

SURGEON'S PERSPECTIVE: REGIONAL ANESTHESIA IN SHOULDER SURGERY

Anesthetic options in arthroscopic and open shoulder surgery include GETA and/or interscalene brachial plexus block (ISB). For more complex surgical procedures that require paralysis for adequate exposure, such as anatomic and reverse shoulder arthroplasty, GETA is typically utilized. ISB, frequently in conjunction with MAC, can be an effective option for arthroscopic surgery procedures including rotator cuff and labral repair/debridement, subacromial decompression, and biceps tenodesis/tenotomy.

Each anesthetic modality has advantages and disadvantages. GETA will predictably render the patient insensible to pain and unconscious, while regional anesthesia (± MAC) is inherently dependent on the anesthesiologist's expertise and the patient's anatomy. If the patient does not experience adequate analgesia, conversion to GETA is sometimes required. Potential side effects of GA may include airway complications, short-term cognitive impairment, PONV, and delayed recovery. For ISB, potential side effects include symptomatic diaphragmatic hemiparesis, pneumothorax, permanent neurologic injury, Horner syndrome, or severe hypotension and bradycardia.

For outpatient rotator cuff repair, many benefits of ISB have been documented (ability to bypass PACU, decreased hospital admissions, decreased pain and incidence of sore

throat, less PONV, quicker time to ambulation, quicker food and water intake, quicker discharge time, and improved patient satisfaction). In April 2018, the FDA approved bupivacaine liposome injectable suspension (Exparel®) for the use in ISB following shoulder surgery in adults. An RCT demonstrated decreased postsurgical opioid consumption, increased opioid-free patients, and increased time to first opioid rescue through 48 h. Compared to previous local anesthetic agents, the analgesic effects of Exparel® can approach 48–72 h and may be superior to a continuous ISB (fewer complications and lower cost).

Suggested Readings

1. Hadzic A, Williams BA, Karaca PE, et al: For outpatient rotator cuff surgery, nerve block anesthesia provides superior same-day recovery over general anesthesia. Anesthesiology 2005; 102:1001–7.
2. Malik O, Kaye AD, Kaye A, et al: Emerging roles of liposomal bupivacaine in anesthesia practice. J Anaesthesiol Clin Pharmacol 2017; 33(2):151–6.
3. Sabesan VJ, Shahriar R, Petersen-Fitts GR, et al: A prospective randomized controlled trial to identify the optimal postoperative pain management in shoulder arthroplasty: liposomal bupivacaine versus continuous interscalene catheter. J Shoulder Elbow Surg 2017; 26(10):1810–7.

ARTHROSCOPIC SHOULDER SURGERY

SURGICAL CONSIDERATIONS

Description

The role of arthroscopy in shoulder surgery has advanced tremendously in the past decade and is now routinely performed by most shoulder surgeons. Arthroscopic procedures include **subacromial decompression (SAD), distal clavicle resection (Mumford procedure), debridement** (for labral tear, infection, or synovitis), **rotator cuff (RC) repair, anterior capsule-labral repair** for recurrent dislocation (**Bankart repair**), **capsular plication** for multidirectional instability (MDI), **capsular release for frozen shoulder,** and **repair of SLAP lesions** (superior labral anterior/posterior tears).

Procedures done arthroscopically are less painful postoperatively than open procedures because they produce less trauma to normal tissues. Rehabilitation is, therefore, facilitated. Interscalene block has been shown to provide good postop analgesia of shorter duration, but its clinical application with arthroscopic procedures is surgeon dependent because the postop pain is usually moderate to mild. Some surgeons prefer

only a GETA for shoulder arthroscopy. The use of indwelling intra-articular pain catheters has fallen out of favor in the past few years due to multiple case reports of chondrolysis, a devastating complication characterized by end-stage arthrosis of the glenohumeral joint.

Arthroscopic shoulder surgery may be performed in the beach chair or lateral decubitus position. Beach chair positioners are available with a trough for the head and a breakaway shoulder pad to provide important access to the posterior shoulder. The lateral decubitus position utilizes distal traction of 5–10 lb, with the arm abducted 30–45°. Both are safe positions for the brachial plexus because the shoulder is not excessively abducted. The "down" arm in the lateral position is placed in forward flexion, and an axillary roll is placed underneath the upper chest wall.

Initially, an 18-ga spinal needle is inserted into the glenohumeral joint, passing through the posterior deltoid and infraspinatus muscle and the posterior capsule of the joint (see shoulder anatomy, Fig. 10.2-1). Placement is verified by injecting saline to inflate the joint capsule. A stab incision is made using a No. 11 blade in the direction previously defined by the finder needle. Sharp and then blunt trocars are used to gain access to the joint and permit insertion of the arthroscopic device. Improper insertion of the instruments can injure the axillary or suprascapular nerves and the cartilage of the glenohumeral joint. Initial diagnostic arthroscopy is carried out through the posterior portal. Bupivacaine 0.5% with epinephrine 1:200,000 often is infiltrated into portals and the joint or subacromial space at the onset of surgery to help with analgesia and hemostasis. An anterior portal is used for instrumentation within the glenohumeral joint. After joint arthroscopy, the scope is placed into the subacromial space, where a direct lateral portal is used for instrumentation. Accessory portals are established as needed, depending on the procedure performed. Joint debridement and anterior capsulolabral stabilization are usually performed through anterior portals. RC repair, subacromial bursectomy, acromioplasty, and distal clavicle resection are done within the subacromial space (deep to the deltoid and superficial to the RC). Epinephrine (1 mg/3 L) in the irrigation fluid and maintaining MAP < 80 mm Hg help control bleeding, thus enhancing visualization during surgery.

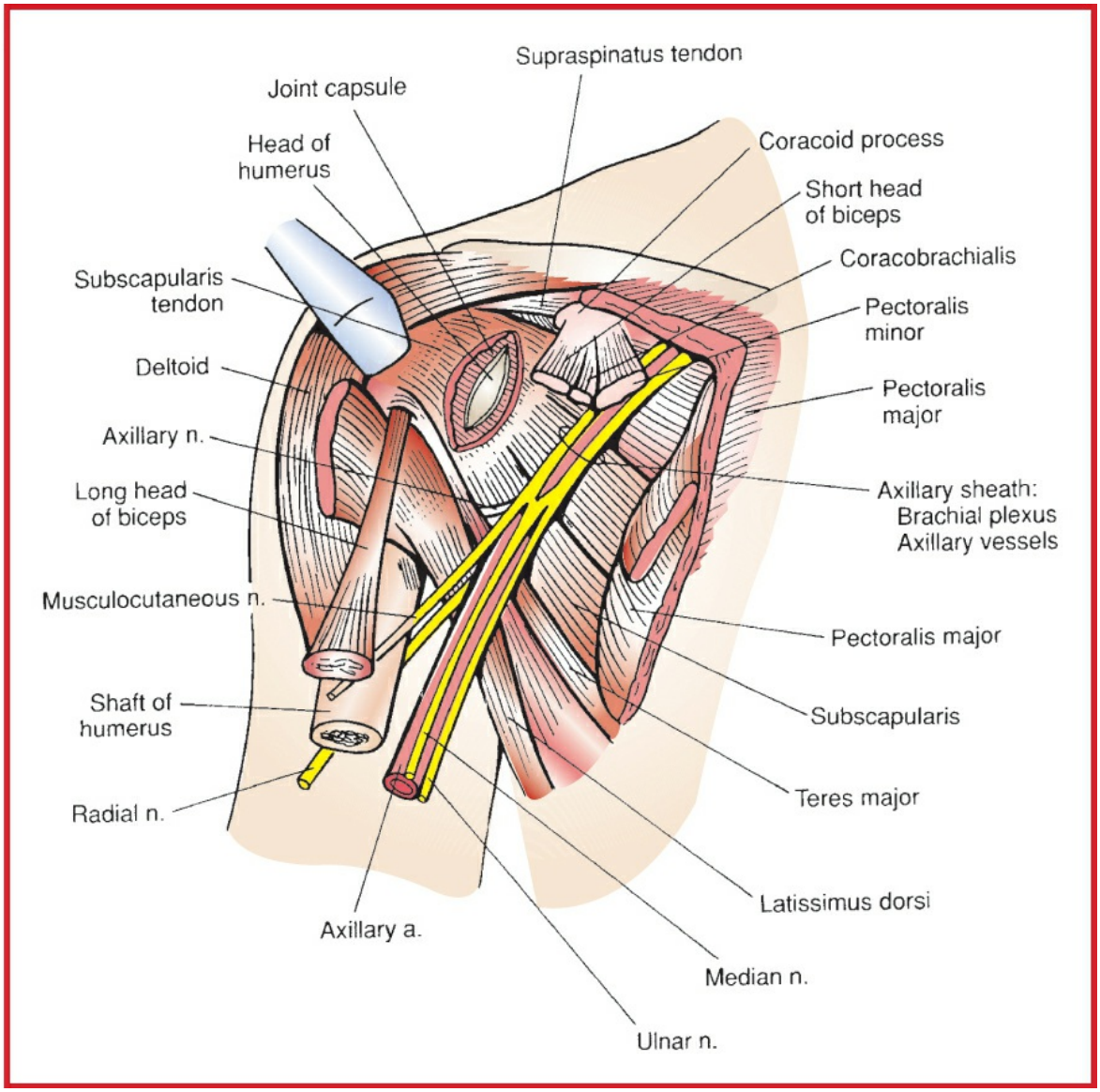

Figure 10.2-1 Anatomy of the shoulder joint, anterior. (Reproduced with permission from Hoppenfeld S, de Boer P:Surgical Exposures in Orthopaedics: The Anatomic Approach, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 1994.)

Usual preop diagnosis

Rotator cuff tear; subacromial impingement; glenohumeral instability; AC arthritis; labral tear

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plans (see Appendix K: Enhanced Recovery After Surgery, p. K-1).

SUMMARY OF PROCEDURE	
Position	Lateral decubitus or beach chair
Incision	Posterior arthroscopic portal, anterior instrumentation portal, lateral instrumentation portal for visualizing subacromial bursa; superior portal for semisitting position
Special instrumentation	Arthroscope; power burrs; arthroscopic shavers; suture-passing instruments; bone anchors; radiofrequency cautery
Unique considerations	Rigid eye patch over ipsilateral eye, to prevent corneal abrasion, suggested. Positioning of the head with appropriate support, removing upper section of operating table, if possible, for better access with semisitting position. ETT taped to opposite side of face. MAP ≤ 80
Antibiotics	Cefazolin 2 g iv preop, particularly if bone work performed
Surgical time	Positioning the patient is time intensive; can add as much as 45 min Reconstructive: 1–4 h Diagnostic: <1–1.5 h
EBL	Minimal: <200 mL (less with use of epinephrine, electrocautery, and laser)
Postop care	Frequently outpatient; may be overnight if interscalene or supraclavicular block is given or reconstructive procedure performed. Intra-articular pain catheter commonly used
Mortality	Rare
Morbidity	VAE possible Extravasation of fluid (NS or LR): >50% Brachial plexus injury (lateral decubitus position): rare Breakage of instruments: <1% Infection: 0–3%

Pain score	4 (diagnostic); 5–7 (reconstruction)

PATIENT POPULATION CHARACTERISTICS

Age range	15–40 yr (instability); 35–75 yr (rotator cuff and acromial pathology)
Male:Female	2:1–4:1
Incidence	Very common: >50,000/yr
Etiology	Young patients: usually sports related Older patients: cuff and acromial pathology; age-wear phenomenon Rotator cuff pathology and acromial impingement (frequently coexist)
Associated conditions	Cervical arthritis and radiculopathy with rotator cuff pathology

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Surgery for Shoulder Instability.

Suggested Readings

1. Dattani R, Smith CD, Patel VR: The venous thromboembolic complications c shoulder and elbow surgery: a systematic review. Bone Joint J 2013; 95-B(1):70–4.
2. Farmer KW, Wright TW: Shoulder arthroscopy: the basics. J Hand Surg Am 2015; 40(4):817–21.
3. Noud PH, Esch J: Complications of arthroscopic shoulder surgery. Sports Med Arthrosc Rev 2013; 21(2):89–96.
4. Sabesan VJ, Shahriar R, Petersen-Fitts GR, et al: A prospective randomize controlled trial to identify the optimal postoperative pain management in shoulder arthroplasty: liposomal bupivacaine versus continuous interscalene catheter. J Shoulder Elbow Surg 2017; 26(10):1810–7.
5. Salazar D, Hazel A, Tauchen AJ, et al: Neurocognitive deficits and cerebra desaturation during shoulder arthroscopy with patient in beach-chair position: a review of the current literature. Am J Orthop (Belle Mead NJ) 2016; 45(3):E63–8.

SURGERY FOR ACROMIAL IMPINGEMENT, ROTATOR CUFF TEARS, AND

ACROMIOCLAVICULAR JOINT ARTHRITIS

SURGICAL CONSIDERATIONS

Description

Subacromial impingement is a common degenerative condition of middle age. It may be related to extrinsic anatomic factors (e.g., hooked acromion), a traumatic episode, or intrinsic factors (e.g., tissue degeneration). The subacromial space (space between the acromion and humeral head) is occupied by the supraspinatus (superior rotator cuff [RC]) muscle and tendon and the bursa, which allows for smooth gliding of the cuff tendon under the acromion. Trauma produces hemorrhage and inflammation in the bursa; swelling of the bursa decreases the space available under the acromion. These tissues may then be "pinched" between the greater tuberosity of the humerus and the lateral aspect of the acromion (Fig. 10.2-2) with forward elevation or abduction of the arm. This further increases the inflammation, producing a vicious cycle.

Impingement of the anterolateral acromion on the insertion of the supraspinatus (along with poor vascularity of this part of the cuff) is a leading hypothesis for the etiology of degenerative **RC tears**.

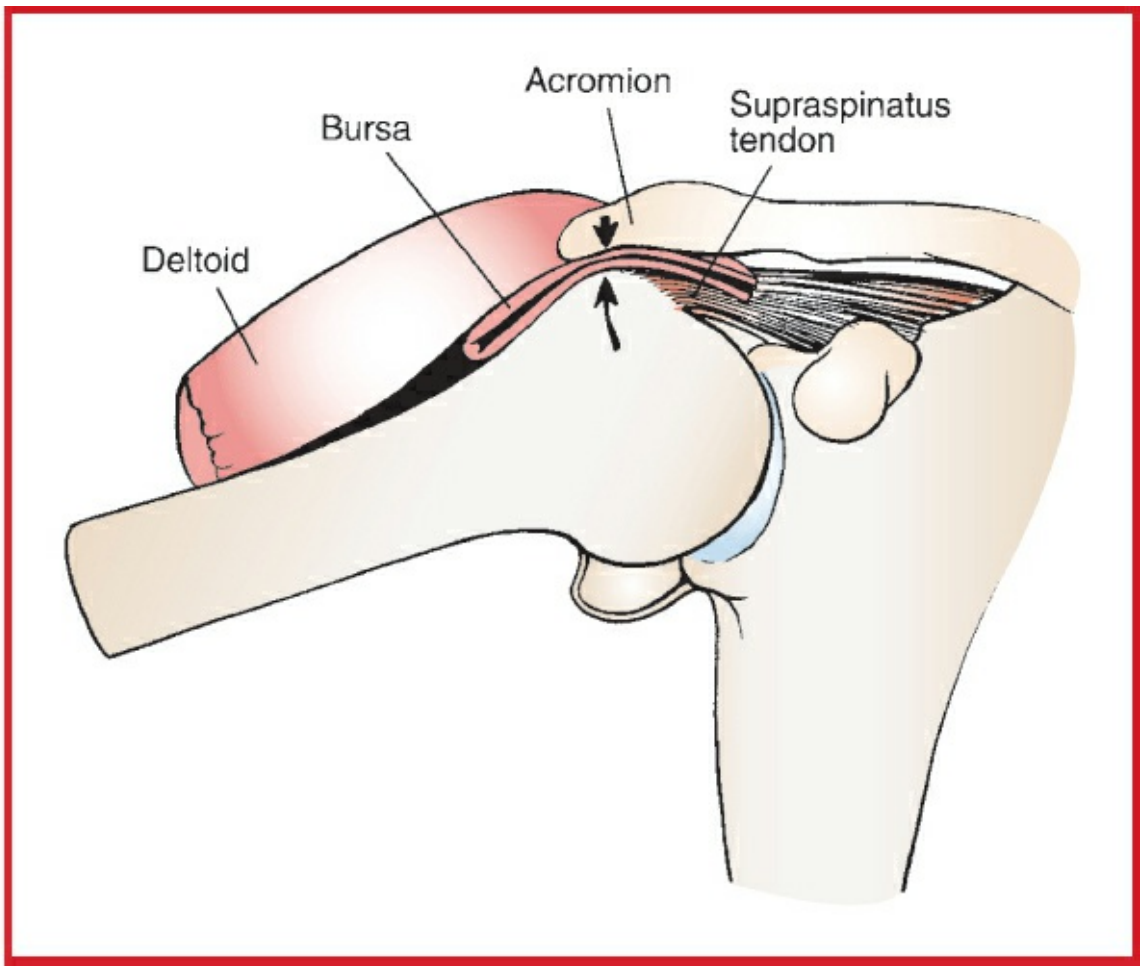

Figure 10.2-2 Abduction of the arm can impinge the subacromial bursa between the greater tuberosity and the undersurface of the acromion and coracoacromial ligament (between arrows). (Reproduced with permission from Hoppenfeld S, de Boer P: Surgical Exposures in Orthopaedics: The Anatomic Approach, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 1994.)

AC joint arthritis is a common radiographic finding in adults, but it is often asymptomatic. Distal clavicle excision is performed for clinically symptomatic AC joint arthritis.

Subacromial impingement

Surgical treatment of subacromial impingement is indicated when nonoperative treatment (e.g., cortisone injection, physical therapy) fails. Surgery involves shaving of the anterolateral aspect of the undersurface of the acromion (creating a flat surface and providing more room in the subacromial space). This may be accomplished with open techniques in combination with open RC repair, but it is more commonly done arthroscopically. The bursa is usually inflamed and quite vascular. Bleeding may obscure arthroscopic visualization and is controlled with electrocautery, with epinephrine in the irrigant, and by maintaining relative ↓ BP (MAP < 80 mm Hg).

Rotator cuff tears

RC (Fig. 10.2-3) repair may be performed using the **direct lateral open approach, the miniopen (deltoid-splitting) approach** in conjunction with arthroscopy, or all arthroscopically. If a deltoid-splitting incision is used, care is taken not to extend the split more than 5 cm distal to the acromion because of possible injury to the axillary nerve, which innervates the deltoid 5 cm or more from the lateral aspect of the acromion. If the beach chair position is used for open RC surgery or arthroscopy, the upper limb is draped free. The arm is manipulated, and traction is frequently applied. It is important that the head is secured (the head may be taped to the table or special beach chair positioner), the eyes are protected, and the anesthesiologist frequently checks to see that the surgeon is not pulling the patient off the table (not always apparent from the surgeon's side of the drape). Traction on the brachial plexus is more likely in the lateral decubitus position 2° arm traction.

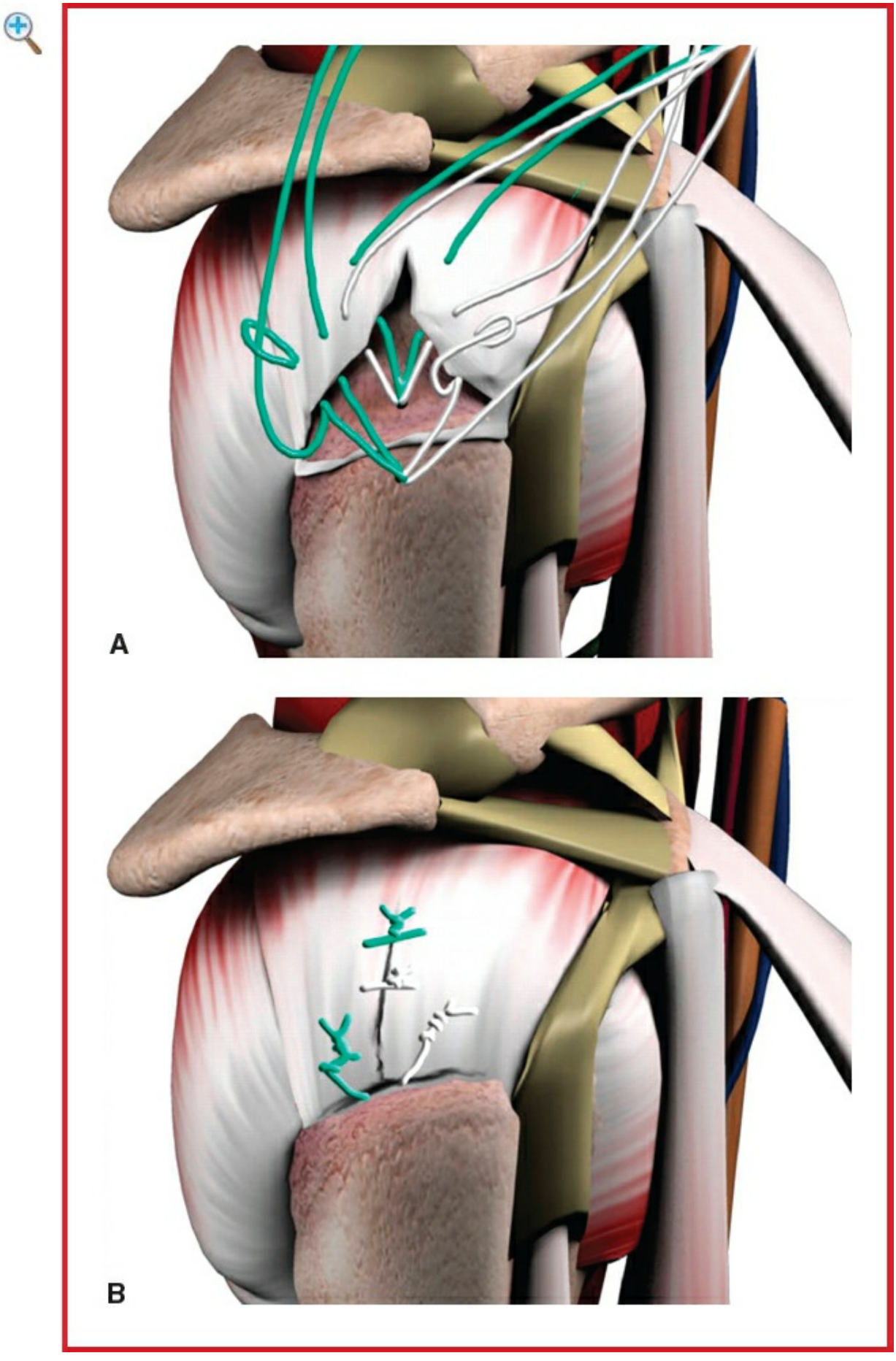
A
B

Figure 10.2-3 Lateral view of the right shoulder showing a rotator cuff repair. **A:** Rotator cuff tear. **B:** Rotator cuff repair with suture anchors. (Reproduced with permission from Lafosse L, Brozska R, Toussaint B, et al: The outcome and structural integrity of arthroscopic rotator cuff repair with use of the double-row suture anchor technique. J Bone Joint Surg 2007; 89(7):1533–41.)

Open RC repair involves suturing the cuff insertion back to the greater tuberosity through drill holes or with suture anchors. Arthroscopic repair requires percutaneous anchor placement and arthroscopic suture passing and knot tying. Bleeding is minimal with the arthroscopic technique but may approach 400 mL with an open procedure. Both require that the patient remains relaxed until all dressings are applied and he/she is fitted with an abduction sling. Patients typically are admitted for 24 h for pain control or if a drain is used.

AC joint disease

Surgery for **AC joint arthritis** is usually performed in conjunction with SAD and/or RC repair and may be done open or arthroscopically. It involves simple resection of the distal 5 mm of the clavicle through an incision directly over the joint or through an accessory anterior portal. Again, relative ↓ BP is required for the arthroscopic procedure.

Repair of AC joint dislocation ("shoulder separation") is uncommon. Most AC separations are treated nonoperatively because long-term functional results are the same or better than those treated surgically. Severe AC separations occasionally require surgery, when the dislocated clavicle is buttonholed posteriorly through the trapezius, the deltoid origin has been avulsed from the clavicle, or the clavicle is displaced inferiorly below the cricoid process. Repair is performed in the beach chair position with the incision carried out over the AC joint and distal third of the clavicle. The clavicle is reduced and held in place with a large screw into the base of the coracoid, a large suture wrapped around the coracoid, or with K-wires across the AC joint. The coracoclavicular ligament often is repaired or reconstructed with tendon graft, or the coracoacromial ligament is transferred from the edge of the acromion to the clavicle. Following reduction and fixation, the deltoid is reattached to the clavicle if it has been avulsed, and the patient is placed in an immobilizer after skin closure. The operation is technically challenging, and the brachial plexus and subclavian vessels are at risk with screw placement and with inferior dislocations.

Usual preop diagnosis

RC tears (partial or complete); AC arthritis; impingement; bursitis; bicipital tendinitis; AC separation

ERAS: **For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plans (see Appendix K, p. K-1).**

SUMMARY OF PROCEDURE	
Position	Beach chair; semisitting, ~40–70°; or lateral decubitus
Incision	Oblique, saber-type incision anteriorly over distal acromion; lateral or deltopectoral incision for wider exposure; deltoid-splitting incision for RC tears
Special instrumentation	Power equipment for bone work; self-retaining retractors for cuff repairs; suture anchors
Unique considerations	Rigid eye protection for ipsilateral eye and careful head positioning
Antibiotics	Cefazolin 2 g iv preop
Surgical time	1–3 h
Closing considerations	Muscle relaxation when mobilizing cuff and during closure. Arm in sling and swathe, or abduction pillow for large tears. Immobilizer should be positioned prior to awakening patient to minimize potential for rupture of repair.
EBL	200–400 mL
Postop care	Maintenance of position in sling and swathe; no active motion of shoulder girdle for 2 d to 6 wk, depending on procedure
Mortality	Rare
Morbidity	Infection: 1–5% Axillary nerve damage: <2% Musculocutaneous nerve damage: <2% Breakage of instruments: <1% Brachial plexus damage (position dependent) Suprascapular nerve at risk for RC mobilization
Pain score	5–8

PATIENT POPULATION CHARACTERISTICS	
Age range	Rotator cuff tears >40 yr (younger for athletes)
Male:Female	3:1
Incidence[2]	5–30% of general population affected by RC and acromial conditions, depending on age, thickness of tear, associated conditions
Etiology	Age related; trauma (70% involved in light work)
Associated conditions	Bursitis; tendinitis; impingement; RC disease (especially in first-time glenohumeral dislocations >40 yr); diabetes and renal failure; hypermobility

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Surgery for Shoulder Instability.

Suggested Readings

1. Audigé L, Flury M, Müller AM: Complications associated with arthroscopic rotato cuff tear repair: definition of a core event set by Delphi consensus process. J Shoulder Elbow Surg 2016; 25(12):1907–17.
2. Chalmers PN, Van Thiel GS, Trenhaile SW: Surgical exposures of the shoulder.J Am Acad Orthop Surg 2016; 24(4):250–8.
3. Mahon HS, Christensen JE, Brockmeier SF: Shoulder rotator cuff pathology: commo problems and solutions. Clin Sports Med 2018; 37(2):179–96.

SURGERY FOR SHOULDER INSTABILITY

SURGICAL CONSIDERATIONS

Description

Shoulder instability is classified as multidirectional (MDI)/atraumatic or unidirectional/traumatic.

MDI is associated with generalized ligamentous laxity (e.g., Ehlers-Danlos or Marfan syndromes or idiopathic) and is treated primarily nonoperatively with physical therapy. Open or arthroscopic **capsular shift** is performed for recalcitrant cases. This involves "plication" of the capsule and/or labrum to decrease the capsular volume of the

shoulder. Patients with MDI, known as "voluntary dislocators," frequently have psychiatric disorders and are very poor candidates for surgery.

Traumatic instability is usually anterior and is quite common in the young, active population. The shoulder is the most commonly dislocated joint. Recurrent dislocation in young, active patients is common (80–90%) and is associated with avulsion of the capsule/labrum from the anterior-inferior glenoid rim (Bankart lesion). The population undergoing a **Bankart repair** is almost invariably young and healthy. Older first-time dislocators (age > 50 yr) more commonly sustain rotator cuff (RC) tears or fractures, which do not result in chronic instability, but may require operative reduction and RC repair or fracture fixation. Posterior traumatic dislocation is much less common and is associated with high-energy trauma, seizures, or electrocution.

Instability surgery is often preceded by exam under anesthesia and arthroscopic examination, either in the beach chair or lateral decubitus position. The essential feature of instability surgery, whether arthroscopic or open, is the reattachment of the anterior-inferior capsulolabral complex back to the rim of the glenoid, thus reestablishing the normal "bumper" effect of the anterior-inferior labrum and decreasing the capsular volume of the shoulder. Nonanatomic procedures (reconstructive) are much less common but are still performed occasionally. These include transfer of the coracoid process to the anterior glenoid rim (**Bristow or Latarjet procedure**).

The **open Bankart repair** is performed in the beach chair position using the deltopectoral approach, with the interval between the deltoid and pectoralis major. The subscapularis (anterior RC muscle) lies just anterior to the joint capsule (Fig. 10.2-4), and this is either detached from its insertion or split. The capsule may then be opened to visualize the joint and rim of the glenoid. The glenoid rim is decorticated, providing bleeding bone to promote healing, and the anterior capsule is reattached through drill holes in the glenoid or with suture anchors. The capsule often is imbricated (overlapping folds) if it is redundant.

The shoulder and deltoid are highly vascular; however, bleeding is usually slight, with careful surgical technique. Major nerves are close but out of the plane of the operative field. The **musculocutaneous nerve** may be stretched by excessive medial retraction of the coracobrachialis (especially if a coracoid osteotomy is used) and the **axillary nerve** may be injured if the surgeon strays too far inferiorly.

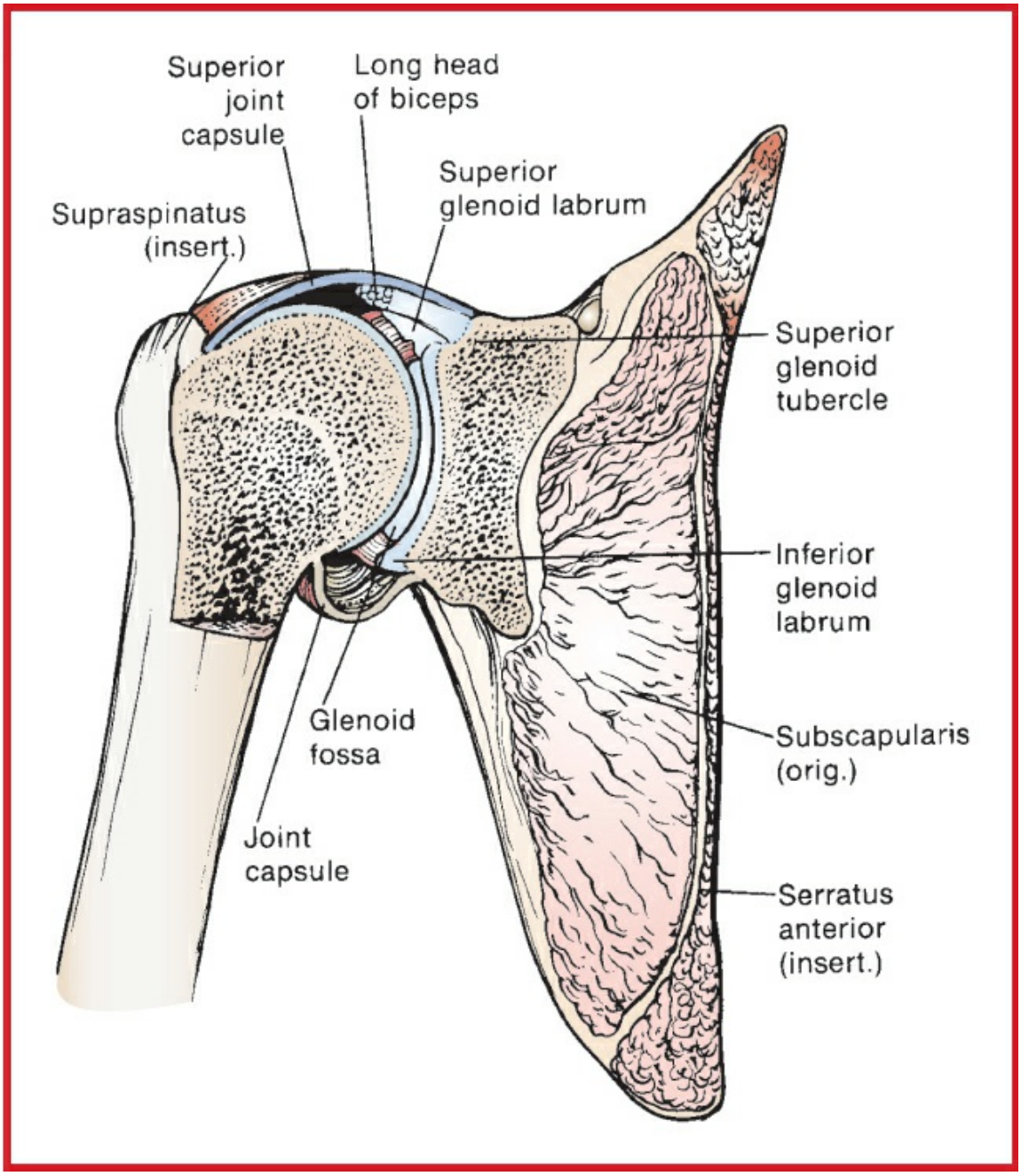

Figure 10.2-4 Cross-section of the joint: The joint capsule is redundant inferiorly to allow abduction. The long head of the biceps tendon traverses the joint. The tendon is surrounded by synovium and, therefore, is anatomically intracapsular but extrasynovial. (Reproduced with permission from Hoppenfeld S, de Boer P:Surgical Exposures in Orthopaedics: The Anatomic Approach, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 1994.)

If a **subscapularis-releasing technique** is used, the muscle is reattached and must be protected postop. External rotation of the shoulder is prevented for several weeks while the repair heals, and the surgeon prefers that the patient remain anesthetized until a shoulder immobilizer is applied.

The **arthroscopic Bankart repair** is similar to the open procedure but is performed

through two anterior portals with the scope coming in posteriorly. This procedure is less painful postop and allows for more rapid rehabilitation, because the subscapularis is not detached.

Open surgery for posterior dislocation is similar to the open Bankart repair, but it is done in the lateral position and utilizes the interval between the infraspinatus and teres minor. The RC attachment is preserved, but the posterior deltoid is detached and must be protected postop.

Usual preop diagnosis

Recurrent traumatic anterior or posterior instability; MDI; fracture dislocation

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plans (see Appendix K, p. K-1).

SUMMARY OF PROCEDURES

	Open	Arthroscopic
Position	Beach chair for anterior; lateral decubitus for posterior	Lateral decubitus or beach chair
Incision	Deltopectoral (anterior); posterior approach (posterior)	Multiple small portals
Special instrumentation	Arthroscopic shaver; suture anchors; glenoid and humeral instrumentation	⇐ + arthroscopic instruments for suture passing and knot tying
Antibiotics	Cefazolin 2 g iv preop if bone work performed	⇐
Surgical time	2–4 h	⇐
Closing considerations	Continuous anesthesia until application of sling and swathe or abduction pillow	⇐

EBL	200–400 mL	Minimal
Postop care	No active motion for 6 wk	⇐
Mortality	Minimal	⇐
Morbidity	Axillary nerve palsy: 15% (may be preexisting) Suprascapular nerve injury	
Pain score	8	5

PATIENT POPULATION CHARACTERISTICS	
Age range	15–35 yr
Male:Female	2:1
Incidence	Common
Etiology	Trauma; hypermobility; Sz
Associated conditions	RC tears (>50 yr); hypermobility syndrome; Sz disorder; Hill-Sachs lesion (humeral head defect) may require bone grafting; superior labral tears; in most axillary nerve palsies from the injury; iatrogenic (rare)

Suggested Readings

1. Hohmann E, Tetsworth K, Glatt V: Open versus arthroscopic surgical treatment for anterior shoulder dislocation: a comparative systematic review and meta-analysis over the past 20 years. J Shoulder Elbow Surg 2017; 26(10):1873–80.
2. Levine WN, Sonnenfeld JJ, Shiu B: Shoulder instability: common problems and solutions. Clin Sports Med 2018; 37(2):161–77.

ANESTHETIC CONSIDERATIONS

(Procedures covered: shoulder arthroscopy; surgery for acromial impingement, RC tears, and AC disease; surgery for shoulder dislocations or instability)

PREOPERATIVE

Typically, three patient populations present for repair of RC tears or shoulder arthroscopy: (a) healthy posttrauma, (b) nonrheumatoid arthritic, and (c) rheumatoid

arthritic. Individuals presenting for repair of shoulder dislocations also may include those with a joint hypermobility syndrome (e.g., Marfan or Ehlers-Danlos) or Sz disorder patients.

Respiratory	Arthritic patients may exhibit Sx of pleural effusion or pulmonary fibrosis. Hoarseness may indicate cricoarytenoid joint (CAJ) involvement → difficult intubation. (See Anesthetic Considerations for Wrist Procedures.) Seizure disorder patients who suffer from recurrent shoulder dislocation as a result of frequent grand mal Sz also may suffer from occult aspiration pneumonia or pneumonitis. **Tests:** Consider CXR; PFTs; ABGs in debilitated rheumatoid patients
Cardiovascular	Arthritic patients may suffer from chronic pericardial effusions, valvular disease, and cardiac conduction defects. Patients presenting for shoulder stabilization because of joint hypermobility syndromes may have valvular dysfunction and are vulnerable to aortic dissection 2° HTN. These patients may require antibiotic prophylaxis for bacterial endocarditis. **Tests:** Consider ECG, ECHO in patients with severe rheumatoid arthritis. Recent ECHO to assess valve function and aortic root size indicated in most patients with Marfan syndrome
Neurologic	Arthritic patients may have cervical or lumbar radiculopathies that should be documented carefully preop. For example, head flexion may cause cervical cord compression. Patients with severe Sz disorders can suffer from recurrent shoulder dislocations 2° frequent violent grand mal Sz. Such patients should be treated maximally for Sz disorder prior to elective surgery. Be aware that as many as 15% of shoulder dislocations can be accompanied by axillary nerve palsy, which should be documented carefully preop. **Tests:** Consider C-spine radiographs to r/o occult subluxations in arthritic patients with neck complaints or upper extremity radiculopathy. Verify

	therapeutic levels of antiepileptic medication in Sz disorder patients.
Musculoskeletal	Arthritic patients may have limited neck and jaw ROM and may require fiberoptic intubation techniques. Bony deformities or muscle contractures may necessitate special attention to positioning. Patients with joint hypermobility syndromes presenting for shoulder surgery also may suffer other joint dislocations 2° positioning problems.
Hematologic	Virtually, all patients will be on some type of anti-inflammatory medication that may result in anemia or Plt inhibition. Ideally, patients should D/C NSAIDs at least 5 d preop; aspirin, 7 d. In addition, selected patients with Ehlers-Danlos are known to have severe coagulation defects that may preclude the use of regional anesthesia. **Tests:** A coag profile is mandatory in Ehlers-Danlos patients.
Endocrine	Rheumatoid patients may be on oral corticosteroids and may require supplemental perioperative steroids (e.g., 100 mg hydrocortisone q8h iv) to treat adrenal suppression, although the routine use of "stress-dose steroids" has been questioned.
Laboratory	Hb/Hct (in healthy patients); other tests as indicated from H&P. Patients with Ehlers-Danlos syndrome should always have banked blood available for surgery, except for minor procedures.
Premedication	Mild-to-moderate premedication (e.g., in adults, midazolam 1–2 mg iv, fentanyl 50–100 mcg iv, titrated to effect) is often desirable before placement of a regional block.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po, ± celecoxib 200 mg po, ± gabapentin 300 mg po. Consider aprepitant 40 mg po for patients with h/o

	severe PONV.

INTRAOPERATIVE

Anesthetic technique

GA or regional anesthesia (interscalene block), or a combination of the two techniques, can be used. A suprascapular block (when interscalene block is contraindicated) can be used for intraop → postop pain control in arthroscopic shoulder procedures. When logistically feasible, a combined technique is ideal. Unless contraindicated, a long-acting local anesthetic should be used in regional anesthesia for shoulder surgery to ameliorate postop pain.

General anesthesia

Induction	Standard induction. Arthritic patients may require awake fiberoptic intubation.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Tranexamic acid (e.g., 10–15 mg/kg) iv before incision has been shown to ↓ EBL and may be requested by the surgeon.
Maintenance	Standard maintenance
Emergence	Management of emergence and extubation should be routine, except in difficult airway cases, which require awake extubation. Patients should remain anesthetized until the shoulder is immobilized. Consider iv acetaminophen if po dose not given <6 h ago. PONV prophylaxis should include ondansetron and dexamethasone.

Regional anesthesia

Local anesthetics	2% lidocaine or 1.5% mepivacaine have similar onset times (10–15 min) and similar duration (4–6 h). If extended postop pain control is desired, 0.5% bupivacaine or 0.5% ropivacaine can be used. Onset is usually within 30 min, with duration >6 h. Ropivacaine may be preferred for peripheral nerve

	block due to its decreased cardiotoxicity.	
Interscalene block	0.5% bupivacaine or ropivacaine 20 mL The skin on the top of the shoulder (C3-C4) and the medial aspect of the upper arm (T2) may require separate subcutaneous field blocks. Phrenic nerve block → hemidiaphragmatic paralysis is an inevitable consequence of the interscalene block, which may not be tolerated by patients with significant preexisting respiratory compromise. Major complications, such as total spinal or pneumothorax resulting from interscalene block, are extremely rare. Interscalene block is contraindicated in patients with contralateral recurrent laryngeal nerve or phrenic nerve palsy (e.g., post CABG). If sedation is needed, midazolam (0.5–1.0 mcg boluses) and propofol (50–100 mg/kg/min by infusion), given initially in subanesthetic doses and thereafter titrated to effect, are good choices.	
Blood and fluid requirements	Minimal-to-moderate blood loss IV: 18 ga × 1 BSS @ 1.5–3 mL/kg/h	IV catheter placed in contralateral upper extremity. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors ± Precordial Doppler ± Arterial line	BP cuff should be placed on the arm for beach chair procedures. To help detect VAE, consider precordial Doppler monitoring when semisitting position used. Consider art line monitoring for high-risk patients (e.g., risk for aortic dissection).
Positioning	✓ and pad pressure points	Postural ↓ BP is the most common complication of

	✓ eyes ↑ VAE risk in semisitting position	the semisitting position. Changing to this position gradually can help prevent ↓ BP, as can the use of antiembolism stockings, plus fluid loading the patient. Marfan and Ehlers-Danlos patients require very gentle positioning to prevent joint dislocations.
Interscalene block complications	Total spinal Accidental epidural injection Local anesthetic toxicity (Sz/dysrhythmias) Stellate ganglion block (Horner syndrome) Laryngeal nerve block Phrenic nerve block Pneumothorax	Resuscitative equipment, including airway management tools, should be immediately available. Nerve blocks should be performed in responsive and cooperative patients to minimize complications.
	Persistent paresthesia	May last ≤ 6 wk
Other complications	↓ BP during surgical prep and positioning	↓ BP during long surgical preps normally can be avoided by using light inhalation anesthesia (e.g., 0.5 MAC) to ensure amnesia, with moderate muscle relaxation to prevent bucking on the ETT, and maintaining adequate hydration. Antiembolism stockings will help prevent venous pooling in lower limbs.
	Cardiac dysrhythmia VAE	Dysrhythmias may be 2° to irrigation fluids

	containing epinephrine.

POSTOPERATIVE

Multimodal pain management	PCA, regional block techniques including CPNB	Combined regional-general anesthetic techniques are excellent for shoulder procedures, especially with respect to postop pain management. Emphasize multimodal approach combining non–opioid and bolus/PCA opioid analgesics with regional anesthetics (e.g., continuous nerve block) whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6) Regional analgesia	Encourage early enteral nutrition, Foley catheter removal, and mobilization.
Tests	None indicated routinely	

Suggested Readings

1. Auyong DB, Allen CJ, Pahang JA, et al: Reduced length of hospitalization in primar total knee arthroplasty patients using an updated enhanced recovery after orthopedic surgery (ERAS) pathway. J Arthroplasty 2015; 30(10):1705–9.
2. Bambaren IA, Dominguez F, Elias Martin ME, et al: Anesthesia and Analgesia in th Patient with an Unstable Shoulder. Open Orthop J 2017; 11:848–60.
3. Borgeat A: Acute and nonacute complications associated with interscalene block and shoulder surgery. Anesthesiology 2001; 95(4):875–80.
4. Grauman S, Boethius J, Johansson J: Regional anaesthesia is associated with shorte postanaesthetic care and less pain than general anaesthesia after upper extremity surgery. Anesthesiol Res Pract 2016; 2016:6308371.
5. Zhu S, Qian W, Jiang C, et al: Enhanced recovery after surgery for hip and knee arthroplasty: a systematic review and meta-analysis. Postgrad Med J 2017;

93(1106):736–42.

GLENOHUMERAL SHOULDER ARTHROPLASTY

SURGICAL CONSIDERATIONS

Description

Shoulder replacement is performed for pain associated with end-stage arthritis. Primary osteoarthritis (wear-and-tear arthritis) is much less common in the shoulder than in the weight-bearing joints, such as the hip and knee. The most common causes of shoulder arthritis requiring **total shoulder arthroplasty (TSA)** are osteoarthritis, rheumatoid arthritis; avascular necrosis (AVN); posttraumatic arthritis; and rotator cuff tear arthropathy. Most patients are older than 65 yr.

TSA involves replacement of the humeral head with a stemmed prosthesis and resurfacing the glenoid with a polyethylene component. Both components may be cemented or uncemented, depending on the surgeon's preference. **Hemiarthroplasty** involves only replacement of the humeral side. This is indicated when the humeral head is involved primarily and the glenoid is in good condition, as in severe proximal humerus fractures, AVN of the humeral head, and some chronic dislocators. Replacement of the glenoid is contraindicated in the presence of an unreconstructable massive RC tear because eccentric forces lead to rapid loosening of the glenoid component. Some revision cases require glenoid bone grafting, which increases the complexity and potential blood loss.

Shoulder arthroplasty utilizes the beach chair position and the deltopectoral incision (Fig. 10.2-5). The deltopectoral interval is developed. The subscapularis insertion is incised, and the muscle is reflected medially. The capsule is incised and the joint exposed. The humeral head is dislocated anteriorly, and the head is removed with an oscillating saw. Reamers and broaches are used to prepare the proximal humerus for the prosthesis. If the glenoid is to be resurfaced, it is done before implantation of the final humeral component. The labrum is excised and a motorized reamer is used to remove the cartilage of the glenoid. Glenoid drill holes are made to conform to the back of the prosthesis. The glenoid prosthesis is cemented into place, with the component held in position manually until the cement hardens (~15 min). Trial humeral components are placed, and the appropriate sizing of the head and stem are assessed. The final humeral component is inserted with or without cement. The joint is reduced, and the subscapularis is repaired. Skin closure is followed by placement of a sling or shoulder

immobilizer. Postop management includes early passive ROM, limiting active internal rotation, and passive external rotation until the subscapularis has healed. Additional limitations may be instituted in revision situations or if RC repair is performed.

Variant approach: **Reverse shoulder arthroplasty** (RSA) was developed to overcome some of the shortcomings (e.g., rotator cuff stress, migration of the humeral component) of more conventional approaches by allowing the deltoid and other muscles to act as functional replacements for a deficient rotator cuff. This is accomplished by reversing the implants so that the socket component is attached to the head of the humerus and the ball component is attached to the native glenoid socket. As a result, RSA is inherently more stable because it creates a new medial center of rotation at the glenoid bone-implant interface, significantly reducing force on the damaged rotator cuff.

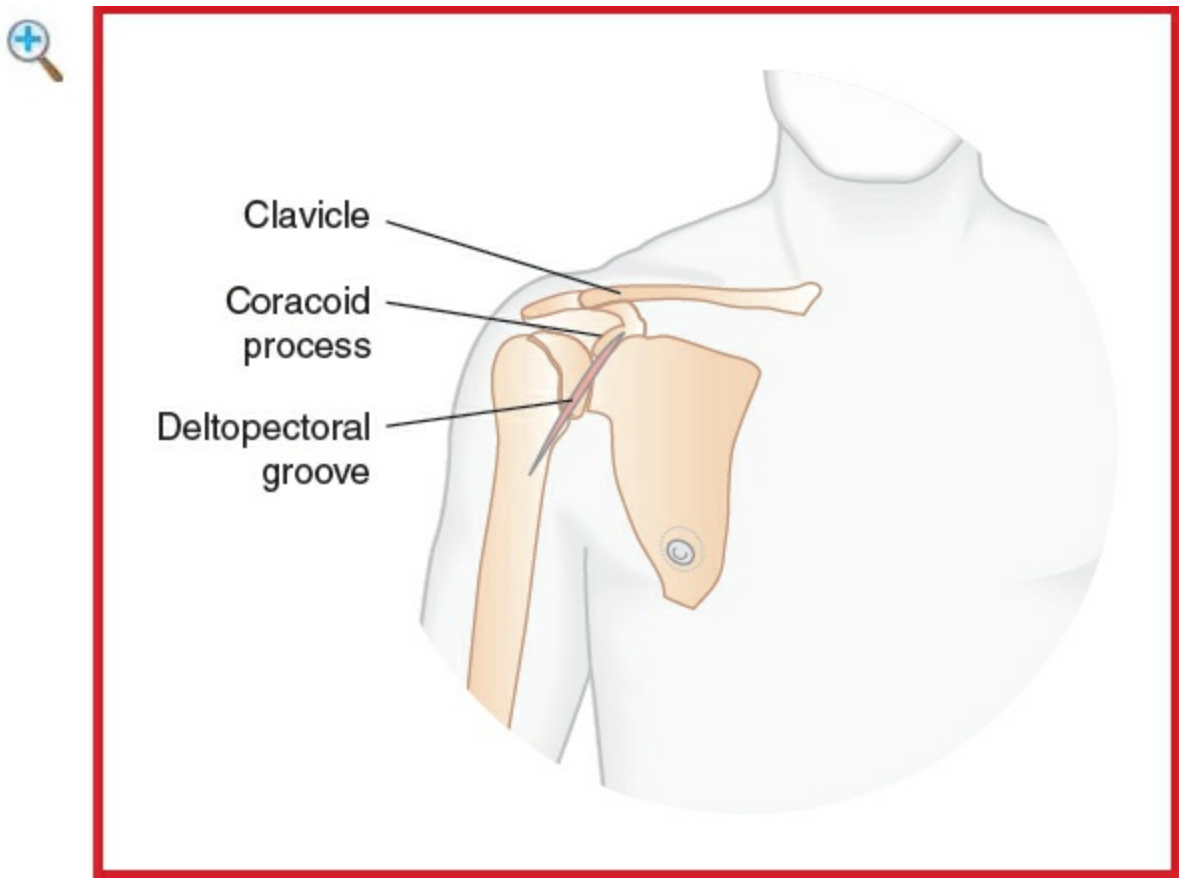

Figure 10.2-5 Incision in the deltopectoral groove. (Reproduced with permission from Hoppenfeld S, de Boer P: Surgical Exposures in Orthopaedics: The Anatomic Approach, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 1994.)

Usual preop diagnosis

Rheumatoid arthritis; posttraumatic arthritis; AVN; RC arthropathy; 4–part proximal humerus fracture

ERAS: **For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plans (see Appendix K, p. K-1).**

SUMMARY OF PROCEDURE

Position	Semisitting, beach chair
Incision	Deltopectoral incision (Fig. 10.2-5) or extended incision for complex revision
Special instrumentation	Glenoid and humeral instrumentation, in addition to usual shoulder instruments; mixing and introduction of cement
Unique considerations	Systemic illnesses of the patient; systemic complications of use of cement in the patient; precautions in pregnant staff working with methyl methacrylate; usage of laminar flow or UV lighting for total joint precautions, depending on the surgeon's preference and capabilities of the OR
Antibiotics	Cefazolin 2 g iv preop, and 48 h postop
Surgical time	2–5 h
Closing considerations	Drain; sling and swathe
EBL	200–1000 mL
Postop care	Immediate passive motion. No active internal rotation for 6 wk
Mortality	<1%
Morbidity	Blood loss Nerve injury: rare ↓ BP 2° cement: rare Infection
Pain score	8

PATIENT POPULATION CHARACTERISTICS

Age range	45–80 yr
Male:Female	1:1
Incidence	Uncommon
Etiology	Osteoarthritis; inflammatory arthritis; trauma; avascular necrosis; systemic disease
Associated conditions	Inflammatory disease; systemic disease; alcoholism; RC pathology; arthritis and radiculopathy; cervical arthritis

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Typically, three patient populations present for shoulder arthroplasty: (a) healthy posttrauma, (b) nonrheumatoid arthritic, and (c) rheumatoid arthritic.

Respiratory	Rheumatoid arthritic patients may exhibit Sx of pleural effusion or pulmonary fibrosis. Hoarseness may indicate cricoarytenoid joint (CAJ) involvement → difficult intubation. (See Anesthetic Considerations for Wrist Procedures.) **Tests:** Consider CXR; PFTs; ABGs in debilitated rheumatoid patients.
Cardiovascular	Rheumatoid arthritic patients may suffer from chronic pericardial effusions, valvular disease, and cardiac conduction defects. **Tests:** Consider ECG and ECHO in patients with severe rheumatoid arthritis.
Neurologic	Arthritic patients may have cervical or lumbar radiculopathies that should be documented carefully preop. For example, head flexion may cause cervical cord compression. **Tests:** C-spine radiographs to r/o occult subluxations in rheumatoid patients with neck complaints or upper extremity radiculopathy
Musculoskeletal	Arthritic patients may have limited neck and jaw

	ROM that may require special intubation techniques. Bony deformities or muscle contracture may necessitate special attention to positioning.
Hematologic	Virtually, all nontrauma patients will be on some type of anti-inflammatory medication that may result in anemia or Plt inhibition. Ideally, patients should d/c NSAIDs at least 5 d preop. Immunosuppressive treatment for RA may ↑ risk of infection.
Endocrine	Rheumatoid patients may be on oral corticosteroids and may require supplemental perioperative steroids (e.g., 100 mg hydrocortisone q8h iv) to treat adrenal suppression, although the routine use of "stress-dose steroids" has been questioned.
Laboratory	Hb/Hct (healthy patients); other tests as indicated from H&P
Premedication	Mild-to-moderate premedication (e.g., in adults, midazolam 1–2 mg iv, fentanyl 50–100 mcg iv, titrated to effect) is often desirable before placement of a regional block.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po, ± celecoxib 200 mg po, ± gabapentin 300 mg po. Consider aprepitant 40 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA or a combination of GETA and regional anesthesia can be used. An interscalene brachial plexus block in combination with GA is excellent for surgical procedures on the shoulder. Unless contraindicated, a long-acting local anesthetic should be used in regional anesthesia for shoulder surgery to ameliorate postop pain.

General anesthesia

Induction	Standard induction. Rheumatoid patients may require awake fiberoptic intubation.

ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Tranexamic acid (e.g., 10–15 mg/kg) iv before incision has been shown to ↓ EBL and may be requested by the surgeon.
Maintenance	Standard maintenance. Avoid N_2O in patients taking methotrexate. Because of the typically long duration of these cases, the opioid selected as part of the balanced anesthetic technique may be given by continuous infusion (e.g., iv sufentanil [0.25–1.0 mcg/kg/h]). Some surgeons prefer muscle relaxation beyond that provided by volatile anesthetic. The surgeon may request reduction in BP: maintain cerebral perfusion pressure.
Emergence	Management of emergence and extubation should be routine except in difficult airway cases that require awake extubation. Emergence from anesthesia should be delayed until patient's shoulder is securely immobilized in the sling and swathe to prevent undesired movement of the newly placed prosthesis. Consider iv acetaminophen if po dose given >6 h ago. PONV prophylaxis should include ondansetron and dexamethasone.

Regional anesthesia

Local anesthetics	Significant discomfort may be associated with this procedure; therefore, extended postop pain control is desirable. When a single-shot technique is used, 0.5% bupivacaine or 0.5% ropivacaine can be used. Onset is usually within 30 min, with duration up to 10–12 h. Ropivacaine may be preferred for peripheral nerve block, due to its decreased cardiotoxicity. For continuous catheter techniques, a postop infusion of 6–8 mL/h of 0.2% of any of these agents is appropriate.
Interscalene block	Typical anesthetics and doses

	0.5% bupivacaine or 0.5% ropivacaine, 20 mL. The skin on the top of the shoulder (C3-C4) and the medial aspect of the upper arm (T2) may require separate subcutaneous field blocks. Phrenic nerve block → hemidiaphragmatic paralysis is an inevitable consequence of the interscalene block, which may not be tolerated by patients with significant preexisting respiratory compromise. A continuous interscalene catheter (tunneled away from the surgical field) may be placed for postop pain management. Major complications, such as total spinal or pneumothorax resulting from interscalene block, are extremely rare. Interscalene block is contraindicated in patients with contralateral recurrent laryngeal nerve or phrenic nerve palsy. If sedation is needed, midazolam (0.5–1.0 mg boluses) and propofol (25–100 mcg/kg/min by infusion), titrated to effect, are good choices.	
Blood and fluid requirements	Moderate-to-significant blood loss IV: 16 ga × 1 BSS @ 1.5–3.0 mL/kg/h	Consider RBC recovery and reinfusion techniques (e.g., Cell Saver) if significant blood loss is anticipated. IV in nonoperative upper extremity. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors	Consider invasive, hemodynamic monitoring in the debilitated or elderly patient.
	Precordial Doppler	Because VAE is a possible complication of the semisitting position, consider using precordial Doppler for cases done in

Positioning	✓ and pad pressure points ✓ eyes ↑ VAE risk	this position. Postural ↓ BP is the most common complication of the semisitting position. Changing patient to this position gradually can help prevent ↓ BP, as can the use of antiembolism stockings and fluid loading the patient. Care with neck positioning. Check head position intraoperatively as shoulder traction may lead to injury.
Interscalene block complications	Total spinal Epidural anesthesia Local anesthetic toxicity (Sz/dysrhythmias) Stellate ganglion block (Horner syndrome) Laryngeal nerve block Phrenic nerve block Pneumothorax	Resuscitative equipment, including airway management tools, should be immediately available.
	Persistent paresthesia	May last ≤6 wk
Other complications	Potential for embolic event ↓ BP during prep and positioning	Because of the increased risk of VAE during shoulder arthroplasty, N_2O may be d/c'd during placement of humeral component. Use of methyl methacrylate cement has been associated with the sudden onset of ↓ BP and even cardiac arrest, presumably due to profound vasodilation ±

		associated VAE. ↓ BP during long surgical prep usually can be avoided by using light inhalation to ensure amnesia, with moderate muscle relaxation to prevent bucking on ETT, and maintaining adequate hydration.

POSTOPERATIVE

Multimodal pain management	PCA or regional block/catheter	Combined regional-general anesthetic techniques are excellent for shoulder procedures, especially for postop pain management. Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics (e.g., continuous nerve block) whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6) Regional analgesia	Encourage early enteral nutrition, Foley catheter removal, and mobilization.
Tests	None indicated routinely	

Suggested Readings

1. Auyong DB, Allen CJ, Pahang JA, et al: Reduced length of hospitalization in primar total knee arthroplasty patients using an updated enhanced recovery after orthopedic surgery (ERAS) pathway. J Arthroplasty 2015; 30(10):1705–9.

2. Bohsali KI, Bois AJ, Wirth MA: Complications of shoulder arthroplasty.J Bone Joint Surg Am 2017; 99(3):256–69.
3. Borgeat A: Acute and nonacute complications associated with interscalene block and shoulder surgery. Anesthesiology 2001; 95(4):875–80.
4. Brolin TJ, Throckmorton TW: Outpatient shoulder arthroplasty.Orthop Clin North Am 2018; 49(1):73–9.
5. Conroy PH, Awad IT: Ultrasound-guided blocks for shoulder surgery. Curr Opin Anaesthesiol 2011; 24(6):638–43.
6. Pohl A, Cullen DJ: Cerebral ischemia during shoulder surgery in the upright position a case series. J Clin Anesth 2005; 17(6):463–9.
7. Singhal K, Rammohan R: Going forward with reverse shoulder arthroplasty.J Clin Orthop Trauma 2018; 9(1):87–93.
8. Weinheimer KT, Smuin DM, Dhawan A: Patient outcomes as a function of shoulder surgeon volume: a systematic review. Arthroscopy 2017; 33(7):1273–81.
9. Zhu S, Qian W, Jiang C, et al: Enhanced recovery after surgery for hip and knee arthroplasty: a systematic review and meta-analysis. Postgrad Med J 2017; 93(1106):736–42.

SHOULDER GIRDLE PROCEDURES

SURGICAL CONSIDERATIONS

Description

Trauma about the shoulder girdle in young patients ranges from athletic injuries to life-threatening trauma. Some of these injuries include common athletic injuries, such as **acromioclavicular joint separations**, which rarely require surgery unless there are associated **acromial** or **clavicular fractures. Posterior sternoclavicular dislocations** may warrant surgical stabilization if the trachea is compressed. **Clavicle fractures**, frequently associated with **scapular fractures**, occasionally require open reduction.

Scapular fractures involving the glenoid also may require surgical stabilization. Extreme fractures involving the shoulder girdle (**scapulothoracic dissociations**) include scapular fracture, clavicle fracture, subclavian or axillary artery disruption, and brachial plexus injury. These may coexist with **proximal humerus fractures,** rib fractures, and pneumothorax. In the older, debilitated patient, the most common injury is proximal humeral fracture, which may be amenable to surgical stabilization or may be so comminuted as to warrant hemiarthroplasty.

A displaced proximal humerus fracture may require open reduction internal fixation

with a plate and screws or hemiarthroplasty through a deltopectoral approach utilizing a beach chair position (see Surgery for Shoulder Instability, and Glenohumeral Shoulder Arthroplasty). A displaced clavicle fracture may require open reduction internal fixation with a plate and screws utilizing a beach chair or supine position. A scapular body fracture would be stabilized with a plate and screws via a posterior approach utilizing a prone or lateral position (see Surgery for Shoulder Instability). As with other shoulder procedures, relaxation is necessary upon awakening the patient after the shoulder is placed into an immobilization device.

Usual preop diagnosis

Trauma about the shoulder girdle

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plans (see Appendix K, p. K-1).

SUMMARY OF PROCEDURES

	Anterior	Posterior
Position	Semisitting or prone	Lateral decubitus (scapula)
Incision	Anterior, superior, or oblique for acromioclavicular; supraclavicular for clavicle; deltopectoral for proximal humerus and glenoid	Posterior lateral border or medial border of scapula, spinous scapula, depending on location
Special instrumentation	Plates and screws; tension band wiring; proximal humerus replacement for comminuted fractures	⇐
Unique considerations	Multiple traumas warrant early stabilization; may require vascular repair and brachial plexus exploration	⇐

Antibiotics	Cefazolin 2 g iv	⇐
Surgical time	2–10 h	⇐
Closing considerations	Fracture dependent; most commonly requires application of sling and swathe	⇐
EBL	200–1200 mL or greater, depending on trauma	⇐
Postop care	May require ICU for multiple-trauma patients; otherwise, early mobilization with physical therapy	⇐
Mortality	Mortality dependent on associated conditions: Infection Neurologic injury Respiratory failure Massive blood loss Unrecognized pneumothorax Cardiac tamponade	⇐
Morbidity	Nerve injury (axillary, brachial plexus) Stiffness Poor healing	Axillary and suprascapular ⇐ ⇐
Pain score	6–10	6 (clavicle and AC joint) 8 (scapula and proximal humerus)

PATIENT POPULATION CHARACTERISTICS

Age range	15–80 yr, depending on nature of trauma
Male:Female	5:1

Incidence	Common
Etiology	Trauma
Associated conditions	Axillary nerve palsy; musculocutaneous nerve palsy; brachial plexus injury; arterial disruption in high-energy trauma; brachial and great vessel injuries and posterior sternoclavicular dislocation; pneumothorax

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Brachial Plexus Surgery.

Suggested Readings

1. Cole PA, Gauger EM, Schroder LK: Management of scapular fracturesJ Am Acad Orthop Surg 2012; 20(3):130–41.
2. Pandya NK, Namdari S, Hosalkar HS: Displaced clavicle fractures in adolescents facts, controversies, and current trends. J Am Acad Orthop Surg 2012; 20(8):498–505.

BRACHIAL PLEXUS SURGERY

SURGICAL CONSIDERATIONS

Description

Brachial plexus injuries occur most commonly in two groups: traumatic birth injuries and high-energy trauma. Surgery ranges from exploration with neurolysis, to repairs, to cable nerve grafting. Typically, the latter requires grafting with the sural nerve and nerve pedicle transfer, such as transfer of the spinal accessory nerve to denervated paralyzed muscle, combined with muscle transfers. C5-C6 is most commonly injured in obstetrical (Erb) palsy. Injuries in adults are more commonly closed traction. Similar to obstetrical palsy, they occur with an outstretched, abducted arm with the neck rotated in the opposite direction. The most severe form includes complete avulsion at the preganglionic level, presenting with a Horner syndrome, winging of the scapula, and a flail arm. These are typically “supraclavicular” injuries and have a poorer prognosis. Surgical exposure may proceed above the clavicle similar to an anterior neck dissection or may require an extension below the clavicle. Occasionally, an osteotomy of the clavicle for extensive dissection is required. For axillary nerve dissection, a posterior approach also is used. Open injuries, such as gunshot or knife wounds, are typically

"infraclavicular" and have a better prognosis. (See diagram of brachial plexus, Fig. 10.2-6.)

Usual preop diagnosis

Obstetrical palsy; adult trauma—most commonly motorcycle accident

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plans (see Appendix K, p. K-1).

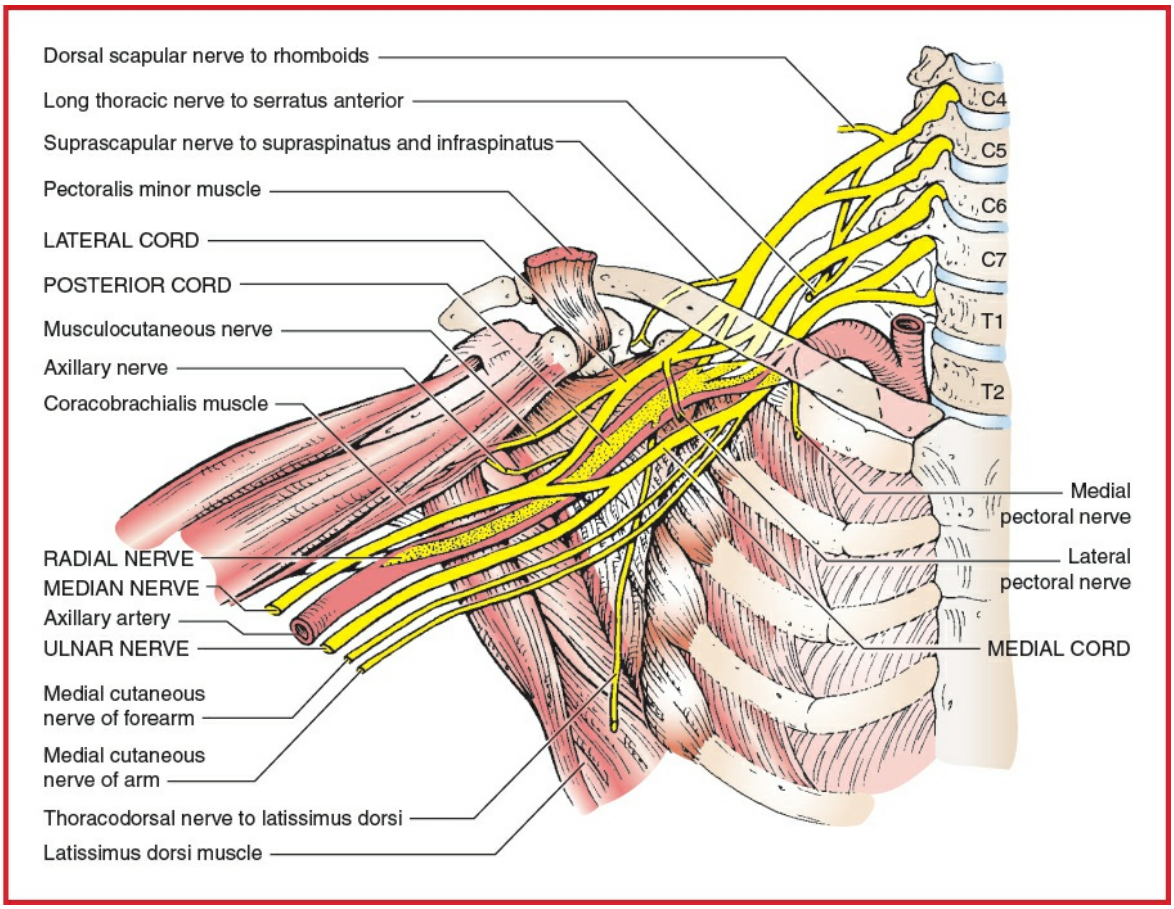

Figure 10.2-6 Brachial plexus: Its division into supraclavicular and infraclavicular portions is apparent. The proximal origin of the dorsal scapular nerve and the long thoracic nerve are demonstrated. The T1 spinal nerve arises below the head of the 1st rib. The relation of the cords of the plexus to the axillary artery at the level of the coracoid process (origin of the pectoralis minor and coracobrachialis muscles) is illustrated. The posterior cord and the radial nerve behind the axillary artery are stippled for clarity. (Reproduced with permission from Tindall GT, Cooper PR, Barrow DL:The Practice of Neurosurgery, Vol. III. Williams & Wilkins, Baltimore: 1996.)

SUMMARY OF PROCEDURE

Position	Lateral decubitus or semisitting

Incision	Supra- or infraclavicular, extensile to include deltopectoral incision. Clavicle osteotomy incision will provide for improved exposure. Supraclavicular incision used for supraclavicular brachial plexus
Special instrumentation	Nerve stimulator
Unique considerations	Associated trauma
Antibiotics	Cefazolin 2 g iv preop
Surgical time	4–10 h
Closing considerations	Other incisions if nerve grafts obtained
EBL	400–2000 mL
Mortality	Minimal
Morbidity	Bleeding Hematoma Pneumothorax Clavicular nonunion
Pain score	8

■ PATIENT POPULATION CHARACTERISTICS	
Age range	Infants and children: 3 mo to 8 yr; adults: 20–40 yr
Male:Female	Adult: 5:1
Incidence	Infants: 0.3–8/1000 births; adults: commonly associated with motorcycle accidents
Etiology	Obstetrical palsy; trauma
Associated conditions	None known

Suggested Reading

1. Kaiser R, Waldauf P, Ullas G, et al: Epidemiology, etiology, and types of severe

adult brachial plexus injuries requiring surgical repair: systematic review and meta-analysis. Neurosurg Rev 2018.

ANESTHETIC CONSIDERATIONS

(Procedures covered: shoulder girdle procedures; brachial plexus surgery)

PREOPERATIVE

With the exception of traumatic birth injuries, most of these patients are healthy males who have suffered major blunt or penetrating trauma. For the acute and subacute trauma victim, the major anesthesia-related concerns center on associated traumatic injuries. Many adult trauma victims with brachial plexus injuries will be operated on in the first few days after their injury. For infants (usually operated on at 6–12 mo), the major anesthesia-related concerns are those routinely associated with pediatric anesthesia. Approximately half of all trauma victims are intoxicated. The anesthesia-related implications of ethanol intoxication include decreased anesthetic requirements, diuresis, vasodilation, and hypothermia.

Respiratory	As suggested by coexisting disease or acute trauma injuries. Look for evidence of occult chest injury, including pneumothorax (tachypnea, wheezing, ↓ BP, ↓ PaO_2, CXR changes) and pulmonary contusion (multiple rib fracture, ↓ PaO_2). **Tests:** Consider CXR and ABGs in victims of significant trauma; other tests as indicated from H&P
Cardiovascular	As suggested by coexisting disease or acute trauma injuries. Look for evidence of occult cardiac or mediastinal injuries, such as myocardial contusion (e.g., ECG abnormalities typically consistent with ischemia) or great vessel rupture (e.g., widened mediastinum). **Tests:** Consider CXR (with NG tube in place to assess mediastinal widening) and ECG in victims of significant trauma; others as indicated from H&P
Neurologic	Victims of shoulder trauma are vulnerable to brachial plexus damage. Look for evidence of upper extremity nerve dysfunction and document any injuries preop.

	The possibility of closed-head injury also should be considered. **Tests:** Head CT prior to beginning a procedure under GA in a patient with evidence of head trauma
Musculoskeletal	As suggested by coexisting disease or acute trauma injuries. The amount of force necessary to produce a brachial plexus injury mandates a C-spine series to r/o C-spine fracture in all victims of brachial plexus trauma.
Laboratory	In general, most victims of significant trauma are best served by obtaining a wide variety of baseline lab studies to screen for unrecognized injury. These studies generally should include Hct, CBC, ABGs, UA, renal function tests, LFTs, and serum amylase.
Premedication	None
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po, ± celecoxib 200 mg po, ± gabapentin 300 mg po. Consider aprepitant 40 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA is preferred over regional techniques because of the unpredictable and prolonged length of these procedures and the need to evaluate brachial plexus function postop.

Induction	Rapid-sequence induction is mandatory in unscheduled cases, unless awake fiberoptic intubation is performed (see Anesthetic Considerations for Thoracolumbar Neurosurgical Procedures). C-spine fracture patients or those with facial injuries may require awake fiberoptic intubation or other special airway techniques, as indicated from H&P. Hemodynamically unstable, acute trauma patients can be induced more safely

	with etomidate (0.3–0.4 mg/kg iv) or ketamine (1–3 mg/kg iv).	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Tranexamic acid (e.g., 10–15 mg/kg) iv before incision has been shown to ↓ EBL and may be requested by the surgeon.	
Maintenance	Balanced anesthesia with low-dose sevoflurane, iv fentanyl, and N_2O in O_2 is suitable for stable patients. Hemodynamically unstable, acute trauma victims undergoing emergency surgery are not likely to tolerate this regimen and are better served by using a combination of medications designed to have minimal hemodynamic consequences (e.g., fentanyl for analgesia, rocuronium for muscle relaxation, and scopolamine or midazolam for amnesia). N_2O is best avoided in the trauma patient. For brachial plexus surgery, some surgeons prefer minimal muscle relaxation after tracheal intubation so that a nerve stimulator can be used to help identify surgical anatomy.	
Emergence	Management of emergence and extubation should be routine except in difficult airway or full-stomach cases, which require that extubation be delayed until the patient's airway reflexes have returned and the patient is fully awake. Consider iv acetaminophen if po dose given >6 h ago. PONV prophylaxis should include ondansetron and dexamethasone.	
Blood and fluid requirements	Significant blood loss IV: 14–16 ga × 1–2 BSS @ 1.5–3 mL/kg/h + replacement of blood loss @ 3 × volume Fluid warmer Airway humidifier	IV catheter placed in the nonoperative upper extremity is usually adequate in hemodynamically stable patients. Unstable, acute trauma victims require a minimum of 2 large-bore iv catheters or large-bore

		central lines. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors. ± SSEP ± TEE	Invasive hemodynamic monitoring and TEE should be considered in acute, multiple-trauma victims. Some surgeons request SSEP to make continuous assessment of preop intact brachial plexus possible. When using SSEP monitoring, high doses of volatile anesthetic agents should be avoided because they adversely affect SSEP readings.
Positioning	✓ and pad pressure points ✓ eyes VAE risk	Postural ↓ BP is the most common complication of the semisitting position, particularly during the surgical prep period. SCD or antiembolism stockings may be beneficial. VAE is a potential complication of this position.
Complications	Hemodynamic instability	Previously unrecognized injuries (e.g., pneumothorax, cardiac tamponade, intracranial bleeding) should be considered as a cause of unexplained intraop hemodynamic instability in all acute trauma

	Possible VAE	victims. VAE risk is increased with patient in semisitting position.

POSTOPERATIVE

Complications	Sepsis ARDS	Many trauma victims survive the initial insult and subsequently develop sepsis or ARDS.
Multimodal pain management	PCA	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics (e.g., continuous nerve block) whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6) Regional analgesia	Encourage early enteral nutrition, Foley catheter removal, and mobilization.
Tests	Based on concurrent injuries	

Suggested Readings

1. Auyong DB, Allen CJ, Pahang JA, et al: Reduced length of hospitalization in primar total knee arthroplasty patients using an updated enhanced recovery after orthopedic surgery (ERAS) pathway. J Arthroplasty 2015; 30(10):1705–9.
2. Cao X, Pan F: Comparison of liposomal bupivacaine infiltration versus interscalene nerve block for pain control in total shoulder arthroplasty: a meta-analysis of randomized control trials. Medicine (Baltimore) 2017; 96(39):e8079.
3. Codding JL, Getz CL: Pain management strategies in shoulder arthroplasty.Orthop Clin North Am 2018; 49(1):81–91.
4. Koshy JC, Agrawal NA, Seruya M: Nerve transfer versus interpositional nerve graf reconstruction for posttraumatic, isolated axillary nerve injuries: a systematic

review. Plast Reconstr Surg 2017; 140(5):953–60.
5. Lee SK, Wolfe SW: Nerve transfers for the upper extremity: new horizons in nerve reconstruction. J Am Acad Orthop Surg 2012; 20(8):506–17.
6. Popinchalk SP, Schaffer AA: Physical examination of upper extremity compressive neuropathies. Orthop Clin North Am 2012; 43(4):417–30.
7. Zhu S, Qian W, Jiang C, et al: Enhanced recovery after surgery for hip and knee arthroplasty: a systematic review and meta-analysis. Postgrad Med J 2017; 93(1106):736–42.

ARM SURGERY

SURGICAL CONSIDERATIONS

Description

Surgical procedures on the arm are primarily for trauma or tumor surgery. Other procedures include extended approaches from the shoulder for significant trauma or tendon transfer. Exploration of peripheral nerves, most commonly of the radial nerve, is also included in this category, as are distal extensile approaches from the elbow for trauma or for lateral epicondylitis ("tennis elbow"). Depending on the lesion or fracture, the incision is developed through an internervous or intramuscular compartment. Procedures include **excisional biopsy** for soft tissue or bone tumors of the arm; **tumor excision,** which may be marginal, wide, or radical, depending on the tumor encountered; **tendon transfers**, such as pectoralis transfer to replace biceps function, used primarily for brachial plexus injuries; and **fractures and nonunion fractures of the humerus**. Positioning and location of incision are dependent on the level of the pathology. For example, for fractures involving the proximal half of the humerus, the standard **deltopectoral incision** may be extended distally along the interval between the biceps and triceps on the lateral aspect of the arm. This approach requires a beach chair (Fig. 10.2-7) or, occasionally, supine position. Distal third fractures are best approached posteriorly with the **triceps-splitting approach**. Distal fractures that extend into the elbow joint often require an olecranon osteotomy to visualize the fractured joint surface. Posterior approaches to the distal humerus are performed in either the lateral or prone position.

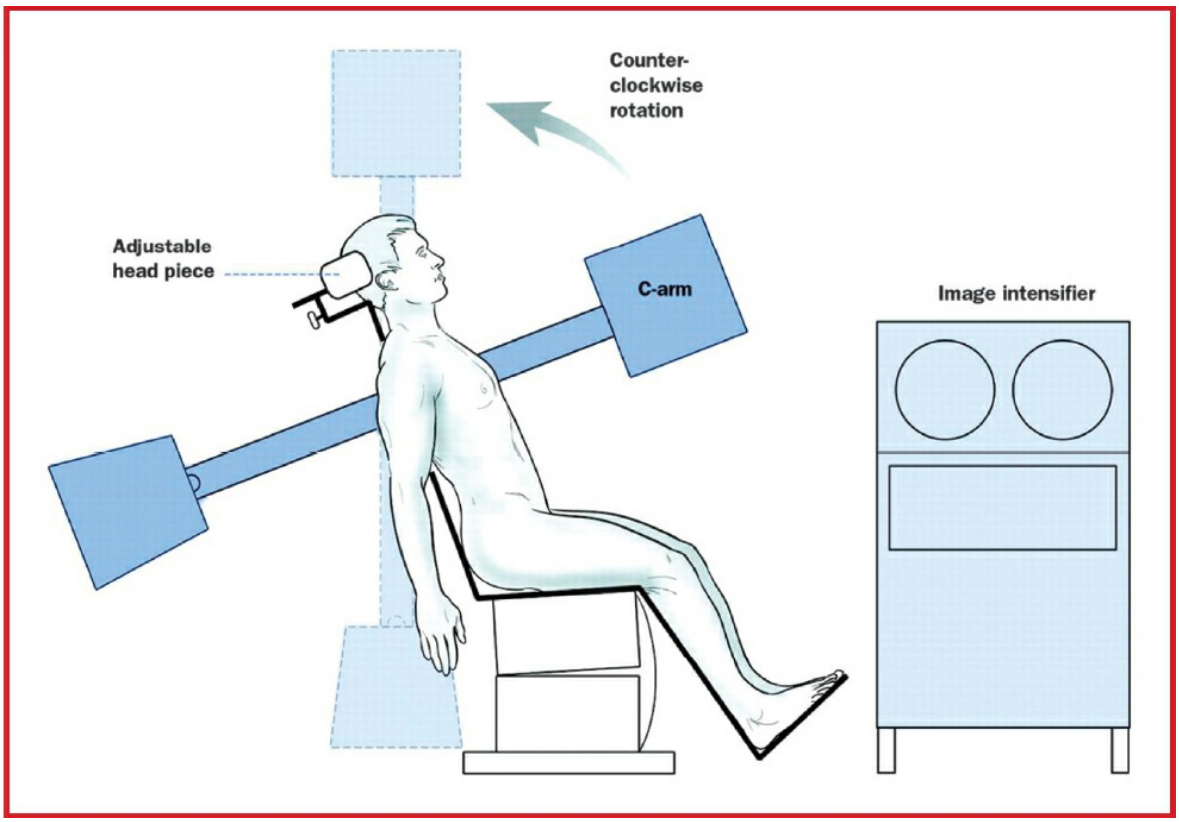

Figure 10.2-7 Beach chair positioning for shoulder surgery. Image intensification may be needed for intraoperative radiography (e.g., fracture surgery). (Reproduced by permission from Robinson CM, Page RS: Severely impacted valgus proximal humerus fractures. J Bone Joint Surg 2004; 86A:143–55.)

Usual preop diagnosis

Trauma; tumor

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plans (see Appendix K, p. K-1).

SUMMARY OF PROCEDURE	
Position	Supine; semisitting position for extended deltopectoral; lateral decubitus or prone for distal humerus fractures
Incision	Anterolateral approach; posterior approach in the lateral decubitus or prone position
Special instrumentation	Plate and screws; external fixators; intramedullary rods; occasionally, methyl methacrylate cement for

	tumor surgery; sterile tourniquet for distal humerus; I.I. for fracture surgery
Unique considerations	CT-guided sclerotherapy preop for vascular tumors; longitudinal incisions for biopsy and tumor excisions (not violating fascial planes)
Antibiotics	Cefazolin 2 g iv preop
Surgical time	45 min to 6 h
Closing considerations	Drain frequently required
EBL	Minimal—500+ mL, depending on pathology
Mortality	Varies with pathology
Morbidity	Bleeding Shoulder stiffness Nerve injury
Pain score	4–9

PATIENT POPULATION CHARACTERISTICS	
Age range	Often relatively young
Male:Female	M > F
Incidence	Etiology dependent
Etiology	Fractures; nerve entrapment (radial) following trauma; tumors
Associated conditions	Radial or ulnar nerve injury with humeral fractures

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients presenting for arm procedures are often relatively young and otherwise healthy. Most of these patients present for elective repair of a traumatic injury. The preop workup is appropriate to patient's medical history. Some arm procedures, such as repair of a compound fracture, require immediate attention and necessitate emergency

surgery and full-stomach considerations.

Laboratory	Hb/Hct (healthy patients); other tests as indicated from H&P
Premedication	Mild-to-moderate premedication (e.g., in adults, midazolam 1–2 mg iv, fentanyl 50–100 mcg iv, titrated to effect) is often desirable before placement of a regional block.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po, ± celecoxib 200 mg po, ± gabapentin 300 mg po. Consider aprepitant 40 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GA or regional anesthesia, or a combination of the two, can be used for surgical procedures on the arm. A brachial plexus block via the supraclavicular, infraclavicular, or axillary approach is excellent for procedures on the distal arm. The interscalene approach to the brachial plexus is suitable for more proximal humerus procedures. Regional anesthesia alone is a means of avoiding the risk of aspiration pneumonitis associated with GA in the patient with a full stomach requiring emergent surgery. Procedures longer than 3 h usually require general anesthesia in addition to regional. Regional anesthesia with sedation is usually well tolerated in shorter procedures.

General anesthesia

Induction	Standard induction except in acute trauma patients, where rapid-sequence induction is appropriate
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance
Emergence	Management of emergence and extubation should be routine, except in difficult airway cases, which

	require awake extubation. Skin closure is frequently followed by application of a splint; patient should remain anesthetized during splinting procedure. Consider iv acetaminophen if po dose given >6 h ago. PONV prophylaxis should include ondansetron and dexamethasone.

Regional anesthesia

Local anesthetics	2% lidocaine or 1.5% mepivacaine have similar onset times (10–15 min) and similar duration (4–6 h). If extended postop pain control is desired, 0.5% bupivacaine or ropivacaine can be used. Onset is usually within 30 min, with duration of 8–12 h. If GA is planned, 0.25% ropivacaine or bupivacaine is sufficient.
Brachial plexus block	For proximal humerus surgery, an interscalene block is indicated with a catheter for postop pain management. Supraclavicular, infraclavicular, and axillary approaches are all suitable for more distal surgery. Supraclavicular or infraclavicular blocks are better tolerated in fracture patients, because the arm need not be moved. Ultrasound guidance can improve speed and comfort during block placement. A peripheral nerve catheter (infraclavicular approach) may be placed to prolong pain relief in appropriate patients. • 2% lidocaine or 1.5% mepivacaine 30 mL for procedures lasting ≤2.5 h • 0.5% bupivacaine or ropivacaine 30 mL for procedures lasting >2.5 h If sedation is needed, midazolam (0.5–1.0 mg boluses) or propofol (25–100 mcg/kg/min by infusion), titrated to effect, are good choices. Sensation to the skin of the upper inner arm is supplied by the intercostobrachial nerve (T2), which must be blocked separately.

Suggested Viewing

Links are available online to the following videos:

Shoulder Arthroscopy, Removal of Bone Spur (Subacromial Decompression): https://www.youtube.com/watch?v=NF1s1MYim30

Brachial Plexus—Structure and Location—3D Anatomy Tutorial: https://www.youtube.com/watch?v=hrKesc_XSzo

Ultrasound-Guided Interscalene Brachial Plexus Nerve Block: https://www.youtube.com/watch?v=Dg9BJ-32yLc

Ultrasound-Guided Infraclavicular Brachial Plexus Nerve Block: https://www.youtube.com/watch?v=hRyDtXrfYqc

Ultrasound-Guided Supraclavicular Brachial Plexus Nerve Block: https://www.youtube.com/watch?v=ztOIvfjsB-U

CHAPTER 10.3

Spine Surgery

SURGEONS
Ivan Cheng, MD
Alexander H. Arzeno, MD

ANESTHESIOLOGISTS
Karl Zheng, MD
C. Philip Larson Jr., MD, CM

MINIMALLY INVASIVE POSTERIOR LUMBAR DISCECTOMY (MICRODISCECTOMY)

SURGICAL CONSIDERATIONS

Description

Since the mid-1990s, a number of techniques have been developed to allow the decompression of lumbar roots (removal of disc material) with as little trauma to the nerves and surrounding tissues as possible. In most instances, little or no bone is removed, and therefore, this is not technically a laminectomy or laminotomy. These minimally invasive procedures typically are carried out in healthy young or middle-aged adults with sciatica and are not done for more involved pathology, such as deformity, tumor, or infection. Transpedicular fixation and short-segment fusions may be attempted using modifications of these techniques.

Microdiscectomy approach

This can be done under general, regional (epidural or spinal), or local anesthesia. The patient is placed in a prone or kneeling position, and the posterior landmarks are palpated to identify the approximate level (e.g., L4-L5); then the overlying skin is

infiltrated with local anesthetic. A spinal needle is placed to the level of the lamina, and an x-ray or fluoroscopic image is taken to confirm the level. A 1-inch incision is made over the proposed interspace, and using either traditional or specialized retractors, the soft tissue is displaced to expose the ligamentum flavum. With the use of an operating microscope, the ligamentum flavum is removed, the nerve retracted, and the extruded disc excised. For a single level, this should take between 30 and 90 min, depending on the size of the patient and whether there is any scarring or adhesions from previous surgery.

Variant approach

Percutaneous discectomy through a posterolateral approach is usually reserved for "contained discs"—protrusions into, but not through, the outer annulus of the disc. These are usually done under MAC with local anesthetic. The percutaneous instruments may be positioned using fluoroscopic guidance with or without a fiberoptic light source and camera/monitor setup. The disc space is entered posterolaterally. The surgeon usually avoids anesthetizing the area around the nerve root so that the patient can alert the team if the root is struck by an instrument (quite painful). After the disc space is entered, fluoroscopic or camera images are used to guide the surgeon in the removal of the herniated disc. The disc material can be removed with specialized grabbers or automatic power-driven shavers.

Usual preop diagnosis

Chronic back pain 2° herniated lumbar disc; lumbar radiculopathy

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include continuing chronic pain meds, limiting NPO duration, alcohol and smoking cessation, review of nutritional status, carb loading, and postop pain management options. See Appendix K: Enhanced Recovery After Surgery, p. K-1.

SUMMARY OF PROCEDURES

	Microdiscectomy	Percutaneous Discectomy
Position	Prone or kneeling, with bolster or frame support. The abdomen must hang free to decompress the epidural veins.	Prone or lateral decubitus
Incision	Posterior midline or	About 8–12 cm lateral to

	slightly off midline, at the appropriate vertebral level	the midline at the appropriate vertebral level
Special instrumentation	Microscope; light source; specialized retraction and dissection instruments for working in a small, deep incision	Percutaneous instruments, including trocars, sounds, and arthroscopic-type grabbers and shavers; fluoroscopy; and, sometimes, camera/monitor and fiberoptic light setup
Unique considerations	Often outpatient procedure. Need to make room for microscope at head of bed	Patient must be alert enough to respond to pain if nerve roots are encountered.
Antibiotics	Cefazolin 2 g iv	⇐
Surgical time	0.5–1.5 h	1–2 h
Closing considerations	Minimal suturing	Usually no closure (Band-Aids)
EBL	25–100 mL	Minimal
Postop care	PACU. Mobilization as soon as tolerated Usually discharged within 24 h	PACU → home. Mobilization as tolerated
Mortality	Very rare	⇐
Morbidity	Nerve injury Dural laceration Infection	Failure to decompress the nerve adequately – ⇐
Pain score	4	2

■ PATIENT POPULATION CHARACTERISTICS	
Age range	16–60 yr
Male:Female	3:2

Incidence	Common
Etiology	Degenerative; trauma (rare)

MINIMALLY INVASIVE ANTERIOR LUMBAR INTERBODY FUSION THROUGH A TRANSPSOAS APPROACH

SURGICAL CONSIDERATIONS

Description

Traditional open techniques of lumbar fusion have shown long-term clinical efficacy. However, the morbidity of the approach, extensive blood loss, and length of postop recovery can offset the benefits of the intervention. Recently, minimally invasive techniques have decreased morbidity. One approach involves lateral approach via a small incision through retroperitoneal fat and the psoas major muscle for access to the lateral lumbar spine with the aid of neuromonitoring to avoid nerves of the lumbar plexus.

The orientation of neural structures of the lumbar plexus has a relatively high level of variability, necessitating the use of neuromonitoring for this approach. After induction of GETA, the surgeon places needle electrodes into muscles of the bilateral lower extremities to record the EMG response to lumbar nerve stimulation. The EMG threshold is the current (mA) required to stimulate the nerve, producing a muscle contraction. Direct nerve stimulation studies have shown that normal nerves elicit an EMG response with an average of 2 mA. Neuromuscular blockade should be avoided and the use of TIVA is encouraged. If neuromuscular blockade is required for intubation, succinylcholine should be used. If rocuronium is used, it is imperative that sugammadex be available for rapid reversal to permit adequate EMG monitoring. In either situation, use of a paralytic should be discussed with the surgeon and adequate reversal confirmed prior to the start of the procedure.

The patient is positioned in the lateral decubitus position and held in position with straps and tape. The arms should remain in a neutral position, and an axillary roll is placed just inferior to the axilla to support the area of the upper rib cage to relieve pressure on the axillary nerve and artery. The table is typically flexed to increase the distance between the iliac crest and the rib cage to gain access to the lateral lumbar

spine. Fluoroscopic imaging is required to determine true anterior/posterior and lateral axes of the desired spinal level. After the patient has been prepped and draped, an incision is made posteriorly at the border between the erector spinae muscles and the abdominal obliques to accommodate the surgeon's index finger and help identify the retroperitoneal space. With care, perforation of the peritoneum is avoided, and the finger is used to sweep this anteriorly. After identifying the psoas muscle, the index finger is swept up to a previously marked direct lateral target over the center of the affected intervertebral segment. An incision is made on the patient's side, through which dilators are placed, and the index finger is used to escort them safely to the psoas muscle, all while protecting the intra-abdominal contents (see Fig. 10.3-1). Careful passage of the dilators and EMG neuromonitoring avoid injury to the lumbar plexus. Once the self-retaining retractor system is positioned, care is taken to determine the course of the lumbar plexus in relation to the blades of the retractor. Once the retractor is positioned over the disc space, under direct vision, a discectomy is performed. Care is taken not to disrupt the anterior longitudinal ligament and risk injury to the main vascular structures coursing anteriorly.

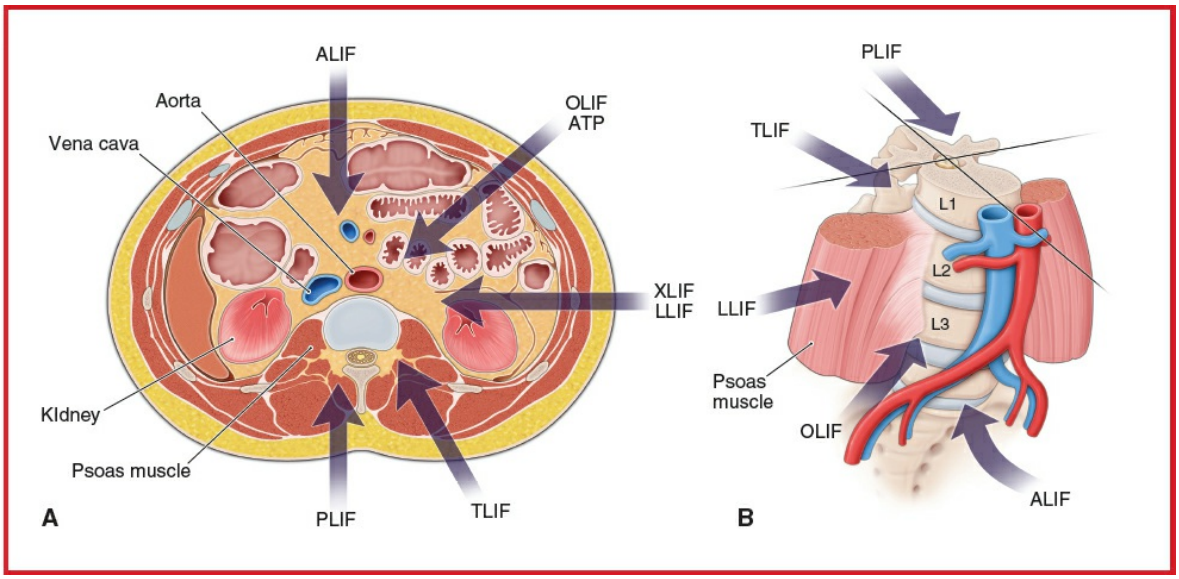

Figure 10.3-1 A and B: Surgical approaches to the lumbar spine for interbody fusion. ALIF, anterior lumbar interbody fusion; LLIF or XLIF, lateral or extreme lateral lumbar interbody fusion; OLIF/ATP, oblique lumbar interbody fusion/anterior to psoas; TLIF, transforaminal lumbar interbody fusion; PLIF, posterior lumbar interbody fusion.

Usual preop diagnosis

Chronic back pain; lumbar radiculopathy

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include continuing chronic pain meds, limiting NPO duration, alcohol and smoking

cessation, carb loading, postop pain management options, and possibility of urinary catheter postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Lateral decubitus with axillary roll. Table flexed
Incision	Posterior border between erector spinae and abdominal oblique muscles
Special instrumentation	Fluoroscopic imaging
Unique considerations	EMG monitoring: avoid muscle relaxation
Antibiotics	Cefazolin 2 g iv
Surgical time	2–3 h
Closing considerations	Minimal suturing
EBL	20–100 mL
Postop care	PACU. Mobilization as tolerated. Usually discharged within 24 h
Mortality	Rare
Morbidity	Reported complication rates: 6.2–52% Iliopsoas weakness Anterior thigh numbness Quadriceps weakness Radiculopathy Foot drop Durotomy
Pain score	4–5

PATIENT POPULATION CHARACTERISTICS	
Age range	30–80 yr
Male:Female	3:2
Incidence	Increasingly common

Etiology	Degenerative

Suggested Readings

1. Adamus M, Hrabalek L, Wanek T, et al: Intraoperative reversal of neuromuscular block with sugammadex or neostigmine during extreme lateral interbody fusion, a novel technique for spine surgery. J Anesth 2011; 25(5):716–20.
2. Arnold PM, Anderson KK, McGuire RA Jr: The lateral transpsoas approach to the lumbar and thoracic spine: a review. Surg Neurol Int 2012; 3(Suppl 3):S198–215.
3. Rodgers WB, Gerber EJ, Patterson J: Intraoperative and early postoperative complications in extreme lateral interbody fusion: an analysis of 600 cases. Spine (Phila PA 1976) 2011; 36(1):26–32.
4. Tohmeh AG, Rodgers WB, Peterson MD: Dynamically evoked, discrete-threshold electromyography in the extreme lateral interbody fusion approach. J Neurosurg Spine 2011; 14(1):31–7.
5. Xu DS, Walker CT, Godzik J, et al: Minimally invasive anterior, lateral, and oblique lumbar interbody fusion: a literature review. Ann Transl Med 2018; 6(6):104.

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients undergoing minimally invasive spine procedures are no more likely than the general population to have any specific comorbidity; they require normal preop evaluation.

Musculoskeletal	Because these patients may have chronic back pain with radiculopathy, they may not be suitable candidates for regional anesthetic techniques. Postop exacerbation of symptoms may be incorrectly ascribed to the anesthetic technique. A careful motor and sensory evaluation of the lower extremities should be documented. Patients commonly taking centrally acting analgesics or narcotics may require higher doses of sedative-hypnotics and analgesics in the periop period.
Hematologic	Patients should stop taking aspirin or NSAIDs at least 1 wk before surgery. In addition, an INR or PT and PTT should be checked preop in the presence of anticoagulation or liver disease.

	Tests: Hct; Plt; INR
Laboratory	Other tests as indicated from H&P
Premedication	Standard premedication
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon possible use of po celecoxib 400 mg po as a component of postop pain management. Consider preop acetaminophen 1000 mg po and, for patients with h/o severe PONV, aprepitant 40 mg po.

INTRAOPERATIVE

Anesthetic technique

Minimally invasive spine procedures are commonly done under GA; however, local or regional anesthetic techniques are suitable in selected patients. Percutaneous discectomies may require only MAC with sedation. These patients must be awake to alert the surgeon to inadvertent nerve root contact. In some centers, regional anesthesia (spinal or epidural) is the anesthetic of choice for elective uncomplicated spine surgery.

General anesthesia

Induction	Standard induction. Consider using wire-reinforced ETT to prevent kinking, with patient in prone position.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Dexamethasone (4–8 mg iv) may ↓ PONV. Sequential pneumatic compression devices should be used to ↓ VTE risk. Consider ketamine (0.25 mg/kg/h) and/or lidocaine (1–2 mg/kg/h) infusions as components of MMPM especially in chronic pain patients.
Maintenance	Standard maintenance. Usually 1- to 2-h operation. After exposure, further muscle relaxant use is unnecessary.
Emergence	No special considerations. Suggest wound infiltration

	with LA. Consider iv hydromorphone (0.2–0.6 mg iv).
MAC	

Regional anesthesia

Although theoretically advantageous, regional anesthesia is not commonly used for spinal surgery.

Spinal	Patient in sitting, lateral decubitus, or prone position for placement of subarachnoid block. Doses of local anesthetics should be adequate to provide a high lumbar level of sensory anesthesia (e.g., bupivacaine 6–10 mg with fentanyl 10 mcg).	
Epidural	Patient in sitting or lateral decubitus position for placement of epidural catheter. A test dose (e.g., 3 mL of 1.5% lidocaine with 1:200,000 epinephrine [5 mcg/mL]) is administered, and the patient is observed for development of subarachnoid block or Sx of an intravascular injection. Titrate lidocaine 2% with epinephrine (3–5 mL at a time) until desired surgical level is obtained.	
Blood and fluid requirements	IV: 18–20 ga × 1 BSS @ 5 mL/kg/h	Blood not likely to be required. Zero balance or Goal-Directed Fluid Management is recommended.
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points	Lateral position: use axillary roll Prone position: Jackson table, Wilson frame, or bolsters to support shoulders/hips and optimize ventilation Knee-chest position: Andrews table

✓ **eyes**	Place head in cushioned holder with cutout for eyes, nose, and chin (e.g., ProneView®). Make certain eyes, nose, and chin are free and clear. Ensure that there is no posterior pressure on the ET tube, as this may result in injury to the uvula or soft palate. Pad elbows, knees, and other pressure points. Limit both upper arm abduction and elbow extension to <90°.

POSTOPERATIVE

Complications	Urinary retention in the older patient	Rx: Consider catheterization.
	Transient numbness/paresthesias, weakness	Due to nerve root irritation from operation. Rx with analgesics and/or muscle relaxants methocarbamol, cyclobenzaprine
Multimodal pain management	PCA	PO analgesics may be suitable: acetaminophen and codeine (Tylenol no. 3 1–2 tab q4–6 h) or oxycodone and acetaminophen (Percocet 1 tab q6h)
	Epidural analgesia	Dose prior to the removal of an epidural catheter at the end of the case if it is already in place
	Acetaminophen 1 g iv ± Fentanyl 25–50 mcg prn ± Ketorolac (30 mg iv) or celecoxib (200 mg po)	If not given preop Consult with surgeon regarding possible hemostasis concern with NSAIDs.
ERAS	Ondansetron 4 mg iv. ± Metoclopramide 10–20	Encourage early enteral nutrition, Foley catheter

	mg iv	removal, and mobilization with physiotherapy.
Tests	As indicated by patient status	Patient usually discharged from hospital within 24–48 h

Suggested Readings

1. Nielsen RV, Fomsgaard JS, Siegel H, et al: Intraoperative ketamine reduces immediate postoperative opioid consumption after spinal fusion surgery in chronic pain patients with opioid dependency: a randomized, blinded trial. Pain 2017; 158(3):463–70.
2. Wainwright TW, Immins T, Middleton RG: Enhanced recovery after surgery (ERAS and its applicability for major spine surgery. Best Pract Res Clin Anaesthesiol 2016; 30(1):91–102.

SPINAL RECONSTRUCTION AND FUSION: THORACIC AND THORACOLUMBAR SPINE

SURGICAL CONSIDERATIONS

Description

Traditionally, most spinal procedures have been approached posteriorly. The advent of surgical treatment for vertebral TB and postpolio spinal deformities during the 1960s saw the development of surgical approaches to the anterior spine. These procedures initially were reserved for patients with significant deformities, especially kyphosis. More recently, the treatments of traumatic, neoplastic, and degenerative conditions have been included in the anterior approach. Regardless of the condition under treatment, the approach is similar for a given level. There are several more or less distinct types of surgical exposures, depending on the level.

Cervicothoracic approach

Most cephalad and difficult is the approach to the upper thoracic spine (T1-T3). This generally includes a modified anterior cervical exposure with a caudal extension, including a resection of the clavicle, part of the manubrium, and sometimes the rib at the thoracic outlet. Dangers in this exposure are to the great vessels at the thoracic outlet, trachea (rare) and esophagus (more common), lung parenchyma, sympathetic ganglia, lymphatic duct (on the left), and brachial plexus. Once the spine is exposed and the

discs and/or vertebrae are removed, the spinal cord is at risk. This procedure occasionally involves entering the thoracic cavity, in which case it is usually done intrapleurally—that is, through the parietal pleura. The lung needs to be collapsed at least partially. Spinal cord monitoring is usually performed; wake-up tests are not. Manipulation of the carotid artery and aortic arch may cause wide HR and BP fluctuations.

Transthoracic approach

Further down the spine, the levels from T5 to T10 are more easily reached via a transthoracic approach (Fig. 10.3-2). This involves a typical thoracotomy with the resection of a rib. The level of the rib resection is usually 1–2 levels above the highest vertebral level being approached. The great vessels and lung parenchyma are at risk, as is the thoracic duct (on the left). The patient is in the lateral decubitus position, and the mediastinum and heart usually fall to the opposite side, out of harm's way. Risk to the spinal cord depends on the difficulty and extent of the vertebral disease and the reconstruction. Spinal cord monitoring usually is performed intraop. The need for the lung to be deflated varies with the extent of the exposure. In centers where this procedure is frequently performed and the surgeons are accustomed to the respiratory motion during operation, DLTs are not routinely used. Because there is no (intended) violation of the lung parenchyma, air leaks and parenchymal repairs are not common.

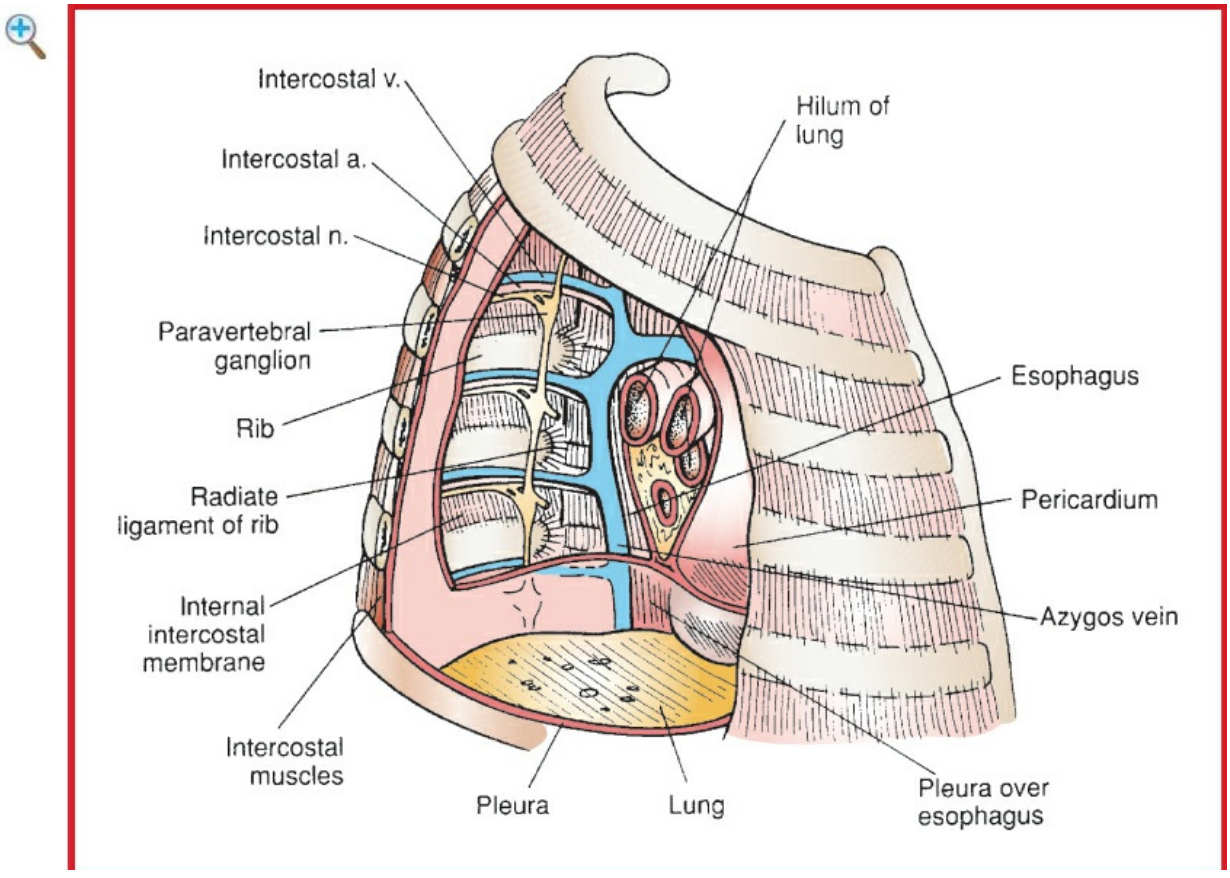

Figure 10.3-2 Surgical anatomy of the transthoracic approach. (Reproduced with permission from Hoppenfeld S, deBoer P: Surgical Exposures in Orthopaedics. JB Lippincott, Philadelphia: 1984.)

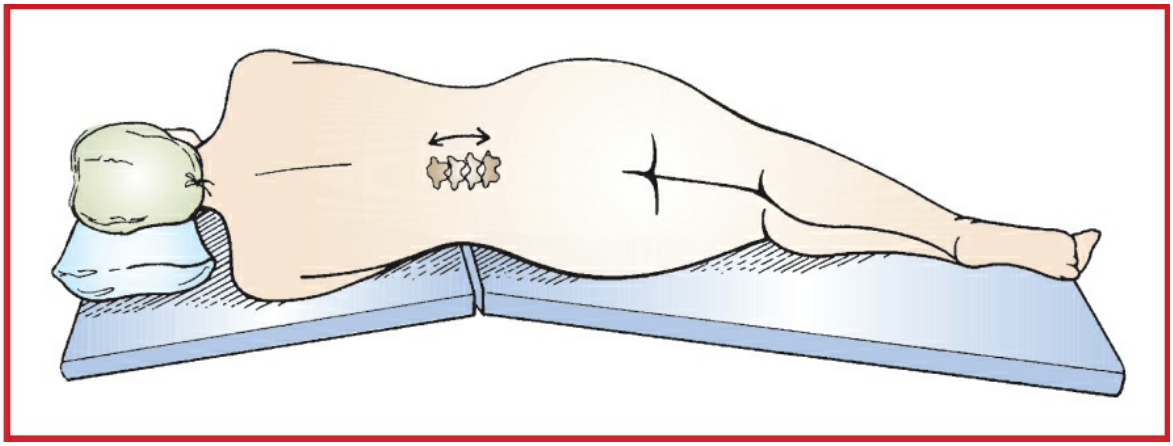

Figure 10.3-3 Patient position for transdiaphragmatic or retroperitoneal approach. (Reproduced with permission from Hoppenfeld S, deBoer P:Surgical Exposures in Orthopaedics JB Lippincott, Philadelphia: 1984.)

Transdiaphragmatic approach

When the exposure must transverse the diaphragm, a combined retroperitoneal and transthoracic approach is used. This requires the diaphragm to be sectioned circumferentially from the chest wall and spine. If only the very low segments of the thoracic spine (T10-T12) are exposed, the required deflation of the involved lung is minimal. The risks are the same as those encountered with the transthoracic or retroperitoneal approaches alone. Regardless of the level of exposure, the operating table may be used during the procedure to manipulate the spine for better exposure and to "lock in" implants, bone grafts, etc. Usually, the area of the spine to be exposed is centered above the "breaking" joint and kidney rests of the table (Fig. 10.3-3). After the initial exposure, the table is angled in the center with the head and legs pointing down and kidney rests elevated to "open up" the section of spine facing the surgeon. After removal of the disc, abscess, or tumor, a reconstruction—using bone graft, metal implants, bone cement, or a combination of these—is performed. In some cases, the operating table is straightened and, with the spine in neutral alignment, the stability of the reconstruction is tested.

The **morbidity** of these procedures depends primarily on the nature of the underlying disease. Obviously, bleeding and visceral injury are more likely when debriding a grapefruit-sized Potts abscess with several destroyed vertebrae than in removing a degenerated lumbar disc for fusion.

In some instances, the anterior procedure may be followed with a posterior fusion,

either immediately, the next day or after 5–7 d of convalescence. If done immediately after, the patient needs to be placed in the prone position, and the second procedure needs to be done through a midline exposure. Sometimes, anterior and posterior surgeries are performed simultaneously by two surgical teams. The most common reason for a staged anterior/posterior procedure (in the United States) is scoliosis; however, fractures at the thoracolumbar junction, after anterior decompression and reconstruction, are often instrumented and fused posteriorly.

Usual preop diagnosis

Fractures (usually at thoracic lumbar junction); idiopathic scoliosis; primary neoplasm or metastatic disease to the spine; pyogenic or TB osteomyelitis of the spine; Scheuermann kyphosis

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include continuing chronic pain meds, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, possibility of urinary catheter postop and rehabilitation plans. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Cervicothoracic Approach	Transthoracic Approach	Transdiaphragmat Approach
Position	Supine; towel roll placed between shoulder blades, head slightly extended and turned away from operated side	Lateral decubitus (Fig. 10.3-3); intended segments over the table break and kidney rests; axillary roll	⇐
Incision	Inverted “L” longitudinally along manubrium to sternal notch, then transversely above clavicle	Along a rib, two levels above the highest segment to be exposed	⇐
Special	Instrumentation rarely	For	⇐ (More common to

instrumentation	used. Strut grafts—using rib, fibula, clavicle or cement—may be used to replace excised vertebrae. ± DLT	thoracolumbar scoliosis, a Zielke-type rod and screws may be used; more rigid instrumentation sometimes used in fractures. ± DLT	use instrumentation at the affected leve than above)
Unique considerations	Aortic arch and carotid manipulation may cause BP/HR changes. Postop respiratory distress well described	During spinal reconstruction, manipulation of operating table may be essential to “lock in” graft or implant (see above).	⇐
Antibiotics	Cefazolin 2 g iv (+ gentamicin 80 mg iv, if indwelling bladder catheter)	⇐	⇐
Surgical time	2–6 h	⇐	⇐
Closing considerations	Patient usually transferred to bed prior to emergence; sudden jerking motions may dislodge graft or implant.	⇐	⇐
EBL	200–5000 mL. Blood loss is extremely variable; when bleeding occurs, it may be torrential	⇐	⇐

	from the aorta, vena cava, or iliac vessels and branches. In nontumor or infection cases, 200–400 mL is usual.		
Postop care	Chest drain; NG suction usually needed; short period of ICU observation is usual.	⇐	⇐
Mortality	<0.1%, except in cases of malignancy or sepsis	⇐	⇐
Morbidity	For elective degenerative cases: 5–10% overall	⇐	⇐
	DVT: 6%	⇐	⇐
	Neurologic: 3%	⇐	⇐
	Infection: 1%	⇐	⇐
	Sexual dysfunction	⇐	⇐
	For sepsis or tumor: 50–80% (overall)	⇐	⇐
	Cardiorespiratory failure	⇐	⇐
	Sepsis	⇐	⇐
Pain score	7–8 (if patient sensate at level of surgery)	7–8 (if patient sensate at level of surgery)	7–8 (if patient sensate at level of surgery)

PATIENT POPULATION CHARACTERISTICS

Age range	12–30 yr (scoliosis surgery); >40 (tumor and infection surgery); 15–35 yr (fractures)

Male:Female	1:1, except more scoliosis surgery in females (1:4) and more fractures in males
Incidence	20,000/yr
Etiology	Scoliosis: idiopathic (50%), neuromuscular (15%), congenital (5%); trauma (20%); infections, tumors (10%)
Associated conditions	Pulmonary HTN and impaired pulmonary function; neuromuscular scoliosis (poliomyelitis, CP, muscular dystrophy, Friedreich ataxia); aspiration; cardiomyopathy

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Spinal Reconstruction and Fusion.

Suggested Readings

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SPINAL RECONSTRUCTION AND FUSION: LUMBOSACRAL SPINE

SURGICAL CONSIDERATIONS

Description

The same general considerations apply here as in thoracolumbar reconstruction segments. The thoracic cavity is not entered, nor is the diaphragm sectioned. Careful

preop assessment is needed, as these patients may have a wide range of coexisting diseases. The same operative procedure is performed for removal of a degenerative disc in a healthy patient as is carried out to decompress the cauda equina in a debilitated patient with metastatic breast carcinoma.

Retroperitoneal approach

Below the diaphragm, exposure of the lumbar spine (L2-S1) can be performed through a retroperitoneal approach (Fig. 10.3-4). This often involves a flank incision, often with resection of the 11th or 12th rib. The patient lies in a decubitus or partial decubitus position. At risk here are the great vessels above and below the bifurcation of the aorta (L4-L5). The ureter crosses the operative field and must be identified and protected. The sympathetic chain may be damaged along the vertebrae, but the consequences of this are minimal. The presacral plexus further down may be injured and result in persistent retrograde ejaculation.

A Pfannenstiel incision may be used to approach L5-S1 or L4-L5. Regardless of the level of exposure, the operating table is used during the procedure to manipulate the spine for better exposure and to "lock in" implants, bone grafts, etc. Usually, the area of the spine to be exposed is centered above the "breaking" joint and kidney rests of the table (Fig. 10.3-3). After initial exposure, the table is angled in the center with the head and legs pointing down and the kidney rests elevated to open up the section of spine facing the surgeon. After the removal of the disc, abscess, or tumor, a reconstruction—using bone graft, metal implants, bone cement, or a combination of these—is performed. The table is then straightened; with the spine in neutral alignment, the stability of the reconstruction is tested by this maneuver, which may need to be repeated several times.

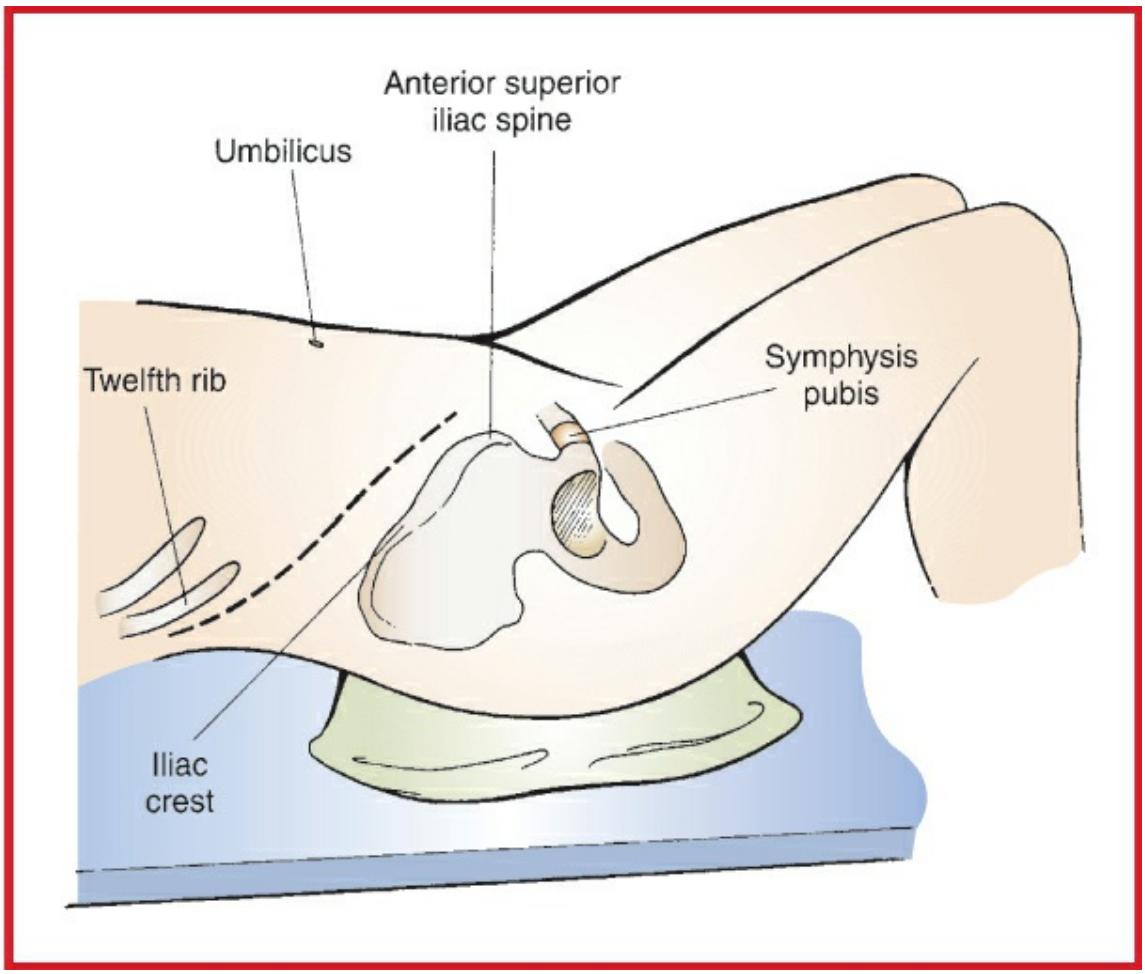

Figure 10.3-4 Retroperitoneal approach to lumbar spine. (Reproduced with permission from Hoppenfeld S, deBoer P: Surgical Exposures in Orthopaedics. JB Lippincott, Philadelphia: 1984.)

In some instances, the anterior reconstruction and fusion is followed with a posterior fusion, either immediately, the next day or after 5–7 d of convalescence. If done immediately after, the patient needs to be positioned prone on the operating table and the second procedure done through a midline exposure. Sometimes, anterior and posterior surgeries can be performed simultaneously by two surgical teams. The most common reason for a staged anterior/posterior procedure (in the United States) was scoliosis. Recent trends in degenerative lumbar disc surgery indicate that anterior and posterior fusion has become more common with some evidence suggesting better results in fusion and pain relief.

Variant procedure or approaches

When the L5 vertebra and sacrum need to be exposed widely, a transperitoneal approach may be needed. This involves a laparotomy or Pfannenstiel incision, displacement of the bowels out of the pelvis, and exposure of the lumbosacral junction (Fig. 10.3-5). The patient is supine for this procedure, and the surgical risks are similar, as with other intra-abdominal approaches.

In a recent modification to the retroperitoneal approach, the patient is placed in the supine position. In this supine retroperitoneal approach, an incision is made in either a longitudinal or transverse fashion between the umbilicus and the pubis. The rectus abdominis fascia is incised and the rectus abdominis is retracted medially or laterally, allowing access to the retroperitoneal space without violating the peritoneal cavity. The advantage of this approach over the transperitoneal approach includes decreased need for bowel manipulation, → ↓ third-space loss of fluid and ↓ heat loss.

Usual preop diagnosis

Degenerative disc disease; segmental instability; vertebral fractures requiring decompression; vertebral osteomyelitis or tuberculosis; neoplastic disease of the lumbar spine

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include continuing chronic pain meds, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, possibility of urinary catheter postop and rehabilitation plans. See Appendix K, p. K-1.

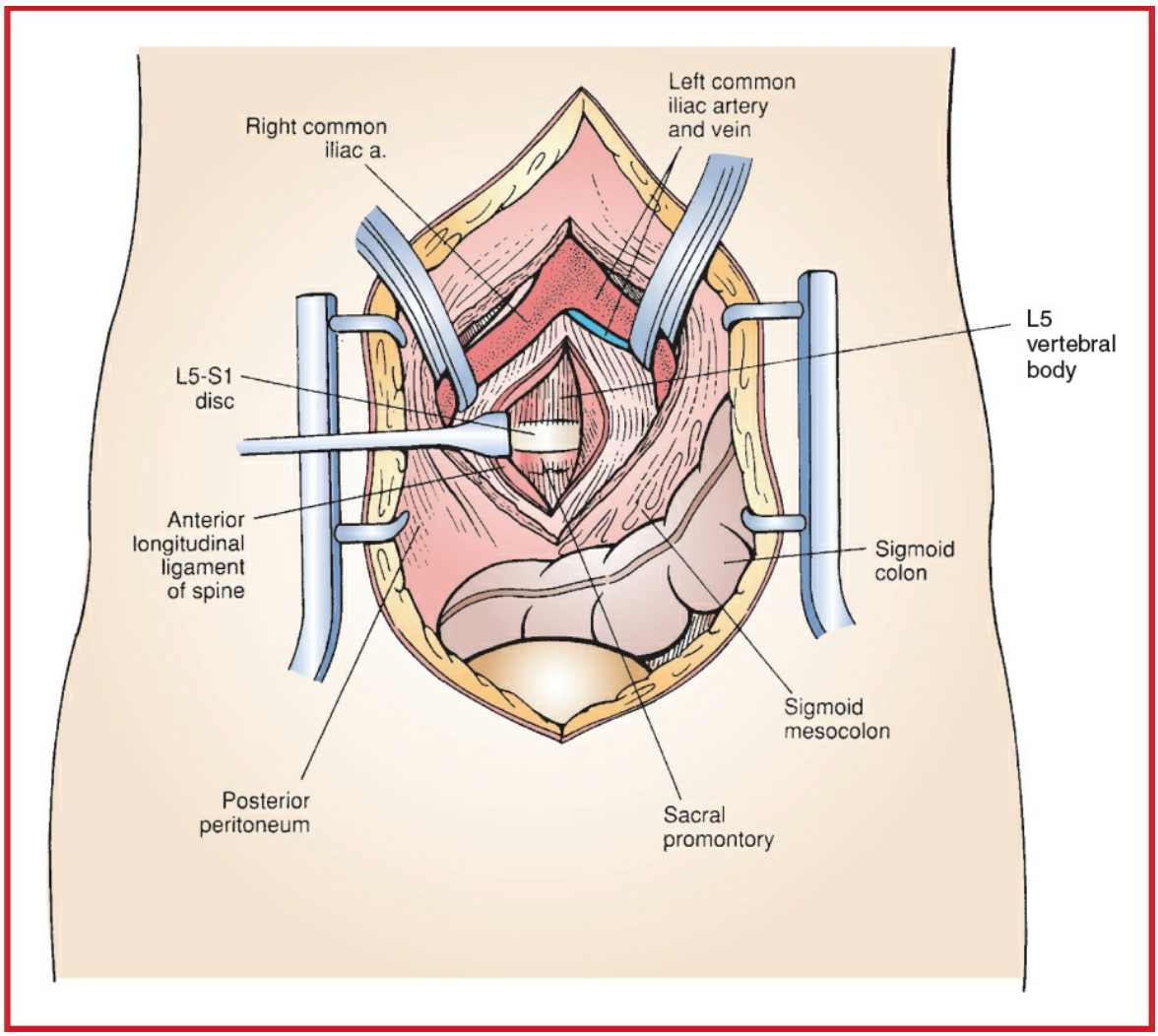

Figure 10.3-5 Transperitoneal approach to lumbosacral junction. (Reproduced with permission from Hoppenfeld S, deBoer P: Surgical Exposures in Orthopaedics. JB Lippincott, Philadelphia: 1984.)

SUMMARY OF PROCEDURES

	Retroperitoneal Approach (Lateral)	Transperitoneal Approach
Position	Lateral decubitus, affected side up. The up hip and knee are flexed to relax psoas muscle and allow its reflection to expose the lumbar vertebral bodies.	Supine
Incision	Flank incision curving anteriorly to the lateral margin of the rectus	Pfannenstiel above the pubis

	abdominis (Fig. 10.3-4)	
Special instrumentation	Occasional use of anterior instrumentation to stabilize fractures or to reconstruct the spine when entire vertebrae are removed	⇐
Unique considerations	In performing spinal reconstruction, manipulation of operating table is essential to “lock in” graft or implant (see above).	⇐ + a general bowel prep usually is performed preop.
Antibiotics	Cefazolin 2 g iv (+ gentamicin 80 mg iv, if indwelling bladder catheter already in place); exception is when infection is suspected and specific cultures are obtained intraop.	⇐
Surgical time	3–6 h	⇐
Closing considerations	The spine may be more or less stable after reconstruction, and patient usually transferred to bed prior to being awakened. Sudden jerking motions may dislodge graft or implant.	⇐
EBL	200–5000 mL. Blood loss extremely variable. When bleeding occurs, it may be torrential from the aorta, vena cava, or iliac vessels and branches. In nontumor/infection cases,	⇐

	200–400 mL is usual.	
Postop care	Patients with degenerative conditions and elective surgeries normally recover in PACU and return to ward. Patients with infections, fractures, and tumors are usually observed in ICU for 24 h postop. Ileus for 24–72 h is usual; NG suction usually continues until bowel sounds and passing flatus are present. Generally, mobilization depends on final stability.	⇐
Mortality	Malignancy or sepsis: 1–2%	⇐
	Elective: <0.1%	⇐
Morbidity	In patients with malignancy, sepsis or fractures with cauda equina compression, overall serious complications: 25–50%	⇐
	Cardiopulmonary failure	⇐
	Neurologic deficit	–
	Pneumothorax	–
	Sepsis	⇐
Pain score	6	6

PATIENT POPULATION CHARACTERISTICS

Age range	Variable (infant-adult)

Male:Female	1:1, except more scoliosis surgery in females (1:4)
Incidence	Uncommon
Etiology	Infection (osteomyelitis, TB); trauma; congenital; neoplasia; idiopathic

SPINAL RECONSTRUCTION AND FUSION: CERVICAL SPINE

SURGICAL CONSIDERATIONS

Description

Both an anterior or posterior approach can be used to decompress nerve roots (radiculopathy) and the spinal cord (myelopathy). Generally, involvement of one- or two-level pathology is best accomplished through an anterior approach, whereas the posterior approach may better serve multilevel pathology. An anterior approach is also preferred when the cervical spine has lost its normal lordotic contour. Posterior pathology, such as unilateral foraminal disc herniations, and ossification of the posterior longitudinal ligament (OPLL) often dictate a posterior approach. Complex pathology may necessitate combined approaches.

Anterior approach

This is done under GA. The patient is positioned supine on the operating table and a roll is placed between the scapulae to facilitate a neutral to slightly extended neck position. The arms are tucked in at the side, and gentle traction of the upper extremities may be applied to provide visualization of C7 using intraop fluoroscopy. Surface landmarks and fluoroscopy are used to locate the intended level. A transverse incision can be used up to four-level discectomies, whereas a longitudinal incision can be utilized for more levels. Generally, a left-sided approach is preferred to minimize recurrent laryngeal nerve (RLN) injury, but more recent data suggest no difference between a right-sided versus left-sided approach. After skin incision, the platysma muscle layer is exposed and divided either longitudinally or in line with the incision. A plane deep to the platysma is developed, and the medial border of the sternocleidomastoid (SCM) muscle is identified. Blunt dissection is initiated between the identified medial border of the SCM and the strap muscles. While staying medial to the carotid sheath, the trachea and esophagus are retracted to the contralateral side, and the dissection is carried deep to expose the spine. The desired disc levels are identified using fluoroscopy. The longus

colli muscle is identified and elevated carefully subperiosteally on either side to facilitate the insertion of deep-bladed, self-retaining retractors. Some data indicate that deflation of the ETT cuff with adjustments of the retractor may reduce the incidence of RLN and esophageal injury. Complete removal of the disc, other compressive pathology, or full versus complete corpectomy can be performed with the aid of curettes and a high-speed burr. Appropriately sized grafts are inserted and further stabilized with the aid of a plate and screws. The operative time for a single level is generally between 1 and 2 h, and the wound is typically closed over a drain to avoid a compression hematoma causing airway compromise. Cases involving three or more levels are at high risk for excessive soft tissue swelling and airway obstruction, and continued intubation may be a strong consideration.

Posterior approach

The patient is placed under GA in the supine position. Prior to turning the patient prone, a head holder (Mayfield vs. Gardner-Wells) is applied, and the surgeon generally controls the head while the anesthesiologist controls the airway in the process of log-rolling. As with the anterior approach, the arms are tucked in at the side, and gentle traction is applied for visualization of the entire cervical spine with fluoroscopy. The hips and knees are gently flexed in a sling while the remainder of the body is supported by bolsters allowing the abdomen to hang free on an open frame (Jackson) operating table. A reverse Trendelenburg position further aids in distribution of blood into the abdomen and legs. An extensive exposure can be created from the greater occipital protuberance to the thoracic spine. Dissection is carried down sharply through subcutaneous tissue and fat to the trapezius fascia with care taken to stay in the midline. A dry surgical dissection with electrocautery can be achieved in this manner as the ligamentum nuchae is relatively avascular. Subperiosteal dissection is then carried from the tip of the spinous processes over the laminae elevating the paraspinal muscles as a cuff. Depending on the intended surgery, procedures such as laminoforaminotomies, laminotomies, and laminectomies can be performed. Blood loss may be significant depending on the length of surgery as well as the extent of bony resection.

Usual preop diagnosis

Cervical radiculopathy; cervical myelopathy; spinal cord syndromes secondary to trauma

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include continuing chronic pain meds, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and possibility of urinary catheter postop. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Anterior	Posterior
Position	Supine, roll between scapulae, tuck arms at sides with gentle traction	Prone, Jackson table, head holder, Gardner-Wells tongs/Mayfield head holder, tuck arms at sides with gentle traction
Incision	Transverse vs. longitudinal depending on number of levels	Longitudinal
Special instrumentation	Microscope; light source; fluoroscopy; specialized retractors and dissection instruments for working in a small, deep incision	⇐
Antibiotics	Cefazolin 2 g iv	Cefazolin 2 g iv ± gentamicin usually 80 mg iv
Surgical time	1.0–2.0 h/level	2–5 h
Closing considerations	Minimal suturing over a drain	Several layer closure over a drain
EBL	Minimal	Wide range
Postop care	PACU, mobilization as soon as tolerated. Multilevel procedures may require continued intubation postop.	⇐
Mortality	Very rare	⇐
Morbidity	Dysphagia Nerve injury Dural laceration Vertebral artery injury Esophageal injury	Nerve injury Dural laceration Vertebral artery injury Infection Air embolus

Airway obstruction
Dysphonia
Horner syndrome

Suggested Readings

1. Audu P, Artz G, Scheid S, et al: Recurrent laryngeal nerve palsy after anterior cervical spine surgery: the impact of endotracheal tube cuff deflation, reinflation, and pressure adjustment. Anesthesiology 2006; 105(5):898–901.
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ANESTHETIC CONSIDERATIONS FOR SPINAL RECONSTRUCTION AND FUSION

(Procedures covered: anterior reconstruction and fusion of thoracic, thoracolumbar, and lumbosacral spine)

PREOPERATIVE

Patients presenting for spinal reconstruction commonly have either idiopathic or acquired scoliosis, a complex deformity involving both lateral curvature and rotation of the spine, as well as an associated deformity of the rib cage → ↓ pulmonary function. Types of scoliosis include idiopathic, congenital, neuromuscular, myopathic, traumatic, tumor-related, and mesenchymal disorders. The majority of cases are idiopathic, with a male:female ratio of 1:4. Normally, the cervical spine and lumbar spine are lordotic, whereas the thoracic spine is kyphotic. The instrumentation is intended to stabilize the spine until bony fusion of the spine has occurred. After the fusion is solid (6–12 mo), the instrumentation may be removed if it is broken, if it causes protrusions or lumps in

the back, or if the patient is having residual back pain. Nonscoliotic patients presenting for this surgery may have spinal instability as a result of trauma, metastatic cancer, or infection (e.g., TB). These patients are usually healthy, apart from their underlying pathology. The patients with metastatic cancer may need a careful workup with regard to respiratory, nutritional, and chemotherapeutic status. (See Anesthetic Considerations for Lobectomy, Pneumonectomy, or Mastectomy.)

Respiratory

Respiratory impairment proportional to angle of lateral curvature (Cobb angle; Fig. 10.3-6)

Cobb angle	30°–60°	60°–90°	>90°
VC	↓ 25%	↓ 50%	↓ 70%
TLC	↓ 27%	↓ 37%	↓ 50%

Restrictive pattern: ↓ TLC + ↓ ↓ VC

- If VC > 70% predicted, respiratory reserve is adequate.
- If VC < 40% predicted, postop ventilation usually is required.

Expect further significant (~40%) ↓ VC immediately postop, requiring 7–10 d to resolve
↑ RR + ↓ TV → ↑ dead space + ↓ alveolar ventilation → V/Q mismatch → hypoxemia
Patients with scoliosis of neuromuscular origin are more susceptible to aspiration and respiratory failure.
Tests: CXR; ABG; PFT; assess exercise tolerance by Hx

Cardiovascular

↑ PVR (*NB:* independent of severity of scoliosis). High incidence of CHD and mitral valve prolapse
Tests: ECG; ECHO—consult cardiologist if apical systolic murmur or evidence of cardiovascular impairment is present

Neurologic

SSEPs (posterior cord) and MEPs (anterior cord) will be monitored in most patients who are undergoing spinal reconstruction. Some surgeons, however, may request that the patient be awakened intraop, after completion of the instrumentation, but before closure of the wound, to ensure that no motor deficits have developed as a result of the correction. If an intraop wake-up test is planned, explain to the patient what the procedure entails, why it is necessary, and what to expect. Reassure the patient that the test will be brief, that the pain will be controlled, and that you will be there to keep them safe and as comfortable as possible. If preop focal neurologic lesions exist, they should be documented to distinguish them from changes associated with the surgical procedure.

Musculoskeletal

When the Cobb angle is >25°, the degree of respiratory impairment will be significant, and the need for postop ventilatory support becomes more likely. Patients with muscular dystrophy may be more sensitive to myocardial depression from anesthetic agents and also may require postop ventilation 2° muscle weakness. Succinylcholine may cause severe rhabdomyolysis with hyperkalemia. These patients also may be at risk for MH.

Hematologic

Avoid use of platelet inhibitors 1 wk before surgery. Have at least 2 U PRBCs available in the room at the start of the operation. Consider use of a red cell salvage device. Discuss use of controlled ↓ BP with surgeon. If anticipated blood loss is substantial and the patient is not anemic, consider encouraging autologous blood donation (time permitting) or performing isovolemic hemodilution intraop. Be aware that patients with previously placed spinal support (e.g., Milwaukee brace) for correction of scoliosis may have more blood loss than usual.

Laboratory

✓ INR, PT, PTT, and Plt count preop. ✓ Hct the morning of operation or after induction of anesthesia if autologous donations have been made because, with modest blood loss and fluid therapy, the Hct may rapidly ↓ to <26%.

Premedication

Standard premedication, if appropriate

ERAS

Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon possible use of po celecoxib 400 mg po as a component of postop pain management. Consider preop acetaminophen 1000 mg po and aprepitant 40 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: For pediatric cases, preheat room to 78°F. For operations in the prone position, use a wire-reinforced tube to prevent kinking and airway obstruction. If a transthoracic approach is used, lung isolation will be necessary. Double-lumen tubes provide the best method of achieving lung isolation overall and are available as small as 28 Fr (OD = 9.3 mm), which is typically suitable for children as young as 12 yr. If a wake-up test is required, consider the use of an endotracheal tube designed to allow laryngotracheal instillation of topical anesthetic (LITA® tube).

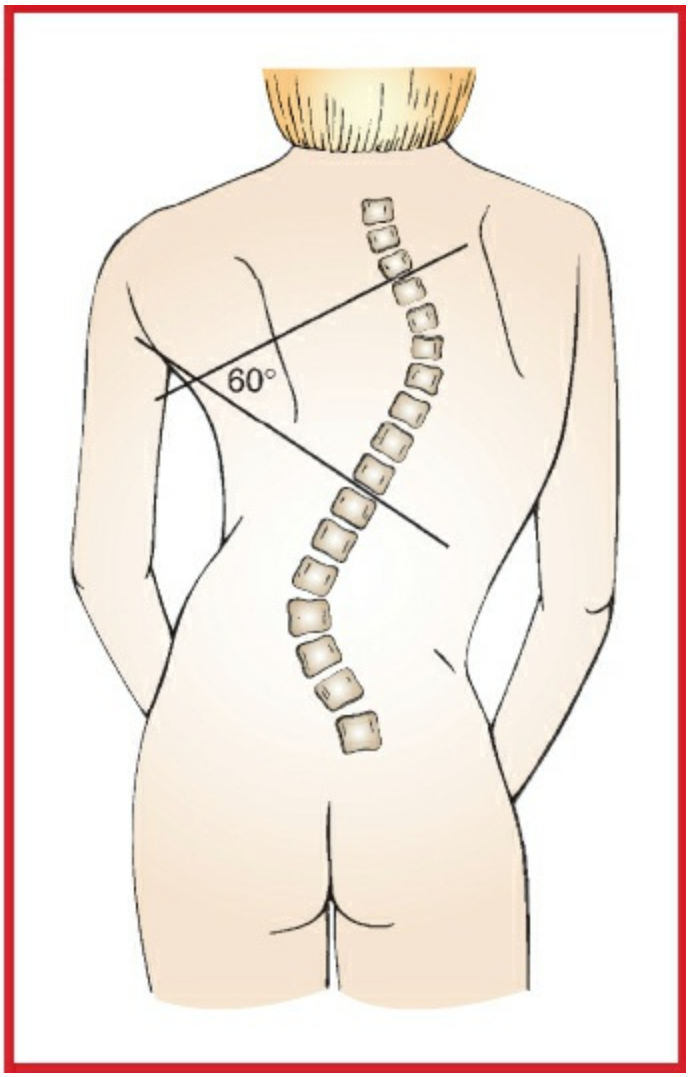

Figure 10.3-6 Cobb angle.

Induction	Standard induction. Assuming MEP monitoring will be used, consider succinylcholine vs. low-dose

	rocuronium (0.5 mg/kg) vs. deep anesthesia and remifentanil bolus (1.5 mcg/kg) to facilitate intubation.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Dexamethasone (4–8 mg iv) may ↓ PONV. Sequential pneumatic compression devices should be used to ↓ VTE risk. Consider ketamine (0.25 mg/kg/h) and/or lidocaine (1–2 mg/kg/h) infusions as components of MMPM especially in chronic pain patients.
Maintenance	Neuromuscular blockers will completely abolish MEPs and must be avoided when using this monitoring technique. Normal doses of volatile anesthetics interfere with MEP and, to a lesser extent, SSEP monitoring. When monitoring MEPs, TIVA may be requested. When monitoring SSEPs only, a continuous infusion of a narcotic (ideally remifentanil) together with a reduced dose of inhaled anesthetic (0.5–1 MAC) and neuromuscular blockade usually produces satisfactory monitoring conditions. A BIS-type monitor may help with the timing of a wake-up test. The neurophysiology monitoring team must be updated if conditions that affect the evoked potentials change (depth of anesthesia, anesthetic agent, blood pressure, PCO_2, PO_2).
Emergence	As soon as neuromonitoring is complete, switching to an inhaled anesthetic and stopping the propofol will allow for a timely emergence. Some surgeons may place an epidural catheter before closure for postop pain management or perform intercostal local anesthetic injections for the transthoracic approach. Prior to emergence, scoliosis patients may be fitted with a plaster mold to be used as a brace that will be worn several mo postop. Transfer from the operating table to bed must be smooth and gentle. The patient is typically extubated following transfer to the bed.

	Keep in mind that remifentanil will not provide postop analgesia and that another longer-acting opioid must be administered before emergence. Suggest wound infiltration with LA. Consider iv acetaminophen 1 g if po dose given >4–6 h ago and hydromorphone (0.2–0.6 mg iv). Discuss possible postop use of ketorolac or celecoxib.	
Blood and fluid requirements	IV: 14–16 ga × 2 BSS @ 1–3 + mL/kg/h not to exceed 40 mL/kg T&C 2–4 U PRBCs ± Red cell salvage	Anticipate substantial blood loss (proportional to the number of levels) from extensive dissection of muscles from bony spine; less so with isolated thoracic fusion. It may vary from 25% to 100% of the patient's blood volume, although blood loss is usually less with the anterior approach. Goal-Directed Fluid Management is recommended.
	Albumin 5% prn Warm all fluids.	Colloid is preferred because it will remain intravascular until metabolized. Use Goal-Directed Fluid Management, p. K-4.
	Humidify gases.	
Control of blood loss	Position to prevent venous engorgement. ↓ MAP to 60 mm Hg Consider ↓ Hct to 25–28% (isovolemic hemodilution)	Although of questionable benefit, some surgeons may request deliberate hypotension. Decreasing MAP may ↓ blood loss. Generally, maintain MAP > 60 mm Hg in young, healthy patients and >80 mm Hg in older patients

		for spinal cord perfusion. Once dissection is complete, higher BP values acceptable. Maintain UO at 0.5–1 mL/kg/h during controlled hypotension.
Monitoring	Standard monitors Arterial line ±CVP line Urinary catheter SSEP, MEP ± BIS	CVP monitor helpful for continuous infusions and to assess fluid Rx. Trends in PPV or CVP will be more reliable than measurement of UO to assess changes in volume status in patients in the prone position. Frequent labs (ABG, lytes, coag) may be useful.
Positioning	✓ and pad pressure points ✓ eyes and neck Bite block (essential for MEP) Avoid posterior pressure on ETT.	**Prone:** Place head on cushioned head holder with cutout for eyes, nose, and chin. Make certain that none of the face rests on bed. ✓ elbows, knees, and feet. **Lateral:** Place head on donut with C-spine in neutral position. Pad and support both arms in neutral position. Ensure no pressure on eyes or ears.
Wake-up test (rarely necessary with intraop neuromonitoring)	30-min advance warning from surgeons is needed. • Decrease anesthetic agents. • Reverse muscle relaxants. • Target BIS in high 50 sec.	The wake-up test is an alternative to intraop neuromonitoring that assesses integrity of motor pathways in the

	• About 10 min before testing turn off anesthetics. • ↓ remifentanil infusion to 0.05 mcg/kg/min or less. • If a LITA tube was used, administer 3–4 mL 1% lidocaine into the trachea. • Begin speaking to the patient. Request movement of all four limbs sequentially. **Dangers:** Air embolus Dislodgement of spinal instrumentation Accidental extubation	ventral cord. Uncontrolled patient movement during wake-up test can result in accidental extubation or dislodgement of the spinal instrumentation. Unrestrained inspiratory efforts may provoke venous air embolism. The anesthesiologist must be prepared to rapidly reanesthetize the patient.
SSEP and MEPs	SSEP: Dorsal cord function only MEPs: Ventral cord function	SSEP and MEP are used routinely. Avoid changes in anesthetic conditions (depth of anesthesia, agents, MAP, PCO_2, PO_2). An increase in the latency (>10%) or decrease in the amplitude (≥50%) usually indicates cord injury from hardware impingement, cord stretch or compression, or hypoperfusion. The surgeon and anesthesiologist should be notified immediately if the evoked potentials change. Unilateral changes to MEP/SSEP signals may indicate a positioning problem.
Complications	Spinal cord ischemia	SSEP indications of spinal

		cord ischemia should be treated by alerting the surgeon and ensuring optimal perfusion (↑ BP, normalize PCO_2, ↑ PO_2, optimal Hct, ↓ PEEP, ↓ traction or pressure on the cord).
	Massive blood loss Fat embolism	Prompt transfusion may be necessary, and blood should be available in the room. Be prepared for the possibility of massive transfusion.

POSTOPERATIVE

Complications	Bleeding	Postop bleeding is common. Rarely, the bleeding occurs in a space that is not drained and can result in complications such as epidural hematoma or hemothorax.
	Pulmonary insufficiency Hypothermia Pneumothorax Dislodgement of internal fixation	Postop ventilation may be required in patients with severe respiratory impairment (see Preoperative Considerations, above). In addition, thoracotomy, surgical trauma to the diaphragm, fat embolism, and inadequate analgesia may further ↑ the risk of postop pulmonary insufficiency. Careful

		handling of patient in transfer is mandatory.
	Neurologic sequelae	Neurologic sequelae probably remain the most feared complication, and it is important to document postop neurologic exam.
Multimodal pain management	PCA Intrathecal morphine 0.1–0.25 mg by surgeon intraop Thoracic/lumbar epidural opiates/local anesthetics	Pain is a significant problem for postop scoliosis patients. Most need analgesia × 3–4 d. Preop consultation with patient (and parents) about different pain management techniques is important.
	IV acetaminophen	1 g q6h for adults, 15 mg/kg q6h if ≤50 kg or ≤12
	± Ketorolac (30 mg iv) or celecoxib (200 mg po)	Consult with surgeon regarding possible hemostasis concern.
ERAS	Ondansetron 4 mg iv ± Metoclopramide 10–20 mg iv	Encourage early enteral nutrition, Foley catheter removal, and mobilization with physiotherapy.
Tests	CXR; ABG; Hct	✓ for pneumothorax and line placement

Suggested Readings

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pain patients with opioid dependency: a randomized, blinded trial. Pain 2017; 158(3):463–70.
4. Paul JE, Ling E, Lalonde C, et al: Deliberate hypotension in orthopedic surger reduces blood loss and transfusion requirements: a meta-analysis of randomized controlled trials. Can J Anesth 2007; 54(10):799–810.
5. Sivaganesan A, Chotai S, White-Dzuro G, et al: The effect of NSAIDs on spina fusion: a cross-disciplinary review of biochemical, animal, and human studies. Eur Spine J 2017; 26(11):2719–28.
6. Tasiou A, Giannis T, Brotis AG, et al: Anterior cervical spine surgery-associated complications in a retrospective case-control study. J Spine Surg 2017; 3(3):444–59.
7. Wainwright TW, Immins T, Middleton RG: Enhanced recovery after surgery (ERAS and its applicability for major spine surgery. Best Pract Res Clin Anaesthesiol 2016; 30(1):91–102.
8. Willner D, Spennati V, Stohl S, et al: Spine surgery and blood loss: systematic review of clinical evidence. Anesth Analg 2016; 123(5):1307–15.
9. Zanirato A, Damilano M, Formica M, et al: Complications in adult spine deformity surgery: a systematic review of the recent literature with reporting of aggregated incidences. Eur Spine J 2018; 27:2272–84.

Suggested Viewing

Links are available online to the following videos:

Posterior Spinal Instrumentation & Fusion for Idiopathic Scoliosis:
https://www.youtube.com/watch?v=TbQaT7z54E4

Scoliosis Spinal Fusion Animation: https://www.youtube.com/watch?v=WBIf4AQj5s0

Minimally Invasive Tubular Microdiscectomy: 3-D Video:
https://www.youtube.com/watch?v=Cpkr_oy5Enc

Dr. Ali Bydon Performs a Minimally Invasive Lumbar Discectomy:
https://www.youtube.com/watch?v=2j9QyiOxVF4

CHAPTER 10.4

Hip, Pelvis, and Upper Leg Surgery

SURGEONS

James I. Huddleston III, MD
Stuart B. Goodman, MD, PhD, FRCSC, FACS, FBSE, FICORS
Michael J. Bellino, MD

ANESTHESIOLOGISTS

Frederick G. Mihm, MD
Christopher J. Painter, MD
Pedro P. Tanaka, MD, PhD, MACM

OPEN REDUCTION AND INTERNAL FIXATION (ORIF) OF THE PELVIS OR ACETABULUM

SURGICAL CONSIDERATIONS

Description

Pelvic fractures present several challenging treatment problems. Surgical management is complex and often difficult in nature. Specialized training and equipment are required for a successful outcome. Major trauma mechanisms produce pelvic ring injuries, and patients with pelvic ring disruptions frequently have associated systemic injuries, which may be life threatening (e.g., hemorrhagic shock). Pelvic stabilization and surgical control of hemorrhage may be performed acutely in the polytrauma patient who is hemodynamically unstable. This is in conjunction with an exploratory laparotomy performed by a trauma surgeon or interventional radiology embolization of vasculature. The majority of patients with pelvic fractures who are treated operatively are taken to the OR on a delayed basis, after they have been stabilized. Pelvic fractures that do not heal are "nonunions," whereas those that heal in an unsatisfactory position are

“malunions.”

Anterior approaches to the pelvis include Pfannenstiel and ilioinguinal incisions, which are utilized for reduction and fixation of dislocations and fracture/dislocations of the symphysis pubis, fractures of the pubic rami, and access to the anterior aspect of the sacroiliac (SI) joint. **Posterior approaches** to the pelvis involve either vertical or curved incisions along the iliac crest and are used for reduction and fixation of SI joint dislocations, fracture/dislocations of the SI joint, and fractures of the iliac wing and of the sacrum. These procedures are often lengthy and are staged, requiring changes in patient position. Reductions are facilitated by neuromuscular paralysis. The posterior approach requires a large operative field, which may prevent the use of an epidural catheter. In addition, postop anticoagulation for DVT prophylaxis is used uniformly and may contraindicate the use of epidural catheters. The goal of pelvic reconstruction is to restore the anatomy and stability of the pelvis, which will decrease hemorrhage in the hemodynamically unstable patient, aid in mobilization of the multiply injured patient, and improve long-term function.

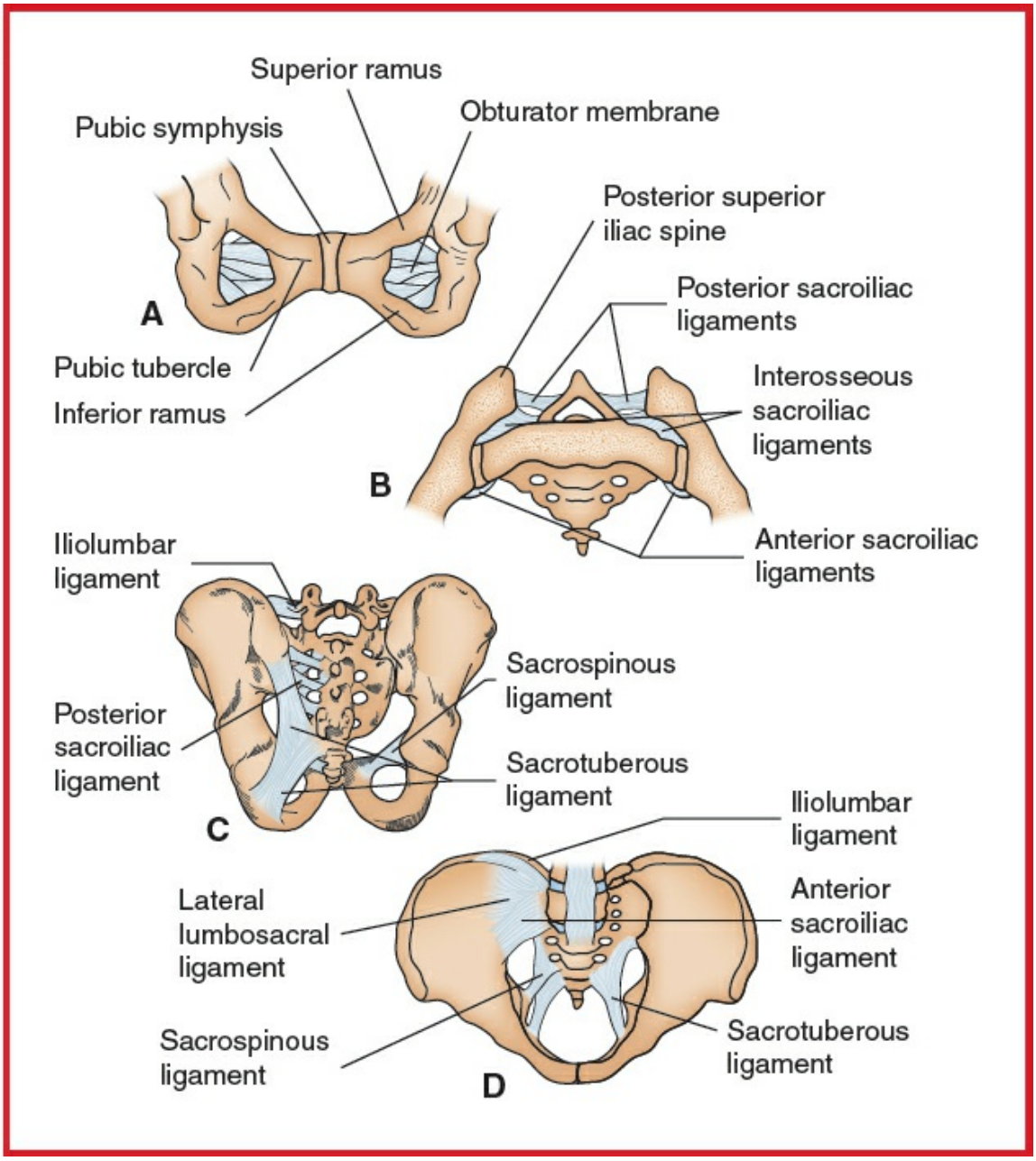

Figure 10.4-1 Schematic views of the pelvis with the principal ligamentous supports. **A:** Symphysis pubis fibrocartilage. **B:** Posterior SI ligaments. **C:** Posterior view. **D:** Anterior view. (Redrawn with permission from Chapman MW: Chapman's Orthopaedic Surgery, Vol. 1, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

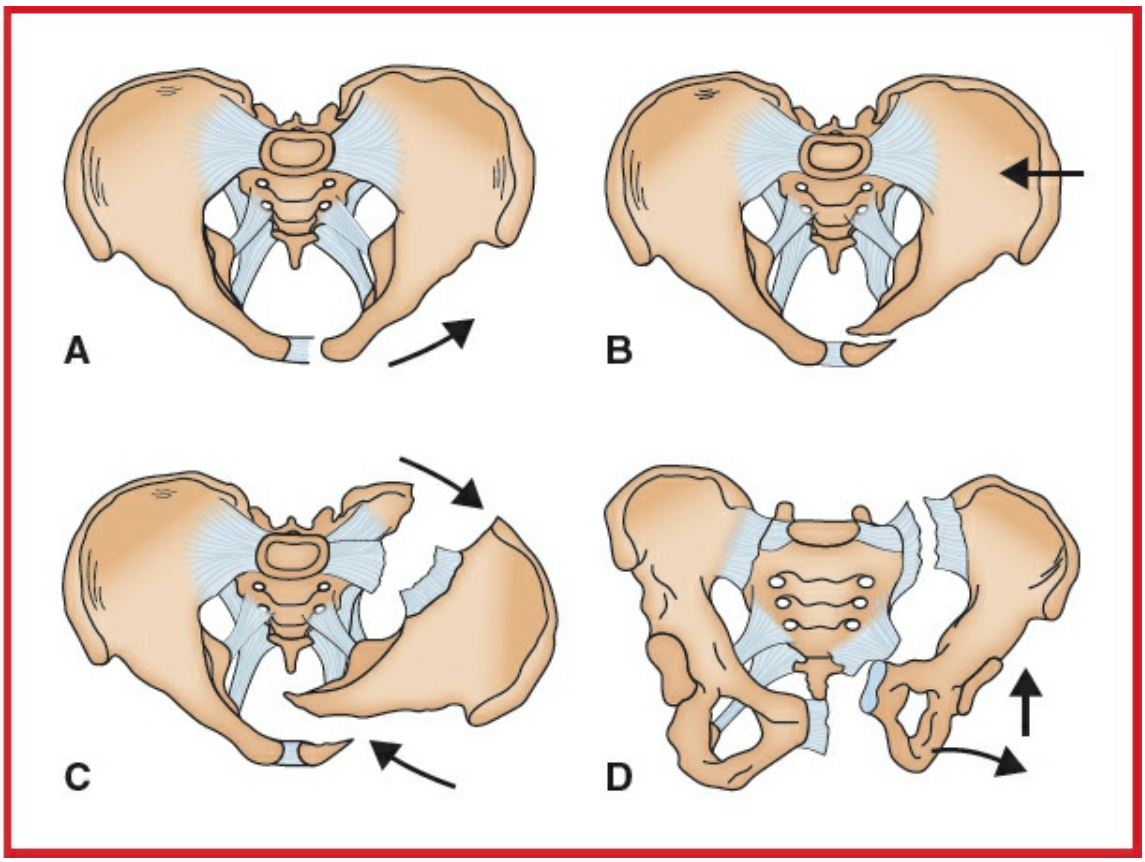

Figure 10.4-2 Schematic view of the principal pelvis injury patterns, as determined by the vector of the provocative blow. **A:** Anterior/posterior compression or external rotation injury. **B:** Stable lateral compression or internal rotation injury. **C:** Unstable lateral compression or internal rotation injury. **D:** Unstable vertical shear disruption. (Redrawn with permission from Chapman MW:Chapman's Orthopaedic Surgery, Vol. 1, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Usual preop diagnosis

Fractures of the pelvis/acetabulum; nonunion/malunion of the pelvis/acetabulum

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plan. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine (anterior); prone (posterior)
Incision	Pfannenstiel's, ilioinguinal (anterior); posterior, curving along the iliac crest (posterior)
Special	Radiolucent table; pelvic instruments and implants;

instrumentation	Cell Saver; I.I.
Antibiotics	Cefazolin 2 g iv q6–8h × 24 h (vancomycin or clindamycin for 24 h if penicillin allergic)
Surgical time	1–6 h (anterior); 3–6 h (posterior)
Closing considerations	May require neuromuscular relaxation to aid reduction and closure; postop radiograph
EBL	≥1000 mL
Postop care	Multiple-trauma patient → ICU; others → PACU
Mortality	10%+, dependent on the extent of multiple trauma
Morbidity	Ileus: Common Neurologic injury: Common Genitourinary injuries: Not uncommon Failure of fixation: Rare Infection: Rare Malunion: Rare Nonunion: Rare
Pain score	9

PATIENT POPULATION CHARACTERISTICS

Age range	Any age, but predominance of males 30–60 yr old
Male:Female	5:1
Incidence	1–2%
Etiology	Motorcycle and motor vehicle accidents (60–80%); falls (10–15%); crush injuries (5%); other (5%)
Associated conditions	Frequently associated with trauma to other organ systems, including the head and neck, chest, abdomen, and extremities. These often will be addressed concurrently with pelvic or acetabular fracture.

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Procedures About the Pelvis and Hip.

Suggested Readings

1. Burkhardt M, Kristen A, Culemann U, et al: Pelvic fracture in multiple trauma: are we still up-to-date with massive fluid resuscitation? Injury 2014; 45(Suppl 3):S70–5.
2. Halawi MJ: Pelvic ring injuries: surgical management and long-term outcomes.J Clin Orthop Trauma 2016; 7(1):1–6.
3. Prevezas N: Evolution of pelvic and acetabular surgery from ancient to modern times. Injury 2007; 38(4):397–409.
4. Rice PL Jr, Rudolph M: Pelvic fractures.Emerg Med Clin North Am 2007; 25(3):795–802.
5. Ruatti S, Guillot S, Brun J, et al: Which pelvic ring fractures are potentially lethal' Injury 2015; 46(6):1059–63.
6. Skitch S, Engels PT: Acute management of the traumatically injured pelvis.Emerg Med Clin North Am 2018;36(1):161–79.
7. Wang H, Robinson RD, Moore B, et al: Predictors of early versus late mortality in pelvic trauma patients. Scand J Trauma Resusc Emerg Med 2016; 24:27.

CLOSED REDUCTION AND EXTERNAL FIXATION OF THE PELVIS

SURGICAL CONSIDERATIONS

Description

This procedure entails manipulating the pelvis to obtain an acceptable reduction by closed means under GA and then applying an anterior external fixation device to maintain the reduction. The pins for the external fixator are inserted into the iliac crest either percutaneously or through small incisions. During this procedure, either radiographs or the I.I. is used to confirm that an acceptable reduction has been obtained. In some centers, this procedure is done in the emergency department as a lifesaving procedure.

Usual preop diagnosis

Displaced fracture of the pelvis; unstable fracture of the pelvis

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plan. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE

Position	Supine
Incision	Percutaneously or through small incisions along the iliac crest
Special instrumentation	External fixation; often performed on a radiolucent table using I.I.
Antibiotics	Cefazolin 2 g iv q6–8h × 24 h (vancomycin or clindamycin for 24 h if penicillin allergic); combination antibiotics, if multiple severe, open fractures or other significant injuries are present
Surgical time	1–1.5 h
EBL	Negligible from surgical procedure; however, anticipate large blood losses (4+ U) from the pelvic fracture alone
Postop care	Multiple-trauma victim → ICU; others → PACU
Mortality	10% or more, depending on the extent of multiple trauma; 50% in open fractures
Morbidity	Ileus: Virtually 100% Sacroiliac (SI) pain: 15–30%+ Genitourinary problems, including bladder or urethral rupture: 13% Neurologic deficit to the lumbosacral plexus: 1–10% Malunion/severe deformity: 5% Leg-length discrepancy: 3–5% Impotence: 1–5% Residual instability: 1–3% Vascular complications: 1% Hypotension 2° to retroperitoneal hematoma: Common Respiratory distress: Common Gynecologic and colorectal injuries: More common with open fractures/dislocations Delayed union, nonunion: Not uncommon Osteomyelitis: Rare Rupture of the diaphragm: Rare

Pain score	7–10

PATIENT POPULATION CHARACTERISTICS	
Age range	Any age, but predominance of males 30–60 yr old
Male:Female	5:1
Incidence	Common
Etiology	Motorcycle and motor vehicle accidents (60–80%); falls (10–15%); crush injuries (5%); other (5%)
Associated conditions	Frequently associated with trauma to other organ systems, including the head and neck, chest, abdomen, and extremities. Patient sustaining a pelvic fracture also has a probability of having other injuries, including musculoskeletal (85%), respiratory (60%), CNS (40%), GI (30%), urologic (12%), and CVS (6%). These often will be addressed concurrently with the pelvic fracture.

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Procedures About the Pelvis and Hip.

Suggested Readings

1. Prevezas N: Evolution of pelvic and acetabular surgery from ancient to modern times. Injury 2007; 38(4):397–409.
2. Rice PL Jr, Rudolph M: Pelvic fractures.Emerg Med Clin North Am 2007; 25(3):795–802.
3. Skitch S, Engels PT: Acute management of the traumatically injured pelvis.Emerg Med Clin North Am 2018; 36(1):161–79.

OPEN REDUCTION AND INTERNAL FIXATION (ORIF) OF ACETABULUM FRACTURES

SURGICAL CONSIDERATIONS

Description

Although the acetabulum is contained within the bony architecture of the pelvis, surgical management of acetabulum fractures is approached separately from pelvic fractures. The goal of surgical treatment of acetabulum fractures is to preserve the hip joint by accurately reconstructing the supporting bony anatomy. Surgical treatments of these challenging injuries are performed by surgeons who have undergone specialized training in orthopedic pelvic surgery. The mechanism of injury is usually high-energy trauma (e.g., motor vehicle, motorcycle accidents), industrial accidents, or a fall from a height that drives the femur into the acetabulum. Associated injuries to the pelvis are common, as are associated systemic injuries.

Optimal results are achieved when surgery is performed within 7 d. The approach is dictated mainly by the unique characteristics of the fractures. Essentially, three approaches are commonly used: the **ilioinguinal** (anterior; Fig. 10.4-3), the **extended iliofemoral** (lateral; Fig. 10.4-4), and the **Kocher-Langenbeck** (posterior; Fig. 10.4-5). The most difficult portion of the procedure is the reduction; it may be facilitated by neuromuscular relaxation, pelvic reduction instruments, and traction. The I.I. is used frequently throughout the procedure to assess the reduction and position of implants, which necessitates the use of lead aprons. A radiograph also is obtained at the end of the case to verify a satisfactory reduction and position of the implants. Patients are anticoagulated in the postop period to prevent thromboembolic complications. Weight-bearing restrictions are maintained until enough healing has occurred to permit functional ambulation.

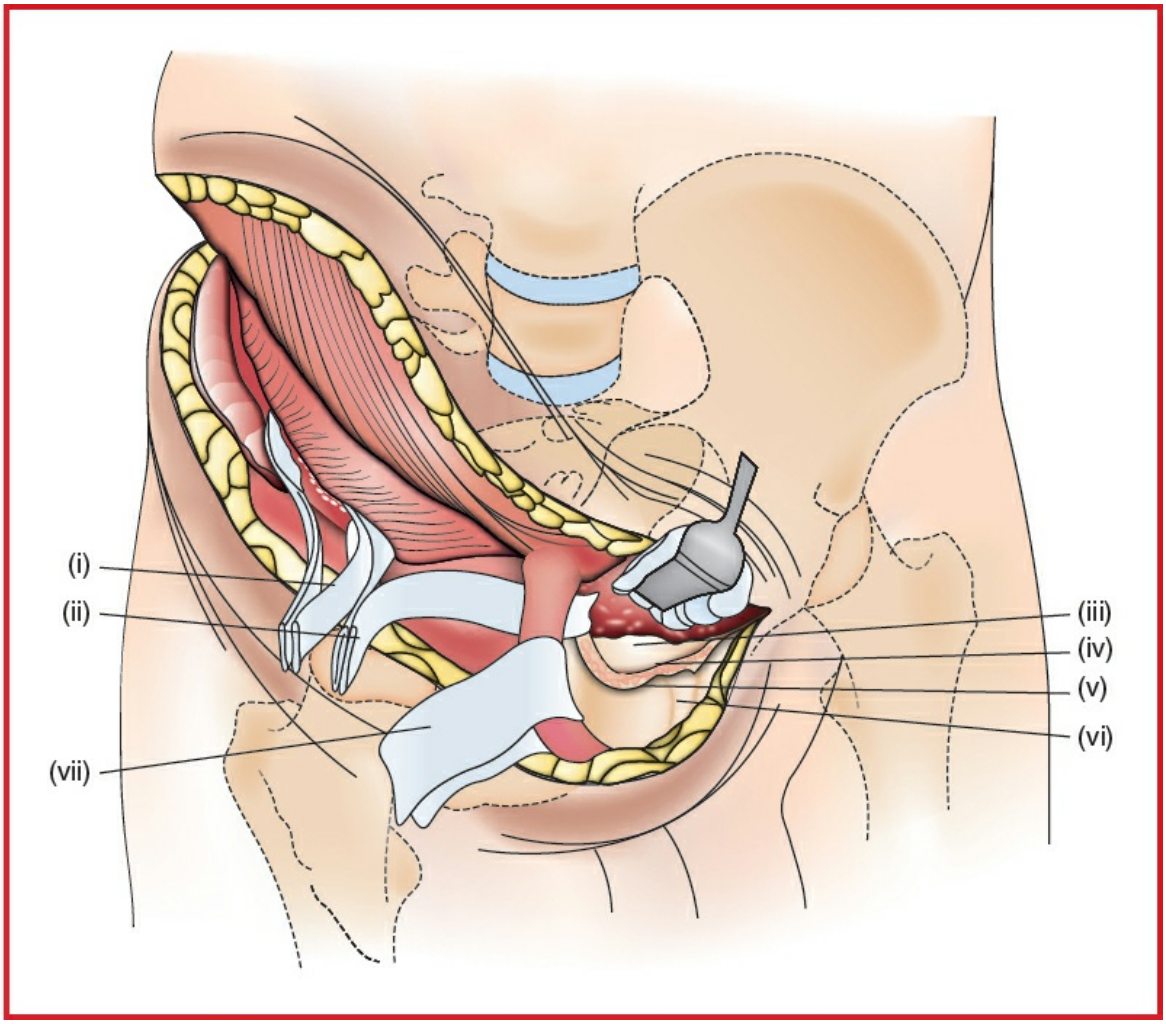

Figure 10.4-3 Ilioinguinal approach, right side: (i) Penrose drain around the iliopsoas, femoral nerve, and lateral femoral cutaneous nerve; (ii) Penrose drain around femoral vessels; (iii) bladder and space of Retzius; (iv) pubis; (v) pubic tubercle; (vi) symphysis pubis; (vii) Penrose drain around spermatic cord. (Redrawn from Sledge CB, ed: The Hip. Lippincott-Raven, Philadelphia: 1998.)

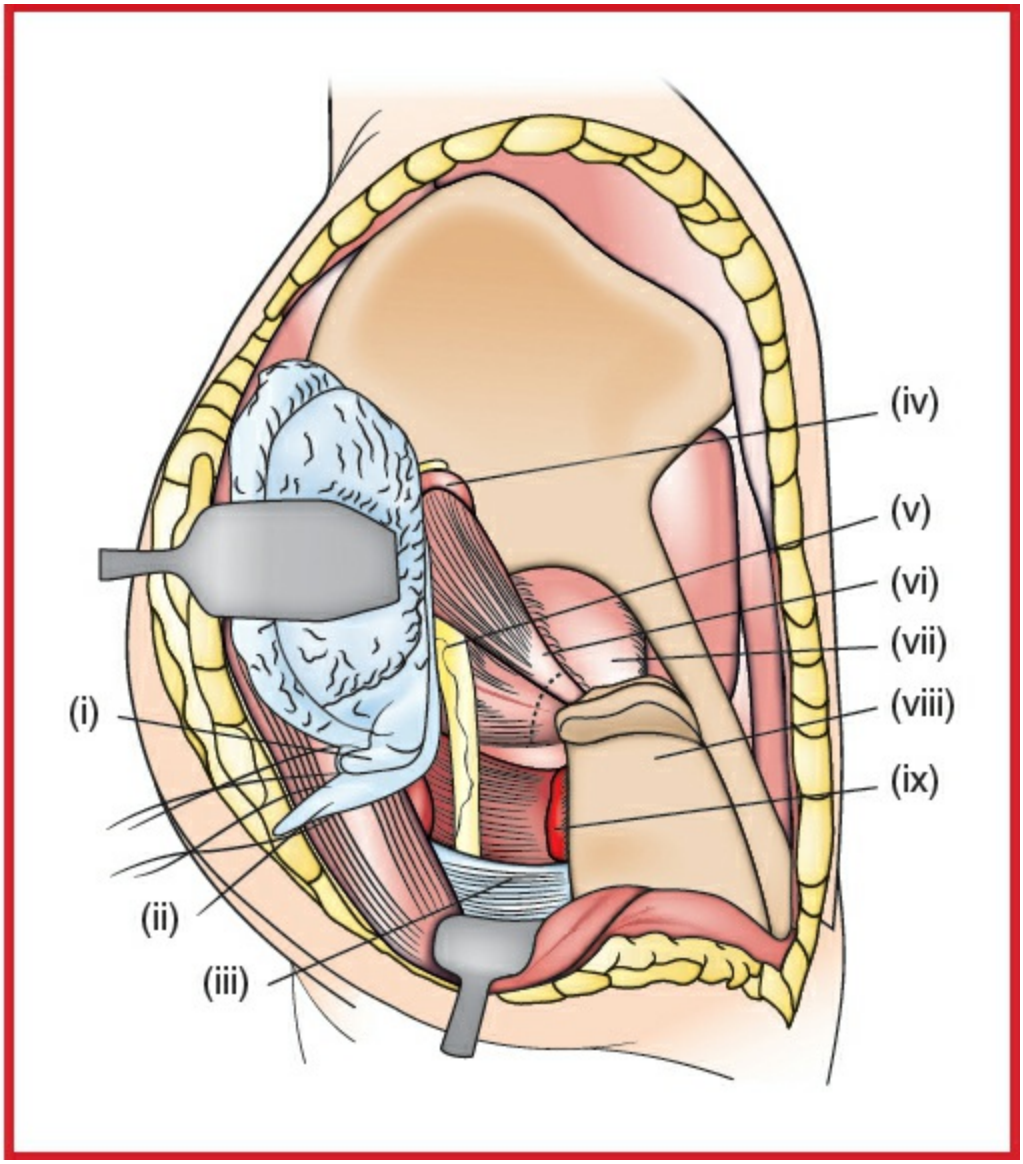

Figure 10.4-4 Extended iliofemoral approach: (i) Gluteus minimus tendon, (ii) gluteus medius tendon, (iii) gluteus maximus tendon, (iv) superior gluteal neurovascular bundle, (v) sciatic nerve, (vi) piriformis and conjoint tendons, (vii) hip joint capsule, (viii) greater trochanter, (ix) medial femoral circumflex artery overlying the quadratus femoris. (Redrawn from Sledge CB, ed: The Hip. Lippincott-Raven, Philadelphia: 1998.)

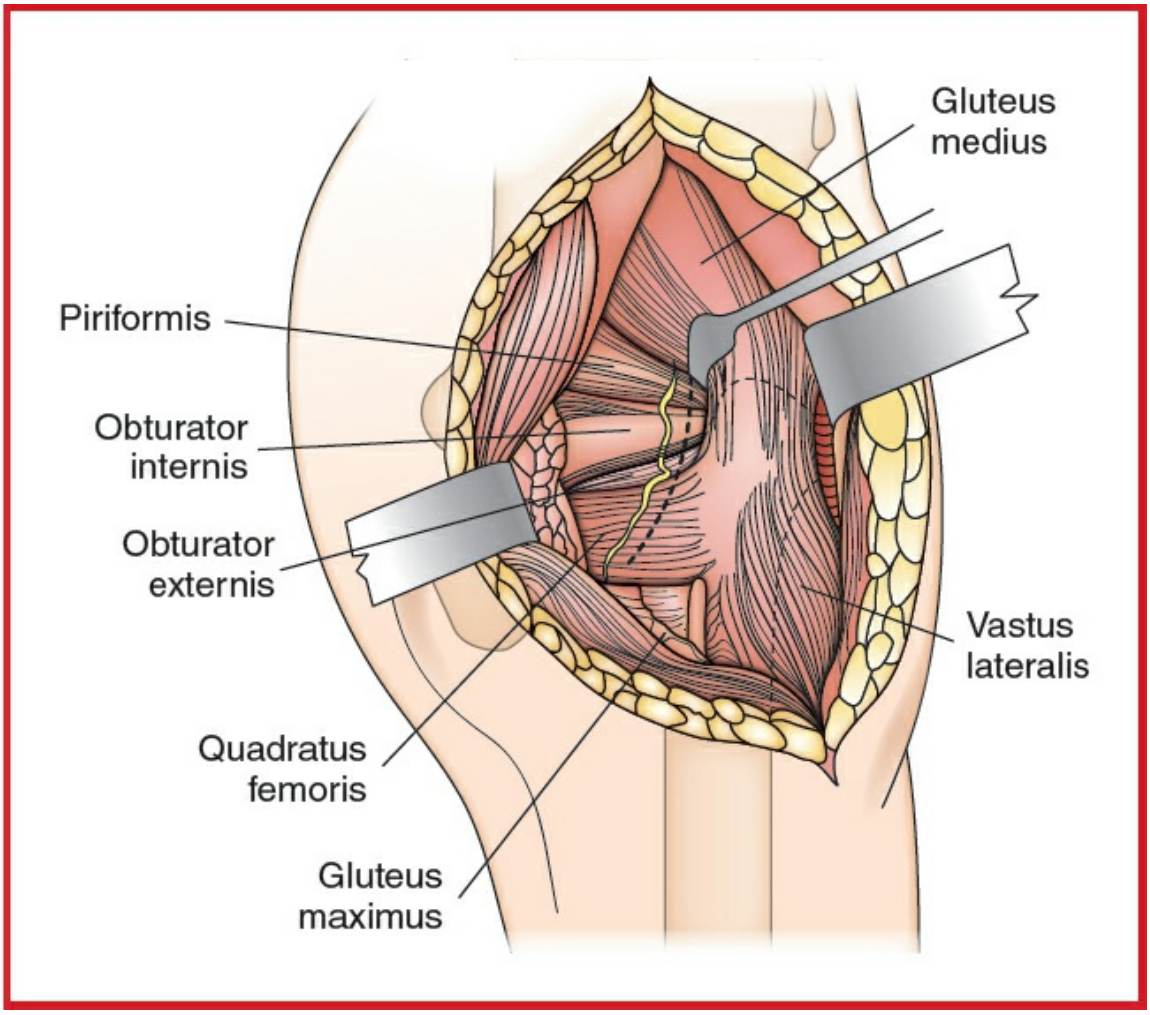

Figure 10.4-5 Kocher-Langenbeck approach. (Redrawn from Sledge CB, ed:The Hip. Lippincott-Raven, Philadelphia: 1998.)

Usual preop diagnosis

Fracture of the acetabulum; nonunion/malunion of the acetabulum

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine (anterior); lateral decubitus (lateral); prone (posterior)
Incision	Ilioinguinal (anterior; Fig. 10.4-3); extended iliofemoral (lateral; Fig. 10.4-4), Kocher-Langenbeck (posterior;

	Fig. 10.4-5)
Special instrumentation	Pelvic table; pelvic instruments and implants; I.I.; Cell Saver
Antibiotics	Cefazolin 2 g iv q6–8h × 24 h (vancomycin or clindamycin for 24 h if penicillin allergic)
Surgical time	2–5 h
EBL	100–2000 mL
Postop care	Multiple trauma: → ICU; others → PACU
Mortality	~2%
Morbidity	Ectopic ossification: 24% Osteoarthritis after perfect reduction: 10.2%; after imperfect reduction: ~36% Injury to lateral cutaneous nerve of the thigh: 12% Sciatic nerve damage: 6% Infection: 4% Avascular bone necrosis: 4% DVT: 3% Wound hematoma: 1.5% Secondary displacement of fracture site: 1.5% PE: 1% Pseudoarthrosis: 0.7% Ileus after ilioinguinal approach: Common
Pain score	7–8

PATIENT POPULATION CHARACTERISTICS	
Age range	12–85 yr
Male:Female	66% (M); 34% (F)
Etiology	Motor vehicle accidents (70%); motor vehicle/pedestrian accidents (13%); falls (14%); other (3%)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Procedures About the Pelvis and Hip.

Suggested Readings

1. Briffa N, Pearce R, Hill AM, et al: Outcomes of acetabular fracture fixation with te years' follow-up. J Bone Joint Surg Br 2011; 93(2):226–36.
2. Gettys FK, Russell GV, Karunakar MA: Open treatment of pelvic and acetabula fractures. Orthop Clin North Am 2011; 42(1):69–83, vi.
3. Prevezas N: Evolution of pelvic and acetabular surgery from ancient to modern times. Injury 2007; 38(4):397–408.
4. Rice PL Jr, Rudolph M: Pelvic fractures.Emerg Med Clin North Am 2007; 25(3):795–802.
5. Skitch S, Engels PT: Acute management of the traumatically injured pelvis.Emerg Med Clin North Am 2018; 36(1):161–79.

OSTEOTOMY AND BONE GRAFT AUGMENTATION OF THE PELVIS

SURGICAL CONSIDERATIONS

Description

Acetabular insufficiency (acetabular dysplasia) is characterized by deficient anterior and lateral coverage of the acetabulum on the femoral head. This condition of the hip produces joint incongruity and instability, eventually leading to arthrosis and a dysfunctional hip joint. Treatment is aimed at reorienting the dysplastic acetabulum (Fig. 10.4-6). In children, bone grafting alone may be sufficient; in adults, however, pelvic osteotomy, to reorient or broaden the weight-bearing surface, is necessary. A supplemental bone graft to expand the weight-bearing surface may be added. In certain instances following pelvic osteotomy, incongruity of the hip may persist. In this situation, the pelvic osteotomy is combined with a proximal femoral osteotomy to restore congruence. Pelvic and proximal femoral osteotomies usually are fixed internally with screws and plates to allow early mobilization without displacement. Weight-bearing is permitted after healing of the osteotomy at ~8 wk.

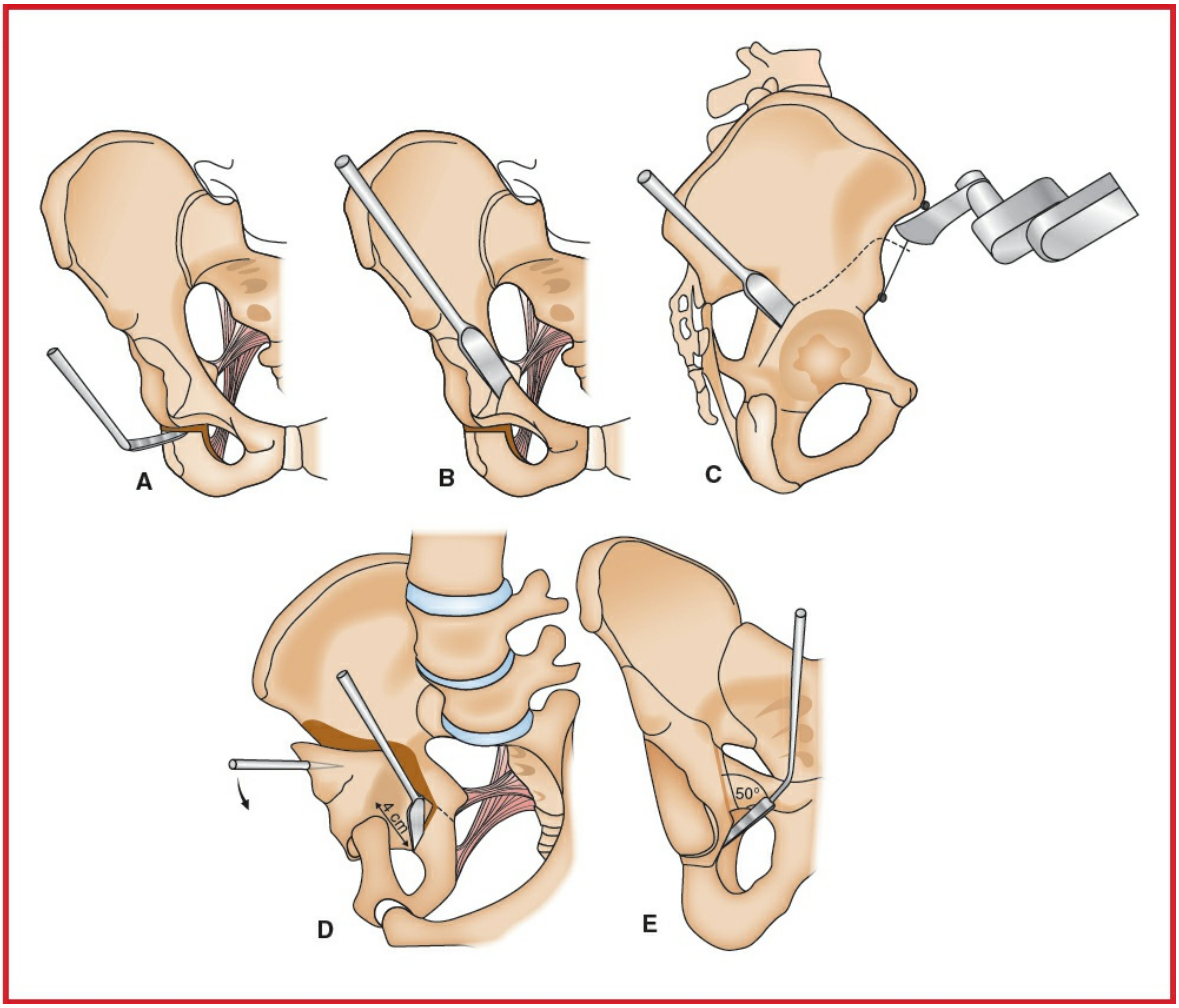

Figure 10.4-6 A–E: The Bernese periacetabular osteotomy. (Redrawn from Ganz R, Klaue K, Vinh TS, et al: A new periacetabular osteotomy for the treatment of hip dysplasias: technique and preliminary results. Clin Orthop 1988; 232:26–36.)

Usual preop diagnosis

Acetabular dysplasia; developmental dysplasia of the hip

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Anterior: ilioinguinal or iliofemoral and Smith-Petersen
Special	Pelvic instruments and implants; special osteotomes

instrumentation	and saws; I.I., Cell Saver
Unique considerations	Intraop radiographs and use of I.I.
Antibiotics	Cefazolin 2 g iv q6–8h × 24 h (vancomycin or clindamycin for 24 h if penicillin allergic)
Surgical time	3 h
EBL	500+ mL
Postop care	PACU → room; usually on protected, weight-bearing walker or crutches × 8 wk
Mortality	Minimal
Morbidity	Ileus: 100% Leg-length discrepancy: Uniformly present after pelvic osteotomy Injury to lateral cutaneous nerve: Common (50%) Sciatic nerve: Uncommon (1%) Thromboembolism: 5–10% Wound infection: 1–5% Septic arthritis, osteomyelitis: 1–7% Delayed union, nonunion, malunion: 1–2% Genitourinary problems—urinary retention requiring catheterization: Common Hematoma: Common Hypotension 2° to retroperitoneal hematoma: Rare Vascular complications: Rare
Pain score	8

PATIENT POPULATION CHARACTERISTICS

Age range	20–50 yr
Male:Female	3–4 times higher incidence in females for congenital hip dysplasia; equal incidence for other causes
Etiology	Congenital hip dysplasia; neuromuscular disorders (cerebral palsy, meningomyelocele); pediatric trauma to acetabular growth plate

Associated conditions	Depends on Dx

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Procedures About the Pelvis and Hip.

ARTHRODESIS OF THE SACROILIAC JOINT

SURGICAL CONSIDERATIONS

Description

In this procedure, a painful and/or unstable sacroiliac (SI) joint is fused, usually by excising the joint through an **anterior** or **posterior approach** and employing an iliac crest bone graft. Supplemental screw fixation of the joint is used. The incision follows the iliac crest from the anterior superior iliac spine past the convexity of the iliac tubercle; the aponeurosis of the external abdominal musculature is elevated from the iliac crest. The internal iliac fossa is exposed subperiosteally, posterior to the SI joint; then, the joint cartilage is excised and packed with cancellous bone strips. The SI joint is fixed with plates and screws. Alternatively, a posterior approach to the SI joint may be used. A straight vertical incision is made just lateral to the posterior superior iliac spine. The origin of the gluteus maximus is elevated from its origin off the posterior ilium and sacrum and reattached laterally. The SI joint is identified, débrided of cartilage, and packed with strips of cancellous bone. It is then fixed with screws.

Variant procedure or approaches

Anterior or posterior approach

Usual preop diagnosis

Arthritis or arthrosis of the SI joint; pelvic instability

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE

Position	Supine (anterior) or prone (posterior)
Incision	Lateral portion of ilioinguinal (anterior); posterior approach to SI joint (posterior)
Special instrumentation	Radiolucent table; pelvic instruments and implants; I.I.; Cell Saver
Unique considerations	Intraop radiographs or use of I.I.
Antibiotics	Cefazolin 2 g iv q6–8h × 24 h (vancomycin or clindamycin for 24 h if penicillin allergic)
Surgical time	2–3 h
EBL	250–500 mL
Postop care	Usually on protected, weight-bearing walker or crutches × 6–8 wk; anticoagulation for DVT prophylaxis
Mortality	Extremely low
Morbidity	Ileus: Virtually always Osteomyelitis: <1% Wound infection: <1% Genitourinary problems; urinary retention requiring catheterization: Common Delayed union, nonunion, malunion, leg-length discrepancy: Not uncommon Neurologic deficit; injury to lumbosacral plexus: Rare, unless present preop; L5 nerve root susceptible in anterior approaches Hypotension 2° to retroperitoneal hematoma: Rare Injury to the bowel: Rare Vascular complications; injury to iliac arteries: Rare Thromboembolism
Pain score	7

PATIENT POPULATION CHARACTERISTICS

Age range	20–50 yr

Male:Female	Increased incidence in males (trauma)
Incidence	Rare
Etiology	Trauma—post–pelvic fracture dislocation; painful septic arthritis

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Procedures About the Pelvis and Hip.

Suggested Readings

1. Rice PL Jr, Rudolph M: Pelvic fractures.Emerg Med Clin North Am 2007; 25(3):795–802.
2. Skitch S, Engels PT: Acute management of the traumatically injured pelvis.Emerg Med Clin North Am 2018; 36(1):161–79.
3. Wise CL, Dall BE: Minimally invasive sacroiliac arthrodesis: outcomes of a new technique. J Spinal Disord Tech 2008; 21(8):579–84.

AMPUTATIONS ABOUT THE HIP AND PELVIS: DISARTICULATION OF THE HIP AND HINDQUARTER AMPUTATION

SURGICAL CONSIDERATIONS

Description

These surgical procedures accomplish an excision of the entire lower extremity. In a **hip disarticulation,** the amputation is performed through the hip joint. An anterior, racquet-shaped incision is made, and all muscles crossing the hip joint are incised or detached. The femoral artery, vein, and nerve, obturator vessels, sciatic nerve, and deep vessels are isolated and ligated. The gluteal flap is brought anteriorly and sewn to the anterior portion of the incision. In a **hindquarter amputation,** excision of the lower extremity, hip joint, and a portion of the pelvis is performed. Anterior and posterior incisions are used, the iliac wing is divided posteriorly, and the symphysis pubis is disarticulated anteriorly. Either the common iliac or external iliac vessels are ligated, as are all nerves to the lower extremity. Usually, the gluteal flap is drawn anteriorly for closure. These procedures are performed very rarely—for severe trauma, tumor, or infection—and are often lifesaving surgeries. They often are performed in conjunction with a

general surgeon, and standard bowel prep is done. The operations are long and tedious, with extensive blood loss, in patients who are usually systemically ill.

Usual preop diagnosis

Malignant tumor of the femur, hip, or pelvis; traumatic amputation to the femur, hip, or pelvis; uncontrollable infection to the leg, hip, or pelvis (e.g., clostridia)

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plan. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Hip Disarticulation	Hindquarter Amputation
Position	Supine	Lateral decubitus; stabilized by beanbag and/or kidney rests
Incision	Anterior racquet type (rare)	Anterior and posterior
Unique considerations	Urinary catheter should be placed.	Urinary catheter; NG tube; scrotum strapped to the opposite thigh; anus stitched closed/sealed
Antibiotics	Cefazolin 2 g iv q6–8h × 24 h (vancomycin or clindamycin for 24 h if penicillin allergic)	⇐
Surgical time	3–4 h	4–5 h
EBL	1000–2000 mL (intraop blood salvage system recommended, except for tumors)	2000–3000 mL
Postop care	ICU	⇐
Mortality	Rare in patients undergoing elective	⇐

	amputation for trauma or localized tumor; higher for patients with debilitated trauma, chronic infection, or extensive invasive malignant tumor; highest in clostridial infections: ~50%+	
Morbidity	Anemia: Common Electrolyte abnormalities: Common Hematoma: Common Neurologic injury to lumbosacral plexus or peripheral nerves: Common Paralytic ileus: Common Psychosocial problems: Common UTI: Common Flap necrosis: Not uncommon Incomplete excision with recurrence of tumor or infection: Not uncommon Injury to peritoneal or retroperitoneal contents, including bowel and bladder: Not uncommon Vascular injury—iliac; other vessels: Not uncommon	⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐
Pain score	10	10

PATIENT POPULATION CHARACTERISTICS

Age range	Any age

Male:Female	Similar, except higher incidence in males for traumatic etiologies
Incidence	Uncommon
Etiology	Malignant tumor; trauma; infection—clostridial myonecrosis, chronic osteomyelitis, etc.

ANESTHETIC CONSIDERATIONS FOR PROCEDURES ABOUT THE PELVIS AND HIP

(Procedures covered: ORIF, pelvis and acetabulum; closed reduction, external fixation, pelvis; osteotomy and bone graft of the pelvis; arthrodesis of SI joint; amputations about the hip and pelvis: disarticulation of the hip and hindquarter amputation)

PREOPERATIVE

Patients presenting for pelvic surgery generally fall into two categories: (a) major trauma—pelvic fracture requires substantial force and seldom occurs alone. These patients require aggressive fluid resuscitation with large-bore ivs and invasive monitors (arterial line and CVP). If the patient can be made hemodynamically stable with volume resuscitation, a thorough evaluation for coexisting neurologic, thoracic, or abdominal trauma should be undertaken before anesthesia. (b) Tumor resection and amputation of the thigh, hip, and pelvis. Because of large intraop blood loss and third spacing of fluids, invasive hemodynamic monitoring is necessary. Although epidural anesthesia is seldom adequate for surgery, postop epidural analgesia is an effective means of controlling the tremendous pain caused by this type of surgery. Other patient populations covered in this section include otherwise healthy patients with congenital or acquired hip dysplasia presenting for augmentation procedures.

Respiratory	Trauma patients are at risk for hemothorax, pneumothorax, pulmonary contusion, fat embolism (preop and postop), impaired respiratory effort secondary to rib fractures, and aspiration. A chest tube will be needed before surgery if either a hemothorax or pneumothorax is present. Pulmonary fat embolus occurs in 10–15% of patients with long-bone fractures and can occur after isolated pelvic fractures. Sx include hypoxemia, ↑HR, ↑RR,

	respiratory alkalosis, mental status changes, conjunctival petechiae, fat bodies in the urine, and diffuse pulmonary infiltrates. Sx of pulmonary aspiration are similar to those of fat embolism. Preop therapy for either should include supplemental O_2 to correct hypoxemia (may necessitate mechanical ventilation) and meticulous fluid management to prevent worsening of pulmonary capillary leak. The best predictor of aspiration/hypoventilation is reduced level of consciousness, usually measured using the Glasgow Coma Scale. **Tests:** CXR or others as indicated from H&P
Cardiovascular	Blunt chest trauma can produce both cardiac contusion and aortic tear. Preop ECG and CPK isoenzymes will help evaluate the presence of myocardial injury. A wide mediastinal silhouette suggests aortic tear, which requires evaluation with TEE or angiography. **Tests:** Consider ECG; CPK isoenzymes; others as indicated from H&P
Neurologic	The possibility of coexistent neurologic trauma necessitates a thorough preop mental status review and peripheral sensory exam. A CT scan of the head is indicated for any patient with loss of consciousness prior to anesthesia.
Musculoskeletal	For trauma patients, C-spine films will evaluate the stability of the C-spine before neck manipulation during ET intubation. Thoracic and lumbar x-rays also should be evaluated for the presence of traumatic spinal deformity or instability that would require special stabilization in the anesthetized patient. **Tests:** C-spine x-rays or others as indicated from H&P
Hematologic	Restore Hct to 25% prior to inducing anesthesia. Have available one blood volume (70 mL/kg) or one total erythrocyte mass (20 mL/kg) for intraop transfusion. Transfusions of more than one blood

	volume will require monitoring and possible replacement of Plts and coag factors. The incidence of DVT is very high in these patients and prophylaxis with SCDs or low-dose sc heparin is indicated whenever feasible.
Renal	Renal injury commonly results from trauma to the collecting system, myoglobinuria from rhabdomyolysis, and ischemic, acute, tubular necrosis from hypovolemia or aortic dissection. Foley catheters should be placed only after urologic consultation for possible urethral tear. Suprapubic catheters are often necessary. Monitoring of UO is mandatory to detect intraop compromise of the collecting system and to monitor adequacy of renal perfusion. **Tests:** Consider UA; BUN; Cr; others as indicated from H&P
Laboratory	Hct; electrolytes; other tests as indicated from H&P
Premedication	In hemodynamically stable patients, pain can be treated with morphine (1–2 mg iv q10min titrated to pain relief) prior to anesthesia.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po, ± celecoxib 200 mg po, and ± gabapentin 300 mg po. Consider aprepitant 40 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA is indicated due to the duration and extent of the surgery, as well as the varied positions that are necessary to accomplish pelvic fixation. Regional anesthesia is generally inadequate for major pelvic surgery; however, in elective surgeries, serious consideration should be given to postop epidural analgesia.

Induction	A rapid-sequence induction is necessary for trauma

	patients to minimize aspiration risk. Elective cases can undergo a standard induction.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Tranexamic acid (e.g., 10–15 mg/kg) iv before incision has been shown to ↓EBL and may be requested by the surgeon.	
Maintenance	Standard maintenance. Ventilation: lung-protective strategy. A ventilatory strategy should be adopted with tidal volumes around 5–8 mL/kg and plateau airway pressures below 30 cmH_2O. A minimum PEEP of 5 cmH_2O should be applied and adjusted.	
Emergence	Extubate trauma patients when fully awake and protective airway reflexes have returned. Do not extubate patients with evolving pulmonary injuries (fat embolism, aspiration, or contusion). Monitoring in an ICU usually is indicated for trauma and cancer patients. Prolonged stays can be anticipated for patients with severe coexistent trauma. Consider iv acetaminophen if po dose given >6 h ago. PONV prophylaxis should include ondansetron and dexamethasone.	
Blood and fluid requirements	Large EBL IV: 14–16 ga × 2 BSS @ up to 12 mL/kg/h 2–4 U PRBC in OR Warm fluids. Humidify gases	Expect large blood losses (from 0.5 to 2 or more blood volumes) with all but augmentation procedures. Use goal-directed fluid management. Cell-scavenging techniques are useful to reduce the requirement for blood. Care should be taken to ensure that cells have been adequately washed to minimize ↓ BP on reinfusion. See Goal-

		Directed Fluid Management, Appendix K, p. K-4.
Control of blood loss	Deliberate hypotension Hemodilution	Patients with severe cardiovascular disease or carotid artery stenosis are not candidates for ↓ BP. Full replacement of any volume deficit is mandatory before inducing ↓ BP. Commonly used agents are isoflurane (1–3%) or esmolol (50–200 mcg/kg/min) ± SNP (0.25–3 mcg/kg/min). These agents are titrated to produce a 30% ↓ in preop MAP (but not <60 mm Hg).
	In trauma patients	A cerebral perfusion pressure of >65 mm Hg is advocated. A case-by-case decision should be made, balancing the requirements of cerebral oxygenation against the risk of worsening hemorrhage. In isolated head injury, hypotension must not be tolerated: an arterial pressure of 85–90 mm Hg may be beneficial.
Monitoring	Standard monitors Arterial line	Patients for shelf procedures may require only standard monitoring.

	CVP line ± PA catheter ± TEE UO	Patients with myocardial dysfunction should have fluid and inotropic/pressor therapy, guided by continuous central venous saturation monitoring, a PA catheter, and/or TEE.
Positioning	✓ and pad pressure points ✓ eyes	Meticulous padding of the chest, pelvis, and extremities is imperative to prevent nerve injury and ischemia of the extremities. ↓ BP → risk of neurovascular injury.
Complications	Hypothermia Damage to urinary collecting system Major blood loss Coagulopathy	Warming of hypothermic patient may unmask severe volume depletion that will increase fluid requirement to well above apparent losses.

POSTOPERATIVE

Complications	Nerve root damage Peripheral nerve damage	Preop or intraop damage to L4-S5 nerve roots and cauda equina, resulting in hemiplegia and bladder and bowel dysfunction. Neuropathy of the femoral, genitofemoral, and lateral femoral cutaneous nerves can result from pressure on the ilioinguinal ligament during surgery.
Multimodal pain	Acetaminophen	Emphasize multimodal

management	NSAIDs IV morphine Spinal/epidural opiates	approach combining nonopioid and bolus/PCA opioid analgesics with regional anesthetics whenever possible (see Appendix K, p. K-6). Epidural hydromorphone 50 mcg/mL infused at 100–250 mcg/h, ± bupivacaine 0.125–0.25% at 4–8 mL/h, provides excellent analgesia.
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6) Regional analgesia	Encourage early enteral nutrition, Foley catheter removal, and mobilization, for example, continuous nerve block.
Tests	Hct CXR Coag profile, as indicated	

Suggested Readings

1. Auyong DB, Allen CJ, Pahang JA, et al: Reduced length of hospitalization in primar total knee arthroplasty patients using an updated enhanced recovery after orthopedic surgery (ERAS) pathway. J Arthroplasty 2015; 30(10):1705–9.
2. Harris T, Davenport R, Hurst T, Jones J: Improving outcome in severe trauma trauma systems and initial management: intubation, ventilation and resuscitation. Postgrad Med J 2012; 88:588–94.
3. Jones J Jr, Southerland W, Catalani B: The importance of optimizing acute pain in the orthopedic trauma patient. Orthop Clin North Am 2017; 48(4):445–65.
4. Masursky D, Dexter F, McCartney CJ, et al: Predicting orthopedic surgeons preferences for peripheral nerve blocks for their patients. Anesth Analg 2008; 106(2):561–7.
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6. Rosencher N, Bonnet MP, Sessler DI: Selected new antithrombotic agents and neuraxial anaesthesia for major orthopaedic surgery: management strategies. Anaesthesia 2007; 62(11):1154–60.

7. Zhu S, Qian W, Jiang C, et al: Enhanced recovery after surgery for hip and knee arthroplasty: a systematic review and meta-analysis. Postgrad Med J 2017; 93(1106):736–42.

ARTHROPLASTY OF THE HIP

SURGICAL CONSIDERATIONS

Description

Total hip arthroplasty is one of the most successful procedures in orthopedic surgery. In this procedure, the hip joint (Fig. 10.4-7) is approached through one of several standard incisions. The femoral head is dislocated from the acetabulum, and the arthritic femoral head and a portion of the neck are excised. The acetabulum is reamed to accept a cemented or cementless cup made of metal and plastic. The femoral stem and head are usually modular, allowing for numerous shapes, sizes, lengths, etc. The metallic femoral component may be cemented or cementless. A hybrid total hip combines a cemented femoral stem and a cementless acetabular cup. After relocation of the new prosthetic hip joint and closure of the tissues, the patient may be given an abduction pillow to minimize the risk of dislocation. Mobilization takes place over the ensuing days.

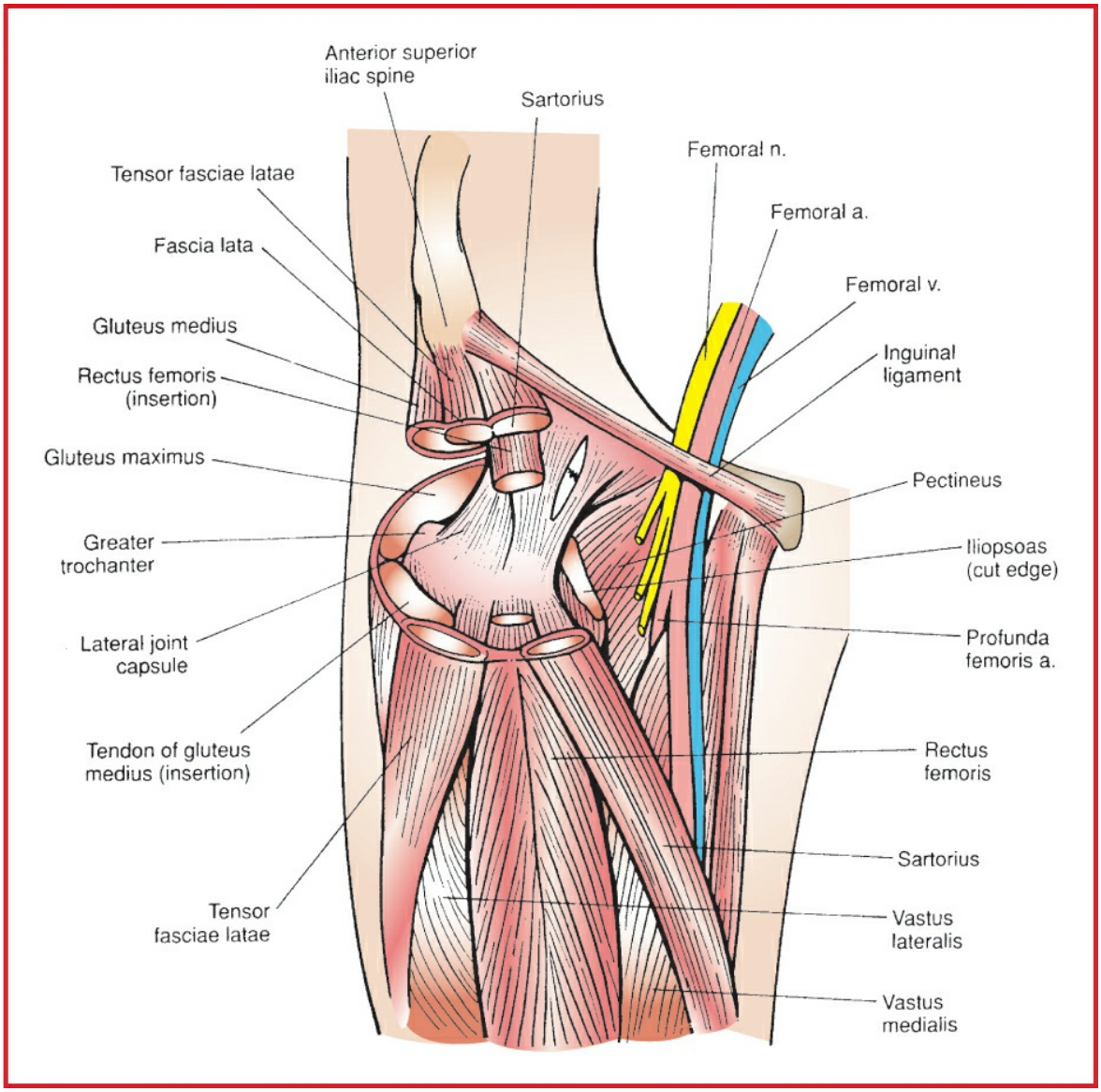

Figure 10.4-7 Surgical exposure of the hip joint. The hip joint may be exposed through a number of approaches. The relevant anatomical landmarks are shown here. (Reproduced with permission from Hoppenfeld S, deBoer P: Surgical Exposures in Orthopaedics. JB Lippincott, Philadelphia: 1984.)

Variant procedure or approaches

Unipolar (only the femoral side is replaced); **bipolar** (both the femoral side and the acetabular side are replaced; the acetabular cup is not fixed to the pelvis). **Revision procedures** are more arduous and time consuming, as the "failed" or loose component(s) must be removed and the bone prepared to accept new cemented or cementless components. These procedures require more specialized equipment for extracting prostheses and cement and rebuilding the femoral or acetabular bone stock (allografts, autografts, etc.). Often, special components are needed for implantation of a new prosthesis. In the **Girdlestone procedure (resection arthroplasty)**, the components are removed, but not replaced. This procedure is usually performed for

infection.

Usual preop diagnosis

Fracture of femoral neck; arthritis of the hip; arthrosis of the hip; loose (or malpositioned) hip prosthesis; chronic dislocation of hip arthroplasty; infected hip arthroplasty

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plan. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Unipolar, Bipolar, Total Hip Replacement	Revision, Total Hip Replacement	Girdlestone Resection Arthroplasty
Position	Supine (for anterior or anterolateral approaches); lateral decubitus position (for lateral or posterior approaches)	⇐	⇐
Incision	Anterior, lateral, or posterolateral over the hip joint	⇐	⇐
Special instrumentation	Appropriate prostheses and instrumentation	Special instruments for excising cement	⇐
Unique considerations	In lateral decubitus position, patient is usually stabilized by beanbag and/or kidney rests. SCDs used	A trochanteric osteotomy may be performed.	⇐
Antibiotics	Cefazolin 2 g iv q6–8h × 24 h (vancomycin or clindamycin for 24 h if	⇐	⇐ after intraop cultures

	penicillin allergic)		
Surgical time	2–3 h	3–6 h or more	3 h or more
EBL	250–750 mL (intraop blood retrieval system may be useful)	≥1000 mL; intraop blood retrieval recommended	⇐
Postop care	Patient's legs immobilized between abduction wedge	⇐	⇐
Mortality	1–2% (increasing with age)	⇐	⇐
Morbidity	DVT: • Without prophylaxis: ≥50% • With chemoprophylaxis and mechanical prophylaxis: 2–3% Heterotopic ossification: 3–50% (average, 13%; significant, 4–5%) Intraop cementless fracture: 5–20% UTI: 7–14% Late aseptic loosening requiring revision: 5–10% (after 10 yr) Wound infection: 1% • Primary psoriatic and diabetic patients: 5–10% • Primary OA: 1% Hematoma (major): <5%	⇐ ⇐ ⇐ >3–50% ⇐ ⇐ >5–10% 3–10% ⇐	⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ 5–10%

	Femoral/sciatic nerve injury: 0.7–3.5%	⇐	⇐
	PE: 1.8–3.4% (if no prophylaxis)	⇐	⇐
	Intraop cemented fracture: 1–3%	2–3%	1–3%
	Postop subluxation/dislocation: 0.5–3%	⇐	–
	Vascular injury to iliac vessels: <0.5%	>0.5%	⇐
	Urinary retention requiring catheterization: Rare	⇐	⇐
	GI bleed, MI, cholecystitis: Rare	⇐	–
			Neurologic injury: 3–10%
Pain score	7	8	8

PATIENT POPULATION CHARACTERISTICS

Age range	Hip fracture and cases of arthrosis of the hip joint: generally >60 yr Arthritis of the hip (e.g., rheumatoid arthritis or juvenile rheumatoid arthritis, traumatic arthritis): all ages
Male:Female	Dependent on disease etiology
Incidence	Common: ~500,000/yr in the United States
Etiology	Osteoarthritis; seropositive or seronegative arthritis; avascular necrosis; traumatic arthritis; congenital dislocation of the hip
Associated conditions	Dependent on primary conditions (e.g., rheumatoid arthritis patients may have numerous deformities, cardiorespiratory disease)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Hip Procedures.

Suggested Readings

1. Barrack RL: Current guidelines for total joint VTE prophylaxis: dawn of a new day.J Bone Joint Surg Br 2012; 94(11 Suppl A):3–7.
2. Berry DJ: Primary total hip arthroplasty. In: Chapman MW, ed.Chapman's Orthopaedic Surgery, Vol. 3, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001, 2769–94.
3. Johnson RL, Kopp SL, Hebl JR, et al: Falls and major orthopaedic surgery wit peripheral nerve blockade: a systematic review and meta-analysis. Br J Anaesth 2013; 110(4):518–28.
4. Russo MW, Parks NL, Hamilton WG: Perioperative pain management and anesthesia: a critical component to rapid recovery total joint arthroplasty. Orthop Clin North Am 2017; 48(4):401–5.
5. Sugano N: Computer-assisted orthopaedic surgery and robotic surgery in total hip arthroplasty. Clin Orthop Surg 2013; 5(1):1–9.
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ARTHRODESIS OF THE HIP

SURGICAL CONSIDERATIONS

Description

In adults, this procedure is accomplished by fusing the femur to the acetabulum. Some form of internal fixation is usually employed; a spica cast is sometimes placed immediately postop or a few days later. The patient is usually not a good candidate for total hip arthroplasty (e.g., a young, healthy male with unilateral traumatic arthritis). The hip usually is fused in 30° of flexion, 10–30° of external rotation, and neutral-to-slight adduction. The surgical procedure may be performed through anterior, lateral, or posterior incisions with the lateral being most common. A **trochanteric osteotomy** facilitates exposure. After excising the cartilage surfaces, internal fixation, using screws ± a plate, is performed (Fig. 10.4-8).

Usual preop diagnosis

Arthritis or arthrosis of the hip; previous septic arthritis of the hip; recurrent subluxation or dislocation of the hip

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plan. See Appendix K, p. K-1.

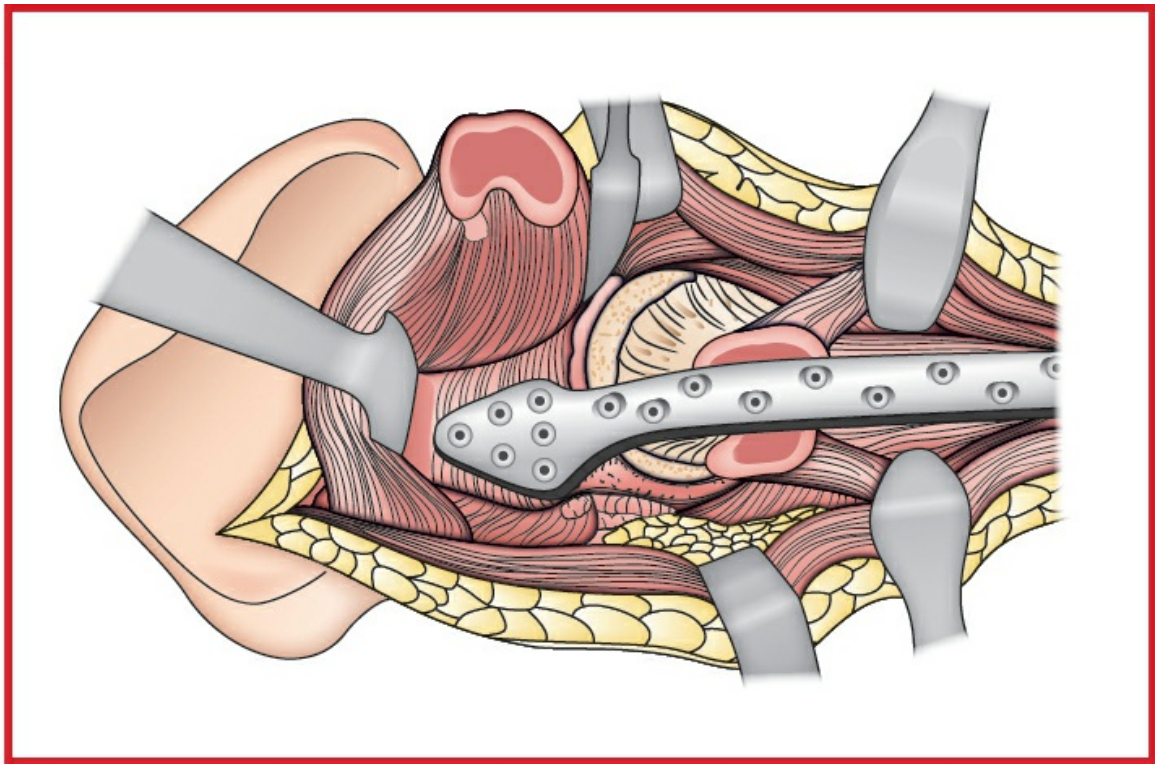

Figure 10.4-8 Application of cobra plate after it has molded to the shape of the acetabulum and femur and initial fixation with one proximal + distal outrigger compression screws. (Redrawn from Sledge CB, ed: The Hip. Lippincott-Raven, Philadelphia: 1998.)

SUMMARY OF PROCEDURE

Position	Usually supine; occasionally lateral decubitus
Incision	Anterior or lateral thigh
Special instrumentation	Plates and screws or other internal fixation; reamers from surface replacement arthroplasty set also may be useful; intraop x-ray; fracture table
Unique considerations	Intraop radiographs or I.I. used with patient on fracture table

Antibiotics	Cefazolin 2 g iv q6–8h × 24 h (vancomycin or clindamycin for 24 h if penicillin allergic)
Surgical time	3–4 h
EBL	500–1000 mL; Cell Saver recommended
Postop care	Spica cast
Mortality	Extremely low
Morbidity	Limb shortening: Some shortening is always present. Delayed union, nonunion, malunion: 10–15% Femoral shaft fracture: 5–10% Wound infection: <1% Genitourinary problems—urinary retention requiring catheterization: Common Ileus: Common Late degenerative arthritis of other lower extremity joints or back: Common, many years later Injury to iliac or femoral vessels: Rare Neurologic deficit; injury to lateral cutaneous nerve, sciatic nerve, or femoral nerves: Not uncommon Osteomyelitis: Rare Vascular complications: Rare Superior mesenteric artery syndrome causing duodenal obstruction: Extremely rare Thromboembolism: See Arthroplasty of the Hip.
Pain score	9

PATIENT POPULATION CHARACTERISTICS

Age range	18–50 yr
Male:Female	Usually males > females
Incidence	Rare
Etiology	Trauma, general; neuromuscular disorders (cerebral palsy, meningomyelocele); trauma to acetabular growth plate; congenital hip dysplasia
Associated	Depends on etiology

conditions

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Hip Procedures.

Suggested Reading

1. Jain S, Giannoudis PV: Arthrodesis of the hip and conversion to total hip arthroplasty: a systematic review. J Arthroplasty 2013; 28(9):1596–602.

SYNOVECTOMY OF THE HIP

SURGICAL CONSIDERATIONS

Description

An **arthrotomy** of the hip joint is performed through one of several standard approaches (anterior, anterolateral, lateral, posterior). A **capsulotomy** is performed and is closed with reabsorbable sutures later in the case. Generally, the hip is not dislocated, but the cartilage surfaces are inspected and documented. The synovium, as well as any loose bodies, cartilage flaps, and osteophytes, is excised. Although weight bearing is usually protected, ROM and strengthening exercises are begun early.

Usual preop diagnosis

Chronic synovitis of the hip; loose bodies in the hip; juvenile and adult rheumatoid arthritis; pigmented villonodular synovitis; synovial chondromatosis

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine for anterior or anterolateral surgical approaches; lateral decubitus for posterior approaches
Incision	Overlying hip joint, depending on specific surgical approach

Unique considerations	Patient may have systemic disease (e.g., rheumatoid arthritis); careful positioning of limbs is necessary to avoid fracture or skin slough.
Antibiotics	Cefazolin 2 g iv q6–8h × 24 h (vancomycin or clindamycin for 24 h if penicillin allergic)
Surgical time	2 h
EBL	<500 mL
Mortality	Rare
Morbidity	Thromboembolism: 10–50% Neurovascular injury—femoral or sciatic nerve or iliac vessels: <3% Wound infection or dehiscence: <3% Septic arthritis and osteomyelitis: <1% (unless synovectomy is performed for infection) Avascular necrosis of femoral head: Rare (if the hip is not dislocated) Hematoma: Rare (if drainage tubes are used) Inability to void, requiring urinary catheterization: Common
Pain score	7–8

PATIENT POPULATION CHARACTERISTICS	
Age range	<60 yr
Male:Female	Dependent on disease etiology (e.g., preponderance of females in rheumatoid arthritis)
Incidence	Rare
Etiology	Septic arthritis (very common); rheumatoid arthritis, juvenile/adult (rare); pigmented villonodular synovitis (rare); trauma (rare)
Associated conditions	See Etiology, above.

ANESTHETIC CONSIDERATIONS FOR HIP PROCEDURES

(Procedures covered: hip arthroplasty, arthrodesis, synovectomy)

PREOPERATIVE

Osteoarthritis is the most common indication for hip arthroplasty. These patients are usually elderly, and their anesthetic management is tailored to any concurrent disease. Rheumatoid and other inflammatory arthritides form another group of candidates for these procedures, and the special anesthetic considerations for these patients are outlined below. Avascular necrosis of the hip is seen in patients with sickle-cell disease and in heart transplant patients. A multimodal approach, aimed at reducing postoperative opioid usage, is commonly used. Consider preemptive analgesia with gabapentin 600 mg po, Celebrex 200 mg po, and acetaminophen 1 g po/iv to be given in the preop holding area.

Respiratory	Patients with rheumatoid arthritis frequently have associated pulmonary complications. SOB on performing activities of daily living or exercise (e.g., climbing a flight of stairs) warrants further evaluation with PFTs. Pulmonary effusions are common. Pulmonary fibrosis (rare) often manifests as cough and dyspnea. Rheumatoid arthritis involvement of the cricoarytenoid joints may produce glottic narrowing (requiring small ETT) and manifest as hoarseness. Arthritic involvement of the TMJ limits mouth opening and may necessitate special techniques (e.g., fiberoptic or light wand) for ET intubation. **Tests:** As indicated from H&P
Cardiovascular	The severity of the arthritis often limits exercise; thus, a dobutamine stress ECHO and/or dipyridamole/thallium imaging may be necessary for adequate cardiac evaluation in patients with poor exercise tolerance. HTN and cardiovascular disease are common in elderly patients (dysrhythmias/TIAs → fall → hip fracture). Rheumatoid arthritis is associated with pericardial effusion, cardiac valve fibrosis, cardiac conduction abnormalities, and aortic regurgitation (AR). An ECG is indicated in all

	rheumatoid arthritis patients, and ECHO is indicated for patients with physical Sx suggestive of tamponade or cardiovascular disease. **Test:** As indicated from H&P
Neurologic	In patients with rheumatoid arthritis, a thorough neurologic exam preop often yields evidence of cervical nerve root compression. Patients with arthritis involving the cervical spine should have lateral neck films preop to determine the stability of the atlanto-occipital joint. After the stability of the spine has been established, full ROM of the neck should be evaluated for evidence of further nerve root compression or cerebral ischemia (suggesting vertebral artery compression). Evidence of cerebral ischemia mandates a neurovascular evaluation to plan intraop BP management. **Tests:** As indicated from H&P
Musculoskeletal	Pain and ↓ joint mobility make positioning and regional anesthesia difficult in patients with arthritis.
Hematologic	Rheumatoid arthritis patients often have anemia. Also, anemia may be 2° NSAID gastritis. Patients with Hb > 12 g/dL are candidates for preop autologous blood donation. Hip fracture → potential large-volume blood loss at fracture site. DVT is common after hip surgery, and prophylaxis for its occurrence reduces mortality. Effective preventive measures include SCDs and sc heparin. NSAID-induced coagulopathy may preclude the use of regional anesthesia. **Test:** As indicated from H&P
Renal	Estimation of renal function may be useful to predict drug clearance and the need for invasive monitoring in this elderly population. **Test:** As indicated from H&P
Laboratory	Other tests as indicated from H&P
Premedication	In the absence of limited pulmonary reserve or

	severe cardiac disease, a standard premedication is appropriate. Full-stomach precautions may be necessary for patients in acute pain. Consider preemptive analgesia (see above).
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po, ±celecoxib 200 mg po, and ±gabapentin 300 mg po. Consider aprepitant 40 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA or regional anesthesia (may be difficult 2° pain on positioning).

General anesthesia

Induction	The lateral position may mandate ET intubation for patients undergoing GA. A careful preop airway evaluation will determine the need for special airway techniques (e.g., fiberoptic intubation, video laryngoscope, or light wand). Aggravation of cricoarytenoid arthritis that is common in rheumatoid arthritis patients can be minimized if a small ETT (6–7 mm cuffed) is used. For otherwise healthy patients, standard induction is appropriate.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Tranexamic acid (e.g., 10–15 mg/kg) iv before incision has been shown to ↓EBL and may be requested by the surgeon.
Maintenance	Standard maintenance. Neuromuscular blockade facilitates the placement and testing of the prosthesis. In otherwise healthy patients, induced hypotension (e.g., ↓ 20%) → ↓ blood loss. Maintain normothermia (forced-air blanket and fluid warmer).

Emergence	No special considerations. PONV prophylaxis (e.g., ondansetron 4 mg iv). Consider iv acetaminophen if po dose given >6 h ago. PONV prophylaxis should include ondansetron and dexamethasone.	

Regional anesthesia

Regional anesthesia offers the advantages of decreased periop DVT and pulmonary embolus, decreased intraop blood loss, and a drier surgical field (which may improve conditions for cementing). However, induction of regional anesthesia, with its attendant positioning requirements, can be uncomfortable in patients with limited joint mobility. Rheumatoid arthritis patients, however, rarely have involvement of the lumbar spine, and regional anesthesia offers the advantages of decreased periop DVT, decreased intraop blood loss, and no need for airway manipulation. Sedation or general anesthesia should be offered to supplement the regional technique. A typical dose for a subarachnoid block is 12.5–15 mg bupivacaine. 10–25 mcg of fentanyl and 100–200 mcg of morphine may be added for improved pain control up to 24 h postoperatively. Anesthesia to T10 is adequate. Full motor blockade is essential for placement of the prosthesis and assessment of the passive ROM. Lumbar epidural block (initial dose of 10–15 mL 2% lidocaine with epinephrine 1:200,000, administered over 10 min) has the advantage of slow onset, allowing time to treat the induced cardiovascular changes. Postop epidural opiates can provide excellent analgesia. Finally, a lumbar plexus block by the posterior approach (psoas compartment block) provides reliable postoperative analgesia, and hypotension and urinary retention are less common than with SAB or epidural analgesia. However, it is not sufficient for surgical anesthesia as the sole anesthetic. Continuous infusion is always initiated after the initial bolus of 15–20 mL of 0.125% bupivacaine or 0.2% ropivacaine. For patients with a high opioid tolerance, the use of a continuous epidural anesthetic (for either hip replacement or knee replacement) should be considered. For opioid-tolerant patients, low-dose iv ketamine (e.g., 250 mcg/kg/h) for all anesthetic techniques (not just GA) may be given intraop as an adjunct. In an effort to reduce adverse events associated with perioperative opioid consumption, there is emerging interest from the orthopedic community in eliminating the routine use of opioids in spinal anesthetics.

Blood and fluid requirements	Major blood loss IV: 14–16 ga × 2 BSS @ 4–8 mL/kg/h	Cell scavenging helps reduce total transfusion requirement. Care should be taken to ensure that cells have been adequately washed to

		minimize ↓ BP on reinfusion. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Control of blood loss	Regional anesthesia Controlled hypotension	These techniques may be appropriate in selected patient populations.
Monitoring	Standard monitors ± CVP line ± Arterial line	Invasive monitoring is indicated in the presence of exercise-limiting cardiac or pulmonary disease.
Positioning	Axillary roll, beanbag ✓ and pad pressure points ✓ eyes	Meticulous padding of extremities and maintaining a neutral neck position are mandatory. A beanbag and axillary roll also are necessary to stabilize patient in the lateral position and to protect dependent arm from neurovascular compression injuries.
Complications	Methylmethacrylate: • ↓ BP 2° vasodilation • ↓ PaO_2 2° embolization • Cardiovascular collapse VAE Major blood loss DVT (femoral vein: 80%) Nerve damage Femur fracture	Microemboli of air, fat, bone fragments, and cement may occur during pressurized cementing, which may lead to hypotension and hypoxia. Hypotension may be used to achieve a dry operating field, which improves cement penetration into the bone. However,

		significant hypovolemia must be avoided because this predisposes to a severe reaction to pressurized cementing. Systemic ↓ BP and pulmonary HTN may occur. Care should be taken to ensure that patient is adequately hydrated before and during the procedure, and pressors may be necessary to maintain BP (ephedrine 5–20 mg iv or epinephrine 10–100 mcg iv and increasing the dose as necessary).

POSTOPERATIVE

Complications	Nerve damage DVT Continued blood loss	Sciatic nerve injury is evidenced by foot drop and an inability to flex the knee.
Multimodal pain management	Neuraxial regimens: • SAB	Intrathecal morphine 0.2–0.3 mg provides analgesia for up to 24 h after administration. May be administered along with bupivacaine for surgical anesthesia.
	• Epidural analgesia	Epidural bupivacaine 0.0125% 6–8 mL/h and hydromorphone 50 mcg/mL infused at 100–

		250 mcg/h provide good analgesia. Prior to removal of the epidural catheter, a 0.2-mg bolus of hydromorphone may be given. Epidural catheters are typically removed on the morning of postoperative day 2. Low molecular weight heparin may be started 2 h after catheter removal.
	Continuous lumbar plexus (psoas compartment) block	Infusion with 0.2% ropivacaine or 0.125% bupivacaine maintained at 6–12 mL/h
	Systemic regimens	Acetaminophen (1 g q6h) and celecoxib (200 mg q d) should be initiated immediately postop (if not contraindicated). Patient-controlled analgesia (PCA) with iv morphine or hydromorphone may be initiated as alternative to neuraxial blocks or to supplement a continuous lumbar plexus (psoas compartment) block. Consider pain service consult.
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6) Regional analgesia	Encourage early enteral nutrition, Foley catheter removal, and mobilization, for example, continuous nerve block.

Tests	Hct CXR, if CVP was placed. Monitor UO.

Suggested Readings

1. Auyong DB, Allen CJ, Pahang JA, et al: Reduced length of hospitalization in primar total knee arthroplasty patients using an updated enhanced recovery after orthopedic surgery (ERAS) pathway. J Arthroplasty 2015; 30(10):1705–9.
2. Masursky D, Dexter F, McCartney CJ, et al: Predicting orthopedic surgeons preferences for peripheral nerve blocks for their patients. Anesth Analg 2008; 106(2):561–7.
3. Miller AG, McKenzie J, Greenky M, et al: Spinal anesthesia: should everyon receive a urinary catheter?: a randomized, prospective study of patients undergoing total hip arthroplasty. J Bone Joint Surg Am 2013; 95(16):1498–503.
4. Ranawat AS, Ranawat CS: Pain management and accelerated rehabilitation for tota hip and total knee arthroplasty. J Arthroplasty 2007; 22(7 Suppl 3):12–5.
5. Russo MW, Parks NL, Hamilton WG: Perioperative pain management and anesthesia: a critical component to rapid recovery total joint arthroplasty. Orthop Clin North Am 2017; 48(4):401–5.
6. Venker BT, Ganti BR, Lin H, et al: Safety and efficacy of new anticoagulants for the prevention of venous thromboembolism after hip and knee arthroplasty: a meta-analysis. J Arthroplasty 2017; 32(2):645–52.
7. Vieira EM, Goodman S, Tanaka PP: Anesthesia and rheumatoid arthritis.Rev Bras Anesthesiol 2011; 61:367–75.
8. Zhu S, Qian W, Jiang C, et al: Enhanced recovery after surgery for hip and knee arthroplasty: a systematic review and meta-analysis. Postgrad Med J 2017; 93(1106):736–42.

OPEN REDUCTION AND INTERNAL FIXATION (ORIF) OF PROXIMAL FEMORAL FRACTURES (FEMORAL NECK, INTERTROCHANTERIC, SUBTROCHANTERIC FRACTURES)

SURGICAL CONSIDERATIONS

Description

Fractures of the proximal femur are seen in two distinct populations: most commonly in elderly patients as the result of falls and in younger patients following trauma. In elderly patients, the fracture occurs through osteoporotic bone in the femoral neck, intertrochanteric, or subtrochanteric area (Fig. 10.4-9). Displaced femoral neck fractures are usually treated by **prosthetic replacement**. Nondisplaced or minimally displaced femoral neck fractures are usually treated by **closed reduction and percutaneous pinning** of the fracture. Intertrochanteric and subtrochanteric fractures, whether displaced or nondisplaced, are usually treated by **ORIF with a sliding hip screw and side plate, cephalomedullary nail, or blade plate** (Fig. 10.4-10). Prosthetic replacement is performed only rarely. Elderly patients frequently have numerous medical problems, which means that the fractures require prompt internal fixation/prosthetic replacement to facilitate early mobilization. In younger patients (16–40 yr), proximal femoral fractures are almost always treated by ORIF with screws plates and screws, or intramedullary devices. These are normally much higher-energy fractures, often associated with multiple traumas.

Variant procedure or approaches

Variants include **percutaneous pinning** of nondisplaced femoral neck fracture, **ORIF of displaced femoral neck fracture** (also see Arthroplasty of the Hip), and **ORIF of intertrochanteric or subtrochanteric fracture**.

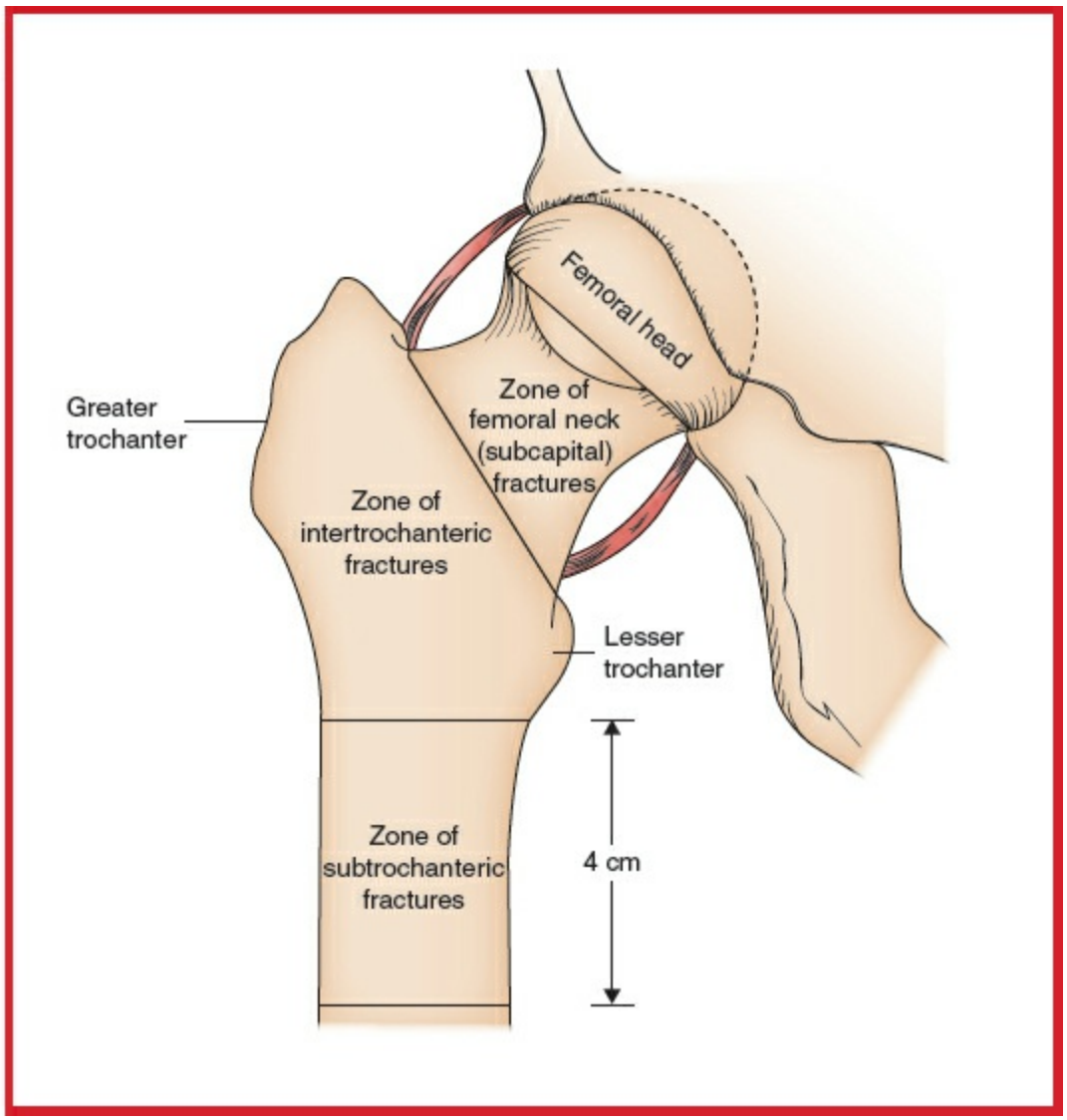

Figure 10.4-9 Anatomical classification of fractures of the proximal femur. (Redrawn with permission from Hardy JD: Hardy's Textbook of Surgery, 2nd edition. JB Lippincott, Philadelphia: 1988.)

Usual preop diagnosis

Nondisplaced femoral neck fracture; displaced femoral neck fracture (those not requiring prosthetic replacement); intertrochanteric ± subtrochanteric fracture

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plan. See Appendix K, p. K-1.

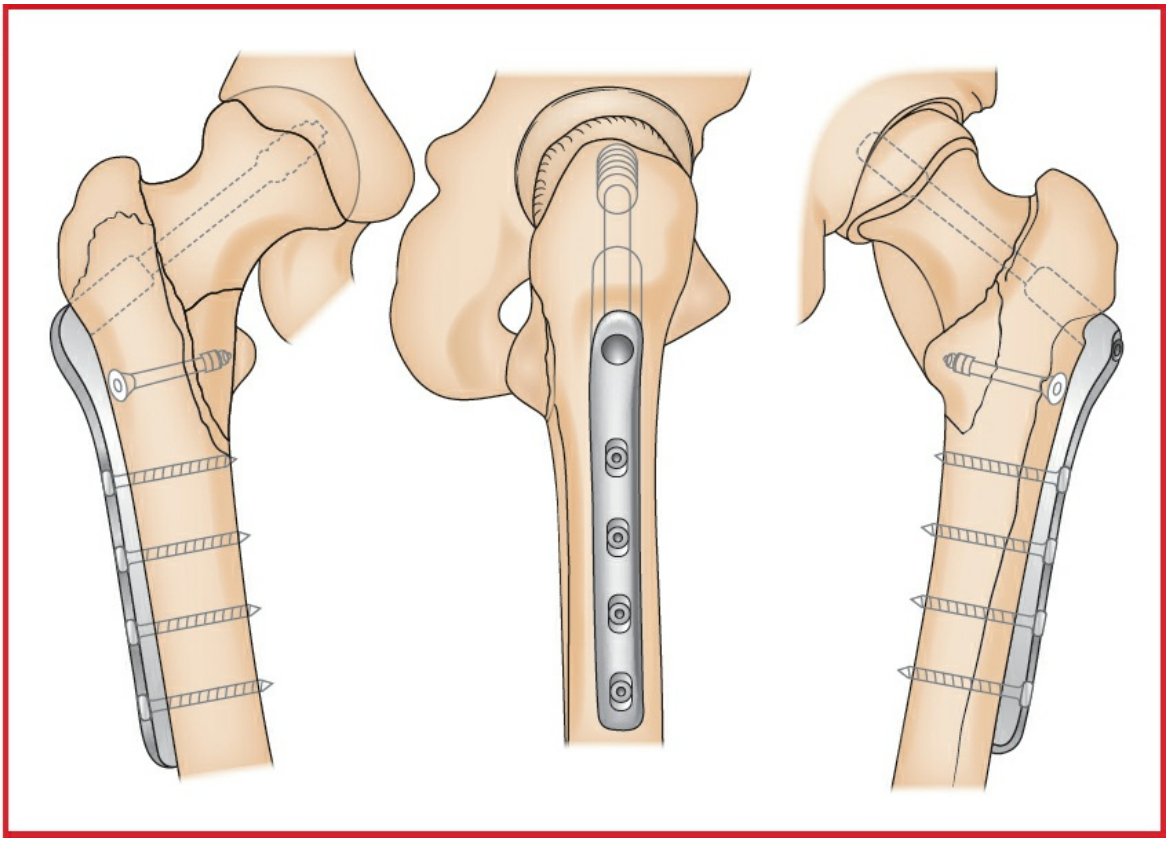

Figure 10.4-10 Intertrochanteric hip fracture treated with dynamic hip screw. (Redrawn from Sledge CB, ed: The Hip. Lippincott-Raven, Philadelphia: 1998.)

SUMMARY OF PROCEDURES

	Nondisplaced Femoral Neck Fracture	Displaced Femoral Neck Fracture	Intertrochanteric ±Subtrochanteric Fracture
Position	Supine, on fracture table	⇐	⇐
Incision	Proximal lateral thigh	⇐	⇐
Special instrumentation	Usually multiple percutaneous pins	Multiple screws or other devices	Screw-plate device or intramedullary device
Unique considerations	Fracture table and I.I. used. Percutaneous pinning may be	⇐	⇐

	accomplished with local anesthesia only.		
Antibiotics	Cefazolin 2 g iv q6–8h × 24 h (vancomycin or clindamycin for 24 h if penicillin allergic)	⇐	⇐
Surgical time	1 h	1.5–2 h, including placing patient on fracture table and obtaining adequate reduction of fracture	1.5–3 h
EBL	<100 mL	250–500 mL	500+ mL
Postop care	Generally PACU → room; if medically unstable → ICU	⇐	⇐
Mortality	10–30% in the first 12 mo postop in elderly; in younger patients, depends on other involved trauma	⇐	⇐
Morbidity	Dysrhythmias: ~50%	⇐	⇐
	MI: ~50%	⇐	⇐
	Respiratory failure: ~50%	⇐	⇐
	Urinary retention requiring catheterization: ~50%	⇐	⇐

	UTI: ~50% Thromboembolism: 40%+	⇐ ⇐	⇐ ⇐
	Avascular necrosis and late segmental collapse: 10–20%	≥15–35%	1%
	Infection, deep: 2–17%	⇐	⇐
	Infection, superficial: 2–17%	⇐	⇐
	Septic arthritis: 2–17%	⇐	⇐
	Nonunion: 5–15%	20–30%	2%
	Malunion: <10%	>10%	10–20%
	Loss of reduction: <%5	>10%	10%
	Hematoma	–	–
	Intraop comminution of the fracture	–	–
	Neurologic injury: Rare	⇐	⇐
	Vascular injury: Rare	⇐	⇐
Pain score	5–6	7	8

PATIENT POPULATION CHARACTERISTICS

Age range	Usually >60 yr (patients with an intertrochanteric fracture average 65–70 yr); occasionally, younger patients, 16–35 yr (as part of multiple-trauma situation)
Male:Female	Elderly 1:4–5
Incidence	Extremely common—about 5–100/100,000; femoral neck fractures are about twice as common as intertrochanteric fractures.
Etiology	Accidents and falls (may be 2° TIA, stroke, MI,

	dysrhythmia); pathologic fracture; multiple trauma (younger patients); stress fracture
Associated conditions	Numerous serious medical conditions often present in elderly; senile dementia; multiple trauma often

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower Extremity Procedures.

Suggested Readings

1. Kearns RJ, Moss L, Kinsella J: A comparison of clinical practice guidelines fo proximal femoral fracture. Anaesthesia 2013; 68(2):159–66.
2. Moja L, Piatti A, Pecoraro V, et al: Timing matters in hip fracture surgery: patients operated within 48 hours have better outcomes. A meta-analysis and meta-regression of over 190,000 patients. PLoS One 2012; 7(10):e46175.
3. Palmer JS, Huber CP: Operative management of hip fractures: a review of the NIC guidelines. Br J Hosp Med (Lond) 2012; 73(9):C141–44.
4. Pivec R, Johnson AJ, Mears SC, et al: Hip arthroplasty.Lancet 2012; 380(9855):1768–77.

OPEN REDUCTION AND INTERNAL FIXATION (ORIF) OF DISTAL FEMUR FRACTURES

SURGICAL CONSIDERATIONS

Description

ORIF of the distal femur fracture involves a longitudinal incision along the femoral shaft, obtaining reduction by direct visualization of the fracture fragments, and applying plates and screws along the femur for rigid internal fixation. An iliac crest bone graft may be necessary. Some intramedullary devices are also available for fixation of these fractures.

Usual preop diagnosis

Fracture of the distal femur; nonunion/malunion of the distal femur; degenerative arthritis of the knee, with deformity

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO

duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine. Patient usually arrives at OR in balanced traction if fracture is acute.
Incision	Anterior knee, lateral or medial thigh along the femoral shaft
Special instrumentation	Special plates, screws, rods, reduction clamps; radiolucent table; intraop blood salvage
Unique considerations	Usually requires intraop radiographs; tourniquet
Antibiotics	Cefazolin 2 g iv q6–8h × 24 h (vancomycin or clindamycin for 24 h if penicillin allergic)
Surgical time	3 h (or more, depending on difficulty)
EBL	750 mL or more
Postop care	Multiple-trauma victim → ICU; others → PACU
Mortality	~3–4%, depending on the extent of multiple trauma
Morbidity	Nonunion: 4–33% Malunion: 4–31% Infection, osteomyelitis, septic arthritis, closed/open: Grade I: 1–5% Grade II: 5–20% Grade III: >20% Delayed union: 0–17% Vascular complications: 2–3% Neurologic deficit to peripheral nerves, peroneal nerve: ~3% Compartment syndrome: Rare Hypotension: Rare Leg-length discrepancy: Rare Respiratory distress and fat embolism: Rare
Pain score	8

PATIENT POPULATION CHARACTERISTICS	
Age range	Any age; predominance of males <40 yr (trauma); degenerative arthritis of the knee <60 yr. Special rare case is elderly patient with a supracondylar fracture above a total knee replacement.
Male:Female	5:1
Incidence	Common in trauma center patients; rare in cases of degenerative arthritis of the knee (osteotomy) or elderly patient with a supracondylar fracture above a total knee replacement
Etiology	Motorcycle and motor vehicle accidents; falls; industrial injury; degenerative arthritis of the knee
Associated conditions	Frequently associated with trauma to other organ systems

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower Extremity Procedures.

OPEN REDUCTION AND INTERNAL FIXATION (ORIF) OF THE FEMORAL SHAFT WITH PLATE

SURGICAL CONSIDERATIONS

Description

ORIF of the femoral shaft involves obtaining a reduction by open means, usually through a longitudinal lateral incision along the length of the femur, and applying plates and screws along the femur to maintain the reduction. An iliac crest bone graft may be necessary.

Usual preop diagnosis

Fracture of the femur

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO

duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine or lateral decubitus
Incision	Lateral thigh along the length of the femur ± iliac crest incision
Special instrumentation	Special plates, screws; reduction clamps; blood salvage device
Unique considerations	Fracture or radiolucent table; I.I. Patient usually arrives at OR in balanced traction.
Antibiotics	Cefazolin 2 g iv q6–8h × 24 h (vancomycin or clindamycin for 24 h if penicillin allergic)
Surgical time	3 h or more, depending on difficulty
EBL	750 mL; Cell Saver recommended
Postop care	Multiple-trauma victims: ICU Others: PACU
Mortality	Dependent on the extent of multiple trauma
Morbidity	Knee stiffness: 20–30% Delayed union, nonunion, malunion: 5–21% Leg-length discrepancy: 0–11% Failure of fixation: 5–10% Infection; osteomyelitis: <5% Hypotension: Not uncommon Respiratory distress and fat embolism: Not uncommon, often subclinical Compartment syndrome: Rare Neurologic deficit to peripheral nerves: Rare Vascular complications: Rare
Pain score	9

PATIENT POPULATION CHARACTERISTICS	
Age range	Any age, but predominance of males <30 yr

Male:Female	5:1
Incidence	Unknown
Etiology	Motorcycle and motor vehicle accidents; falls; industrial injuries
Associated conditions	Frequently associated with trauma to other organ systems

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower Extremity Procedures.

Suggested Reading

1. Nahm NJ, Vallier HA: Timing of definitive treatment of femoral shaft fractures in patients with multiple injuries: a systematic review of randomized and nonrandomized trials. J Trauma Acute Care Surg 2012; 73(5):1046–63.

INTRAMEDULLARY NAILING OF FEMORAL SHAFT

SURGICAL CONSIDERATIONS

Description

Intramedullary nailing of the femur is the standard procedure for fractures of the femoral shaft (Fig. 10.4-11). It is indicated for virtually any fracture, from the lesser trochanter to the distal femur, within 7 cm of the articular surface. The procedure also is used for the treatment of nonunions and malunions of the femoral shaft. Typically, the nail is placed in an anterograde fashion from proximal to distal. There are, however, indications in which the nail is inserted in a retrograde fashion from distal to proximal (e.g., bilateral femur fractures, ipsilateral femur and tibia fractures, distal femur fractures, and multiple-trauma, obese, and pregnant patients). Early fixation of femoral shaft fractures in severe polytrauma has several benefits. The advantages of early fixation of long bones include improved pain control, early mobilization, improved pulmonary function, and decreased morbidity and mortality.

Femoral nails are inserted after reaming the intramedullary canal, which allows a larger-diameter implant and improves the mechanical properties of the bone implant interface. Reaming may produce systemic effects by embolic showering of medullary contents to the pulmonary vasculature, a phenomenon that has been documented by TEE.

This situation may be exacerbated in the polytrauma patient with pulmonary injury and may produce posttraumatic pulmonary failure. Patients with femur fractures may have associated injuries.

Patients may arrive from the ICU in skeletal traction or from the emergency department especially in the case of an open fracture. Hemorrhage up to 1 L may be contained in the thigh following a femur fracture; therefore, patients may be hypovolemic at the start of the procedure. Because the procedure is essentially percutaneous, apparent blood loss may be underestimated because of the hemorrhaged blood contained in the thigh.

The patient is placed in the supine or lateral decubitus position on either a radiolucent table or a fracture table. Antegrade insertion of the nail requires a lateral incision several cm in length proximal to the greater trochanter. The hip abductors are split, and portal into the femoral canal is created in the piriformis fossa. The femoral canal is reamed over a guide wire. The intramedullary nail is then inserted into the intramedullary canal with gentle taps, using a hammer.

Retrograde insertion of the nail is performed through an incision several cm long over the anterior aspect of the knee. The knee joint is entered and the portal to the intramedullary canal is made in the non–weight-bearing portion of the intercondylar notch. The nail is inserted in the same fashion as the anterior nail. Cross-locking screws are commonly used, and they are inserted through the rod.

Variant procedure or approaches

The application of femoral nailing has been expanded to treat nonunions, malunions, posttraumatic deformities of the femur, and leg-length differences. Specialized additional equipment, such as an intramedullary saw or an external fixator, may be required for these procedures.

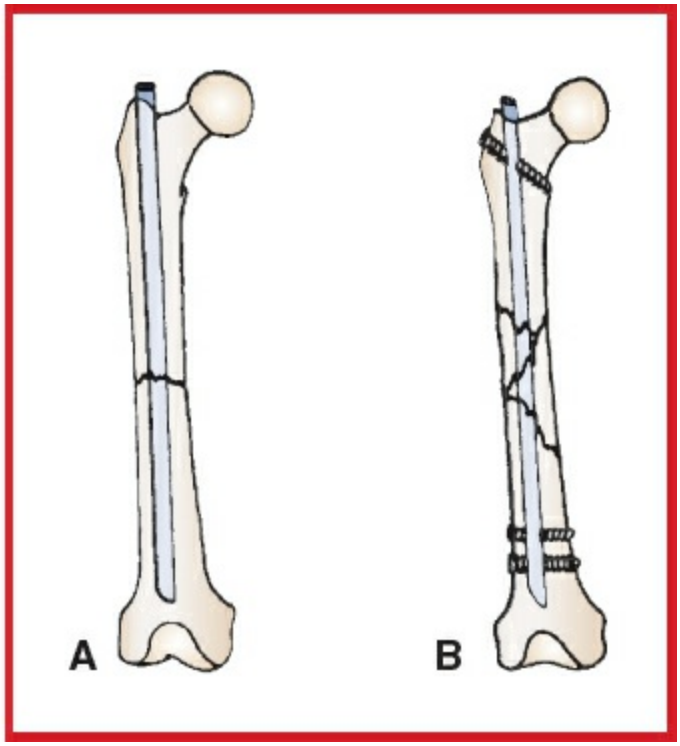

Figure 10.4-11 Simple **(A)** and locked **(B)** intramedullary fixation of the femoral shaft. (Reproduced with permission from Hardy JD:Hardy's Textbook of Surgery, 2nd edition. JB Lippincott, Philadelphia: 1988.)

Usual preop diagnosis

Femur fracture; nonunion/malunion of the femur; leg-length discrepancy

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine or lateral decubitus
Incision	Proximal lateral thigh or anterior knee
Special instrumentation	Intramedullary nails; intramedullary saw for closed femoral shortening of the femur; fracture or radiolucent table; I.I.
Unique considerations	Patient may have multiple traumas with other associated injuries. Procedure is heavily dependent on I.I.

Antibiotics	Cefazolin 2 g iv q 6–8 h × 24 h (vancomycin or clindamycin for 24 h if penicillin allergic)
Surgical time	2–3 h; 3+ h for nonunion/malunion of the femur or closed femoral shortening of the femur
EBL	250–500 mL; ≥750 mL for nonunion/malunion of the femur or closed femoral shortening of the femur (Cell Saver recommended)
Postop care	If surgery is performed acutely, patient is usually a multiple-trauma victim with numerous injuries and extensive blood loss; usually goes to ICU.
Mortality	Dependent on the extent of trauma
Morbidity	Respiratory distress and fat embolism: 10% Malunion: 5–10% Infection, osteomyelitis: Open technique: 1–10% Closed technique: 0–1% Neurologic deficit to peripheral nerves: 2% Vascular complications: ~2% (up to 15% have occult vascular abnormalities) Delayed union: 1% Nonunion: 1% Hypotension: Common in multiple-trauma situations Knee stiffness: Common Leg-length discrepancies: Not uncommon Compartment syndrome: Rare Failure of fixation: Rare
Pain score	6

PATIENT POPULATION CHARACTERISTICS

Age range	Any age, but predominance of males <30 yr
Male:Female	5:1
Incidence	Very common
Etiology	Motorcycle and motor vehicle accidents (60–80%); falls (5–10%); industrial injuries (5–10%); previous

	trauma (rare)
Associated conditions	Frequently associated with trauma to other organ systems

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower Extremity Procedures.

Suggested Readings

1. Rhorer AS: Percutaneous/minimally invasive techniques in treatment of femoral shaft fractures with an intramedullary nail. J Orthop Trauma 2009; 23(5 Suppl):S2–5.
2. Ricci WM, Gallagher B, Haidukewych GJ: Intramedullary nailing of femoral shaft fractures: current concepts. J Am Acad Orthop Surg 2009; 17(5):296–305.

REPAIR OF NONUNION/MALUNION OF PROXIMAL THIRD OF THE FEMUR, PROXIMAL FEMORAL OSTEOTOMY FOR OSTEOARTHRITIS

SURGICAL CONSIDERATIONS

Description

Operations for nonunion/malunion of the proximal femur entail realigning the bones with a femoral osteotomy (as necessary), stabilizing the reduction with internal fixation (using a nail/plate-nail/rod device), and supplementing this with a bone graft. In young patients (<50 yr) in whom early osteoarthritis of the hip spares some of the cartilage, the hip may be realigned with **proximal femoral osteotomy**. This entails cutting the bone at the level of the lesser trochanter, realigning the hip, and stabilizing the osteotomy with internal fixation.

Variant procedure or approaches

Osteotomy of proximal 1/3 of the femur for degenerative arthritis of the hip.

Usual preop diagnosis

Nonunion/malunion of proximal 1/3 of the femur; early degenerative arthritis of the hip

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO

duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Repair Nonunion/Malunion	Proximal Femoral Osteotomy
Position	Supine or lateral decubitus	⇐
Incision	Proximal lateral thigh	⇐
Special instrumentation	Plates, screws; reduction clamps; occasionally, an intramedullary device. Cell Saver recommended. Some surgeons use fracture or radiolucent table with I.I.	⇐
Antibiotics	Cefazolin 2 g iv q6–8h × 24 h (vancomycin or clindamycin for 24 h if penicillin allergic)	⇐
Surgical time	2 h for bone grafting alone; 3 h or more if difficult malunion	3 h
EBL	500–750 mL or more	500 mL +
Mortality	Rare: <1%	⇐
Morbidity	Leg-length discrepancy: Common	–
	Technical complications/fixation failure: 1–5%	⇐
	Superficial, deep infection/osteomyelitis: 1%	⇐
	Malunion: Not uncommon	–
	Compartment syndrome: Rare	⇐

	Neurologic deficit to peripheral nerves: Rare Vascular complications: Rare	⇐ ⇐ Progressive pain/arthritis (by 5–10 yr): 40–50% Delayed union: 5–10% Nonunion: 1–5%
Pain score	8	8

PATIENT POPULATION CHARACTERISTICS		
Age range	Any age	⇐
Male:Female	1:1	⇐
Incidence	Rare	⇐
Etiology	Previous surgery (rare); previous trauma (rare)	Early degenerative arthritis of the hip (not uncommon)
Associated conditions	May accompany multiple traumas	⇐

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower Extremity Procedures.

CLOSED REDUCTION AND EXTERNAL FIXATION OF THE FEMUR

SURGICAL CONSIDERATIONS

Description

This procedure entails manipulating the femur to obtain an acceptable reduction by closed or limited-open means and then applying an external fixation device to maintain the reduction. The pins for the external fixator are inserted percutaneously or through small incisions. This method of treatment may be used for severe open fractures (e.g., grade III) with extensive bone and soft-tissue injury.

Usual preop diagnosis

Displaced, open fracture of the femur

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine or lateral
Incision	Done percutaneously or through small incisions
Special instrumentation	External fixation device of surgeon's choice; radiolucent table with I.I.
Unique considerations	Fracture is usually an open, extremely comminuted fracture in a multiple-trauma patient.
Antibiotics	Cefazolin 2 g iv q6–8h × 24 h (vancomycin or clindamycin for 24 h if penicillin allergic)
Surgical time	1 h
EBL	Operative blood loss usually 100–200 mL; however, blood loss may be extensive before surgery.
Postop care	Multiple-trauma victims → ICU; others → PACU
Mortality	Dependent on the extent of trauma
Morbidity	Refracture: 2–12% Hypotension 2° blood loss and other injuries: Common Stiffness of the knee: Common Delayed union, nonunion, malunion: More common in comminuted, open fractures Leg-length discrepancy: More common in severely comminuted fractures Osteomyelitis: More common in open fractures Respiratory distress: More common in multiple-trauma situations Amputation: Rare Compartment syndrome: Rare

	Neurologic deficit to peripheral nerves: Rare Vascular complications: Rare
Pain score	9–10 (due to extensive open fracture)

PATIENT POPULATION CHARACTERISTICS	
Age range	Any age, but predominance of males <30 yr
Male:Female	5:1
Incidence	Common
Etiology	Motorcycle and motor vehicle accidents; falls; industrial injury
Associated conditions	Frequently associated with trauma to other organ systems, including the head and neck, chest, abdomen, and extremities; these will often be treated simultaneously with the femur fracture.

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower Extremity Procedures.

Suggested Viewing

Links are available online to the following videos:

Hip Fractures, Types and Fixation—Everything you Need to Know—Dr. Ebraheim: https://www.youtube.com/watch?v=6wok5JGEpTQ

Hip Replacement Surgery: https://www.youtube.com/watch?v=BYwVaKkRdF4

Femoral Shaft Fracture Intramedullary Nailing: https://www.youtube.com/watch?v=vOCf8MhnQBs

Ultrasound-Guided Femoral Nerve Block: https://www.youtube.com/watch?v=5ht_N8j2KL8

Ultrasound-Guided Subgluteal Sciatic Nerve Block: https://www.youtube.com/watch?v=rl8rZOEMveE

CHAPTER 10.5

Knee Surgery

SURGEONS

James I. Huddleston III, MD
Stuart B. Goodman, MD, PhD, FRCSC, FACS, FBSE, FICORS

ANESTHESIOLOGISTS

Frederick G. Mihm, MD
Christopher J. Painter, MD
Pedro P. Tanaka, MD, PhD, MACM

ARTHROPLASTY OF THE KNEE

SURGICAL CONSIDERATIONS

Description

In this procedure, an arthrotomy of the knee joint is performed, and metallic and plastic components are used for replacement of the knee joint surfaces (total knee replacement). See Figure 10.5-1. The femur, patella, and tibia are exposed; cartilage and minimal bone are excised with a saw. The new components may be cemented or uncemented. Alternatively, arthroplasty may be performed on only one compartment of the knee (i.e., medial/lateral unicompartmental knee replacement). In revision procedures, one or more components of the old joint are removed, and new components are placed. In resection or excision arthroplasty of the knee (usually for infection of the prosthesis), the components are removed but not replaced.

Usual preop diagnosis

Arthritis of the knee; arthrosis of the knee; loose (or malpositioned) knee prosthesis; infected knee

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plans. See Appendix K: Enhanced Recovery After Surgery, p. K-1.

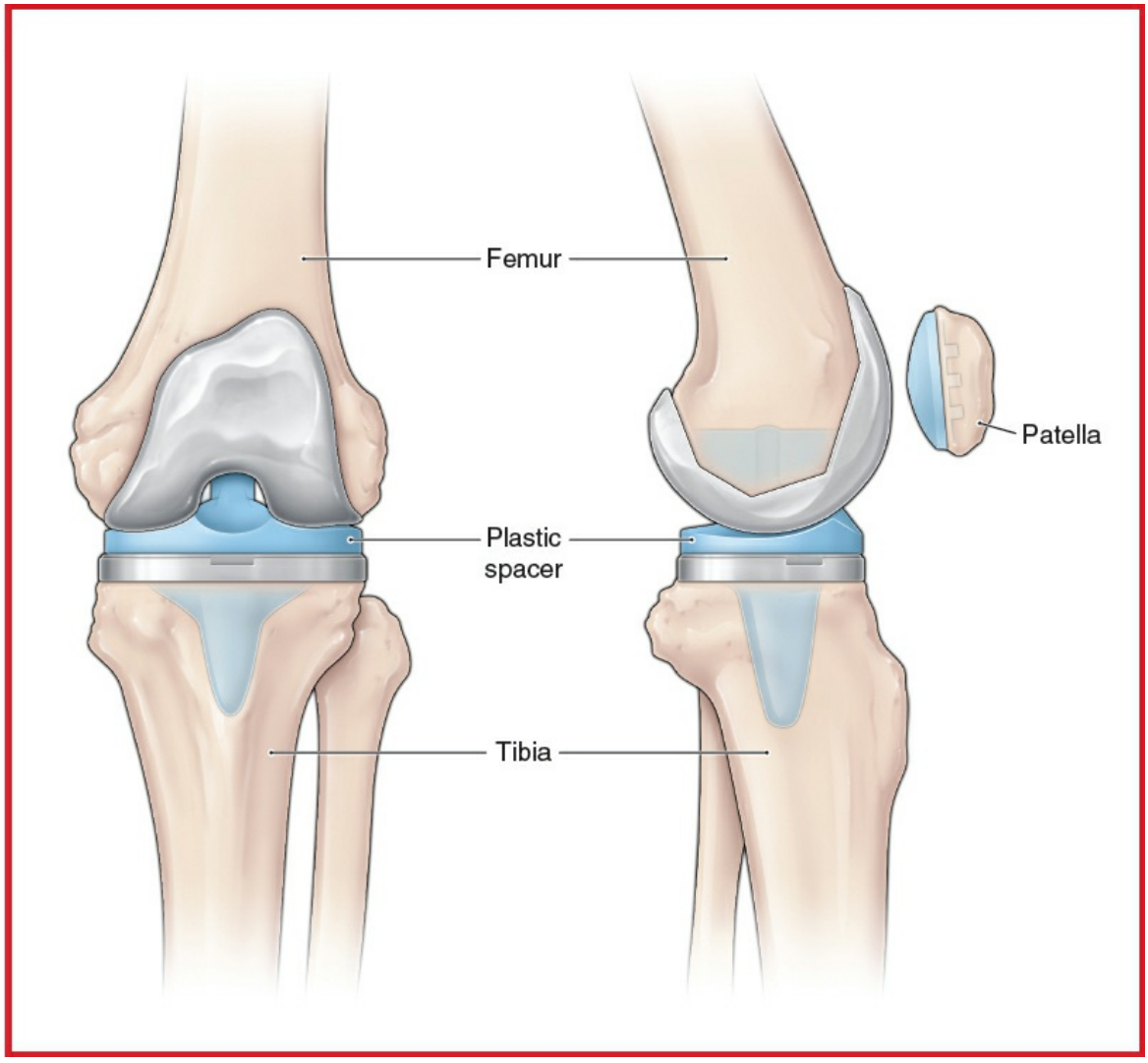

Figure 10.5-1 AP and lateral views of the components used for TKR.

SUMMARY OF PROCEDURES

	Knee Replacement	Revision	Resection/Excision
Position	Supine	⇐	⇐
Incision	Anterior or anteromedial over patella	⇐	⇐

Special instrumentation	Appropriate prostheses and instrumentation	Special instruments for excising cement	⇐
Unique considerations	± Tourniquet; ± SCD	⇐	⇐
Antibiotics	Cefazolin 2 g iv q6–8h × 24 h (vancomycin or clindamycin for 24 h if true penicillin allergic)	⇐	⇐
Surgical time	2 h	3–4 h or more	3 h
Closing considerations	In infected or complex revision cases (rare), a local or free flap is required.	⇐	⇐
EBL	300–500 mL	500–1000 mL	⇐
Postop care	Bulky dressing or splint; continuous passive motion (CPM) may begin in the PACU or ward.	⇐	Splint/cast
Mortality	Rare	⇐	⇐
Morbidity	DVT, without prophylaxis: 50–75%	⇐	⇐
	DVT, with prophylaxis (e.g., low molecular weight heparin, Coumadin, SCD, antiembolism stockings): 2–3%	⇐	⇐
	Postop subluxation/dislocation of patella: 20%	>30%	–

	Superficial wound necrosis: 10–15%	>10–15%	≥10–15%
	Wound infection: primary rheumatoid or psoriatic arthritis, diabetes: 5–10% Primary osteoarthritis (OA): 1%	>5–10%	Rare
	PE: 1–7%	⇐	⇐
	Postop subluxation/dislocation of knee joint: 1–6%	≥1–6%	–
	Late aseptic loosening requiring revision after ~10 yr: 5%	–	–
	Peroneal nerve injury: 1–5%	>1–5% (more common in difficult revisions)	1–5%
	Urinary retention requiring catheterization: common	–	–
	Hematoma requiring reoperation: rare	–	–
	Hypotension	–	–
	Knee stiffness	–	–
	Intraoperative fracture: rare	⇐	⇐
	Wound dehiscence: rare	–	–
	Fat embolism: rare	–	–
	Vascular injury to popliteal vessels: rare	–	–
Pain score	7	8	9

PATIENT POPULATION CHARACTERISTICS	
Age range	Generally, >60 yr. Arthritis of the knee (e.g., rheumatoid arthritis or juvenile rheumatoid arthritis); hemophilia, ≥18 yr
Male:Female	1:1
Incidence	Common (~400,000/yr in the United States)
Etiology	Arthrosis of the knee (degenerative joint disease [DJD] or OA); seropositive or seronegative arthritis; traumatic arthritis; hemophiliac arthropathy of the knee
Associated conditions	Dependent on primary condition (e.g., osteoarthritis)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Knee Procedures.

Suggested Readings

1. Johnson RL, Kopp SL, Hebl JR, et al: Falls and major orthopaedic surgery wit peripheral nerve blockade: a systematic review and meta-analysis. Br J Anaesth 2013; 110(4):518–28.
2. Lieberman JR, Heckmann N: Venous thromboembolism prophylaxis in total hip arthroplasty and total knee arthroplasty patients: from guidelines to practice. J Am Acad Orthop Surg 2017; 25(12):789–98.
3. Lu Q, Peng H, Zhou GJ, et al: Perioperative blood management strategies for tota knee arthroplasty. Orthop Surg 2018; 10(1):8–16.
4. Tzatzairis T, Fiska A, Ververidis A, et al: Minimally invasive versus conventional approaches in total knee replacement/arthroplasty: A review of the literature. J Orthop 2018; 15(2):459–66.
5. Yu ZX, Yang ZZ, Yao LL: Effectiveness of liposome bupivacaine for postoperative pain control in total knee arthroplasty: a PRISMA-compliant meta-analysis o randomized controlled trials. Medicine (Baltimore) 2018; 97(13):e0171.

ARTHRODESIS OF THE KNEE

SURGICAL CONSIDERATIONS

Description

In this procedure, the femur is fused to the tibia, obliterating the knee joint. Through a midline incision and anterior or median parapatellar arthrotomy, the cartilage surface and a small amount of bone are excised. The cut ends are opposed and aligned in 0°–20° of flexion and 5–10% of valgus. The bones are stabilized with plates, screws, an intramedullary rod, or an external fixator.

Usual preop diagnosis

Arthritis or other arthrosis of the knee; previous septic arthritis of the knee; failed or infected knee arthroplasty

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plan. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES	
Position	Usually supine
Incision	Anterior midline over knee
Special instrumentation	External fixator; internal fixation with plates and screws or intramedullary nail
Unique considerations	Intraop radiographs or I.I.; tourniquet
Antibiotics	Cefazolin 2 g iv q6–8h × 24 h (vancomycin or clindamycin for 24 h if true penicillin allergic)
Surgical time	3 h (+1 h, if necessary, to excise total knee arthroplasty)
Closing considerations	Cast or splint while anesthetized
EBL	<100 mL, if tourniquet and local fixation used 500–1000 mL, if no tourniquet used, or if intramedullary procedures are used
Mortality	Rare but depends primarily on age and medical condition of patient

Morbidity	Thromboembolism ≥ incidence following total knee replacement DVT (without prophylaxis): 50–75% DVT (if prophylaxis used): 10–20% PE (if no prophylaxis; reduced if anticoagulation or SCDs used): 1–7% Failure of fusion (nonunion), malunion: 10% After failed knee replacement: 19–44% With Charcot joint: as high as 50% Pin tract infection: ≥1–10% Wound infection: 5% Deep infection and osteomyelitis Urinary retention requiring catheterization, UTI: common Breakage or failure of internal or external fixation: rare Fat embolism: rare GI bleed, MI: rare Hematoma: rare Hypotension: rare Intraop femoral or tibial fracture: rare Neurologic injury, usually popliteal nerve or peroneal nerve: rare Superficial wound necrosis and wound dehiscence: rare Vascular injury to popliteal vessels: rare Amputation: extremely rare (usually 2° acute arterial occlusion or uncontrollable local sepsis)
Pain score	9

PATIENT POPULATION CHARACTERISTICS

Age range	Any age
Male:Female	1:1
Incidence	Rare
Etiology	Failed or infected total knee replacement (probably most common etiology); trauma to knee—

	unreconstructable, intra-articular fractures; total unstable knee or failed ligament repairs with severe DJD in a young patient

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Knee Procedures.

Suggested Reading

1. Schwarzkopf R, Kahn TL, Succar J, et al: Success of different knee arthrodesi techniques after failed total knee arthroplasty: is there a preferred technique? J Arthroplasty 2014; 29(5):982–8.

OPEN REDUCTION AND INTERNAL FIXATION (ORIF) OF PATELLAR FRACTURES

SURGICAL CONSIDERATIONS

Description

In ORIF of patellar fractures, a short incision over the patella is used to perform a reduction by direct visualization of the fracture fragments of the patella. Because this is generally an intra-articular fracture, the fragments should be reduced precisely. The torn quadriceps retinaculum is also repaired. Part or the entire patella may be excised; pins, wires, and/or screws are normally used to fix the patellar fragments together internally. Thereafter, the knee is casted, or early motion of the knee is started.

Usual preop diagnosis

Fracture of patella; severe degenerative arthritis of patellofemoral joint

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES	
Position	Supine
Incision	Anterior over patella

Special instrumentation	Wire, pins, screws as necessary
Unique considerations	Intraop radiographs may be obtained; tourniquet
Antibiotics	Cefazolin 2 g iv q6–8h × 24 h (vancomycin or clindamycin for 24 h if true penicillin allergic)
Surgical time	1.5–2 h
Closing considerations	Splint or cast usually applied
EBL	<100 mL
Mortality	<1%
Morbidity	Late degenerative arthritis of patellofemoral joint: ~50–60% DVT: ~5% Wound infection, septic arthritis, osteomyelitis: ~5% Delayed union, nonunion, malunion: ~2–5% Knee stiffness: common Weakness: common Avascular necrosis: rare Complex regional pain syndrome: rare Following patellectomy—quadriceps strength: ~75% of normal
Pain score	7

PATIENT POPULATION CHARACTERISTICS

Age range	Any age; frequently seen in young, active, healthy adults
Male:Female	1:1
Incidence	~1% of all skeletal injuries
Etiology	Trauma: falls (60%); motorcycle and motor vehicle accidents (25–35%); industrial injury (6%); degenerative arthritis of patellofemoral joint (rare)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Knee Procedures.

Suggested Readings

1. Callaghan JJ, O'Rourke MR, Saleh KJ: Why knees fail: lessons learnedJ Arthroplasty 2004; 19(4 Suppl 1):31–4.
2. Dy CL, Little MT, Berkes MB, et al: Meta-analysis of re-operation, nonunion, an infection after open reduction and internal fixation of patella fractures. J Trauma Acute Care Surg 2012; 73(4):928–32.
3. Kakazu R, Archdeacon MT: Surgical management of patellar fractures.Orthop Clin North Am 2016; 47(1):77–83.

REPAIR OR RECONSTRUCTION OF KNEE LIGAMENTS

SURGICAL CONSIDERATIONS

Description

Collateral ligaments usually are repaired by direct suture or by stapling the torn ligaments to bone. Cruciate tears are generally repaired only if bone is avulsed at one end of the ligament, again with direct suture, staples, or screws. For collateral ligament repair, a longitudinal incision is made directly over the ligament medially or laterally. The ligament is exposed by deep dissection and elevation of skin flaps. The torn ligament is repaired by direct suture or by fixing it to bone with a screw or staple. Following closure, the knee is immobilized with a long leg splint or cast. Cruciate ligaments are repaired in similar fashion, except for the approaches: medial parapatellar (with anterior arthrotomy) for the anterior cruciate ligament (ACL) and posteromedial (with posterior arthrotomy) for the posterior cruciate ligament (PCL). Cruciate ligament reconstruction is performed for instability 2° intrasubstance tears of these ligaments. Homografts, such as a portion of the patellar tendon or semitendinosus tendon, normally are used, but allografts or synthetics also are available. (The ligaments of the knee are illustrated in Figs. 10.5-2 and 10.5-3.)

Usual preop diagnosis

Trauma

ERAS: Preop counseling by the surgeon/anesthesiologist should include patient

education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plans. See Appendix K, p. K-1.

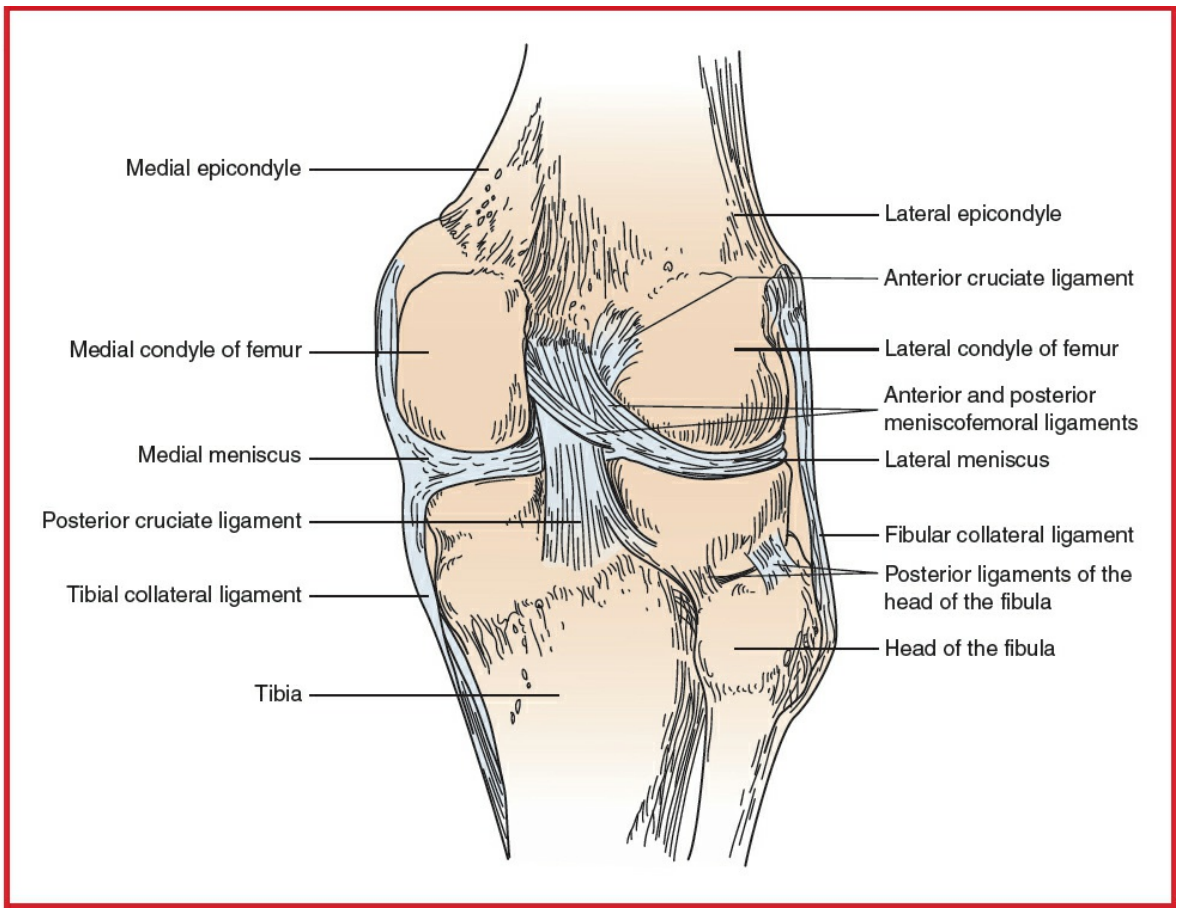

Figure 10.5-2 The cruciate ligaments (posterior view). (Reproduced with permission from Clemente CD: Clemente's Dissector, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2007, 270.)

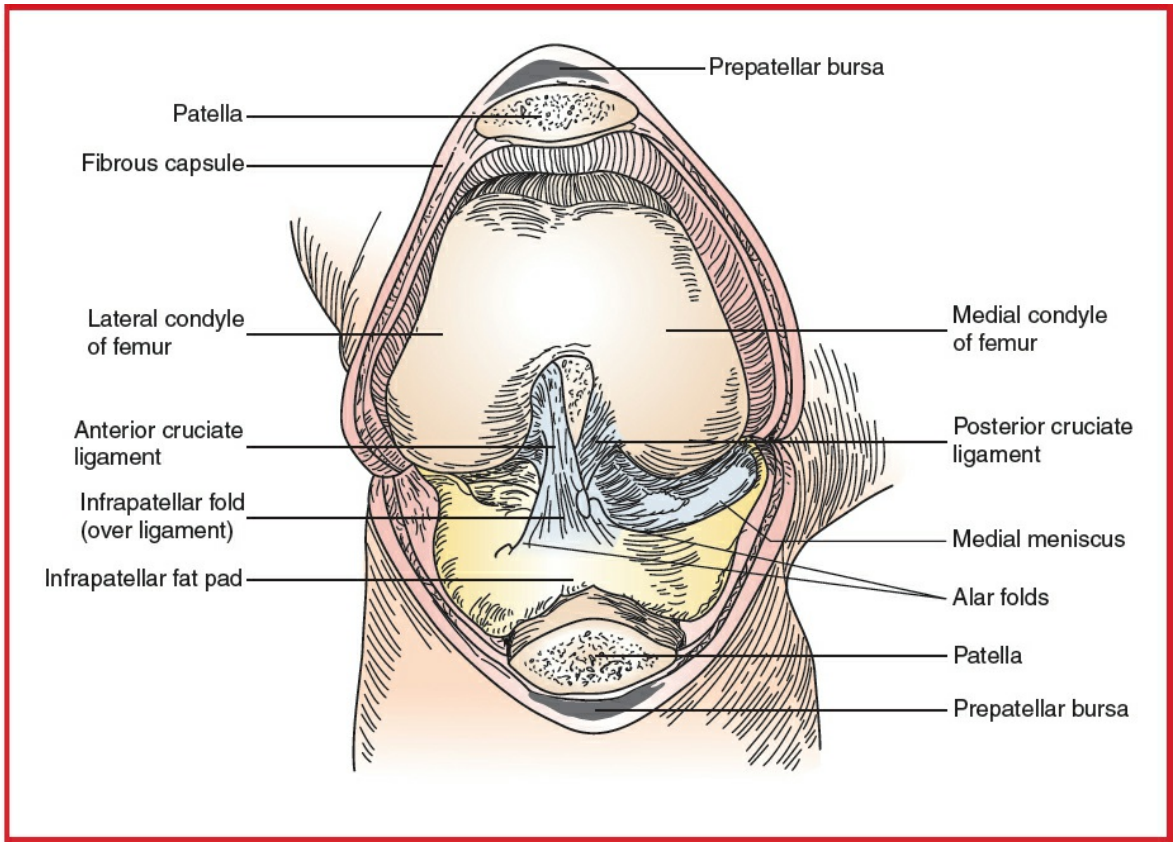

Figure 10.5-3 The knee joint opened anteriorly. (Reproduced with permission from Clemente CD: Clemente's Dissector, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2007, 269.)

SUMMARY OF PROCEDURES

	Repair or Collateral Reconstruction	Repair or Cruciate Reconstruction
Position	Supine	⇐
Incision	Over collateral ligament	Anterior and lateral ACL or medial PCL
Special instrumentation	Staples	Drill guides, staples, screws
Unique considerations	Often arthroscopically assisted; tourniquet	⇐
Antibiotics	Cefazolin 2 g iv (vancomycin or clindamycin if penicillin allergic)	⇐
Surgical time	2 h	⇐

Closing considerations	Splint or cast while anesthetized	⇐
EBL	100 mL	⇐
Postop care	PACU → room or home	⇐
Mortality	Minimal	⇐
Morbidity	Infection: <1% Thrombophlebitis: <5%	⇐ ⇐
Pain score	4	7

PATIENT POPULATION CHARACTERISTICS

Age range	Young adult
Male:Female	2:1
Incidence	Common
Etiology	Trauma: 100%

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Knee Procedures.

Suggested Readings

1. Cole BJ, Cotter EJ, Wang KC, et al: Patient understanding, expectations, outcomes and satisfaction regarding anterior cruciate ligament injuries and surgical management. Arthroscopy 2017; 33(5):1092–6.
2. Nadarajah V, Roach R, Ganta A, et al: Primary anterior cruciate ligament reconstruction: perioperative considerations and complications. Phys Sportsmed 2017; 45(2):165–77.
3. Siegel L, Vandenakker-Albanese C, Siegel D: Anterior cruciate ligament injuries anatomy, physiology, biomechanics, and management. Clin J Sport Med 2012; 22(4):349–55.
4. Tjoumakaris FP, Herz-Brown AL, Bowers AL, et al: Complications in brief: anterio cruciate ligament reconstruction. Clin Orthop Relat Res 2012; 470(2):630–6.

PATELLAR REALIGNMENT

SURGICAL CONSIDERATIONS

Description

The goal of this procedure is prevention of chronic subluxation or dislocation of the patella. Soft tissue components of the surgery include incision (release) of the lateral patellar retinaculum and reefing or tightening of the medial retinaculum (Fig. 10.5-4). In cases of severe malalignment of the extensor mechanism, the insertion of the patellar tendon may be moved to a new, more medial location (**tibial tubercle transfer**). In this procedure, the tibial tubercle generally is detached with a saw or osteotomes, leaving a bone pedicle attached distally. The tubercle is then rotated medially on the pedicle and fixed in its new position with a screw. Many surgeons routinely perform an anterior compartment fasciotomy to prevent postop compartment syndrome.

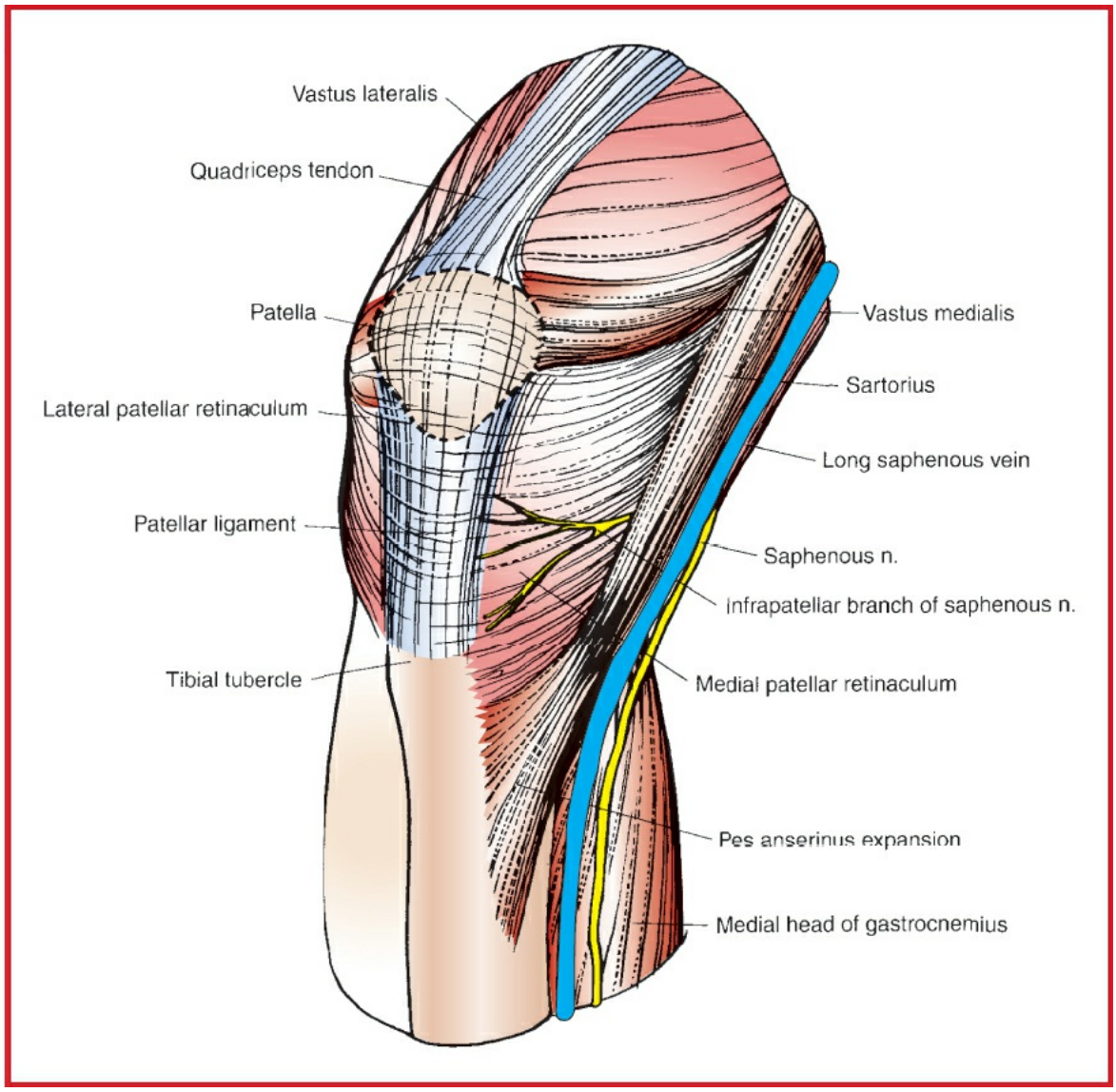

Figure 10.5-4 Outer layer of anteromedial aspect of the knee joint. Shows anatomy of the patellar retinaculum. (Reproduced with permission from Hoppenfeld S, de Boer P:Surgical Exposures in

Orthopaedics: The Anatomic Approach, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 1994.)

Usual preop diagnosis

Chronic patellar subluxation or dislocation

ERAS: Preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Patellar Realignment	Tibial Tubercle Transfer
Position	Supine	⇐
Incision	Anteromedial or anterolateral to the knee	⇐
Special instrumentation	None	Screws or staples
Unique considerations	Tourniquet	⇐
Antibiotics	Cefazolin 2 g iv (vancomycin or clindamycin if true penicillin allergic)	⇐
Surgical time	1 h	1.5 h
Closing considerations	None	Splint or cast while anesthetized
EBL	50 mL	100 mL
Postop care	PACU → room or home	⇐
Mortality	Minimal	⇐
Morbidity	Hemarthrosis: 100% Redislocation: 20%	5% 25%
	Thrombophlebitis: 10–20%	⇐

	Compartment syndrome: <1% Infection: <1%	⇐ ⇐
Pain score	6	7

PATIENT POPULATION CHARACTERISTICS	
Age range	Usually young adult
Male:Female	1:2
Etiology	Trauma (70%); congenital (30%)
Associated conditions	Patellofemoral dysplasia (60–70%)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Knee Procedures.

Suggested Reading

1. Koh JL, Stewart C: Patellar instability. Orthop Clin North Am 2015; 46(1):147–57.

ARTHROSCOPY OF THE KNEE

SURGICAL CONSIDERATIONS

Description

Knee arthroscopy is used to diagnose and treat intra-articular problems, most commonly torn meniscus, but the procedure is also used for ligament injuries (Figs. 10.5-2 and 10.5-3), osteochondral fractures, loose bodies, arthritis, and infections. In knee arthroscopy, multiple portals or entry points for the arthroscope and instruments generally are used. The most common portals are anteromedial and anterolateral adjacent to the patellar ligament. Other portals may be suprapatellar, parapatellar, and posterior. Portals are made by making a stab wound with a knife and then entering the joint with a combination of sharp and blunt trocars. A diagnostic inspection from one of the anterior portals is normally performed at the outset. A second portal is used with a nerve hook to manipulate intra-articular tissues. If resection or repair is performed, the appropriate instruments are inserted through one of the portals. Meniscus repair and cruciate reconstruction may require separate longitudinal incisions, which are usually

posteromedial or posterolateral, for placement of sutures and/or drill holes.

Meniscectomy and/or **debridement** often are performed in conjunction with arthroscopy. **Cruciate ligament reconstruction** usually is performed with arthroscopic assistance. At the end of the procedure, the knee joint is copiously irrigated with NS or LR solution through one of the portals. Portals are closed with a single suture and Steri-Strips®; compression bandages are applied; and often a knee immobilizer is used.

Usual preop diagnosis

Torn meniscus; cruciate ligament tear; arthritis

ERAS: Preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plan. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Arthroscopy	Meniscectomy/Debridement	Cruciate Reconst
Position	Supine	⇐	⇐
Incision	1- to 2-cm portals	⇐	⇐ + ante midline a lateral
Special instrumentation	Arthroscopic video system; small biters and graspers	⇐ + shaver	⇐ + drill and drills fixation s
Unique considerations	Thigh holder; foot of table 90°; ± tourniquet	⇐	⇐
Antibiotics	Cefazolin 2 g iv (vancomycin or clindamycin if true penicillin allergic)	⇐	⇐
Surgical time	0.5 h	1–2 h	2–3 h

Closing considerations	No splint; local anesthetic injected	⇐	⇐
EBL	Minimal	⇐	50 mL
Postop care	PACU → home	⇐	⇐ or ove
Mortality	<0.1%	⇐	⇐
Morbidity	Hemarthrosis: 5–20%	5%	⇐
	Thrombophlebitis: <2%	⇐	⇐
	Infection: 0.1%	⇐	⇐
	Stiffness: <0.1%	<4%	⇐
Pain score	3	4	6

PATIENT POPULATION CHARACTERISTICS

Age range	10–70 yr (usually 20–40 yr)
Male:Female	2:1
Incidence	Most common arthroscopic procedure (85% of total)
Etiology	Trauma (~85%); arthritis (~10%); infection (~5%)
Associated conditions	Usually healthy; systemic arthritis (<5%)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Knee Procedures.

Suggested Readings

1. Bollen SR: Is arthroscopy of the knee completely useless? Meta-analysis—a reviewer's nightmare. Bone Joint J 2015; 97-B(12):1591–2.
2. Gwathmey FW Jr, Golish SB, Diduch DR: Complications in brief: meniscus repair. Clin Orthop Relat Res 2012; 470(7):2059–66.
3. Minas T: A primer in cartilage repair. J Bone Joint Surg Br 2012; 94(11 Suppl A):141–6.

KNEE ARTHROTOMY

SURGICAL CONSIDERATIONS

Description

Arthrotomy of the knee is the opening of the joint for drainage, excision of intra-articular tissue (synovium, meniscus, loose bodies), ligament repair/reconstruction, or fracture fixation. The knee generally is opened with a parapatellar incision, either medial or lateral, and the joint capsule is incised just adjacent to the patella. After the intra-articular pathology is addressed, a tight capsular closure is performed, followed by subcutaneous tissue and skin closure.

Variant procedure or approaches

Arthrotomy with debridement may be used for infection or arthropathy, which produces debris. In both cases, **synovectomy** may be necessary.

Usual preop diagnosis

Infection; trauma (fracture, sprain, torn meniscus); arthritis

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Arthrotomy	Arthrotomy with Debridement	Arthrotomy with Synovectomy
Position	Supine	⇐	⇐
Incision	Medial or lateral parapatellar	⇐	⇐
Special instrumentation	Tourniquet	⇐	⇐
Antibiotics	Cefazolin 2 g iv (vancomycin or clindamycin if true penicillin allergic)	⇐	⇐

Surgical time	1 h	2 h	2 h
Closing considerations	Compressive dressing; may be splinted; suction drain	⇐	⇐
EBL	100 mL	⇐	⇐
Postop care	PACU → room	⇐	⇐
Mortality	Minimal	⇐	⇐
Morbidity	Hemarthrosis: 100%	⇐	⇐
	Degenerative arthritis: 5–20%	⇐	⇐
	Stiffness: 5%	⇐	⇐
	Thrombophlebitis: 5%	⇐	⇐
	Infection: 1%	10%	20%
Pain score	7	7	8

PATIENT POPULATION CHARACTERISTICS	
Age range	Infant–elderly (usually young adult)
Male:Female	1:1
Incidence	Common
Etiology	Infection; trauma; arthritis
Associated conditions	Inflammatory arthritis (20%)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Knee Procedures.

REPAIR OF TENDONS—KNEE AND LEG

SURGICAL CONSIDERATIONS

Description

Acute ruptures of tendons in the lower limb are repaired by **direct suture** and sometimes reinforced with part of another tendon. At the knee, patellar tendon ruptures are most common; at the ankle, Achilles tendon ruptures are most common. A longitudinal incision generally is made directly over the tendon. The tendon sheath is opened, and tendon ends are reapproximated with a nonabsorbable tendon stitch. If necessary, the repair may be augmented by synthetic tape or fascia or protected with a wire that takes tension off the repair. The tendon sheath is closed separately from the skin incision, and a cast or splint is applied. **Achilles tendon repair** and **posterior tibial tendon repair** require different positioning. For an Achilles tendon repair, the patient is placed prone, and a longitudinal incision is made just medial to the tendon, spanning the rupture. The tendon sheath is incised and carefully protected. Torn ends of the tendon are approximated with multiple tendon stitches and may be protected with a fascial flap developed from the gastrocnemius fascia. The tendon sheath is closed carefully, followed by skin wound closure. A splint or cast is applied with the foot in equinus (plantar flexion).

Usual preop diagnosis

Tendon rupture

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, carb loading, postop pain management options, and rehabilitation plan. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Posterior Tendon Repair	Achilles Tendon Repair
Position	Supine	Prone
Incision	Over tendon	⇐
Special instrumentation	Wire or synthetic tape for augmentation	⇐
Unique considerations	Tourniquet	⇐
Antibiotics	Cefazolin 2 g iv (vancomycin or clindamycin if penicillin	⇐

	allergic)	
Surgical time	1 h	⇐
Closing considerations	Splint or cast while anesthetized	⇐
EBL	Minimal	⇐
Postop care	PACU → room or home	⇐
Mortality	Minimal	⇐
Morbidity	Weakness: ~10% Wound slough: 5% Adhesions: <1% Infection: <1%	⇐ ⇐ ⇐ ⇐ Rerupture: 5–10%
Pain score	3	3

PATIENT POPULATION CHARACTERISTICS	
Age range	Any age
Male:Female	1:1
Incidence	Uncommon
Etiology	Trauma (90%); chronic tendinitis (10%)
Associated conditions	Obesity; diabetes mellitus (DM); inflammatory arthritis

ANESTHETIC CONSIDERATIONS FOR KNEE PROCEDURES

(Procedures covered: arthroplasty; arthrodesis; ORIF of patellar fractures; repair/reconstruction of ligaments; patellar realignment; arthroscopy; arthrotomy; tendon repair—knee and leg)

PREOPERATIVE

Trauma and osteoarthritis (OA) are the most common indications for these procedures. Trauma patients (e.g., those with sports injuries) are often young and healthy, whereas arthritic patients are often elderly, and anesthetic management must be tailored to any concurrent disease. Patients with rheumatoid and other inflammatory arthritides form

another group of candidates for these procedures; the special anesthetic considerations for these patients are described in Anesthetic Considerations for Hip Procedures. A final group of patients undergoing these procedures are hemophiliacs, who develop arthritis from recurrent bleeding into their joints. The hematologic management of these patients is discussed below.

Respiratory	These patients often have **rheumatoid arthritis** and associated pulmonary conditions. For example, pulmonary effusions are common. Limited respiratory reserve warrants further evaluation. Pulmonary fibrosis (rare) often manifests as a cough and dyspnea. Rheumatoid arthritis involving the cricoarytenoid joints may manifest as hoarseness, glottic narrowing, and difficult intubation. Arthritic involvement of the TMJ and cervical spine may further complicate airway management. **Test:** As indicated from H&P
Cardiovascular	The severity of the arthritis often limits exercise and makes assessment of cardiovascular status difficult. Dobutamine stress ECHO and dipyridamole thallium imaging may be necessary for an adequate cardiac evaluation. Rheumatoid arthritis is associated with pericardial effusion, cardiac valve fibrosis, cardiac conduction abnormalities, and aortic regurgitation (AR). **Tests:** ECG and others as indicated from H&P
Neurologic	In arthritic patients, a thorough preop neurologic exam often yields evidence of cervical nerve root compression. After the stability of the neck has been established, the full range of neck motion should be evaluated for evidence of nerve compression or cerebral ischemia (suggesting vertebral artery compression). Consider preop lateral neck films to determine stability of atlanto-occipital joint and evidence of vertebral spurs that may interfere with intubation. **Test:** As indicated from H&P

Musculoskeletal	Pain and ↓ joint mobility may make positioning and regional anesthesia difficult in this patient population.
Hematologic	**Hemophiliacs** require restoration of clotting factors preop. Administer 1 U of factor concentrate/kg body weight for each 2% increase necessary to achieve clotting factor activity of 40% normal. FFP contains l U/mL and cryoprecipitate 20 U/mL. Hemophilia B (factor IX deficiency), but not hemophilia A (factor VIII deficiency), can be treated with prothrombin complex concentrate; however, these products can activate clotting factors and → DIC. Approximately 10% of hemophiliacs develop antibodies to exogenous clotting factors, and the care of these patients should be guided by a hematologist. **Tests:** Hct; other tests as indicated from H&P
Laboratory	Other tests as indicated from H&P
Premedication	Standard premedication. Preop patellar pain is treated effectively with a femoral nerve block at the inguinal ligament, using 10 mL of lidocaine 1.5% with epinephrine 1:200,000. Consider preemptive analgesia (depending on anticipated postop pain) with gabapentin 300 mg po, celecoxib 200 mg po, and acetaminophen 1 g po/iv to be given in the preop holding area.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider aprepitant 40 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

For many of these patients, regional anesthesia may be the preferred technique, offering the advantages of ↓ blood loss, ↓ DVT, minimal respiratory impairment, and effective postop analgesia. Patients with rheumatoid arthritis rarely have involvement of the lumbar spine. Because rheumatoid arthritis frequently affects the C-spine, however,

these patients may have limited range of neck motion, an unstable atlanto-occipital joint, and cricoarytenoid and TMJ arthritis. Careful airway evaluation, therefore, is importan to determine the appropriateness of special intubation techniques (e.g., fiberoptic).

Regional anesthesia

A continuous peripheral nerve block (CPNB), adductor canal, or common femoral nerve blocks provide similar effect on postop length of hospital stay and rehabilitation compared to an epidural pain management but have a lower incidence of side effects (urinary retention, hypotension, and dysesthesia). A combined femoral and sciatic nerve block provides superior pain control in the first 36 postoperative hours over a single, femoral nerve block. In addition to the nerve block, either a GA or an SAB is needed for the intraoperative phase because a CPNB does not reliably provide surgical anesthesia. Both nerves can be localized conventionally using a nerve stimulator or with ultrasound guidance. A typical initial local anesthesia dose for each nerve is 20 mL of 0.5% bupivacaine or 0.75% ropivacaine. As an alternative, a continuous adductor canal (lower femoral nerve) block can be used to provide good analgesia with minimal motor blockade during repair of tendons. A bolus of 30 mL of 0.5% ropivacaine with epinephrine 1:200,000 is used, and a continuous infusion (0.2% at 10 mL/h) started in the recovery room. There are emerging data supporting the safe and efficacious use of adductor canal blocks/indwelling catheters and local infiltration of analgesics in total knee arthroplasty. Currently this is our preferred approach, in combination with a general anesthetic, for total knee arthroplasty.

An epidural block provides both intraop surgical anesthesia and postop pain control, but it is contraindicated in patients receiving Coumadin postop. If the patient prefers not to receive a peripheral nerve or an epidural block, a subarachnoid block provides a useful alternative regional anesthesia technique, depending on the patient population (e.g., younger patients may be at ↑ risk of spinal headache following SAB). Anesthesia extending from S2 to T12 (T8, if tourniquet is used) is adequate for knee surgery. Full motor blockade is essential for fixation of the patella or placement of the joint prosthesis and assessment of the passive ROM of the prosthesis. Typical drugs and doses include subarachnoid: 12.5–15 mg of 0.75% bupivacaine with morphine 0.2 mg, and epidural: 15–20 mL 2% lidocaine with epinephrine 1:200,000 in divided doses.

Tranexamic acid (TXA) reduces intraop and postop blood loss through inhibition of fibrin-clot degradation by plasmin. This results in stable clot formation with less fibrinolysis. Furthermore, TXA has been proven to be safe in wide range of patient populations without increasing the incidence of DVT or PE. Investigations are still underway in patients with coronary stents to prove TXA's safety in this population.

Dosing is 10–15 mg/kg given prior to incision and again upon closure—with data showing total blood loss (throughout hospitalization) being reduced by 500 mL.

General anesthesia

Induction	Standard induction is appropriate for patients with normal airways.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia. Tranexamic acid (e.g., 10–15 mg/kg) iv before incision has been shown to ↓EBL and may be requested by the surgeon.	
Maintenance	Standard maintenance. Neuromuscular relaxation facilitates the placement of the prosthesis. Hemophiliacs will require infusion of clotting factors. For hemophilia A and von Willebrand disease, 1.5 U/kg/h; for hemophilia B, 0.75 U/kg/h. Maintain normothermia (forced air blanket), and use fluid warmer.	
Emergence	The tourniquet is deflated around the time of emergence. In patients with moderate-to-severe lung disease, controlled ventilation should be continued until after the lactic acid that has accumulated in the leg has been metabolized (3–5 min) because these patients may be unable to increase ventilation to buffer this acid load. Provide PONV prophylaxis with ondansetron 4 mg iv and dexamethasone (4 mg iv).	
Blood and fluid requirements	IV: 14–16 ga × 1 BSS @ maintenance during the case, and 5–10 mL/kg bolus prior to tourniquet deflation	A tourniquet blocks intraop blood loss. When it is deflated, prepare for a 1–2 U blood loss over the ensuing hour, more if the posterior tibial artery has been damaged in the dissection. Avoid under-resuscitation. See Goal-Directed Fluid

		Management, Appendix K, p. K-4.
Control of blood loss	Tourniquet	Inflation pressure is typically 100 mm Hg + systolic pressure. Maximum tourniquet time is 2 h, followed by a 30 min reperfusion interval, if further tourniquet time is necessary.
	Tranexamic acid (TXA)	10–15 mg/kg prior to incision and upon surgical closure. Caution in those with cardiac stents
Monitoring	Standard monitors	
	± CVP line	A CVP line is indicated if monitoring the CVP trend is expected to affect anesthetic care.
	± Arterial line	
	Additional monitoring	CVO_2 Sat, PA cath, TEE may be indicated in special cases.
Positioning	✓ and pad pressure points ✓ eyes	In rheumatoid arthritis patients, meticulous padding of the extremities is mandatory.
Complications	Posterior tibial artery trauma Peroneal nerve palsy	A 20% ↓ MAP is common on tourniquet deflation. Additional crystalloid (5–10 mL/kg) may be necessary to replace edema fluid and blood loss to the leg.

POSTOPERATIVE

Complications	Hemorrhage from the posterior tibial artery	✓ surgical drain output
	Peroneal nerve palsy → foot drop	Examine patient for evidence of neurologic dysfunction, and notify surgeons as necessary.
	Tourniquet-related nerve injury, posttourniquet syndrome (PTS)	PTS is a self-limiting condition in which the affected limb is edematous, pale, and weak.
Multimodal pain management	Neuraxial regimens:	
	• Epidural anesthesia	Epidural bupivacaine 0.0125% infused at 6–8 mL/h with hydromorphone 50 mcg/mL infused at 100–250 mcg/h provides good analgesia. Prior to removal of the epidural catheter, a 0.2-mg bolus of hydromorphone may be given. Epidural catheters are typically removed on the morning of postop day 2. Low molecular weight heparin may be started 2 h after catheter removal.
	• SAB	Intrathecal morphine 0.2–0.3 mg provides analgesia for up to 24 h. May be administered along with bupivacaine for surgical anesthesia

	Peripheral regimens: • Single-shot peripheral nerve block (femoral or combined femoral/sciatic block)	These nerves may be blocked preop or postop as a pain rescue measure. A typical dose for each nerve is 20 mL of 0.5% bupivacaine or 30 mL of 0.5% ropivacaine.
	• CPNB	Continuous infusion of bupivacaine 0.125% through standard or portable infusion pumps at 6–10 mL/h. Anticoagulation may continue with a peripheral nerve catheter in place. Catheter is removed on POD#2 at the latest. Foley catheters are not required with peripheral nerve catheters.
	Systemic regimens:	Oral pain management with acetaminophen (1 g every 6 h if not contraindicated) should be continued immediately postop. Celecoxib (Celebrex®) 200 mg once a day. Oxycodone 5–20 mg po q2h prn. Morphine 0.5–2 iv mg q3h prn. Consider pain service consult as well as the use of controlled-release oxycodone (OxyContin®) and PCA with iv morphine or hydromorphone in opioid-dependent patients, as an

		alternative to neuraxial blocks or to supplement peripheral nerve blocks.
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6) Regional analgesia	Encourage early enteral nutrition, Foley catheter removal, and mobilization.
Tests	Hct; other studies as indicated	Patients with coagulopathies require replacement therapy for 6–10 d.

Suggested Readings

1. Auyong DB, Allen CJ, Pahang JA, et al: Reduced length of hospitalization in primar total knee arthroplasty patients using an updated enhanced recovery after orthopedic surgery (ERAS) pathway. J Arthroplasty 2015; 30(10):1705–9.
2. Bono JV, Robbins CE, Mehio AK, et al: Pharmacologic pain management before and after total joint replacement of the hip and knee. Clin Geriatr Med 2012; 28(3):459–70.
3. Caparrini C, Miniati I, Ponti M, et al: Perioperative pain management in fast-track knee arthroplasty. Acta Biomed 2017; 88(2S):139–44.
4. Ganapathy S: Wound/intra-articular infiltration or peripheral nerve blocks for orthopedic joint surgery: efficacy and safety issues. Curr Opin Anaesthesiol 2012; 25(5):615–20.
5. Gibbs DM, Green TP, Esler CN: The local infiltration of analgesia following total knee replacement: a review of current literature. J Bone Joint Surg Br 2012; 94(9):1154–9.
6. Hebl J: Clinical pathways for total joint arthroplasty: essential components for success. Refresher Course Lect Anesthesiol 2012; 324:1–10.
7. Jæger P, Zaric D, Fomsgaard JS, et al: Adductor canal block versus femoral nerve block for analgesia after total knee arthroplasty: a randomized, double-blind study. Reg Anesth Pain Med 2013; 38(6):526–32.
8. Johnson RL, Kopp SL, Hebl JR, et al: Falls and major orthopaedic surgery with peripheral nerve blockade: a systematic review and meta-analysis. Br J Anaesth 2013; 110(4):518–28.
9. Kuper M, Rosenstein A: Infection control in total knee and total hip arthroplasties. Am J Orthop 2008; 37(1):E2–5.
10. Lieberman JR, Heckmann N: Venous thromboembolism prophylaxis in total hip

arthroplasty and total knee arthroplasty patients: from guidelines to practice. J Am Acad Orthop Surg 2017; 25(12):789–98.
11. Lin ZX, Woolf SK: Safety, efficacy, and cost-effectiveness of tranexamic acid in orthopedic surgery. Orthopedics 2016; 39(2):119–30.
12. Melvin SJ, Stryker LS, Sierra RJ: Tranexamic acid in hip and knee arthroplasty. J Am Acad Orthop Surg 2015; 23(12):732–40.
13. Webb CA, Mariano ER: Best multimodal analgesic protocol for total knee arthroplasty. Pain Manag 2015; 5(3):185–96.
14. Zhu S, Qian W, Jiang C, et al: Enhanced recovery after surgery for hip and knee arthroplasty: a systematic review and meta-analysis. Postgrad Med J 2017; 93(1106):736–42.

Suggested Viewing

Links are available online to the following videos:

Total Knee Replacement Surgery by Dr. Eric W. Janssen:
https://www.youtube.com/watch?v=GRSWV57u9eg

Knee Arthroscopy: Portal Placement and Examination Course: https://www.youtube.com/watch?v=y0WDWZX9WLk

Anterior Cruciate Ligament (ACL) Reconstruction Animation: https://www.youtube.com/watch?v=q96M0jRqn7k

Knee Ligament Anatomy Animation: https://www.youtube.com/watch?v=RTV5Yo3E7VQ

Continuous Adductor Canal (Saphenous Nerve) Block: https://www.youtube.com/watch?v=jPJISpkf4rE

Continuous Femoral Nerve Block: https://www.youtube.com/watch?v=UVMxkZH4CNc

CHAPTER 10.6

Lower Leg, Ankle, Foot, and Other Lower-Extremity Procedures

SURGEONS
Ariel Palanca, MD
David Oji, MD

ANESTHESIOLOGISTS
Frederick G. Mihm, MD
Christopher J. Painter, MD
Pedro P. Tanaka, MD, PhD, MACM

OPEN REDUCTION AND INTERNAL FIXATION (ORIF) OF THE TIBIAL PLATEAU FRACTURE

SURGICAL CONSIDERATIONS

Description

ORIF of the tibial plateau or proximal tibia fracture involves making a longitudinal incision along the proximal leg, lateral to the knee, obtaining a reduction by direct visualization of the fracture fragments, and applying plates and screws along the tibia for rigid internal fixation. An additional posteromedial incision may also be utilized. Occasionally, surgeons will also perform a knee arthroscopy to assess for intra-articular reduction. An iliac crest bone graft may be necessary. Patients may have initial stabilization with an external fixator based on the extent of the fracture and the soft tissue envelope. A **proximal tibial osteotomy** involves correcting malalignment (valgus and varus) of the lower extremity by excising a wedge of bone from the tibia and correcting the mechanical axis or by adding a bony wedge for an opening wedge

osteotomy based on the deformity and surgeon preference.

Usual preop diagnosis

Tibial plateau or proximal tibial fracture; nonunion/malunion of the tibial plateau or proximal tibia; degenerative arthritis of the knee, with varus or valgus deformity

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

SUMMARY OF PROCEDURES

	ORIF Tibial Plateau Fracture	Proximal Tibial Osteotomy
Position	Supine	⇐
Incision	Lateral to knee, usually; posteromedial, occasionally; ± arthroscopy	Transverse or lateral incision
Special instrumentation	Special plates, screws; reduction clamps; radiolucent table; possible bone graft	⇐
Unique considerations	Intraop radiographs or I.I.; tourniquet	⇐
Antibiotics	Cefazolin 2 g iv q6–8h × 48 h	⇐
Surgical time	~2.5–3 h; more, depending on difficulty	⇐
Closing considerations	Splint, cast while anesthetized	⇐
EBL	<200 mL	⇐
Postop care	Multiple-trauma victim → ICU; others → PACU; ±	PACU → ward

	CPM	
Mortality	Rare, except in severe multiple trauma	None
Morbidity	Compartment syndrome: 10–20% Wound infection: 7–15% DVT (symptomatic): 3–5% Delayed union, nonunion, malunion: <5% Peripheral nerve damage: 3% Intra-articular fracture: 2% Hypotension (multiple trauma) Leg-length discrepancy Osteomyelitis, septic arthritis Respiratory distress and fat embolism Vascular complications	<25% ~2% 2% ⇐ 0.2%
Pain score	7	7

PATIENT POPULATION CHARACTERISTICS

Age range	Any age; fracture most common in younger trauma patients and elderly Degenerative arthritis of knee, <50 yr
Male:Female	1:1
Incidence	Common
Etiology	Trauma: Falls, motorcycle and motor vehicle accidents, industrial injuries Degenerative: Arthritis of knee

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower-Extremity Procedures.

Suggested Readings

1. Atesok K, Doral MN, Whipple T, et al: Arthroscopy-assisted fracture fixation.Knee Surg Sports Traumatol Arthrosc 2011; 19(2):320–9.
2. Berkson EM, Virkus WW: High-energy tibial plateau fractures.J Am Acad Orthop Surg 2006; 14(1):20–31.
3. Kugelman D, Qatu A, Haglin J, et al: Complications and unplanned outcomes following operative treatment of tibial plateau fractures. Injury 2017; 48(10):2221–9.
4. McNamara IR, Smith TO, Shepherd KL, et al: Surgical fixation methods for tibial plateau fractures. Cochrane Database Syst Rev 2015; (9):CD009679.
5. Schuster P, Geßlein M, Schlumberger M, et al: Ten-year results of medial open-wedge high tibial osteotomy and chondral resurfacing in severe medial osteoarthritis and varus malalignment. Am J Sports Med 2018; 46(6):1362–70.

INTRAMEDULLARY NAILING, TIBIA

SURGICAL CONSIDERATIONS

Description

In intramedullary nailing of the tibia, a metal nail is placed into the medullary canal of the tibia to stabilize (or prevent) a fracture. Following the incision, an awl may be used to make an entry hole in the proximal metaphysis of the tibia, through which a guide wire is introduced. The guide wire is placed across the aligned fracture, and the nail is introduced and driven over the guide wire. Before nail insertion, the medullary canal often is reamed to allow use of a larger nail. Most nails are interlocked both proximally and distally with screws that pass from the bone through holes in the nail.

Usual preop diagnosis

Fracture, nonunion or malunion of the tibia

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine, on fracture table. Consider inducing anesthesia before moving patient.
Incision	Proximal longitudinal incision over the patellar tendon;

	stab wounds for interlocking screws
Special instrumentation	Nails, screws, and insertion instruments; intramedullary reamers; I.I.
Antibiotics	Cefazolin 2 g iv preop
Surgical time	2 h
Closing considerations	No splint or cast
EBL	200 mL
Postop care	PACU → room
Mortality	Minimal
Morbidity	Compartment syndrome: <5% Infection: <2% Neurapraxia: <1%
Pain score	5

PATIENT POPULATION CHARACTERISTICS

Age range	>16 yr
Male:Female	5:1
Etiology	Trauma (95%); tumor (5%)
Associated conditions	Multiple trauma (50%); compartment syndrome (5%)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower-Extremity Procedures.

Suggested Reading

1. Duan X, Al-Qwbani M, Zeng Y, et al: Intramedullary nailing for tibial shaft fractures in adults. Cochrane Database Syst Rev 2012; (1):CD008241.

EXTERNAL FIXATION, TIBIA

SURGICAL CONSIDERATIONS

Description

Fractures of the tibia are fixed with percutaneous pins that are clamped to an external frame. Stainless steel pins are drilled into the proximal and distal fragments of the fracture through stab wounds in the skin and subcutaneous tissues. Usually 2–3 pins are placed on either side of the fracture. Pin clamps and an external frame are attached and the fracture is aligned with the assistance of the I.I. or under direct vision. Following fracture alignment, the pin clamps and frames are tightened to hold fracture alignment. External fixation is often used with open fractures. **Small-pin ringed fixators** (e.g., Ilizarov) are used for fracture fixation, leg lengthening, and treatment of bony defects. Wound irrigation and debridement often accompany application of the fixation frame.

Usual preop diagnosis

Tibial fracture; tibial nonunion or malunion; tibial shortening

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Stab wounds. Small-pin fixator may require metaphyseal incision for osteotomy.
Special instrumentation	Pins; fixation frame; I.I.
Antibiotics	Cefazolin 2 g iv preop
Surgical time	0.5–1 h Small-pin fixator: 3–5 h
Closing considerations	May be open fracture (usually left open)
EBL	50 mL; small-pin fixator, 100 mL
Postop care	PACU → room
Mortality	Minimal

Morbidity	Infection: 15% Compartment syndrome: <2% Neurapraxia: <1%
Pain score	2–3

PATIENT POPULATION CHARACTERISTICS	
Age range	All ages
Male:Female	5:1
Incidence	Common
Etiology	Trauma (95%); shortened limb (<2%); ununited or malunited fracture (<2%)
Associated conditions	Open fracture (95%); compartment syndrome (<2%); congenital anomaly (<1%)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower-Extremity Procedures.

OPEN REDUCTION AND INTERNAL FIXATION (ORIF) OF DISTAL TIBIA, ANKLE, AND FOOT FRACTURES

SURGICAL CONSIDERATIONS

Description

ORIF is nearly always required for displaced fractures involving the ankle or joints in the foot. A longitudinal incision is made over the fractured medial and/or lateral malleoli or affected area of the foot. Dissection is carried directly down to the bone, and the fracture is identified and reduced under direct vision.

Open fractures may require **irrigation and debridement**. The fractures are realigned under direct vision and fixed and stabilized with pins, plates, and/or screws. An intraop radiograph is obtained to confirm reduction and placement of hardware. The incisions are closed and a splint or cast is applied.

Usual preop diagnosis

Fracture of the distal tibia, ankle, or foot

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	ORIF Ankle	With Irrigation and Debridement
Position	Supine; lateral (calcaneus fractures)	⇐
Incision	Longitudinal over fracture site	⇐ + extension of existing wound
Special instrumentation	Pins, plates, and screws; tourniquet; x-ray or I.I.	⇐
Antibiotics	Cefazolin 2 g iv preop	⇐
Surgical time	2 h	2–3 h
Closing considerations	Splint or cast while anesthetized	Splint or cast; may leave wound open
EBL	50 mL	100 mL
Postop care	PACU → room	⇐
Mortality	Minimal	⇐
Morbidity	Wound dehiscence: 10% Loss of reduction: 7% Infection: 3%	⇐ ⇐ 15%
Pain score	4	4

PATIENT POPULATION CHARACTERISTICS

Age range	Infant-elderly
Male:Female	1:1

Incidence	~250,000 cases/yr in the United States
Etiology	Trauma: 100%
Associated conditions	Alcohol abuse; obesity; diabetes mellitus (DM)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower-Extremity Procedures.

Suggested Readings

1. Assal M, Ray A, Stern R: Strategies for surgical approaches in open reductio internal fixation of pilon fractures. J Orthop Trauma 2015; 29(2):69–79.
2. Belmont PJ Jr, Davey S, Rensing N, et al: Patient-based and surgical risk factors fo 30-day postoperative complications and mortality after ankle fracture fixation. J Orthop Trauma 2015; 29(12):e476–82.
3. Crist BD, Khazzam M, Murtha YM, et al: Pilon fractures: advances in surgica management. J Am Acad Orthop Surg 2011; 19(10):612–22.
4. Hsu AR, Anderson RB, Cohen BE: Advances in surgical management of intra articular calcaneus fractures. J Am Acad Orthop Surg 2015; 23(7):399–407.

REPAIR NONUNION/MALUNION, TIBIA

SURGICAL CONSIDERATIONS

Description

This procedure is used to treat a fracture that has not healed or was misaligned upon healing. The fracture is mobilized, usually grafted with autogenous or allograft bone, and realigned. With an anterior approach, a longitudinal incision is made anteromedial or anterolateral to the shaft of the tibia. Dissection is carried directly down to the bone and the nonunion identified. If the tibia is approached with a posterolateral incision, the patient is turned prone or lateral, and a longitudinal incision is made just posterior to the fibula. Dissection is carried down posteriorly to the interosseous membrane, to the tibia, and the procedure becomes identical to the anterior approach. Tissue interposed between the bone ends may or may not be débrided. The cortex of the bone adjacent to the nonunion is roughened with an osteotome. Autogenous or allograft bone is placed adjacent to or in the nonunion site. In the case of a malunion, the bone may be osteotomized with a saw or osteotomes to allow realignment. For skeletal fixation, a

plate may be attached to the bone through the same incision. Alternatively, an intramedullary nail may be placed through an incision anterior to the tibial tubercle. If an intramedullary device is used, the canal may be reamed with intramedullary reamers prior to placement of the nail. A third type of **skeletal fixation** is the external fixator that stabilizes the nonunion via percutaneous pins placed into the proximal and distal tibia, which are then spanned by a device with pin clamps at both ends. An intraop x-ray or I.I. is used to confirm fixation and placement of devices and alignment.

Variant procedure or approaches

Autogenous **bone grafting from the iliac crest** is commonly used to stimulate healing. An incision is made directly over the iliac crest, and muscles are stripped from the crest and table of the ilium. Osteotomes and gouges are used to remove either the inner or outer table of the ilium and cancellous bone between the two tables.

Usual preop diagnosis

Ununited or malunited fracture

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURES

	Basic Repair with Skeletal Fixation	With Iliac Graft
Position	Supine (prone with posterior lateral graft)	⇐
Incision	Anteromedial or posterolateral to shaft of tibia	Anteromedial; parallel to iliac crest
Special instrumentation	Tourniquet; x-ray or I.I., pins, plates, screws, rods, external fixator; tourniquet	⇐
Antibiotics	Cefazolin 2 g iv preop. (If infected nonunion anticipated, antibiotics are withheld until cultures are	⇐

	obtained.)	
Surgical time	2–3 h	2.5 h
Closing considerations	Splint or cast applied while anesthetized.	⇐
EBL	100 mL	200–300 mL
Postop care	PACU → room	⇐
Mortality	Minimal	⇐
Morbidity	Thrombophlebitis: 5% Compartment syndrome: 1% Infection: 1% Hematoma: <1%	⇐ ⇐ ⇐ 5%
Pain score	5–8	8

PATIENT POPULATION CHARACTERISTICS

Age range	10–80 yr (usually 20–40 yr)
Male:Female	5:1
Incidence	5–10% of tibia fractures; 50–75% of open fractures
Etiology	Trauma: 100%
Associated conditions	Poor nutrition (50%); infection (10%); metabolic disease (10%)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower-Extremity Procedures.

Suggested Readings

1. Lark RK, Lewis JS Jr, Watters TS, et al: Radiographic outcomes of ring externa fixation for malunion and nonunion. J Surg Orthop Adv 2013; 22(4):316–20.
2. Mechrefe AP, Koh EY, Trafton PG, et al: Tibial malunion. Foot Ankle Clin 2006; 11(1):19–33, vii.
3. Ng A, Barnes ES: Management of complications of open reduction and interna fixation of ankle fractures. Clin Podiatr Med Surg 2009; 26(1):105–25.

ARTHROSCOPY OF THE ANKLE

SURGICAL CONSIDERATIONS

Description

Ankle arthroscopy is usually a diagnostic procedure, although it may be used for debridement or removal of loose bodies. The ankle joint generally is inspected through anterolateral and anteromedial portals A posterolateral portal also may be used. Each portal is made via a 5-mm stab wound in the skin (Fig. 10.6-1); then instrumentation is placed, using trocars. Based on the procedure and surgeon preference, a mechanical distractor consisting of a strap that wraps around the ankle and attaches to the bed frame may be used. The portals are closed with sterile tape or a single suture. **Debridement** may be used to treat local or generalized articular damage. Bone marrow aspirate or platelet-rich plasma may be injected to promote healing.

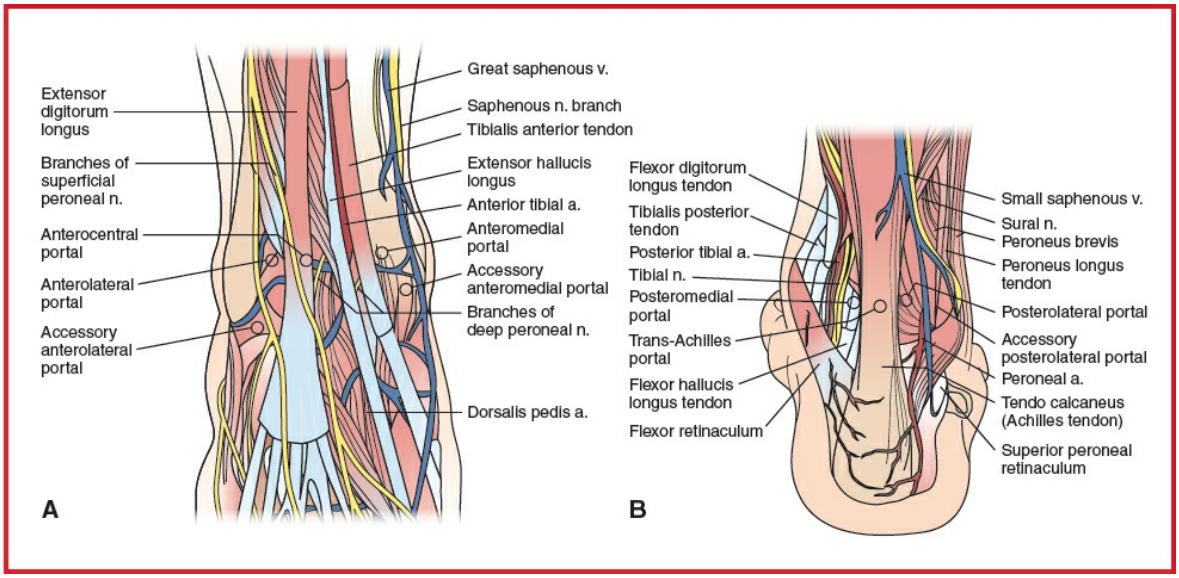

Figure 10.6-1 Portals for ankle arthroscopy. **A:** Anterior anatomy and portals. The anterolateral and anteromedial portals are used routinely. **B:** Posterior anatomy and portals. The posterolateral portal also is used routinely. (Redrawn with permission from Ferkel RD: Arthroscopic Surgery: The Foot and Ankle Lippincott-Raven, Philadelphia: 1996.)

Usual preop diagnosis

Trauma; infection; arthritis

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain

management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE

	Arthroscopy
Position	Supine
Incision	0.5 cm portals (incisions)
Special instrumentation	Arthroscopic video system; arthroscopy-specific instruments, leg positioner and ankle distractor
Unique considerations	± Tourniquet. May use ankle distractor
Antibiotics	Cefazolin 2 g iv preop (optional)
Surgical time	1–2 h
Closing considerations	± Splint; incisions injected with local anesthetic.
EBL	Minimal
Postop care	PACU → home
Mortality	<0.01%
Morbidity	Hemarthrosis: 5% Thrombophlebitis <2% Infection: <1% Superficial peroneal nerve irritation: <1%
Pain score	2–3

PATIENT POPULATION CHARACTERISTICS

Age range	12–70 yr (usually 20–40 yr)
Male:Female	1:1
Incidence	Uncommon
Etiology	Trauma (70%); arthritis (20%); infection (5%)
Associated conditions	Usually healthy; may have systemic arthritis

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower-Extremity Procedures.

Suggested Readings

1. Glazebrook MA, Ganapathy V, Bridge MA, et al: Evidence-based indications fo ankle arthroscopy. Arthroscopy 2009; 25(12):1478–90.
2. Hsu AR, Gross CE, Lee S, et al: Extended indications for foot and ankle arthroscopy J Am Acad Orthop Surg 2014; 22(1):10–9. doi: 10.5435/JAAOS-22-01-10. Review.
3. Lui TH: Arthroscopy and endoscopy of the foot and ankle: indications for new techniques. Arthroscopy 2007; 23(8):889–902.

ANKLE ARTHROTOMY

SURGICAL CONSIDERATIONS

Description

Arthrotomy of the ankle is the opening of the joint for drainage, debridement, or fracture treatment. The joint usually is opened with an anterolateral midline or anteromedial longitudinal incision. Tendons and neurovascular structures are carefully retracted to expose the joint capsule, which is then opened in line with the skin incision. After intra-articular pathology is addressed, careful closure of the capsule is performed, taking care to obtain good hemostasis.

Usual preop diagnosis

Infection; trauma; arthritis

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Anterior midline or anteromedial longitudinal
Special	Tourniquet

instrumentation	
Antibiotics	Cefazolin 2 g iv preop unless infection is suspected
Surgical time	1–2 h
Closing considerations	± Splint while anesthetized; may have suction drain
EBL	Minimal
Postop care	PACU → room
Mortality	Minimal
Morbidity	Hemarthrosis: 20% Thrombophlebitis: 5% Infection: 1%
Pain score	5

PATIENT POPULATION CHARACTERISTICS	
Age range	Infant-elderly
Male:Female	1:1
Incidence	Rare
Etiology	Trauma (70%); arthritis (20%); infection (10%)
Associated conditions	Inflammatory arthritis; multiple trauma; immunosuppression

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower-Extremity Procedures.

ANKLE ARTHRODESIS

SURGICAL CONSIDERATIONS

Description

An **ankle fusion** may need to be performed for severe pain 2° arthritis of the ankle. Fusion can be performed via an anterior, lateral, or posterior approach. It can also be

performed arthroscopically; for this, please refer to the "Arthroscopy of the Ankle" section. For the lateral approach, the fibula is osteotomized. The ankle joint is exposed, and the surfaces of the joint are débrided. Cancellous bone is exposed on the distal tibia and talus, and the joint is compressed with bone screws from the distal tibia into the talus with or without a plate (see Fig. 10.6-2) or sometimes with an external fixation device with pins going through the distal tibia and talus. The wound is closed, sometimes over a drain, and a splint is applied.

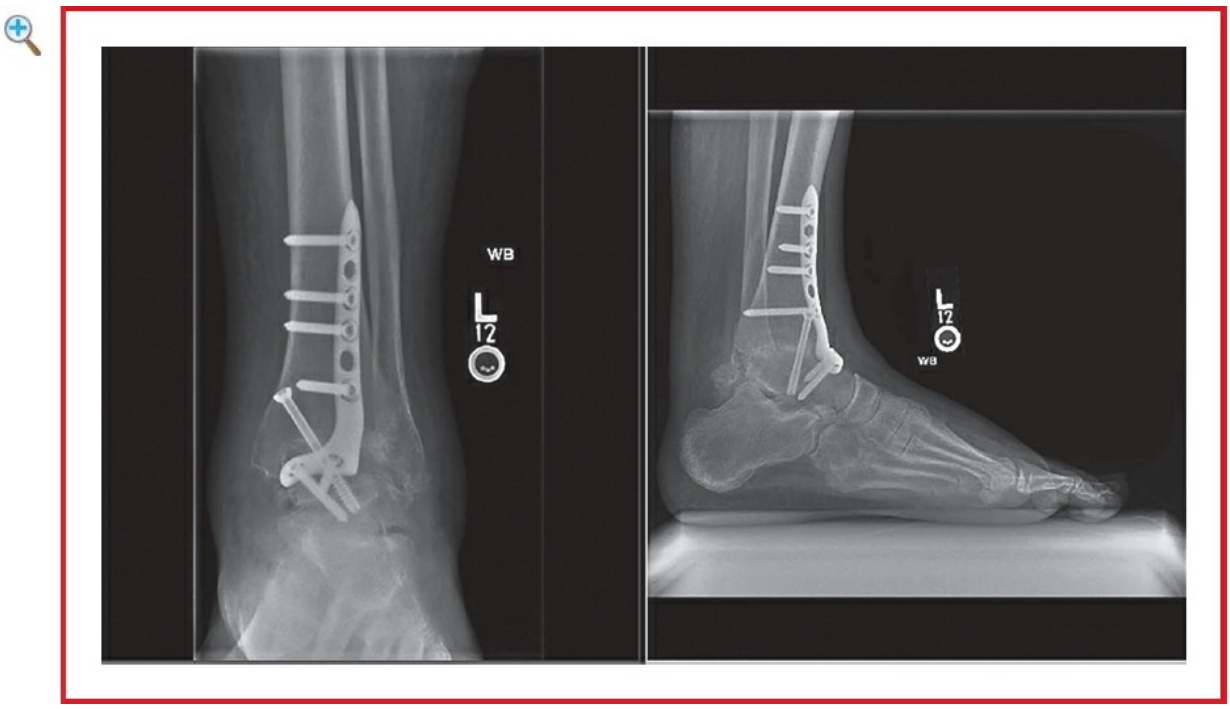

Figure 10.6-2 Tibiotalocalcaneal (TTC) arthrodesis.

Usual preop diagnosis

Arthritis of the ankle

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Anterior midline, lateral, or posterior over ankle joint
Special	Tourniquet; bone plate and screws or external fixator

instrumentation	
Unique considerations	Intraop radiographs; tourniquet use
Antibiotics	Cefazolin 2 g iv preop
Surgical time	2 h
Closing considerations	Splint; suction drain
EBL	100 mL
Postop care	PACU → room
Mortality	Minimal
Morbidity	Nonunion (late): 15% Thrombophlebitis: 10% Hematoma: 5% Wound dehiscence: 5% Infection: 1%
Pain score	8

PATIENT POPULATION CHARACTERISTICS	
Age range	All adult
Male:Female	1:1
Etiology	Degenerative arthritis; trauma; avascular necrosis of talus; septic arthritis
Associated conditions	Inflammatory arthritis; any disease requiring steroids

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower-Extremity Procedures.

TOTAL ANKLE REPLACEMENT

SURGICAL CONSIDERATIONS

Description

A **total ankle replacement or arthroplasty** may need to be performed for severe pain 2° arthritis of the ankle joint. An anterior approach is utilized. The tibiotalar joint is exposed, and the surfaces of the joint are débrided. A series of different jigs are utilized in order to make the proper bony cuts to align the joint. These are performed with the assistance of x-ray. The final implants are sized and selected, and then press fit to the tibia and the talus (see Fig. 10.6-3). A polyethylene spacer is then placed between the metal components. Additional procedures may be needed to better align the joint. The wound is closed, sometimes over a drain, and a splint is applied.

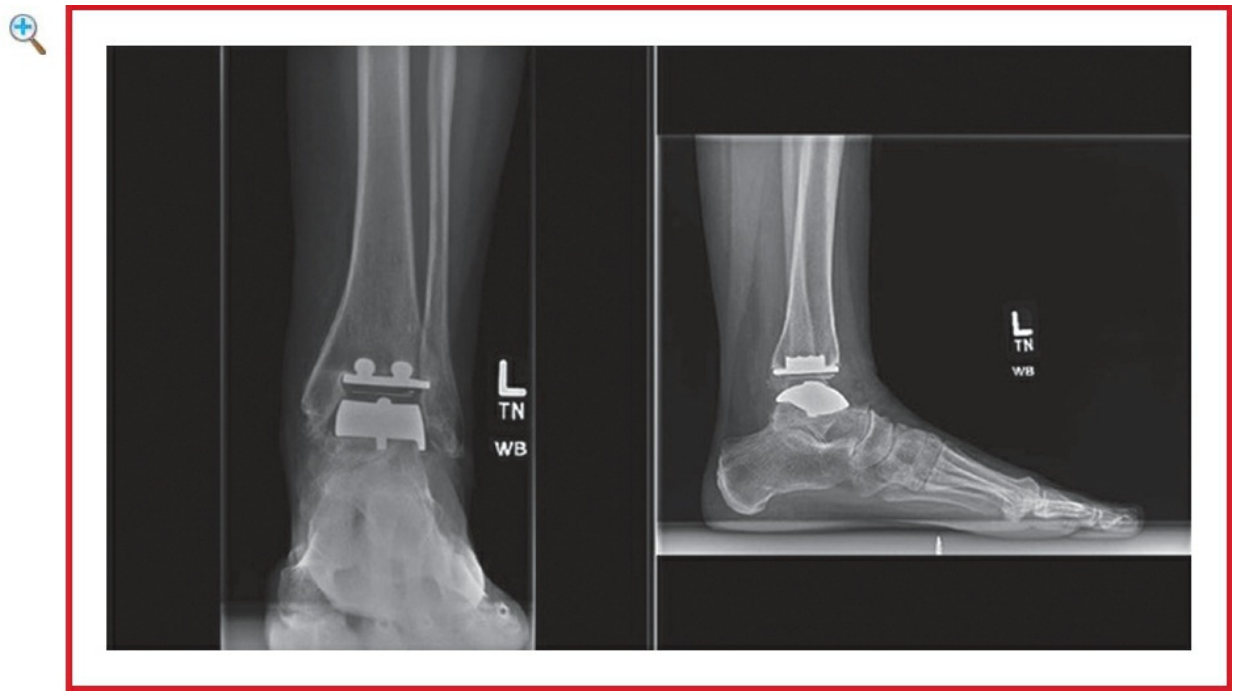

Figure 10.6-3 AP and lateral views following total ankle replacement.

Usual preop diagnosis

Arthritis of the ankle

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE

Position	Supine
Incision	Anterior midline over ankle joint
Special instrumentation	Tourniquet; alignment jigs and final implants
Unique considerations	Intraop radiographs; tourniquet use
Antibiotics	Cefazolin 2 g iv preop
Surgical time	2–3 h
Closing considerations	Splint; suction drain
EBL	100 mL
Postop care	PACU → room
Mortality	Minimal
Morbidity	Aseptic loosening: 15% Thrombophlebitis: 10% Wound dehiscence: 5% Infection: 1%
Pain score	8

PATIENT POPULATION CHARACTERISTICS	
Age range	Adult > 50 yo
Male:Female	1:1
Etiology	Degenerative arthritis; trauma; rheumatoid arthritis
Associated conditions	Inflammatory arthritis; hemophilia; posttraumatic arthritis

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower-Extremity Procedures.

Suggested Readings

1. Chou LB, Coughlin MT, Hansen S Jr, et al: Osteoarthritis of the ankle: the role o

arthroplasty. J Am Acad Orthop Surg 2008; 16(5):249–59.
2. DeOrio JK, Gadsden J: Total ankle arthroplasty and perioperative pain.J Surg Orthop Adv 2014; 23(4):193–7.

REPAIR/RECONSTRUCTION OF ANKLE LIGAMENTS

SURGICAL CONSIDERATIONS

Description

Lateral ankle ligaments are repaired in the setting of chronic ankle instability. An incision is made posterior to the distal fibula, curving around the lateral malleolus and ending in the anterolateral ankle. The lateral ankle ligaments are incised and imbricated. The extensor retinaculum is also advanced to add strength to the repair. Occasionally, the peroneus brevis tendon is also used, usually in cases of revision surgery. The brevis is identified and detached from its musculotendinous junction in the leg, and one end is sutured to the peroneus longus tendon. A hole is drilled from anterior to posterior in the distal lateral malleolus; then the detached end of the peroneus brevis tendon is threaded through the hole. It is then attached to either the calcaneus or the talus, anterior to the lateral malleolus, with a staple or by suturing into a hole in the bone. The skin and subcutaneous tissues are closed and a splint or cast is applied.

Usual preop diagnosis

Lateral instability of the ankle

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine or lateral decubitus
Incision	Posterolateral aspect of ankle
Special instrumentation	Tourniquet; suture tacks or suture tape

Antibiotics	Cefazolin, 2 g iv preop
Surgical time	2 h
Closing considerations	Splint or cast while still anesthetized.
EBL	Minimal
Postop care	PACU → room or home
Mortality	Minimal
Morbidity	Infection: <1% Rerupture: <1% Wound dehiscence: <0.1%
Pain score	5

PATIENT POPULATION CHARACTERISTICS	
Age range	Young adults
Male:Female	2:1
Etiology	Ankle sprain
Associated conditions	Peroneal tendon tears; osteochondral lesions of the talus

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower-Extremity Procedures.

AMPUTATION THROUGH ANKLE (SYME)

SURGICAL CONSIDERATIONS

Description

Syme amputation (Figs. 10.6-4 and 10.6-5) is ankle disarticulation with closure, using a posterior flap, including the heel pad. It is more functional than below-knee amputation because patients can bear weight on the end of the stump; however, success is poor in patients with vascular disease or peripheral neuropathy. The posterior flap is

dissected directly from the calcaneus, carefully preserving the tough heel pad and its blood supply. The heel pad is sutured directly to the distal tibia to prevent migration and to cover the bone end. The posterior flap is then sutured to the anterior flap with interrupted sutures, and a compression dressing or cast is applied.

Usual preop diagnosis

Trauma; infection

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

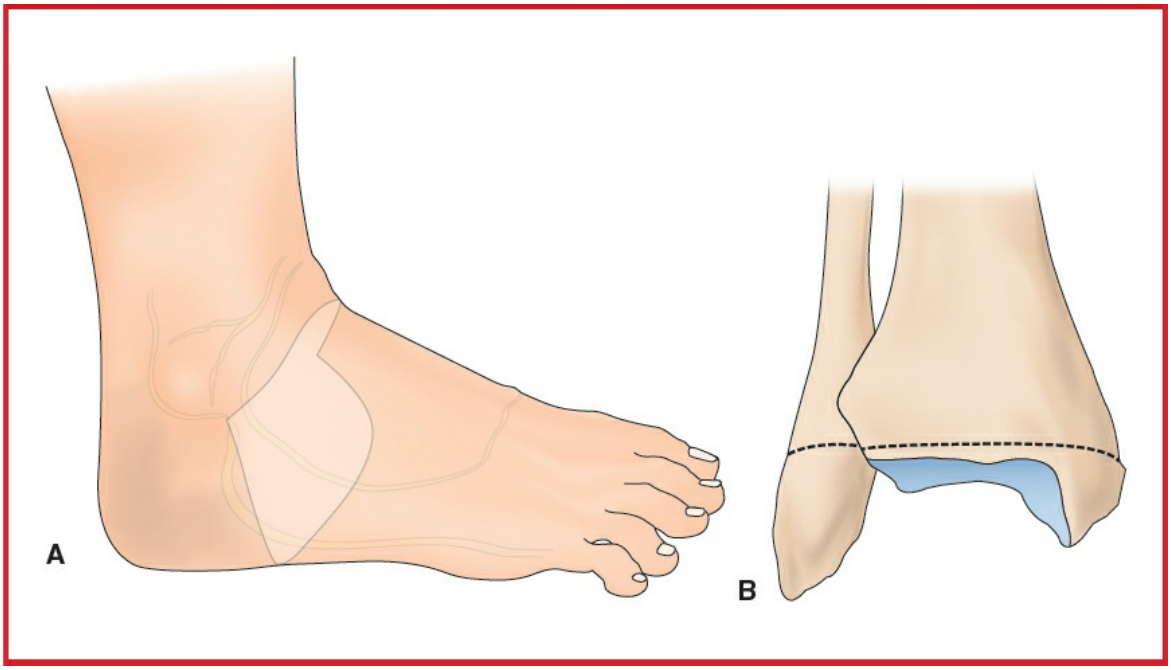

Figure 10.6-4 Syme amputation. **A:** Skin incisions. **B:** Level of bone transection in adults. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al, eds: Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

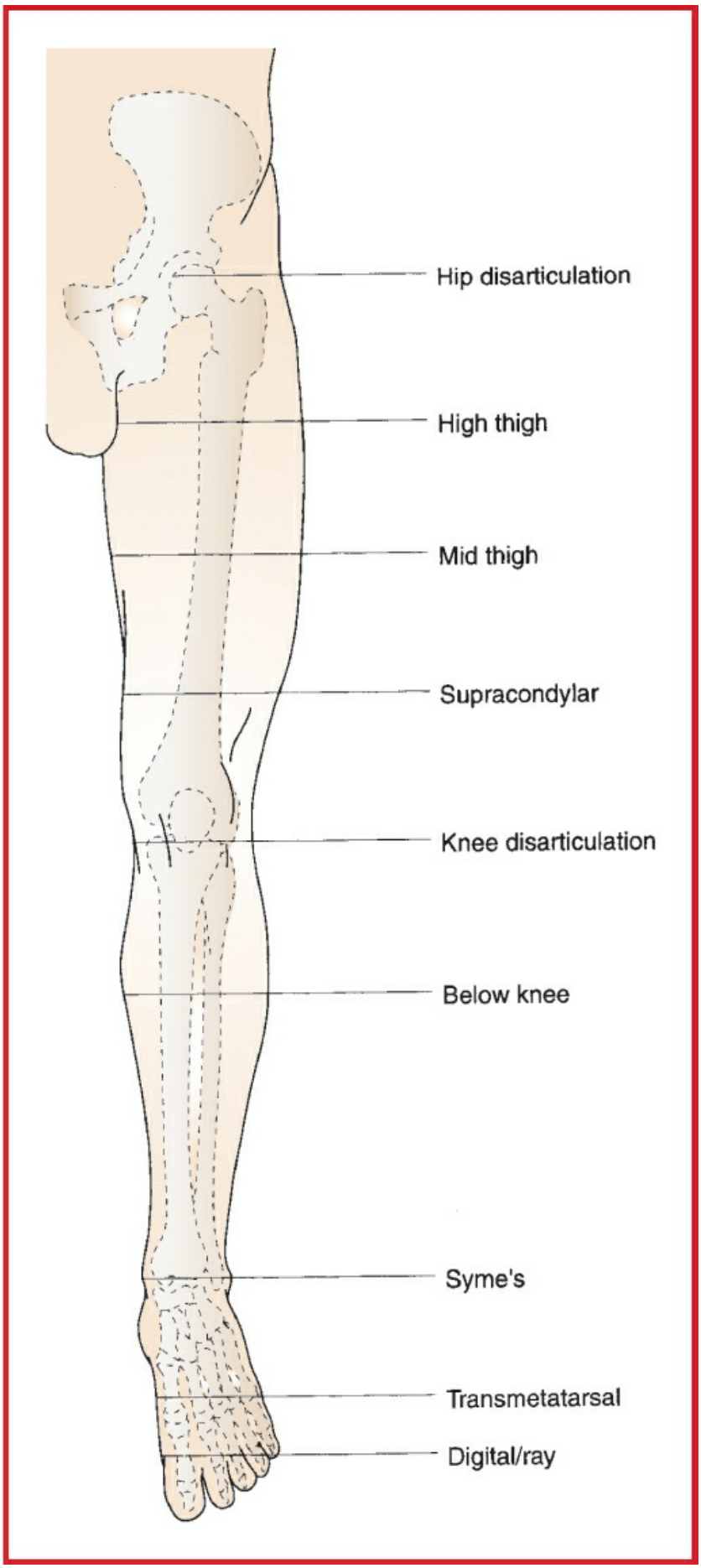
Hip disarticulation
High thigh
Mid thigh
Supracondylar
Knee disarticulation
Below knee
Syme's
Transmetatarsal
Digital/ray

Figure 10.6-5 Common amputation levels for the lower extremity. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al, eds:Surgery: Scientific Principles and Practices, 3rd edition. Lippincott Williams & Wilkins: 2001.)

SUMMARY OF PROCEDURE

Position	Supine
Incision	Anterior and posterior flaps
Special instrumentation	Tourniquet
Antibiotics	Cefazolin 2 g iv preop
Surgical time	1.5–2 h
Closing considerations	Bulky dressing or cast; if infection present, wound may be left open.
EBL	100 mL
Postop care	PACU → room
Mortality	Minimal
Morbidity	Phantom pain: 90% Infection: 10–15% Wound breakdown: 10–15% Pneumonia: 12% MI: 7% PE: 6% Hematoma: 5% Stroke: 5%
Pain score	5

PATIENT POPULATION CHARACTERISTICS

Age range	Typically, >60 yr, though also children with congenital deformities
Male:Female	3:1
Incidence	20,000–30,000/yr
Etiology	Trauma (50%); infection (30%); congenital anomaly

	(5%)
Associated conditions	Peripheral vascular disease (30–40%); diabetes mellitus (DM) (<20%)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower-Extremity Procedures.

AMPUTATION, TRANSMETATARSAL

SURGICAL CONSIDERATIONS

Description

This amputation, usually for infection or ischemic necrosis of the toes, is performed at the midmetatarsal level, leaving the patient able to walk without a prosthesis. A transverse dorsal incision is made at the transmetatarsal level, and a plantar incision is made beginning at the corners of the dorsal incision and extending distally to the metatarsal heads to create a long plantar flap. The plantar flap is reflected proximally to the midmetatarsal level and tapered distally. The metatarsals are sectioned with a saw, and nerves and tendons are sectioned proximal to the osteotomies. The plantar flap is then brought over the ends of the bones and sutured with interrupted sutures to the dorsal flap. A compression dressing or splint is applied.

Variant procedure or approaches

Other partial-foot amputations, such as **midtarsal** and **ray amputation**, are much less common. They are managed in a fashion similar to that of the transmetatarsal amputation.

Usual preop diagnosis

Gangrene of the toes; infection

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE

Position	Supine
Incision	Dorsal and plantar flaps
Special instrumentation	Tourniquet
Antibiotics	Cefazolin 2 g iv preop
Surgical time	1–2 h
Closing considerations	Bulky dressing
EBL	50 mL
Postop care	PACU → room
Mortality	Minimal
Morbidity	Phantom pain: 90% Infection: 10–15% Wound breakdown: 10–15% Hematoma: 5%
Pain score	5

PATIENT POPULATION CHARACTERISTICS	
Age range	>60 yr
Male:Female	3:1
Incidence	20,000–30,000 total amputations/yr
Etiology	Vascular disease (70%); infection (25%); trauma (<5%); congenital anomalies (<1%)
Associated conditions	Vascular disease (70%); diabetes mellitus (30%); pulmonary disease (30%)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower-Extremity Procedures.

LENGTHENING OR TRANSFER OF TENDONS,

ANKLE, AND FOOT

SURGICAL CONSIDERATIONS

Description

In cases of motor imbalance from neuromuscular disease or trauma, tendons are lengthened or transferred to a new insertion to partially restore balance or normalize joint motion. For **tendon lengthening**, a longitudinal incision generally is made directly over the tendon. Subcutaneous tissues and tendon sheath are incised to expose the tendon, which is transected with a Z-type incision. The tendon is placed in its lengthened position, and the ends of the Z are closed with suture. If present, the tendon sheath is closed separately from the skin closure. In a **tendon transfer**, the tendon usually is cut close to its insertion and transferred to a new bony insertion, which often requires a separate incision. The tendon is attached to the bone either with a suture anchor or by a bone tunnel and fixation by a screw or sutures.

Variant procedure or approaches

Achilles tendon lengthening is used to bring the ankle out of equinus. A **posterior tibial tendon lengthening** and/or **posterior ankle capsulotomy** may accompany the procedure.

Usual preop diagnosis

Contracture of muscle

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Tendon Lengthening	Achilles Tendon Lengthening
Position	Supine	Prone
Incision	Over tendon; sometimes multiple incisions	Over tendon
Special instrumentation	Tourniquet	⇐

Antibiotics	If young, none; in elderly or infirm, cefazolin 2 g iv preop	⇐
Surgical time	2 h	1 h
Closing considerations	Splint or cast while anesthetized	⇐
EBL	10 mL	⇐
Postop care	PACU → room	PACU → room or home
Mortality	Minimal	⇐
Morbidity	Infection: <1%	⇐
Pain score	4	3

PATIENT POPULATION CHARACTERISTICS	
Age range	Any age
Male:Female	1:1
Incidence	Rare
Etiology	Neuromuscular disease (80%); trauma (20%)
Associated conditions	Static encephalopathy/cerebral palsy (75%); other neuromuscular disease (25%)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower-Extremity Procedures.

AMPUTATION ABOVE THE KNEE

SURGICAL CONSIDERATIONS

Description

In above-knee amputations, the distal part of the lower extremity is excised, starting just above the knee at the level of the distal third of the femur (Fig. 10.6-5). A stump is fashioned and will require prosthetic fitting at a later time. The most commonly

performed stumps incorporate anterior and posterior flaps of equal length. The underlying muscles (hamstrings and quadriceps) are either sewn to each other (**myoplasty**) or to bone (**myodesis**). In a **guillotine**, or **open amputation**, the stump is not fashioned (tissues are not closed) until later. This is a multistage procedure used for dirty, traumatic amputations, infection, or above-knee amputations with questionable survival and usually is done as a lifesaving measure. Internal fixation of part of the remaining femur may be indicated in traumatic amputations. The patient returns to the OR every 1–3 d for redebridement until closure of the clean stump can be performed.

Usual preop diagnosis

PVD or gangrene of lower extremity; trauma to lower extremity; open-femur fracture with traumatic amputation; tumor of lower extremity

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, rehabilitation plans, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Anterior and posterior on thigh
Special instrumentation	Amputation saw and rasp; drill for myodesis
Unique considerations	Patient often very ill from sepsis, chronic disease, or trauma
Antibiotics	Cefazolin 2 g iv q6–8h), ± gentamicin (80 mg iv q8h); adjust dosage for renal status, ± penicillin (1–2 million U iv q4h).
Surgical time	1–2 h
Closing considerations	Compressive dressing ± special stump sock
EBL	250 mL or more; higher for traumatic amputations
Postop care	Generally PACU → room (if medically unstable → ICU)

Mortality	~10–20%; higher in PVD (10–39%)
Morbidity	Phantom limb: 85–95% Phantom pain: 2–15% Wound infection ± deep infection: <15% in PVD Respiratory failure or pneumonia: 10–15% MI: 7–10% Thromboembolism: 6–10% Cerebrovascular accident: 5–10% Contractures—flexion and abduction: Common Urinary retention requiring catheterization: Common Failure to heal ± wound dehiscence: Uncommon Hematoma: Rare Neuromas: Rare Reamputation: Rare UTI: Rare Contralateral amputation, especially in diabetics and those with PVD Postop depression
Pain score	7–10

PATIENT POPULATION CHARACTERISTICS

Age range	PVD, diabetic gangrene: 70–90% >60 yr Multiple trauma with traumatic amputation, tumor of lower extremity: 18–35 yr
Male:Female	Overall, 3:1 Elderly, predominance of males Multiple trauma, 4–5:1 Tumor 1:1
Incidence	Common for PVD patients; rare for trauma or tumor
Etiology	PVD and diabetic gangrene (70–90%); multiple trauma (younger patients) (rare—usually with severe grade IIIC injuries with neurovascular severance); tumor (rare); uncontrollable infection (e.g., gas gangrene) (rare)
Associated conditions	Diabetes (70–80% of patients presenting for this procedure); numerous other serious medical conditions; multiple trauma in younger patients

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Above- and Below-Knee Amputation.

AMPUTATION BELOW THE KNEE

SURGICAL CONSIDERATIONS

Description

Below-knee amputation is ablation of the lower limb, usually at the level of the midleg. A long, posterior flap normally is used to cover the stump. The condition of the soft tissues may dictate the level and/or type of flaps used. The procedure begins with an anterior transverse incision made over the midtibia. A long posterior flap, which is 2–3 times the diameter of the leg in length, is then made. The bone is exposed anteriorly, and the anterolateral neurovascular structures and muscles are transected and ligated as appropriate (Fig. 10.6-6A). The bone is then transected with a bone saw, and the posterior structures are transected and ligated as appropriate. The amputated leg and foot are then removed from the table, and the posterior flap is tapered and shaped for closure (Fig. 10.6-6B). Deep sutures are placed to secure the posterior muscles to the anterior tibia. The skin opening and subcutaneous tissues are closed with interrupted sutures. Finally, a drain is placed (sometimes), and either a compression dressing or an immediate postop cast is applied.

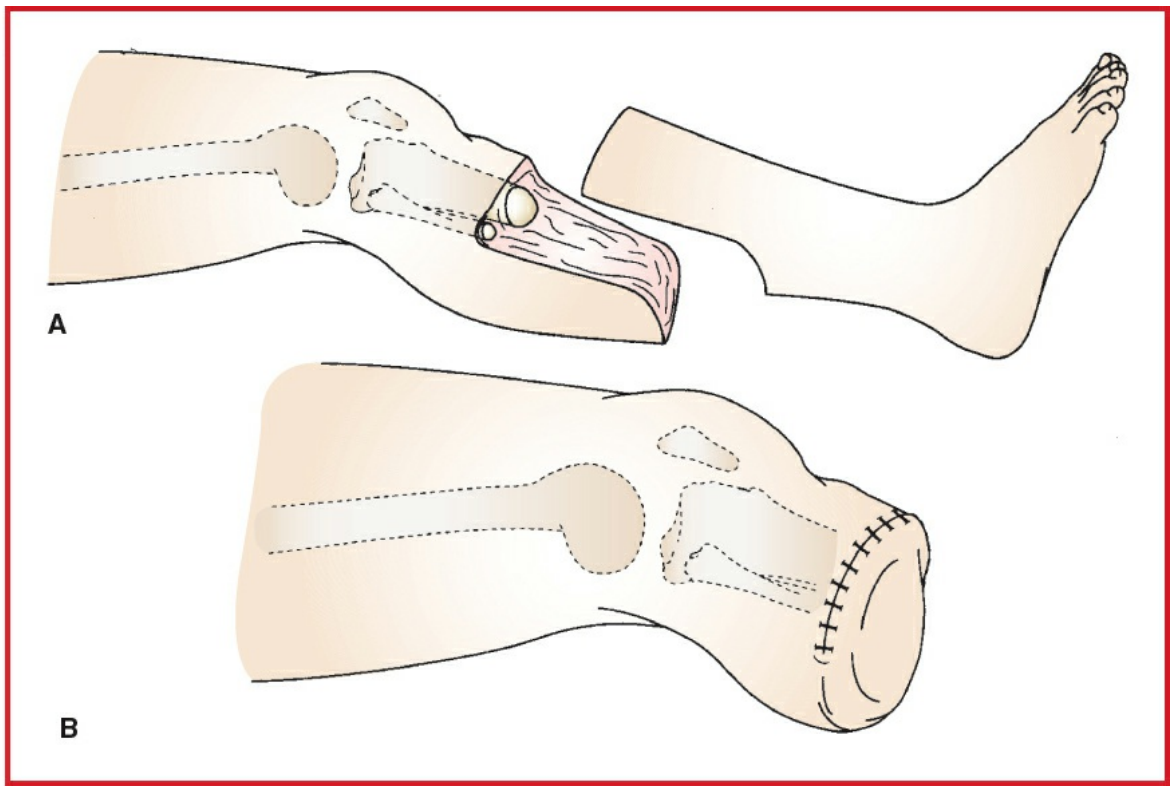

Figure 10.6-6 Below-knee amputation. **A:** The tibia is transected 1 cm proximal to the skin incision, and the fibula is transected an additional 1 cm proximal to the level of the tibial transection. The posterior calf muscles are incised along the plane of the skin incision. **B:** The posterior flap is rotated anteriorly and approximated. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al, eds: Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Variant procedure or approaches

Guillotine amputation may be used as the first of a two-stage procedure in infected or contaminated cases. With a guillotine amputation, the bone and soft tissues are transected very quickly in guillotine fashion at the midtibial level. Neurovascular structures are ligated as appropriate. These wounds are usually left open and a compression dressing applied.

Usual preop diagnosis

Dysvascular limb; infection; trauma

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, rehabilitation plans, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE

Position	Supine
Incision	Anterior and posterior flaps; for guillotine amputation, circumferential incision
Special instrumentation	Bone saw; tourniquet, if traumatic (tourniquet contraindicated if infected or avascular)
Antibiotics	Cefazolin 2 g iv preop
Surgical time	1.5 h; for guillotine amputation, 0.5 h
Closing considerations	May use cast; drain. Bulky dressing needed for guillotine amputation.
EBL	200 mL
Postop care	PACU → room
Mortality	10%
Morbidity	Phantom pain: 90% Infection: 10–15% Wound breakdown: 10–15% Pneumonia: 12% MI: 7% PE: 6% Hematoma: 5% Stroke: 5%
Pain score	5

PATIENT POPULATION CHARACTERISTICS

Age range	Usually, >60
Male:Female	3:1
Incidence	20,000–30,000 total amputations/yr
Etiology	Dysvascular limb (70%); trauma (20%); infection (5%); tumor (5%); congenital anomaly (<1%)
Associated conditions	Vascular disease (70–80%); malnutrition (50%); diabetes mellitus (30%); pulmonary disease (30%)

ANESTHETIC CONSIDERATIONS FOR ABOVE- AND BELOW-KNEE AMPUTATION

PREOPERATIVE

Vascular disease and tumors are the two most common indications for these surgeries. Patients presenting for amputations often have severe systemic vascular disease. Their inability to perform exercise limits the usefulness of preop Hx in evaluating cardiopulmonary reserve and often necessitates invasive studies for full evaluation.

Respiratory	Smoking is a risk factor common to both vascular and pulmonary diseases. Chronic bronchitis or COPD patients should have maximum medical therapy (e.g., inhaled bronchodilators, theophylline, and steroids, when appropriate) prior to anesthesia. Regional anesthesia is an excellent choice for patients with severe pulmonary disease. **Tests:** As indicated from H&P
Cardiovascular	Significant cardiovascular disease is present in ~30% of these patients. Particularly in diabetics, CAD is often silent. Dipyridamole thallium imaging of the heart can reveal the preop myocardium at risk of ischemia; however, therapy of stenotic coronary arteries usually can be undertaken only after the amputation. Medical management, to include β-blockers when tolerated, will reduce perioperative MIs. **Tests:** ECG; others as indicated from H&P
Neurologic	Peripheral and autonomic neuropathies may be present in the diabetic patient. Hence, these patients may be more susceptible to injury from malpositioning and are less able to tolerate the hemodynamic changes associated with regional anesthesia. Preexisting neurologic deficits should be carefully documented. Autonomic neuropathy is diagnosed by any of the following: postural ↓ BP (in patient not bedridden); loss of sinus arrhythmia; resting ↑ HR; miosis-abnormal response to darkness.

Musculoskeletal	Rhabdomyolysis can occur in the presence of partial ischemia. (See Renal, below.)
Hematologic	Often a trial of heparin, warfarin, or thrombolytic therapy will have been undertaken before amputation. Coag studies, including PT, PTT, and bleeding time, are, therefore, often necessary to determine the appropriateness of epidural or intrathecal anesthesia. Warfarin-induced elevation of the PT can be reversed preop with FFP 5–10 mL/kg body weight. This therapy may induce fluid overload in patients with poor cardiac reserve. For these patients, diuretics should be administered to maintain normovolemia. **Tests:** As indicated from H&P
Renal	Limb ischemia can result in myoglobinemia from rhabdomyolysis. Evidence of progressive renal failure or rising CPK-MM fractions should be treated with hydration, forced alkaline diuresis, and prompt amputation. **Tests:** Consider Cr; BUN; CPK enzymes; urine myoglobin.
Laboratory	Diabetic patients require preop control of blood glucose and periop glucose monitoring.
Premedication	Standard premedication
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po, ±celecoxib 200 mg po, and ±gabapentin 600 mg po. Consider aprepitant 40 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Either regional or GA may be appropriate.

Regional anesthesia

Both SAB and epidural blocks are useful techniques. Subarachnoid anesthesia has the advantage of limited spread of the block above the level of surgery while obtaining adequate blockade of the sacral roots that are resistant to low-dose epidural techniques. Epidural anesthesia allows for extending the duration of anesthesia and for the administration of postop epidural analgesia. Anesthesia from T12 (T8 with tourniquet) is adequate. Full motor blockade is not necessary. Typical drugs and doses include subarachnoid, 75 mg of 5% lidocaine in 5% dextrose (controversial) with morphine 0.2 mg, and epidural, 12–15 mL 2% lidocaine with epinephrine 1:200,000 in divided doses.

General anesthesia

Induction	Standard induction is appropriate for patients with normal airways. Intubation is indicated for diabetic patients with gastroparesis. Beware of difficult airway in long-standing insulin-dependent diabetics.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance	
Emergence	No special considerations. Consider iv acetaminophen if po dose given >6 h ago. PONV prophylaxis should include ondansetron and dexamethasone.	
Blood and fluid requirements	Moderate blood loss IV: 16 ga × 1 BSS @ 4–6 mL/kg/h	Expect 100–200 mL blood loss, mostly during cleaning of the wound made while developing a flap. See Restrictive Fluid Management, Appendix K, p. K-4.
Control of blood loss	Tourniquet may be used.	Inflation pressure is typically 100 mm Hg + systolic pressure. Maximum "safe" tourniquet time is 1.5–2

		h, followed by a 5- to (preferably) 15-min reperfusion interval, if further tourniquet time is necessary.
Special considerations	Tourniquet deflation and limb reperfusion	Mild ↓ BP is common. In patients with moderate-to-severe lung disease, continue controlled ventilation until after the lactic acid accumulated in the ischemic leg is metabolized (3–5 min) because these patients may be unable to increase ventilation adequately to buffer this acid load.
Monitoring	Standard monitors ± CVP line ± Arterial line	Invasive monitoring is indicated in the presence of severe cardiac or pulmonary disease. Serial blood glucose determination should be made in the diabetic patient.
Positioning	✓ and pad pressure points ✓ eyes	Meticulous padding of the extremities is necessary to prevent ischemic skin ulceration in patients with vascular insufficiency.

POSTOPERATIVE

Complications	Hematoma Bleeding	✓ drains

Multimodal pain management	Spinal opiates Epidural analgesia	Epidural hydromorphone 50 mcg/mL infused at 50–200 mcg/h provides excellent analgesia. Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional analgesia (e.g., continuous nerve block) whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and p. B-6) Regional analgesia	Encourage early enteral nutrition, Foley catheter removal, and mobilization.
Tests	CXR if CVP was placed.	Other studies as indicated

Suggested Readings

1. De Jong R, Shysh AJ: Development of a multimodal analgesia protocol fo perioperative acute pain management for lower limb amputation. Pain Res Manag 2018; 2018:5237040.
2. Salinas FV: Evidence basis for ultrasound guidance for lower-extremity peripheral nerve block: update 2016. Reg Anesth Pain Med 2016; 41(2):261–74.
3. Sites BD, Brull R: Ultrasound guidance in peripheral regional anesthesia philosophy, evidence-based medicine, and techniques. Curr Opin Anaesthesiol 2006; 19(6):630–9.

FASCIOTOMY OF THE THIGH

SURGICAL CONSIDERATIONS

Description

There are three compartments in the thigh. Increased intracompartmental pressure in the thigh requires surgical release of tight skin and fascial structures (Fig. 10.6-7). This usually occurs after severe trauma to the thigh (e.g., crush injury, comminuted fracture),

after prolonged vascular surgery (with ischemia to the thigh), or with infection. Compartment syndrome is a true emergency and must be treated within minutes of recognition. Failure to do so may result in loss of limb. Conventional devices may be used to measure intracompartmental pressure (normal ≤ 30 mm Hg), or diastolic pressure minus compartment pressure should be >30 mm Hg). **Fasciotomy of the thigh** involves incising the skin and fascia typically through an anterolateral incision to release the anterior and posterior compartment and to débride any necrotic tissue. A medial incision can be done to release the adductor compartment. The wound is left open for later redebridement, delayed primary closure, or skin grafting. Typically, a negative pressure dressing is applied at the time of surgery. Thus, the fasciotomy begins a multistage procedure of incision and debridement with subsequent attempt at closure.

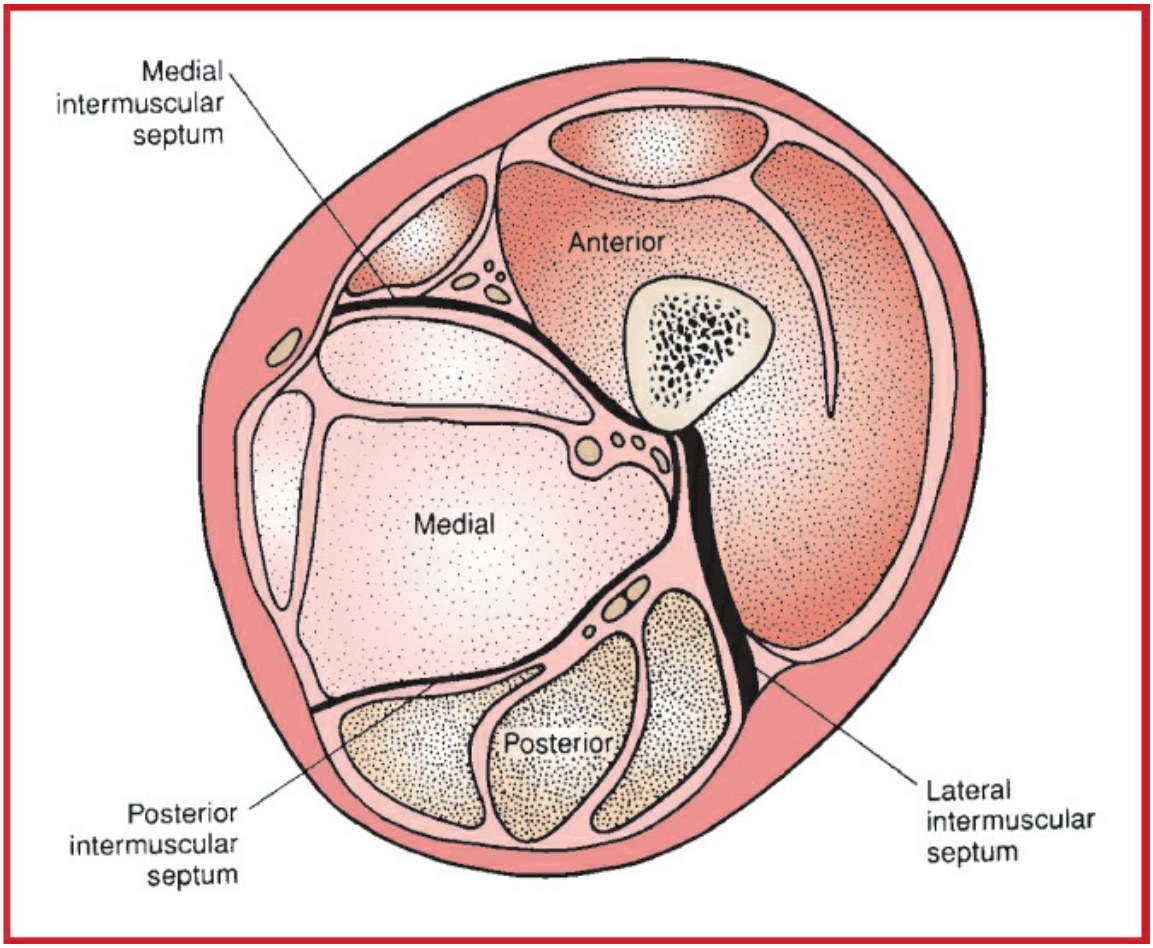

Figure 10.6-7 Cross section of the thigh showing the three major compartments.

Usual preop diagnosis

Compartment syndrome of thigh; crush injury to thigh; necrotizing fasciitis

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist

should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine or lateral decubitus
Incision	Lateral thigh, medial thigh
Unique considerations	Patient may be very ill. If an ipsilateral femoral fracture is present with a compartment syndrome, the surgeon may want to perform ORIF, intramedullary nailing, or external fixation of the fracture.
Antibiotics	Cefazolin 2 g iv q6h
Surgical time	1.5–2 h for fasciotomy alone
Closing considerations	Wound left open and covered by sterile dressings
EBL	250–500 mL
Postop care	If surgery is performed acutely, patient frequently will be a multiple-trauma victim with numerous injuries and extensive blood loss; usually goes to ICU.
Mortality	Dependent on extent of multiple trauma
Morbidity	Hypotension and fluid loss: Common Neurologic deficit to peripheral nerves: Common, if decompression delayed Respiratory distress and fat embolism: Not uncommon, if concomitant femur fracture Vascular complications: Not uncommon Amputation: Rare, if decompression prompt Systemic sepsis: Rare Wound infection: Rare New compartment syndrome; insufficient fasciotomy: Rare
Pain score	7–8

PATIENT POPULATION CHARACTERISTICS	
Age range	Any age, but predominance of males <30 yr
Male:Female	5:1
Incidence	Extremely rare
Etiology	Trauma—motorcycle and motor vehicle accidents, falls, industrial injury, crush injuries; postop—local hematoma and swelling; thrombosis or disruption of blood supply to thigh (e.g., failed proximal vascular bypass surgery, aortic dissection); massive infection of thigh compartment (e.g., gas gangrene)
Associated conditions	Burns; drug and alcohol overdose; frequently associated with trauma to other organ systems

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Fasciotomy of the Leg.

Suggested Readings

1. Rush RM Jr, Arrington ED, Hsu JR: Management of complex extremity injuries tourniquets, compartment syndrome detection, fasciotomy, and amputation care. Surg Clin North Am 2012; 92(4):987–1007, ix.
2. von Keudell AG, Weaver MJ, Appleton PT, et al: Diagnosis and treatment of acute extremity compartment syndrome. Lancet 2015; 386(10000):1299–310.

FASCIOTOMY OF THE LEG

SURGICAL CONSIDERATIONS

Description

This procedure is the surgical decompression of fascial compartments for treatment or prevention of compartment syndrome. Patients are often very ill and unstable with other injuries or disease. Compartment syndrome is a true emergency and must be treated within minutes of recognition. Failure to do so may result in loss of limb. There are four compartments in the lower leg: anterior, lateral, deep posterior, and superficial posterior (Fig. 10.6-8). Generally, all four compartments are released during the

procedure. A **four-compartment fascial decompression** can be performed through two incisions—medial and lateral. A medial longitudinal incision is made just posterior to the tibia; through this incision, the superficial and deep posterior compartments are identified and the fascia incised in longitudinal fashion. A straight, lateral, longitudinal incision is made, and the deep fascia overlying the anterior and lateral compartments is identified. The fascia of each compartment is then incised longitudinally. Skin incisions are rarely closed because of swelling and need for possible repeat debridement. A negative pressure dressing is typically applied along with a splint postop. Multistage procedure may be needed after primary release for repeat debridement, delayed primary closure, or skin grafting.

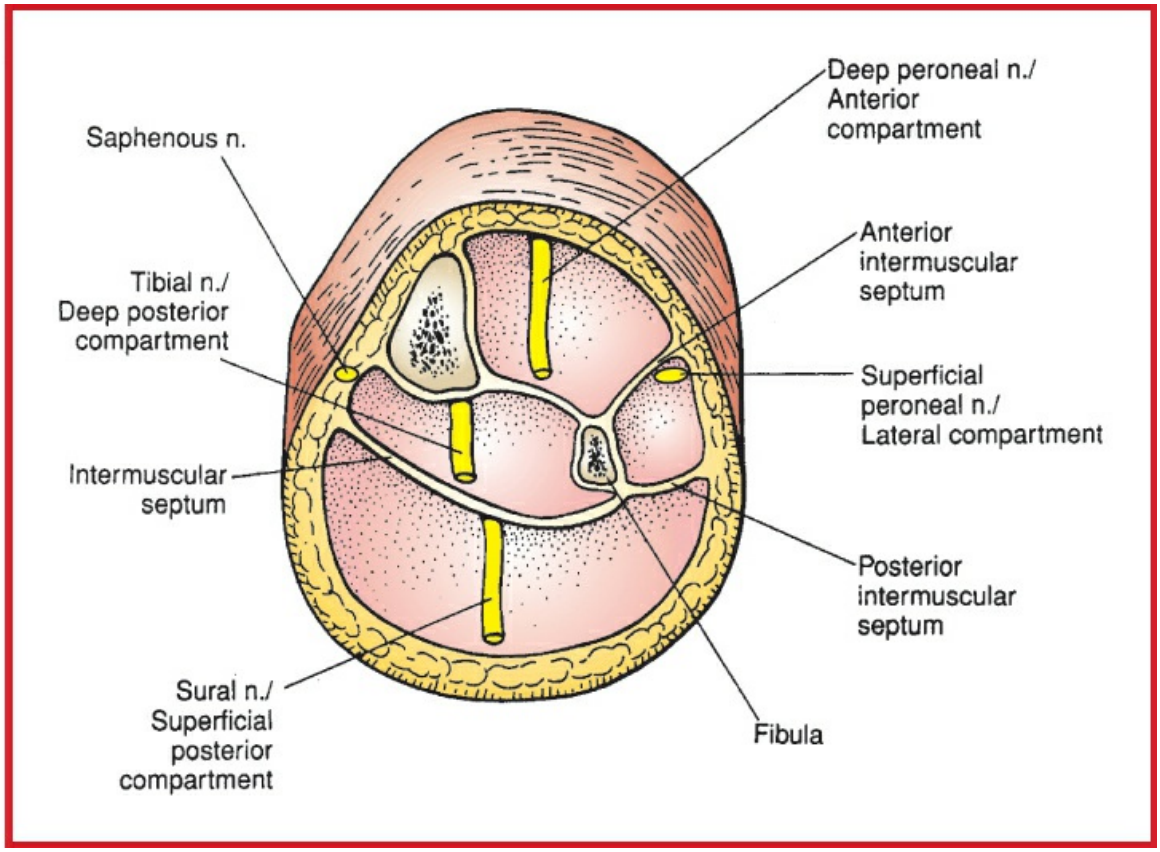

Figure 10.6-8 Cross section of the left leg, middle lower third, showing the four compartments with associated peripheral nerves.

Usual preop diagnosis

Compartment syndrome; vascular trauma

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Medial and lateral parallel to tibia
Unique considerations	Often associated with fracture; may require fixation
Antibiotics	Cefazolin 2 g iv preop
Surgical time	30 min+
Closing considerations	Wounds left open; splint may be required.
EBL	100 mL
Postop care	PACU → room; vascular monitoring is carried out clinically via a pulse oximeter on toes.
Mortality	Minimal
Morbidity	Myonecrosis: 50% Thrombophlebitis: 10–20% Infection: 10–15%
Pain score	3

PATIENT POPULATION CHARACTERISTICS	
Age range	All ages
Male:Female	1:1
Incidence	~5% of tibia fractures
Etiology	Trauma—blunt fracture, vascular (90%); drug overdose (10%); burns (<5%); revascularization (<5%)
Associated conditions	Multiple trauma (60%); vascular disease (15%)

Suggested Readings

1. Cone J, Inaba K: Lower extremity compartment syndrome.Trauma Surg Acute Care Open 2017; 2(1):e000094.

2. von Keudell AG, Weaver MJ, Appleton PT, et al: Diagnosis and treatment of acute extremity compartment syndrome. Lancet 2015; 386(10000):1299–310.

ANESTHETIC CONSIDERATIONS FOR FASCIOTOMY OF THIGH AND LEG

PREOPERATIVE

Compartment syndromes and necrotizing fasciitis are the indications for these procedures (necrotizing fasciitis also may cause compartment syndrome). Patients with compartment syndrome often have no systemic disease, whereas patients with necrotizing fasciitis have a rapidly life-threatening infection that requires prompt surgical debridement and often is complicated by rhabdomyolysis and DIC.

Respiratory	Usually no special considerations, unless massive sepsis.
Cardiovascular	Sepsis is uniformly present in patients with necrotizing fasciitis. Management includes antibiotics and hemodynamic support with dopamine (5–15 mcg/kg/min) or epinephrine (0.02–0.25 mcg/kg/min), with therapy guided by invasive hemodynamic monitoring, which may include PA catheter.
Neurologic	If fasciotomy is for compartment syndrome, there may be compromise of distal nerves and blood flow. Perform a thorough neurologic exam of the involved extremity to document preop deficits.
Hematologic	If infection is the indication for the fasciotomy, DIC is likely. Evaluate for pathologic bleeding. Administer factors necessary to correct coagulopathy during the procedure. **Tests:** CBC; PT; PTT; fibrinogen; fibrin split products; Plt count
Renal	Both necrotizing fasciitis and compartment syndrome often cause myoglobinuria and rhabdomyolysis. Myoglobinuria can be inferred from urine that is dipstick-positive for occult blood but microscopically free of RBCs in the absence of hemolysis (therefore,

	no free Hb in the urine).
Laboratory	Hct; serial K^+ levels if there is an active diuresis; other studies as indicated from H&P
Premedication	Standard premedication
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po. Consider aprepitant 40 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Regional techniques

Generally, most surgeons do not want regional anesthesia for compartment release in order to monitor neurologic status. In the absence of surgeon preference, regional anesthesia can be used for compartment syndrome decompression, unless there is evidence of DIC or systemic infection. These surgeries are usually of short duration (<1 h). Sepsis and hemodynamic instability usually mandate GETA for fasciotomy in patients with necrotizing fasciitis.

Regional anesthesia

Subarachnoid anesthesia has the advantage of adequate blockade of the sacral roots that are resistant to low-dose epidural techniques. Anesthesia from T10 to S2 is adequate. Typical drugs and dosages include subarachnoid, 12.5–15 mg of 0.5% bupivacaine, and epidural, 12–15 mL 2% lidocaine with epinephrine 1:200,000 in divided doses.

General anesthesia

Induction	Standard induction
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance
Emergence	Consider postop ventilation for patients with impaired oxygenation or ongoing hemodynamic instability; otherwise, no special considerations.

	Consider iv acetaminophen if po dose given >6 h ago. PONV prophylaxis should include ondansetron and dexamethasone.	
Blood and fluid requirements	IV: 16 ga × 1 (compartment syndrome) 14–16 ga × 2 (necrotizing fasciitis)	To prevent renal damage, **insure adequate circulatory volume**; induce osmotic diuresis with mannitol 0.25 g/kg iv.
	BSS @ 4–6 mL/kg/h	Furosemide 10–100 mg also may be necessary to maintain diuresis. Replace UO with BSS as guided by invasive monitoring. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Monitoring	Standard monitors UO	Fluid losses (third-spacing, bleeding) may be significant.
	± Arterial line (± ABG) ± CVP or PA catheter ± $S_{cv}O_2/S_vO_2$	Patients with necrotizing fasciitis require an arterial line with PPV and either a CVP or PA catheter with $S_{cv}O_2/S_vO_2$ to guide fluid and inotropic/pressor therapy.
Positioning	✓ and pad pressure points ✓ eyes	

POSTOPERATIVE

Complications	DIC Renal failure 2° rhabdomyolysis

	Hypo/hyperkalemia Sepsis syndrome, including ARDS	
Multimodal pain management	PCA or epidural analgesia	Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional analgesia (e.g., continuous nerve block) whenever possible (see Appendix K, p. K-6).
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6) Regional analgesia	Encourage early enteral nutrition, Foley catheter removal, and mobilization.
Tests	Hct Electrolytes UA (dipstick and microscopic)	For patients with sepsis: coag profile, including PT/PTT, fibrin split products, and Plt count

BIOPSY, LEG AND FOOT

SURGICAL CONSIDERATIONS

Description

Biopsy is performed to excise tissues for pathologic evaluation, usually through a small, longitudinal wound. For **incisional biopsy**, a longitudinal incision is made over the mass. Overlying soft tissues are incised with minimal undermining. The area in question is incised and the biopsy removed, with care being taken to prevent spillage into the adjacent tissues. The pathologist often is asked to perform a frozen section to determine whether diagnostic tissue is present. The wound is closed with interrupted sutures and a compression dressing applied. A splint or cast may be used if a significant amount of bone has been removed. If the lesion is small, x-ray control or image intensification may be necessary for localization. **Needle biopsy** may be used for distinct osseous lesions to obtain small amounts of tissue for culture or histology. **Excisional biopsy** may be used for benign lesions like exostoses or lipomas.

Usual preop diagnosis

Tumor; infection

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, regional/local anesthetic options, limiting NPO duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Incisional Biopsy	Needle Biopsy	Excisional Biopsy
Position	Supine	⇐	⇐
Incision	Short longitudinal	Stab wound	Stab wound
Special instrumentation	Bone-cutting instruments; x-ray or I.I.	Trephine (e.g., Craig needle); x-ray or I.I.	X-ray or I.I.
Unique considerations	Tourniquet	⇐	⇐ (Bone graft may be necessary.)
Antibiotics	None (may be given postop)	⇐	⇐
Surgical time	I h	0.5 h	0.5–2 h
Closing considerations	May be splinted	Usually no splint	May be splinted
EBL	50 mL	Minimal	100–200 mL
Postop care	PACU → room or home	⇐	PACU → room
Mortality	Minimal	⇐	⇐
Morbidity	Hematoma: 5% Tumor spread: <5% Infection: <1%	⇐ ⇐ ⇐	⇐ ⇐ ⇐
Pain score	3	2	3

PATIENT POPULATION CHARACTERISTICS	
Age range	All ages
Male:Female	1:1
Incidence	Rare
Etiology	Tumor (75%); infection (25%)
Associated conditions	Metastatic disease; immune compromise

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lower-Extremity Procedures.

BIOPSY OR DRAINAGE OF ABSCESS/EXCISION OF TUMOR

SURGICAL CONSIDERATIONS

Description

This procedure involves obtaining a piece of tissue for histologic and/or bacteriologic Dx by closed, percutaneous means or by open biopsy. Subsequently, the area may be drained (abscess or infection) or an open excision of a tumor may follow (± internal fixation). For excision of tumors of the pelvis, acetabulum, or femur, please consult the appropriate section describing fractures of the area. Each case must be individualized.

Variant procedure or approaches

Excision of infection or tumor of proximal or distal femur, femoral shaft, pelvis, or acetabulum

Usual preop diagnosis

Femur: biopsy of mass; infection; osteomyelitis. Pelvis or acetabulum: biopsy of pelvis or acetabulum; drainage of abscess or infection of pelvis or acetabulum; osteomyelitis of pelvis or acetabulum; septic arthritis of acetabulum

ERAS: For elective surgery, preop counseling by the surgeon/anesthesiologist should include patient education, local/regional anesthetic options, limiting NPO

duration, alcohol and smoking cessation, discussion of carb loading, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine or lateral decubitus
Incision	Percutaneous, short or long; location depends on site of lesion.
Special instrumentation	Biopsy needles and instruments to take a core biopsy; bone cement may be used to plug biopsy site. Some surgeons use fracture table or radiolucent table with I.I.
Unique considerations	May require intraop frozen section and Gram stain
Antibiotics	After tissue has been obtained, cefazolin 2 g iv q6h × 48 h. A Gram stain will help decide immediate antibiotic coverage, but cultures and sensitivities are ultimately necessary.
Surgical time	1 h for simple procedures; much longer (up to 12 h) for more extensive excisional procedures ± further reconstruction
EBL	100–1000 mL or more
Postop care	If procedure is extensive with much blood loss, or the patient is unstable or ill from chronic sepsis or invasive tumor, it is prudent to send patient to ICU.
Mortality	Dependent on extent of procedure. Biopsy or drainage of a small, localized abscess in soft tissue or bone is rarely life-threatening. Wide/radical excision of a malignant tumor in the pelvis or extremities is frequently life- and/or limb-threatening.
Morbidity	The following are dependent on site and procedure: Intraop fracture Nonunion Chronic osteomyelitis Compartment syndrome

	Residual instability of pelvis or hip joint Fracture of pelvis or acetabulum, nonunion Chronic osteomyelitis or septic arthritis Hypotension 2° to blood loss Respiratory distress Neurologic injury to lumbosacral plexus, sciatic nerve, or other peripheral nerves Vascular injury to iliac or other vessels Injury to GI, genitourinary, or gynecologic organs
Pain score	2–10

PATIENT POPULATION CHARACTERISTICS	
Age range	Any age; predominance of elderly patients with tumors
Male:Female	1:1
Incidence	Rare
Etiology	Benign and malignant tumors (common); infection (rare); previous surgery (rare); previous trauma (rare)
Associated conditions	Metastatic disease or other foci of infection

ANESTHETIC CONSIDERATIONS FOR LOWER-EXTREMITY PROCEDURES

(Procedures covered: ORIF of femur, tibia, ankle, and foot; intramedullary nailing of femur and tibia; closed reduction and external fixation of femur and tibia; distal tibia, ankle, and foot procedures; repair nonunion/malunion of femur and tibia; ankle arthroscopy, arthrotomy, arthrodesis; repair/reconstruction, ankle ligaments; Syme amputation; transmetatarsal amputation; tendon (ankle, foot) lengthening; biopsy of leg and foot; biopsy or drainage of abscess/excision of tumor)

PREOPERATIVE

Trauma victims constitute the largest group of patients for these procedures. Early administration of antibiotics and minimizing the time between fracture and surgery for open wounds significantly reduce the incidence of wound infection. Evaluations for

other injury, adequacy of fluid resuscitation, and preexisting conditions need to be undertaken promptly and used as a guide for anesthetic management. Patients with bone cancer form another subset of patients and often have concurrent medical conditions and have undergone chemotherapy or radiation therapy preop.

Respiratory	Pulmonary fat embolus occurs in 10–15% of patients following bone fracture. Sx include hypoxemia, ↑ HR, tachypnea, respiratory alkalosis, mental status changes, and conjunctival petechiae. Lab analysis may reveal fat in the urine. Preop therapy for this condition should include supplemental O_2 with mechanical ventilation, to correct hypoxemia, and meticulous fluid management to prevent worsening pulmonary capillary leak. **Tests:** Consider CXR; others as indicated from H&P
Cardiovascular	Cardiac contusion or tamponade are possible if blunt chest trauma has occurred during the injury. A large volume of blood can be hidden around a long bone fracture site. ↑ HR, orthostasis, or ↓ BP indicate hypovolemia, and this should be corrected with crystalloid (10–40 mL/kg) or blood if Hct < 24%. In patients with a tibial or distal femur fracture, and who are presenting with hemodynamic instability and ongoing blood loss, consider applying a tourniquet to the thigh prior to induction. **Tests:** Consider ECG; CPK enzyme levels and ECHO will help evaluate the presence of cardiac injury.
Neurologic	Perform a thorough neurologic evaluation, including mental status and peripheral sensory exams. A CT scan of the head is indicated for any patient with prolonged loss of consciousness prior to anesthesia. Drug abuse is common in trauma patients, and they should be asked specifically about any drug use. **Tests:** Patients with inappropriate behavior or a positive drug abuse Hx should undergo a urine and plasma drug screen.
Musculoskeletal	Consider cervical instability, and obtain spine films if

	mechanism of injury included rapid deceleration or trauma to the head or neck. Myoglobinemia and ↑ K^+ may result from crush injury.
Hematologic	Patients with cancer who have undergone chemotherapy and multiple transfusions often develop sensitivities to blood products and may require specialized blood products, such as leukocyte-poor PRBC or red cells negative for a particular antigen. The availability of these blood products should be confirmed before surgery. **Tests:** Hct and others as indicated from H&P
Renal	**Tests:** UA
Laboratory	Other tests as indicated from H&P
Premedication	Due to the risk of gastric aspiration, minimal or no premedication is given to trauma victims. For other patients, standard premedication. Narcotic premedication (morphine 1–2 mg iv q10min titrated to effect) is appropriate for patients experiencing pain with movement.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po. Consider aprepitant 40 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

For trauma patients, regional anesthesia permits evaluation of mental status, provides intact airway reflexes, and ↓ blood loss. Combative patients and those requiring multiple concurrent surgical procedures or prolonged (>2 h) procedures are often managed with GETA.

Regional anesthesia

Either subarachnoid or epidural blocks are useful techniques. Subarachnoid anesthesia has the advantage of adequate blockade of the sacral roots that are resistant to low-dose epidural techniques. Epidural anesthesia allows for the administration of postop

epidural analgesia. Anesthesia from T12 (T8 with tourniquet) to S2 is adequate. Full motor blockade is desirable. Typical drugs and doses include subarachnoid, 12.5–15 mg of 0.5% bupivacaine with morphine 0.2 mg (omit if outpatient), and epidural, 12–15 mL 2% lidocaine with epinephrine 1:200,000 in divided doses (Na bicarbonate 0.1 mg/mL will speed onset of block).

General anesthesia

Induction	Standard induction is appropriate for patients with normal airways. Trauma patients require a rapid-sequence induction and intubation with cricoid pressure to prevent gastric aspiration.	
ERAS	Verify pre-incision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia and normothermia.	
Maintenance	Standard maintenance. Trauma patients are often cold and require active warming if <35°C (convection blanket and active humidifier). Warming the patient may unmask severe hypovolemia that should be corrected.	
Emergence	Trauma patients should have full return of protective airway reflexes and, given the possibility of fat embolism, ensure that oxygenation is adequate on 50% O_2 before extubation. PONV prophylaxis, should include ondansetron and dexamethasone.	
Blood and fluid requirements	IV: 14–16 ga × 2 BSS @ 4–8 mL/kg/h Warm fluids. Humidify gases.	Some fractures can involve large (30 mL/kg) blood losses that are hidden in the leg or thigh. Clinical signs of hypovolemia and serial Hct determination should guide fluid therapy. See Goal-Directed Fluid Management, Appendix K, p. K-4.
Control of blood loss	Tourniquet	Inflation pressure is

		typically 100 mm Hg + systolic pressure. Maximum "safe" tourniquet time is 1.5–2 h, followed by a 5- to (preferably) 15-min reperfusion interval, if further tourniquet time is necessary.
Monitoring	Standard monitors ± Arterial line ± CVP line	Arterial/CVP lines indicated for patients with ↓ BP not readily correctable with crystalloid infusion, massive blood loss (>1 blood volume), or the need for postop ventilation.
Positioning	✓ and pad pressure points ✓ eyes	
Special considerations	Release of tourniquet	A 20% ↓ MAP is common on tourniquet deflation. Additional crystalloid (5–10 mL/kg) may be necessary to replace edema fluid and blood loss to the leg.
Complications	Fat embolism Myoglobinemia	

POSTOPERATIVE

Complications	Hypoxemia VTE (DVT)	May be 2° fat embolism.
Multimodal pain management	Spinal opiates: Epidural anesthesia	Epidural hydromorphone 50 mcg/mL infused at

	Spinal anesthesia	100–250 mcg/h provides excellent analgesia. Intrathecal morphine 0.2–0.3 mg provides analgesia for up to 24 h after administration. (Monitor for delayed respiratory depression.) Emphasize multimodal approach combining nonopioid and bolus/PCA opioid analgesics with regional analgesia (e.g., continuous nerve block) whenever possible (see Appendix K, p. K-6).
	For elective cases, consider multimodal analgesia.	Gabapentin, 300 mg, given preop can significantly reduce postop pain and opioid consumption.
ERAS	PONV protocol (see Appendix B, p. B-4 and B-6) Regional analgesia	Encourage early enteral nutrition, Foley catheter removal, and mobilization.
Tests	Hct CXR, if CVP placed or oxygenation is impaired.	Other studies as indicated

Suggested Readings

1. Crisologo PA, Monson EK, Atway SA: Gabapentin as an adjunct to standard postoperative pain management protocol in lower extremity surgery. J Foot Ankle Surg 2018; 57(4):781–4.
2. Fraser TW, Doty JF: Peripheral nerve blocks in foot and ankle surgery. Orthop Clin North Am 2017; 48(4):507–15.
3. Ganapthy S: Wound/intra-articular infiltration or peripheral nerve blocks for orthopedic joint surgery: efficacy and safety issues. Curr Opin Anaesthesiol 2012;

25(5):615–20.
4. Johnson RL, Kopp SL, Hebl JR, et al: Falls and major orthopaedic surgery wit peripheral nerve blockade: a systematic review and meta-analysis. Br J Anaesth 2013; 110(4):518–28.
5. McDonald E, Winters B, Nicholson K, et al: Effect of postoperative ketorola administration on bone healing in ankle fracture surgery. Foot Ankle Int 2018; 39(10):1135–40.
6. Patterson JT, Morshed S: Chemoprophylaxis for venous thromboembolism ir operative treatment of fractures of the tibia and distal bones: a systematic review and meta-analysis. J Orthop Trauma 2017; 31(9):453–60.
7. Sites BD, Brull R: Ultrasound guidance in peripheral regional anesthesia philosophy, evidence-based medicine, and techniques. Curr Opin Anaesthesiol 2006; 19(6):630–9.

Suggested Viewing

Links are available online to the following videos:

Tibial Plateau Fracture Surgery (Arthroscopically Assisted): https://www.youtube.com/watch?v=mfbgeC5H9To

Treatment of Ankle Fractures: https://www.youtube.com/watch?v=fKDAhnwy0ec

Ultrasound-Guided Popliteal Sciatic Nerve Block: https://www.youtube.com/watch?v=kzhSiQBPE7s

SECTION 11.0

PLASTIC AND RECONSTRUCTIVE SURGERY

CHAPTER 11.1

Facial Cosmetic Surgery

SURGEONS
Jeff Chang, MD
David M. Kahn, MD

ANESTHESIOLOGISTS
Richard A. Jaffe, MD, PhD
Vanila M. Singh, MD, MACM

INTRODUCTION TO COSMETIC FACIAL SURGERY

The presenting signs of the aging face are predictable, based on the effects of gravity, soft tissue atrophy, changes in the bony skeleton, facial expression, ultraviolet radiation exposure, and connective tissue changes. Patients present with concerns about appearing tired, angry, or aged. They may also have functional difficulties, such as difficulty breathing or visual field obstruction due to drooping brows or overhanging eyelids. Other common complaints are wrinkles around the eyes and mouth, and a sagging or fatty chin and neck (turkey waddle).

Cosmetic facial surgery aims to rejuvenate and restore the facial form by surgical manipulation of the hard and soft tissues. The techniques used involve any or all of the following: soft tissue release, resection, plication, augmentation, and resuspension.

Facial aging takes place simultaneously in all areas of the face and neck; combined procedures are not uncommon. Generally in combined procedures, a brow lift would precede a neck lift, followed by a facelift. Blepharoplasty procedures can be performed at different times in the surgical scheme because of their effect on eyelid tissue and brow posture. A rhinoplasty ideally is reserved for last, as it can cause bleeding and swelling that can obscure other facial surgical fields.

FACELIFT AND NECK LIFT

SURGICAL CONSIDERATIONS

FACELIFT (OR MELOPLASTY OR RHYTIDECTOMY)

Description

Facelifts and **midface lifts** are procedures to rejuvenate the face by surgical manipulation of the soft tissues between the inferior orbital rim and the inferior border of the mandible. The lips and nose are generally unaffected. Many types of "facelift" procedures have been developed to address the diverse challenges of facial aging and rejuvenation. Traditional facelift procedures took place in the subcutaneous plane, with some skin resection. Today, three planes of dissection are used (Fig. 11.1-1). **Subcutaneous dissection** continues to be popular, traversing the adipose tissue below the skin and many of the vessels supplying the skin. The **sub-SMAS** technique develops the plane between the superficial musculoaponeurotic system of the face (SMAS) and the parotid gland.

Finally, **subperiosteal dissection** (midface lift) elevates the periosteum off the overlying bones thereby keeping the skin and underlying soft tissues as one unit. Combinations of these dissection planes have also been described. More recently, greater attention has been paid to minimal access techniques. Surgeries such as the minimal access cranial suspension lift, as well as adjunctive procedures such as the barbed suture lift, are being performed more frequently. See Figure 11.1-2.

Local anesthetics with epinephrine are injected prior to making the incision for the various procedures. A number of subcutaneous infiltration mixtures may be used, including one described by **Klein** that consists of NS 1000 mL with 1.0 mL epinephrine (1:1000) and 50 mL of 1% lidocaine ± 12.5 mL of 8.5% sodium bicarbonate solution. It has been shown that with the use of this mixture, 5–7 times the traditionally accepted maximum dose of lidocaine with epinephrine can be injected safely into the subcutaneous space. Not only does this solution provide hemostasis and hydrodissection, but decreased operative time and excellent perioperative analgesia also have been attributed to its use.

The traditional incision used begins either in the hair or at the hairline in the temporal region. It then extends inferiorly in front of the ear. If needed, the incision will curve around the earlobe and go superiorly behind the ear and then turn posteriorly into the hair or follow the hairline toward the occiput. The approaches for the subcutaneous and

SMAS techniques resemble those used for bilateral facial palsy and parotid gland operations. Techniques to address the midface may be carried out through intraoral, temporal, and/or lower-lid incisions. These techniques may be performed separately or may be combined with other facelift procedures.

A typical facelift begins with subcutaneous dissection of the facial skin flap (Fig. 11.1-3) with meticulous hemostasis accomplished with bipolar electrocautery. Then either a plication of the SMAS layer, excision of a strip of SMAS and closure, or a sub-SMAS dissection with elevation and resuspension of the SMAS can be accomplished. Some surgeons continue on the same side with skin resection and closure before beginning on the other side, whereas others temporarily pack the first side and perform an identical procedure on the opposite side. In the latter case, a second look for bleeding is made on each side after a waiting period.

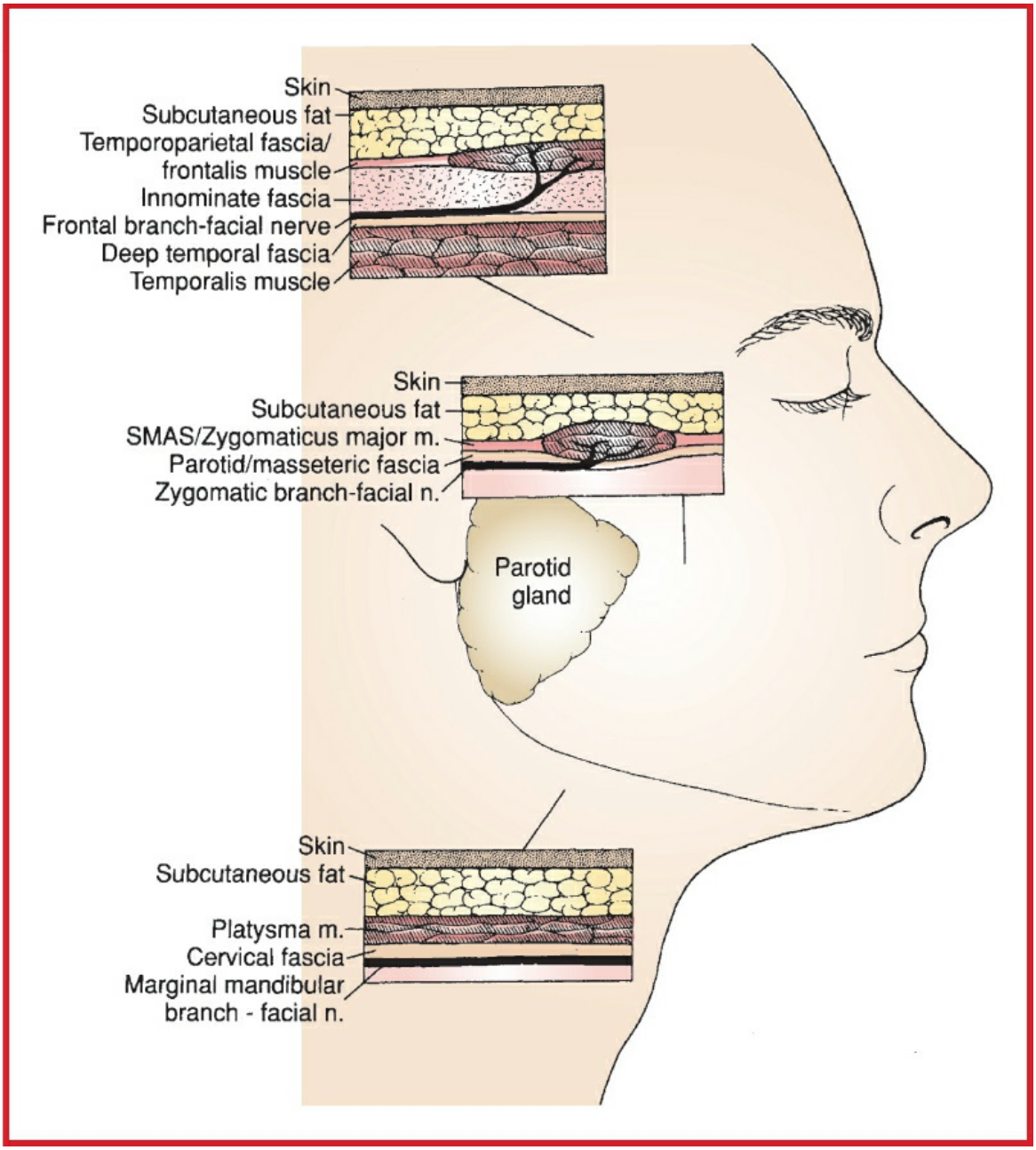

Figure 11.1-1 Anatomic layers of the face. Although the names vary, the arrangement persists, regardless of the area of the face. The facial nerve (CN VII) branches innervate their respective muscles of the SMAS layer via the deep surfaces. (Reproduced with permission from Thorne CHM, Aston SJ: Aesthetic surgery of the aging face. In: Aston SJ, Beasley RW, Thorne CHM, edsGrabb & Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

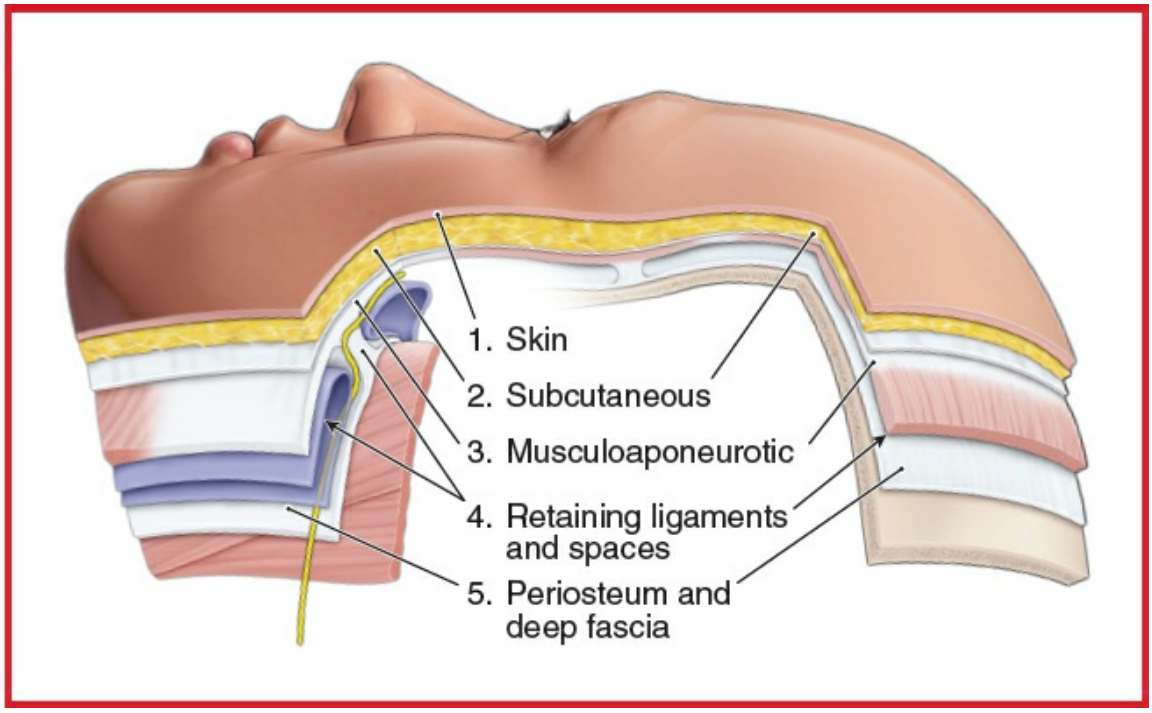

Figure 11.1-2 Tissue layers of the face and neck.

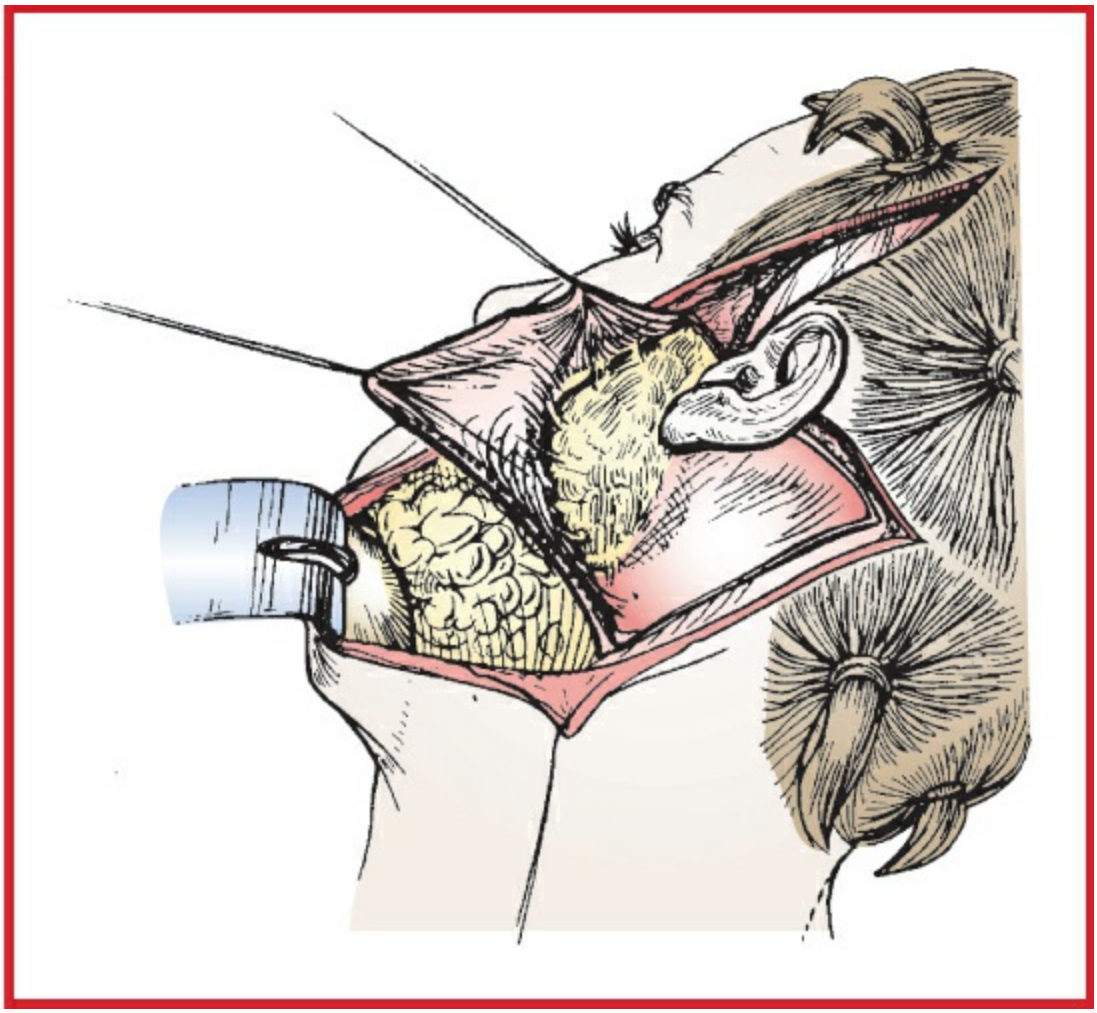

Figure 11.1-3 Dissection of SMAS/platysma flap. If a composite rhytidectomy is performed, the same

plane of dissection is used. If SMAS dissection extends to the zygomaticus major muscle, it is termed "extended." (Reproduced with permission from Thorne CHM, Aston SJ: Aesthetic surgery of the aging face. In: Aston SJ, Beasley RW, Thorne CHM, eds.Grabb & Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

Hematoma is the most common complication of facelift surgery. Because hypertension is a frequently encountered medical condition in the age group that typically presents for facelift, perioperative hypertension must be anticipated and treated preemptively to avoid bleeding risk and the subsequent development of hematoma. The risk is higher in male patients, perhaps due to increased perfusion of the bearded region, hormonal gender differences, or increased sebaceous gland density. Medications that can increase the risk of bleeding are typically discontinued around the time of surgery (i.e., aspirin, NSAIDs, fish oil, etc.).

Smoking also has been shown to be detrimental to facelift results, especially with regard to skin flap survival. As this is elective surgery, most physicians will have patients stop smoking 2–4 wk prior to and after surgery

One of the least desirable complications is injury to the facial nerve, which can produce a disastrous result following an elective cosmetic surgery. Many surgeons prefer that no paralytics be used during the procedure to allow for careful monitoring of facial nerve function.

NECK LIFT

Description

Neck lift is the rejuvenation of the area from the inferior border of the mandible to the clavicles. The goal of the procedure is to sharpen the chin and smooth the anterior neck (i.e., improve the cervicomental angle). This procedure often is combined with a facelift procedure where the neck skin is elevated and redraped on the face where it can be addressed by facelift. Patients undergoing isolated neck lifts without a facelift typically have smaller amounts of neck skin laxity/redundancy.

A neck lift is usually achieved by extending the facelift dissection inferiorly through the preauricular incision. A small submental incision may also be used to allow for **submental liposuction, direct fat excision,** or **platysma muscle modifications** (plication, suspension, resection, or transection techniques). Some platysmal suspension techniques require the facelift incisions to remain open with continuity in the subcutaneous plane laterally. See Figure 11.1-4.

Variant procedures or approaches

Laser resurfacing, especially in the perioral and periorbital regions; **blepharoplasty** and **brow lift** are common adjunct procedures.

Usual preop diagnosis

Facelift: facial rhytids (wrinkles/creases); solar or senile elastosis; jowling; deep nasolabial folds; tear troughs; nasojugal folds; malar bags. Neck lift: "turkey gobbler" neck; platysmal bands; cervical laxity; cervical rhytids

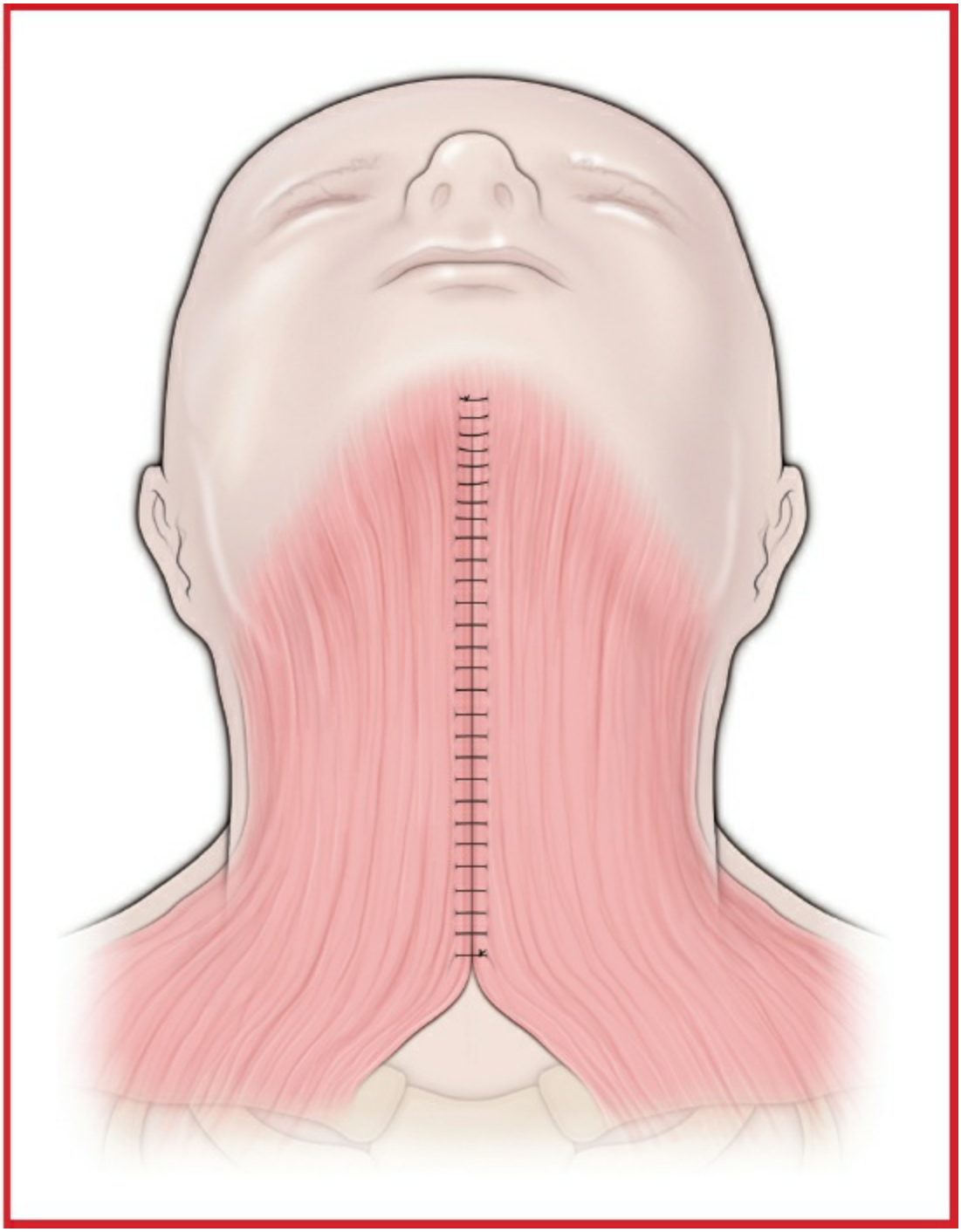

Figure 11.1-4 Platysmaplasty.

ERAS: **Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, preop carb loading, and postop pain management options.** **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

SUMMARY OF PROCEDURES

	Facelift	Neck Lift	Midface Lift
Position	Supine, reverse Trendelenburg	⇐	⇐
Incision	Preauricular, scalp	Postauricular extension of facelift incision + submental incision	Intraoral ± subciliary or inferior lid
Special instrumentation	Infiltration equipment for tumescent techniques; endoscopic equipment (more frequent with brow lifts)	⇐ ± liposuction instrumentation	—
Unique considerations	Oral intubation; ability to move ETT side to side. Consider securing ETT with floss or suture around teeth. Watch for oculocardiac reflex (OCR), retrobulbar hematoma with periorbital approaches.	⇐	⇐
	If laser is used: • Special fire-retardant ETT and	⇐	⇐

	drapes • Laser eye protection for all in room • Cannula-administered O_2 should be far away from laser (fire safety). • Smoke evacuation system (See Facial Laser Resurfacing). Infiltration of large volumes of local anesthetic with epinephrine in facelift and liposuction procedures		
Antibiotics + other meds	Cefazolin 2 g iv (± methylprednisolone 125 mg iv). Antivirals periop if laser used (e.g., acyclovir 2400 mg × 2 d preop and 14 d postop)	⇐	⇐
Surgical time	4–6 h	1–2 h	2–4 h
Closing considerations	Trendelenburg for final hemostasis ± drains	—	—
	Some surgeons prefer gentle ↑ in BP during hemostasis.	⇐	⇐
	Tissue thrombin	⇐	—

	agents may be used between the elevated flaps.		
	Sensory nerve blocks by surgeon	⇐	⇐
	± Full head/face wrap before patient awakens	—	—
	Gentle, nonagitated awakening to prevent sudden ↑ BP		
EBL	<50 mL	⇐	⇐
Postop care	Monitor for hematoma: most common complaint is pain; therefore, r/o hematoma before increased analgesia or sedation.	⇐	⇐
	Lightly compressive dressing, ± drains: both removed at 24 h	⇐	⇐
	2–4 wk no aspirin, moderate activity	⇐	⇐
Mortality	Rare	⇐	⇐
Morbidity	Early hematoma: • Large expanding: 1–15% (return to OR) • Small (<30 mL): 10–15% (± aspiration in office)	⇐	Very rare
	Late hematoma	⇐	—

(average = 9 d postop; 2° to exertion or aspirin use; from superficial temporal vessels)		
Infection: 0–0.33%	⇐	⇐
Nerve injury:		
• Motor (temporal/marginal mandibular branches)		Very rare
• Temporary: 0.1–2.6%	⇐	
• Permanent: 0–0.66%	⇐	
• Motor (spinal accessory nerve): Rare	⇐	—
Sensory injury:		—
• Great auricular nerve → ↓ sensation in lower ½ of ear ± painful neuromas or paresthesias		
• Lesser occipital nerve painful → neuroma	⇐	—
Alopecia: 0.4% (most temporary, along the incision)	⇐	—
Skin slough: 14% (especially in retroauricular area) (12.5 × greater in smokers)		—

	Dehiscence: 0.1–0.35% Parotid cysts: Rare Poor cosmetic result: • Hyperpigmentation • Telangiectasia (preexisting lesions may worsen) • Hypertrophic scarring • Keloids: Very rare • "Pixie" (pulled-down earlobe) deformity (technique dependent) • Hairline shifts Ectropion (midface, approached via lid incisions only): Up to 3%	⇐ ⇐ ⇐	⇐ — ⇐
Pain score	3	3	3

PATIENT POPULATION CHARACTERISTICS

Age range	>35 yr
Male:Female	1:9 to 1:5 (increased from 1:17 in the 1970s)
Incidence	131,106 facelift procedures in the United States (2016); 5th most common cosmetic plastic surgery procedure 55,227 neck lift procedures in the United States (2016); 10th most common cosmetic plastic surgery procedure
Etiology	Facial rhytids 2° solar elastosis, senile elastosis, facial expression

Associated conditions	Cancers of the skin (basal cell carcinoma, squamous cell carcinoma and precursors, and melanoma), in solar elastosis cases, especially fair-skinned patients

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Brow Lift and Blepharoplasty.

Suggested Readings

1. American Society of Plastic Surgeons: Website: www.plasticsurgery.org
2. American Society of Plastic Surgeons: Website: www.plasticsurgery.org/news/plastic-surgery-statistics
3. Bloom JD, Immerman SB, Rosenberg DB: Face-lift complicationsFacial Plast Surg 2012; 28(3):260–72.
4. Chuang J, Barnes C, Wong BJF: Overview of facial plastic surgery and current developments. Surg J (N Y) 2016; 2(1):e17–28.
5. Derby BM, Codner MA: Evidence-based medicine: face lift.Plast Reconstr Surg 2017; 139(1):151e–67e.
6. Marcus BC: Rhytidectomy: current concepts, controversies, and the state of the art Curr Opin Otolaryngol Head Neck Surg 2012; 20(4):262–6.
7. Ramanadham SR, Costa CR, Narasimhan K, et al: Refining the anesthesi management of the face-lift patient: lessons learned from 1089 consecutive face lifts. Plast Reconstr Surg 2015; 135(3):723–30.
8. Rasko YM, Beale E, Rohrich RJ: Secondary rhytidectomy: comprehensive review and current concepts. Plast Reconstr Surg 2012; 20(4):262–6.
9. Warren RJ, Aston SJ, Mendelson BC: Facelift. Plastic Reconstr Surg 2001; 128:747–64.

BROW LIFT AND BLEPHAROPLASTY

SURGICAL CONSIDERATIONS

BROW LIFT (OR FOREHEAD LIFT)

Description

Brow lift is the elevation of the eyebrows that softens forehead rhytids and redrapes the skin that can hood over the lateral orbit to restore the youthful appearance of the upper face. This procedure is often performed in conjunction with an upper lid blepharoplasty. Patients presenting for brow lift usually have specific concerns about lateral brow hooding, forehead wrinkles, and a glabellar creases that give them an angry appearance.

Like facelift procedures, brow lifts have been performed in the subcutaneous plane, but the relatively avascular subgaleal and subperiosteal planes are more commonly used. The subgaleal and subperiosteal approaches have become more popular with the incorporation of **endoscopic techniques**. A coronal incision is used for an open brow lift. A more limited lateral temporal brow lift uses only a portion of this incision for each side. For an endoscopic technique, three to five small, interrupted access incisions are made along the hairline or within the hair-bearing scalp (Fig. 11.1-5).

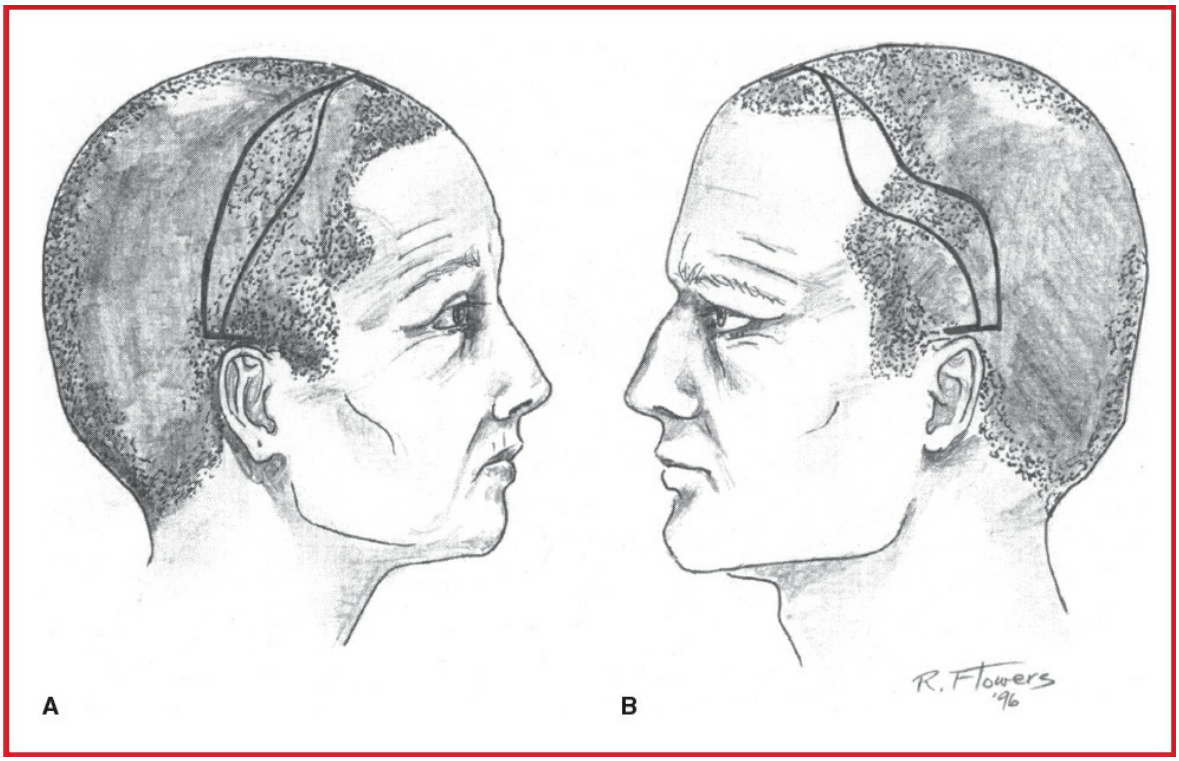

Figure 11.1-5 Incisions for forehead/brow lifting. Consistent blepharoplasty results demand appropriate frontal lifting technique. **A:** Standard coronal incision. **B:** Male and female balding incision. Note the posterior displacement of the ascending incision for maximum camouflage. Hair perimeter incisions are rarely necessary. The central brow corrects nicely from only parietotemporal scalp excisions (after appropriate supraperiosteal release). (Reproduced with permission from Flowers RS, DuVal C: Blepharoplasty and periorbital aesthetic surgery. In: Aston SJ, Beasley RW, Thorne CHM, eds.Grabb & Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

In the open technique, the bicoronal flap is dissected off the upper face (Fig. 11.1-6). The brows are elevated by **scalp resuspension** ± **resection**. Closure of the scalp anchors this resuspended position. The soft tissues may also be fixated directly to the cranium with screws, resorbable fixation devices, or sutures to the temporal fascia to maintain their new positions. Release of the periosteum along the superior orbital rims is a prerequisite to adequate resuspension when using a subperiosteal approach. Elimination of the upper facial rhytids (i.e., glabellar wrinkles) is achieved by resection of the medial brow musculature (corrugator and procerus) from beneath the elevated

flap. Muscular bleeding is controlled with bipolar electrocautery.

Variant procedures or approaches

The brow lift has become the facial plastic surgery procedure most adaptable to the techniques of **endoscopy**. Multiple smaller (1–1.5 inches) incisions are used within the scalp for access, and small, elliptical excisions also may be used to achieve the desired effect. The muscle resection is accomplished endoscopically with very small biting forceps from beneath the flap. See Figure 11.1-7.

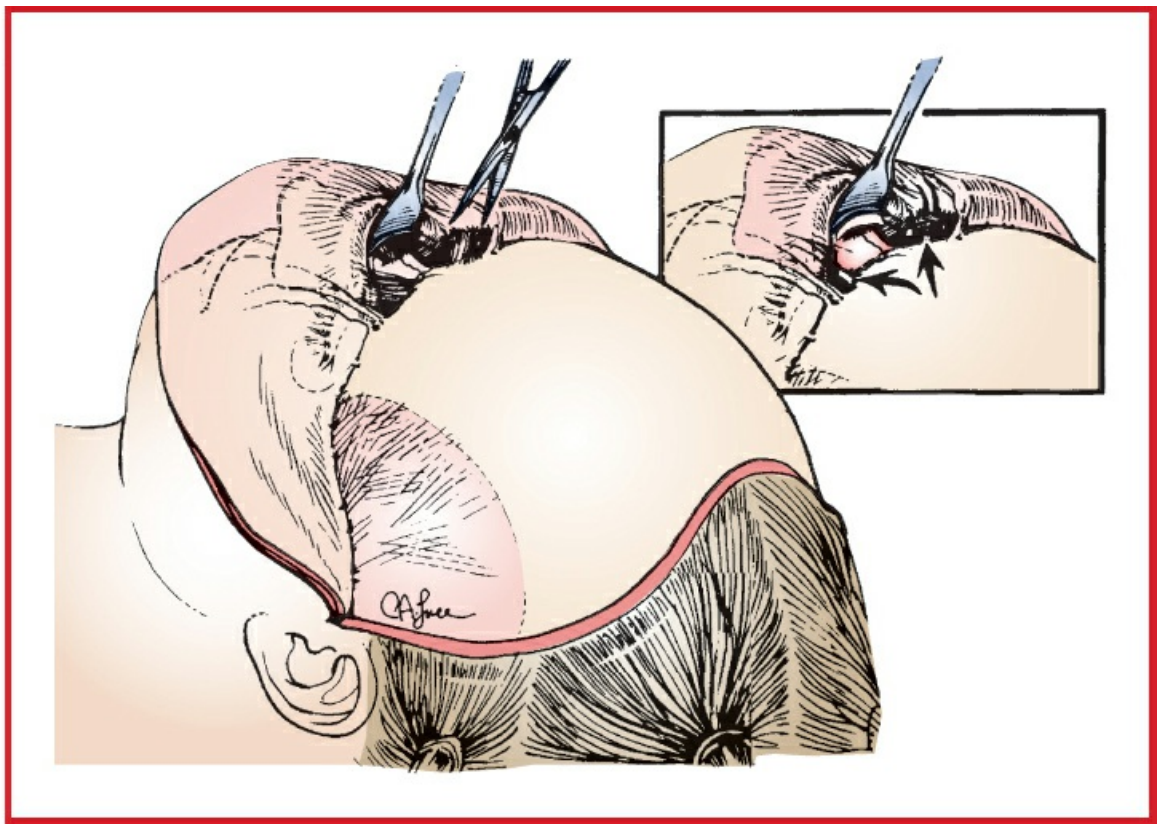

Figure 11.1-6 Exposure after subgaleal, supraperiosteal dissection of the forehead. The supraorbital nerves can be seen easily, but the supratrochlear nerves are more superficial and are hidden by the corrugator muscles. Scissors are used to tease through the corrugator muscles to locate the supratrochlear nerve branches. The muscle is then aggressively resected, preserving the sensory branches. (Reproduced with permission from Thorne CHM, Aston SJ: Aesthetic surgery of the aging face. In: Aston SJ, Beasley RW, Thorne CHM, eds.Grabb & Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

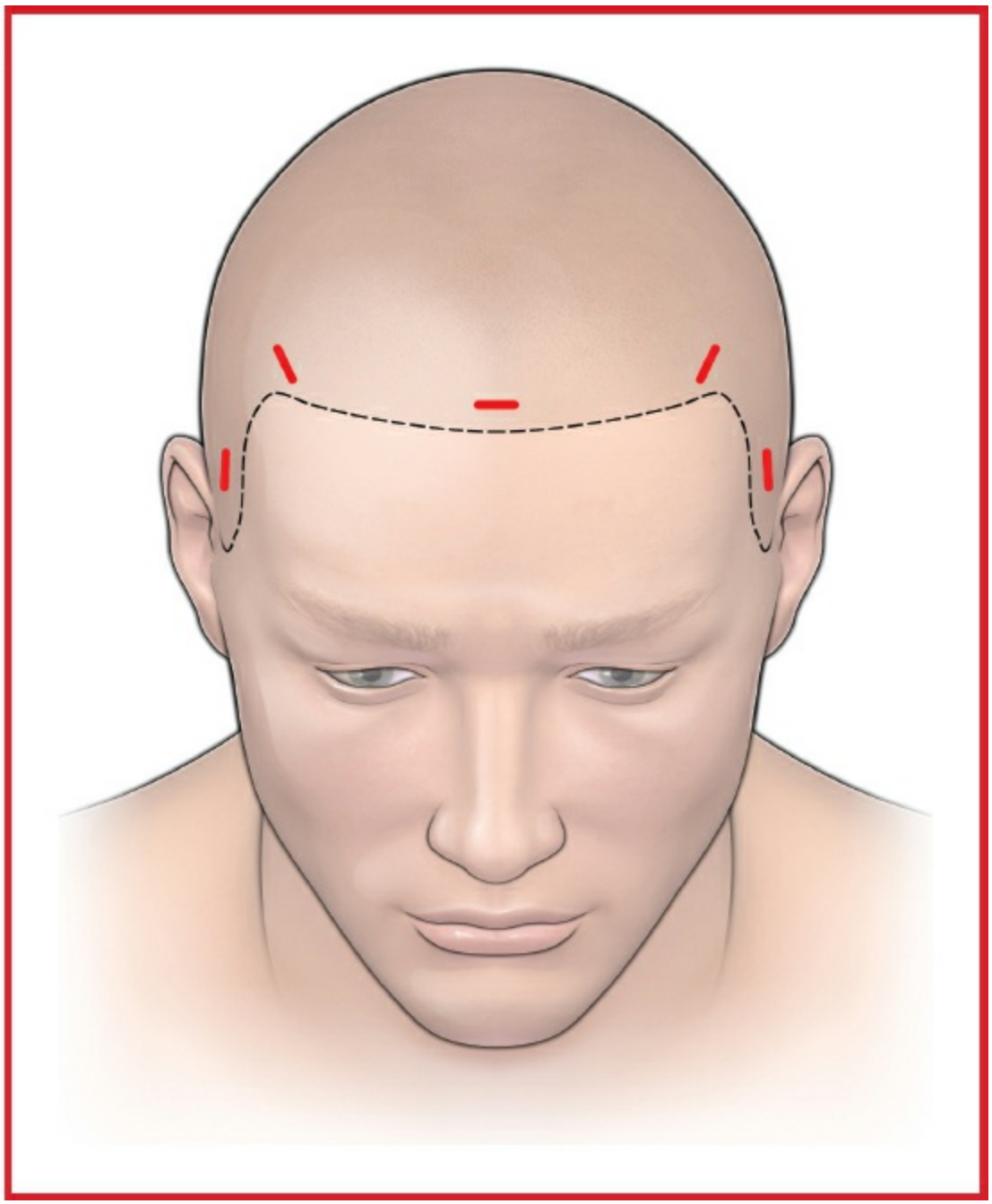

Figure 11.1-7 Typical endoscopic portals for facelift.

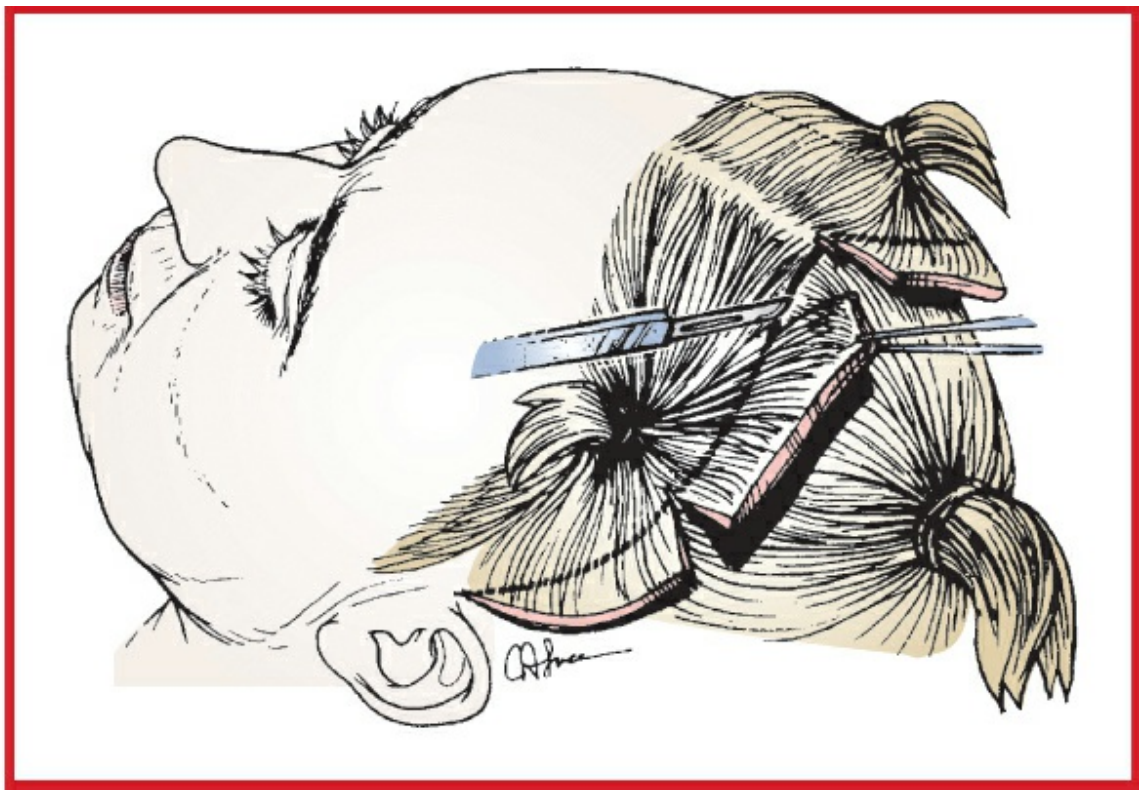

Figure 11.1-8 Redraping the forehead/brow using "key" fixation sutures. Maximal tension is placed laterally to elevate the lateral brow to a greater extent than the medial brow. (Reproduced with permission from Thorne CHM, Aston SJ: Aesthetic surgery of the aging face. In: Aston SJ, Beasley RW, Thorne CHM, eds. Grabb & Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

Usual preop diagnosis

Brow ptosis; brow droop; upper facial rhytids (wrinkles or creases)

BLEPHAROPLASTY (OR LID LIFT)

Description

Blepharoplasty (Fig. 11.1-9) is the surgical rejuvenation of the periorbital region to eliminate the tired and aged appearance of the eyes. Westernizing the Asian eyelid also has become quite commonplace. Presenting complaints include excess lid skin, prominent periorbital fat, and absence of upper lid folds. Blepharoplasty can involve resection of skin, muscle (orbicularis oculi), and fat. Patients presenting for this procedure may also benefit from a simultaneous brow lift to reestablish the baseline position of the brows, revealing the true amount of upper-lid redundancy. Eyelid ptosis repair also can be achieved in the same surgery.

Although a seemingly benign procedure, the manipulation of periorbital fat can have very serious consequences. Retrobulbar hematoma and blindness can occur postop, and

the oculocardiac reflex (OCR) can complicate the intraop course with bradycardia and hypotension. This generally resolves with elimination of the stimulus.

Blepharoplasty, as an isolated procedure, is often performed with local anesthetic and intravenous sedation so that patients can open and close their eyes during the surgery. This helps to tailor the amount of eyelid skin to be removed without tension thus limiting the risk of lagophthalmos (inability to close the eyelids) and scleral show. Having the patient able to respond to commands can be useful if a ptosis repair is also planned.

Variant procedures or approaches

Once more, popular CO_2 **laser blepharoplasty** techniques have proven effective but must be done under the safety parameters of eye protection and fire and burn prevention. With this technique, the fat and skin resections are achieved with a laser, replacing the use of a scalpel. Using the laser to gain some of the skin tightening associated with blepharoplasty has also been described.

Usual preop diagnosis

Blepharochalasis; periorbital fat; blepharoptosis; dermatochalasis; supratarsal fold absence; Asian eyelid

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, preop carb loading, and postop pain management options. See Appendix K, p. K-1.

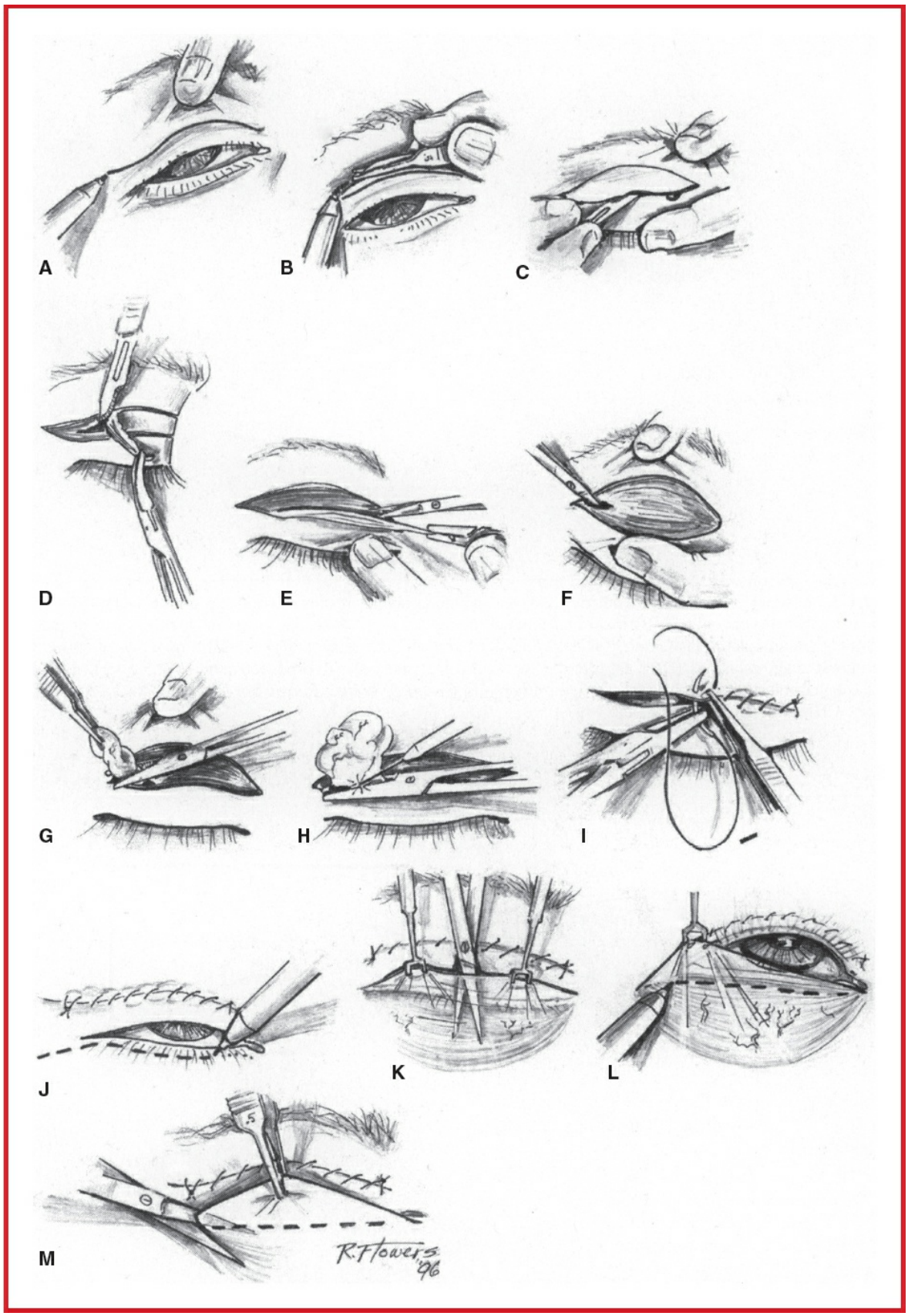

Figure 11.1-9 Traditional blepharoplasty technique. **A:** The caudal margin of the excision is marked and the upper eyelid skin is pinched **(B)**. Skin and muscle are excised **(C, D, E)**; excess or herniated fat is removed from medial and lateral compartments **(F, G, H)**; and the wound is closed **(I)**; on the lower lid, the traditional approach is flap elevation, consisting of skin or skin with attached muscle **(J, K)**. The

skin is draped upward and outward so the surgeon can assess and remove excess skin **(L, M)**. (Reproduced with permission from Flowers RS, DuVal C: Blepharoplasty and periorbital aesthetic surgery. In: Aston SJ, Beasley RW, Thorne CHM, eds.Grabb & Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

SUMMARY OF PROCEDURES

	Brow Lift	Blepharoplasty
Position	Supine; table rotated 90° or 180°	⇐
Incision	Hairline, coronal; multiple scalp for endoscopic procedure	Upper, tarsal fold; lower, subciliary, transconjunctival
Special instrumentation	Fibrin glue, screws, or resorbable fixation devices for suspension; endoscopic equipment	Bipolar electrocautery
Unique considerations	Local anesthetic with epinephrine	Retrobulbar hematoma; OCR; local anesthetic with epinephrine
Antibiotics	Cefazolin 2 g iv ± methylprednisolone 125 mg iv	⇐
Surgical time	1–2 h	⇐
Closing considerations	Place dressing before arousing patient. Gentle arousal from anesthesia (↑ in BP or emesis → risk of hematoma)	No dressing (ointment)
EBL	50 mL	Minimal
Postop care	PACU → room/home Lightly compressive dressing Head of bed elevated	⇐ Cool packs ⇐ Ophthalmic lubricant

		Vision checks
Mortality	Rare	⇐
Morbidity	Hematoma: Rare	⇐
	Alopecia: Rare (more common with bicoronal approach)	—
	Infection: <1%	⇐
	Frontalis paralysis: Rare (usually transient)	—
	Poor cosmetic result	⇐
	Sensory nerve dysfunction	⇐
	Lagophthalmos	⇐
		Blindness: Extremely rare
		Ectropion
		Entropion
Pain score	3	2–3

PATIENT POPULATION CHARACTERISTICS	
Age range	Most ≥35 yr
Male:Female	Blepharoplasties: 1:4 Brow lifts: 1:7.33
Incidence	Blepharoplasties: 209,020 (4th most common cosmetic procedure in the United States, 2016) Brow lifts: 43,038 (11th most common cosmetic procedure in the United States, 2016)
Etiology	Facial rhytids secondary to solar elastosis, senile elastosis, facial expression, and increased muscle resting tone; Asian eyelids
Associated conditions	Cancers of the skin (basal cell carcinoma, squamous cell carcinoma and precursors, and melanoma) in solar elastosis cases, especially fair-skinned patients

Suggested Readings

1. American Society of Plastic Surgeons: Website: www.plasticsurgery.org
2. Angelos PC, Stallworth CL, Wang TD: Forehead lifting: state of the art.Facial Plast

Surg 2011; 27(1):50–7.
3. Mack WP: Blepharoplasty complications. Facial Plast Surg 2012; 28(3):273–87.
4. Matarasso A: The oculocardiac reflex in blepharoplasty surgery. Plast Reconstr Surg 1989; 83(2):243–50.
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6. Yang P, Ko AC, Kikkawa DO, et al: Upper eyelid blepharoplasty: evaluation treatment, and complication minimization. Semin Plast Surg 2017; 31(1):51–7.

ANESTHETIC CONSIDERATIONS

(Procedures covered: facelift, neck lift; brow lift, blepharoplasty)

PREOPERATIVE

Cosmetic facial surgery is elective and should be performed preferably on ASA I or I patients. Often, several cosmetic procedures (including facial laser resurfacing) are performed during the same surgical session. A preop discussion with the surgical team is important to help define the anesthetic plan. The above procedures are usually done under GA in the hospital but can also be done under MAC with local anesthesia.

Airway	A careful inspection of the airway should be performed. Surgeon may request intraop manipulation of the oral ETT from side to side or may prefer a nasal ETT.
Cardiovascular	A thorough cardiovascular evaluation should be performed. HTN is the most common medical condition in this patient population. Many procedures involve the use of significant amounts of local anesthetic with epinephrine, placing the patient at higher risk for iatrogenic HTN, dysrhythmias, and coronary artery spasm. In addition, consider patient suitability for the use of mild controlled ↓ BP (particularly the facelift patient). **Tests:** ECG, if indicated from H&P
Hematologic	✓ for recent aspirin/NSAID use and h/o easy bleeding, bruising, frequent epistaxis, etc. If possible, stop aspirin 1 wk before surgery. **Tests:** CBC, if indicated from H&P

Laboratory	Other tests as indicated from H&P
Premedication	Preop sedation with midazolam usually is appropriate. Preop steroids (dexamethasone 4–8 mg) also may be used to reduce PONV and swelling.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss possibility of nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po. Consider aprepitant 40 mg po for patients with h/o PONV.

INTRAOPERATIVE

Anesthetic technique

Cases are usually done under GA, using an ETT or LMA, as appropriate. Several authors describe the use of a propofol/ketamine MAC or "dissociative anesthetic" in the office-based setting. There are varying descriptions of this technique, generally involving a propofol infusion with incremental ketamine boluses or infusion, resulting in elimination or significant reduction in the administration of iv opiates.

MAC with local anesthetic also is an option and may be advantageous for certain patients (e.g., with Hx of PONV) or for cases that benefit from a patient's intraop ability to follow commands (e.g., ptosis repair).

Induction	For those procedures done under GETA, a standard induction is appropriate. An oral RAE ETT may be used to minimize intrusion into the surgical field. For cases involving a laser, a shielded ETT manufactured for laser surgery should be used. (Note: No shielded ETT is 100% laser proof; always use standard precautions.)
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia (Goal-Directed Management) and normothermia. Consider preincision placement of nerve blocks (see Appendix K, p. K-6).

Maintenance	Standard maintenance with volatile anesthetic ± propofol infusion is appropriate in most cases. Muscle relaxation should be avoided in cases with facial nerve monitoring. Mild, controlled ↓ BP may be requested and used to facilitate hemostasis. HTN should be avoided and treated immediately if it occurs. Maintain anesthesia during application of head/face wrap.	
Emergence	Antiemetic prophylaxis (e.g., ondansetron 4 mg iv + dexamethasone 4 mg iv if nondiabetic ± preop aprepitant 40 mg po) is recommended, as postop emesis greatly increases the likelihood of hematoma formation. Perform thorough oropharyngeal suctioning. A smooth emergence with no notable increase in BP is the goal. Consider nerve block placement.	
Blood and fluid requirements	Blood loss generally minimal IV: 18 ga × 1 BSS @ 1–3 mL/kg/h	Goal-Directed Fluid Management (see Appendix K, p. K-4)
Monitoring	Standard monitors	
Control of blood loss	Local infiltration with epinephrine Surgical hemostasis Mild degree of ↓ BP	
Positioning	✓ and pad pressure points. Rotate OR table 90–180°.	Scleral shields ± ophthalmic ointment
Complications	OCR Retrobulbar hematoma Local anesthetic toxicity	Remove inciting stimulus. Consider atropine 0.5 mg and deepening anesthetic. Rx: 20% lipid emulsion: 1.5 mL/kg iv bolus (may repeat × 2) + start infusion @ 0.5 mL/kg/min (max dose in 30 min = 12 mL/kg).

POSTOPERATIVE

Complications	PONV	Vigorous treatment of nausea is important.
Multimodal pain management	Local infiltration + iv/po narcotics, if needed Acetaminophen	R/O expanding hematoma as cause of increasing pain. Consider regional or local blocks.
ERAS	PONV protocol	Encourage early enteral nutrition and early mobilization.

Suggested Readings

1. Bogan V: Anesthesia and safety considerations for office-based cosmetic surgery practice. AANA J 2012; 80(4):299–305.
2. Mustoe TA, Buck DW II, Lalonde DH: The safe management of anesthesia, sedation and pain in plastic surgery. Plast Reconstr Surg 2010; 126(4):165e–76e.
3. Nekhendzy V, Ramaiah VK: Prevention of perioperative and anesthesia-related complications in facial cosmetic surgery. Facial Plast Surg Clin North Am 2013; 21(4):559–77.
4. Ramanadham SR, Costa CR, Narasimhan K, et al: Refining the anesthesi management of the face-lift patient: lessons learned from 1089 consecutive face lifts. Plast Reconstr Surg 2015; 135(3):723–30.

RHINOPLASTY

SURGICAL CONSIDERATIONS

Description

Rhinoplasty is one of the greatest challenges of plastic surgery. It is the surgical manipulation of the nasal form for either aesthetic or functional improvement. In combination with nasal septal surgery, it is called **septorhinoplasty.** Common patient requests are for dorsal hump reduction and improved tip definition. Cosmetic surgery of the nose can address four major components: **the tip, the dorsum, the width (either of bones or alae), and the septum,** in addition to other ancillary procedures to enhance airway function.

Tip and **dorsal procedures** may be accomplished by either **reduction** or **augmentation.** Augmentation can be performed with either synthetic or biologic grafts. Examples of synthetic grafts include silicone, expanded fibrillated polytetrafluoroethylene polymer (Gore-Tex), porous polyethylene implants (Medpor™), and hydroxyapatite. Examples of biologic grafts include cadaveric or autologous tissue (cartilage, bone, fascia, or dermis). Common donor sites for cartilage are the ear concha (via an anterior or posterior approach), the nasal septum (internal nasal approach), and the ribs. Bone harvest sites may include the outer table of cranium, the iliac crest, and the ribs. Dermal graft is commonly harvested from the groin, and fascial graft harvest is often taken from the temporoparietal region. (Table 11.1-1 shows the range of open and closed rhinoplasty techniques.) Add positive pressure to avoid PTX.

A throat pack is useful to prevent aspiration or ingestion of blood, as significant blood pooling can occur in the naso/oropharynx area, especially with nasal osteotomies used to narrow or straighten the nasal dorsum. Cases where such pooling is expected are safer under GA with a throat pack. Often, rhinoplasties are done with local or regional (nasociliary and infraorbital blocks) anesthesia with sedation. Vasoconstriction may be performed by the administration of oxymetazoline in the preop holding area or in the OR with soaked nasal packs (cocaine vs. epinephrine vs. oxymetazoline) placed before the first incision.

The decision of open versus closed technique is based on patient requirements and surgeon preference. An **open approach** will utilize a transcolumellar incision to allow elevation of a nasal skin flap and degloving of the lower alar cartilages for direct and wide exposure of the nasal framework (see Fig. 11.1-10) . **Closed approaches** use intercartilaginous, intracartilaginous, infracartilaginous, rim, hemitransfixion, and transfixion incisions (all hidden within the nose).

Table 11.1-1 Rhinoplasty Techniques

Open	Closed/Open	Closed
Incisions/skin flap elevation ↓ Tip analysis/cephalic crura excision ↓ Extramucosal	Intercartilaginous/transfixion incisions ↓ Skin elevation/extramucosal tunnels ↓ Rasp bony hump/excise cartilaginous hump	Transcartilaginous/trar incision ↓ Skin elevation/extramu tunnels ↓ Rasp bony hump/ex cartilage hump

tunnels ↓ Dorsal modification ↓ Caudal septum/anterior nasal spine ↓ Septoplasty/harvest ↓ Osteotomies ↓ Graft preparation ↓ Definitive dorsum/spreader grafts ↓ Tip: Columella strut/tip sutures ↓ Closure ↓ Alar base modification ↓ Dressing/postop management	↓ Radix reduction ↓ Check profile line/septal angle ↓ Caudal septum/anterior nasal spine ↓ Infracartilaginous/transcolumellar incisions ↓ Tip exposure and analysis ↓ Septal correction/harvest ↓ Osteotomies ↓ Definitive dorsum/spreader grafts ↓ Tip/columellar modification (excision/sutures/grafts) ↓ Closure ↓ Alar base modification ↓ Dressing	↓ Radix reduction ↓ Check profile line/septa ↓ Caudal septum/anterio spine ↓ Septoplasty/harve ↓ Infracartilaginous inci ↓ Alar cartilage deliv ↓ Excision/incision/sut ↓ Osteotomies ↓ Grafts (spreader/dorsum/colun ↓ Closure ↓ Alar base modificat ↓ Dressing

Note: Only those steps appropriate for the individual case are performed.

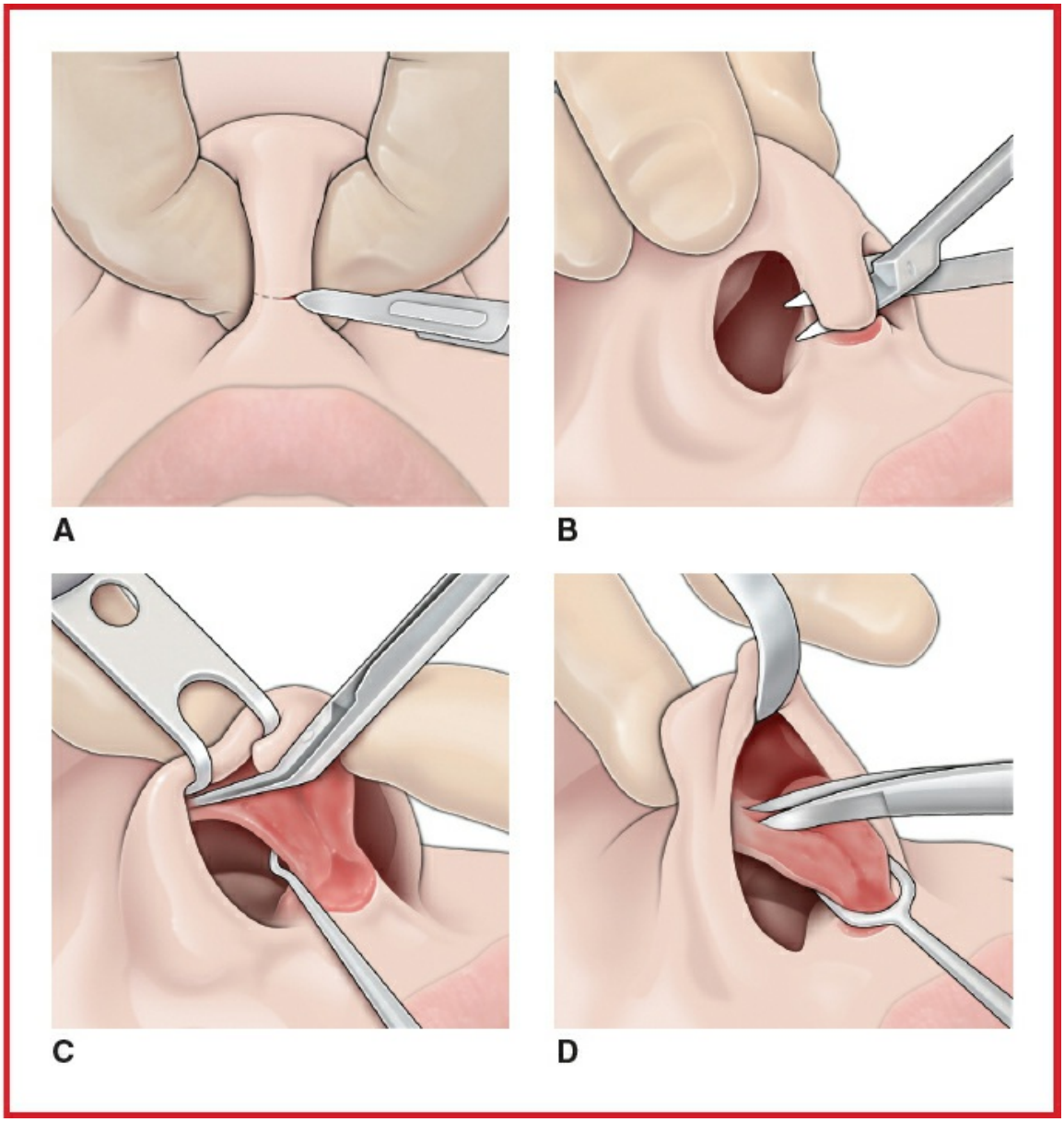

Figure 11.1-10 Initial steps for an open rhinoplasty producing a wide exposure of the nasal framework.

A typical **closed rhinoplasty** (Fig. 11.1-11) begins with dorsal work through intercartilaginous incisions. The dorsum may be reduced using a scalpel and/or rasps beneath the undermined dorsal skin and periosteum. The septum is addressed as necessary through a hemitransfixion incision (±cartilage harvest). Tip reduction by scalpel or scissor resection of the lower alar cartilage ± tip suture is next. Nasal osteotomies with an osteotome and mallet begin at the base of the nasal bones along the piriform aperture. Access points for the osteotomies can be intranasally, externally, or through an intraoral vestibular incision. Digital manipulation completes the fractures, and this is when most of the blood loss occurs. Dorsal and tip grafts are applied as necessary, with alar modifications made last. **Alar reduction** entails wedge resection of the lateral alar base and primary closure.

Depending on the type of rhinoplasty performed, different dressings will be applied at the end of the procedure. When nasal bone osteotomies are used, the patient will require a dorsal nasal splint ± bilateral nasal packing. Nasal packing is generally removed at 24–72 h postoperatively. When septal manipulation is needed, nasal packing or some sort of septal splint may be placed. The packs are generally removed within 3 d, but the splints can be maintained much longer and the nasal airways kept patent with vasoconstrictor nasal sprays.

Variant procedures or approaches

Release of the tip depressor muscle is achieved via intraoral vestibular incisions (behind the upper lip).

Usual preop diagnosis

Posttraumatic nasal deformity (including disordered breathing, "saddle nose," crooked nose, septal deviation); developmental nasal deformities (bulbous tip, flat tip, drooping tip, broad dorsum, dorsal hump, alar widening, "Pinocchio nose"); congenital nasal malformation (cleft nasal deformities)

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, preop carb loading, VTE risl assessment, and postop pain management options. **See Appendix K, p. K-1.**

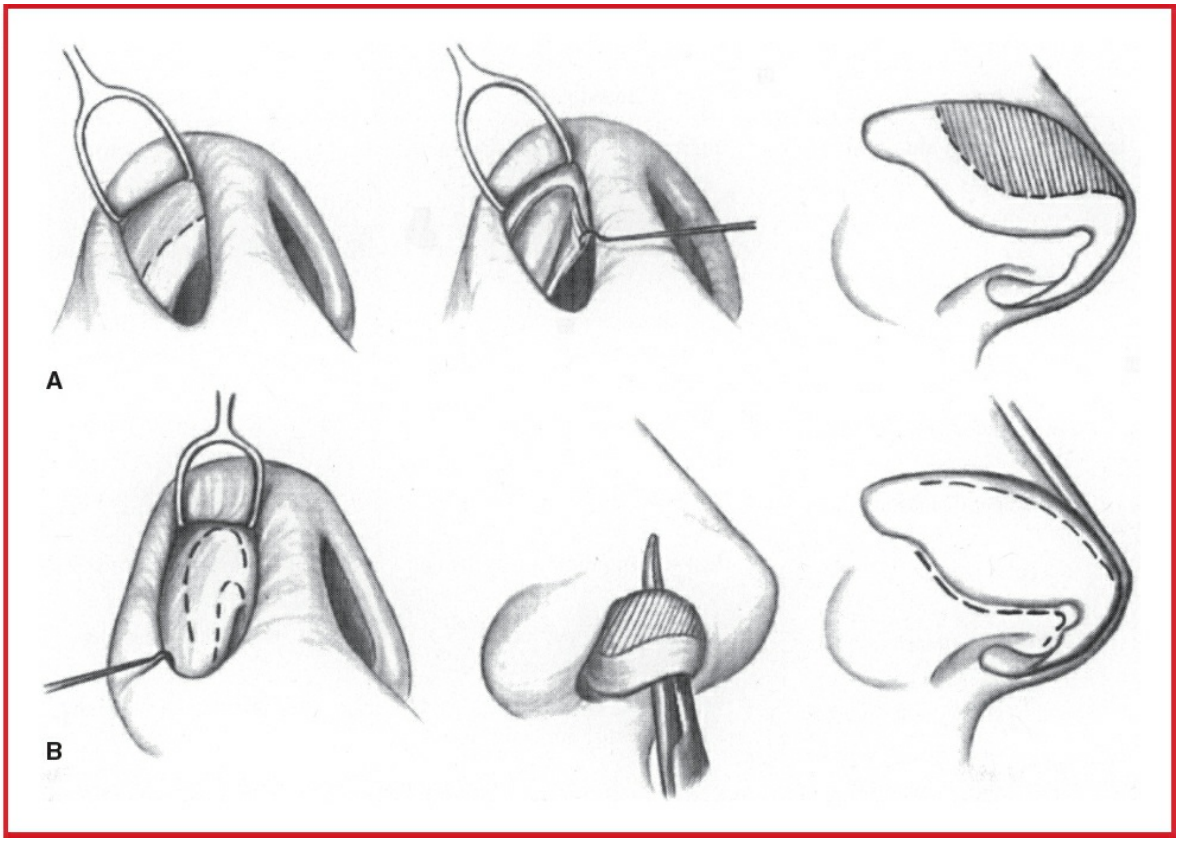

Figure 11.1-11 Closed rhinoplasty. **A:** Transcartilaginous approach using an intracartilaginous incision. **B:** Delivery approach, using a high intercartilaginous incision and a marginal incision to facilitate delivery of the lateral crura. (Reproduced with permission from Daniel RK: Rhinoplasty. In: Aston SJ, Beasley RW, Thorne CHM, eds. Grabb & Smith's Plastic Surgery. 5th edition. Lippincott-Raven, Philadelphia: 1997.)

SUMMARY OF PROCEDURE

Position	Supine, table may be rotated 180°. If GA: oral ETT toward foot of bed, shoulder roll, neck extended, scleral lubricant, shields
Incision	External vs. internal nasal incisions
Special instrumentation	Headlight
Unique considerations	Throat pack for expected nasopharyngeal bleeding. Intranasal vasoconstrictors
Antibiotics	Cefazolin 2 g iv
Surgical time	1–2.5 h
Closing considerations	Suction stomach via OG tube at the end of surgery. **Remove throat pack prior to extubation.** Internal and/or external nasal splints are placed for dressings.
EBL	Tip rhinoplasty: 20 mL Dorsum with osteotomies: 75–150 mL Septoplasty: +50 mL
Postop care	PACU → room (most patients are home the same day). Ensure minimal PONV; elevate head of bed; no pressure on nose (e.g., O_2 mask).
Mortality	Rare
Morbidity	Infection: >1% Adverse cosmetic result: Alar notching Alar collapse Dorsal irregularity Asymmetry Tip droop

	Adverse functional result (i.e., poor airway) Septal perforation
Pain score	3 (4 with osteotomies)

PATIENT POPULATION CHARACTERISTICS	
Age range	Most ≥ 15 yr
Male:Female	1:1.7
Incidence	223,018 (third most common cosmetic procedure in the United States, 2016)
Etiology	Developmental; acquired (posttraumatic); congenital (see Secondary Cleft Lip and Nasal Surgery)
Associated conditions	Breathing difficulties; psychosocial issues (body dysmorphic disorder)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Nasal and Sinus Surgery.

Suggested Readings

1. American Society of Plastic Surgeons: Website: www.plasticsurgery.org
2. Angelos PC, Been MJ, Toriumi DM: Contemporary review of rhinoplasty.Arch Facial Plast Surg 2012; 14(4):238–47.
3. Cannon DE, Rhee JS: Evidence-based practice: functional rhinoplasty.Otolaryngol Clin North Am 2012; 45(5):1033–43.
4. Cuzalina A, Qaqish C: Revision rhinoplasty. Oral Maxillofac Surg Clin North An 2012; 24(1):119–30.
5. Friedman O, Cekic E, Gunel C. Functional rhinoplasty.Facial Plast Surg Clin North Am 2017; 25(2):195–9.
6. Stevens MR, Emam HA: Applied surgical anatomy of the nose.Oral Maxillofac Surg Clin North Am 2012; 24(1):25–38.
7. Tanna N, Nguyen KT, Ghavami A, et al: Evidence-based medicine: current practices in rhinoplasty. Plast Reconstr Surg 2018; 141(1):137e–51e.

OTOPLASTY

See Chapter 12.8, Surgery for Craniofacial Malformations, Otoplasty.

FACIAL LASER RESURFACING

Description

Laser resurfacing is a technique by which a controlled burn is administered to the skin of the face with laser technology, creating a healing process that reduces the signs of aging or acne. **Various wavelengths of lasers are** commonly used with facial cosmetic procedures including CO_2 (λ = 10.6 μm: mid-infrared), erbium (λ = 2.94 μm: mid-infrared), and Nd:YAG (λ = 1.064 μm: near-infrared). Longer wavelength = deeper tissue penetration. These lasers are used widely for the periorbital and perioral creases and wrinkles not addressed by previously described facial cosmetic surgical techniques. Nerve blocks, local anesthesia, intravenous sedation, and GA are all possibilities for laser treatment. The choice of anesthetic depends more on the specific surgical procedures to be performed first, as the laser procedure is usually adjunctive and added at the end. Facial laser resurfacing is done frequently in an office-based setting (see Chapter 14.0, Office-Based Procedures). Because laser resurfacing is usually an adjunct to another facial cosmetic procedure, the following discussion pertains primarily to the unique set of **safety issues** that must be addressed in the OR.

Ocular Hazards

These include direct and reflected injury to the eye. Everyone present, including the patient and all medical personnel, requires laser-specific (i.e., wavelength-specific) safety eyewear. Laser-specific scleral shields must be available for the patient in cases where the patient's eyewear would be in the operative field. Protective eyewear must be undamaged and have

- Permanent labels with wavelength and optical density tolerance
- Side shields
- Damage threshold of >10 sec
- No surface reflection
- Good fit
- Approval from the laser safety officer

Fire and reflectivity hazards

Many items used in the OR (e.g., drapes, sponges, plastic cannulas) are made of materials that can be fire hazards if not kept from interacting with the laser beam. Protection from fire and reflectivity is provided by:

- Having fire-retardant or moist draping
- Having water basin available

- Having a fire extinguisher readily available
- Avoiding all alcohol-containing prep solutions
- Avoiding use of plastic and rubber instruments (may melt or ignite)
- Using special fire-resistant ETTs or wet sponge protection for plastic ETTs to decrease the possibility of tube breach or ignition
- Avoiding open sources of O_2 (nasal cannulas, etc.) or reducing the amount of O_2 delivered temporarily
- Avoiding metal or other reflective materials

Airborne contaminants

The laser destruction of cells releases carbon particles, microbials, DNA, and toxic fumes. Protection for the patient and medical personnel is provided by:

- Utilizing a smoke evacuation system 2 cm from created plume.
- Wearing high-filtration (e.g., N95) masks. Note that these masks become less effective if moistened from perspiration during a long case; if the laser is to be used at the end of a case, changing masks before using the laser may be prudent.

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Brow Lift and Blepharoplasty or Office Based Laser Skin Resurfacing.

Suggested Readings

1. Carniol PJ, Hamilton MM, Carniol ET: Current status of fractional laser resurfacing JAMA Facial Plast Surg 2015; 17(5):360–6.
2. Cillo JE Jr, Finn R: Moderate intravenous sedation for office-based full face laser resurfacing using a continuous infusion propofol pump. J Oral Maxillofac Surg2005; 36(7):903–7.
3. Hamilton M, Campbell A, Holcomb JD: Contemporary laser and light-based rejuvenation techniques. Facial Plast Surg Clin North Am 2018; 26(2):113–21.
4. Potter JK, Finn R, Cillo J: Modified tumescent technique for outpatient facial laser resurfacing. J Oral Maxillofac Surg 2004; 62(7):829–33.
5. Ramos-Zabala A, Pérez-Mencía MT, Fernández-García R, et al: Anesthesia technique for outpatient facial later resurfacing. Lasers Surg Med 2004; 34(3):269–72.
6. Wald D, Michelow BJ, Guyuron B: Fire hazards and CO_2 laser resurfacing. Plast Reconstr Surg 1998; 101(1):185–8.

Suggested Viewing

Links are available online to the following videos:

Live Surgery Split Thickness Skin Graft: https://www.youtube.com/watch?v=pvbxmm9inoo

Liposuction Surgery Video: https://www.youtube.com/watch?v=nfRsBijqS4E

BSSO & Osseous Genioplasty: https://www.youtube.com/watch?v=oQI8L5Sxa6w

LeFort III Osteotomy: https://www.youtube.com/watch?v=Hk_AUbVuDWE

LeFort II Osteotomy: https://www.youtube.com/watch?v=5YddYjhThgw

LeFort I Osteotomy: https://www.youtube.com/watch?v=7z5TNrJcE3U

TRAM flap narrated: https://www.youtube.com/watch?v=xcew3ycbG50

CHAPTER 11.2

Nonfacial Aesthetic Surgery

SURGEON
David M. Kahn, MD

ANESTHESIOLOGISTS
Richard A. Jaffe, MD, PhD
Vanila M. Singh, MD

We gratefully acknowledge the past contributions of surgeon, George W. Commons, MD.

AUGMENTATION MAMMOPLASTY

SURGICAL CONSIDERATIONS

Description

Augmentation mammoplasty is accomplished through the use of saline or silicone gel–filled breast implants and more recently using autologous fat grafting. The surgery may be performed under GA or local anesthesia with sedation. The patient is positioned with the arms either abducted at 90°, with the hands tucked at the sides, or draped across the lower abdomen. Local anesthetic (±epinephrine) is infiltrated into the skin at the incision site and under the glandular tissue. Implant insertion can be done through inframammary, periareolar, transaxillary, or transumbilical incisions. The implant is placed in a pocket that is created beneath the mammary gland (subglandular), beneath the pectoralis fascia (subfascial), under the pectoralis muscle (submuscular), or in a dual plane partially subglandular and partially submuscular (dual plane), depending on the surgeon's preference and the thickness of the soft tissue coverage available. An endoscope may be used to assist with dissection of the pocket. When the implant is

placed in the dual plane position, the pectoralis muscle is divided from its insertion along the inframammary fold up to the sternal insertion to allow the muscle to drape over the implant. Regardless of the location of the pocket, the surgical wound is carefully irrigated and inspected for hemostasis. Sizers, either predetermined volumes of silicone gel or adjustable saline- or air-filled temporary implants, may be used to help determine the appropriate final volume and placement. The patient may be placed in the seated position to assess the size, shape, and symmetry of the breasts. The sizers are then replaced with the permanent prostheses. If permanent saline implants are used, they are filled with saline until the desired volume is reached; gel-filled implants do not have alterable volumes. The wounds are closed, and dressings are applied (Fig. 11.2-1).

Augmentation mammoplasty usually is performed as an outpatient procedure, although some patients may want an overnight stay for pain management and antiemetics. PONV is not uncommon, and all efforts should be made to decrease its frequency.

Variant procedure or approaches

The endoscopic transumbilical approach is used much less frequently. Autologous fat transfer is an evolving procedure, with graft survival depending on many factors including fat harvesting, processing, and injection techniques.

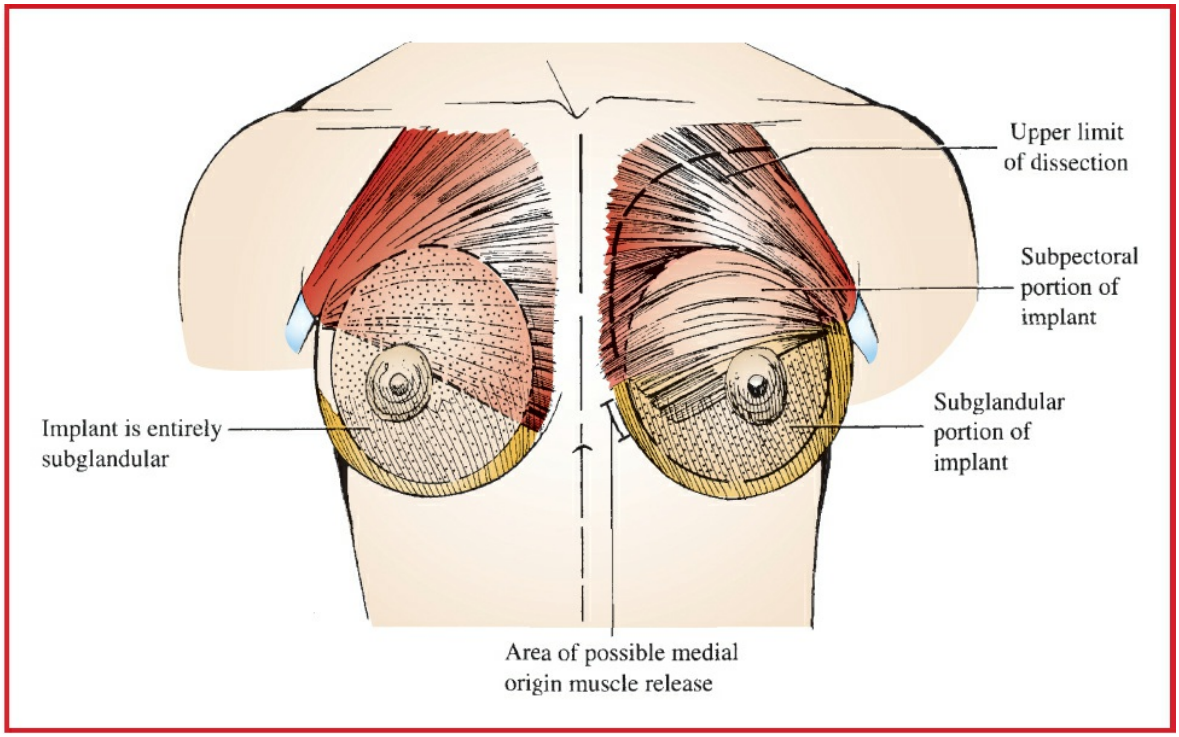

Figure 11.2-1 Breast augmentation. Implants may be placed in a subglandular or subpectoral position. (Reproduced with permission from Spear SL:Surgery of the Breast: Principles and Art Lippincott-Raven, Philadelphia: 1998.)

Preop diagnosis

Hypomastia; breast ptosis

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, preop carb loading, VTE risk assessment, and postop pain management options. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Inframammary, periareolar, transaxillary, or transumbilical
Antibiotics	Cefazolin 2 g iv
Unique considerations	May place patient in sitting position during procedure
Surgical time	1 h
Closing considerations	May need patient in sitting position for application of dressings
EBL	Minimal
Postop care	Outpatient procedure
Mortality	Rare
Morbidity	Prosthesis failure: 5% Capsular contracture: 5% Hematoma: 3% Infection: 2% Wound dehiscence: <1% Anaplastic large cell lymphoma (ALCL): <1% Cosmetic disappointments
Pain score	3–4

PATIENT POPULATION CHARACTERISTICS	
Age range	Typically 17–45 yr but also may be done on the contralateral breast in a patient undergoing breast

	reconstruction
Incidence	290,467 performed in the United States in 2016; the most common cosmetic surgical procedure
Etiology	Developmental; involution after breast-feeding; age-related atrophy or ptosis
Associated conditions	Not common but can be seen with Poland syndrome

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Mastopexy/Breast Lift.

Suggested Readings

1. Al Sufyani MA, Al Hargan AH, Al Shammari NA, et al: Autologous fat transfer fo breast augmentation: a review. Dermatol Surg 2016; 42(11):1235–42.
2. Coopey SB, Specht MC, Warren L, et al: Use of preoperative paravertebral bloc decreases length of stay in patients undergoing mastectomy plus immediate reconstruction. Ann Surg Oncol 2013; 20(4):1282–6.
3. Ducic I, Zakaria HM, Felder JM III, et al: Nerve injuries in aesthetic breast surger systematic review and treatment options. Aesthet Surg J 2014; 34(6):841–56.
4. Graf RM, Bernandes A, Rippel R, et al: Subfascial breast implant: a new procedure Plast Reconstr Surg 2003; 111(2):904–8.
5. Nahabedian MY, Patel K: Management of common and uncommon problems afte primary breast augmentation. Clin Plast Surg 2009; 36:127–38.
6. See Suggested Readings Mastopexy/Breast Lift.
7. Tan P, Martin MS, Shank N, et al: Comparison of 4 analgesic regimens for acut postoperative pain control in breast augmentation patients. Ann Plast Surg 2017; 78(6S Suppl 5):S299–304.
8. Tebbetts JB, Thorne CH: An evidence-based approach to augmentatio mammaplasty. Plast Reconstr Surg 2012; 126:2184.
9. Vyas KS, Rajendran S, Morrison SD, et al: Systematic review of liposoma bupivacaine (Exparel) for postoperative analgesia. Plast Reconstr Surg 2016; 138(4):748e–56e.

REDUCTION MAMMOPLASTY

SURGICAL CONSIDERATIONS

Description

Breast reduction surgery can be done as an outpatient procedure or with an overnight stay. One might choose to admit the patient overnight in a hospital setting to monitor for hematoma formation and evidence of decreased blood supply to the nipple-areola complex. For these patients, the pain from this procedure is relatively low; therefore, PONV tends to be the greater issue in the immediate postoperative period.

The traditional type of breast reduction performed in the United States is the **inferior pedicle technique** using a Wise pattern ("anchor-type" scar) for the skin excision (Fig. 11.2-2). Markings are made with the patient upright in the preop holding area. The patient is then brought to the OR for the procedure. The areola is marked circumferentially with an areola sizer and incised. The remaining incision lines are scored with a scalpel. Next, the inferior pedicle (the inferior portion of the breast), which contains the neurovascular supply to the nipple-areola complex, is de-epithelialized. Excess skin and breast tissue are excised, preserving the pedicle of tissue that will compose the breast mound. The resected tissue from each breast, which can range from 200 to 2000 g, is weighed as to an adjunctive method of ensuring equal resections. Temporary skin closure with staples allows the patient to be placed in a sitting position so that the breasts can be evaluated for symmetry. When the surgeon is satisfied with the appearance of the breasts, they are closed with sutures. Drains may be placed, depending on surgeon preference (Fig. 11.2-2). After the skin has been closed, the location of the nipple and areola is marked and excised, and the nipple-areola complex is delivered and sutured into position. Soft, supportive dressings are placed.

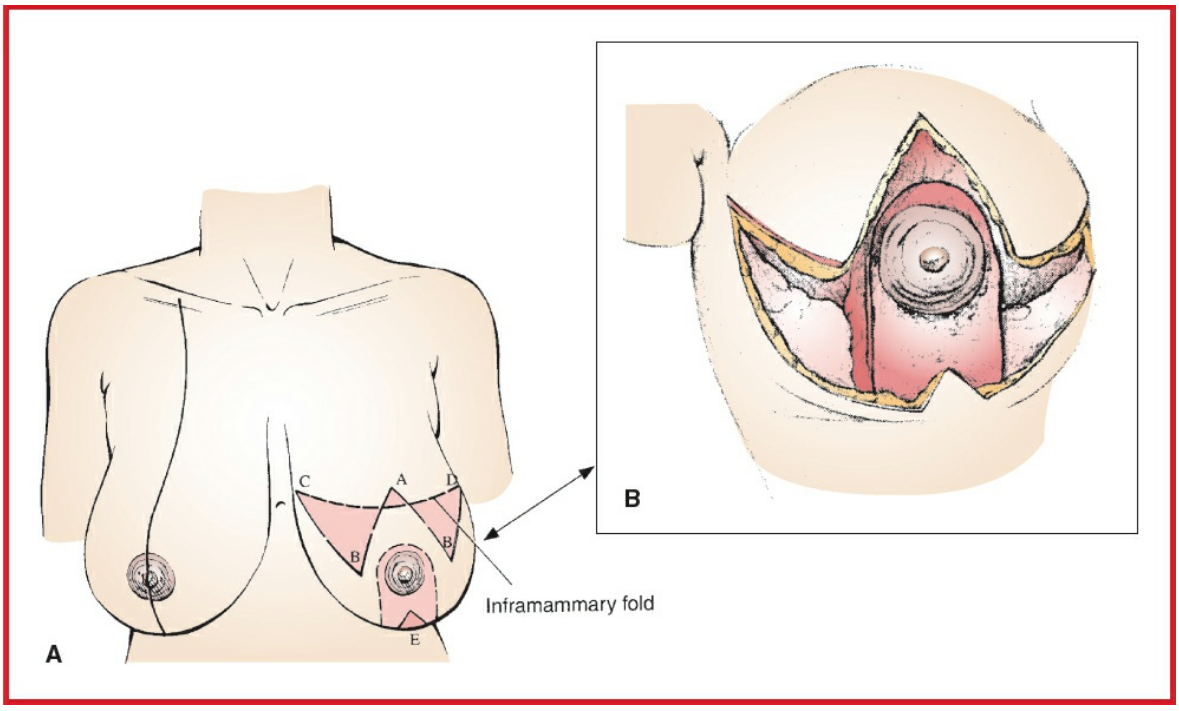

Figure 11.2-2 Reduction mammoplasty using an inferior pedicle technique. **A:** The skin and breast tissue on the medial and lateral sides of the pedicle are resected. **B:** The medial and lateral skin envelopes are sutured at the midline, leaving an inverted T-shaped scar. (Reproduced with permission from Spear SL: Surgery of the Breast: Principles and Art. Lippincott-Raven, Philadelphia: 1998.)

A technique that has gained in popularity recently is the **vertical reduction mammoplasty**, which shares the fundamental principles of excision of excess breast tissue and preservation of blood flow to the nipple-areola complex but differs in choice of skin incision and pedicle. Due to the shorter length of the incision, the wound closure time is greatly decreased (resulting in a "lollipop-type" scar) compared with the traditional Wise-pattern anchor-type scar.

Variant procedure or approaches

Liposuction may be used in combination with this procedure. Reduction mammoplasty using liposuction alone has increased in popularity.

Preop diagnosis

Macromastia; gigantomastia; mammary hypertrophy

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, preop carb loading, VTE risl assessment, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	Supine, arm abducted 90°
Incision	Marked preop. Most have circumareolar incision with an inferior anchor-shaped extension (Fig. 11.2-2) or a short vertical component ("lollipop" scar).
Antibiotics	Cefazolin 2 g iv
Unique considerations	May place patient in sitting position during procedure to assess symmetry; Foley catheter; SCDs
Surgical time	2–5 h, depending on volume of reduction and technique
Closing considerations	May place patient in sitting position for application of dressings
EBL	100–200 mL

Postop care	Outpatient or 24-h stay for pain/nausea management. Avoid the use of Toradol in the first 24 h because of the large, raw surface created between the skin flaps and breast tissue.
Mortality	Minimal
Morbidity	Dehiscence: 5% Infection: 1% Seroma/hematoma: <1% (may require reexploration) Skin flap necrosis Loss of nipple-areola complex (may require urgent reexploration) Loss of nipple-areola sensation Hypertrophic scarring Cosmetic disappointments
Pain score	3–4

PATIENT POPULATION CHARACTERISTICS	
Age range	25–65 yr
Incidence	39,148 performed in the United States in 2016 (asthetic patients only)
Etiology	Developmental; childbearing; obesity
Associated conditions	None common

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Mastopexy/Breast Lift.

Suggested Readings

1. Greco R, Noone B: Evidence-based medicine: reduction mammaplasty.Plast Reconstr Surg 2017; 139(1):230e–9e.
2. Palmieri B, Benuzzi G, Costa A, et al: Breast reduction and subsequent cancer: a prophylactic perspective. Breast 2006; 15(4):476–81.
3. See Suggested Readings Mastopexy/Breast Lift.
4. Shestak KC, Davidson EH: Assessing risk and avoiding complications in breas reduction. Clin Plast Surg 2016; 43(2):323–31.

MASTOPEXY/BREAST LIFT

SURGICAL CONSIDERATIONS

Description

Mastopexy procedures reduce the volume of the skin envelope to match the volume of the breast gland. Depending on the degree of ptosis ("droopy breasts") and the wishes of the patient, the ptosis may be treated by augmentation alone to increase the volume of the breast, by skin excision alone to reduce the skin envelope appropriately, or by a combination of a mastopexy and an augmentation.

The operation itself resembles a reduction mammoplasty, except that breast tissue is generally excised minimally or not at all, and an implant may be added (**augmentation/mastopexy**). The patient is marked before surgery in the upright position. After the induction of anesthesia, the arms are positioned either tucked at the patient's sides or abducted 90°. The procedure begins with the areola being marked circumferentially with an areola sizer and then incised. Next, the skin flaps are elevated. The breast tissue is moved to a higher position on the chest wall, and the skin is redraped and tailor-tacked closed. The patient is placed in a sitting position to assess for symmetry and nipple location. The nipple-areola complex is then brought out into its new position, and dressings are applied.

Preop diagnosis

Breast ptosis

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, preop carb loading, VTE risl assessment, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Circumareolar ± inferior vertical extension or complete anchor
Antibiotics	Cefazolin 2 g iv
Unique considerations	May place patient in sitting position during procedure

Surgical time	2–4 h
Closing considerations	May place patient in sitting position for application of dressings
EBL	<100 mL
Postop care	Outpatient or 24-h stay
Mortality	Minimal
Morbidity	Wound healing: 5% Infection: 1% Seroma/hematoma: <1% Hypertrophic scarring Cosmetic disappointments
Pain score	3–4

PATIENT POPULATION CHARACTERISTICS	
Age range	35–65 yr
Incidence	101,264 performed in the United States in 2016
Etiology	Age-related ptosis; involution after breast-feeding; weight loss
Associated conditions	None common

ANESTHETIC CONSIDERATIONS FOR MAMMOPLASTY/MASTOPEXY

PREOPERATIVE

Typically, three patient populations present for mammoplasty: (a) healthy individuals, for breast reduction, augmentation, breast lift, or removal of an implant; (b) morbidly obese for breast reduction; and (c) breast cancer patients, for reconstruction after mastectomy or a symmetry procedure on the noncancer breast (breast reduction, or augmentation). (For preop considerations in the morbidly obese patient, see Anesthetic Considerations for Abdominoplasty.) Breast cancer patients undergoing mastectomy with immediate reconstruction typically will not have had either chemotherapy or radiation. The following considerations are for breast cancer patients undergoing

delayed reconstruction post-chemotherapy.

Respiratory	Pulmonary fibrosis may complicate chemotherapy. Alkylating agents (e.g., cyclophosphamide and melphalan), used to treat breast cancer, have some pulmonary toxicity. Consider pulmonary fibrosis in a patient reporting dyspnea, nonproductive cough, and fever. **Tests:** Consider CXR; ABG, PFTs as indicated from H&P.
Cardiovascular	Cardiomyopathy and CHF may result from chemotherapy, especially doxorubicin (Adriamycin) >550 mg/m^2. **Tests:** Consider ECG; echo, if indicated from H&P.
Neurologic	Note any preexisting injury to long thoracic nerves, as evidenced by winged scapula deformity.
Musculoskeletal	Avoid upper extremity iv and BP cuff on mastectomy side.
Hematologic	Leukopenia, thrombocytopenia, and anemia from chemotherapy may be present. **Tests:** CBC; Plt count
Renal/Hepatic	Methotrexate can produce some renal and hepatic dysfunction. **Tests:** Cr; LFTs
Laboratory	Other tests as indicated from H&P, prior chemotherapy
Premedication	Midazolam 1–2 mg iv immediately preop. Surgeon may want to mark the patient's skin preop, with patient standing. Delay premedication until this has been done.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss possibility of nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po. Consider aprepitant 40 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA

Induction	Standard induction. ✓ with surgeons regarding use of a nerve stimulator during dissection (and the need to avoid muscle relaxants). Consider intratracheal lidocaine 4% LTA to minimize coughing during position changes.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia (Goal-Directed Management) and normothermia. Consider preincision placement of nerve blocks (see Appendix K, p. K-6).	
Maintenance	Standard maintenance. Surgeons may want patient sitting for part of the procedure. Pneumothorax should be considered with any change in lung inflation pressure, O_2 sat, or BP.	
Emergence	During some of the procedure and for application of dressing, patient may be moved to sitting position, with consequent coughing, bucking, etc. (Rx: deeper anesthesia, e.g., propofol 0.5 mg/kg or lidocaine 1 mg/kg). Watch BP carefully and treat orthostatic hypotension if it occurs, usually with a fluid bolus if the patient does not have h/o CHF or renal failure. Consider nerve block placement or reinforcement if initially placed >4–6 h ago (see p. 1239).	
Blood and fluid requirements	IV: 16–18 ga × l BSS @ 4–8 mL/kg/h	Minimal blood loss for simple reconstruction, augmentation, or reduction; larger blood losses anticipated for combined procedures (e.g., mastectomy with immediate reconstruction

		or flap reconstruction). Goal-Directed Fluid Management (see Appendix K, p. K-4)
Monitoring	Standard monitors	Arterial line in the morbidly obese may be necessary to obtain accurate BP measurements.
Positioning	Patient may need to be sitting for application of dressing.	Avoid HTN, bucking, and straining; these may cause or exacerbate bleeding at reconstruction site. Careful padding of arms to protect them during position change.

POSTOPERATIVE

Complications	Pneumothorax	
Multimodal pain management	PCA Regional nerve blocks Acetaminophen NSAID Gabapentin	Consider multimodal therapy including gabapentin, opiates, and paravertebral/intercostal nerve blocks. Regional or local blocks. Continuous infusion catheters may be beneficial.
ERAS	PONV protocol	Encourage early enteral nutrition, Foley catheter removal, and early mobilization.

Suggested Readings

1. Massenburg BB, Sanati-Mehrizy P, Ingargiola MJ, et al: Flap failure and woun

complications in autologous breast reconstruction: a national perspective. Aesthetic Plast Surg 2015; 39(6):902–9.
2. O'Halloran N, Potter S, Kerin M, et al: Recent advances and future directions i postmastectomy breast reconstruction. Clin Breast Cancer 2018; 18(4):e571–85.
3. Temple-Oberle C, Shea-Budgell MA, Tan M, et al; ERAS Society: Consensu review of optimal perioperative care in breast reconstruction: enhanced recovery after surgery (ERAS) society recommendations.Plast Reconstr Surg 2017; 139(5):1056e–71e.
4. Terkawi AS, Tsang S, Sessler DI, et al: Improving analgesic efficacy and safety o thoracic paravertebral block for breast surgery: a mixed-effects meta-analysis. Pain Physician 2015; 18(5):E757–80.

BRACHIOPLASTY

SURGICAL CONSIDERATIONS

Description

Brachioplasty is performed as outpatient surgery for patients who note laxity or a "bat-wing" appearance of their upper arms. Markings are done in the preoperative holding area with the patient upright, arms abducted and flexed. The arms are positioned on arm boards or the hand table. An incision is made starting along the chest wall or in the axilla, extending onto the upper arm, and stopping before the elbow. Excess skin and soft tissue are excised, and the incision is closed, typically over a drain. Dressings are applied, often followed by a compression garment or ACE wraps. See Figure 11.2-3.

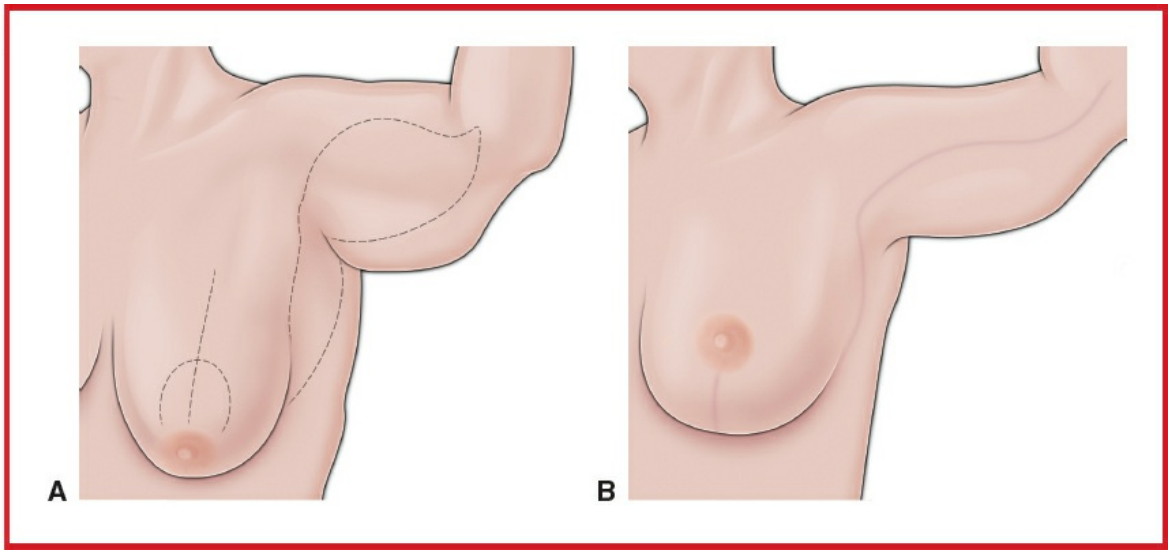

Figure 11.2-3 Preop incision planning **(A)** and postop results **(B)**.

Usual preop diagnosis

Upper arm laxity or redundancy; lipodystrophy

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, preop carb loading, VTE risl assessment, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine, arms abducted
Incision	From the chest/axilla, extending along the lower inner arm
Unique considerations	Both arms must be mobile and prepped circumferentially; SCDs.
Antibiotics	Cefazolin 2 g iv
Surgical time	1–2 h
EBL	Minimal
Postop care	Avoid ketorolac in the first 24–48 h.
Mortality	Minimal
Morbidity	Seroma: 10% Hypertrophic scarring: 10% Infection: 5–7% Nerve injury: 5%
Pain score	3–4

PATIENT POPULATION CHARACTERISTICS	
Age range	20–65 yr
Male:Female	1:50
Incidence	17,860 performed in the United States in 2016
Etiology	Overweight; aging; massive weight loss
Associated conditions	Obesity

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients presenting for brachioplasty have often undergone gastric bypass surgery with massive weight loss. IV access may be difficult, and the arms may be prepped all the way down to and including the hands. Consider the need for iv access in the lower limb or neck due to bilateral arm surgery. (See Anesthetic Considerations in Morbid Obesity.)

INTRAOPERATIVE

Anesthetic technique

GETA, routine monitors

Procedure may be combined with other plastic procedures, necessitating position changes.

Induction	Standard induction for healthy patients. Special considerations for the morbidly obese include prophylaxis for aspiration, followed by rapid-sequence induction in an appropriately positioned patient (see Fig. 7.2-6). If mandibular and cervical mobility are decreased by excessive soft tissue, an awake fiberoptic intubation with the patient sitting may be necessary. Anticipate rapid O_2 desaturation (2° ↓ FRC) during periods of hypoventilation, even with adequate preoxygenation.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia (Goal-Directed Management) and normothermia. Consider preincision placement of nerve blocks (see Appendix K, p. K-6).
Maintenance	Standard maintenance. Calculate most drug doses on basis of lean body mass. In the obese, controlled ventilation with larger TVs, PEEP, and high inspired O_2 concentration is recommended. Positioning may

	be difficult, and care must be taken to give adequate padding and support.	
Emergence	Give antiemetics (e.g., ondansetron 4 mg) 20 min before conclusion of surgery. Consider nerve block placement or reinforcement if initially placed >4–6 h ago (see p. 1239).	
Blood and fluid requirements	Minimal blood loss, 18 ga × 1 BSS @ 4–8 mL/h	Goal-Directed Fluid Management (see Appendix K, p. K-4)
Monitoring	Standard monitors	

POSTOPERATIVE

Multimodal pain management	PCA Oral medications for outpatients Acetaminophen	Consider regional or local blocks
ERAS	PONV protocol	Encourage early enteral nutrition and early mobilization.
Tests	As indicated by patient condition	

Suggested Readings

1. Hurwitz D: Brachioplasty. Clin Plast Surg 2014; 41(4):745–51.
2. Knoetgen J III, Moran SL: Long-term outcomes and complications associated wit brachioplasty: a retrospective review and cadaveric study. Plast Reconstr Surg 2006; 117(7):2219–23.

ABDOMINOPLASTY

SURGICAL CONSIDERATIONS

Description

Patients who present for **abdominoplasty** have laxity in the abdominal wall musculature and excess skin and adipose tissue. This laxity may be associated with rectus muscle diastasis. **Liposuction** is sometimes performed in conjunction with abdominoplasty to

remove additional adipose tissue and improve contour.

Incision lines are marked on the patient preoperatively in the upright position (Fig. 11.2-4). If the procedure will include liposuction of the flanks, the procedure may start in the prone position. Once completed, the patient will then be turned to the supine position. The umbilicus is circumscribed, with care taken to preserve its blood supply. An incision is made above the pubic hairline and extended bilaterally to each anterior-superior iliac spine. Electrocautery is used to raise a flap of skin, subcutaneous tissue, and fat at the level of the abdominal wall fascia. The dissection extends cephalad to the costal margin. The operating table is flexed to place the patient in the semi-Fowler position. The elevated flap is pulled down to overlap the inferior incision, and the redundant soft tissue is excised in a tailor-tack fashion (Fig. 11.2-5). The surgical area is inspected for hemostasis and irrigated. Sutures may be placed to plicate the abdominal wall musculature if there is laxity. Fibrin sealant may be sprayed to aid in hemostasis. The wound is closed typically over drains, and the umbilicus is brought out through a new incision. Dressings, which may include an abdominal binder, are applied. The patient is maintained in the semi-Fowler position during transfer from the operating table. The patient may elect to have the procedure as an outpatient or with an overnight stay in a monitored facility.

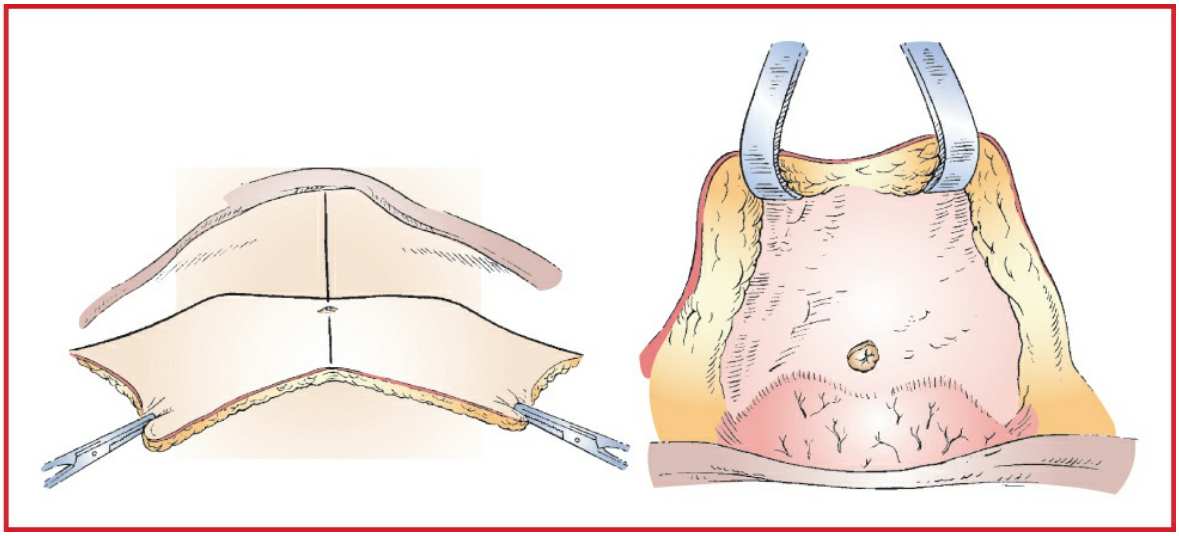

Figure 11.2-5 After the lower incision has been made and the abdominal flap has been elevated, the flap is pulled down to overlap the inferior incision, and the redundant soft tissue is excised in a tailor-tack fashion. (Reproduced with permission from Aston SJ, Beasley RW, Thorne CHM, edsGrabb & Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

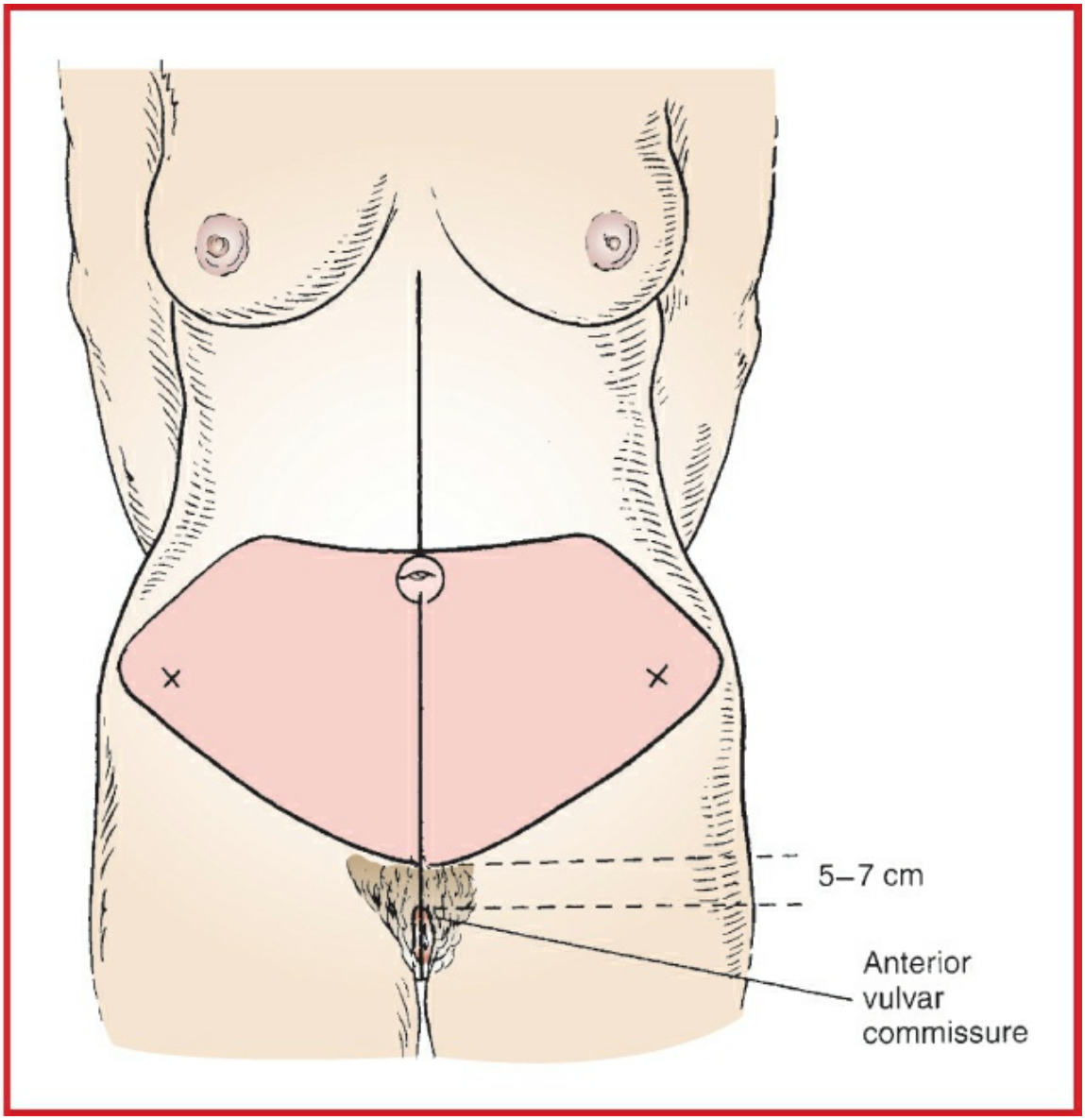

Figure 11.2-4 Abdominoplasty, markings for incisions. (Reproduced with permission from Aston SJ, Beasley RW, Thorne CHM, eds.Grabb & Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

Variant procedure or approaches

Patients who have laxity above the umbilicus may require additional reduction with a fleur-de-lis abdominoplasty (vertical midline extension of incision and scar), or this can be addressed secondarily with a reverse abdominoplasty with the final scar underneath the breasts. Panniculectomy (simple resection of overhanging skin and soft tissue) can be performed alone without the fascial plication, particularly in the case of morbidly obese patients. Miniabdominoplasty may be performed in those patients who require less extensive dissection. Panniculectomy and abdominoplasty can also be combined with hernia repairs and gynecologic procedures.

Usual preop diagnosis

Abdominal wall laxity; rectus diastasis; lipodystrophy; redundant skin and soft tissue

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, preop carb loading, VTE risl assessment, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Extended Pfannenstiel's; periumbilical; vertical midline extension if needed
Unique considerations	Foley catheter; SCDs
Antibiotics	Cefazolin 2 g iv
Surgical time	1.5–4 h
Closing considerations	Flex table to facilitate closure; patient must subsequently remain in semi-Fowler position.
EBL	~100 mL, not including blood contained in specimen.
Postop care	Maintain flexed position; avoid ketorolac in the first 24–48 h.
Mortality	0–1%
Morbidity	Ileus: 10% Infection: 2–3% Dehiscence: 1% Fat embolism: 1% DVT: 1% Hematoma Seroma
Pain score	4–6

PATIENT POPULATION CHARACTERISTICS	
Age range	20–65 yr

Male:Female	1:25
Incidence	127,633 performed in the United States in 2016
Etiology	Overweight; laxity of skin after pregnancy; massive weight loss
Associated conditions	Obesity; post–gastric bypass

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Typically, there are two patient populations for abdominoplasty: the generally healthy and the morbidly obese. Some patients have Hx of amphetamine, cocaine, or thyroid hormone abuse and ↑ incidence of hiatal hernia. The following considerations focus on the morbidly obese patient (body weight ≥2 × ideal weight. Ideal body weight can be estimated by subtracting 100 (male) or 105 (female) from height in cm.

Respiratory	In the morbidly obese patient, findings include ↑ O_2 consumption, ↑ CO_2 production, restrictive lung disease, ↓ FRC, ↓ ERV, ↓ VC, and ↓ PaO_2. These changes are exacerbated by the supine position. Younger patients may show alveolar hyperventilation in response to hypoxemia; older patients may not and may therefore retain CO_2. Patients may have obesity hypoventilation syndrome (pickwickian syndrome) and sleep apnea, with intermittent airway obstruction, hypoxemia, and hypercarbia during sleep, which may → pulmonary HTN. Obese patients are at ↑ risk of pulmonary aspiration due to ↑ incidence of hiatal hernia, GERD, and ↑ gastric volumes (typically >25 mL with pH < 2.5). See Premedication, below, for aspiration prophylaxis. **Tests:** Consider CXR, room-air ABG, and PFT (helpful, but may not predict postop complications, e.g., atelectasis, pneumonia).
Cardiovascular	↑ CO and ↑ blood volume → LVH. Chronic hypoxia and pulmonary compromise may produce right heart

	failure, ↓↓ exercise tolerance, ↑ risk of CAD, and pulmonary HTN. Patients with LVH may have ↑ dysrhythmias. Some patients may have previously taken fenfluramine alone or in combination with phentermine for weight loss. Those patients should be evaluated for pulmonary HTN (e.g., dyspnea, central cyanosis, right axis deviation, and CXR changes) and valvular heart disease. **Tests:** ECG (↑ HR, conduction abnormalities, LVH); CXR (cardiomegaly)
Metabolic	Increased incidence of diabetes, hypercholesterolemia, hypertriglyceridemia, liver abnormalities; ↓ plasma folate and B_{12}; ↑ incidence of cholelithiasis, nephrolithiasis. Determine whether electrolyte abnormalities are present in patient s/p ileojejunal bypass. **Tests:** As indicated from H&P
Hematologic	Polycythemia suggests chronic hypoxemia (see Respiratory, above). **Tests:** Hb/Hct
Laboratory	Other tests as indicated from H&P
Premedication	Sedative premedication is usually avoided in the morbidly obese due to their pulmonary compromise and increased sensitivity to sedative agents. Aspiration prophylaxis is useful: ranitidine 50 mg iv 30–60 min before surgery, plus nonparticulate antacid (Na citrate 0.3 M, 30 mL po) preinduction. In addition, metoclopramide 10 mg iv may be given, although it has not been shown to be more effective in combination with an H_2-blocker than the H_2-blocker alone. For the healthy outpatient, midazolam 1–2 mg iv immediately before transport to the OR may lessen anxiety.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po. Consider aprepitant 40 mg po for patients with h/o

	severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: Morbidly obese patients may not tolerate the supine position for an extended period of time. Consider placement of thoracic epidural for postop pain control.

Induction	Standard induction for healthy patients. Special considerations for the morbidly obese include prophylaxis for aspiration (see above), followed by rapid-sequence induction in an appropriately positioned patient (see Fig. 7.2-6). If mandibular and cervical mobility are decreased by excessive soft tissue, an awake fiberoptic intubation with the patient sitting may be necessary. Anticipate rapid O_2 desaturation (2°↓FRC) during periods of hypoventilation, even with adequate preoxygenation (e.g., 4 VC breaths of 100% O_2 in 30 sec).
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia (Goal-Directed Management) and normothermia. Consider preincision placement of nerve blocks (see Appendix K, p. K-6).
Maintenance	Standard maintenance. Calculate most drug doses on basis of lean body mass. In the obese, increased plasma fluoride concentrations are found after anesthesia with volatile anesthetics; controlled ventilation with larger TVs, PEEP, and 50% O_2 is recommended. Because epinephrine infiltration generally is used to decrease blood loss, isoflurane is recommended as the least dysrhythmogenic of the inhalation agents. **NB:** Midazolam has a prolonged half-life in obese patients, but awakening times from inhalational or narcotic-based anesthetics are comparable to those of nonobese patients.

Emergence	Smooth emergence with minimal bucking, coughing, or retching to minimize tension on the suture line; give antiemetics (metoclopramide 10 mg and ondansetron 4 mg) 20 min before conclusion of surgery. Maintenance of flexed position will minimize tension on suture line. Small additional doses of narcotic (e.g., meperidine 10–20 mg) may be titrated to RR if patient is allowed to resume spontaneous respiration before the end of the case. Consider iv acetaminophen if po dose is given >4–6 h ago.	
Blood and fluid requirements	Moderate blood loss IV: 16–18 ga × 1 BSS @ 6–10 mL/kg/h	Goal-Directed Fluid Management (see Appendix K, p. K-4)
Monitoring	Standard monitors ± Arterial line ± CVP line	Additional monitoring for the morbidly obese patient may include arterial and CVP lines.
Positioning	Flexed position Pillows under knees ✓ and pad pressure points ✓ eyes	Flexed position minimizes tension on suture line. Morbidly obese may require two OR tables side by side. Supine position may be poorly tolerated; monitor ventilation closely.
Complications	Fat emboli Rhabdomyolysis	More common during liposuction Increased risk with prolonged surgery

POSTOPERATIVE

Complications	Patients may have postop ileus of 1- to 2-d duration.	The morbidly obese should not be outpatients; they have ↑

		incidence of wound infection, DVT, PE, and postop pulmonary complications. Provide supplemental O_2 for the first 2 d postop. Keep patient in semisitting or flexed position to avoid undue stress on wound.
Multimodal pain management	Epidural narcotics or PCA may be used. Acetaminophen.	Monitor patient for postop respiratory depression. Consider regional or local blocks.
ERAS	PONV protocol	Encourage early enteral nutrition and early mobilization.
Tests	Pulse oximetry	Maximum reduction of arterial saturation may occur on postop day 2–3.

Suggested Readings

1. Aldenkortt M, Lysakowski C, Elia N, et al: Ventilation strategies in obese patients undergoing surgery: a quantitative systematic review and meta-analysis. Br J Anaesth 2012; 109(4):493–502.
2. Joshi GP, Ankichetty SP, Gan TJ, et al: Society for ambulatory anesthesia consensus statement on preoperative selection of adult patients with obstructive sleep apnea scheduled for ambulatory surgery. Anesth Analg 2012; 115(5):1060–8.
3. Kirkham L, Thomas M: Anaesthesia in obese patients. Br J Hosp Med (Lond) 2011; 72(9):515–20.
4. Peterson PL, et al: The transversus abdominis plane block: a valuable option for postoperative analgesia? A topical review. Acta Anaesthesiol Scand 2010; 54(3):529–35.
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606e.

BODY LIFTS

SURGICAL CONSIDERATIONS

Description

With heightened awareness of the importance of nutrition and exercise as well as the advent of improved gastric bypass and restriction techniques, more patients with massive weight loss are presenting to plastic surgeons for treatment of the resultant skin excess and laxity. Patients frequently have multiple areas of concern, from the face (see **Facelifts**) to the breasts (see **Mastopexy**) to the abdomen and thighs. Often patients will require circumferential torsoplasty (combining **Abdominoplasty** with excision of the lower back roll) and/or extensive lower body work also lifting the medial and lateral thighs. All of these body lift procedures may be combined with **liposuction** for additional contouring.

The patient is marked in the standing position in the preoperative holding area. Depending on surgeon preference, the initial operative position may begin supine, lateral decubitus, or prone. Incisions are made, and the marked excess skin and soft tissues are elevated and excised. The patient's position is changed as needed to allow for access to all of the surgical areas. Drains are placed. During wound closure, care is taken to close in several layers, beginning with the strength layer of the superficial fascial system. Dressings are applied, and compression garments or ACE wraps may also be used. The patient may elect to have the procedure as an outpatient but frequently chooses to stay overnight in a monitored facility. See Figure 11.2-6.

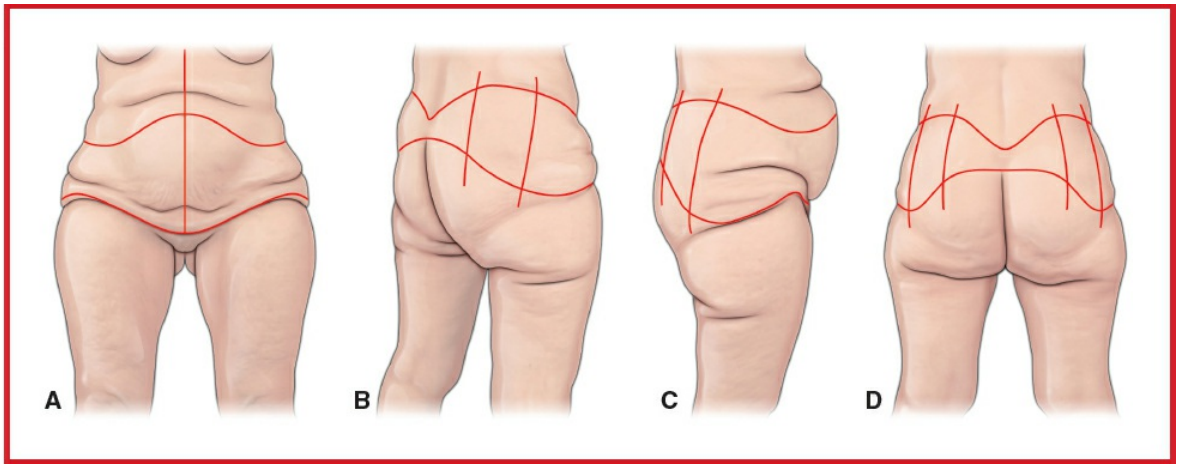

Figure 11.2-6 A–D: Preop incision planning.

Usual preop diagnosis

Thigh and buttock laxity; lipodystrophy; redundant skin and soft tissue

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, preop carb loading, VTE risk assessment, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE

Position	Multiple: supine, lateral decubitus, prone
Incision	Depending on the combination of procedures; may include circumferential waistline, transverse groin crease, and possible medial thigh vertical extension
Unique considerations	Foley catheter; knee-high SCDs; appropriate pressure point padding, repositioning the patient during the case
Antibiotics	Cefazolin 2 g iv
Surgical time	2–6 h
EBL	50–100 mL, not including blood contained in specimen
Postop care	Avoid ketorolac in the first 24–48 h; maintain semi-Fowler position for any procedures involving abdominoplasty.
Mortality	Minimal
Morbidity	Seroma: 1–16% Dehiscence: 1–32% Skin necrosis: 1–10% Infection: 0.5–3.5% DVT/PE: 2–3%
Pain score	4–6

PATIENT POPULATION CHARACTERISTICS

Age range	20–65 yr
Male:Female	1:4
Incidence	Thigh lift: 10k performed in the United States in 2016 Lower body lift: >11k performed in the United States in 2016
Etiology	Overweight; massive weight loss
Associated conditions	Obesity; post–gastric bypass

ANESTHETIC CONSIDERATIONS

Patients may have had massive weight loss or may be morbidly obese. (See Anesthetic Considerations for Abdominoplasty). Body lift procedures may be combined with liposuction. (See Anesthetic Considerations for Liposuction.)

Suggested Readings

1. Hamra ST, Small KH: Cosmetic body lift. Plast Reconstr Surg 2016; 137(2):453–61.
2. Hurwitz DJ, Ayeni O: Body contouring surgery in the massive weight loss patient. Surg Clin North Am 2016; 96(4):875–85.
3. Shermak MA: Body contouring. Plast Reconstr Surg 2012; 129(6):963e–78e.
4. Shermak MA: Pearls and perils of caring for the postbariatric body contouring patients. Plast Reconstr Surg 2012; 130(4):586e–97e.

LIPOSUCTION

Body contour surgery remains one of the most commonly performed cosmetic surgical procedures in North America. The surgical techniques used to achieve body contour change continue to evolve. The use of epinephrine-containing tumescent solutions injected in the subcutaneous tissue prior to aspiration of fat has dramatically reduced perioperative blood loss and allowed the surgeon to achieve a more dramatic body contour change. Perioperative surgical and anesthetic complications continue to occur during liposuction surgery. Adverse outcome associated with body contour surgery includes pulmonary embolus, fat emboli, fluid overload, and local anesthetic toxicity. Confirmation of the planned surgical procedure, the planned volume of injection of tumescent solution, and the final composition of the tumescent solution must be done prior to the start of surgery. Local anesthetic dosing errors during liposuction have led

to complications and death during liposuction surgery. Adequate time (10 min or longer) after injection of the tumescent solution must be given for epinephrine-induced vasoconstriction to take effect.

External ultrasound/internal ultrasound/laser

The application of energy to disrupt the integrity of fat tissue prior to aspiration may be used to achieve improvements in body contour. Disruption of fat tissue with ultrasound or laser prior to aspiration reduces the physical work of the surgical procedure. Complications reported with the use of ultrasound or laser include seroma formation, increased blood loss, skin loss secondary to burn, and body cavity perforation. Small incisions are made in strategic locations to hide scars. Prefabricated wound protection inserts may be used to protect the skin from cannula irritation. Postop pain is highly variable depending on surgical area and the magnitude of the surgical procedure. Oral analgesics starting with opioids and rapidly tapering to nonnarcotic analgesics over the course of 1–2 wk are usually satisfactory.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, preop carb loading, VTE risk assessment, and postop pain management options. **See Appendix K, p. K-1.**

SUMMARY OF PROCEDURE	
Position	According to body region (repositioning during surgery is common)
Incision	Incisions may be hidden in skin folds and by clothing. Long infusion cannulas and long liposuction probes help minimize the number of incisions necessary.
Special instrumentation	Specialized laser cannulas, ultrasonic probes, and power assisting equipment. Suction machines and canisters used to aspirate and collect fat
Antibiotics	Cefazolin 2–3 g iv
Surgical time	2–9 h depending on the volume of resection and the number of surgical sites
EBL	2–8% of total aspirate volume when using epinephrine-containing tumescent solution before aspiration

Postop care	PACU for small-volume liposuction; hospitalization for postop monitoring for resection volume >5–6 L of fat depending on body size of the patient and the number of regions of the body undergoing surgery
Mortality	Rare
Morbidity	Pulmonary emboli, fat emboli, fluid overload, local anesthetic toxicity, body cavity perforation, skin burn, and tissue loss from ultrasonic energy application or tissue trauma from lipo cannula
Unique considerations	Tumescent solution must be warmed before infiltration to prevent hypothermia; Foley catheter should be used during larger-volume surgeries to monitor fluid status and prevent bladder distension. TEDs, SCDs used on all cases. Postop use of anticoagulant drugs during the 1st wk may lead to excessive bleeding.

PATIENT POPULATION CHARACTERISTICS	
Age range	Teens to 70 yr
Female:Male	10:1
Etiology	Quest for eternal youth

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients considering liposuction should be ASA category I or II. The ideal candidate for surgery should be physically active and have maintained a stable body weight for 6 mo to 1 yr. Current techniques use the injection of a tumescent solution into the fat prior to aspiration to reduce blood loss and to deliver local anesthetic for analgesia. A typical tumescent solution contains lidocaine 500 mg, epinephrine 1 mg, and bicarb 12 mEq in 1000 mL NS. Typically, 1 mL of tumescent solution will be injected for each 1 mL of anticipated fat resection. Determining the maximum amount of fat that is safe to remove in one surgical setting is complex. Safety is partially determined by the size of the patient and the number or surgical regions planned to have liposuction. Large-volume (>5000 mL) resection may require overnight medical observation and monitoring (fluid shifts, drop in Hct, fluid overload). Large volumes of tumescent solution are often used

in these procedures and require limiting iv fluid administration. In contrast, small-volume liposuction often requires larger volumes of iv fluid administration because of the small volumes of tumescent solution that would be available for postop redistribution from the fat tissue into the central circulation. Performing several small-volume resections may be preferable than a single very large resection given concerns with fluid shifts, blood loss, respiratory compromise, and local anesthetic toxicity.

Respiratory	Postop discomfort following chest, upper back, and upper abdomen liposuction may interfere with respiration. Restrictive compression garments applied to the chest or upper abdomen may also restrict breathing. Patients with respiratory impairment may not be candidates for this procedure. Careful postop monitoring of O_2 saturation is mandatory.
Cardiovascular	Patients with a history of cardiac dysfunction will not be candidates for liposuction. Fluid management is based on estimation of the patient's intravascular volume status, the volume of tumescent (tumescent) fluid injected during surgery, and the quantity of iv fluid given. Tumescent solution injected into the subcutaneous tissue is absorbed over 48 h. Postop pulmonary edema has been reported secondary to fluid overload. Regional anesthesia may make perioperative fluid management more difficult in large-volume surgeries secondary to peripheral vasodilation. Large doses of epinephrine may lead to increases in blood pressure and cardiac arrhythmias. After tumescent injection, epinephrine levels peak at 5–6 h vs. 10–12 h for local anesthetic levels.
Neurologic	Preop neurologic exam should be normal. Local anesthetic in the tumescent solution may cause numbness in the surgical region for several hours after surgery. Nerve trauma caused by the liposuction instruments has been reported. Careful body positioning during surgery is mandatory as the patient's position on the operating room table is frequently changed during the course of the surgery.

	Repeated checking of the patient's body position on the table is needed because of the vigorous motion of the liposuction procedure.
Hematologic	Vasoconstriction from epinephrine-containing tumescent solutions reduces blood loss to 2–8% of the total aspirate volume. Heavy bleeding during liposuction should cause the procedure to be halted and the cause of bleeding investigated. Failure to add epinephrine to the tumescent solution as a cause of bleeding has been reported. Blood vessel injury, accidental puncture of a body cavity, or unknown coagulopathy may be the cause of increased blood loss. **Tests:** Hct, PT, PTT, platelet count
Laboratory	No other preop testing is needed in healthy patients.
Premedication	Midazolam 1–2 mg iv or lorazepam 1 mg po 1–2 h preop
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po. Consider aprepitant 40 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

Local anesthesia may be suitable for smaller-volume liposuction. Regional anesthesia (spinal, epidural) may be used when the surgical regions are appropriate for this type of anesthetic. Concerns have been raised because of vasodilation causing an increase in blood loss and an increased risk of fat embolization. Adding local anesthetics to an epidural catheter in combination with local anesthetic in the tumescent solution require careful planning to avoid local anesthetic toxicity. Contrary to standard recommendations, which limit the total lidocaine (with epi) dose to 7 mg/kg, for tumescent anesthesia, a total lidocaine dose of up to 55 mg/kg seems well tolerated.

GA ensures patient comfort and allows liposuction to be performed on all body regions. Control of the airway and control of ventilation provide safety during surgery,

particularly for patients in the prone position. SCDs or foot/ankle compression devices are used for all patients to reduce the risk of PE. Routine use of one or two forced air thermal blankets to maintain normal body temperature is recommended.

Induction	Standard induction. Steroids (dexamethasone 8 mg) may be used to reduce postop swelling, reduce the incidence of postop nausea, and may be of benefit in the event of fat embolism.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia (Goal-Directed Management) and normothermia.	
Maintenance	Standard maintenance with volatile anesthetics or propofol infusion. Neuromuscular blockade as appropriate. GA is maintained during application of compression garments at the end of the procedure.	
Emergence	Antiemetic prophylaxis with combination drug therapy (metoclopramide 10–20 mg) and ondansetron (4 mg) is appropriate. Careful monitoring of respiratory function is necessary when surgery has been performed on the chest, back, or upper abdomen because compression garments and postop pain may limit respiration.	
Blood and fluid requirements	IV: 18 or 20 ga ×1 BSS as appropriate.	Fluid administration determined by the needs of the case. Open surgery (abdominoplasty) performed in combination with liposuction will require careful monitoring of intravascular status and monitoring of urine output during surgery. Transfusion is rarely needed; diuretics (furosemide 5–10 mg) may be needed for patients receiving large

		volumes of tumescent solution. Larger intravenous fluid volumes are needed during smaller-volume liposuction because less tumescent solution has been used. IV fluids may need to be limited in patients undergoing larger-volume liposuction because larger volumes of tumescent solution will be absorbed into the circulation. Goal-Directed Fluid Management (see Appendix K, p. K-4).
Monitoring	Standard monitoring Foley catheter	Urine output monitoring mandatory on all large-volume lipo cases Careful temperature monitoring
Positioning	✓ and pad pressure points. ✓ and protect eyes. Repeat positioning. Check frequently.	Frequent intraop position checks are needed as patient position may change during surgery → ↑ risk of peripheral nerve injury. Document eye checks q15min while patients are in the prone position.
Complications	Local anesthetic systemic toxicity (LAST) Excessive blood loss Volume overload Abdominal cavity perforation Peripheral nerve injury	Lidocaine up to 55 mg/kg in the tumescent solution with epinephrine has been shown to produce safe serum levels when used for tumescent injection during prolonged

	Hypothermia	liposuction. Peak plasma lidocaine levels occur 10–12 h after infusion. Peak epinephrine levels occur 5–6 h after infusion and may lead to increases in heart rate and/or blood pressure. At the first signs of LAST, lipid emulsion (1.5 mL/kg iv) should be used to rapidly reduce blood levels of lidocaine.
	Fat embolism Pulmonary embolism	Postop hypoxia may be caused by multiple factors, including fluid overload and pulmonary edema, pneumothorax, restricted ventilation, pulmonary embolus, and respiratory depression. Unexplained postop hypoxia will require hospitalization. Anticoagulation for PE may lead to severe blood loss because of large tissue areas that have been injured during liposuction. Blood transfusion must be readily available before beginning anticoagulation therapy in a patient who has recently undergone liposuction. IVC filter may be needed for a patient with PE.
		Hypertension may be

		caused by fluid overload, delayed epinephrine effect, or surgery-induced pain.
Multimodal pain management	PO analgesics IV opiates Acetaminophen	Patients often will be comfortable 2° to residual local anesthesia that may persist for 8–24 h. Oral analgesics are usually satisfactory for postop pain control.
ERAS	PONV protocol.	Encourage early enteral nutrition and early mobilization.
Tests	Rarely needed, Hct	

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CHAPTER 11.3

Craniofacial Surgery

SURGEON
Stephen A. Schendel, MD, DDS, FACS

ANESTHESIOLOGIST
Richard A. Jaffe, MD, PhD

REPAIR OF FACIAL FRACTURES

SURGICAL CONSIDERATIONS

Description

Facial fractures are classified by location and the involved bones.

Upper and midface region

Frontal sinus fractures may involve the anterior wall alone or also may involve the nasofrontal ducts and/or posterior wall. Nasofrontal duct disruption may require obliteration of the duct and sinus, which is done with an electric burr and loupe magnification to remove all mucosa before grafting the area with bone, fat, or pericranium. A posterior wall disruption is a fracture into the anterior cranial fossa that may require CSF leak repair ± cranialization of the sinus (complete removal of the posterior wall of the sinus). Each frontal bone forms a large component of the orbital roof, and as such, ocular injury or periorbital entrapment must be considered.

Fractures of the maxilla are classified as **Le Fort I, II,**or **III**, depending on the level of the fracture (Fig. 11.3-2). **Le Fort I** is a horizontal fracture, separating the teeth and lower maxillary components from the upper facial structures. **Le Fort II**is a triangular fracture with a fracture line across the nose, below the infraorbital rims, and extending through the entire lower maxillary structures. **Le Fort III**is essentially a disassociation

of the cranium and face. In these cases, the maxilla is usually mobile or impacted posteriorly and occasionally closes off the posterior airway. Further mobility of the segments may be present with a sagittal split of the palate. Associated fractures in the maxillary region include fractures of the zygoma, orbital fractures (most commonly orbital floor), isolated nasal fractures, naso-orbital-ethmoid (NOE) fractures (usually with severe comminution of the upper face), and cranial base fractures with the potential for dural tears and CSF rhinorrhea. Added procedures that may be required to complete the repair of these fractures include **local flap closure** of a CSF leak and **primary bone grafting,** usually from cranium or distant sites, such as the ilium, to highly comminuted areas (e.g., NOE, orbital floors).

Lower face

Fractures of the mandible are classified by the type of fracture and location (Fig. 11.3-3), the most common being the subcondylar fracture. Fractures involving the mandibular body, such as a parasymphyseal fracture, may result in unstable mandibular segments. In cases of bilateral mandibular body fractures associated with symphyseal fractures, the mandible can be flail and fall posteriorly in the supine position, allowing the tongue to block off the airway. All of the fractures involving change in occlusion (Le Fort maxillary and all mandibular fractures) require reestablishment of a normal occlusion by the application of arch bars, temporary anchorage devices (TAD: a small, screw-like device placed between the roots of teeth), or other means of providing support for intermaxillary fixation (IMF). This may be combined with rigid fixation, most commonly internal plates. In some cases, rigid fixation will allow removal of the IMF at the end of the case; in others, IMF may be required for postop healing. Removal of the throat pack prior to final IMF is of paramount importance.

Trismus may be associated with any of the above injuries 2° direct injury to the muscles of mastication but is more commonly associated with fractures of these muscular attachments (e.g., mandible, zygoma). Associated **dentoalveolar fractures** of the maxilla or mandible may require preop wiring in the ER. The intent is to hold steady those segments with tenuous stability and blood supply. Intubation techniques should avoid displacing these segments. Fractures not involving change in occlusion (e.g., orbital zygomatic, nasal fracture) can be orally intubated. Most fractures with a change in occlusion should be nasally intubated with RAE or 60° curved connector. Exceptions include edentulous segments allowing tube to pass versus edentulous patient with a splint fabricated for oral intubation. Another preop consideration is the amount of blood loss at the scene or in the ER. Facial and scalp vessels can bleed profusely (hypovolemia), and patients may arrive in the OR with both anterior and posterior nasal packs in place (difficult ventilation).

The **surgical approach** depends on the extent of fractures and associated lacerations. Periorbital incisions can be external, on or below the lower eyelid and over the brow, or internal, along the lower eyelid conjunctiva. Upper facial repair may include a bicoronal approach (Fig. 11.3-4) designed to peel the face off the upper facial skeleton via an ear-to-ear scalp incision. Rainey clips are used to minimize scalp bleeding. Of note, periorbital dissection to explore and repair NOE or orbital floor fractures involves some retraction on the globe. This may cause ↓ HR and ↓ BP via the oculocardiac reflex. The mandible can be approached through external, preauricular or inferior border, or intraoral incisions. A panfacial fracture treatment protocol is illustrated in Figure 11.3-1.

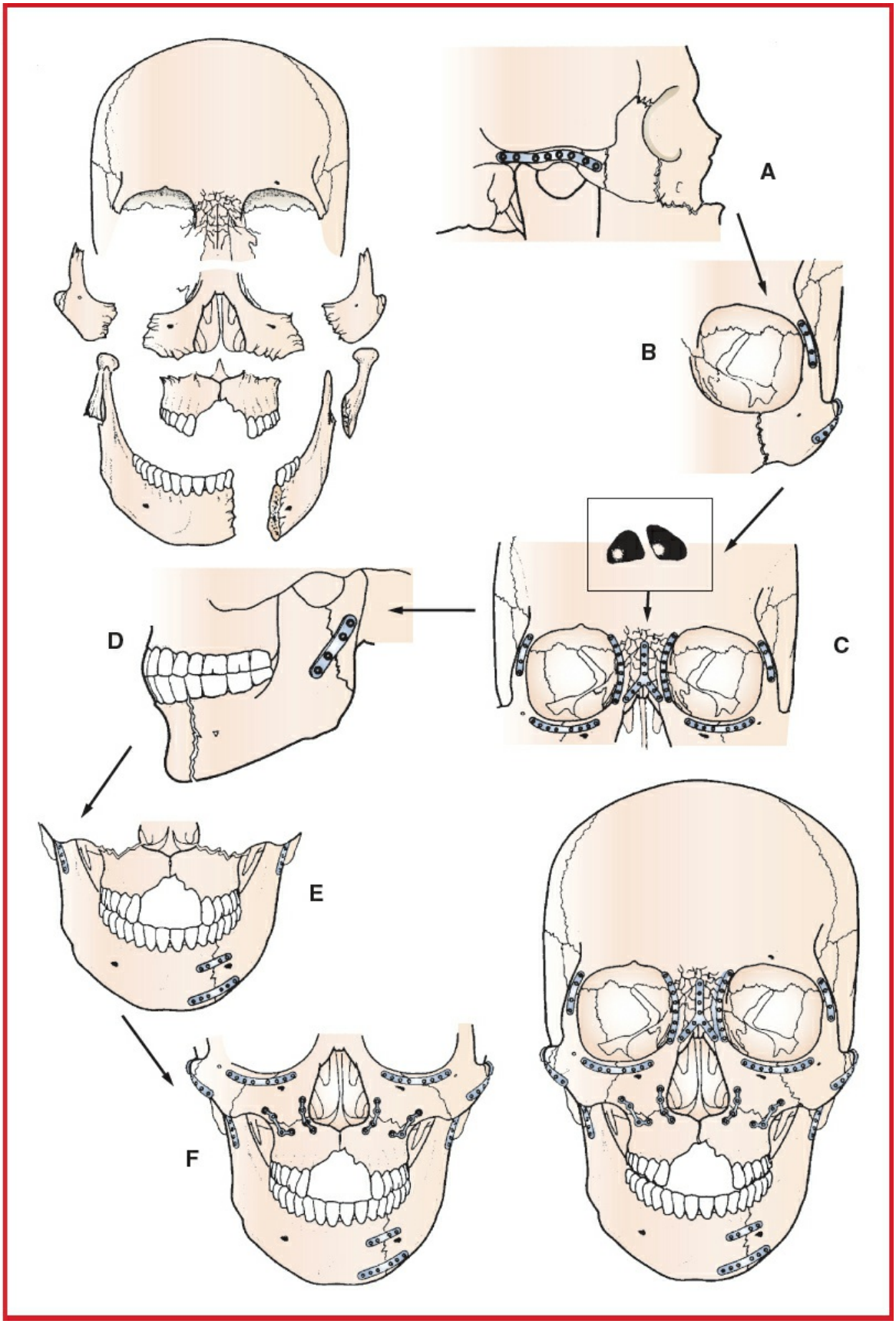

Figure 11.3-1 Panfacial fracture treatment protocol, based on reconstructing load-bearing structures of the facial skeleton. **A:** Projection of the midface is created by reconstructing the zygomatic arches, starting from the stable part of the temporal bone. **B:** The zygomas are fixed to the arches and to the

frontal bone to create the final projection of the midface. **C:** The width of the midface is reconstructed by repositioning the central midface (orbits and nose) to its correct position, in relation to the zygomas and frontal bone. Concomitantly, canthopexy is fixed, and the frontal bone and sinus fractures are treated. (This procedure is independent of the occlusion.) **D:** The posterior vertical height of the face is reconstructed by positioning and fixing the condylar fractures. **E:** Intermaxillary fixation is applied, and the mandible is reconstructed. **F:** Finally, the Le Fort I–level fractures are positioned to natural occlusion. (Reprinted from Booth PW, Schendel SA, Hausamen J-E, edsMaxillofacial Surgery, Vol. 1, 1st edition. Churchill Livingstone, Edinburgh: 1999. Copyright © 1999 Elsevier. With permission.)

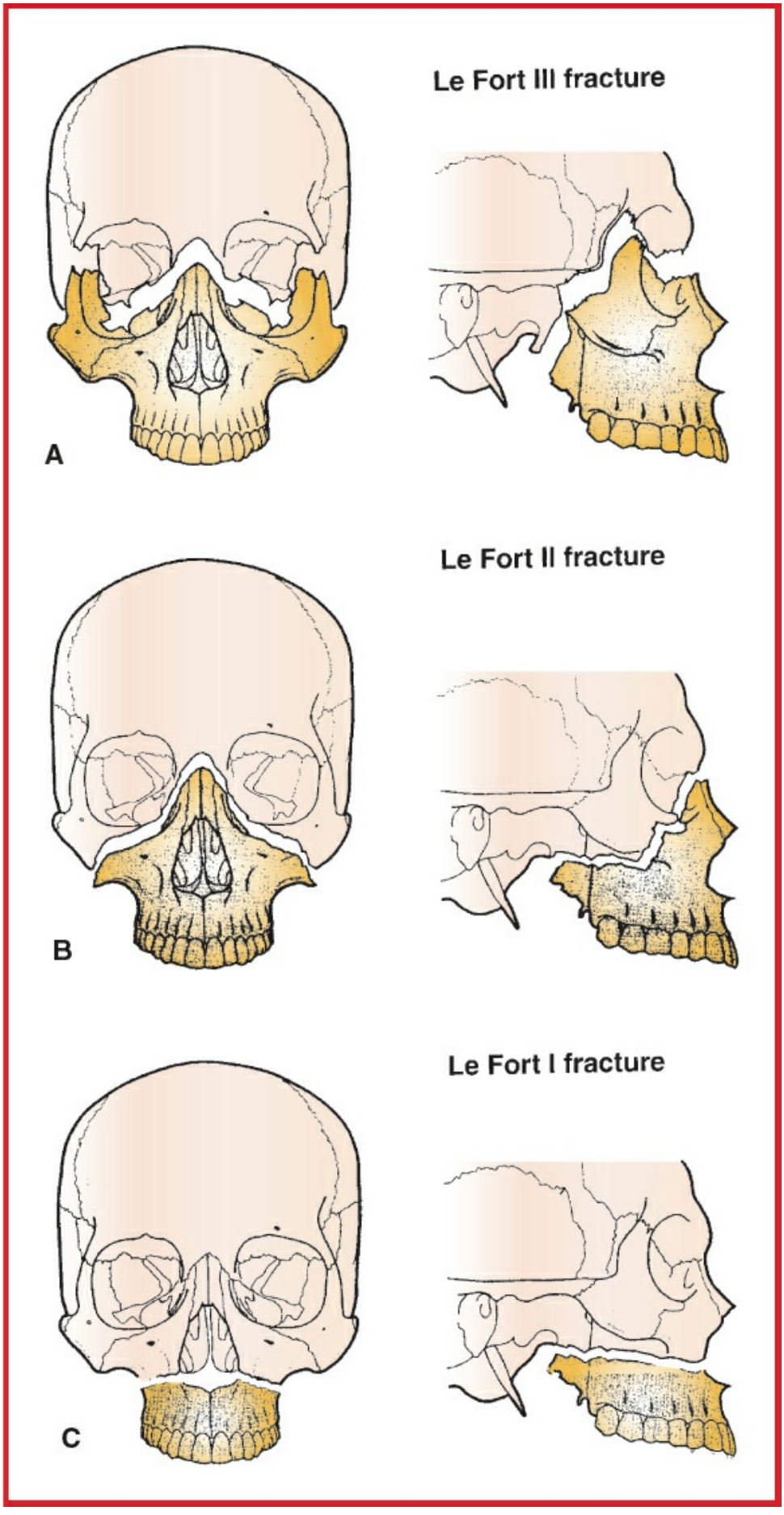
Le Fort III fracture
A
Le Fort II fracture
B
Le Fort I fracture
C

Figure 11.3-2 Schematic of the Le Fort fracture lines. **A:** Le Fort III involves separation of cranium from facial bone structure. **B:** Le Fort II is a pyramid-shaped fracture, including the dentition and nasal structures. **C:** Le Fort I is a horizontal fracture involving mobilization of dentition and maxilla. (Reprinted from Booth PW, Schendel SA, Hausamen J-E, edsMaxillofacial Surgery, Vol. 1, 1st edition. Churchill Livingstone, Edinburgh: 1999. Copyright © 1999 Elsevier. With permission.)

Variant procedure or approaches

Endoscopic approaches are being developed for multiple fracture sites. **Resorbable plates and screws**, especially for pediatric cases, can be applied through the same surgical approaches.

Usual preop diagnosis

Facial trauma

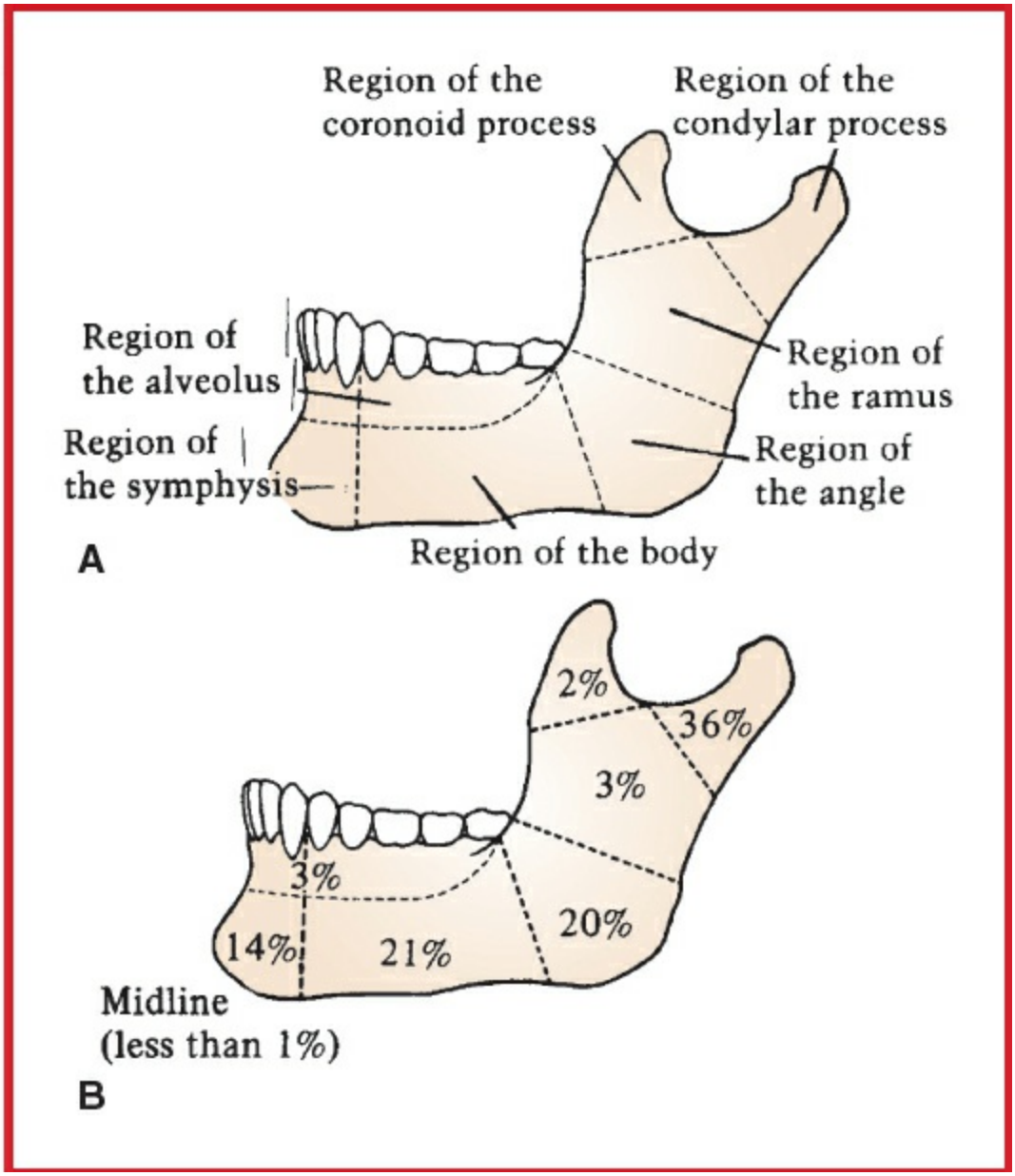

Figure 11.3-3 **A:** Anatomic regions of the mandible. **B:** Frequency of fractures in those regions. (Reproduced with permission from Aston SJ, Beasley RW, Thorne CH, eds:Grabb and Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

ERAS: For elective cases, preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status and possible benefits of weight reduction (time permitting), preop carb loading, VTE risk assessment, and postop pain management options. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

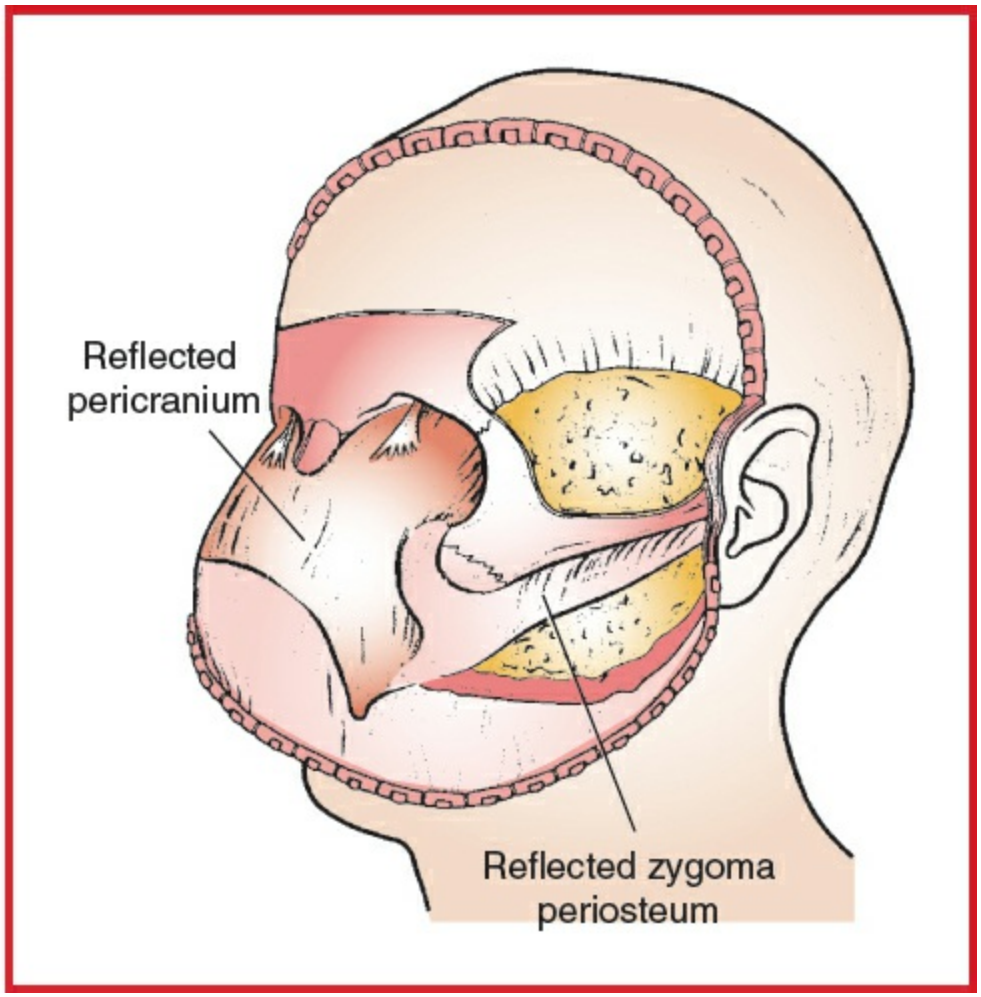

Figure 11.3-4 Bicoronal approach. (Reprinted from Booth PW, Schendel SA, Hausamen J-E, eds: Maxillofacial Surgery, Vol. 1, 1st edition. Churchill Livingstone, Edinburgh: 1999. Copyright © 1999 Elsevier. With permission.)

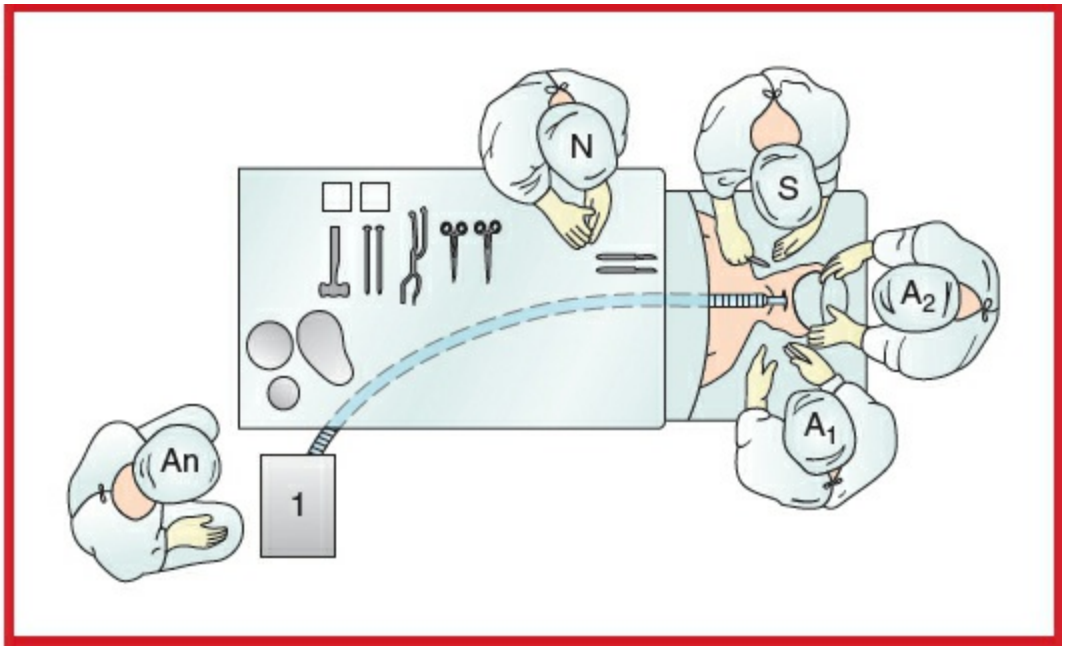

Figure 11.3-5 Standard anesthesia and surgical setup for a maxillofacial surgical procedure and certain craniofacial surgical procedures. The table may be rotated 90°–180° with anesthesia equipment and personnel at the foot or off to one side. (Reprinted from Bell WH, ed:Modern Practice of Orthognathic Surgery, Vol. I. WB Saunders, Philadelphia: 1992. Copyright © 1992 Elsevier. With permission.)

SUMMARY OF PROCEDURES

	Mandibular	Maxillary Orbital/Zygomatic	Nasal
Position	Supine	⇐	⇐
Incision	Intraoral; lateral, submandibular	Intraoral, ± subciliary; possibly coronal	Closed reducti possibl intrana
Special instrumentation	Air power tools; plate fixation; headlight	⇐ + Periorbital malleable retractors; Rowe disimpaction forceps; acrylic dental split	⇐
Unique considerations	Nasal RAE (sutured to dentition or septum); throat pack; corticosteroids periop to ↓ edema	Panfacial smash; airway swelling associated with head injury; burns	—

		or other system involvement. Consider preop tracheostomy. Close monitoring for and removal of stimulus until oculocardiac reflex recovery	
Antibiotics, etc.	Cefazolin 2 g iv	⇐ + Methylprednisolone 125 mg iv (adults)	⇐
Surgical time	1–3 h	1–6 h (bicoronal approach adds 1.5 h)	1 h
Closing considerations	NG at end of procedure, maintained for 24 h; IMF postop; **NB:** Throat pack removal	⇐	—
EBL	100–800 mL, depending on extent of fractures, need for graft harvest, patient age	⇐	⇐
Postop care	Airway or respiratory status may be compromised (preop and postop swelling/aspiration/associated injuries), requiring maintenance of intubation → ICU.	⇐	⇐
Mortality	Minimal (↑ due to associated injuries and blood loss)	⇐	⇐
Morbidity	Trismus	⇐	–
	Poor occlusion	⇐	–
	Drooling	⇐	–
	Poor cosmetic result	⇐	⇐

	Chronic pain/sensation changes	⇐	⇐
	Loss of taste	Loss of smell	⇐
	Visual problems/epiphora	–	
	Sinus problems	⇐	
	Breathing difficulty	⇐	
Pain score	4–8	4–8	4–8

PATIENT POPULATION CHARACTERISTICS

Age range	>4 yr
Male:Female	1:1 (varies by age group)
Incidence	The most common are nasal bones, zygoma and arch, mandible, and orbital floor (on the rise due to airbags in autos).
Etiology	Adults: Motor vehicle accidents (MVAs), mostly young males (43–67%); assaults (13–49%); sports related (4%); falls (4%); gunshot wounds (3%) **Children:** Uncommon: only ~5% of all facial fractures occur in ages <12 yr; falls (33%); MVA (28%); abuse (3%); dog bites (rare). 69% are periorbital or nasal.
Associated conditions	Airway compromise/closed head trauma (40%); extremity fractures (33%); thoracic injury (29%); open or radiographic brain injury (25%); intra-abdominal (12%); globe injuries (11%); oral trauma (11%); pelvic fractures (10%); C-spine fractures (4–10%); T-L spine injuries (4%); shock; multisystem trauma; burns; massive soft tissue loss. Mandibular fractures during MVAs are associated with a 65% incidence of life-threatening injuries and mortality of up to 8%; up to 1/3 of Le Fort fractures will require intubation, most often due to upper respiratory tract blood and secretions.

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

The forces required to produce facial fractures are considerable and frequently result in other associated trauma (e.g., closed head trauma; spine injuries; thoracic injury, including pneumothorax and myocardial contusion; intra-abdominal bleeding). Soft tissue injury to the tongue or larynx can make airway management difficult. When in doubt, a tracheostomy under local anesthesia or awake intubation should be considered. In mandible or maxillary fractures, nasal intubation is usually best (in the absence of basilar skull fracture or midface instability) because the patient will be placed in intermaxillary fixation (IMF; teeth brought together via wires or rubber bands) at the conclusion of the procedure. In malar or nasal bone fractures, the fixation may be precarious, making it undesirable to use mask ventilation at the termination of the procedure and necessitating awake extubation. Facial nerve monitoring may be required, contraindicating the use of persistent muscle relaxation.

Frequently, the anesthesiologist's first encounter with these patients is in the ER, where prompt airway management decisions are essential—often before diagnostic imaging studies are complete. These patients should be treated with full-stomach precautions and may have already aspirated. Patients may be unable to open their mouths 2° pain or mechanical factors. The cause of limited mouth opening should be determined before induction of anesthesia. Several options exist. Often, the airway can be managed simply by inserting an oropharyngeal airway; failing this, an emergency intubation or tracheostomy will be necessary. Blind nasal intubation should be avoided in patients with CSF rhinorrhea or other evidence of nasopharyngeal trauma, where the potential for creating false passages and additional trauma is significant. An awake oral intubation with topical anesthesia is often the safest approach. Emergency oral intubation may be complicated by an unstable C-spine and limited jaw opening, together with blood and debris in the oropharynx, making visualization difficult if not impossible. Often, the only recourse is tracheostomy under local anesthesia. As with any trauma victim, attention is first directed toward maintaining the airway and restoration of fluid volume. Repair of the facial fracture may be carried out incidental to the primary trauma surgery or, more often, is deferred until the patient's condition is stabilized. The following preop assessment will focus primarily on the patient coming to the OR for semielective repair of a facial fracture.

Airway	**Semielective:** Usually, facial swelling and intraoral bleeding will have resolved, although mouth opening may be limited 2° pain or mechanical factors. Airway management requires knowledge of the fracture site(s). Patients with a maxillary fracture may benefit from an oral intubation to allow inspection of the

	nasopharynx before nasal intubation and definitive repair. The possibility of an awake fiberoptic intubation should be discussed with the patient. Patients with an isolated orbital, zygomatic, or nasal fracture usually do not present airway management problems. The surgeon should be consulted regarding the preferred intubation route. **Trauma:** Airway and nasal obstruction following trauma can be extreme, as a result of soft tissue swelling and accumulated blood and secretions. The extent of facial fractures, particularly in the midface, should be identified as they may preclude nasal intubation. Mandibular fractures may make access to the oropharynx difficult. Unstable dentoalveolar fractures may require preop wiring or temporary screw fixation in the ER. In the case of massive trauma to the face, urgent tracheostomy should be considered. **Tests:** As indicated from H&P
Respiratory	**Trauma:** Evaluate for associated trauma and respiratory insufficiency 2° aspiration. ✓ that chest tubes are functioning properly. **Tests:** CXR; others as indicated from H&P
Cardiovascular	**Semielective:** Typically, several days will have elapsed since the initial trauma, and the patient should be hemodynamically stable. **Trauma:** Blunt chest trauma may be associated with myocardial contusion, pericardial effusion/tamponade, and aortic tear/dissection. **Tests:** ECG; others as indicated from H&P
Neurologic	**Semielective:** Document any neurologic deficits and altered mental status. Meningitis may occur in patients with persistent CSF rhinorrhea or pneumocephalus. **Trauma:** Intracranial injury may be associated with facial fractures. Patients with head trauma may have ↑ ICP; therefore, appropriate methods (e.g.,

	hyperventilation, smooth induction/intubation) are used to prevent further ↑ ICP. Basilar skull fractures preclude passage of nasotracheal and NG tubes. In the presence of otorrhea or rhinorrhea, positive-pressure mask ventilation is inadvisable due to the potential for causing pneumocephalus.
Musculoskeletal	**Tests:** Review skull and C-spine x-rays. **Semielective:** May be associated with other fractures and soft tissue trauma that may affect patient positioning. **Trauma:** C-spine injuries are commonly associated with facial injuries. The C-spine should be cleared by clinical and x-ray exam before transport to OR. If C-spine cannot be cleared, intubation should be done with the head in a neutral position (splinted or with axial stabilization), using direct FOL.
Hematologic	**Trauma:** Maxillary surgery may be associated with major blood loss. For elective cases, autologous donation should be encouraged. **Tests:** Hct; others as indicated from H&P
Laboratory	Other tests as indicated from H&P
Premedication	Standard premedication is appropriate for nontrauma, neurologically intact patients with normal airways. **Trauma:** Trauma patients should be considered to have full stomachs, and sedative premedications are best avoided. Aspiration prophylaxis with 0.3 M Na citrate (30 mL po), ± metoclopramide 10 mg iv ± ranitidine 50 mg iv, should be considered.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po or iv. Consider aprepitant 40 mg po or fosaprepitant 125 mg iv for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

The majority of patients presenting for elective procedures are otherwise healthy and have normal airways. In the case of facial trauma, however, intubation of the trachea may be impossible and a tracheostomy under local anesthesia may be lifesaving.

Induction	If there is any doubt regarding the ease of intubation, an awake FOL should be performed. Nasal intubation is preferred for patients with mandibular and maxillary (Le Fort) fractures involving a change in occlusion. Patients with orbital, zygomatic, or nasal fractures usually are intubated orally. In patients with normal airways, a standard induction is appropriate. Nasal or oral ETTs (RAE) or anode ETTs are commonly used to minimize intrusion into the surgical field. A nasal or oral ETT may not be appropriate in some patients (e.g., with midface fractures who also require maxillomandibular fixation). An alternative to tracheostomy in these patients is submental intubation: following oral ETT placement using a wire-reinforced tube, the surgeon will tunnel the covered connector end of the tube (with pilot balloon) through the floor of the mouth to emerge below the submental area of the mandible where it is reconnected to the ventilator.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia (Goal-Directed Management) and normothermia.
Maintenance	Standard maintenance; muscle relaxation usually is required except with facial nerve monitoring. Controlled ↓ BP may be appropriate. Administration of an antiemetic (e.g., ondansetron 4 mg iv ± aprepitant 125 mg iv) is beneficial in patients who have their jaws wired or banded together.
Emergence	Patients with difficult airways or with jaws wired together should be extubated when fully awake.

	Extubation over a tube changer may be appropriate. A wire cutter (or scissors for elastic bands) should be at the bedside at all times. Ensure that any throat packing has been removed before extubation. Thorough oropharyngeal suctioning is essential. NG tube may be used postop, so consider placement prior to extubation. Some patients with multiple trauma or extensive soft tissue swelling may require continued postop intubation and mechanical ventilation. Consider iv acetaminophen if po dose given >4–6 h ago.	
Blood and fluid requirements	Moderate—large blood loss IV: 16–18 ga × 1–2 **Trauma:** BSS @ 6–8 mL/h **Other:** BSS @ 2–4 mL/h	Blood loss from facial fractures or orthognathic procedures can be extensive. T&C patient so blood is immediately available in OR. Goal-Directed Fluid Management (see Appendix K, p. K-4)
Monitoring	Standard monitors ± Arterial line	Invasive monitoring may be required in patients with intracranial or other trauma or for controlled ↓ BP. Muscle relaxants will interfere with facial nerve monitoring.
Control of blood loss	Surgical hemostasis	Surgical hemostasis should control most bleeding in these procedures.
	Tranexamic acid	TXA: 1 g iv bolus + 1 g iv infused during surgery will ↓ need for transfusion (NB: 95% renal elimination).
	Topical vasoconstrictors	Topical vasoconstrictors, such as phenylephrine or

		cocaine, can be applied on the surgical field.
	Posterior oropharyngeal packing	Posterior oropharyngeal packing can keep blood from passing undetected into the upper GI tract.
	Controlled ↓ BP	Hypotensive anesthesia often can be achieved simply by increasing volatile anesthetic levels. The lowest acceptable MAP depends on preop BP (MAP) and comorbidities. Usual range = 50–65 mm Hg (MAP).
Positioning	✓ and pad pressure points ✓ eyes	Some surgeons prefer that the OR table be rotated 90° or 180°. Be prepared with long hoses and appropriate connectors. Consider protecting eyes with an ophthalmic ointment.
Complications	ETT damage	Nasal ETT may be wired inadvertently to the maxilla, making extubation difficult. In case of ETT damage, be prepared to reestablish the airway rapidly by reintubation, usually over an intubating stylet.
	Oculocardiac reflex ↓↓ HR + ↓ BP	Notify surgeon (stop surgical stimulus). Consider atropine and increasing depth of anesthesia.

POSTOPERATIVE

Complications	Airway obstruction	Wire cutters (or scissors) should be available at bedside to facilitate emergent reintubation or other form of airway management. Consider retained throat pack.
	PONV	Multimodal treatment of PONV is important.
Multimodal pain management	Acetaminophen NSAID Gabapentin Parenteral narcotics or PCA	Local anesthetic commonly infiltrated at end of procedure by surgeon. Continuous infusion catheters may be beneficial.
ERAS	PONV protocol	Encourage early enteral nutrition, Foley catheter removal, and early mobilization.

Suggested Readings

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LE FORT OSTEOTOMIES

SURGICAL CONSIDERATIONS

Description

Le Fort osteotomies are used to correct maxillary deformities. The most common is the **Le Fort I**, a transverse osteotomy, above the apices of the teeth, used to correct maxillary retrusion or maxillary vertical excess or deficiency. One of the goals in achieving improved function is to improve the occlusion, as classified by Angle (Fig. 11.3-6). One or both jaws may be moved to achieve normocclusion. An intraoral vestibular incision is used for this approach, followed by an osteotomy of the maxilla, with either a burr or a saw, and completed with osteotomes. The osteotomy extends through the maxillary sinus toward the ETT, within the piriform aperture. There is potential for nasal ETT damage with this maneuver. Of note, BP usually will increase at the start of the osteotomies, increasing bleeding if anesthesia/analgesia is inadequate. The maxilla is subsequently downfractured (Fig. 11.3-7) and mobilized with Rowe disimpaction forceps. This is when most of the bleeding occurs. Further interdental osteotomies creating multiple maxillary segments may be required. **Le Fort II** or **Le Fort III** maxillary osteotomies may be used to correct severe midfacial retrusion. In these cases, infraorbital incisions are used with either brow or coronal (Fig. 11.3-4) incisions. With maxillary advancements, iliac or cranial bone grafts are often necessary to close the bony gap created. Most of these patients have orthodontic appliances and will require IMF, with either wire or elastics at the end of the procedure, with or without a prefabricated splint. The maxilla is fixed rigidly in the new position with miniplates.

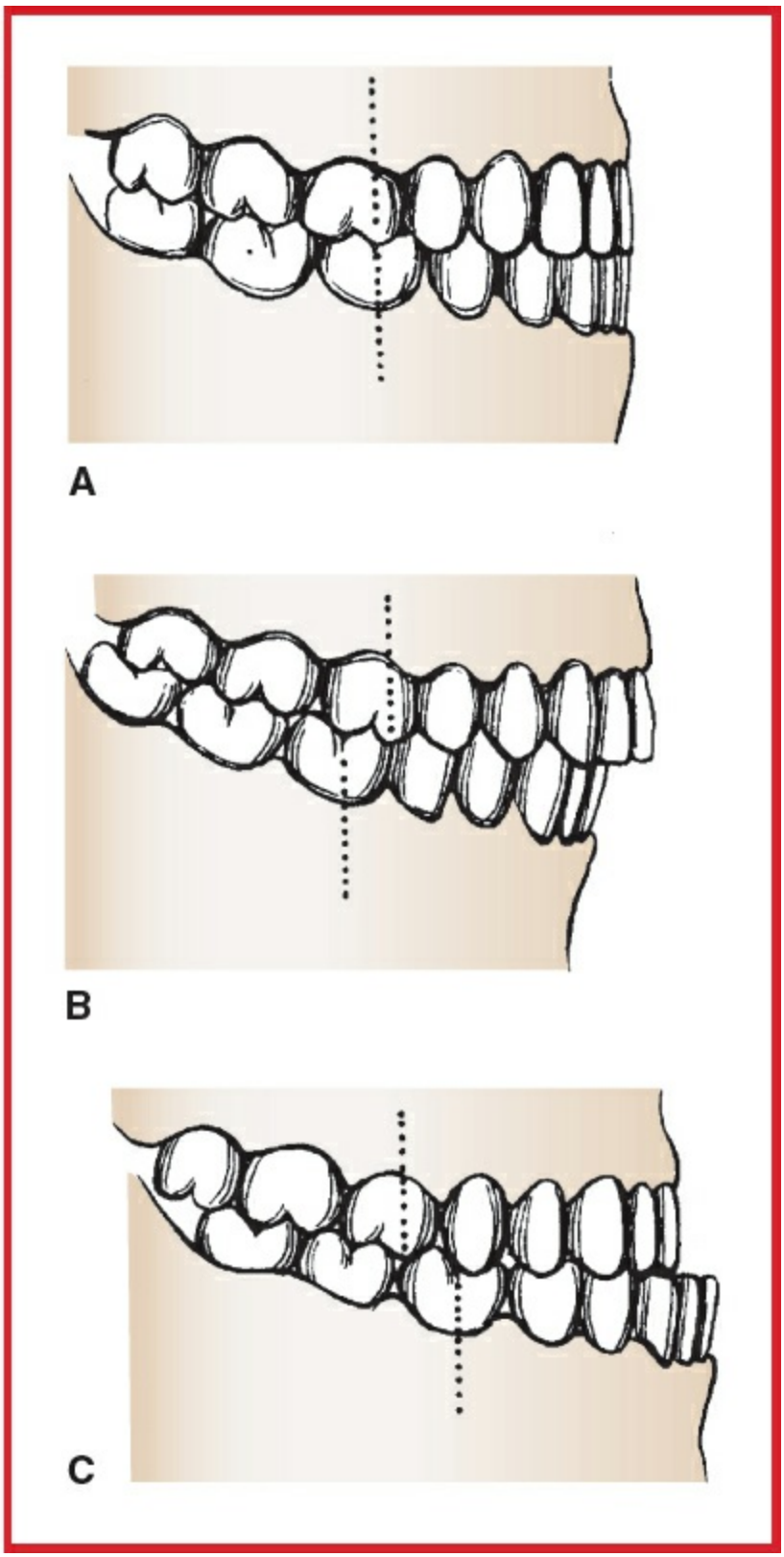

Figure 11.3-6 The Angle classification of occlusion. **A:** Class I, normal occlusion. **B:** Class II, retro-occlusion or mandibular deficiency. **C:** Class III, prognathic occlusion (maxillary deficiency or mandibular excess). The key relationships to be discerned are those of the first molar teeth, cuspids, and incisors. (Reproduced with permission from Aston SJ, Beasley RW, Thorne CH, edsGrabb and Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

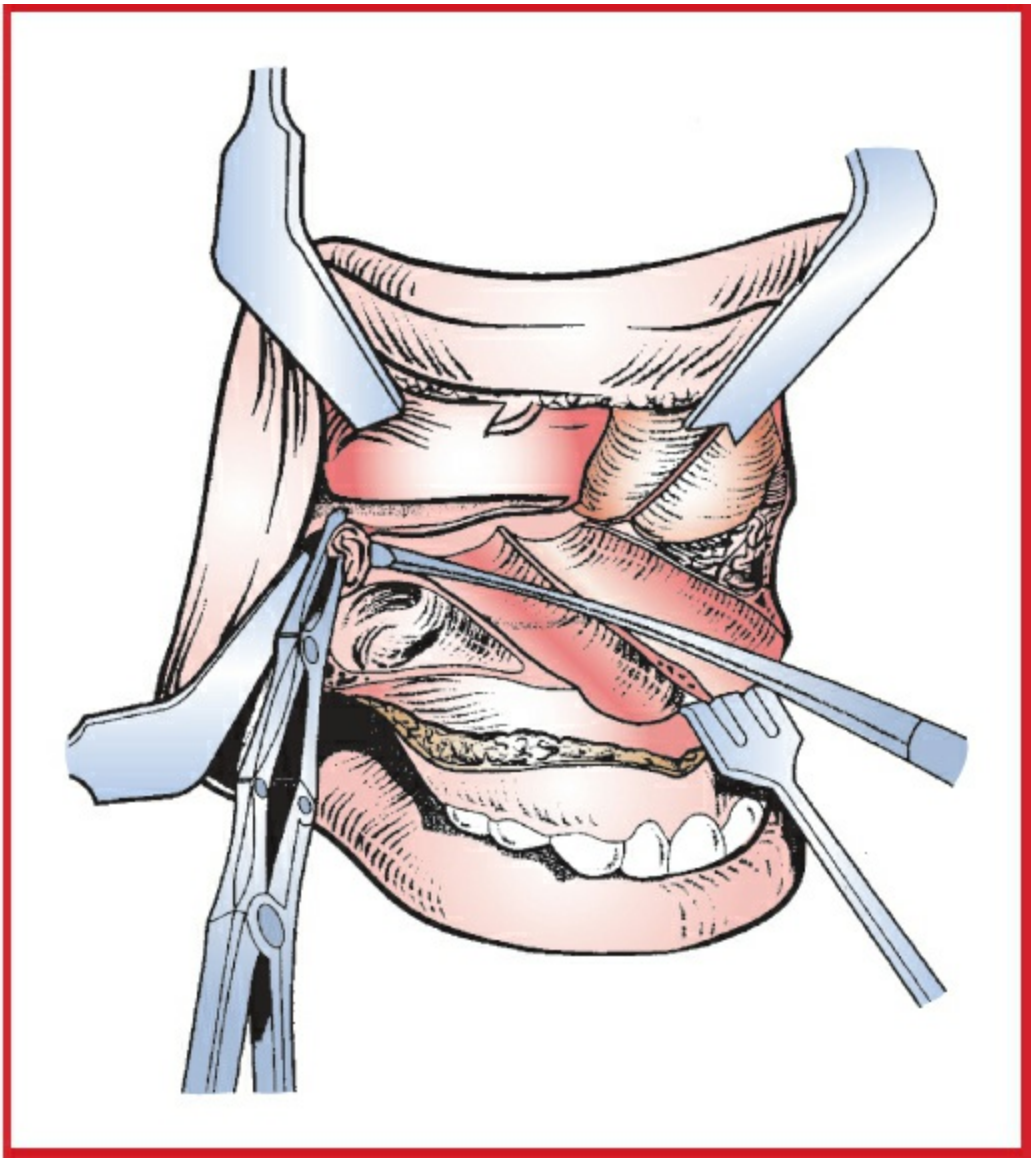

Figure 11.3-7 Removal of bone around the perpendicular plate of the palatine bone. The descending palatine vessels may be ligated. (Reprinted from Booth PW, Schendel SA, Hausamen J-E, eds: Maxillofacial Surgery, Vol. 1, 1st edition. Churchill Livingstone, Edinburgh: 1999. Copyright © 1999 Elsevier. With permission.)

Variant procedure or approaches

Recently, **distraction osteogenesis** after Le Fort osteotomy has been shown to be effective for correction of severe deformity that would be difficult to correct with single movements and internal fixation. This technique creates new bone as the osteotomized bones are slowly separated. No bone grafts are necessary. Distraction hardware is applied either internally or externally. External devices are stabilized via halo and compression bolts into the skull. IMF is not indicated, as the upper jaw must be free to be distracted in relation to the lower jaw. A second operation may be required for removal of distractor hardware. **Absorbable internal devices** also are available.

Usual preop diagnosis

Facial deformities; dentoskeletal dysplasia

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status and possible benefits of weight reduction (time permitting), preop carb loading, VTE risk assessment, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Le Fort I	Le Fort II	Le Fort III	Distractor
Position	Supine; table may be rotated 90° or 180°	⇐	⇐	⇐
Incision	Intraoral	Intraoral and facial ± coronal	⇐	⇐
Special instrumentation	Miniplates and screws; burr or saws	⇐	⇐	Distractors
Unique considerations	Jaw frequently closed (wires or elastic); nasal RAE or armored tube. **NB: Keep SBP < 100 mm Hg during osteotomy closure.**	⇐	⇐	No IMF
	With cranial bone graft harvest, the nasal ETT goes opposite to the donor side and is repositioned later.	⇐	⇐	⇐
Antibiotics, etc.	Cefazolin 2 g iv; methylprednisolone 125 mg iv (adults)	⇐	⇐	⇐
Surgical time	3–6 h	⇐	⇐	⇐

Closing considerations	**NB: Throat pack removal.** NG at end of case × 24 h. NSAIDs contraindicated.	⇐	⇐	⇐
EBL	400–800 mL	⇐	⇐	⇐
Postop care	PACU → room	ICU × 1 d	⇐	⇐
Mortality	Rare	⇐	⇐	⇐
Morbidity	Relapse Infection Bone/tooth loss: Uncommon Severe intraop bleeding: Uncommon Blindness: Very rare Temporomandibular joint dysfunction Nasal obstruction Nasolacrimal obstruction Oronasal fistulas (multipiece osteotomies, uncommon) Poor cosmetic result Sensory nerve dysfunction	⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐	⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐	⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ Distractor malfunction
Pain score	4	5	5	5

PATIENT POPULATION CHARACTERISTICS

Age range	15 yr–adulthood, usually <30 yr
Male:Female	1:1
Incidence	Up to 5% of population
Etiology	Usually developmental in nature; also cleft lip and palate patients Rarely syndromic: Apert (1/100,000); Crouzon (1/25,000)
Associated conditions	Usually none with developmental cases; sleep apnea; or part of a recognized condition associated with congenital anomalies (e.g., cleft lip and palate, proptotic eyes, severe mitten-hand syndactylies)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Mandibular Osteotomies/Genioplasty.

Suggested Readings

1. Adke M, Medonca C: Concealed airway complication during LeFort I osteotomy Anesthesia 2003; 58(3):294–5.
2. Bidoli SJ, Dumont L, Mattys M, et al: A serious anesthetic complication of a Lefort osteotomy. Eur J Anesthesiol 1999; 16(3):201–3.
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MANDIBULAR OSTEOTOMIES/GENIOPLASTY

SURGICAL CONSIDERATIONS

Description

Mandibular deformities include either a retruded mandible or a prognathic mandible involving a malocclusion (class II or III) and may occur in combination with a smal chin (microgenia). Surgical correction of the basic mandibular deformity involves either advancing or retruding the mandible. The most common procedure for this is the **sagittal ramus split osteotomy** (Fig. 11.3-8). An intraoral approach to the mandible is used to sagittally split the mandible (BSSO) with the inferior alveolar nerve solely within the anterior segment, such that the tooth-bearing anterior segment can slide forward or backward to correct the original deformity. A variety of other techniques of mandibular osteotomies exist, often involving the ramus area of the mandible, and are performed via an intraoral approach.

In some very large deformities, an external incision (**Risdon** type) and bone graft placement may be necessary to complete the mandibular ramus reconstruction. Many patients will be treated for dentoskeletal deformities with a combination of Le Fort movement and sagittal split osteotomies of the mandible. When the mandible is set back, mandibular bone is resected and often can be used in combined procedures as bone

graft for the Le Fort osteotomy. This avoids cranial bone harvest and, therefore, avoids repositioning the ETT during the procedure for cranial bone access and avoids donor site morbidity. Occasionally, deformities may be corrected by mandibular body osteotomies.

Rigid fixation of mandibular osteotomies is often accomplished by the use of small miniplates and screws. Fixation (if needed) also can be accomplished with elastic traction (rarely, wire fixation) between mandible and maxilla (IMF), placed either at the time of surgery or several days following, and held in position for 1–2 wk. These procedures may be combined with a **genioplasty** to correct the chin deformity, or genioplasty may be performed as an isolated procedure. The most common type is a horizontal osteotomy of the inferior mandible, with the chin segment repositioned with internal fixation (Fig. 11.3-9A). Augmentation of the chin also is accomplished with alloplastic onlay materials (Fig. 11.3-9B) placed via either the oral route or the extraoral route through a small submental incision. As an isolated procedure, genioplasty is performed most frequently with local anesthesia and sedation.

Maxillomandibular advancement, otherwise known as a **bimax procedure**, is frequently used in the correction of obstructive sleep apnea (OSA). The advancement is usually large in the neighborhood of 1 cm and frequently requires bone grafts. These patients commonly have hypertension and other medical conditions associated with OSA and can be difficult to manage both intraop and postop. Most of these patients will be transferred to the ICU for the first postop night.

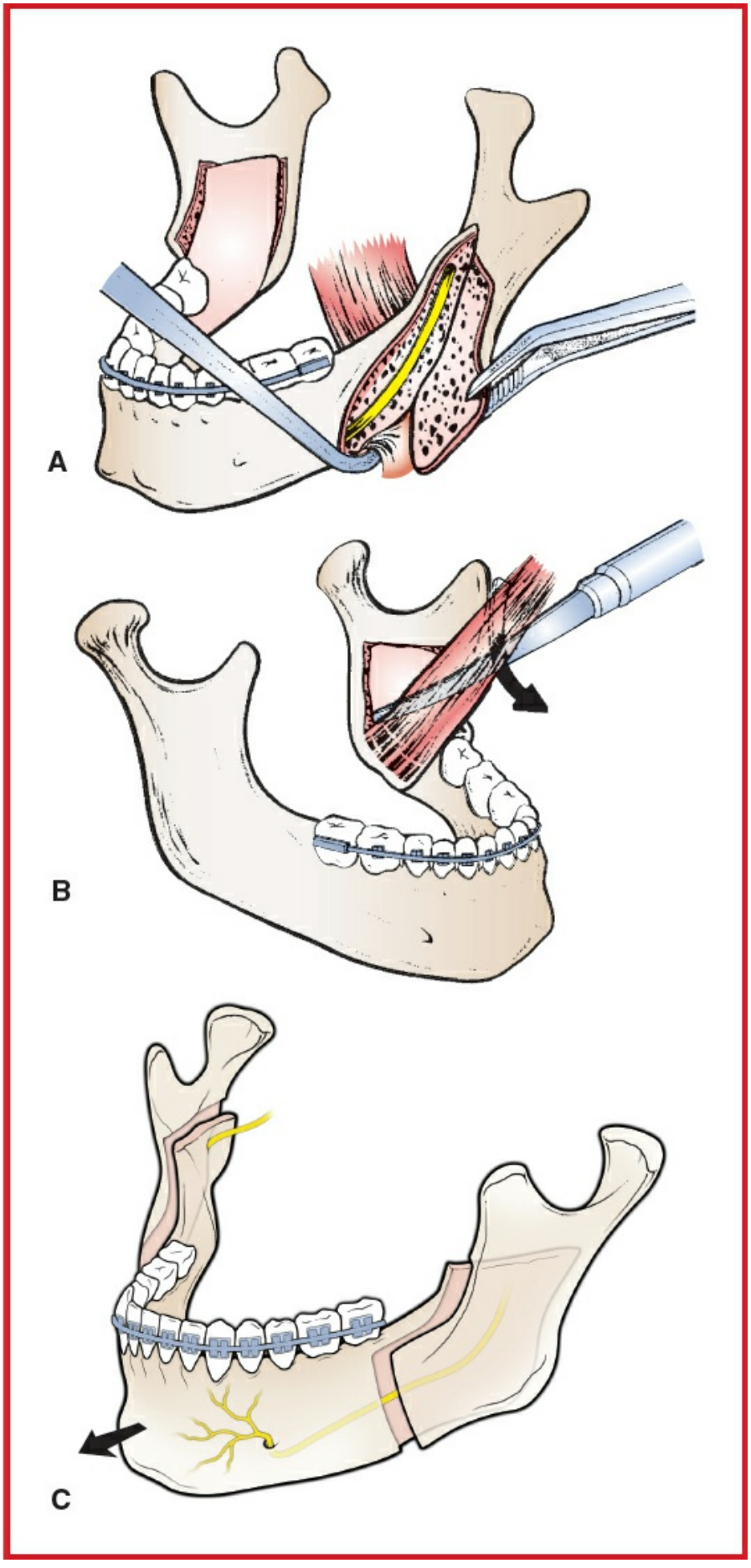
A
B
C

Figure 11.3-8 **A, B:** "J" stripper used to remove muscle attachments from medial aspect of distal segment. Used through the osteotomy split. (Reprinted from Booth PW, Schendel SA, Hausamen J-E, eds: Maxillofacial Surgery, Vol. 1, 1st edition. Churchill Livingstone, Edinburgh: 1999. Copyright © 1999 Elsevier. With permission.) **C:** Bilateral sagittal split osteotomy (BSSO).

Variant procedure or approaches

Distraction osteogenesis is being used more frequently in treating certain acquired and congenital jaw deformities. This involves a partial mandibular osteotomy and placement of a distraction device (Fig. 11.3-10). Depending on the application, this may be an external or internal device. External devices are visible over the skin with percutaneous pins into the bone. Internal devices are placed beneath the oral soft tissues, with a single adjustment pin exposed.

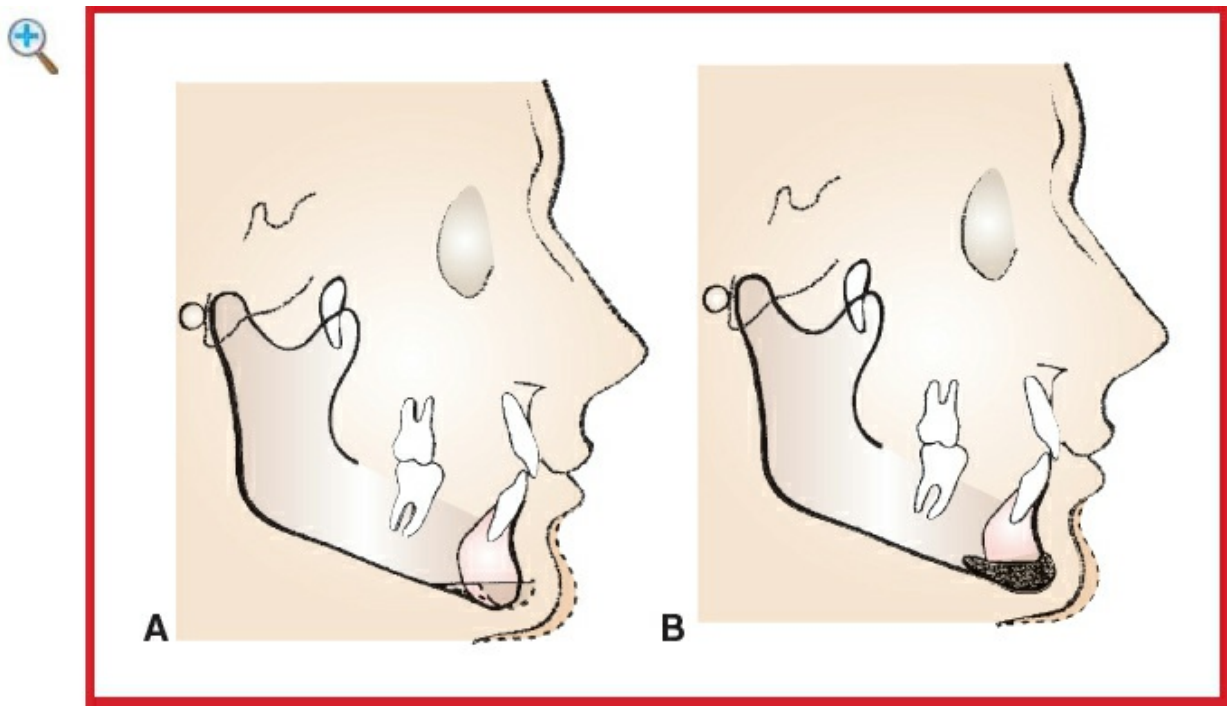

Figure 11.3-9 An osseous genioplasty (**A**) can be used to augment the chin, move it posteriorly, alter its vertical position, or change the transverse position of the chin. Alloplastic implants (**B**) can be used to augment the chin anteriorly. These are less effective for vertical augmentation. (Reprinted from Booth PW, Schendel SA, Hausamen J-E, edsMaxillofacial Surgery, Vol. 1, 1st edition. Churchill Livingstone, Edinburgh: 1999. Copyright © 1999 Elsevier. With permission.)

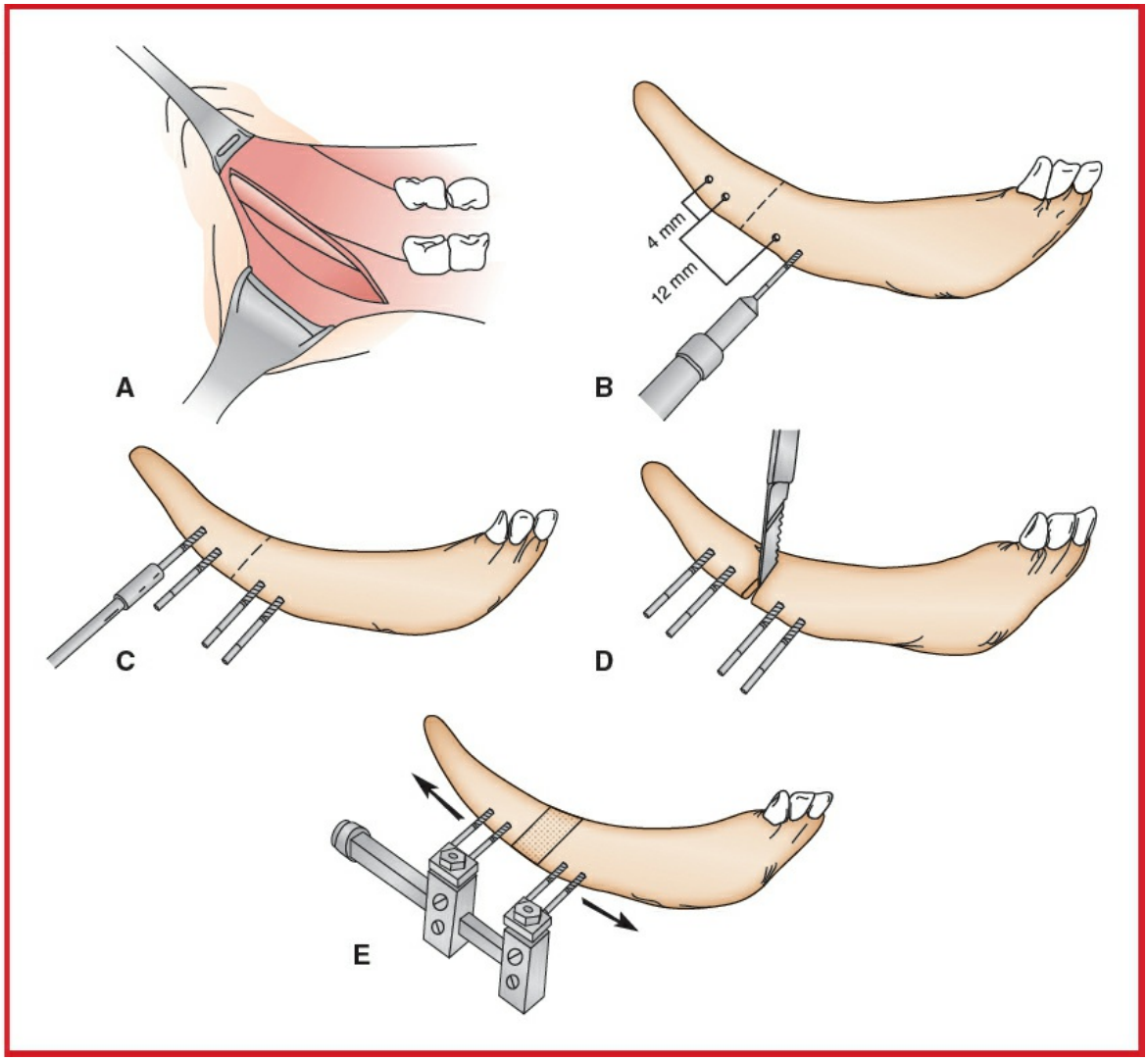

Figure 11.3-10 Mandibular distraction technique. **A:** An intraoral incision is made along the oblique line of the mandibular remnant. **B:** Sites of the pinholes and proposed osteotomy (interrupted line). **C:** Pins have been inserted. **D:** The osteotomy is performed. **E:** Commencement of distraction with the appliance in position. The arrows designate the movement of the mandibular segments with formation of bony regenerate in the resulting gap. (Reproduced with permission from Aston SJ, Beasley RW, Thorne CHM, eds: Grabb and Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

Usual preop diagnosis

Mandibular deformity

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status and possible benefits of weight reduction (time permitting), preop carb loading, VTE risk assessment, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURE

Position	Supine; table may be rotated 90° or 180°. Nasal RAE tube toward head of bed (sutured through nasal septum), padded, and secured to forehead; shoulder roll; neck extended
Incision	Usually oral but may be external in the submental or posterior mandibular area; preinjection with local anesthetic with epinephrine
Special instrumentation	Miniplates and screws; burrs/saws; osteotomes; distractor for distraction osteogenesis; throat pack
Unique considerations	Scleral lubricant and shields needed. Postop, patient may have IMF with inability to open the mouth (IMF not used with distractor cases). **NB: Remove any throat pack** before extubation; thorough oro- and nasopharyngeal suction.
Antibiotics, etc.	Cefazolin 2 g iv; methylprednisolone 125 mg iv (adults)
Surgical time	Genioplasty: 0.5–1 h Mandibular osteotomy: 2–4 h
EBL	Genioplasty: 50 mL Mandibular osteotomy: 100–200 mL
Postop care	PACU → room. If sleep apnea present, ICU overnight + extubation
Mortality	Rare
Morbidity	Mandibular relapse: ≤30% Mental nerve paresthesia: 5–20% Lingual nerve injury: 1–16% Infection/nonunion: <1% Facial nerve injury: Rare (most reported cases resolve without treatment) Aseptic necrosis (buccal plate or genioplasty fragment) Worsening TMJ problems Adverse cosmetic result
Pain score	4

PATIENT POPULATION CHARACTERISTICS	
Age range	Infant-adult
Male:Female	Unknown
Incidence	Unknown
Etiology	Developmental (90%); acquired (10%)
Associated conditions	Usually none with developmental cases; sleep apnea; congenitally small mandible may be associated with a large tongue and cleft palate (Pierre Robin syndrome), hemifacial microsomia (which may be associated with heart, vertebral, and other anomalies), Treacher Collins syndrome, or Nager syndrome (many of the congenital cases may be tracheostomy and gastrostomy dependent, with associated TMJ ankylosis).

ANESTHETIC CONSIDERATIONS

(Procedures covered: Le Fort osteotomies; mandibular osteotomies; genioplasty)

PREOPERATIVE

These surgeries are usually performed on patients with facial disproportion. In general, this patient population is young and healthy; however, many of them will present with challenging airway management problems. In addition, facial disproportion will often accompany congenital anomalies (e.g., Crouzon, Apert, Pierre Robin, or Treacher Collins syndromes). (For discussion of specific syndromes, see Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Limbs.)

Airway	As usual, a careful airway evaluation is essential because many of these patients have abnormal airway anatomy and may be difficult to mask ventilate or intubate. Visual inspection often reveals the reasons for the surgery and allows the anesthesiologist to determine the safest approach to intubation. When a difficult intubation is anticipated, the need for awake fiberoptic intubation should be

	discussed with the patient.
Respiratory	Consider the anesthetic implications of associated congenital syndromes in this patient population. Obstructive sleep apnea (OSA) also may be associated with patients presenting for mandibular surgery. **Tests:** As indicated from H&P
Cardiovascular	As above, consider the implications of possible congenital syndromes. Assess whether patient is a suitable candidate for the use of controlled ↓ BP, particularly those undergoing maxillary procedures. **Tests:** As indicated from H&P
Hematologic	Encourage autologous blood donation for maxillary procedures. **Tests:** Hct
Laboratory	Other tests as indicated from H&P
Premedication	Standard premedication is usually appropriate.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss possibility of nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po. Consider aprepitant 40 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA

Induction	If there is any doubt regarding the ease of intubation or ability to mask ventilate, an awake FOL should be performed. Nasal intubation is preferred for patients undergoing elective mandibular or maxillary osteotomies, as well as genioplasty. In patients with normal airways, a standard induction is appropriate. Nasal or oral ETTs (RAE) or anode ETTs are

	commonly used to minimize intrusion into the surgical field.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia (Goal-Directed Management) and normothermia. Consider preincision placement of nerve blocks (see Appendix K, p. K-6).	
Maintenance	Standard maintenance; muscle relaxation is usually required. Administration of an antiemetic (e.g., ondansetron 4 mg iv ± fosaprepitant 125 mg iv) is essential in patients who have their jaws wired or banded together.	
Emergence	Patients with difficult airways or with their jaws wired (or banded) together should be extubated when fully awake. Perform thorough oropharyngeal suctioning. If not placed previously, an NG tube is often placed before extubation. A wire cutter (or scissors for elastic bands) should be at the bedside at all times. Ensure that all throat packing has been removed before extubation. Consider iv acetaminophen if po dose given >4–6 h ago.	
Blood and fluid requirements	Moderate—large blood loss IV: 16–18 ga × 1–2 BSS @ 5–8 mL/kg/h	Maxillary osteotomies may be associated with major blood loss (e.g., 1500–2000 mL). The majority of blood loss occurs when the maxilla is downfractured. Controlled ↓ BP may be particularly useful during this part of the case (see Control of Blood Loss, p. 1256). Blood should be readily available for this and all maxillary procedures. Goal-Directed Fluid Management (see

		Appendix K, p. K-4)
Monitoring	Standard monitors ± Arterial line ± CVP line or 2nd iv	Direct arterial pressure measurements are useful for deliberate ↓ BP. Central venous access or a 2nd peripheral iv may be useful for vasodilator infusions.
Positioning	✓ and pad pressure points ✓ eyes	Eyes should be protected with an ophthalmic ointment and eye shields or possible tarsorrhaphy by the surgeons. Some surgeons prefer to have the OR table rotated 90° or 180°. Be prepared with circuit extension tubing.
Complications	ETT damage Hemorrhage	ETT may be cut during maxillary osteotomy, necessitating rapid reintubation.

POSTOPERATIVE

Complications	Airway obstruction	Wire cutters (or scissors) should be available at bedside to facilitate emergent reinduction or other form of airway management. Consider retained throat pack.
	PONV	Multimodal treatment of nausea is important.
Pain management	Parenteral narcotics or PCA with antiemetics Acetaminophen NSAID	Regional or local blocks. Continuous infusion catheters may be beneficial.

	Gabapentin	
ERAS	PONV protocol	Encourage early enteral nutrition, Foley catheter removal, and early mobilization.

Suggested Readings

1. Adke M, Mendonca S: Concealed airway complication during LeFort I osteotomy Anesthesia 2003; 58(3):294–5.
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CHAPTER 11.4

Functional Restoration

SURGEONS

James Chang, MD
David M. Kahn, MD
Jacinta Leyden, BS

ANESTHESIOLOGISTS

Richard A. Jaffe, MD, PhD
Vanila M. Singh, MD

MICROSURGERY FREE-FLAP RECONSTRUCTION

SURGICAL CONSIDERATIONS

James Chang and Jacinta Leyden

Description

Microsurgical reconstruction involves moving tissue from one site of the body to another (see Fig. 11.4-1, Table 11.4-1). This may be muscle, skin, bone, or any combination of these tissues. An artery and vein that supply the tissues are connected to an artery and vein at the new recipient site, thereby reestablishing blood flow and ensuring tissue survival. Once transplanted, the tissue is molded and shaped to replace the missing part. Vascular anastomoses are performed on vessels as small as 1.5 mm in diameter. Complex reconstructions may require up to 12 h of GA with significant blood loss and fluid shifts. Patients with comorbid conditions may need additional medical tests before surgery to ensure that they are able to withstand this type of operation.

Peripheral, central, and arterial lines should be placed at the start of the case only after consultation with the reconstructive surgeon. For example, radial forearm flap may be

injured by placement of a peripheral iv in the antecubital fossa or within the body of the flap. The neck is a common site for microvascular anastomoses in head and neck reconstruction. The placement of internal jugular lines should be discussed with the surgeon before surgery. The rectus muscle flap relies on the deep inferior epigastric vessels for its perfusion. Femoral arterial or venous line placement may injure these vessels and is, therefore, contraindicated. In bilateral breast reconstruction with free flaps, the iv lines should be placed in the lower extremities if possible. The reconstructive surgeon will try to operate in conjunction with the extirpative surgeon to minimize operating time. This often necessitates repositioning the patient as the case progresses.

Microsurgical reconstructions are often long operations, and large surface areas of the patient are exposed during the surgery. The patient's core temperature should be monitored closely with the use of a bladder or esophageal temperature probe. Body and fluid warmers should be used routinely to maintain the patient's body temperature. There is no standard practice for anticoagulation in microsurgery. No randomized prospective clinical trial has definitively documented the efficacy of a particular type of anticoagulation in routine reconstructive microsurgery. Aspirin, dextran, and heparin are the most commonly used agents. Close communication between the surgeon and anesthesiologist is critical so that the desired agent is administered at the appropriate time.

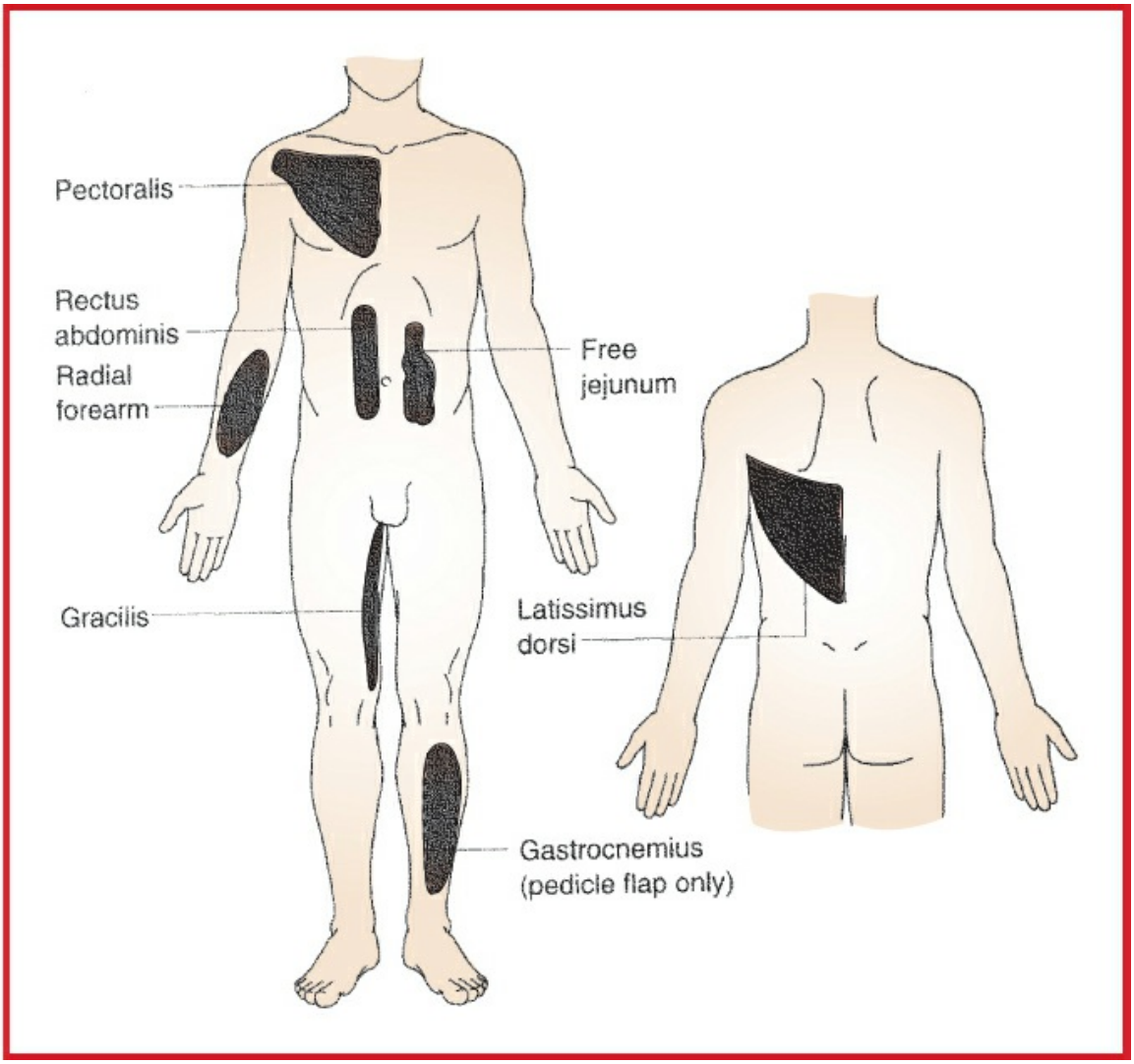

Figure 11.4-1 Locations of commonly used flaps. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al., eds: Surgery: Principles and Practice, 2nd edition. Lippincott-Raven, Philadelphia: 1997.)

Table 11.4-1 Types of Flaps

Reconstruction	Commonly Used Flaps	Location	Positioning
Head and neck	Fibula	Leg	Supine
	Radial forearm	Arm	Supine
	Scapula	Back	Lateral decubitus
	Iliac crest	Hip	Supine
	Anterolateral thigh	Thigh	Supine

	Gracilis	Thigh	Supine
Breast	TRAM	Abdomen	Supine
	Gluteal	Buttocks	Lateral decubitus
	Rubens/iliac crest	Hip	Supine
	Tensor fascia lata	Lateral thigh	Supine
	Latissimus dorsi	Back	Lateral decubitus
Lower extremity	Rectus abdominis	Abdomen	Supine
	Latissimus dorsi	Back	Lateral decubitus
	Serratus anterior	Back	Lateral decubitus
	Gracilis	Thigh	Supine

The survival of the flap relies on the patency of the anastomoses. Thrombosis requires reexploration and may lead to complete loss of the tissue. If thrombosis is encountered during reexploration, tissue plasminogen activator (tPA) may sometimes be administered to help reestablish patency. Anastomotic patency is diminished by vasospasm or vascular constriction. The common causes of vasoconstriction include dehydration, hypothermia, pain, and administration of vasoconstrictors; therefore, during microsurgery, vasoconstrictors are contraindicated and should be given only when absolutely necessary, after consultation with the reconstructive surgeon. The patient must be adequately hydrated so that there is good perfusion to the transplanted tissue. Diuretics should be avoided. Postop pain control is important to prevent vasoconstriction on emergence from anesthesia. After surgery, patients are transferred to an area of the hospital where the free flap can be monitored. In many hospitals, this is an ICU.

Usual preop diagnosis

Trauma, cancer, chronic wounds, congenital anomalies, and burns are some of the common diagnoses that result in the need for microsurgical reconstruction.

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status and possible benefits of weight reduction (time permitting), preop carb loading, VTE risk assessment, and postop pain management options. **See Appendix K: Enhanced Recovery After Surgery, p. K-1.**

SUMMARY OF PROCEDURE

Position	Requirements of the recipient site take precedence; optimal position for the donor site is then considered.
Incision	Each site will have specific incision.
Special instrumentation	Microscope; tourniquet for extremities
Unique considerations	Multiple surgical teams; avoid hypothermia; ± anticoagulation; if intraop nerve stimulation is planned, muscle relaxants should be avoided.
Antibiotics	Cefazolin (2 g iv) in uncomplicated cases; broader coverage in complicated circumstances
Surgical time	Simple flap: 4–6 h Complex cases: 8–12 h
Closing considerations	Splints and dressings should be secured before emergence.
EBL	Skin flap: 200 mL Muscle flap: 200–500 mL Bone flap: 500–1000 mL
Postop care	ICU for flap perfusion monitoring
Mortality	<2% (usually associated with coexisting disease)
Morbidity	Soft tissue complications: 20–30% Vascular complications requiring reexploration: 5–10% Flap failure: 5%
Pain score	3–5

PATIENT POPULATION CHARACTERISTICS

Age range	2–90 yr
Male:Female	1:1
Incidence	50–200/yr/major center
Etiology	Malignancy; trauma; chronic infection
	Complications of underlying disease (e.g., anemia)

Associated conditions	

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

These surgeries are carried out on patients who have sustained major soft tissue losses and require flap procedures to cover the defects. There are four typical patient populations presenting for this surgery: (a) those presenting for reconstruction following cancer surgery (e.g., radical neck dissection and mastectomy); (b) patients following trauma, usually with upper or lower limb defects; (c) patients with congenital defects; and (d) previous burn victims. In general, these patients should present few problems for the anesthesiologist. In a patient with a congenital lesion, however, it is prudent to look for evidence of CHD, musculoskeletal deformities, and airway problems.

Respiratory	Exposure of the thorax to radiation may produce pathologic changes in the lungs and related structures, including pneumonitis (→ dyspnea, hypoxemia) that may progress to fibrosis (→ ↓ pulmonary compliance). Tracheal or bronchial fibrosis may → partial airway obstruction. Many burn patients have pulmonary pathology 2° smoke inhalation injury. The pathology usually includes edema, inflammation, and loss of ciliary activity but can vary depending on the length and amount of smoke exposure, as well as the composition of the material that burned. Patients with breast cancer may have been treated with chemotherapeutic agents (e.g., methotrexate, cyclophosphamide, bleomycin) that may cause pulmonary fibrosis, interstitial infiltrates, and pleural effusions. **Tests:** Consider CXR, PFT, and pulmonary consult.
Cardiovascular	Exposure of the heart to radiation may produce pathologic changes in the heart and related structures, including accelerated atherosclerotic changes, myocardial fibrosis, pericarditis, and valvular dysfunction. Patients with breast cancer may have been treated with doxorubicin (Adriamycin™),

	which may produce cardiomyopathy (usually seen at total doses >550 mg/m^2) → CHF. XRT increases the incidence of clinically significant cardiomyopathy.
Hematologic	Myelosuppression may be present in patients with Hx of chemotherapy. **Tests:** CBC, with differential and Plt count
Laboratory	Other tests as indicated from H&P
Premedication	Standard premedication
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss possibility of nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po. Consider aprepitant 40–80 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: Coordinate iv and/or invasive monitoring sites with the surgical team. Adjunctive regional anesthesia is an option for the appropriate patient who will not be anticoagulated. Some authors propose that the resultant vasodilation causes ↑ blood flow through the flap, but this has not been definitely shown in clinical trials.

Induction	Standard induction and intubation. Avoid succinylcholine in burn patients.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia (Goal-Directed Management) and normothermia. Consider preincision placement of nerve blocks (see Appendix K, p. K-6).
Maintenance	Standard maintenance with sevoflurane. Muscle relaxation usually is required. The patient must be kept warm and well hydrated to minimize peripheral vasoconstriction, which might impair graft perfusion. Surgeon may request intraop anticoagulation, usually in the form of aspirin, dextran, or heparin.

Emergence	Smooth emergence to avoid disrupting the surgical repair. Patients usually are transported to the ICU for continuous monitoring of flap perfusion. Consider nerve block placement or reinforcement if initially placed >4–6 h ago (see Appendix K, p. K-5). Consider iv acetaminophen if po dose given >4–6 h ago.	
Blood and fluid requirements	Moderate blood loss IV: 16 ga × 1 BSS @ 2–4 mL/kg/h Warm fluids. Humidify gases.	Keep patient warm, and maintain a goal-directed fluid balance. An Hct of 30–35% will provide adequate O_2 transport while minimizing viscosity effects on perfusion. Dextran 40 may be used to further ↓ viscosity, thereby ↑ flap blood flow. Goal-Directed Fluid Management (see Appendix K, p. K-4)
Monitoring	Standard monitors UO ± Arterial line	An arterial line may be useful for prolonged procedures where regular ABGs and blood chemistries will be needed.
Positioning	✓ and pad pressure points. ✓ eyes.	These can be very lengthy surgeries, and careful monitoring of pressure points is essential.
Complications	Hypothermia	Maintain normal body temperature with warming blankets and

		fluid and airway warmers.
	Decubitus ulcer	Pressure necrosis can occur in as little as 2 h. Carefully pad and repeatedly ✓ pressure points.
	Dextran reaction	If the patient develops any immediate cardiopulmonary changes, dextran infusion should be stopped immediately.

POSTOPERATIVE

Complications	Arterial thrombosis	May require reexploration.
	Hematoma	May require reexploration.
Multimodal pain management	Acetaminophen NSAID Gabapentin	Consider a multimodal approach using a combination of gabapentin, iv acetaminophen, opiates, and regional nerve block. Continuous infusion catheters may be beneficial.
	Parenteral opiates PCA	Pain should be treated promptly to minimize reflex peripheral vasoconstriction and impaired graft perfusion.
ERAS	PONV protocol	Encourage early enteral nutrition, Foley catheter removal, and early mobilization.

Suggested Readings

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MICROSURGERY REPLANTATION

SURGICAL CONSIDERATIONS

Description

Patients who require replantation surgery are trauma victims and must be evaluated carefully preop, by both surgeons and anesthesiologists, to ensure that replantation is appropriate and that other injuries are not overlooked. In these cases, time is critical, as the amputated tissue is ischemic and may require immediate revascularization if it is to be salvaged. Coordination between the microsurgeon, anesthesiologist, and trauma team is important to minimize the time between injury and replantation.

As in any microsurgical procedure, it is critical to prevent vasoconstriction in these

procedures. These patients may have experienced significant blood loss at the time of the trauma and require iv hydration and/or blood transfusion. The need for hemodynamic support often indicates another injury that may preclude transplantation. The patient may be hypothermic and require active rewarming. Vasoconstrictors and diuretics should be avoided unless absolutely necessary. During the replantation procedure, other tissues (e.g., skin, vein, bone) are required to aid in the reconstruction. These are routinely harvested from the leg, groin, or foot, which will be prepped into the surgical field.

The amputated stump is initially examined using loupe magnification. The arteries, veins, and nerves are dissected and tagged. The surgeon determines if the part is replantable. The amputated stump is prepared by dissecting the recipient arteries, veins, and nerves. The need for a vein graft may be determined at this time. The sequence of replantation varies; however, a general algorithm is:

Bone fixation → Extensor tendon repair → Flexor tendon repair → Nerve repair → Venous and arterial anastomoses → Skin closure

The replanted tissue must be monitored on an hourly basis to ensure continued viability. In many hospitals, this is performed in a microsurgical unit, whereas in others, the ICU is used. Patients should be kept adequately hydrated, warm, and pain-free to prevent vasoconstriction and subsequent thrombosis. Vascular thrombosis requires immediate exploration and revision of the vascular anastomosis.

Specific variations of replantation procedures have unique features, as follows.

Replantation of fingers and hands

Generally, two surgeons work simultaneously. One surgeon at the back table explores the amputated parts, tagging significant nerves, vessels, and tendons. A second surgeon debrides the amputation sites and identifies the stumps of reparable structures. The surgeons then proceed with replantation. Generally, bone fixation and tendon repairs are performed first. Vessel and nerve repairs are performed next, using a microscope. The need for vein grafting and anticoagulation is determined intraop. Blood transfusions are rarely needed except when using anticoagulants.

Replantation of extremities

Replantation of arms or legs must be handled very efficiently because irreversible muscle damage occurs within 4 h of ischemia. Generally, the sequence of surgery is similar to finger replantation, with the exception being that a temporary arterial circulation (using a dialysis shunt) is established as soon as possible to minimize

ischemia time in an amputated part. Ongoing venous blood loss occurs while skeletal repairs are done, and transfusion is frequently required. Definitive vessel repairs (often requiring vein grafts) and nerve repairs are done under the microscope.

Scalp replantation

Scalp avulsions are caused by entanglement of hair in machinery. These amputations are possibly replantable, sparing the patient a significant aesthetic and functional problem. Initial evaluation should include careful assessment of the C-spine because the patient transiently hangs by the neck until the scalp separates. Initial blood loss can be significant and should be replaced preop. Replantation proceeds by identifying matching vessels at the margin of the defect and the avulsed scalp. The superficial temporal vessels are most commonly repaired, and use of vein grafts should be anticipated. Following the first artery repair, brisk bleeding generally occurs at the scalp margin until vein repairs are completed. This blood loss should be anticipated.

Usual preop diagnosis

Trauma

ERAS: Because of the urgent nature of these procedures preop counseling by the surgeon/anesthesiologist is rarely possible.

SUMMARY OF PROCEDURES

	Fingers/Hands	Extremities	Scalp
Position	Supine, injured arm extended	Supine	Supine or side (depending on vessel position)
Incision	Conventional hand exposure	Extension of injury; fasciotomies may be done.	Preauricular
Special instrumentation	Microscope; hand table; tourniquet	Microscope; tourniquet	Microscope; neurosurgical headrest
Unique considerations	Anticoagulation	⇐	RAE or anode tube; table, turned 180°

Antibiotics	Cefazolin 2 g iv	⇐	⇐
Surgical time	1st finger: 3–4 h; 2 h/subsequent finger Hand: 4 h	4–8 h	4 h
Closing considerations	Splint applied before emergence.	Cast or splint applied before emergence.	Elevate head as much as possible.
EBL	100–200 mL	2–6 U	2–8 U
Postop care	ICU for monitoring	⇐	⇐
Mortality	None	Rare	None
Morbidity	Replant failure: 5–15%	Failure: 10–20%	Vascular occlusion → reexploration
Pain score	5–6	5–6	3–5

PATIENT POPULATION CHARACTERISTICS			
Age range	Childhood–old age	⇐	Young adult
Male:Female	>10:1	⇐	1:2
Incidence	250/yr/major center	Rare	⇐
Etiology	Trauma	⇐	⇐
Associated conditions	Other injuries	Other injuries, blood loss	C-spine injuries, blood loss

ANESTHETIC CONSIDERATIONS FOR REPLANTATION

PREOPERATIVE

In general, there are two patient populations for replantation procedures: (a) isolated limb and scalp injury patients (common) and (b) multiple trauma victims (rare). Most patients are otherwise healthy, and the preop workup is routine.

Gastrointestinal	All of these patients should be considered to have full stomachs and, therefore, are at increased risk for

	aspiration pneumonitis. In general, they should receive preop medication to reduce stomach volume and acidity (e.g., metoclopramide 10 mg iv and ranitidine 50 mg iv) 30–60 min before induction, time permitting.
Metabolic	~50% of trauma victims are intoxicated. Anesthesia-related implications of acute ethanol intoxication include ↓ anesthetic requirements, diuresis, vasodilation, and hypothermia.
Neurologic	Assess for possible head or C-spine injury, particularly in the trauma patient presenting with facial or scalp injuries.
Laboratory	As suggested by coexisting disease
Premedication	Standard premedication. Full-stomach precautions: Na citrate 0.3 M 30 mL po immediately before induction of anesthesia

INTRAOPERATIVE

Anesthetic technique

GETA, after rapid-sequence induction. These procedures are often lengthy, and regional anesthesia is usually not appropriate as the primary technique but may be considered as an adjunct.

Induction	Rapid-sequence induction is mandatory in emergency cases, unless awake intubation is performed. C-spine fracture patients or those with facial injuries may require awake fiberoptic intubation.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia (Goal-Directed Management) and normothermia. Consider preincision placement of nerve blocks (see Appendix K, p. K-6).
Maintenance	Standard maintenance for stable patients
Emergence	Difficult airway or full-stomach cases require awake extubation. Consider nerve block placement or

	reinforcement if initially placed >4–6 h ago (see Appendix K, p. K-5). Consider iv acetaminophen 1 g as part of MMPM.	
Blood and fluid requirements	Significant blood loss possible IV: 16 ga × 1–2 (extremity/scalp) IV: 18 ga × 1 (digit) BSS @ 1.5–3 mL/kg/h + 3 × blood loss	A 16-ga iv catheter in a nonoperated upper extremity should be adequate in hemodynamically stable patients. Keep patient warm and hydrated to maximize perfusion to the replanted site. Vasopressors are not contraindicated and may be preferable to volume overload.
	Fluid/blood warmers, heating blanket, warmed circuit humidifier	HCT > 33% may ↑ viscosity + ↓ perfusion Goal-Directed Fluid Management (see Appendix K, p. K-4)
Monitoring	Standard monitors. ± Arterial line, CVP	Invasive hemodynamic monitoring should be considered in cases where large blood loss is anticipated.
Positioning	✓ and pad pressure points ✓ eyes	
Control of blood loss	Tourniquet may be used.	Inflation pressure is typically 100 mm Hg greater than systolic pressure. Maximum "safe" tourniquet time is 1.5–2 h, followed by a 5 to 15-min reperfusion interval if further tourniquet time is necessary.

Special considerations	Tourniquet deflation and limb reperfusion	Mild ↓ BP is common. In patients with moderate-to-severe lung disease, continue controlled ventilation until after the lactic acid that has accumulated in the ischemic limb is metabolized (3–5 min) because these patients may be unable to increase ventilation adequately to buffer this acid load.
Complications	Hemodynamic instability	Previously unrecognized injuries (e.g., pneumothorax, cardiac tamponade, intracranial bleeding) should be considered as a cause of unexplained intraop hemodynamic instability in all acute trauma victims.

POSTOPERATIVE

Complications	Reperfusion failure	May require immediate reexploration.
Multimodal pain management	Acetaminophen NSAIDs Gabapentin PCA Regional nerve block	Regional or local blocks. Continuous infusion catheters may be beneficial.
ERAS	PONV protocol	Encourage early enteral nutrition, Foley catheter

		removal, and early mobilization.
Tests	None routinely indicated	Reimplant perfusion must be monitored.

Suggested Readings

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BREAST SURGERY—INTRODUCTION

David M. Kahn

Patients presenting for plastic surgery of the breast can be grouped into four basic categories along a continuum ranging from amastia/hypomastia to hypertrophy. Plastic surgery procedures are designed to create or make adjustments in the amounts of skin and glandular tissue or to make adjustments in their relationship to each other to create an aesthetic breast. The first type of patient is one who has acquired amastia after undergoing a mastectomy; it is this patient who is featured in this section on functional restoration. In this patient, the goal is to replace the missing tissue, both skin and glandular, with like tissue or an implant. The second type is a person presenting for augmentation mammoplasty. In this situation, the breast is deficient of skin and glandular tissue. The third type is the patient who presents for a reduction mammoplasty. In this situation, there is an excess of glandular tissue and skin. The fourth type is the patient who presents for a mastopexy or breast lift. In this patient, there exists a discrepancy between the amount of glandular tissue present and the volume of the skin envelope, resulting in ptosis.

For all breast procedures, the patient's breasts are marked preop with the patient in either sitting or standing position. This is a necessity, and its importance cannot be overstated. The appearance of the breasts in the supine position versus the upright position is significantly different due to the effects of gravity.

BREAST RECONSTRUCTION

SURGICAL CONSIDERATIONS

Description

The goal of breast reconstruction is to create an aesthetic breast that is symmetrical with the contralateral breast. Typically, this can be accomplished in three ways: expander/implant reconstruction; latissimus flap reconstruction, ± an implant; and transverse rectus abdominis muscle (TRAM) flap reconstruction, performed using either a pedicled technique or a free tissue transfer. If abdominal tissue is not available, autologous breast reconstruction can also be performed using free flaps from other areas such as the gluteal region (superior gluteal artery perforation flap) or medial thigh (transverse upper gracilis flap). Each type of reconstruction follows the principle of replacing glandular and cutaneous breast tissue. In patients undergoing mastectomy, reconstruction may be performed immediately after the mastectomy or it may be delayed and performed at a later date.

I n **expander/implant reconstruction** (Fig. 11.4-2), a tissue expander is placed underneath the pectoralis major muscle and a portion of the serratus anterior muscle, followed by skin closure. Thus, two layers exist above the implant—skin and muscle. The patient returns to the office for expansions, with saline being injected into the implant port. This is continued until the desired size is reached. Then, the patient returns to the OR for the exchange of the expander for a permanent implant that contains either saline or silicone gel as filler material. Except for the psychosocial aspects of patient management, much of the technique and perioperative concerns are similar to those for breast augmentation.

Autologous breast reconstructions

Two types of flaps are used for these procedures—latissimus myocutaneous flap and TRAM flap. The**latissimus dorsi myocutaneous flap** consists of the muscle with overlying skin that is rotated from the back to the anterior chest for the creation of a breast. The flap does not supply sufficient bulk to be used in breast reconstruction unless the contralateral breast is very small. Usually a breast implant is placed between

the latissimus and pectoralis muscles, thus increasing the volume of the reconstruction. The patient is placed in the lateral decubitus position for the latissimus flap harvest. The incision is designed to surround the skin paddle. The ellipse of skin is incised, and the dissection then proceeds along the superficial surface of the latissimus muscle toward its lateral, superior, and inferior borders. Dissection is performed underneath the latissimus muscle to separate it from the deep tissues of the back. The muscle is released from its insertions on the posterior superior iliac crest, medial fascial attachments, and surrounding muscle attachments (i.e., serratus anterior, teres major). The flap is tunneled through the axilla, and the back wound is closed (Fig. 11.4-3). The patient is then returned to the supine position. The muscle is disinserted from the humerus, if necessary, and brought out onto the anterior chest wall. At this point, the muscle is inset into the mastectomy defect. An implant or tissue expander may be placed under the muscle if necessary for size and symmetry. Often, the patient is placed in the seated or semi-Fowler position for closure. The incisions are closed over a drain, and dressings are applied. The skin flap is monitored postop for signs of flap ischemia and congestion, which may necessitate a return to the OR.

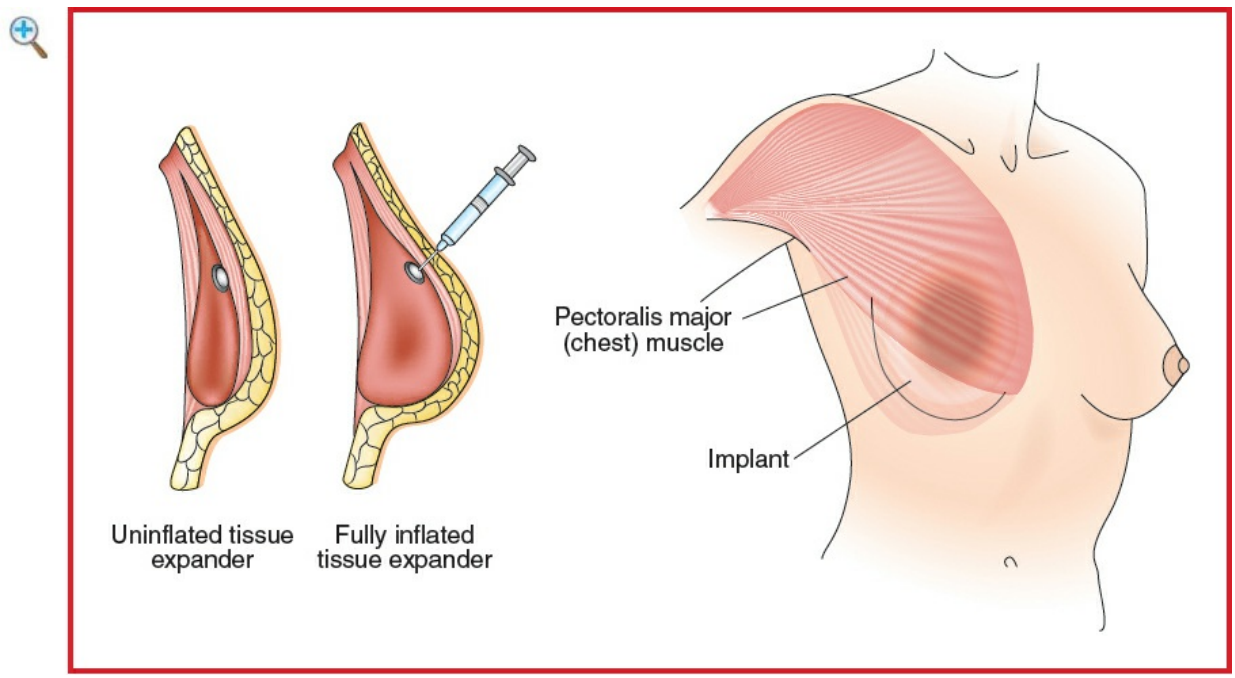

Figure 11.4-2 Expander-implant reconstruction. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al., eds: Surgery: Scientific Principles and Practices, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

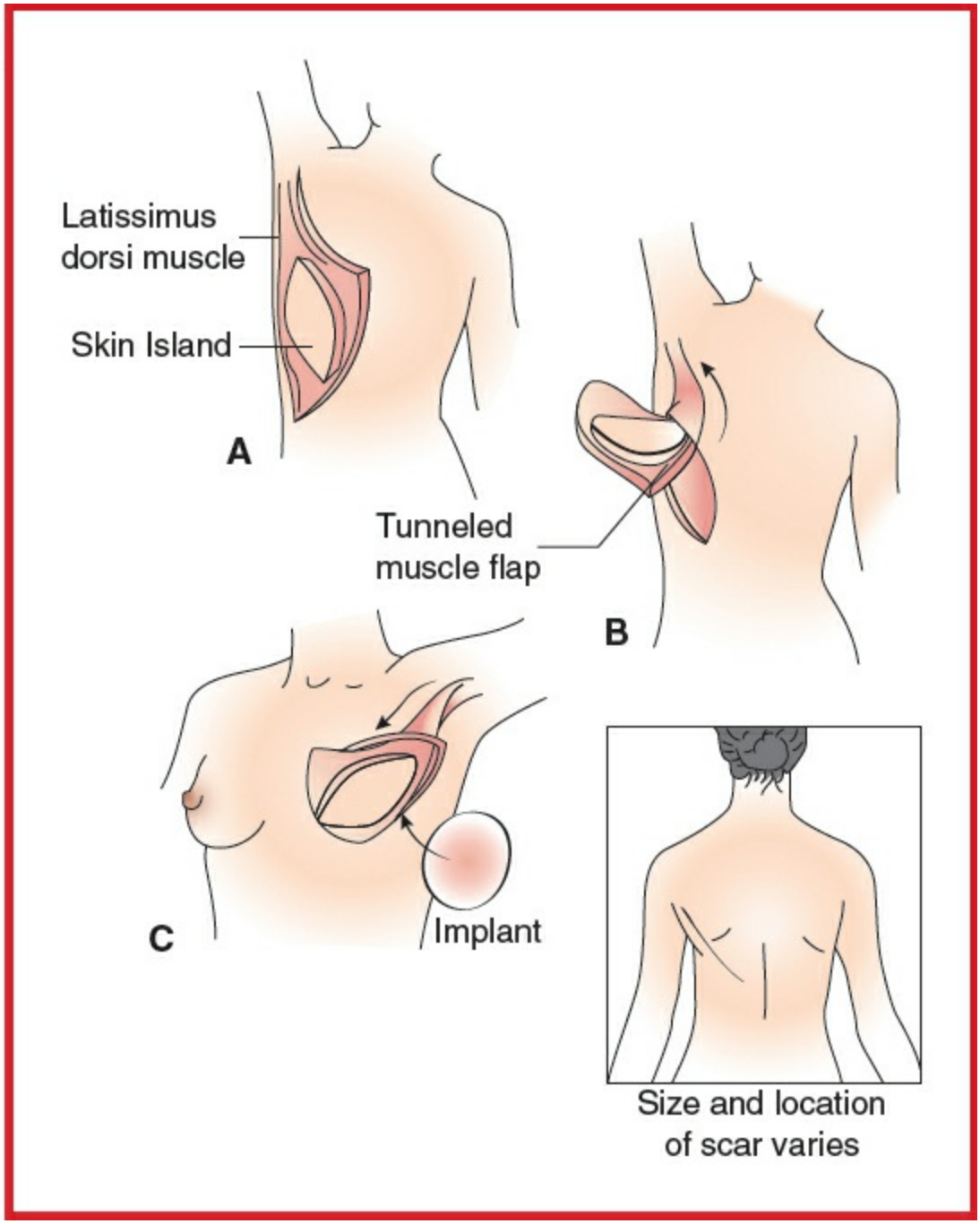

Figure 11.4-3 A–C: Latissimus dorsi flap reconstruction. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al., eds: Surgery: Scientific Principles and Practices, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

The **TRAM flap** procedure replaces the breast with an ellipse of abdominal skin and subcutaneous tissue based on the rectus abdominis muscle (Fig. 11.4-4). There are several variations in the type of abdominal tissue that is transferred. Traditionally, the TRAM flap consists of the entire rectus muscle and overlying subcutaneous tissue and skin. Modified techniques minimize the amount of muscle removed to decrease the occurrence of postoperative hernias. These include muscle-sparing TRAM (MS

TRAM) flaps that take out only a small portion of rectus. Deep inferior epigastric artery perforator (DIEP) flaps involve only the skin and subcutaneous tissue with the perforators dissected from the rectus muscle. See Figure 11.4-5.

DIEP flaps require more tedious dissection. Superficial inferior epigastric artery (SIEA) flaps are based off the SIEA and do not involve any dissection within the rectus muscle. In selecting patients for a TRAM flap reconstruction, the patient must have adequate lower abdominal tissue to make a breast; however, obese patients, smokers, diabetics, and those with a Hx of prior abdominal surgery may have a higher incidence of complications and flap loss. The benefit of this procedure is that it creates a natural appearing breast from the patient's own tissue without an implant. As a bonus, the abdominal donor site is closed as though the patient had undergone abdominoplasty ("tummy tuck"). The myocutaneous perforators that arise from the superior epigastric and inferior epigastric arteries provide blood supply to the flap. This flap can be harvested in either a pedicled fashion, based on the superior epigastric artery, or as a free flap, based on the inferior epigastric artery. The inset of the flap and closure of the donor site are the same in both cases. The basic difference between the two methods of flap transfer is that, in the free TRAM procedure, the flap is removed from the abdomen, brought into the mastectomy wound, and the operating microscope is used to suture the vascular pedicle of the flap to the recipient vessels, either the thoracodorsal or internal mammary arteries. In the case of the pedicled TRAM flap, the flap is passed through a tunnel, created under the skin, maintaining the blood supply via the superior epigastric artery. The flap is brought out into the mastectomy wound where it is sutured into position.

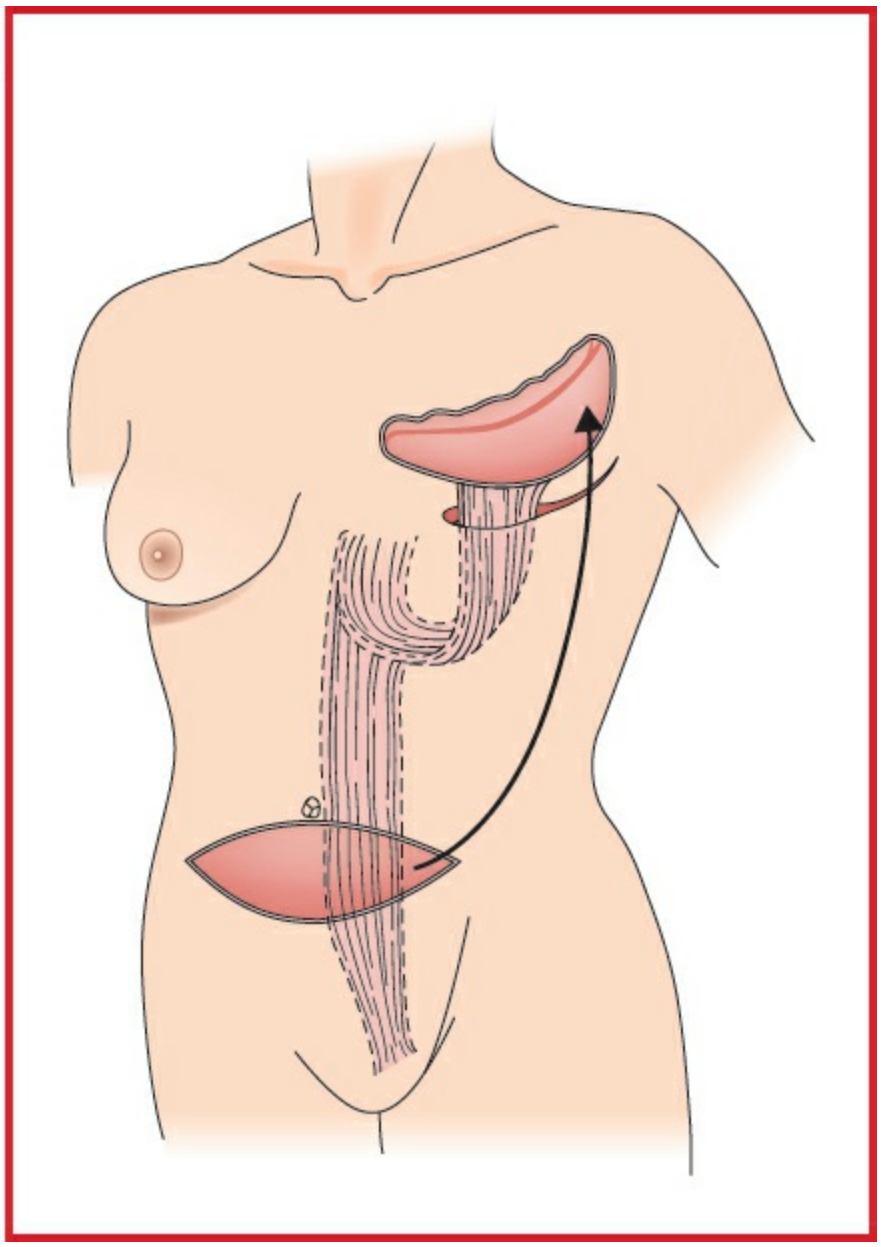

Figure 11.4-4 Breast reconstruction using pedicled TRAM flap. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al., eds:Surgery: Principles and Practice, 2nd edition. Lippincott-Raven: 1997.)

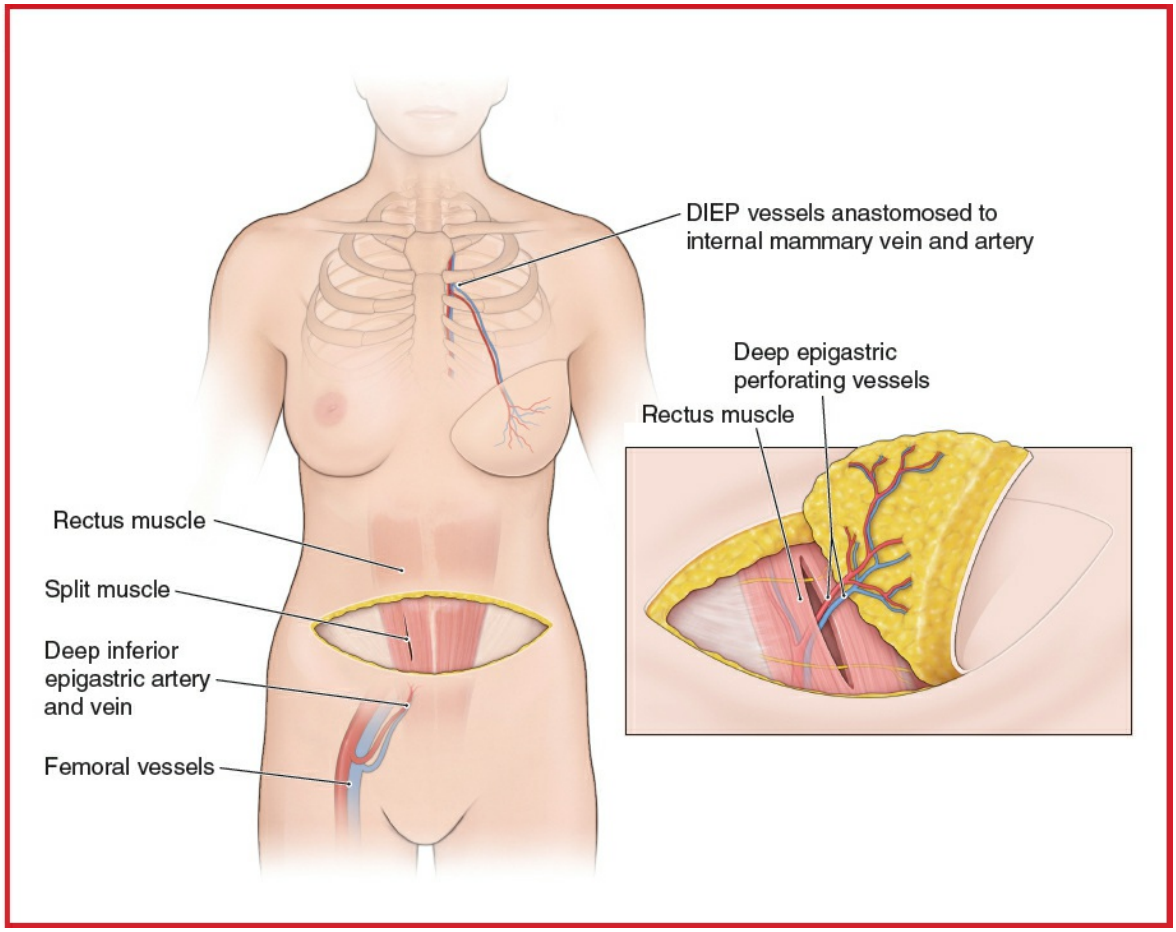

Figure 11.4-5 Unlike a TRAM flap, the DIEP (and SIEA) flap reconstruction spares the rectus muscle.

Pedicled TRAM flap

The patient is marked preop in the upright position. The midline and inframammary folds are marked, as is the abdominal ellipse. The arms are placed at 90° abduction. The breasts and abdomen are prepped and draped. A general surgeon performs the mastectomy and, if possible, the TRAM flap harvest is started at the same time. Incising the skin along the superior marking of the abdominal ellipse begins the harvest of the flap. The upper abdominal skin and subcutaneous fat are elevated off the abdominal wall fascia up to the level of the costochondral cartilage, as in an abdominoplasty. The table is then flexed, and the upper skin and subcutaneous tissue are brought to overlap the TRAM flap to ensure that the location of the marked incision at the lower border of the flap will allow for abdominal closure. The patient is returned to the supine position. The skin and subcutaneous tissue of the flap are raised from a lateral to medial direction off the abdominal wall fascia until the lateral border of the rectus muscle is identified. Care is taken to preserve the myocutaneous perforators supplying the flap. The anterior rectus sheath is incised, and the rectus muscle is elevated away from the posterior rectus sheath. The inferior epigastric vascular pedicle is identified and divided,

preserving as much length as possible. The portion of the rectus muscle below the flap is transected so that the muscle, along with the overlying ellipse of skin and subcutaneous tissue, can be rotated into the mastectomy site. A tunnel is created under the skin to connect the abdominal wound and mastectomy site. The flap is passed through this tunnel and rotated into position on the chest wall (Fig. 11.4-6).

In flap reconstructions, the harvested tissue receives its blood supply through a single artery and vein. It is important in these cases to maintain a stable BP that will allow for continued perfusion of the flap tissue. Vasopressors are to be avoided, as they will constrict the artery and thus restrict the inflow into the flap. Paralytics may be requested in the case of DIEP flaps to minimize muscular twitching while the surgeon dissects through the rectus to follow the vascular pedicle. It is preferred, if possible, to maintain a stable BP with volume replacement. Once the flap is in place at the mastectomy site, the table is again flexed as much as 45°–60° for closure. Drains are placed within both the chest and abdominal wound beds. The flap is trimmed and sutured into position to create symmetry with the contralateral breast. The abdomen is closed in a fashion similar to an abdominoplasty. Many surgeons prefer that N_2O (which can distend the abdomen) be avoided during the abdominal closure. The surgeon will evaluate the flap to monitor for signs of ischemia and congestion. This is done both by clinical evaluation (color, temperature, and turgor) and by Doppler. If inflow or outflow is inadequate for flap survival, blood flow may be supplemented by performing a microvascular anastomosis between the inferior epigastric pedicle and the thoracodorsal vessels. In some cases, the surgeon may choose to convert the pedicled flap to a free flap.

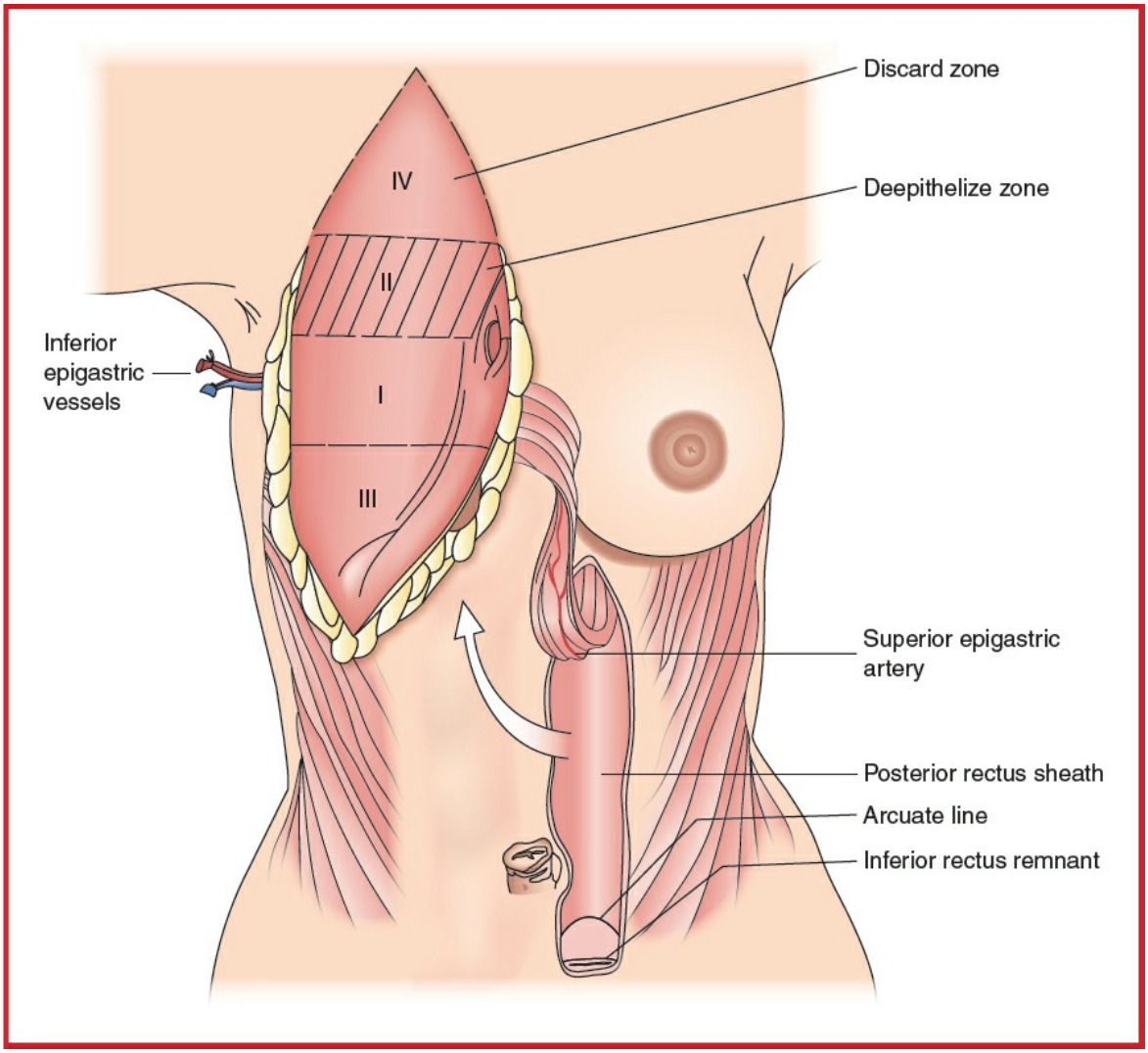

Figure 11.4-6 TRAM flap reconstruction of the breast. A contralateral pedicle TRAM flap has been elevated and will be tunneled under the skin to be inset at the mastectomy site. The zone of tissue furthest from the blood supply is discarded. A portion of the TRAM flap will be de-epithelialized and placed under the mastectomy skin flaps. (Reproduced with permission from Spear SL:Surgery of the Breast: Principles and Art. Lippincott-Raven, Philadelphia: 1998.)

Usual preop diagnosis

Carcinoma of the breast; radiation therapy; cardiovascular surgery; Poland syndrome

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status and possible benefits of weight reduction (time permitting), preop carb loading, VTE risk assessment, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

Tissue	**Latissimus Dorsi**

	Expander/Implant	Flap	TRAM Flap
Position	Supine	Lateral decubitus → supine	Supine
Incision	Breast	Posterior (supine); lateral (thorax)	Abdominal
Unique considerations	May have to place patient in sitting position during procedure; SCDs; Foley catheter if case >3–4 h	⇐	⇐ + Avoid use of N_2O.
Antibiotics	Cefazolin 2 g iv	⇐	⇐
Surgical time	1–2 h	4 h (+ mastectomy time)	6–8 h (free TRAM) 4 h (pedicled TRAM) (not including mastectomy time)
Closing considerations	Extensive dressing required	⇐	⇐ + Flex table for abdominal closure.
EBL	Minimal to 100 mL	200–300 mL	200–400 mL
Postop care	PACU → room	⇐	⇐ (free TRAM flap → ICU)
Mortality	Rare	⇐	⇐
Morbidity	Capsular contraction: ± 30%	—	—
	Decreased sensation: 15%	⇐	⇐
	Hematoma: 2.2%	⇐	⇐
	Fat/skin necrosis: 1.7–1.9%	⇐	⇐
	Nipple areola necrosis: 1.4%	—	—
		Flap loss: Rare	⇐
			Abdominal hernia:

			infrequent
Pain score	5	5	5

PATIENT POPULATION CHARACTERISTICS

Age range	30–70 yr
Male:Female	Mostly female
Incidence	Breast reconstruction is performed in 9% of female population.
Etiology	Cancer; trauma; idiopathic; radiation or postcardiovascular surgery
Associated conditions	Breast cancer; cardiovascular disease; S/P chemotherapy; pulmonary disease

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Breast and Chest Wall Reconstruction.

Suggested Readings

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2. DellaCroce FJ, Wolfe ET: Breast reconstruction.Surg Clin North Am 2013; 93(2):445–54.
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CHEST WALL RECONSTRUCTION

SURGICAL CONSIDERATIONS

Description

Chest wall reconstruction is most commonly performed for infections, sternal dehiscence, tumor extirpation, and radiation injuries. Complications after median sternotomy make up a large number of these cases. The patients often have comorbidities and are at high risk for anesthetic and surgical complications. The goals of reconstruction are to provide a stable chest wall for respiration, to eradicate infection, and to obtain a healed wound.

Sternal wound infections and dehiscences

Wound complications after median sternotomy include dehiscence of the sternum and mediastinitis. In these cases, radical debridement of all devitalized tissue is the cornerstone to a successful outcome. The initial debridement is, therefore, performed in conjunction with the cardiovascular surgeons. During this debridement, blood loss may be extensive, requiring transfusion. The resulting dead space around the heart and great vessels is obliterated, most commonly with **pectoralis major or rectus abdominis muscle (TRAM) flaps.** For patients who have failed the initial reconstruction or are not candidates for these flaps, a **latissimus dorsi muscle flap** may be used. The omentum can also be used to help obliterate the dead space. Despite radical excision of the sternum, the respiratory function of these patients remains adequate, and no bony stabilization is required.

Tumor extirpation and radiation injury

Tumor resection or removal of osteoradionecrosis of the chest wall often involves the full-thickness removal of skin, muscle, and underlying rib cage. The rib cage may be reconstructed with prosthetic mesh or bone grafts. These structures are then covered with muscle flaps. The pectoralis major, rectus abdominis, and latissimus dorsi muscles are the muscle flaps most commonly used. After surgery, the patient's ventilatory capacity may be diminished by the rib resection, and this should be anticipated preop.

Usual preop diagnosis

Chest wall infections; tumor; sternal dehiscence; radiation injuries

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status and possible benefits of weight reduction (time permitting), preop carb loading, VTE

risk assessment, and postop pain management options. See Appendix K, p. K-1.

SUMMARY OF PROCEDURES

	Pectoralis Flap	Latissimus Flap	Rectus (TRAM) Flap	Omental Flap
Position	Supine	Lateral decubitus → supine	Supine; table flexed	Supine
Incision	Chest	Posterolateral thorax	Abdominal	Abdominal
Antibiotics	Cefazolin 2 g	⇐	⇐	⇐
Surgical time	3 h	⇐	4–6 h	3 h
Closing considerations	✓ flap perfusion	⇐	⇐	⇐
EBL	200–400 mL	⇐	300–500 mL	200 mL
Postop care	PACU → room	⇐	⇐	⇐
Mortality	Rare	⇐	⇐	⇐
Morbidity	Thrombosis/flap failure Hematoma Fat/skin necrosis	⇐ ⇐ ⇐	⇐ ⇐ ⇐ Abdominal hernia: Infrequent	⇐ Diaphragmatic hernia Bowel obstruction Bowel perforation
Pain score	4–5	4–5	4–5	4–5

PATIENT POPULATION CHARACTERISTICS

Age range	30–80 yr
Male:Female	1:1
Incidence	Uncommon
Etiology	Cancer; trauma; radiation; postcardiovascular surgery
Associated conditions	Breast cancer; cardiovascular disease; S/P chemotherapy; pulmonary disease; mediastinitis

ANESTHETIC CONSIDERATIONS FOR BREAST AND CHEST WALL RECONSTRUCTION

PREOPERATIVE

These surgeries are performed most commonly for reconstruction following cancer

surgery, such as radical neck dissection and mastectomy (see Anesthetic Considerations for the primary procedure), as well as complications after median sternotomy. The following considerations focus on patients undergoing reconstruction postchemotherapy. Always enquire about any treatment side effects.

Respiratory	Pulmonary toxicity (e.g., pneumonitis, fibrosis) may complicate some chemotherapeutic agents including paclitaxel and trastuzumab. Bleomycin (>200 mg/m^2) carries the greatest risk of pulmonary toxicity (10%), but alkylating agents (e.g., cyclophosphamide and melphalan) may cause a degree of pulmonary toxicity as well. Avoid FiO_2 > 30% in bleomycin patients (to prevent progressive pulmonary fibrosis and edema). Patients presenting with complications from a prior sternotomy may have ↓ respiratory function/reserve and will require further workup. **Tests:** CXR; ABG and PFTs as indicated from H&P
Cardiovascular	Cardiomyopathy and CHF may result from chemotherapy, especially with trastuzumab and anthracyclines (e.g., doxorubicin >550 mg/m^2). Previous XRT increases risk of clinically significant cardiomyopathy and CAD. Patients with median sternotomy-related complications who have undergone prior cardiac surgery will require careful evaluation of their current cardiovascular status. **Tests:** ECG; echo, if indicated from H&P
Neurologic	Note any previous damage to long thoracic nerves, as evidenced by winged scapula deformity. Taxanes (e.g., paclitaxel) can cause a dose-dependent, cumulative neuropathy and pain syndrome.
Musculoskeletal	It is traditional (not evidence based) to avoid iv and BP cuff in the upper extremity on mastectomy side. Myalgias/arthralgias occur with paclitaxel.
Hematologic	Myelosuppression/toxicity from chemotherapeutic agents may be present. **Tests:** CBC; Plt count; coag profile; Hb/Hct

Renal/hepatic	Taxanes (e.g., taxlitaxel) are mildly hepatotoxic. Methotrexate can produce renal and hepatic dysfunction. Elevated alkaline phosphatase may suggest metastatic bone invasion. **Tests:** Electrolytes; BUN; Cr; LFTs
Gastrointestinal	Tamoxifen, paclitaxel, docetaxel, and carboplatin can cause preop N/V and dehydration.
Laboratory	Other tests as indicated from H&P, prior chemotherapy
Premedication	Midazolam 1–2 mg iv immediately preop
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss possibility of nerve blocks for postop pain management. Consider preop acetaminophen 1000 mg po. Consider aprepitant 40–80 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA

Induction	Standard induction and intubation. Avoid iv and NIBP monitoring on mastectomy side (a non–evidence-based tradition).
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia (Goal-Directed Management) and normothermia. Consider preincision placement of nerve blocks (see Appendix K, p. K-6).
Maintenance	Standard maintenance. Muscle relaxation is usually appropriate. These patients should be kept warm and hydrated to minimize peripheral vasoconstriction, which might impair graft perfusion.
Emergence	During some of the procedure and for application of dressing, patient may be moved to sitting position,

	with consequent coughing, bucking, etc. (Rx: deeper anesthesia, e.g., propofol 0.5 mg/kg or lidocaine 1 mg/kg). Watch BP carefully, and treat orthostatic hypotension if it occurs, usually with a pressor or fluid bolus if the patient is not volume sensitive (e.g., Hx of CHF or renal failure). Consider nerve block placement or reinforcement if initially placed >4–6 h ago (see Appendix K, p. K-5). Consider iv acetaminophen if po dose given >4–6 h ago.	
Blood and fluid requirements	IV: 16 ga × 1 BSS @ 4–6 mL/kg/h	Extensive blood loss may occur with debridement of sternum in cases of infection or dehiscence. Goal-Directed Fluid Management (see Appendix K, p. K-4)
	Warm fluids.	Keep patient warm and maintain a slightly positive fluid balance.
	Humidify gases.	Hypothermia may impair flap perfusion.
Monitoring	Standard monitors UO	Use invasive monitoring in cardiovascular-challenged patients or in cases with significant expected blood loss, where regular ABGs and blood chemistries will be useful.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Pneumothorax	Pneumothorax should be considered with any ↑ lung inflation pressure, ↓ O_2 sat, or ↓ BP.
	Decubitus ulcer	Pressure necrosis can occur in as little as 2 h.

		Carefully pad and repeatedly ✓ pressure points.
	Dextran reaction	Dextran is now rarely used because risks (e.g., allergic reactions, ARDS, pulmonary edema) outweigh benefits.

POSTOPERATIVE

Complications	Pneumothorax ↓ Flap perfusion	
Multimodal pain management	Acetaminophen NSAID Gabapentin Parenteral opiates. PCA	Regional or local blocks. Continuous infusion catheters may be beneficial. Pain should be treated promptly to minimize reflex peripheral vasoconstriction and impaired graft perfusion.
	Regional nerve blocks	Paravertebral and TAP blocks are effective for pain control.
ERAS	PONV protocol	Encourage early enteral nutrition, Foley catheter removal, and early mobilization.

Suggested Readings

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PRESSURE SORE RECONSTRUCTION

SURGICAL CONSIDERATIONS

Description

Pressure sores occur when constant pressure is placed on an area of the body. They tend to occur in debilitated, bedridden, paralyzed, and wheelchair-bound patients. Multiple factors—including altered sensory perception, poor nutrition, incontinence, moisture, and shear forces—also may contribute to the formation of the pressure sores. The most common locations are the sacrum, ischium, and greater trochanter regions, as well as the heel and scalp.

The management of pressure sores is multidisciplinary and involves more than just debridement and wound closure. Patient compliance is the most important factor of wound management, as recurrence rates after closure are high. All components that contributed to the formation of the ulcer must be addressed before wound closure. This is best done in a team setting, with the goal of preventing further sores. In this effort, nutrition must be optimized; infection, muscle spasm, and contractures controlled; pressure relief measures instituted; and the psychological issues addressed. Once these are in place, wound reconstruction may begin.

Reconstruction is based on adequate debridement, elimination of dead space and pressure points, and closure of the wound with healthy, durable tissue. Multiple flap designs have been described for the coverage of pressure sores, depending on their location (Fig. 11.4-7). An important point in the design of a flap is the consideration for future reconstructions because of the high incidence of recurrent wounds. The choice of flap also needs to take into consideration the donor site morbidity. Skin-only flaps, fasciocutaneous flaps, and musculocutaneous flaps are commonly used.

The patient is placed in the prone position and may be jackknifed to facilitate exposure of the wound. Debridement of the wound is performed; and the bursa and underlying

bony prominences may be removed. Hemostasis is obtained, and the wound is irrigated with pulsed lavage. The flap to be used is designed over the vascular pedicle. The donor site for sacral, gluteal, and greater trochanteric wounds are typically the tissues of the buttocks and posterior thigh. The skin is incised and the flap is raised to include the appropriate layers of tissue, depending on whether a skin, fasciocutaneous, or musculocutaneous flap is to be used. The flap is then rotated into position in the wound. A portion of the flap may be de-epithelialized and placed into the wound to eliminate dead space. Drains are placed into the wound, and the flap is sutured into its new location. The donor site defect that occurs after rotation of the flap may be closed directly or may require a skin graft. Once the operation is complete, the patient is transferred to a pressure-relief bed (e.g., Clinitron™ or air-fluidized bed) and extubated.

Usual preop diagnosis

Pressure sores

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, alcohol and smoking cessation, review of nutritional status, preop carb loading, VTE risk assessment, and postop pain management options. **See Appendix K, p. K-1.**

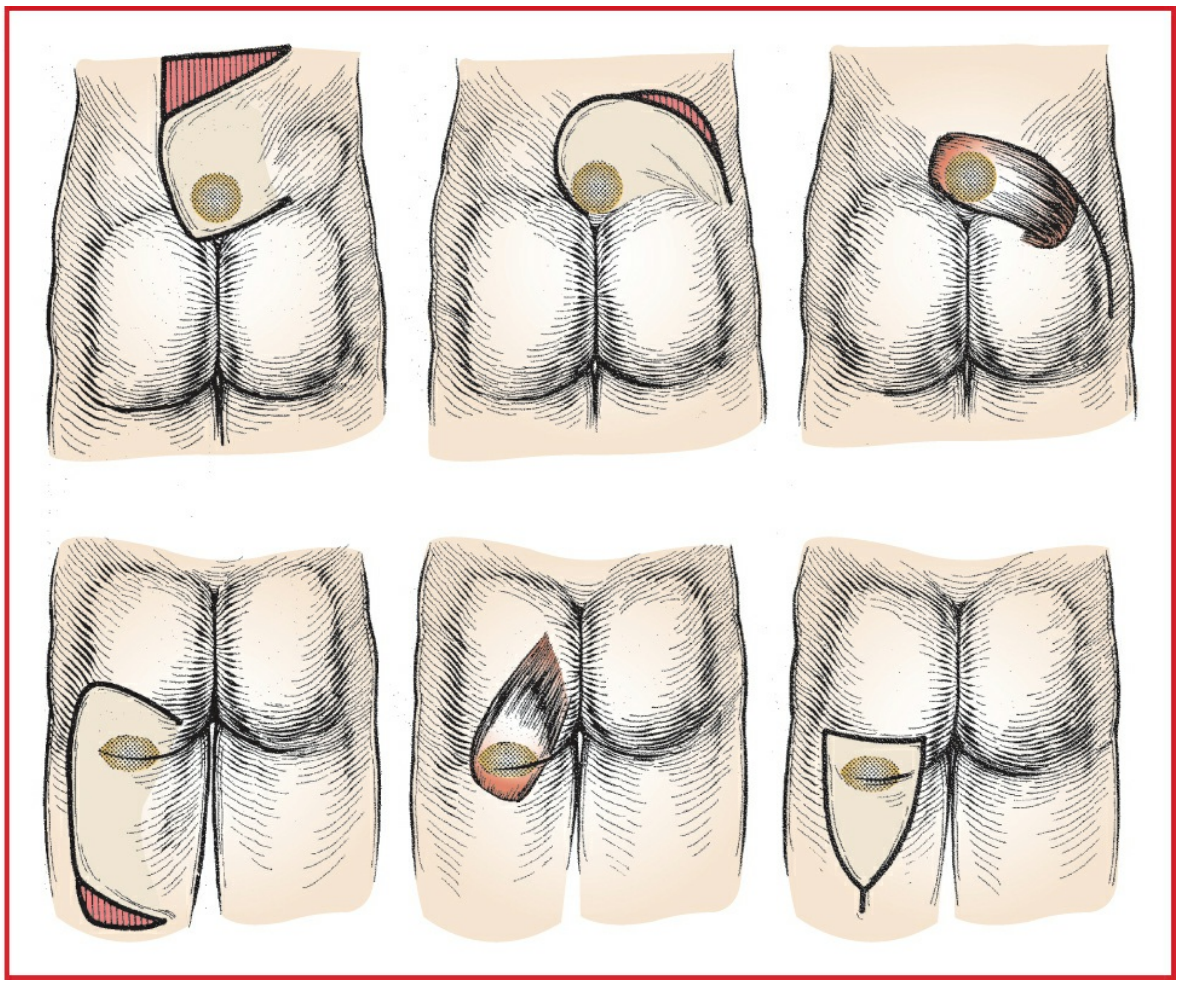

Figure 11.4-7 Commonly used flap designs for coverage of sacral and ischial pressure sores. (Reproduced with permission from Aston SJ, Beasley RW, Thorne CHM, eds. Grabb and Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

SUMMARY OF PROCEDURE

Position	Prone or lateral decubitus
Incision	Gluteal or posterior thigh
Unique considerations	Foley catheter; SCDs
Antibiotics	Cefazolin 2 g iv. Some surgeons may prefer broader polymicrobial coverage.
Surgical time	3 h
Closing considerations	None
EBL	200–300 mL

Postop care	Strict bed rest on a pressure-relief bed for up to 3 wk. Care must be taken to ensure that the patient is turned every 2 h so that excessive pressure is not transferred to a new location. Antibiotics and the control of urine and stool are important to prevent soiling of the suture lines.
Mortality	0–1%
Morbidity	Infection: 2–3% Dehiscence: 1% DVT: 1% Recurrence
Pain score	4–6 (depends on spinal cord status)

PATIENT POPULATION CHARACTERISTICS	
Age range	20–70 yr
Male:Female	Predominantly male
Etiology	Immobility; unrelieved pressure; altered sensation
Associated conditions	Paraplegia; debilitation; quadriplegia

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Typically, these surgeries are carried out on nonambulatory patients, with the spinal cord injury patient constituting a large subset. Anesthesia for plegic patients may well present several challenges, as discussed below.

Respiratory	Plegic patients may have intercostal muscle weakness → atelectasis and ↓ clearance of secretions → recurrent URIs and V/Q mismatching → hypoxemia. **Tests:** PFT; ABG; others as indicated from H&P
Cardiovascular	Autonomic dysreflexia (AD) may present as acute episodes of uninhibited hyperactivity in the patient with an injury level of T10 or above. The main

	clinical signs are paroxysmal HTN and bradycardia, in response to stimulation below the lesion. Severe HTN can result in pulmonary edema, myocardial ischemia, and cerebral hemorrhage. Identify triggering stimuli (e.g., bowel or bladder distension, cutaneous stimulation). T4 or higher lesions may → ↓ BP on induction of GA or regional anesthesia, initiation of IPPV, or postural changes. **Tests:** ECG; others as indicated from H&P
Neurologic	✓ level of cord injury. AD in patient with spinal cord injury (see Cardiovascular, above) may manifest as headaches, sweating, facial flushing, or syncope. Hyperreflexia below injury level.
Musculoskeletal	Immobility → skeletal muscle atrophy, osteoporosis, and decubitus ulcer formation
Gastrointestinal	Spinal cord injury → ↓ GI function → constipation/full stomach
Renal	Chronic spinal cord injury → recurrent UTIs and calculi → renal failure. Foley catheter placement may → AD. **Tests:** UA; BUN; Cr; others as indicated from H&P
Laboratory	Immobility → ↑ Ca^{++}, → dysrhythmias and nausea. **Tests:** Others as indicated from H&P
Premedication	Standard premedication is usually appropriate. Patients with limited respiratory reserve should receive minimal sedation. Nifedipine (10 mg sublingually 5 min or po 20 min before induction) may be used to blunt AD.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 1000 mg po. Consider aprepitant 40 mg po for patients with h/o severe PONV.

INTRAOPERATIVE

Anesthetic technique

GETA: If flap donor and recipient sites are confined to the lower half of the body, regional anesthesia may be considered for short procedures. Spinal or epidural anesthesia will minimize AD; however, anesthetic level may be difficult to assess, and regional anesthesia may not be tolerated for prolonged surgery. Lighter levels of GA will not prevent AD.

Induction	Standard induction and intubation. Although the risk of ↑ K^+ 2° succinylcholine is reportedly decreased 6 mo after injury, NMRs are still preferred. AD may occur with Foley catheter placement.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K). Maintain normovolemia (Goal-Directed Management) and normothermia. Consider preincision placement of nerve blocks (see Appendix K, p. K-6).	
Maintenance	Standard maintenance. Muscle relaxation is usually appropriate and may be necessary to reduce muscle spasticity. Avoid drugs that are primarily renally excreted in patients with CRI. Direct arterial vasodilators and alpha-adrenergic blocking agents should be readily available. Plegic patients are prone to hypothermia. These patients should be kept warm and hydrated to minimize peripheral vasoconstriction, which might impair graft perfusion.	
Emergence	AD 2° distended bladder or rectum may occur on emergence from anesthesia. Consider nerve block placement or reinforcement if initially placed >4–6 h ago (see Appendix K, p. K-5). Consider iv acetaminophen if po dose given >4–6 h ago.	
Blood and fluid requirements	IV: 16 ga × 1 BSS @ 2–4 mL/kg/h Warm fluids. Humidify gases.	Keep patient warm and maintain a slightly positive goal-directed fluid balance. Hypothermia may impair

		flap perfusion. Initial debridement of ulcer may be extensive and significant blood loss can occur. T&C as appropriate. Goal-Directed Fluid Management (see Appendix K, p. K-4)
Monitoring	Standard monitors UO	
	± Arterial line	An arterial line may be useful in patients susceptible to AH and for prolonged procedures where regular ABGs and blood chemistries will be useful.
Positioning	✓ and pad pressure points ✓ eyes	Many of these patients may be osteoporotic, so great care should be used in moving and positioning.
Complications	Hypothermia	Patients with spinal cord injury often have impaired thermoregulation. Maintain normal body temperature with warming blankets and fluid and airway warmers.
	AD	Remove inciting stimulus. ↑ BP should be promptly controlled with NTG, SNP, or clevidipine bolus and infusion, while anesthesia is deepened.

	Decubitus ulcer	Pressure necrosis can occur in as little as 2 h. Carefully pad and repeatedly ✓ pressure points.

POSTOPERATIVE

Complications	Respiratory insufficiency	Quadriplegic patients may have ↓ VC and ↓ ERV and be uniquely susceptible to residual respiratory depressant effects.
	AD	AD may occur 2° distended bladder or rectum. Rx: remove inciting stimulus and NTG, SNP, or clevidipine bolus/infusion.
Multimodal pain management	Acetaminophen NSAID Gabapentin PCA (see p. C-3)	Regional or local blocks. Continuous infusion catheters may be beneficial. Pain should be treated promptly to minimize reflex peripheral vasoconstriction and impaired graft perfusion. Avoid respiratory depression.
	Regional nerve block	Useful for pain control in extremities
ERAS	PONV protocol	Encourage early enteral nutrition, Foley catheter removal, and early mobilization.

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CHAPTER 11.5

Burn Surgery

ANESTHESIOLOGISTS
Richard A. Jaffe, MD, PhD
Melissa T. Berhow, MD, PhD

We gratefully acknowledge the past contributions of surgeon, Kenneth K. Yim, MD, FACS.

FREE SKIN GRAFT FOR BURN WOUND (WITH TANGENTIAL EXCISION, EXCISION TO FASCIA, OR DEBRIDEMENT)

SURGICAL CONSIDERATIONS

Description

Until the mid-1970s, management of burn wounds involved daily debridement, hydrotherapy, and spontaneous eschar separation, with subsequent skin grafts applied to the granulated tissue. Operative management has become much more aggressive with the description of **tangential excision** by **Janzekovic**. In burn patients without inhalation injury, early excision and grafting (days 1–5) can reduce mortality and length of hospital stay. There are two surgical approaches to burn wounds—tangential excision and fascial excision.

Tangential excision (TE) is the more frequently performed procedure. The concept of TE is extremely simple but requires considerable experience and teamwork. Thin slices of burn eschar (burned, necrotic tissue) are shaved sequentially with manual or power dermatomes until a healthy wound bed is developed. Assessment of the wound bed is

done with visualization of bleeding and/or the clinical appearance of the excised bed. Blood loss is generally diffuse and can be massive; therefore, communication between anesthesiologist and surgeon is essential. In large excision, PRBCs should be available in the OR before excision so that the anesthesiologist does not get behind in blood and fluid replacement.

Diffuse bleeding, especially dermal, is controlled by laparotomy pads soaked with warm 1:100,000 epinephrine solution. These pads are replaced every 3–5 min and, after ~10 min, are removed one at a time, with persistent bleeding points controlled by electrocautery. Although very high plasma epinephrine levels have been reported after major burn excision, systemic manifestations are very rare in acute burn patients (probably 2° chronic high-level endogenous catecholamine secretion).

TE in the extremities usually is accomplished with a pneumatic tourniquet to minimize blood loss. In some centers, subcutaneous injection of a diluted (1:1,000,000) epinephrine solution under the burn wound also is used to minimize blood loss; however, the resulting vasoconstriction makes the end point of excision—that is, bleeding—difficult to ascertain.

Fascial excision involves removing the burn eschar and all underlying fat en bloc to the level of muscle fascia or beyond. Fascial excision can be performed more rapidly and with less blood loss than TE. Its disadvantages, however, are the marked cosmetic deformities and functional limitations that occur because of the loss of all soft tissue overlying the musculature. Because of its disadvantages, fascial excision is reserved for 4th-degree burns or for patients with very extensive, life-threatening, full-thickness (3rd-degree) burns.

In patients with serious burns (>40% total body surface area [TBSA]), excision usually commences on postop days 2–5, after completion of fluid resuscitation, and is performed every 2–3 d, as the patient's condition permits. If eschar excision can be completed before secondary sepsis supervenes, management of the patient is easier and the complications and morbidity are lessened considerably.

The end points for surgical excision in large burns are (a) operative time of 2–3 h, (b) core temperature of 35°C, or (c) blood loss of 10 U of PRBC. The violation of any o these parameters invites coagulopathy and increasing problems with hemostasis and VS stability. Adverse effects occurring after 3–4 h of operative time are usually the result of massive transfusion or hypothermia.

Due to loss of skin integrity and large exposed surfaces, these patients lose heat rapidly.

Fluids, gases, and the OR should be warm, although there is no demonstrable benefit to warming the OR past the point of isothermic neutrality (~82°F [28°C]). Many surgeons however, will maintain the room at ~100°F (38°C). All areas not in the operative field should be covered, and a warming blanket (Bair Hugger™) is used frequently.

Coverage

After excision of wounds and attainment of hemostasis, wounds are covered, using either an autograft or temporary coverage with an allograft, xenograft, or synthetic/biologic dressing. An autograft is used for coverage when the wound bed is deemed suitable, a donor site is available, and the patient is stable. A split-thickness skin graft (STSG) often is used for coverage of a burn wound. Because an STSG is harvested at the dermal level, bleeding also is controlled with topical epinephrine-soaked laparotomy pads before application of dressings. Depending on the location of donor sites, many surgeons use subcutaneous infiltration of diluted (1:1,000,000) epinephrine in saline solution to smooth out irregularities (e.g., underlying ribs) or to create a flat surface (e.g., scalp) to physically improve the ease of taking skin grafts. A substantial volume of saline may be infiltrated, and this should be added into the total fluids administered to the patient.

Intraop position change may be necessary between the burn excision and the STSG harvest. For example, donor skin may be harvested from the back for application to the chest or abdomen.

The STSG is held temporarily in place with staples or sutures. Uncontrolled patient movement may dislodge the graft. To protect against this, grafts are secured with circumferential bolsters, dressings, and/or splints. This procedure may be time consuming, and any uncontrolled patient movement should be avoided.

It has become apparent that early eschar excision is advantageous even if wounds are so extensive they cannot be covered with autografts. In this situation, temporary coverage of the excised wound is accomplished with the application of an allograft, porcine xenograft, or synthetic/biologic dressing. The wound is maintained in this way, with further debridement and biologic dressing changes as necessary, until autograft becomes available.

Usual preop diagnosis

Thermal, electrical, or chemical burn

ERAS: Since these procedures are often urgent and repeated at short intervals, the usual preop ERAS considerations are not often applicable. The maintenance of

normal temperature, volume, and nutritional status can be challenging.

SUMMARY OF PROCEDURES

	Tangential Excision	Fascial Excision
Position	Supine, prone, or lateral	⇐
Incision	Anywhere eschar is to be excised	⇐
Special instrumentation	Dermatomes, as determined by the surgeon—manual or powered. Humby and Goulian knives	—
Temperature considerations	Keep room T at ~82°F (28°C).	⇐
Unique considerations	Possible subcutaneous infiltration of diluted lidocaine-epinephrine-saline solution	None
Antibiotics	Cefazolin (adult = 2 g; child = 15 mg/kg) iv on induction of anesthesia	⇐
Surgical time	2–3 h	⇐
EBL	Massive; limit surgery to 10 U PRBC transfusion	250–500 mL
Postop care	Generally, patients with smaller burns can be extubated at the end of these procedures, recovered in the PACU, and returned to the burn center. Patients with larger burns or those with inhalation injuries will often remain intubated. These patients are transported	⇐

	directly to the burn center, where body T can be maintained more easily.	
Mortality	18–40% (Mortality is a function of burn size, plus other associated conditions, especially inhalation injury [Figs. 11.5-1 and 11.5-2; Table 11.5-1].)	⇐
Morbidity	Massive blood loss	—
	Sepsis	⇐
	Infection 2° to catheters and lines	⇐
Pain score	2–10 (Most patients are maintained on opiates for periop pain control.)	⇐

PATIENT POPULATION CHARACTERISTICS

Age range	All
Male:Female	More commonly male
Incidence	45,000 burn center admissions per year
Etiology	Scald; flame burns; chemicals; electric burns
Associated conditions	Generally few, except in elderly patients. Mental illness and substance abuse have been increasing recently in this patient population.

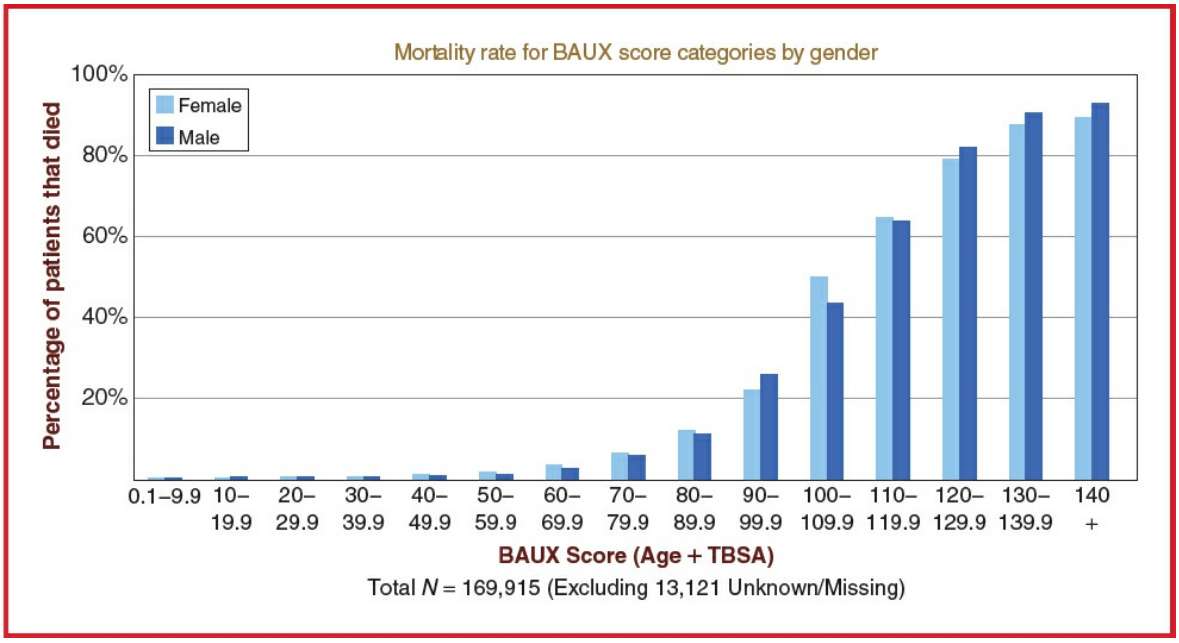

Figure 11.5-1 This figure demonstrates the relationship between death, increasing age, and burn size. The proportion of patients who died (case fatality) is plotted as a function of the sum of age and the total percentage of BSA burned, the so-called BAUX score. There is a strong association between BAUX score and case fatality for both men and women. Overall, women had a higher case fatality than did men (4.20% vs. 3.48%, $P < 0.01$). The sum of age and burn size (BAUX score) associated with a case fatality of 50% (P 50) was 108. There was no significant difference between genders. A report from the American Burn Association, 2012.

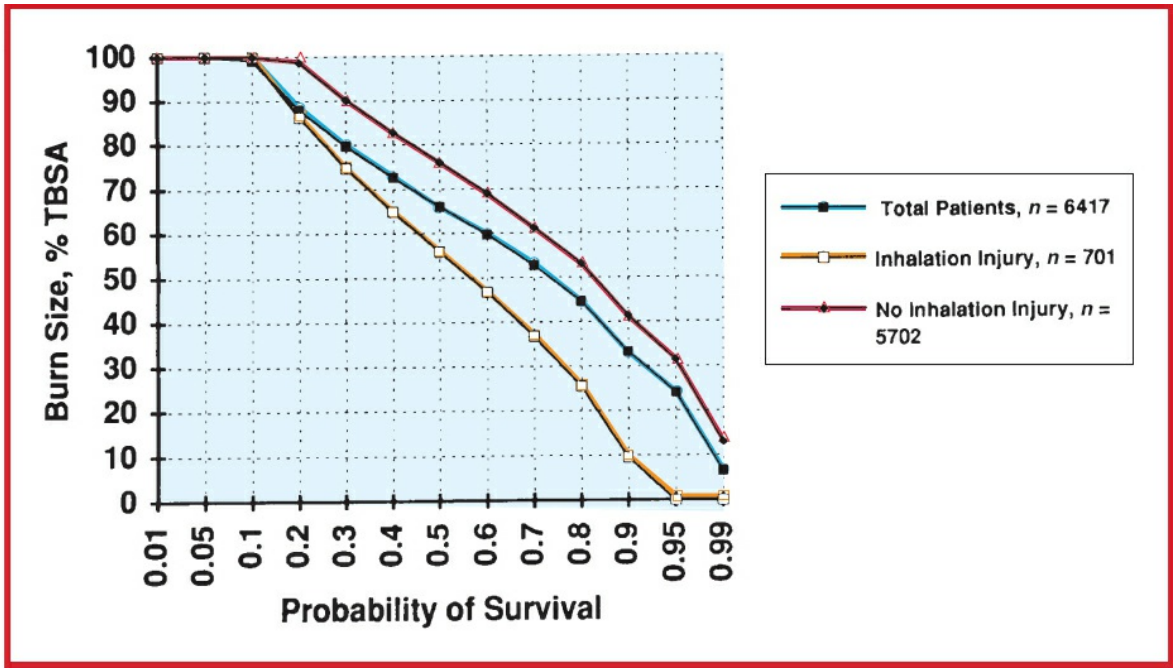

Figure 11.5-2 Probability of survival for patients with and without inhalation injury. (From Saffle JR, Davis B, Williams P, et al: Recent outcomes in the treatment of burn injury in the United States: a report from the American Burn Association Patient Registry. J Burn Care Rehab 1995; 16(3 Pt 1):219–32. Reproduced by permission of Burn Science Publishers, Inc.)

Table 11.5-1 Burn Wounds—Classified According to Depth of Burn		
Degree	**Burn Depth**	**Tissue Involved**
1st degree	Superficial	Epidermis only
2nd degree	Partial thickness	Various thickness of dermis
3rd degree	Full thickness	Entire thickness of dermis
4th degree	To underlying tissue	Beyond dermis (e.g., subcutaneous fat, fascia, or muscle)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Burn injuries may result in a broad spectrum of physiologic impairments. These vary, depending on the percent of TBSA burned, location of burns, age of the patient, time elapsed since initial injury, and interim treatment. In the first hours following burn injury, patients may be affected by both carbon monoxide (CO) and cyanide (CN) toxicities. CO impairs O_2 transport, O_2 release at the tissue level, and mitochondrial function → tissue hypoxia + metabolic acidosis. Pulse oximetry measurement will be falsely high in the presence of CO. CN toxicity is usually the result of inhaled combustion products that include cyanide and hydrocyanic acid → metabolic acidosis, ↓ BP, and dysrhythmias. Ideally, burn patients are fluid resuscitated and stabilized before being brought to the OR. Typically, skin grafts to cover the burn area start on postinjury day 3. Blood loss and hypothermia are the predominant considerations during surgery on burn patients. Blood loss can be rapid and massive, as much as 8 U in 15 min, and can be difficult to estimate as it generally is not collected into the suction.

Respiratory	**Upper airway:** A patient with burns around the airway (e.g., singed nose hairs) should be intubated as early as possible. Direct inhalational/thermal injury and fluid resuscitation may make delayed intubation more difficult 2° upper airway edema. **Lower airway:** Physiologic derangements may include pulmonary edema and ARDS even without inhalation injury. In addition, burn patients may be

	severely hypermetabolic (e.g., a patient with 40% TBSA burns may have twice the normal metabolic rate) with corresponding ↑ CO_2 production. These patients may have high PIPs and high minute ventilation requirements. Pressure control ventilation and high levels of PEEP may be useful. Other possible effects of severe burns include ↓ lung and chest wall compliance, ↓ FRC, ↑ A-a gradient, pneumonia, and pulmonary embolism. **Tests:** ABG, depending on pulmonary status; CXR, PRT
Cardiovascular	1–48 h postburn injury is associated with ↑ cardiac demand and a greatly elevated circulating levels of catecholamines; however, ↓ intravascular volume, myocardial depression, and ↑ SVR/PVR may → ↓ CO and ↓ urine output. 48–72 h post burn, the hypermetabolic/hyperdynamic phase begins. ↓ SVR may mimic sepsis. **Tests:** As indicated from H&P
Neurologic	Evaluate for burn encephalopathy. Characterize baseline mental status before anesthesia to allow evaluation of recovery postop.
Musculoskeletal	Damaged muscle → ↑ acetylcholine receptor density, resulting in ↓ sensitivity to nondepolarizing muscle relaxants and potentially fatal elevations of K^+ in response to succinylcholine. In burns >5% TBSA, avoid succinylcholine after 24 h post burn and for at least 1 yr thereafter for burns >10% TBSA (↑↑ K^+). Recovery of normal response to muscle relaxants does not occur until burns have healed completely.
Hematologic	Coagulopathies may result directly from the burn injury, as well as from rapid replacement of blood loss during operative procedures. **Tests:** Hb/Hct; electrolytes; coagulation profile
IV access	May be difficult; assess preop. Consider central line placement with a large-bore catheter (e.g., Cordis®).

Fluid resuscitation guidelines	Parkland formula: LR @ 4 mL/kg/%TBSA/24 h (50% given in first 8 h); next 24h: 5% albumin @ 0.3–0.5ml/kg/%TBSA Brooke formula: LR @ 1.5 mL/kg/%TBSA + colloid 0.5 mL/kg/%TBSA (50% given in first 8 h); next 24h: 5% albumin @ 0.3–0.5ml/kg/%TBSA. UO goal: 0.5-1ml/kg/hr
Laboratory	Other tests as indicated from H&P. For recent injury, blood COHb should be measured. FENa < 1% or BUN/Cr > 20 suggests hypovolemia.
Premedication	Patients are commonly placed on high-dose narcotics after the initial injury; additional narcotics are frequently required to provide adequate analgesia for transport and movement to the OR table. It is important to identify opioid-tolerant patients to plan pain management.
Transport	For patients with severe ARDS, transportation from burn unit to OR may pose formidable challenges with regard to ventilation. Cardiopulmonary monitoring must be continued during transport; the ventilation system used in transport must be capable of delivering high minute volumes, PEEP, and inspiratory pressures. These requirements may not be satisfied by standard bag-valve systems and may require a high-quality transport ventilator.

INTRAOPERATIVE

Anesthetic technique

GETA: Regional techniques are rarely feasible, given the multiple surgical sites for harvesting and grafting. Some surgeons will employ tumescent infiltration of the burn and donor sites using a large volume of lidocaine-epinephrine-saline solution to facilitate debridement and graft harvest (↓ blood loss + ↓ postop pain). LMAs are not recommended, given the potential for significant fluid resuscitation and subsequent airway edema, as well as the frequent repositioning of patient intraop.

Induction	If the patient is adequately volume resuscitated, propofol (1.5–2.5 mg/kg iv) may be used. If the patient is intravascularly volume depleted, etomidate (0.3 mg/kg) or ketamine (1–3 mg/kg) is recommended. Patients with extensive burns (>30% TBSA) will develop a decreased sensitivity to nondepolarizing NMBs; therefore, 1.5× the usual intubating dose of NMB is recommended: vecuronium (1.5 mg/kg) or rocuronium (1.5 mg/kg). If rapid-sequence induction is indicated, succinylcholine should not be used if the initial injury is >24 h old. Under these circumstances, high-dose rocuronium (2 mg/kg) can be used. If the face is burned, awake FOI may be necessary and securing the ETT may be difficult. Alternatives to taping the ETT include wiring/suturing the tube to the teeth or using an umbilical tape strap.
Maintenance	Standard maintenance. Physiologic derangements of the respiratory system (ARDS, pulmonary edema) and a hypermetabolic state may require minute volumes >30 L/min and high inspiratory pressures and PEEP for adequate ventilation. Depending on the anesthesia machine, an ICU ventilator (capable of high-frequency oscillatory ventilation) may be necessary. Intraop, surgeons may use epinephrine-soaked sponges to ↓ blood loss. Systemic absorption of epinephrine will cause tachycardia and increase the probability of dysrhythmias; therefore, it is best to avoid halothane or desflurane. Isoflurane and sevoflurane are acceptable. Remifentanil is associated with opiate-induced hyperalgesia in this patient population and should be avoided. A low-dose ketamine infusion (0.1–0.5 mg/kg/h) is useful, especially in patients with opiate tolerance.
Emergence	Estimation of an adequate dose of narcotic to provide postop analgesia may be difficult because these patients are often receiving high doses of narcotics preop. An aggressive dosing strategy may

	be necessary. Ketamine has been used with success in providing improved analgesia in the setting of escalating opioid doses. If large-volume resuscitation has occurred intraop, there is the possibility of clinically significant airway edema; use caution before extubating to ensure a patent airway.	
Blood and fluid requirements	Extensive blood loss IV: 14–16 ga × 2 or a Cordis® BSS @ 8–10 mL/kg/h Keep UO @ 0.5–1 mL/kg/h. Blood: ~200 mL/1% BSA excised and grafted Fluid warmer T&C 2–4 U PRBC (to keep ahead)	Blood must be in OR before induction. Major blood loss generally is associated with eschar excision, usually the first procedure. For patients without contraindications to hemodilution (e.g., CAD, anemia), it may be better to consider delaying PRBC transfusion until major blood loss is complete. IV hyperalimentation should be continued during surgery or replaced with 10% dextrose infusion to avoid hypoglycemia. If sudden ↓ BP occurs during very rapid infusion of blood (>150 mL/min), consider using Ca^{++} to counteract the chelating effect of citrate. Avoid fluid overload, especially if patient has ARDS, is a small child, or is elderly. As the surgical site is superficial, there is not much 3rd-space loss.
Thermal	Room = ~82°F	Severe burn injury will

considerations	Warm all fluids. Humidify gases. Warming blanket Reflective head cover	disrupt thermal homeostasis. Temperature must be monitored throughout the case. The surgeon should be notified if patient's core T is dropping. 82°F is isothermic, however some surgeons will request substantially higher OR T, although there is no convincing evidence to support this practice.
Monitoring	Standard monitors + ART line ± CVP line ± PA catheter/TEE	ECG may require needle electrodes or alligator clip electrodes to skin graft samples if there is no skin availability to apply adhesive electrodes. The hemodynamically unstable patient should be monitored with a PA catheter/TEE and ART line.
Positioning	✓ and pad pressure points ✓ eyes	The burn patient may be uniquely susceptible to laryngeal or upper airway edema in the prone position; therefore, examination of the upper airway before extubation is recommended to avoid emergent reintubation.
Complications	Massive blood loss VTE	

POSTOPERATIVE

Complications	Hypothermia Coagulopathy	May occur as the result of massive blood loss and replacement
Transport	Continue cardiopulmonary monitoring. High minute ventilation requirements ↑ PIP ↑ PEEP	Verify adequacy of transport ventilation system before departing OR.
Multimodal pain management	Oral methadone or sustained-release morphine sulfate IV (PCA if possible) fentanyl or hydromorphone	Opiate requirements may become impressively large. IV or PO acetaminophen, NSAIDs, and gabapentin, often combined with a low-dose ketamine infusion, are all useful in acute burn and skin graft pain management.
Tests	Hct, ABG, electrolytes, PT, PTT, Plt, if massive transfusion given	

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SECTION 12.0

PEDIATRIC SURGERY

CHAPTER 12.1

Pediatric Neurosurgery

SURGEONS

Gerry A. Grant, MD
Michael S. B. Edwards, MD, FAANS, FACS, FAAP
Samuel H. Cheshier, MD

ANESTHESIOLOGISTS

Michael I. Chen, MD
Lisa Wise-Faberowski, MD, MS, FAAP

CRANIECTOMY FOR CRANIOSYNOSTOSIS (CRANIOFACIAL SURGERY)

SURGICAL CONSIDERATIONS

Description

Craniofacial surgery is a broad term that refers to reconstructive surgery of the cranial or facial bones. Craniofacial surgery is most commonly performed for the correction of craniosynostosis (also known as cranial dysostosis). Craniosynostosis is the maldevelopment of the cranial base or vault due to premature fusion of cranial sutures (growth plates). The surgical correction of craniosynostosis involves resection of the affected suture(s) and reconstruction of the cranial or orbital bones, sometimes referred to as complex cranial vault reconstructive surgery (CCVR). The most common form o craniosynostosis is scaphocephaly, which is caused by the premature fusion of the sagittal suture. Other forms of craniosynostosis, in decreasing frequency, are brachycephaly (coronal synostosis), trigonocephaly (metopic synostosis), and posterior plagiocephaly (lambdoidal synostosis). Craniofacial surgery is also performed for craniofacial dysmorphism (abnormality of the lower craniofacial bones). Examples

include Crouzon, Apert, Pfeiffer, and Saethre-Chotzen syndromes. Deformational plagiocephaly (flattening of an infant's head due to a preferred sleep position) can often be confused for unilateral lambdoid craniosynostosis. Plagiocephaly can be distinguished from craniosynostosis by the position of the ears. In lambdoid synostosis, the ipsilateral ear is displaced posteriorly, whereas in positional plagiocephaly, the ipsilateral ear is displaced anteriorly. Plagiocephaly is not a surgical condition.

In most cases, craniosynostosis presents at birth but may be difficult to recognize until the rapid phase of brain growth during the first year of life. Early recognition and correction of craniosynostosis result in the best cosmetic and neurologic outcome. The repair is usually performed during the first 3–9 mo of life because the early release of the fused suture allows for normal brain growth and development thereby aiding the correction of the abnormal cranial shape. The surgical repair of craniosynostosis involves removal of the abnormal suture through a craniectomy or craniotomy, followed by reconstruction of the calvarium and/or orbit(s) to overcome the cranial deformity.

Due to the complexity of the repair and risk for significant blood loss, the surgery is often performed by both a pediatric neurosurgeon and a craniofacial plastic surgeon. The surgical teams should make every effort to reduce blood loss during the procedure by infiltrating the scalp with 1:400,000 epinephrine, using point electrocautery, preserving the pericranium, and fastidiously waxing the bone edges. The most common skin incision is a bicoronal opening that allows for access to the entire calvarium. The extent of the bone removal and reconstruction varies, depending on the type and number of sutures involved. In patients with both craniosynostosis and craniofacial dysmorphism, the procedure is staged: first with correction of the cranial component, then of the facial component, as originally described by Tessier.

Variant procedure or approaches

If certain criteria are met, a minimally invasive technique, known as endoscopically assisted strip craniectomy (EASC), can be considered (see Fig. 12.1-1). In contrast to the traditional CCVR, the surgeon makes a small incision and removes the fused suture (hence craniectomy instead of craniotomy). At the time of surgery, the shape of the cranial vault is not surgically changed but instead it is the postop helmeting therapy and subsequent brain growth that reshapes the skull. It is typically limited only to simple craniosynostosis detected in the first month of life. At this age, the cranium is plastic enough to allow for the good cosmetic results. Advantages of EASC are small incision a shorter surgery time, minimal blood loss, and short hospital course. The disadvantage is that the cranial vault may not remodel enough and a traditional CCVR may be necessary. A specific risk seen in endoscopic repair of sagittal synostosis (the most

common suture repaired endoscopically) is VAE. The intraop "sphinx" position (prone with the neck extended) positions the head/surgical field above the level of the heart increasing the risk of air entrainment, although it does allow the airway to be more accessible to the anesthesiologist.

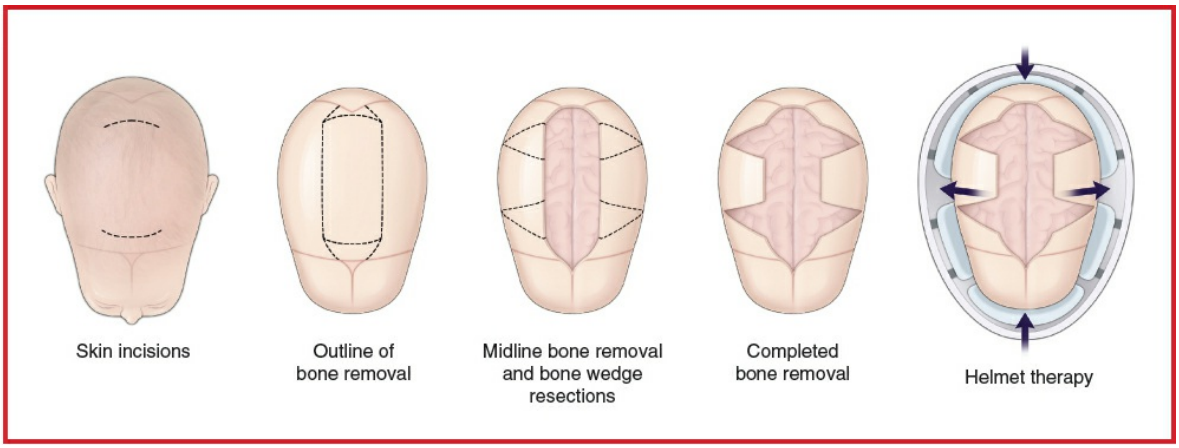

Figure 12.1-1 Endoscopic sagittal synostosis repair.

Usual preop diagnosis

Craniosynostosis (sagittal, coronal, metopic, lambdoidal); craniofacial dysmorphism; Apert syndrome; Crouzon syndrome; Pfeiffer syndrome; Saethre-Chotzen syndrome

ERAS: For elective surgery, preop family counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, discussion of carb loading, postop pain management options, possibility of lines, and urinary catheter postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Supine or prone (less common); or table 180°
Incision	Bicoronal, biparietal, midsagittal. Prior to incision, inject local anesthetic with 1:400,000 epi to ↓ bleeding
Special instrumentation	Midas Rex® craniotome; absorbable plates and screws
Unique considerations	Repair of synostosis with multiple sutures may result in ↑ ICP. Rarely occurs in single-suture craniosynostosis (<5%). If significant ↑ ICP, a shunt should be placed prior to craniosynostosis surgery.

Antibiotics	Cefazolin (30 mg/kg). For patients with β-lactam allergies, clindamycin (5–10 mg/kg) or vancomycin (15 mg/kg, infused over 60 min). Redosing interval is longer in infants <1 mo. A second antibiotic, metronidazole (15 mg/kg) or gentamicin (2.5–5 mg/kg), may be added for procedures involving the nasal sinus.
Surgical time	1–2 h for EASC; 4–8 h for conventional repair
EBL	Highly variable and depends on the preop condition, number of sutures involved, age of the patient, and magnitude of the repair. EBL must be minimized. Operative injury to the venous sinuses may be catastrophic if hemostasis cannot be achieved quickly.
Postop care	PICU. Postop Hct/Hgb levels required. If significant blood loss occurs during surgery, INR and coagulation parameters should be obtained. Blood transfusion is often necessary in infants (<10 kg) or if Hct is between 21 and 23.
Mortality	<2%
Morbidity	Meningitis Infection CSF rhinorrhea Pseudomeningocele formation due to unrecognized dural tear ↑ ICP (2° skull reshaping) Venous thrombosis or injury Neurologic injury: Rare
Pain score	1–3

PATIENT POPULATION CHARACTERISTICS

Age range	Newborn–young adult
Male:Female	1.2:1
Incidence	0.04–0.1%

Etiology	Sporadic; heritable (monogenic and chromosomal syndromes); environmentally induced (amniotic bands, iatrogenic) The origin of craniosynostosis can be heterogeneous: hereditary, mechanical, teratogenic, and idiopathic. Idiopathic, nonsyndromic craniosynostosis accounts for more than 70% of cases.
Associated conditions	Congenital defects (limbs, heart, brain, kidneys); hydrocephalus; encephalocele

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Craniosynostosis has been associated with ~150 syndromes. While most of these syndromes are associated with intellectual disability and developmental delay, some are associated with difficult intubations (i.e., Crouzon's and Apert's) while others are associated with cardiac conditions (i.e., Opitz's, Saethre-Chotzen, Carpenter's). As a result, preop preparation for each case should be customized.

Airway/Respiratory	Patients with craniosynostosis can be challenging intubations. The cranial abnormalities often cause the head to roll from side to side during laryngoscopy. Placing a large shoulder roll can be helpful. Syndromic craniosynostosis patients with midface hypoplasia (such as Crouzon's and Apert's) should be carefully evaluated for a difficult airway. Consider preparing for FOI or video laryngoscope.
Neurologic	Presenting Sx in infants with craniosynostosis includes progressive head deformation, progressively increasing irritability, crying, failure to eat, and failure to grow in head circumference. These Sx may be due in part to ↑ ICP. On physical examination, one or more of the cranial sutures are fused. Infants with other types of craniofacial deformity usually have no Sx related to their abnormalities.
Laboratory	Tests as indicated from H&P. Preop Hct/Hgb, platelets, INR

	3D model printed using MRI or CT can be very advantageous to surgical planning. However, standard CT, MRI, or even cranial ultrasound can be used.
Premedication	Usually not needed in infants. Older children may receive midazolam 0.5 mg/kg po. Oversedation should be avoided in patient with ↑ ICP.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 15 mg/kg po (2–12 yo).

INTRAOPERATIVE

Anesthetic technique

GETA: However, because craniofacial surgery can range from a minimally invasive endoscopic craniectomy to a combined anteroposterior open cranial vault remodeling, the preop anesthetic preparation can be quite varied. Three common risks exist with all craniosynostosis repairs: airway management, blood loss, and venous air embolism.

The first major risk is related to airway management. Since most craniosynostosis repairs are done during infancy, intubation can be challenging for those not familiar with intubating infants. The distortion of the cranial vault, caused by the growth of the brain expanding the skull in the direction opposite to the fused suture, can make positioning difficult. For example, scaphocephaly (fusion of the sagittal suture) causes an anteroposterior elongation of the skull, which can make it difficult to keep the head from turning to the side. The risk of accidental extubation is very significant given the liberal use of irrigation along with patient movement required to achieve proper intraop positioning (sometimes prone and rotated 180° from the anesthesiologist). Special measures should be taken to avoid extubation: liquid adhesives (benzoin, Mastisol®), waterproof films (OpSite®, Tegaderm®), and/or suturing of the endotracheal tube to the mandible.

The second major risk is blood loss. The blood loss for EASC is usually minimal, and transfusion only occurs in ~10% of procedures. However, the risk of massive blood loss can occur if an underlying venous sinus is injured. If rapid blood loss occurs, conversion to an open procedure may be required. In contrast, 95% of CCVR patients receive at least one unit of blood and 50% receive two or more units. Blood loss

usually occurs from the scalp and bone. The surgeon must remain mindful of the volume contained within the surgical field and communicate this to the anesthesiologist when bleeding is felt to be either continuous or excessive. Often, the bleeding is underestimated because of its insidious nature during a multi-hour procedure. Starting both packed red blood cells and fresh frozen plasma replacement at the beginning of the case is not uncommon for this significant blood loss procedure.

To further reduce blood loss, antifibrinolytics (e.g., tranexamic acid) are given. Antifibrinolytics act by blocking the lysine-binding sites of plasminogen, preventing activation to plasmin, and stopping the lysis of polymerized fibrin. A loading dose (e.g., 10–50 mg/kg) followed by an infusion (e.g., 1–5 mg/kg/h) should be given to maximize its effectiveness. The risks of seizures and/or thromboembolic events are not increased if excessive doses are not given. Avoidance of hypertension, coagulopathy or DIC, and preop recombinant erythropoietin may also reduce the need and/or volume of an intraop transfusion. In healthy infants, hematocrit values of 21–23% are well tolerated; however, continual bleeding after the procedure into the subgaleal space should be expected during the first 24 h postop.

The third major risk is VAE. Infants undergoing CCVR are at significant risk for VAE because of the numerous bony cuts required to perform the repair allowing air to enter through the bone marrow as well as epidural veins or dural sinuses. Infants have an added risk because their relatively larger head may result in having their heads unintentionally being positioned above their hearts. The pressure gradient between the surgical field and the right atrium allows for entrainment of air. The vascular nature of the infant scalp may further increase the blood loss. The smaller vascular system also makes the systemic effects of the VAE more pronounced, and the persistence of a patent cardiac atrial or ventricular foramen poses a risk for paradoxical air embolism. The incidence of VAE in CCVR has been reported to be 30–80%. Hypotension and $\downarrow ETCO_2$ are late signs for VAE; therefore, the use of a precordial Doppler should be considered to allow for early detection. If a VAE is detected, interventions include positioning the head below the heart (Trendelenburg position), flooding the surgical field with saline, increasing intravascular volume, administration of vasoactive agents, and providing CPR as indicated.

Induction	Standard pediatric induction. Tape the tube firmly in place at one side of the mouth using liquid adhesive. Some surgeons like to suture the ETT in place. Verify ETT placement after the patient is in final position. In prone cases, the patient is usually placed in a

	horseshoe and not in pins. For supine cases, the surgery usually involves reflection of the scalp down over the eyes and nose. Corneal shields or suturing the eyelids shut is preferred over eye tape.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K, p. K-6). Maintain normovolemia. Avoid hypothermia. Avoid long-acting opioids or scopolamine patch, which may interfere with postop neuro exam. When possible, sequential pneumatic compression devices should be used to ↓ VTE risk. Consider fosaprepitant 4 mg/kg iv over 20 min (2–12 yo) with a $5HT_3$ antagonist to minimize PONV especially following posterior fossa procedures or in patients with a history of severe PONV.	
Maintenance	Standard maintenance (most institutions use inhalational anesthetic). Muscle relaxation is often useful during line placement and positioning. The surgeon may request mild hypotension during the removal of the bone flap to minimize bleeding. Hyperventilation to PCO_2 = 30 mm Hg is often desired to ↓ ICP at the beginning of the case.	
Emergence	If the case is uncomplicated, the patient is extubated and goes to PICU for observation. In the rare situation that large amounts of blood products are transfused, extubation should be handled with care, as facial and airway swelling may result in airway compromise or loss of airway. Leave intubated if in doubt. If the ETT or eyes are sutured shut, the suture should be removed before extubation.	
Blood and fluid requirements	PIV (infants): 20–22 ga × 2–3 NS or BSS Albumin 5% (consider) Fluid warmer	Expect moderate blood loss. Most of the bleeding is occult (lost in the drapes and sponges), and so consider starting transfusions during incision to avoid getting behind. Correct any

		intraop coagulopathies. Aggressive transfusion and crystalloid administration must be tempered to prevent ↑ ICP. A tight dura may result in risk of dural sinus injury or get in the way of replacing the bone flaps. Tranexamic acid (TXA) 50 mg/kg followed by infusion of 5 mg/kg/h has been shown to decrease blood loss.
Monitoring	Standard monitors Foley catheter Precordial Doppler (recommended) Arterial line ±CVP (seldom needed)	Life-threatening VAE is rare with monitoring and prompt treatment. Due to the young age of these patients, a central line may be difficult. Some surgeons feel that an IJ central line may ↓ venous drainage. ↑ K^+ and ↓ Ca^{++} may occur with transfusions of blood products.
Positioning	OR table usually rotated 180° ✓ and pad pressure points ✓ eyes	Prevent compression to the patient's thorax by placing a Mayo stand over the chest area.
Complications	Major blood loss Hypothermia VAE	 Maintain normothermia using a multimodal approach. Rx VAE—notify surgeon, flood the surgical field,

		d/c N_2O, attempt to aspirate air from CVP line. Lower head of bed, compress jugular veins to decrease the rate of air entry. CPR as needed. PEEP is not recommended and may be deleterious. VAE is more likely if dural sinus is entered.

POSTOPERATIVE

Because of the potential space created by the extensive surgery requiring elevation of the scalp and galea, significant bleeding may continue into this space in the postop period. However, drains are not routinely placed. Coagulation status should be assessed, and any coagulopathy should be corrected. Patients should be closely monitored during this period, and their hematocrit and platelet count should be checked on a regular basis. Postoperatively, a head wrap is sometimes placed, which can result in flexion of the neck resulting in airway compromise. Airway edema from significant volume resuscitation can worsen this issue. Swelling of the periorbital regions and face should be expected.

Complications	Bleeding hypovolemia	Significant bleeding may continue in the postop period.
Multimodal pain management	Acetaminophen (30–40 mg/kg pr) or (10–15 mg/kg iv) Fentanyl 0.25–0.5 mcg/kg MSO_4 0.25–0.05 mg/kg Opioid-sparing adjuvants should be encouraged.	If not given preop or if 4–6 h has elapsed since previous dose
ERAS	Ondansetron 0.1 mg/kg iv	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Tests	Hct/Hgb Coagulation parameters	Hct/Hgb levels are necessary to determine adequacy of blood replacement. Monitor closely for hypovolemia.

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REPAIR OF MYELOMENINGOCELE

SURGICAL CONSIDERATIONS

Description

Spina bifida is a spectrum of birth defects resulting from the failure of the neural tube to close during embryonic development including the backbone and the membranes surrounding the spinal cord. Myelomeningocele is the most serious form of spina bifida making up 10% of cases. Myelomeningocele is an open spina bifida, usually presenting

at the base of the spine. These defects contain the meninges and spinal cord outside the vertebral arch. In contrast, meningoceles possess the meninges without any spinal cord elements. Myelomeningocele can be diagnosed in utero by elevated maternal serum alpha-fetoprotein, fetal ultrasound, or fetal MRI scans.

The fundamental goals of surgery are preservation of neural tissue, reconstitution of a normal intrathecal environment, and complete closure of the skin to prevent spinal fluid leak and meningitis. A thin parchment of dystrophic epithelium usually covers most myelomeningoceles; however, this layer does not prevent leakage of spinal fluid. Because of the risk of central nervous system infection associated with the exposed subarachnoid space, closure of the myelomeningocele is recommended within 72 h of birth.

The surgical goals are to identify the various anatomic layers from skin to pia and reapproximate them. In cases of large defects, local skin and myocutaneous flaps may be necessary to cover the spinal defect adequately. After the closure of the myelomeningocele, hydrocephalus often presents and requires cerebral spinal fluid diversion (usually a ventriculoperitoneal shunt).

Variant procedure or approaches

The efficacy of **intrauterine myelomeningocele repair** is still in debate. In a randomized multicenter trial, it was demonstrated that intrauterine repair resulted in improved mental development and motor score as well as a decrease need for shunting of cerebral spinal fluid; however, this group also had a significantly increased risk of preterm delivery and complications during delivery.

Usual preop diagnosis

Myelomeningocele; myeloschisis; meningocele; myelodysplasia; spina bifida aperta

ERAS: For elective surgery, preop family counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, discussion of carb loading, postop pain management options, possibility of lines, and urinary catheter postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Prone with rolls under chest and hips
Incision	Surrounding the defect, preserving skin that can be utilized in the closure

Special instrumentation	Loupes and/or operating microscope
Unique considerations	Latex precautions
Antibiotics	Neonates <1 mo: cefazolin (30 mg/kg). For patients with β-lactam allergies, clindamycin (5 mg/kg) or vancomycin (15 mg/kg, infused over 60 min). Redosing interval is significantly longer in neonates.
Surgical time	1.5–3 h
Closing considerations	Skin closure may be complex and require rotation of flaps and aid of plastic surgeon.
EBL	Negligible–25 mL (in most cases)
Postop care	Neonates should go to NICU. Patients should remain prone to avoid pressure on the incision. Head size and head ultrasound to monitor for progressive hydrocephalus
Mortality	<1%
Morbidity	Meningitis/ventriculitis Hind brain dysfunction Wound infection CSF leak Apnea, vocal cord paralysis Urinary dysfunction (neurogenic bladder)
Pain score	2–5

PATIENT POPULATION CHARACTERISTICS

Age range	Newborn (diagnosed at birth)
Male:Female	1:1
Incidence	Incidence of all spina bifida was 1/1000; however, since enriched grain products are now fortified with folate, the incidence has decreased by 70%. Incidence is higher in third world countries.

Etiology	Congenital
Associated conditions	Hydrocephalus; lower extremity weakness; bowel and/or bladder dysfunction (neurogenic bladder) and/or hydronephrosis; scoliosis; Chiari II malformations; congenital cardiac anomalies

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Since myelomeningoceles are usually repaired in the first few days of life, their preop management is usually carried out by the NICU. The patient should be screened for conditions, which are often associated with myelomeningocele.

Cardiovascular	Associated cardiac anomalies **Tests:** Echo
Neurologic	Often associated with motor and/or sensory deficits in the lower extremities, neurogenic bladder, and lower cranial nerve dysfunction. Nearly all patients with myelomeningocele have an associated supraspinal defect, Arnold-Chiari II malformation, creating hydrocephalus, which may require a ventriculoperitoneal shunt after the myelomeningocele repair. **Tests:** MRI or ultrasound of brain
Renal	At least 95% of patients with myelomeningocele have neurogenic bladder. Steps should be taken to reduce bladder pressure in older patients.
Laboratory	**Tests:** CBC, T&S, coags, serum electrolytes
Premedication	Not indicated in newborns
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 15 mg/kg po (2–12 yo).
Other	Latex precautions

INTRAOPERATIVE

Anesthetic technique

GETA: Patients with myelomeningoceles are kept in the NICU on their abdomen prior to surgery to avoid placing pressure on the spinal defect. However, since intubation is performed in the supine position, the defect should be dressed with moist-sterile occlusive dressing. The patient is then positioned supine onto donuts or rolls in a manner that does not put pressure on the myelomeningocele.

Induction	Most patients will have an iv and should undergo a standard iv induction with NMR (see Appendix D, p. D-1). Care should be taken to limited neck movement because of possible brain stem compression from Chiari II malformation. After verification of the ETT placement, the tube is taped securely to one side of the mouth. Use of a liquid adhesive is advised. Patients should be turned prone as soon as possible.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K, p. K-6). Maintain normovolemia. Avoid hypothermia. Dexamethasone iv may ↓ PONV. When possible, sequential pneumatic compression devices should be used to ↓ VTE risk.
Maintenance	The choice of anesthetic is dependent on whether neuromonitoring is being used. If not, then standard maintenance (see Appendix D, p. D-3) may be used. If intraop neurophysiologic monitoring is used, then consider TIVA with propofol/remi or propofol/fentanyl. Inhalational agents not to exceed 0.5 MAC. No additional neuromuscular-blocking agents should be administered. Adjust O_2 mixture to maintain arterial O_2 sat at 95–97%. Maintain a near-normal BP. Ventilation is controlled to maintain $PetCO_2$ = 35–40 mm Hg.
Emergence	Patients undergoing simple repair are usually extubated at the end of the case. Those undergoing complex repair with fascial releases and a tight abdomen almost always remain intubated for the

	first 24 h. All patients are kept prone for the first few postop days to avoid putting pressure on the incision.	
Blood and fluid requirements	IV: 22–24 ga × 2 D10 ¼ NS NS or BSS	Administer dextrose containing solution (usually D10 ¼ NS) at 4 mL/kg/h via a continuous infusion pump. Blood is not necessary.
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes for pressure	The patient is placed in a prone position with chest and abdominal rolls. Avoid excessive lordosis, which would compromise surgical access. The head is turned to the side that the ETT is taped. The head is padded using a gel donut or foam. ✓ bilateral breath sounds after positioning.
Complications	Hypothermia Bradycardia Hypotension	Maintain normothermia by keeping OR warm and using warming lights and forced air warming as needed. Close monitoring, atropine Fluids and vasopressors as needed

POSTOPERATIVE

The patient should not lay supine after completion of the case. If there is concern whether the patient will tolerate extubation, then the patient should be left intubated overnight. This can make it easier for the NICU to manage postop pain and does no prolong hospitalization.

Complications	CSF leak Wound healing complications Infection Renal failure Respiratory compromise from a tight abdomen	
Multimodal pain management	Acetaminophen (30–40 mg/kg suppository) or (10–15 mg/kg iv) Fentanyl 0.25–0.5 mcg/kg MSO_4 0.25–0.05 mg/kg Opioid-sparing adjuvants should be encouraged.	If not given preop or if 4–6 h has elapsed since previous dose
ERAS	Ondansetron 0.1 mg/kg iv	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Adzick NS, Thom EA, Spong CY: A randomized trial of prenatal versus postnata repair of myelomeningocele. N Engl J Med 2011; 364:993–1004.
2. Afroza S, Ali Z, Prabhakar H: Severe systemic hypotension during repair of leaking large meningomyelocele. J Anesth 2008; 22:59–60.
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6. Gupta N, Farrell JA, Rand L, et al: Open fetal surgery for myelomeningoceleJ Neurosurg Pediatr 2012; 9(3):265–73.
7. Idowu OE, Oyeleke SO: Spinal anesthesia and monitored conscious sedation fo repair of infantile meningomyelocele. Childs Nerv Syst 2011; 27(11):1985–8.
8. Karlin L, Weinstock P, Hedequist D, et al: The surgical treatment of spinal deformity in children with myelomeningocele: the role of personalized three-dimensional printed models. J Pediatr Orthop B 2017; 26(4):375–82.

LAMINECTOMY, WITH RELEASE OF TETHERED SPINAL CORD (SPINA BIFIDA OCCULTA)

SURGICAL CONSIDERATIONS

Description

Unlike open spina bifida (aperta), which occurs as a result of defective primary neurulation, closed spina bifida (occulta) is the result of defective secondary neurulation. Except for an occasional sacral dimple, hairy patch, or fatty mass, most closed spina bifida do not have any physical skin manifestations over the spinal defect. Closed spina bifida is made up of a large constellation of spinal cord defects. These include intramedullary lipoma, lipomyelomeningocele, split cord malformations (diastematomyelia), dermal sinus tracts, meningocele manqué, neurenteric cyst, tight filum terminale, and myelocystocele. However, they all share three common features: congenital spinal defects, defect covered by intact skin, and spinal cord tethering. These lesions cause tethering or stretching of the spinal cord as the vertebral axis elongates during normal growth. The fixed spinal cord is stretched by motion and by the growing spine, resulting in neurologic dysfunction, which is most likely the result of reduced spinal cord blood flow. Tethered cord syndrome (TCS) can present as leg weakness or numbness, change in gait, urinary incontinence or retention, back pain, scoliosis, or bowel control issues. In some cases, TCS is the first clue that the patient has spina bifida. Aside from congenital causes, TCS can also be caused by spinal trauma, prior spinal surgery, and tumors in the spinal column. Release of the tethering elements is recommended to prevent either the onset or worsening of cord dysfunction.

The surgical principles for correction of tethered cord involve excision of the intradural lesion and release of the tissue element that is tethering the spinal cord, while preserving the normal neural structures. The difficulty in untethering the spinal cord can range from easy to extremely challenging. A tight filum terminale can be easily incised with little threat to the spinal cord or nerve root function. On the other hand, excision of lipomyelomeningoceles may prove to be very challenging because removing the tethering lesion is usually intertwined with the spinal cord and adjacent nerve root. Intraop neurophysiologic monitoring (IONM) of the spinal cord and nerve roots is highly recommended. Once untethered, a tight closure of the dura and myofascial layers is critical to prevention of postop spinal fluid leaks. Dural grafts may be necessary in some cases.

Usual preop diagnosis

Spina bifida occulta; occult spinal dysraphism; tethered cord; fibrolipoma filum terminale; lipomyelomeningocele; lipoma of the filum (filar lipoma); dermal sinus tract; caudal agenesis; caudal regression, anterior sacral meningocele; intramedullary lipoma; split cord malformations (diastematomyelia); meningocele manqué; neurenteric cyst; myelocystocele

ERAS: For elective surgery, preop family counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, discussion of carb loading, postop pain management options, possibility of lines, and urinary catheter postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Prone
Incision	Posterior midline centered over abnormality
Special instrumentation	Operating microscope; laser
Unique considerations	Minimize latex exposure
Antibiotics	Neonates <1 mo: cefazolin (30 mg/kg). For patients with β-lactam allergies, clindamycin (5 mg/kg) or vancomycin (15 mg/kg, infused over 60 min). Redosing interval is longer in infants.
Surgical time	1.5–4 h (longer for diastematomyelia and lipomyelomeningocele)
Closing considerations	After dural closure, the integrity of the repaired dura is tested with a sustained (~20 sec) Valsalva (inspiratory pressure at 30 cmH_2O). If a graft leak is detected, then the defect is repaired and the Valsalva is repeated. This process may be repeated several times until a watertight seal is achieved.
EBL	Negligible–25 mL (in most cases)
Postop care	ICU. Patients should remain flat postop to prevent CSF leakage and pseudomeningocele.

Mortality	<1%
Morbidity	Infection Neurologic deficit Aseptic meningitis CSF leak Pseudomeningocele formation Urinary dysfunction (neurogenic bladder)
Pain score	3–5

PATIENT POPULATION CHARACTERISTICS

Age range	Newborn–adults
Male:Female	1:1
Incidence	Rare
Etiology	Congenital
Associated conditions	Ankle/foot deformity (talipes); neurologic impairment; neurogenic bowel/bladder; scoliosis; vertebral abnormalities; VACTERL/VATER association (vertebral, anal, cardiac, tracheoesophageal, renal, and limb anomalies); cutaneous anomaly over spine; syringomyelia; caudal agenesis; urinary anomalies; check abdominal ultrasound, renal function prior to OR

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Because TSC can be caused by a wide spectrum of diseases, each with its owr associated conditions; the patients should be screened for possible cardiac, neurologic, gastrointestinal, urologic, and musculoskeletal systems. Congenital syndromes such as VACTERL (vertebral, anal, cardiac, tracheoesophageal, renal, and limb anomalies) car present for repair of tethered cord.

Neurologic	Presenting symptom in older children is usually pain in the lower back radiating into the legs and/or progressively worsening motor or sensory deficits in the anal region or involving the lower extremities.

	Tests: MRI of spine
Musculoskeletal	Lower extremity foot deformity as well as sensory or motor deficits may be present.
Renal	Renal function may be impaired in patients with Hx of recurrent UTIs. **Tests:** UA; BUN; Cr; others as indicated from H&P
Laboratory	**Tests:** Hct, platelets, T&S, coags
Premedication	Usually not needed in infants. Older children may require midazolam (0.5 mg/kg po).
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 15 mg/kg po (2–12 yo).
Latex allergy	Latex precautions are often necessary.

INTRAOPERATIVE

Anesthetic technique

GETA: However, unlike open spina bifida, TSC patients have complete skin closure of their defect and, therefore, can lay supine for induction. TSC is usually occult until it is discovered when the child becomes symptomatic. These patients are not usually admitted preop and therefore do not have an iv on arrival to OR.

Induction	Standard induction with sevoflurane, N_2O, and O_2 followed by establishment of iv access. Propofol (2–3 mg/kg) along with muscle relaxant (rocuronium 0.6 mg/kg) is given. The patient is intubated with an ETT that is taped to one side of the mouth, using a liquid adhesive (e.g., benzoin).
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K, p. K-6). Maintain normovolemia. When possible, sequential pneumatic compression devices should be used to ↓ VTE risk.
Maintenance	The choice of anesthetic is dependent on whether neuromonitoring is being used. If not, then a

	standard maintenance (see Appendix D, p. D-1 and p. D-3) may be used. If the lesion is intertwined with the spinal cord, then neuromonitoring will be required and an anesthetic conducive to neuromonitoring should be used (e.g., TIVA with propofol/remi or propofol/fentanyl). Additional agents such as dexmedetomidine and/or ketamine infusions may be used as appropriate. Inhalational agents not to exceed 0.5 MAC. No additional neuromuscular-blocking agents should be administered. Maintain normal BP. Ventilation is controlled to maintain $PetCO_2$ = 35–40 mm Hg.	
Emergence	The ETT is removed at the conclusion of the anesthetic.	
Blood and fluid requirements	IV: 20–22 ga × 2 NS/BSS @ 4–6 mL/kg/h	A dextrose containing solution should be used in <6 mo. Blood is not necessary.
Monitoring	Standard monitors ± Foley catheter ± UO	If the operation is anticipated to last several hours, or in the case of neurogenic bladder, a Foley catheter should be inserted.
Positioning	✓ and pad pressure points ✓ eyes	The patient is placed in a prone position with chest and abdominal rolls. Avoid excessive lordosis, which would compromise surgical access. The head is turned to the side in younger patients. The head is padded using a gel donut or foam. Listen for bilateral breath sounds after positioning.

		Older children should use a prone face pillow if an appropriate size is available.
Complications	Severe bradycardia	Manipulation of the spinal cord may produce ↓↓ HR reflex.
	Latex allergy	See Appendix G, p. G-1 for latex allergy considerations.

POSTOPERATIVE

Like open spina bifida, the patient should not lay on their incision (supine) postop. However, because these patients are older, there are fewer concerns regarding airway management and oversedation related to opioid administration.

Complications	Neurologic deficits Infection CSF leak Urinary retention Incontinence	
Pain management	Acetaminophen (30–40 mg/kg suppository) or (10–15 mg/kg iv) Fentanyl 0.25–0.5 mcg/kg MSO_4 0.25–0.05 mg/kg Opioid-sparing adjuvants should be encouraged.	If not given preop or if 4–6 h has elapsed since previous dose
ERAS	Ondansetron 0.1 mg/kg iv	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Filippidis AS, Kalani MY, Theodore N, et al: Spinal cord traction, vascular

compromise, hypoxia, and metabolic derangements in the pathophysiology of tethered cord syndrome. Neurosurg Focus 2012; 29(1):E9.
2. von Koch CS, Quinones-Hinojosa A, Gulati M, et al: Clinical outcome in childre undergoing tethered cord release utilizing intraoperative neurophysiological monitoring. Pediatr Neurosurg 2002; 37(2):81–6.
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INTRACRANIAL NEUROENDOSCOPY (ENDOSCOPIC THIRD VENTRICULOSTOMY, COAGULATION OF CHOROID PLEXUS, FENESTRATION OF CYST)

SURGICAL CONSIDERATIONS

Description

Intracranial neuroendoscopy (or ventriculoscopy as it is better known) is a minimally invasive procedure performed through standard cranial burr holes. By using rigid or flexible fiberoptic endoscopes, structures located in the lateral, 3rd, and, occasionally, 4th ventricles can be accessed for both diagnostic and therapeutic purposes. Since the lesions can distort the anatomy, ventriculoscopy is often used in conjunction with stereotactic guidance technology fused to a preop MRI or CT. It is most commonly applied in the setting of hydrocephalus since enlarged ventricles contribute to the safety and feasibility of endoscopic approaches. **Endoscopic third ventriculostomy (ETV)** is the more common endoscopic procedure and refers to fenestration of the floor of the 3rd ventricle to create a communication between the 3rd ventricle and the basilar cistern (Fig. 12.1-2). This technique is most commonly applied to patients with obstructive (noncommunicating) hydrocephalus. Successful third ventriculostomy alleviates the need for shunt placement. A temporary external ventricular drain (EVD) may be placed in some situations to control CSF drainage postop and/or to allow assessment of ICP Other procedures that can be performed by neuroendoscopy include positioning of ventricular catheters and coagulation of the choroid plexus, ventriculocisternostomy, fenestration of arachnoid cysts, biopsy of masses, and even resection of intraventricular tumors.

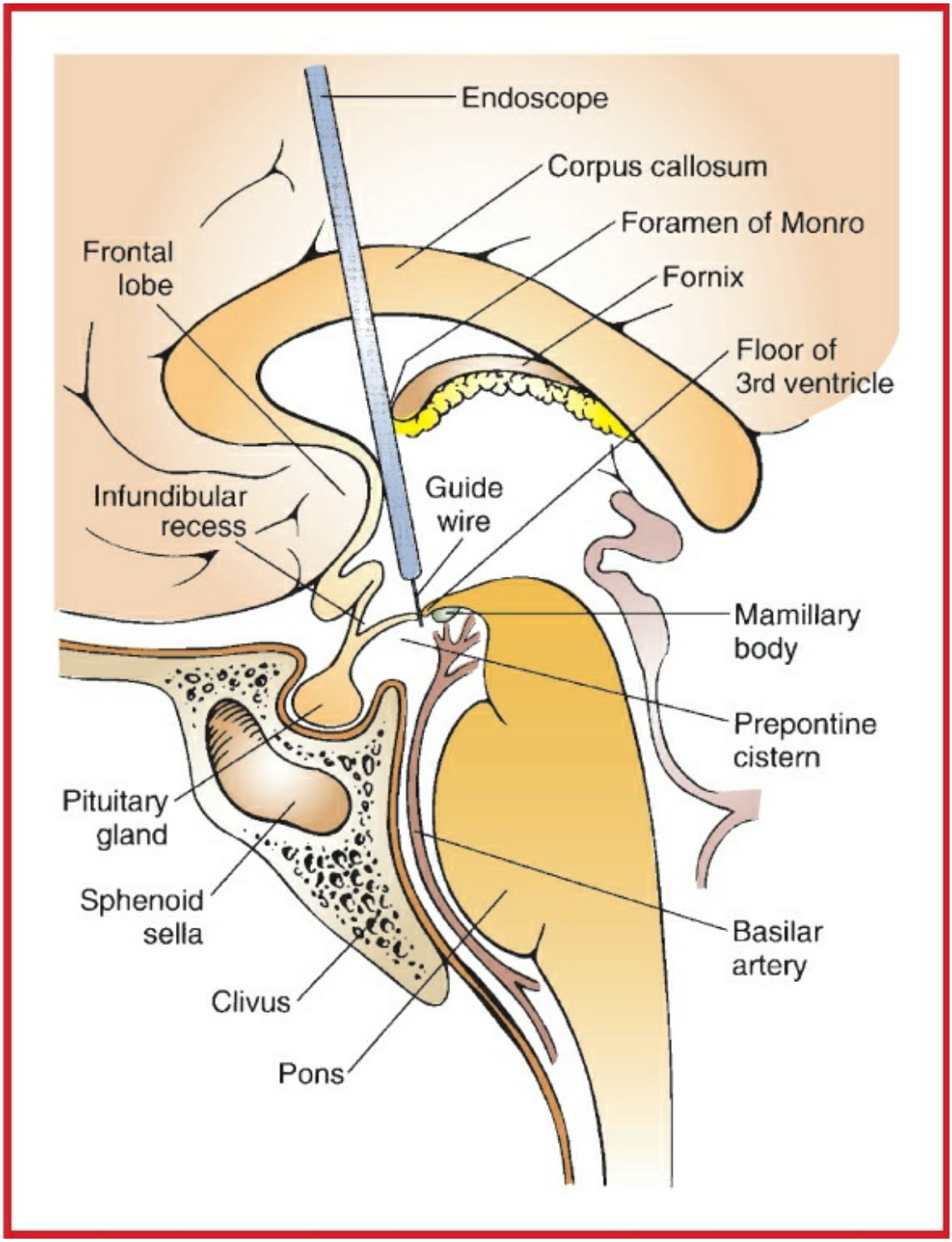

Figure 12.1-2 Endoscopic third ventriculostomy. The figure depicts fenestration of the floor of the 3rd ventricle by a blunt probe inserted through the endoscope.

Neuroendoscopes vary in size from 1 mm, for use inside a standard shunt catheter, to 6 mm scopes equipped with working channels to perform more complex intraventricular procedures. Most scope systems have a separate channel for fluid irrigation if bleeding obscures visibility. Fortunately, bleeding is usually minor and can be controlled easily by steady irrigation. In the event of excessive bleeding, however, conversion to an open

craniotomy is unlikely to improve control of the hemorrhage. The benefits of endoscopic procedure include smaller incision, faster recovery, fewer side effects, and reduced neurologic damage. However, endoscopy also carries unique risks such as cardiorespiratory depression and cardiac arrhythmia resulting from cold irrigant irritating the hypothalamic nuclei or increased ICP (from excessive irrigation, decrease in extracranial egress of fluid). Additional complications associated with neuroendoscopic procedures include intraventricular hemorrhage, pneumocephalus, injury to paraventricular structures (basal ganglia, hypothalamus, brainstem), cardiorespiratory depression, and delayed arousal from anesthesia. When working next to the brainstem, additional risks include mesencephalic injury, hypothalamic dysregulation, cranial nerve injury, and hemorrhage from the basilar artery.

Usual preop diagnosis

Obstructive hydrocephalus; shunt malfunction; loculated multicompartmental hydrocephalus; intraventricular mass; arachnoid cyst; retained catheter

ERAS: For elective surgery, preop family counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, discussion of carb loading, postop pain management options, possibility of lines, and urinary catheter postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Positioning	Supine with a bolster under the shoulder on the operative side and the neck slightly flexed. The head, chest, and abdomen are prepped for possible VP shunt insertion. Anesthesia monitors and lines should be routed away from the chest and abdomen. In simple procedures, the head can be positioned with a horseshoe. Otherwise, the head should be secured with a Mayfield clamp.
Incision	Small frontal or parietal-occipital
Special instrumentation	Endoscope (1–6 mm diameter); video system
Unique considerations	Watch for signs of ↑ ICP; irrigation should be normothermic.

Antibiotics	Cefazolin (30 mg/kg). For patients with β-lactam allergies, clindamycin (5 mg/kg) or vancomycin (15 mg/kg, infused over 60 min)
Closing considerations	Monitor for delayed intraventricular or subdural hemorrhage, ventricular collapse, acute hydrocephalus, and CSF leaks.
Postop care	Floor or ICU setting depending on extent of surgical intervention. CT scan if signs of ↑ ICP or intraventricular hemorrhage. EVD may be required in cases of third ventriculostomy for draining CSF and testing ICP.
Mortality	<1%
Morbidity	Intraventricular hemorrhage Acute hydrocephalus CSF leak/pneumocephalus Meningitis/ventriculitis Subdural effusions or hematoma Cranial nerve palsy Hemiparesis Diabetes insipidus SIADH Temperature dysregulation
Pain score	1–3. Higher if VP shunt is placed

PATIENT POPULATION CHARACTERISTICS

Age range	Newborn–adult
Male:Female	1:1
Incidence	<1%
Etiology	Congenital and acquired
Associated conditions	Hydrocephalus; spinal dysraphism; Chiari malformation; posthemorrhagic hydrocephalus; arachnoid cyst

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Most patients undergoing ventriculoscopy will have some degree of hydrocephalus. Conditions that further increase intracranial pressures (oversedation by anxiolytics, increases in $PaCO_2$, and seizures) should be avoided.

Cardiovascular	↑ ICP →↑ BP & ↓↓ HR (Cushing reflex) **Tests:** As indicated from H&P
Neurologic	Patients commonly present with headaches if ICP is elevated (>15 mm Hg). Other symptoms include N/V, drowsiness, papilledema, Sz, and focal neurologic defects.
Laboratory	**Tests:** CBC, T&S, coags, serum electrolytes
Premedication	Avoid in infants. Older children may receive midazolam (0.5 mg/kg PO). Oversedation should be avoided in patient with ↑ ICP.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 15 mg/kg po (2–12 yo).

INTRAOPERATIVE

Anesthetic technique

GETA; forced air warmer.

Induction	Standard pediatric induction. If ↑ ICP, iv induction with propofol (1.5–3.5 mg/kg) is preferred, because of its ability to decrease cerebral blood volume and, hence, ICP. ETT intubation with rocuronium (0.6 mg/kg). Tape the tube firmly in place at one side of the mouth using benzoin adherent.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K, p. K-6). Maintain normovolemia. When possible, sequential pneumatic compression devices should be used to ↓ VTE risk.

Maintenance	Standard maintenance. Normocarbia; avoid hypercarbia as ↑ ICP; however, hypocarbia is also undesirable because it can make cannulation of the ventricle(s) more difficult for the surgeon. Maintain normotension.	
Emergence	Extubate at the end of procedure. Ventriculoscopy can be emetogenic; administer prophylactic antiemetic (ondansetron 0.1 mg/kg, max = 4 mg) as well as avoiding excessive opioids.	
Blood and fluid requirements	IV (for children): 18–20 ga × 1 (22 ga for children) NS/BSS @ 4–6 mL/kg/h	Administer crystalloid (via measured volume system in a child). Blood is not usually necessary.
Management of ICP	Minimize fluids Isoflurane <1% or sevoflurane <2% Hyperventilate to $PaCO_2$ = 25–30 mm Hg	Steps should be taken to reduce ICP if there is a sudden ↑↑ ICP, and CSF cannot be evacuated by the surgeon. Sustained increases in ICP > 25–30 mm Hg are associated with severe neurologic injury and poor outcome.
Monitoring	Standard monitors	
Positioning	Table turned 90–180° ✓ and pad pressure points ✓ eyes	A VP shunt may electively be placed at the end of the procedure so anesthesia monitors and lines should be routed away from the chest and abdomen.
Complications	Cardiorespiratory depression Cardiac dysrhythmia	When working next to the brainstem, additional risks include mesencephalic injury, hypothalamic dysregulation, cranial

		nerve injury, and hemorrhage from the basilar artery.

POSTOPERATIVE

Some patients experience delayed emergence after an endoscopic procedure. Hydrocephalus may persist postop in spite of the surgical intervention. Avoid hypercarbia by monitoring for airway obstruction and avoiding excessive opioids.

Multimodal pain management	Acetaminophen (30–40 mg/kg suppository) or (10–15 mg/kg iv) Fentanyl 0.25–0.5 mcg/kg MSO_4 0.25–0.05 mg/kg Ketorolac (0.5 mg/kg) with surgeon's approval	Procedure is painful if a VP shunt is placed. Otherwise, opioid-sparing adjuvants should be encouraged.
ERAS	Ondansetron 0.1 mg/kg iv	Encourage early enteral nutrition, Foley catheter removal, and mobilization.

Suggested Readings

1. Bouras T, Sgouros S: Complications of endoscopic third ventriculostomy: a systematic review. Acta Neurochir Suppl 2012; 113:149–53.
2. Kirolous RW, Javadpour M, May P, et al: Endoscopic treatment of suprasellar and third ventricle-related arachnoid cysts. Childs Nerv Syst 2001; 17(12):713–8.
3. Maldonado IL, Valery CA, Boch AL: Shunt dependence: myths and facts.Acta Neurochir (wien) 2010; 152(9):1449–54.

SURGERY FOR INTRACRANIAL ARTERIOVENOUS MALFORMATION

SURGICAL CONSIDERATIONS

Description

Intracranial or brain arteriovenous malformations (AVMs) are the most common cause

of nontraumatic intracranial hemorrhage in childhood. AVMs are abnormal connections between arteries and veins that bypass the normal interposed capillary network. The direct connection exposes the thin-walled venules to arterial pressures causing them to dilate and create a tangle network of malformed vessels. AVM may occur in any location of the brain, brain stem, or spinal cord; however, cerebral malformations (80–90%) are the most common. Intracranial AVM can vary in size from having only one feeding vessel to very complex lesions, which have multiple feeders and can encompass an entire hemisphere.

Larger intracranial AVMs sometimes present as seizures due to "steal" (local ischemia) phenomenon caused by the lack of an interposed capillary network. As the AVM grows, the increased pressure in the venous system results in other parts of the brain developing venous congestion, which results in reduced perfusion and progressive neurologic deficit. Small AVMs are more likely to present as spontaneous hemorrhage. Presenting symptoms include headaches, neurologic deficit, coma, and occasionally death. Other risk factors for hemorrhage include previous hemorrhage, location (deep seated or infratentorial), deep venous drainage, female sex, and associated aneurysms. AVMs that rupture in the brain stem or cerebellum are more likely to cause permanent neurologic deficit or death than compared to those in the cerebral hemispheres. In general, pediatric patients are more likely than adults to present with hemorrhage. Also, the more extensive the AVM, the earlier it presents. Neonatal AVMs can present as high output congestive heart failure (CHF) (see vein of Galen malformation [VGAM]).

Magnetic resonance angiography (MRA) or CT angiography (CTA) is very sensitive in the diagnosis of intracranial AVM, but cerebral angiography is the gold standard for defining the anatomy of these lesions. The ideal treatment of AVM is complete surgical excision; however, the decision to operate or observe a child with an AVM is complex. Factors include the size and location of the AVM, presence of associated aneurysms, patient age, neurologic status, and surgeon's expertise. Some lesions situated in eloquent or deep regions of the brain should be managed with interventional or stereotactic radiosurgery rather than craniotomy and resection. If surgery is not performed, the risk of hemorrhage is 2% per year; however, after a hemorrhage, it increases from 6% to 20% per year.

Cerebral embolization is performed in the interventional radiology suite. Intraop neurophysiologic monitoring (EEG, sensory and motor evoked potentials) is usually required for embolizations. It is not uncommon for complex AVM to undergo multiple embolizations, performed over many months, before surgery or radiosurgery can be performed.

Ideally, lesions in eloquent cortex, especially those involving speech, should be performed as an awake craniotomy and direct brain mapping. Some teenagers may be good candidates, but generally, most children are not.

Usual preop diagnosis

Surgery of aneurysm; carotid-cavernous fistula; cavernous malformation

ERAS: For elective surgery, preop family counseling by the surgeon/anesthesiologist should include continuing any AED meds, limiting NPO duration, discussion of carb loading, postop pain management options, possibility of lines, and urinary catheter postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Supine, lateral decubitus, Concorde (modified prone), or semisitting; for burr hole, lateral Table 180° Avoid excessive neck flexion or extension, which may impair venous drainage. Secure cranium with radiolucent head holder if an intraop angiogram is planned.
Incision	Temporal or occipital. Prior to incision, inject local anesthetic with 1:400,000 epi to ↓ bleeding.
Special instrumentation	Operating microscope, microscopic instruments, intraop neurophysiologic monitoring, and image guidance for stereotactic surgery. For intraop angiography—endovascular catheters and fluoro
Unique considerations	If a lumbar subarachnoid drain is needed, it should be placed before pinning. If intraop angiography is needed, the femoral catheter sheath should be placed after pinning. Once the femoral artery is accessed, a sterile dressing is placed over the catheter site and then covered with the standard craniotomy drapes. A hole can later be made through the sterile drapes to access the catheter.
Antibiotics	Cefazolin (30 mg/kg). For patients with β-lactam

	allergies, clindamycin (5–10 mg/kg) or vancomycin (15 mg/kg, infused over 60 min)
Surgical time	3–7 h
Closing considerations	Meticulous hemostasis
EBL	Usually <250 mL; however, significant bleeding can occur
Postop care	PICU
Mortality	<5%, however can be much greater if the AVM has not been adequately embolized or if AVM is located in brain stem
Morbidity	Deep venous infarct: 5–10% Intracranial hemorrhage Hydrocephalus Stroke Subdural hygroma Infection: Rare
Pain score	3–4

PATIENT POPULATION CHARACTERISTICS

Age range	Birth–adulthood
Male:Female	1:1
Incidence	0.003–0.02%
Etiology	With the exception of hereditary hemorrhagic telangiectasia, AVMs are not inherited. However, primitive AV connections may develop while in utero. Cause unknown
Associated conditions	Other intracranial vascular malformations

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Most AVMs should undergo embolization prior to craniotomy. While embolizations carry a lower risk, they often involve similar management: intraop neurophysiologic monitoring (IONM), tight blood pressure control, propofol (barbiturate) therapy for cerebral protection, etc.

Cardiovascular	Infants may present with high-output CHF, which carries a very high risk for mortality if not treated (see vein of Galen malformations).
Neurologic	Subarachnoid hemorrhage Seizures Headaches Stroke
Laboratory	Tests as indicated from H&P. Preop Hct, Hgb, platelets, INR CTA; MRA; cerebral angiography (check renal function)
Premedication	Usually not needed in infants. Older children may receive midazolam 0.5 mg/kg PO to avoid HTN. Nasal midazolam or dexmedetomidine may be used in children who refuse PO meds. Oversedation should be avoided in patient with ↑ ICP. Preop anticonvulsants if there is a history of seizures
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss possibility of scalp block for postop pain management. Consider preop acetaminophen 15 mg/kg po (2–12 yo).

INTRAOPERATIVE

Anesthetic technique

GETA: Strict control of MAP is mandatory. BP goals should be within 10% of the patient's normal range; however, the size and location of the AVM may affect the range. The use of inotropes and vasoactive infusions and/or boluses (ephedrine, epinephrine, and/or phenylephrine) is often necessary. For ↓BP, labetalol can be used in less complex cases; however, most patients require continuous infusion of antihypertensive

(nicardipine, nitroprusside, clevidipine, or esmolol) postop especially if remifentanil infusions are used.

Induction	Mask induction is acceptable for very young children. Otherwise, iv induction is preferred. An oral premed and topic local anesthetic patches may be used to avoid agitation during iv placement. Propofol (1–2 mg/kg) and fentanyl (2–3 mcg/kg) should be slowly titrated to avoid acute changes in BP. An initial dose of rocuronium (0.6–1 mg/kg) can be given to facilitate intubation, lines, and pinning even if IONM is planned. Generally, etomidate and ketamine should be avoided in craniotomies (because of possible paradoxical exacerbation of ischemic injury and increased ICP); however, if there is significant cardiac compromise, then avoiding further depression of cardiac function should take precedence.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix D, p. D-1 and Appendix K, p. K-6). Maintain normovolemia. Avoid hypothermia unless indicated for brain protection. Consider preincision placement of scalp blocks. Dexamethasone iv may ↓ PONV. Avoid long-acting opioids or scopolamine patch, which may interfere with postop neuro exam. When possible, sequential pneumatic compression devices should be used to ↓ VTE risk. Consider fosaprepitant 4 mg/kg iv over 20 min (2–12 yo) with a $5HT_3$ antagonist to minimize PONV especially following posterior fossa procedures or in patients with a history of severe PONV.
Maintenance	Intraop neuromonitoring (IONM) is commonly used. Analgesics like fentanyl and remifentanil (0.05–0.2 mcg/kg/min) infusions do not affect evoked potentials. Typically maintenance anesthetic is propofol (100–150 mcg/kg/min). Dexmedetomidine (0.4–1 mcg/kg/h), ketamine (0.25–0.5 mg/kg/h), volatile anesthetics (0.5 Mac), and N_2O (50%) are

	sometimes used to facilitate a smoother or faster wakeup. Dexmedetomidine has been shown to reduce time to awakening and may add an element of neuroprotection. Both the neurosurgeon and IONM team should be consulted regarding risks for cerebral steal, pneumocephalus, or ↑ ICP. Once the neuromonitoring electrodes are placed, muscle relaxants should not be given. NMR reversal agents (neostigmine or sugammadex) can be given if the train-of-four is <4/4. If a deeper plane of anesthesia is required quickly, remifentanil (0.5–2 mcg/kg) should be used to preserve IONM. If surgeons plan to temporarily occlude a major feeding vessel, propofol (barbiturate) therapy should be administered.	
Emergence	In certain situations, it may be beneficial to leave the patient intubated postop to facilitate tighter BP control. Typical reasons include excessive bleeding, size of AVM, or location of AVM. Sedatives, such as propofol (50–100 mcg/kg/min), dexmedetomidine, or fentanyl/versed, should be administered during this period. Usually, patients are extubated the following day. Consider scalp block placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >4–6 h ago.	
Blood and fluid requirements	PIV (children): 20–22 ga × 2–3 NS/BSS Albumin 5% (consider) Fluid warmer	If the AVM has undergone coiling, then usually the blood loss is mild. However, sudden blood loss can occur. Blood should be available in the room at all times. If there is significant bleeding, FFP should be given with pRBC to avoid coagulopathy. However, aggressive transfusion

		can cause significant brain swelling, which can hinder surgical exposure. Therefore, blood products, colloids, and crystalloids should be used judiciously. Zero balance fluid management is recommended.
Control of brain volume	Lumbar drain to remove CSF Reverse Trendelenburg IV fluid restriction Hyperventilation ($PaCO_2$ to 30–35 mm HG) Furosemide (0.5–1 mg/kg) Mannitol (0.5 g/kg) Dexamethasone Hypertonic (3%) saline Avoid hypotonic IVF (such as LR)	If the AVM is deep, brain relaxation may be required to improve the surgeon's exposure and decrease the amount of brain retraction required during surgery. Hyperventilation usually has a limited period of effectiveness and should be reserved for periods when other means to ↓ ICP are not available. Keep serum Na^+ ~140–150 mEq using hypertonic saline if necessary. Dexamethasone (1–2 mg/kg/d; max 16 mg/d) is controversial but is used frequently.
Monitoring	Standard monitors Foley catheter Precordial Doppler (recommended) Arterial line CVP (in older pediatric patients)	CVP line is placed if significant blood loss is anticipated or if vasoactive drips are planned (cross-clamping or recent stroke). However, in younger

		patients, the risk of pneumothorax can outweigh the benefit. IJ central lines should be avoided in younger pediatric patients because it can decrease venous drainage from the brain and affect the competency of the internal jugular valve. Since obtaining an ultrasound view for a subclavian approach may be difficult, an ultrasound-guided infraclavicular axillary approach may be considered.
Control of BP	Goal = normal range for age	Tight BP control is essential for optimal surgical conditions and brain perfusion. Keeping the BP within 10% of the patient's normal BP should be the goal. If necessary, vasoactive infusions to raise BP (epinephrine or phenylephrine) should be chosen based on HR. An antihypertensive infusion (SNP, clevidipine, esmolol) may be necessary. To ↓ BP, labetalol can be used in less complex cases. Tachycardia should be avoided.

Positioning	OR table usually rotated 180° ✓ and pad pressure points ✓ eyes	Placing a Mayo stand over the chest area prevents compression to the patient's thorax.
Complications	Coagulopathy	If large volumes of blood are needed, a coagulopathy may ensue. Monitoring of coagulation status during surgery is important.
	Hypothermia	If intraop hypothermia (33–34°C) is requested, then appropriate cooling and warming measures must be taken. In children, hypothermia can normally be accomplished by cooling the OR and setting the Bair Hugger® to blow ambient air. For older patients, a cooling blanket may be required.
Special	Intraop angiogram Intraop MRI	Even with stereotactic surgery, intraop C-arm, and O-arms, it is often difficult to determine how successful the resection has been without higher resolution imaging. Intraop MRI and hybrid ORs with high-resolution 3D radiographic capabilities represent the latest technologic advances. The risks

		associated with strong magnetic fields are significant, and only personnel who have received adequate safety training should be involved. If intraop MRI is not available, an immediate postop MRI may be required. These patients should remain intubated until after completion of the scan. Ideally, the surgical instruments should remain sterile until the scan is completed in the event the patient needs to return to the OR for further resection.

POSTOPERATIVE

Complications	Neurologic deficits IC hemorrhage Heart failure Hypothermia	
Multimodal pain management	Acetaminophen (30–40 mg/kg suppository) or (10–15 mg/kg iv) Fentanyl 0.25–0.5 mcg/kg MSO_4 0.25–0.05 mg/kg Opioid-sparing adjuvants should be encouraged. Reinforce scalp blocks.	If not given preop or if 4–6 h has elapsed since previous dose. For follow-up rectal dosing of acetaminophen, use 20 mg/kg PR. 0.5% bupivacaine with epi is as effective as liposomal bupivacaine.

ERAS	Ondansetron 0.1 mg/kg iv	Encourage early enteral nutrition, Foley catheter removal, and mobilization.
Tests	Postop Hct/Hb levels required. If significant blood loss occurs during surgery, INR and coagulation parameters should be obtained. Monitor for ↑ ICP resulting from venous HTN and hyperemia 2° rapid occlusion of AV fistula. ICU × 1–3 d. An extraventricular or lumbar drain can be used to remove CSF. If intraop MRI or angio was not performed, most patients will require a postop MRI the following day. Consult with surgeons to determine if the patient should remain intubated until the scan is complete.	

Summary of procedures

See Chapter 1, Craniotomy for Intracranial Aneurysms.

Anesthetic considerations

See Chapter 1, Craniotomy for Intracranial Aneurysms.

Suggested Readings

1. Bissonnette B: Cerebral protection. Pediatr Anesth 2004; 14:403–6.
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CRANIOTOMY FOR VEIN OF GALEN MALFORMATION

SURGICAL CONSIDERATIONS

Description

A vein of Galen malformation (VGAM) is a large, arteriovenous (AV) fistula betweer

arteries of the posterior cerebral circulation and an enlarged vein of Galen (deep venous drainage of the brain). VGAM present during infancy as high-output congestive heart failure (CHF), macrocephaly from hydrocephalus, and sometimes intracranial hemorrhage.

The cerebral venous system of the developing brain does not mature until 16–18 mo of age; CSF is reabsorbed across the ventricular ependyma and brain parenchyma into the medullary veins. VGAM causes a rise in venous system pressure impairing the reabsorption of CSF. Over time, the congestion of the brain parenchyma leads to impaired oxygenation and subependymal atrophy "melting brain" syndrome. Left untreated, VGAMs have a poor prognosis and are almost always fatal. Some infants (10–15%) develop permanent neurologic deficits even if managed appropriately.

Initially, the care should be directed toward stabilizing cardiac function; however, the only solution to correcting the CHF is to correct the malformation. VGAM should not be managed primarily by open microsurgical techniques due to very high risk of mortality. Instead, VGAMs are managed primarily by serial embolizations. Over the course of several months, staged occlusion of the arterial feeders of the AV fistula and thrombosis of the fistula from the venous side results in reduction in the aneurysmal flow. Most VGAM patients also have accompanying hydrocephalus, but placement of ventricular shunt should be postponed until after the malformation has been treated, as hydrocephalus may resolve spontaneously with reduction in intracranial venous pressure.

Variant procedure or approaches

If access to the VGAM is difficult, an alternative approach may be to access the torcula (confluence of venous sinuses) through an occipital burr hole, which will allow retrograde placement of thrombogenic coils in the fistula.

Usual preop diagnosis

Vein of Galen aneurysm; IC hemorrhage; hydrocephalus; progressive neurologic deficits

ERAS: For elective surgery, preop family counseling by the surgeon/anesthesiologist should include continuing any AED meds, limiting NPO duration, review of nutritional status, discussion of carb loading, postop pain management options, possibility of lines, and urinary catheter postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE

Position	Lateral decubitus, Concorde (modified prone). For burr hole, lateral
Incision	Temporal or occipital. For burr hole, occipital. Prior to incision, inject local anesthetic with 1:400,000 epi to decrease bleeding.
Special instrumentation	Operating microscope, microscopic instruments, intraop angiography, intraop neurophysiologic monitoring. For burr hole, endovascular catheters and equipment
Antibiotics	Cefazolin (30 mg/kg). For patients with β-lactam allergies, clindamycin (5–0 mg/kg) or vancomycin (15 mg/kg, infused over 60 min)
Surgical time	3–7 hr
EBL	Usually <250 mL; however, significant bleeding can occur
Postop care	Same as (pediatric) intracranial AVM. Monitor for ↑ ICP as a result of venous HTN 2° rapid occlusion of VGAM. Consider extraventricular or lumbar drain in older patients. PICU or NICU
Mortality	<5%; however, if CHF is not treated, then mortality approaches 40%. Extremely high, if high-output CHF is not resolved
Morbidity	Same as (pediatric) intracranial AVM. Deep venous infarct: 5–10% Intracranial hemorrhage Hydrocephalus Stroke Subdural hygroma Infection: Rare
Pain score	3–4. Less if performed via burr hole

PATIENT POPULATION CHARACTERISTICS

Age range	Birth–6 mo

Male:Female	3:1
Incidence	Rare
Etiology	Congenital but not inherited
Associated conditions	Other intracranial vascular malformations; high-output CHF

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Optimization of high-output CHF is the anesthesiologist's primary concern in patients that present with VGAM. CHF will progressively worsen until the VGAM is addressed. Embolization should be started as soon as possible to preserve cardiac function.

Cardiovascular	Cardiology should be consulted. As the patient undergoes embolizations, the cardiac function should be reassessed.
Neurologic	Infants usually present with an abnormal head size, Sz disorder, neurologic signs, such as high-pitched crying, posturing, or failure to eat or thrive.
Laboratory	Preop Hct, Hgb, platelets, INR, and any other test as indicated from H&P CT, MRI, cerebral angiography. Check renal function prior to angiogram.
Premedication	Not needed in infants. Avoid oversedation in patient with ↑ ICP.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss possibility of scalp block for postop pain management. Consider preop acetaminophen 15 mg/kg po (2–12 yo).

INTRAOPERATIVE

Anesthetic technique

GETA: The anesthetic management will mirror that for AVMs. As with AVM, tight BP control is important because hypertension can cause increased surgical bleeding. With

VGAM, hypertension can cause stress on the failing heart.

Induction	IV induction is preferred. Propofol 1–2 mg/kg, fentanyl 2–3 mcg/kg, and rocuronium 0.6–1 mg/kg should be slowly titrated to avoid acute changes in BP. If cardiac function is poor, then etomidate or ketamine should be considered regardless of the ramifications (↑volume of brain infarct and ↑ ICP).
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix D, p. D-1 and Appendix K, p. K-6). Maintain normovolemia. Avoid hypothermia unless indicated for brain protection. Consider preincision placement of scalp blocks. Dexamethasone iv may ↓ PONV. Avoid long-acting opioids or scopolamine patch, which may interfere with postop neuro exam. When possible, sequential pneumatic compression devices should be used to ↓ VTE risk. Consider fosaprepitant 4 mg/kg iv over 20 min (2–12 yo) with a $5HT_3$ antagonist to minimize PONV especially following posterior fossa procedures or in patients with a history of severe PONV.
Maintenance	Same as (pediatric) intracranial AVM
Emergence	Often the patient is kept intubated postop to facilitate tighter BP control. Consult surgeon. Sedatives (propofol, dexmedetomidine, or midazolam infusion) should be administered during this period. Consider scalp block placement or reinforcement if initially placed >4 h ago. Consider iv acetaminophen if po dose given >4–6 h ago.
Blood and fluid requirements	Same as (pediatric) intracranial AVM
Complications	Same as (pediatric) intracranial AVM

POSTOPERATIVE

See (Pediatric) Intracranial AVM.

Suggested Readings

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CHAPTER 12.2

Pediatric Ophthalmic Surgery

SURGEONS

Natalia F. Callaway, MD, MS
Darius M. Moshfeghi, MD

ANESTHESIOLOGIST

Olga Wolke, MD

STRABISMUS SURGERY

SURGICAL CONSIDERATIONS

Description

Surgical correction of strabismus is a common procedure in ophthalmic practice, as strabismus occurs in 3–5% of the general population. Strabismus surgery is the most common pediatric eye surgery performed. The goal of this procedure is to correct the ocular misalignment caused by this condition. This can be achieved by several methods: (a) **weakening the muscles** (either by recession, marginal myotomy, or inserting a spacer); (b) **strengthening the muscles**, by shortening their length (resection), by moving the muscle's insertion toward the limbus (advancement), or by tightening the muscle's fibers (plication or tuck); or (c) **transposing the muscles**. Surgery can be performed on any of the four recti muscles (medial rectus, lateral rectus, superior rectus, and/or inferior rectus muscle) or the two oblique muscles (superior oblique and inferior oblique).

There are many indications for strabismus surgery. These include maintaining and restoring binocular vision, improvement in diplopia, improvement of anomalous eye movements, locating and/or transposition surgery for lost muscle, improvement in asthenopic symptoms, improvement in anomalous/altered head posture, dampening of

nystagmus, and improvement in psychosocial function.

Often, **forced duction testing (FDT)** is performed during surgery to determine if there is evidence of limited ductions. This helps to differentiate a paretic muscle versus a restriction that may limit motility. The eyes should be immobile during FDT as well as during surgery. If succinylcholine has been used, at least 20 min should pass before performing duction testing because succinylcholine causes contraction of extraocular muscles. Alternatively, a different muscle relaxant may be used.

Eye position under GA is well documented: the eyes will become more divergent, and this tendency is increased in misaligned eyes; therefore, exotropic eyes appear more outwardly deviated, and esotropic (inward deviation) eyes actually appear straighter (less esotropic). Hence, it is important that the surgeon have solid measurements preoperatively.

The surgery usually is performed through one of two possible approaches. The **limbal incision** is made at the junction of the cornea and the conjunctiva, with radial relaxing incisions in the quadrants on either side of the muscle. The other is a **fornix** or **cul-de-sac incision**, which is made ~4–8 mm from the limbus in the quadrant adjacent to the muscle on which to operate. This approach is subposterior to Tenon capsule. Comfort and cosmesis immediately postop are superior with the fornix incision.

Variant procedure or approaches

In very cooperative older children, an **adjustable suture** technique may be used. Unlike fixed sutures, the adjustable suture technique allows modification of the position of the muscle. An adjustable suture involves temporarily positioning the muscle but not finally tying it down until the patient is awake and has been remeasured. After the patient is free of the effects of anesthesia, measurements are retaken, and the muscle is placed in its optimum position, to properly align the eyes, and then securely tied down. This adjustment may be performed the same day of surgery or the following day. **Adjustable strabismus surgery** ideally reduces the frequency of reoperations by eliminating undesirable early postop undercorrections or overcorrections and increases the rate of surgical success.

Minimally invasive strabismus surgery reduces tissue disruption by replacing one large incision with several small keyhole incisions placed far from the limbus. This approach reduces corneal complications, improves muscle function, and decreases postop pain.

Although GA is most commonly used, strabismus surgery may be done using a

retrobulbar, **peribulbar**, **sub-Tenon**, or **subconjunctival block**, or even **topical anesthesia**. Both topical and peribulbar anesthesia have the advantage of providing good akinesia and anesthesia but without the risks associated with a retrobulbar injection (e.g., hemorrhage, optic nerve damage, ocular perforation). When using topical anesthesia, this may be augmented by the use of minimal sedation and/or antianxiety medications.

Usual preop diagnosis

Strabismus

ERAS: Family preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, carb loading, and postop pain management options. **See Appendix K: Pediatric ERAS, p. K-6 to K-8.**

SUMMARY OF PROCEDURE	
Position	Supine (turned 180°)
Incision	Limbal or fornix
Antibiotics	Topical and/or conjunctival by surgeon
Unique considerations	Avoid neuromuscular blockade for forced duction test. Succinylcholine will compromise forced duction test for 15–20 min after administration. A stable deep plane of anesthesia will keep eyes from moving or being disconjugate. Incidence of PONV is 45–85% without prophylaxis. Topical tetracaine may ↓ postop pain. Oculocardiac reflex (OCR) may cause ↓ ↓ HR. Hypercarbia, light anesthesia, propofol, and remifentanil may increase incidence of OCR.
Surgical time	20–90 min, dependent on procedure and number of involved muscles. Some surgeons use preop antibiotic eye drops (day of surgery, at time of surgery) or use of topical 5% povidone-iodine solution in conjunctival fornices with surgical prep. Timing of antibiotic administration may add to surgical time.
EBL	Minimal
Mortality	Rare

Morbidity	Failure to achieve ocular alignment Infection Hemorrhage Anterior segment ischemia Dissatisfaction with cosmetic result
Postop care	PACU with discharge home within hours. Typically eye patches not required but varies by surgical preference. Some children may need "no-nos" or arm restraints. High incidence of emergence delirium. Topical tetracaine, one drop at beginning of case, and one drop at end has been shown to ↓ postop pain. Postop issues: All patients respond differently to the strabismus surgery. Some may be drowsy or have PONV. Pain is usually mild and responds to acetaminophen. Many physicians avoid NSAIDs due to potential bleeding. Children may be frightened to open their eyes, but generally this improves within a few days.
Pain score	2–4 (moderate)

PATIENT POPULATION CHARACTERISTICS

Age range	Children
Male:Female	1:1
Incidence	3–5% of general population
Etiology	Generally idiopathic; muscle palsies may be associated with trauma, inflammation, tumors, and/or ischemia; restrictive strabismus may occur with thyroid disease (Graves' disease), fibrosis syndromes, or to a scleral buckle or mass.
Associated conditions	↑ incidence in premature infants, small-for-gestational-age infants, those with a positive family history of strabismus, craniosynostosis syndromes, or associated craniofacial syndromes (Apert, Crouzon, Pfeiffer, etc.), trisomy 21, fetal alcohol syndrome, CNS disease affecting ocular muscles or nerves. No longer considered an independent risk factor for malignant hyperthermia.

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Strabismus is the most frequent ophthalmic condition in children requiring surgical repair. Most children will be healthy, but the association of strabismus with cerebral palsy, prematurity, and craniofacial and neurologic disorders requires careful preop evaluation. Unlike adult eye surgeries that often are performed using retrobulbar or peribulbar blocks, in children GETA is usually required to achieve successful operative conditions. For the anesthesiologist, there are three key perioperative problems associated with strabismus surgery: the oculocardiac reflex (OCR), an extremely high incidence of PONV in the untreated patient (45–85%), and a high incidence of emergence delirium (10–80%). At one time, it was believed that children undergoing strabismus surgery were at increased risk for malignant hyperthermia. Although this has been shown to be inaccurate, many neuromuscular syndromes are associated with musculoskeletal abnormalities including strabismus and ptosis. A thorough family history of anesthetic problems must be obtained. The surgeon may plan to execute a forced duction test (FDT) in which the eye is grasped at the limbus causing a slight proptosis and moved into each field of gaze to determine if the strabismus is the result of paresis or restrictive extraocular muscles. Succinylcholine compromises the test by causing tonic contractions of the extraocular muscles for 15–20 min after administration, so it is avoided when possible. Neuromuscular blockade may also confuse the results of the FDT.

Anesthetic technique

GETA, LMA

Induction	Following standard pediatric induction, the anesthesiologist should have available a vagolytic agent (atropine or glycopyrrolate 0.01–0.02 mg/kg) to attenuate the OCR. Sevoflurane maintenance is associated with diminished OCR compared to propofol and remifentanil. FDT may be performed before the administration of NMB. Rocuronium (0.6 mg/kg) may be used to facilitate endotracheal intubation. An oral endotracheal tube or flexible LMA secured to the mandible will keep the airway away from the surgical field.

ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K: Pediatric ERAS, p. K-6 to K-8). Maintain normovolemia and normothermia.	
Maintenance	May use inhalation anesthetic or TIVA. Avoid N_2O in this highly emetogenic surgery. Propofol infusion (150–200 mcg/kg/min) may require NMB or augmentation with remifentanil to maintain a motionless patient (be aware that both propofol and remifentanil may increase OCR). Postop analgesia should be multimodal to minimize opioids (due to high risk of PONV). Acetaminophen (30–40 mg/kg pr or 10–15 mg/kg iv) and a short-acting opioid (fentanyl 1–2 mcg/kg iv) should be used. "Super" hydration with 30 mL/kg of crystalloid has also been shown to ↓ PONV in long NPO patients. Children exhibiting OCR are more likely to have PONV.	
Emergence	The surgeon may request "deep extubation." In this case, the anesthetic (sevoflurane or TIVA) is increased until the patient has no response to airway manipulation such as suctioning but has steady spontaneous ventilation. The ETT or LMA is removed, and an oral airway is placed. The patient is allowed to awaken with no further stimulation, monitoring carefully for signs of laryngospasm. Combination therapy for PONV prevention is most effective. Ondansetron (0.1 mg/kg up to 4 mg) plus dexamethasone (0.15 mg/kg up to 5 mg) is preferred.	
Blood and fluid requirements	Peripheral iv: 22–20 g BSS	Crystalloid to replace calculated deficit plus maintenance during care. Hydration with 30 mL/kg has been shown to reduce PONV.
Monitoring	Standard monitors Temperature	
Positioning	Supine ± shoulder roll	Head of bed usually rotated 180° away
Complications	Oculocardiac reflex	Traction on the extraocular muscles or the levator, or

		external pressure to the globe, initiates a trigeminal reflex via parasympathetic output from the vagus nerve. This may cause bradycardia, AV block, ventricular ectopy, or even asystole. May be attenuated by pretreatment with anticholinergics (see above). Tends to extinguish with repeated manipulation. Treat by removing pressure to globe or tension on the extraocular muscle and administer atropine or glycopyrrolate. Rarely may require epinephrine (1–10 mcg/kg). The oculorespiratory reflex (ORR) is a less well-understood response to trigeminal nerve stimulus that results in cessation of spontaneous ventilation and should be considered if spontaneous ventilation via LMA is the preferred technique.
	Accidental extubation	May result from surgical repositioning or removal of drapes. The ETT/LMA should be firmly secured, and the anesthesiologist should be attentive in changes to positioning (e.g., moving from one eye to the other) and removal of drapes.
	Emergence delirium	Dexmedetomidine (0.5–1 mcg/kg iv over 10 min) or

		clonidine (1–2 mcg/kg iv) decreases emergence delirium and may increase parental satisfaction. Ketamine 1–2 mg/kg iv, may also help decrease delirium, however both drugs may be associated with increased length of stay in PACU. The sub-Tenon block, usually performed by the surgeon, also may decrease emergence delirium.

POSTOPERATIVE

Complications	PONV	Even with prophylaxis, up to 10% experience PONV. Rescue antiemetic therapy: ondansetron 0.01 mg/kg up to 4 mg; metoclopramide 0.1 mg/kg up to 10 mg; promethazine (>2 yr old) 0.25–1 mg/kg, po/pr/im/iv up to 25 mg.
	Emergence delirium	May be decreased with use of alpha-agonists dexmedetomidine or clonidine (see above). At emergence or in the PACU, treat with opioid analgesia (fentanyl 0.2–0.5 mcg/kg iv) or propofol (1 mg/kg iv).
Multimodal pain management	Continue acetaminophen 10–15 mg/kg po q4h	May require opioids in PACU. Intraop NSAIDs are typically avoided due to concern for local bleeding but may be discussed with surgeon for

		postop analgesia.
ERAS	PONV protocol (see p. D-1)	Encourage early enteral nutrition and mobilization.

Suggested Readings

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PEDIATRIC VITREORETINAL SURGERY

OVERVIEW

The majority of pediatric vitreoretinal surgery requires GA for children 18 yr and younger. As with any surgery, preop education of the common risks must be discussed with the family and understood by all members of the patient care team. Initial ophthalmic examination can be performed with simple sedation, using mask blow-by, with conversion to GETA should the exam demonstrate pathology requiring intervention. If the patient is a mature, cooperative adolescent (without claustrophobia) undergoing longer laser procedures (e.g., panretinal photocoagulation [PRP]) or a noncomplex vitrectomy (e.g., nonclearing vitreous hemorrhage), then MAC with a retrobulbar block may be considered. The surgeon uses a 25-gauge 1.5-inch needle on a 10-mL syringe containing a 1:1 ratio of 0.75% bupivacaine with epinephrine and 4% lidocaine. The needle is introduced along the inferior orbital rim 1/3 of the way from the lateral orbital rim, aspirated to ensure proper placement, and then the anesthetic is administered at the appropriate quantity for the patient age, weight, and gender (usually ~5 mL).

Communication and teamwork are essential to optimize the surgical experience for all. Discussion should focus on (a) what the surgical requirements are for the procedure, (b) the best anesthetic approach tailored to the patient and procedure, and (c) alternative situations and complications that may require conversion to GA. The anesthesia team often has a better understanding of what the child may tolerate, but to make informed decisions in the OR, they must understand the surgical procedure and potential complications. These are discussed below.

LASER PHOTOCOAGULATION

Background

Laser photocoagulation is a safe prophylactic and treatment modality for a variety of retinal and choroidal abnormalities. In the pediatric population, laser photocoagulation has success with respect to improving vision outcomes and optimizing vision potential when used for the treatment of severe retinopathy of prematurity (ROP), retinal tear and

detachment, familial exudative vitreoretinopathy, incontinentia pigmenti, and other, rarer, retinal vascular disorders. Laser photocoagulation may be performed in conjunction with other vitreoretinal procedures, such as vitrectomy (described in laser section), intravitreal injection, and fluorescein angiography.

Procedure

Laser photocoagulation takes advantage of the spatial precision offered by collimated light energy to selectively (to the level of cells) ablate pathologic tissues—usually retina. When the laser is targeted at an ocular structure, the tissue absorbs the light energy and generates heat, and the surgeon can photocoagulate the aberrant tissue while minimally damaging other structures.

The surgeon uses an indirect ophthalmoscope with a condensing lens to treat the fundus. The time and extent of irradiation varies by indication—ranging from 5 min for repair of a monocular retinal tear to an hour per eye, treated for severe ROP. Other pathologies usually fall between these two timelines, for example, a scattered PRP can take 20–60 min for one or both eyes. Two procedures commonly accompany laser photocoagulation: intravitreal injection and fluorescein angiography.

Intravitreal injection of steroids or anti-VEGF medications is performed by opening the eyelid with a speculum, thoroughly sterilizing the injection area with povidone-iodine, locating the limbus and determining the injection location with calipers (varies by age, 1–4 mm from limbus), and then injecting the required medication into the vitreous substance. This is most often performed for vascular proliferative retinopathy secondary to retina ischemia. **Fluorescein angiography** may be used to identify ischemic areas of retina for panretinal or scattered photocoagulation. Intravenous injection of fluorescein carries the dye to the retina and choroidal circulation within seconds, and thus, the ophthalmologist can visualize perfusion of the choroids and retina over the next 5–15 min. The anesthesiologist is usually asked to perform the iv fluorescein push while the retina physician operates the camera.

The potential complications for laser photocoagulation include inadvertent irradiation of other, usually more anterior, ocular structures such as the cornea, iris, lens, and so on. In addition, choroidal effusions, cataract, new retinal tears, hemorrhage, anterior segment ischemia, and retinal pigment epithelium (RPE) tears can complicate the procedure. Optimizing the laser delivery (intensity, duration, and exposure), distributing the treatment over multiple sessions, and continually reassessing the patient's status minimize the occurrence of adverse events. When complications do occur, early intervention can often prevent or minimize the long-term consequences in visual outcomes; therefore, it is critical for the entire operating team to vigilantly watch for

early signs of complications.

VITRECTOMY IN PEDIATRIC PATIENTS

Background

Vitrectomy is usually performed to clear the visual axis or reattach the retina with the goal to restore the highest vision potential. The procedure removes the vitreous gel in the eye. In children, vitrectomy is indicated for a variety of vitreoretinal conditions, but most commonly severe ROP, partial or complete retinal detachments, nonaccidental trauma, persistent hyperplastic primary vitreous, genetic conditions affecting the retina, and malignancy.

Vitrectomy in a child under 1 yr of age is the most difficult and least forgiving surgery in ophthalmology. The infant needs to have GETA, with paralysis, and no movement of the bed/table is permissible. The surgery can last from 45 to 75 min. In older children with complex retinal detachments, typically the procedure takes from 45 to 75 min. From an anesthesia perspective, it is imperative that the child awakens without coughing or bucking.

Traumatic and/or rhegmatogenous retinal detachment cases, usually in older children, are often accompanied by a **scleral buckle** procedure, which involves isolating and manipulating the four recti muscles. This ocular manipulation can induce extreme bradycardia or asystole from the OCR and can be associated with significant postop pain that must be adequately controlled. A scleral buckle typically adds 30–45 min to a case duration.

Procedure

After ensuring the eye is fully anesthetized and sterilized, the ophthalmologist creates a three-point sclerotomy with 23- or 25-gauge incisions through the pars plana, which is located 3–4 mm from the limbus (in a child >2 yr; in younger children, pars plicata incisions may be made 1 mm posterior to the limbus), at the inferotemporal, superonasal, and superotemporal locations. At the inferotemporal post, an infusion cannula maintains the pressure of the eye by allowing saline to replace the excised tissue. The other two ports are then used for the instrumentation necessary to perform a bimanual vitrectomy (see Fig. 12.2-1). One of these instruments has a light attached to maintain visualization of the retina throughout the procedure. The surgical microscope and a wide-angle viewing system are used to perform the operation. To remove the actual vitreous substance, the posterior hyaloid is carefully elevated and cut with a microvitrectomy hand piece that simultaneously aspirates vitreous components. The

core vitrectomy is then performed for all 360° of the globe, utilizing all surgical ports as necessary. Silicone oil may be slowly infused into the posterior portion of the eye to replace the removed vitreous. Ports are sequentially closed. A subconjunctival injection of an antibiotic (usually cefazolin) and steroid (dexamethasone) is then administered.

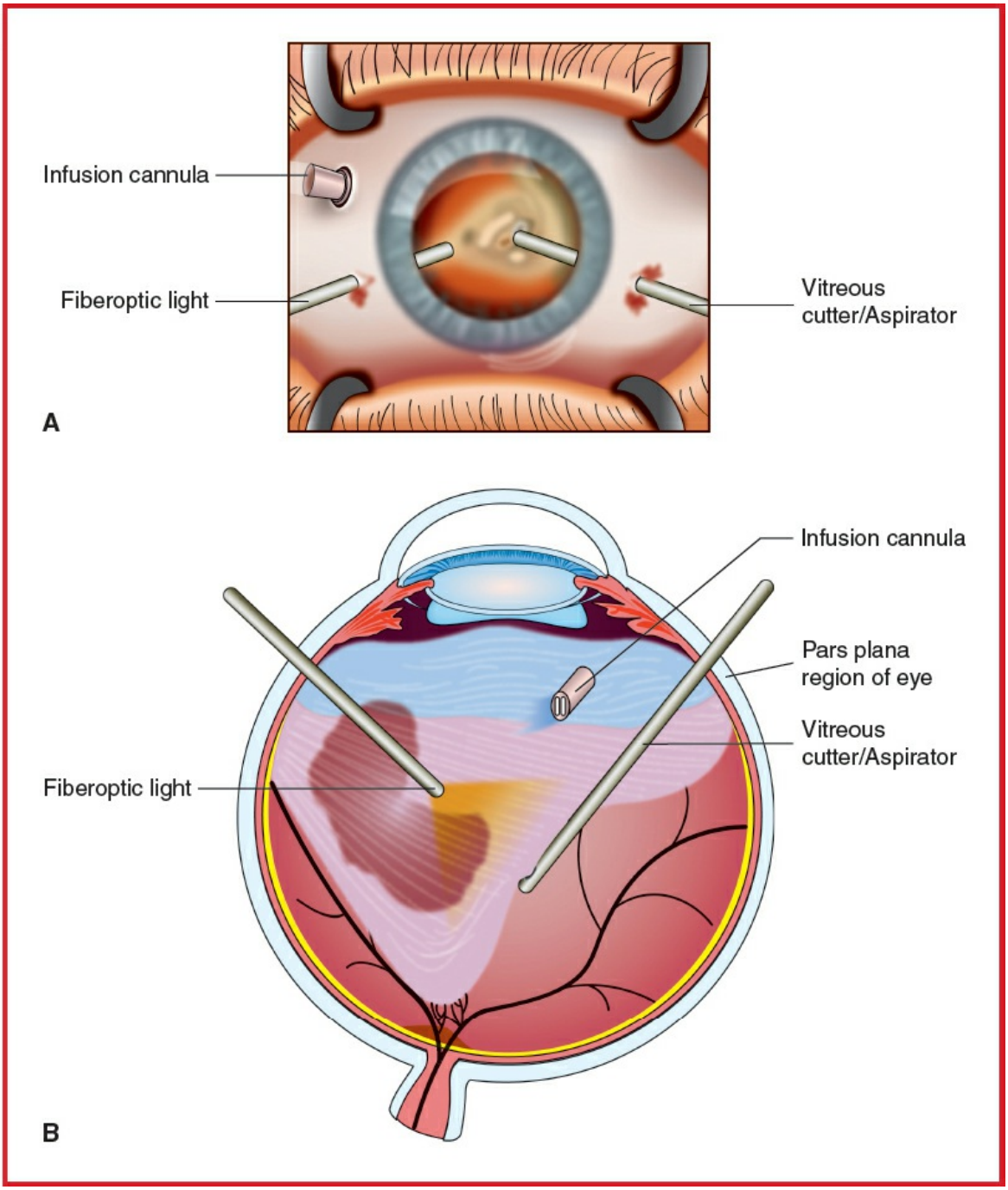

Figure 12.2-1 Vitrectomy procedure. **A:** Ophthalmologist's view. **B:** Cross-sectional view showing removal of vitreous in progress.

Complications of vitrectomy include corneal edema, retinal detachment, ↑ IOP (exacerbated when patient has preexisting glaucoma), hypotony (↓ IOP),

endophthalmitis (infection), and intraocular hemorrhage. Due to their high regenerative capacity, children have robust scarring responses that create vision-threatening proliferative vitreoretinopathy (PVR) requiring a return to the OR, usually 6–12 wk after the initial surgery. If PVR develops and a scleral buckle is not present, then one will be placed in older children (>1 yr). Otherwise, if a buckle is present, a complex vitrectomy with possible diathermy, lens removal, iridectomy, retinectomy, perfluoron, laser, and silicone oil may be needed. This procedure can take 45–75 min. If silicone is placed, it must be removed 6 wk to 6 mo later in a vitrectomy, with possible membrane peel in a 30–45 min procedure, to minimize the risk of vision loss and optimize the child's long-term vision potential.

ERAS: Family preop counseling by the surgeon and anesthesiologist should include limiting NPO duration, carb loading, and postop pain management options. **See Appendix K: Pediatric ERAS, p. K-6 to K-8.**

■ SUMMARY OF PROCEDURE (VITRECTOMY AND OTHER OP GLOBE PROCEDURES)	
Position	Supine (turned 180°)
Incision	Pars plana or pars plicata
Antibiotics	Subconjunctival
Unique considerations	A stable deep plane of anesthesia will keep eyes from moving or being disconjugate during initial exam, often done under mask anesthesia. Vitrectomy for infants and open globe emergencies require neuromuscular blockade with GETA and emergence without coughing or bucking. OCR may cause profound bradycardia. Intraocular gas placement (sulfur hexafluoride) or an open globe precludes the use of nitrous oxide. Silicone oil may be injected into the posterior eye to replace vitreous humor. Subconjunctival injection of steroids at the end of procedure is painful. Patients are often premature infants at high risk for postop apnea.
Surgical time	45–75 min for vitrectomy. Scleral buckle adds 30–45 min.
EBL	Minimal
Mortality	Rare

Morbidity	Infection, hemorrhage, retinal tear or detachment, corneal edema, cataract
Postop care	For outpatients, PACU with discharge to home or inpatient floor within hours. Eye patches may be required. Some children may need arm restraints. Ex-premature neonates and infants may need inpatient monitoring for apnea. NICU babies may have procedure performed at bedside. They may also require postop controlled ventilation.
Pain score	Moderate to severe (scleral buckle)

PATIENT POPULATION CHARACTERISTICS	
Age range	For vitreoretinal surgery, cataracts, and glaucoma: premature newborns, infants Eye injuries: any age, but most common in 10–30 yr old
Male:Female	1:1 for complications of prematurity 4:1 for penetrating eye injuries
Incidence	ROP occurs in >50% of ELBW babies (<1500 g) Injury occurs ~1 in 100, ages 0–19 yr
Etiology	Retinopathy of prematurity, accidental or nonaccidental trauma, malignancy
Associated conditions	Prematurity, Down syndrome (trisomy 21), Alport syndrome, Marfan and Ehlers-Danlos syndromes, homocystinuria, mucopolysaccharidoses, craniofacial syndromes, and phakomatoses (neurofibromatosis, Sturge-Weber syndrome, tuberous sclerosis, incontinentia pigmenti, and ataxia telangiectasia)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Vitreoretinal and open globe surgery in pediatrics may involve special high-risk populations—infants, often premature, and trauma patients. Retinopathy of prematurity (ROP) is a leading cause of blindness worldwide, related to abnormal retinal vascular development and correlated to low birth weight and prematurity. In the United States,

all infants with a gestational age ≤30 wk or birth weight <1500 g are screened for ROP starting at postnatal age 4–6 wk. Laser therapy is instituted based on the area and severity of retinal vascular proliferation in an attempt to prevent loss of visual acuity or retinal detachment. The ETROP trial demonstrated improved outcomes with early treatments. Vision-saving surgery for infants with ROP, congenital cataracts, or glaucoma may require surgical intervention while still extremely small (<1000 g) with significant systemic comorbidities including intraventricular hemorrhage, pulmonary hypertension, congenital heart disease, and acute or chronic pulmonary disease. These infants are at higher risk for perioperative complications than are older children. Perioperative apnea is common in infants below 52–60 wk postconceptual age. Even in the infant requiring no supplemental oxygen preop, controlled ventilation may be necessary even after minor surgical intervention. For term or older infants presenting from home, postop inpatient apnea monitoring is recommended before 48 wk postgestational age. For infants with comorbidity or prematurity, consider inpatient admission for those <52–60 wk postgestational age.

An initial examination under anesthesia is often performed to determine the need for surgical intervention. Mask anesthesia can allow for an excellent exam with attention to obtaining a deep enough plane for the eyes to return to midline rather than "sundowning" or being disconjugate. Even small premature infants may tolerate a brief exam using mask ventilation. If the exam reveals need for further intervention, intravenous access can then be obtained and the trachea intubated. Having a motionless field is essential for vitreoretinal surgery. GETA with neuromuscular blockade provides a motionless field without requiring a depth of anesthesia that may cause hypotension leading to compromise in retinal artery perfusion and ocular ischemia. Very premature or small infants or those with neurologic disease such as hydrocephalus or significant intraventricular hemorrhage may require controlled ventilation for even a brief exam under anesthesia.

Children with craniofacial syndromes and mucopolysaccharidoses should have careful airway evaluations and are expected to present with challenging airways. Alport syndrome is associated with renal failure and development of myopathy that may preclude the safe use of succinylcholine. Trisomy 21 and Marfan and Ehlers-Danlos syndromes are associated with structural (especially valvular) heart disease. The phakomatoses may have neurologic involvement and seizures as part of the presentation.

Open globe injury presents a different, but also challenging, patient population. In the case of trauma, other life-threatening injuries must be ruled out. Risk of aspiration of gastric contents must be weighed against vision-threatening increases in intraocular

pressure (IOP) that may occur during induction with resulting extrusion of intraocular contents including the iris, lens, and vitreous. Painful eye injuries may cause crying and rubbing of the eyes that ↑ IOP. Placement of an intravenous line to accomplish a rapid sequence induction may itself cause screaming and crying that may significantly and dangerously ↑ IOP. Oral benzodiazepine **premedication** (midazolam 0.5 mg/kg) may be given to calm the child and facilitate intravenous access. In the absence of an intravenous line, inhalational induction (avoiding contact of the mask on the eye) or intramuscular ketamine (with or without succinylcholine or rocuronium) may be considered, balanced against the risk of aspiration of gastric contents. Succinylcholine causes a transient mild ↑ IOP (7–12 mm Hg for 5–6 min, in contrast to coughing which is believed to explosively increase IOP to 40 mm Hg or more). A deep plane of anesthesia does not reliably attenuate the succinylcholine-induced ↑ IOP. "High-dose" rocuronium (1–2 mg/kg) takes longer to achieve neuromuscular blockade but is not associated with ↑ IOP. Etomidate and propofol in combination with lidocaine (1 mg/kg iv) and/or fentanyl should be used to achieve a deep plane of anesthesia before laryngoscopy. If necessary, the surgeon can physically shield the eye to contain contents during induction. The same attention to stability of IOP is needed at the time of extubation.

Once the trachea is intubated, the ETT and circuit should be secured to be away from the surgical field and still accessible by the anesthesiologist. Maintenance may be inhalational or intravenous agents, planning for a smooth transition to spontaneous ventilation and extubation at the end of the case when appropriate. The oculocardiac reflex (OCR) may occur with manipulation of the eye (see Section Strabismus Surgery for more on the OCR). Before extubation, gastric contents should be aspirated by suction catheter and prophylaxis for PONV and adequate analgesia given to ensure a smooth emergence.

INTRAOPERATIVE

Induction	Following standard pediatric induction, the surgeon may perform an exam under anesthesia. Conversion to GETA may then be required. The anesthesiologist may give vagolytic agent (atropine or glycopyrrolate 0.01–1.02 mg/kg) to attenuate the OCR. Sevoflurane maintenance diminishes the OCR compared to propofol and remifentanil. Forced duction test (FDT) may be performed before the administration

	of NMB. Rocuronium (0.6 mg/kg) may be used to facilitate endotracheal intubation. An oral RAE tube or flexible LMA secured to the mandible will keep the airway away from the surgical field.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix K: Pediatric ERAS, p. K-6 to K-8). Maintain normovolemia and normothermia.	
Maintenance	May use either inhalational anesthetic or TIVA. Many avoid N_2O, as this is highly emetogenic surgery. N_2O should always be avoided if sulfur hexafluoride or carbon octofluorine (perfluoropropane) gas will be used or has been used in the past 6 wk. Propofol infusion (150–200 mcg/kg/min) may require NMB or augmentation with remifentanil to maintain a motionless patient (be aware remifentanil may ↑ OCR). **Multimodal analgesia** may decrease opioid use and risk of PONV. Acetaminophen (30–40 mg/kg PR or 10–15 mg/kg iv) and short-acting opioid (fentanyl 1–2 mcg/kg iv) should be used.	
Emergence	The surgeon may request "deep extubation." In this case, the anesthetic (sevoflurane or TIVA) is increased until the patient has no response to airway manipulation such as suctioning but maintains steady spontaneous ventilation. The ETT or LMA is removed, and an oral airway may be placed. The patient is allowed to awaken with no further stimulation, monitoring carefully for signs of laryngospasm. Combination prophylactic therapy for PONV prevention is most effective. Ondansetron (0.1 mg/kg up to 4 mg) plus dexamethasone (0.15 mg/kg up to 5 mg) is preferred. "Super" hydration with 30 mL/kg of crystalloid has also been shown to decrease PONV. Children exhibiting the OCR are more likely to have PONV.	
Blood and fluid requirements	Peripheral iv: 20–22 g BSS	BSS to replace calculated deficit plus maintenance during case. Consider augmented hydration with 30-mL/kg BSS to reduce

		PONV if pulmonary edema (i.e., extreme prematurity) is not a risk.
Monitoring	Standard monitors Temperature, especially for premature infants TOF	
Positioning	Supine or supine with shoulder roll Head of bed usually rotated 180° away	
Complications	Oculocardiac reflex (OCR) (see Fig. 12.2-2)	Traction on the extraocular muscles or the levator, or external pressure to the globe, initiates an afferent trigeminal nerve signal evoking parasympathetic output from the vagus nerve. This may cause bradyarrhythmias, AV block, ventricular ectopy, or even asystole. May be attenuated by pretreatment with anticholinergics (see above). Tends to extinguish with repeated manipulation. Treat by removing pressure to globe or tension on the extraocular muscle and administer atropine or glycopyrrolate. Rarely may require epinephrine 1–10 mcg/kg. The **oculorespiratory reflex** (ORR) is a less well-understood response to trigeminal stimulus that results in cessation of spontaneous ventilation and should be accounted for if spontaneous ventilation via

	LMA is the preferred technique.
Systemic effect of topical ophthalmic agents	See Table 12.2-1.
Accidental extubation	May result from surgical repositioning or removal of drapes. The ETT/LMA should be firmly secured, and the anesthesiologist should be attentive to changes in positioning (e.g., moving from one eye to the other) and removal of drapes.
Coughing or bucking on emergence	Consider lidocaine 1 mg/kg iv 3 min before extubation.

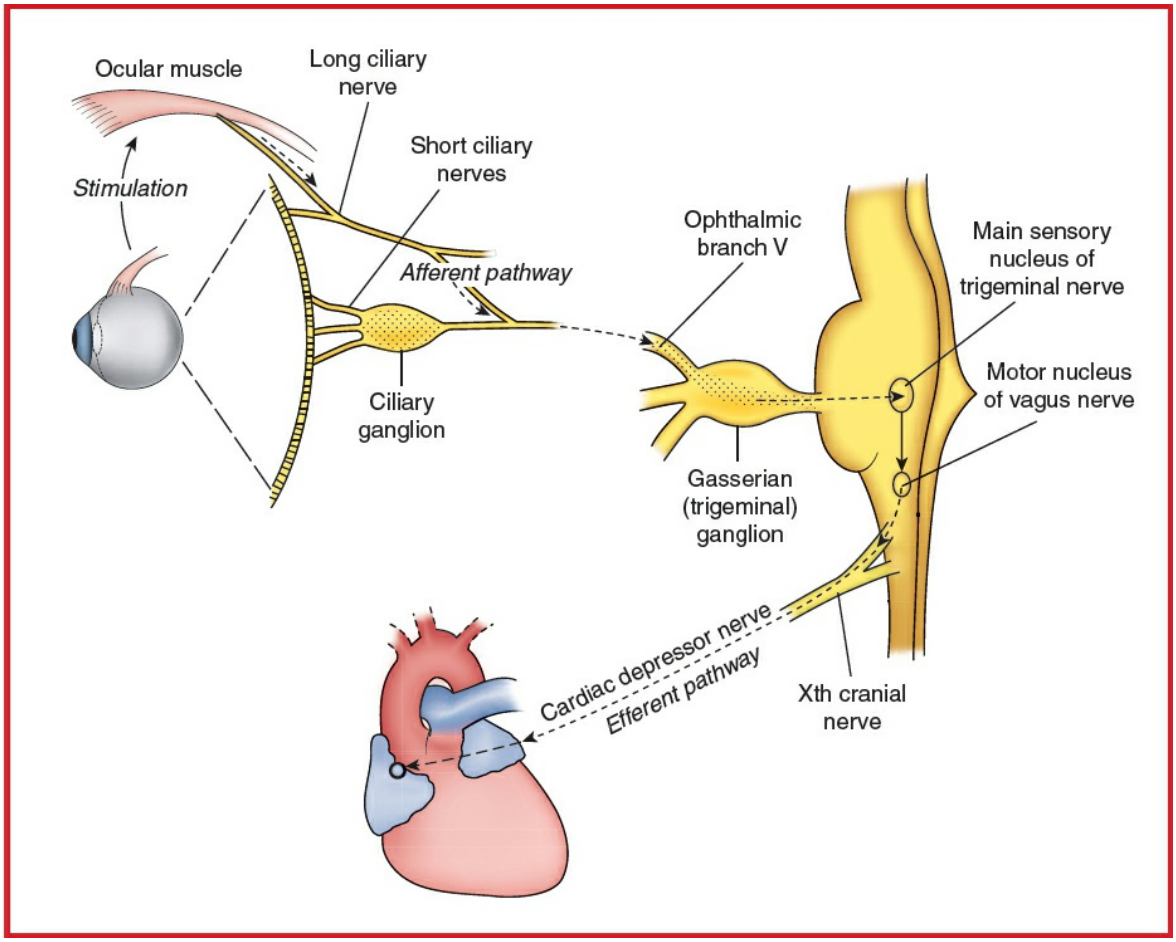

Figure 12.2-2 Anatomy and physiology of the oculocardiac reflex.

Table 12.2-1 Ophthalmic Medications with Systemic Effects		
Medication	**Type**	**Effect**
Cyclopentolate	Cycloplegic (paralyzes accommodation)	Muscarinic agonist: GI disturbance, atropine-like toxicity (hyperthermia, tachycardia, delirium), inhibition of plasma cholinesterase
Phenylephrine	Mydriatic	α agonist: hypertension, reflex bradycardia or tachycardia, pulmonary edema, cardiac arrhythmia, cardiac arrest, subarachnoid hemorrhage
Acetylcholine	Miotic (constricts the pupil)	Cholinergic agonist: bradycardia, hypotension, bronchospasm
Pilocarpine	Miotic agent, decrease intraocular pressure, used for acute and chronic angle glaucoma	GI disturbance, diaphoresis
Timolol, levobunolol	Nonselective β-antagonists, reduce intraocular pressure	Bronchospasm, bradycardia, hypotension, apnea in neonates

Adapted from Rickets K, Valley RD, Bailey AG, et al: Anesthesia for ophthalmic surgery. In: Davis PJ, Cladis FP eds. Smith's Anesthesia for Infants and Children, 9th edition. Elsevier, Philadelphia, PA: 2017, p. 892–912e5.

POSTOPERATIVE

Complications	Emergence delirium	Dexmedetomidine (0.5–1 mcg/kg iv over 10 min) or clonidine (1–2 mcg/kg iv) decreases emergence delirium and may increase parental satisfaction. Dexmedetomidine plus ketamine (1–3 mg/kg/h)

		decreased emergence delirium, the OCR, pain, and postop analgesia requirement in one study. The sub-Tenon block (performed by surgeon) also may decrease emergence delirium.
	Postop apnea	Many patients undergoing vitreoretinal surgery are ex-premature neonates or infants. Postop apnea may necessitate ICU monitoring or even postop ventilation. Caffeine 10 mg/kg iv may protect against postop apnea.
Multimodal pain management	Acetaminophen	Continue acetaminophen 10 mg/kg po q4h. May require additional opioids in PACU. Intraop NSAIDS are typically avoided due to concern for local bleeding but may be discussed with surgeon for postop analgesia.
ERAS	PONV protocol (see p. D-1)	Encourage early enteral nutrition and mobilization.

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CHAPTER 12.3

Pediatric Otolaryngology

SURGEONS
Mai Thy Truong, MD
Anna H. Messner, MD

ANESTHESIOLOGISTS
Samuel A. Mireles, MD
Ellen Ya-Ping Wang, MD
Gregory B. Hammer, MD

MYRINGOTOMY AND TYMPANOSTOMY TUBE PLACEMENT

SURGICAL CONSIDERATIONS

Description

Tympanostomy (PE or pressure equalizing) tubes are placed in the patient with chronic serous otitis media (fluid in the middle ear for >3 mo), recurrent acute otitis media (six or more episodes of otitis media over the prior year), or eustachian tube dysfunction and hearing loss. Occasionally, PE tubes are placed in a child with meningitis of otitic origin or with acute otitis media that is unresponsive to antibiotics. The patient is supine and the OR table in the 0° position. The microscope is positioned over the bed and the head turned to expose the ear. An ear speculum is inserted into the ear canal, cerumen is removed, and an incision is made in the tympanic membrane. Fluid is sometimes suctioned from the middle ear; then, a tympanostomy tube is inserted into the ear, straddling the tympanic membrane. Antibiotic eardrops frequently are inserted into the external auditory canal. Sometimes lidocaine and/or oxymetazoline drops are also inserted into the ear canal. If the eardrum is significantly retracted, nitrous oxide will

expand middle ear volume and help with PE tube placement. The surgeon moves to the other side of the table, the microscope is repositioned, the head is turned, and the procedure is repeated on the other ear. The myringotomy incision is painful at the time of the incision, and suctioning can cause discomfort in a patient who is alert. Typically, there is minimal postop pain.

Usual preop diagnosis

Chronic serous otitis media (CSOM); recurrent acute otitis media (RAOM); eustachia tube dysfunction

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, carb loading, and postop pain management options. **See Appendix K: Pediatric ERAS, p. K-6 to K-8.**

SUMMARY OF PROCEDURE	
Position	Supine; head to anesthesia
Incision	Tympanic membrane
Special instrumentation	Operating microscope
Antibiotics	No parenteral antibiotics (except for SBE prophylaxis); topical antibiotic eardrops
Surgical time	5–10 min. Patients with stenotic ear canals (e.g., Down syndrome) can take longer, or if the patient has had several previous ear tubes in the past and may have more tympanic membrane abnormalities.
EBL	Typically scant to none. Occasionally <1–5 mL
Postop care	PACU → home
Mortality	Rare
Morbidity	Bleeding from the ear Purulent drainage from the ear (otorrhea)
Pain score	1–3

PATIENT POPULATION CHARACTERISTICS	
Age range	3 mo+ (most common, 1–3 yr)

Male:Female	1:1
Incidence	Very common
Etiology	Chronic middle ear infections
Associated conditions	Cleft palate

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

The majority of children presenting for PE tubes are <3 yr and generally in good health. Many of these children, however, have recurrent URI, which contributes to edema of the eustachian tubes, predisposing to episodes of acute otitis media. Intervals between URI may be brief, and scheduling surgery during these interludes is often impractical. Children with mild URI generally can be anesthetized safely for PE tube placement. Surgery should be delayed for patients with acute, febrile illnesses and in those with evidence of lower respiratory tract infection. Surgery need not be delayed if fever is 2° to acute otitis media.

Respiratory	Surgery in patients with URI Sx referable to the extrathoracic airway alone is generally not delayed. These Sx include nasal congestion and/or discharge and mild conjunctivitis. Fever accompanied by productive cough and wheezing are Sx of lower respiratory tract involvement and should prompt rescheduling of the procedure 2–3 wk after these Sx have abated. In borderline cases (e.g., those with rales auscultated on chest exam but no other lower tract Sx), O_2 sat may be measured by pulse oximetry. Procedures in patients with SpO_2 < 95% due to respiratory illness should be deferred.
Laboratory	None
Premedication	Some practitioners advocate withholding premedication, as the duration of action of the premed may outlast the surgery. Consideration for preop anxiety and agitation with separation from parents or introduction of the mask without premed

	must be balanced with the potential for postop emergence delirium with midazolam premed. Intranasal dexmedetomidine is another option, if given 30–45 min prior to induction; dexmedetomidine may prevent postop delirium in addition to providing preop sedation. Acetaminophen may be given preop for postop analgesia. Parental presence and/or the use of distraction techniques may obviate the need for premed in selected cases. Avoid long-lasting sedative medications.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 10–15 mg/kg iv or po as an elixir.

INTRAOPERATIVE

Anesthetic technique

GA via face mask

Induction	A standard inhalation induction with sevoflurane and O_2 ± N_2O is performed with routine monitoring. An oral airway commonly is inserted, as soft-tissue obstruction may occur when the head is turned fully to the side during surgery. CPAP 5–8 cm H_2O also may be useful in maintaining airway patency. Tracheal intubation is rarely indicated. Following induction, a one-time dose of rectal acetaminophen (30–40 mg/kg) may be given for postop analgesia.
ERAS	Assess volume status (see Appendix D, p. D-1 and Appendix K, p. K-6 to K-8). Maintain normovolemia and normothermia.
Maintenance	For most cases, an iv catheter is not necessary. Sevoflurane ± N_2O is continued for maintenance anesthesia. For pain management in the absence of an iv, im or intranasal medications such as fentanyl (1–2 mcg/kg im or in) and ketorolac (0.5 mg/kg im) may be

	given (consult with surgeon first, as some may not wish to administer due to concern about postop bleeding). Intraoperative use of intranasal dexmedetomidine is not recommended because the procedure time is shorter than the time to onset of this medication.	
Emergence	The inhaled anesthetic is discontinued, and the child is allowed to emerge undisturbed. Marked agitation ("emergence delirium") has been noted following emergence from sevoflurane and other inhaled agents. A variety of strategies have been used to minimize this phenomenon such as allowing the child to emerge undisturbed, avoidance of preop midazolam, intraop administration of analgesics, and acupuncture.	
Blood and fluid requirements	None	
Monitoring	Standard monitors. Temperature monitoring is optional for very short procedures such as this.	
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Laryngospasm	Secretions → laryngospasm 2° irritation of the vocal cords, especially in children with URI. Rx: 100% O_2 and CPAP or manual ventilation with PEEP ≤ 20–25 cm H_2O. If no improvement, immediate iv placement, and administration of propofol, 1–2 mg/kg iv may be given if iv is present to help break laryngospasm and to facilitate ventilation. If desaturation is severe or if there is no improvement after propofol administration, succinylcholine (2–4 mg/kg im or 0.5–1 mg/kg iv if iv is

		present) may be needed if a significant decrease in SpO_2 occurs and ventilation is not possible. Atropine (0.01 mg/kg iv or im, minimum 0.1 mg) may be given to mitigate bradycardia associated with hypoxia as well as a potential side effect of succinylcholine. Oropharyngeal suctioning and manual ventilation usually result in resolution of the laryngospasm. Rarely, tracheal intubation may be indicated for recurrent laryngospasm.

POSTOPERATIVE

Complications	Laryngospasm	Laryngospasm may occur and should be treated as described above.
Multimodal pain management	Acetaminophen 10 mg/kg po/iv q6h or 30–40 mg/kg pr loading dose, followed by 20 mg/kg pr or 10 mg/kg po q6h. PR bioavailability is highly variable, so this route may not be desirable Ibuprofen 10 mg/kg po q6h If iv present Fentanyl 1–2 mcg/kg iv or hydromorphone 2–5 mcg/kg iv (titrated to respiratory rate)	Consider previously administered dosing. Use nonopioid analgesics. Back up with bolus opioid analgesics.

ERAS	PONV protocol (see Appendix D, p. D-4)	Encourage early enteral nutrition and mobilization.

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TONSILLECTOMY AND ADENOIDECTOMY

SURGICAL CONSIDERATIONS

Description

The dissection is carried out with the patient supine, shoulders slightly elevated by a shoulder roll (typically, a rolled towel). A mouth gag is inserted, and a small suction catheter is passed through the nose and brought out the mouth to elevate the soft palate and expose the nasopharynx. The adenoids are viewed with a mirror and/or palpated. A curette, adenotome, microdebrider, or suction electrocautery is used to remove the

adenoids; then, typically, the nasopharynx is packed. There are two major types of tonsillectomy: total tonsillectomy and subtotal (partial) tonsillectomy. The traditional total tonsillectomy is performed by grasping the tonsil with Allis forceps and pulling it medially. A vertical incision is made in the anterior tonsillar pillar with a sickle knife, scissors, or electrocautery instruments; then, the tonsil is dissected from the surrounding tissue and removed. A snare may be used to amputate the inferior pole of the tonsil before removal. Hemostasis is obtained through the use of packs and suction electrocautery. After hemostasis has been obtained in the tonsillar fossae, the pack is removed from the nasopharynx, and hemostasis is achieved in the nasopharynx using suction electrocautery. Tonsils can also be completely removed using radiofrequency (coblation), bipolar scissors, bipolar forceps, or laser. The same approach and setup are used for a subtotal tonsillectomy, which can be performed using radiofrequency or a microdebrider. The literature on incisional local anesthetic injection is mixed with some studies reporting benefit and some showing no benefit. Therefore, injection is not generally recommended.

Usual preop diagnosis

Obstructive sleep apnea (OSA); chronic tonsillitis and/or adenoiditis; tonsillar and adenoid hypertrophy; asymmetric enlargement of tonsils (to r/o cancer)

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, carb loading, and postop pain management options. **See Appendix K: Pediatric ERAS, p. K-6 to K-8.**

SUMMARY OF PROCEDURE	
Position	Supine, shoulder roll, head extended; table turned 90°; surgeon at head of table
Incision	Intraoral mucosal
Special instrumentation	Mouth gag (McIvor, Crowe-Davis, Dingman)
Unique considerations	Observe for compression of ETT or accidental extubation when mouth gag is manipulated. Patients with Down syndrome or skeletal dysplasia may need to be evaluated preop for possible atlantoaxial subluxation, as the neck is typically extended. Alternatively, extension of the neck can be completely avoided for the procedure as a precaution. A single dose of dexamethasone (0.5 mg/kg)

	iv is recommended for children undergoing tonsillectomy for postop pain and nausea, with some surgeons recommending a maximum dose of dexamethasone of 10–20 mg. If electrocautery is being used in the oral cavity, open-delivery FiO_2 should be limited to 30% to reduce fire risk.
Antibiotics	Not used routinely
Surgical time	30 min
EBL	10–200 mL. Monitor closely.
Postop care	Lateral position; suction in midline only. Most commonly, PACU → home. Overnight stay, if <2 yr, severe OSA, or other comorbidities
Mortality	Rare
Morbidity	Bleeding: 1–4% in children, 4–10% in teenagers Aspiration: Rare Tooth damage: Rare
Pain score	Adenoidectomy, 3–5; tonsillectomy, 6–9

PATIENT POPULATION CHARACTERISTICS	
Age range	1 yr+ (most common, 2–8 yr)
Male:Female	1:1
Incidence	300,000 cases/yr in the United States
Etiology	OSA; chronic infection; peritonsillar abscess; snoring. (R/O lymphoma, carcinoma, lymphoproliferative disease)
Associated conditions	Down syndrome

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Although most children presenting for tonsillectomy and/or adenoidectomy are healthy, a variety of medical problems may coexist. Severe adenoidal hyperplasia may cause

nasopharyngeal obstruction, obligate mouth breathing, failure to thrive 2° poor feeding, and disturbances of speech and sleep. Chronic nasal obstruction may result in narrowing of the upper airway and dental and facial changes (so-called adenoidal facies). Tonsillar hyperplasia may cause airway obstruction, OSA, CO_2 retention, cor pulmonale, and failure to thrive. Most of these changes are reversible with removal of the adenoids and tonsils. Children with severe OSA should be considered for postop hospital admission for cardiorespiratory monitoring. Children presenting for adenoidectomy/tonsillectomy also frequently have URI (see Anesthetic Considerations for Myringotomy and Tympanostomy Tube Placement).

Respiratory	See discussion under Anesthetic Considerations for Myringotomy and Tympanostomy Tube Placement.
Dental	Examination of the airway should include inspection of the teeth. Parents should be advised that loose teeth may be dislodged during placement of the mouth gag or laryngoscopy.
Cardiovascular	Severe and prolonged OSA can lead to cor pulmonale and heart failure. An echocardiogram is recommended in children with severe OSA and signs or symptoms of cardiac dysfunction.
Hematologic	A careful Hx is taken for Sx of easy bruising or bleeding. If present, a CBC with Plt count, as well as PT, INR, PTT, and bleeding time, is performed. In patients with a negative Hx, we order no preop lab tests.
Premedication	Children with severe OSA (airway obstruction) who are very anxious may receive a reduced dose of oral midazolam in a well-monitored environment (e.g., with an experienced RN or member of the anesthesia team present). Intranasal dexmedetomidine (1-2mcg/kg 45-60min before induction) is another option for premedication. SpO_2 should be monitored following administration of premedication. Avoid long-lasting sedative medications.
ERAS	Check compliance with presurgical ERAS

	recommendations (see above) including NPO status. Consider preop acetaminophen 10–15 mg/kg iv or po as an elixir.

INTRAOPERATIVE

Anesthetic technique

GA with ETT or LMA

Induction	Standard inhalation induction is common, but iv induction with propofol can be faster and safer, especially in patients with severe OSA; airway obstruction is common in these patients and usually is alleviated with placement of an oral airway and administration of CPAP @ 10–20 cm H_2O. An iv catheter should be placed as soon as possible. Propofol (2–3 mg/kg) is usually given to facilitate intubation. If needed, rocuronium (0.5 mg/kg) may be used. Glycopyrrolate (4–6 mcg/kg) may be used if needed to reduce secretions. If intubation is planned, an oral ETT (reinforced standard or RAE) is used and taped securely to the midline position to facilitate placement of the mouth gag. A cuffed ETT is commonly used because, in combination with a throat pack, it minimizes the risk of entry of blood and oral secretions into the trachea during surgery. Especially if an oral RAE tube is used, care should be exercised that the ETT is long enough for the cuff to pass beyond the vocal cords as the depth of these tubes is limited by the curvature of the tube. A short tube may easily dislodge with changes in head position, or the cuff may cause vocal cord trauma. Bilateral breath sounds and chest excursion should be confirmed after placement of the mouth gag, which may cause kinking and obstruction of the ETT. An LMA (flexible or reinforced LMA) can be used as an alternative to the ETT in healthy, nonobese patients without OSA, with advantages of reduced airway irritation and total procedure time. Problems with the LMA include inadequate surgical exposure and leaking or kinking

	resulting in dislodgement. Evidence to support the use of an LMA (flexible or reinforced) is mixed. Although LMA use may reduce case times and decrease airway irritation, the risks include airway obstruction, aspiration, and/or failure requiring intubation. Given the potential risks, we advocate the use of an ETT.
ERAS	Assess volume status (see Appendix D, p. D-1 and Appendix K, p. K-6 to K-8). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance. An intermediate-acting NMR (e.g., rocuronium 0.6–1.0 mg/kg or vecuronium 0.1 mg/kg) may be given to facilitate tracheal intubation if needed. Opioids (e.g., fentanyl 1–2 mcg/kg iv, hydromorphone 2–5 mcg/kg iv, or morphine 0.05–0.1 mg/kg) are given for postop analgesia. In the patient with OSA, careful titration of opioids is necessary as the threshold for opioid-induced apnea is reduced. One option is to allow the return of spontaneous ventilation and carefully titrate to respiratory rate. Acetaminophen (10 mg/kg iv or 30–40 mg/kg pr) may be given before or after induction. Dexmedetomidine (1 mcg/kg bolus iv over 10 min, followed by 0.4–0.7 mcg/kg/h infusion) can be used as an adjunct to reduce opioid requirements and emergence agitation. The use of total iv anesthesia (TIVA), instead of inhaled anesthetic, may ↓ PONV, which is common following tonsillectomy/adenoidectomy.
Emergence	Blood and secretions should be suctioned from the oropharynx and stomach following the completion of surgery. Care must be taken to not be overly aggressive in suctioning as this may lead to increased bleeding at the surgical site. Awake or deep extubation may be performed supine or in the lateral position with the head down. Verify removal of throat packs. Deep extubation decreases coughing but requires vigilance to avoid airway obstruction and aspiration at emergence, during transport, and during early PACU recovery until

	spontaneous airway reflexes are fully recovered. Ondansetron (0.1 mg/kg, up to 4 mg) and dexamethasone (0.5 mg/kg) are given to reduce airway edema and PONV. Administration of 30 mL/kg of iv fluids (BSS or normal saline) has been associated with reduced PONV. Ketorolac may be avoided out of concern for postop hemorrhage; however, ibuprofen may be acceptable.	
Blood and fluid requirements	IV: 22 or 20 ga × 1 BSS (10–30 mL/kg may reduce PONV)	Blood loss is typically ~4 mL/kg and may accumulate in the stomach → N/V (unless prevented by antiemetics). Ensure that stomach contents are adequately suctioned before extubation.
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Airway obstruction	
	ETT dislodgement/kinking	Usually caused by insertion/manipulation of mouth gag

POSTOPERATIVE

Complications	Airway obstruction	Retention of throat pack → airway obstruction. Remove with Magill forceps. Recurrent airway obstruction may require application of positive pressure via face mask (CPAP vs. manual ventilation with PEEP) ± placement of an oral airway. Severe postop airway obstruction is more common in patients <2 yr. In these

		patients, admission to PICU may be necessary. CPAP via face mask or nasal mask may be helpful. On rare occasions, tracheal intubation and mechanical ventilation are required until swelling of the airway resolves.
	Hemorrhage	Bleeding may occur in the immediate postop period or several days later. Patients present with anemia and hypovolemia, as well as airway compromise and a full stomach 2° swallowed blood. IV should be placed, and iv fluids administered prior to induction. Rapid-sequence intubation should be performed with cricoid pressure in preparation for surgical treatment. Practitioners should be prepared to transfuse blood in cases of hemodynamic instability, severe anemia, or active bleeding.
Multimodal pain management	Fentanyl 1 mcg/kg iv Acetaminophen Hydromorphone 1–2 mcg/kg iv or Morphine 0.025–0.05 mg/kg iv	May be given incrementally in PACU. Subsequently, acetaminophen (10 mg/kg po) alternating with ibuprofen (7.5 mg/kg po) may be used. IV opioid doses should be reduced compared to other procedures due to decreased responsiveness to hypercapnia in patients with OSA and possible risk of

		oversedation and respiratory compromise. Care must be taken for adequate postoperative monitoring in those patients who demonstrate severe OSA. **NB1**: Respiratory depression may continue to be a risk in the first 24 h postoperatively. **NB2:** Codeine should NOT be used, as some patients may be ultrarapid metabolizers (due to cytochrome P4502D6 [CYP2D6] variant), and this may lead to respiratory depression and death.
ERAS	PONV protocol (see Appendix D, p. D-4)	Encourage early enteral nutrition and mobilization.

Suggested Readings

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BRONCHOSCOPY/ESOPHAGOSCOPY/REMOVAL OF FOREIGN BODY

SURGICAL CONSIDERATIONS

Description

Flexible bronchoscopy is performed when the dynamics of the larynx and trachea need to be visualized. The child is supine on the OR table, which is turned 90°–180°. With the child sedated or under GA but breathing spontaneously, the bronchoscope is passed through the nose into the pharynx by way of an adapter attached to a standard anesthesia mask. Alternatively, the bronchoscope can be passed through an LMA if visualization of the pharynx is not required. The larynx is viewed with the patient breathing spontaneously so that vocal cord movement can be observed; topical anesthetic is applied to the cords, and then the anesthesia is deepened and the bronchoscope passed into the trachea. The trachea and bronchi are viewed, and when indicated, bronchoalveolar lavage or bronchial biopsy can be performed.

Rigid bronchoscopy is preferred when direct ventilation of the trachea is required and/or when foreign bodies (FBs) need to be removed. It also can be used for diagnosis of airway lesions. Direct laryngoscopy is performed, and topical anesthetic is applied to the larynx and trachea. The rigid bronchoscope is passed through the vocal cords into the trachea. The anesthesia tubing is connected to the bronchoscope, and the patient is ventilated through the scope. If a FB is present, the telescope within the bronchoscope will be removed and optical forceps inserted through the bronchoscope to remove the FB. During the time when the telescope is being changed, a leak will be present in the ventilation system.

Usual preop diagnosis

Airway obstruction; stridor; bronchial FB; pneumonia (requiring bronchoalveolar

lavage); tracheal or bronchial lesion

Flexible or rigid esophagoscopy can be performed for diagnostic or therapeutic (removal of FB) purposes. Flexible esophagoscopy can be performed under sedation; however, GETA is preferred for rigid esophagoscopy. Direct laryngoscopy is performed to expose the esophageal inlet, and the esophagoscope is inserted through the mouth into the esophagus, and the entire length of the esophagus is viewed. If a FB is to be removed with the rigid esophagoscope, the optical forceps are passed through the lumen of the esophagoscope. If a FB (especially foodstuff) is to be removed with the flexible esophagoscope, the scope may need to be passed several times.

Esophageal dilation may be performed in one of several ways. Balloon dilation can be performed with the flexible esophagoscope. Alternatively, a guide wire can be passed through the esophagoscope; then Savary-Gilliard dilators, in successively larger sizes, are passed over the wire. Another option is to remove the esophagoscope after the stenosis has been visualized; then, Maloney or Hurst dilators are passed blindly through the mouth and into the esophagus. Care must be taken to avoid accidental extubation of the patient while the dilators are being inserted and removed.

Usual preop diagnosis

GERD; esophageal FB; esophageal stricture

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, carb loading, and postop pain management options. **See Appendix K: Pediatric ERAS, p. K-6 to K-8.**

SUMMARY OF PROCEDURES

	Bronchoscopy	Esophagoscopy
Position	Patient supine; table turned 90°	⇐
Unique considerations	Ventilate through rigid bronchoscope. Ventilate via mask with adapter for flexible bronchoscope or via LMA. Dexamethasone (0.5 mg/kg) may be indicated, if glottic or subglottic edema is present.	Observe for accidental extubation. ETT is taped to the lower left side of the mouth.
Antibiotics	None	⇐
Surgical time	10 min–1.5 h	15 min–1 h

EBL	None	<10 mL
Postop care	Watch for airway compromise; PACU.	PACU
Mortality	Rare	⇐
Morbidity	Laryngospasm	Esophageal perforation
	Laryngeal edema	Bleeding
	Dental trauma	⇐
Pain score	3–4	3–4

PATIENT POPULATION CHARACTERISTICS	
Age range	Newborn+
Male:Female	1:1
Incidence	Common
Associated conditions	Bronchoscopy requiring bronchial alveolar lavage (BAL): immunocompromised patient Esophageal stricture: tracheoesophageal fistula (TEF) Esophageal FB: esophageal stricture

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Laryngoscopy, Supraglottoplasty, and Excision of Laryngeal Lesions.

LARYNGOSCOPY, SUPRAGLOTTOPLASTY, AND EXCISION OF LARYNGEAL LESIONS

SURGICAL CONSIDERATIONS

Description

Flexible laryngoscopy typically is performed in the clinic setting but may be performed in the OR in an unstable or uncooperative child to assess dynamic function of the larynx and vocal fold mobility. Vocal cord function is best assessed with the child only mildly sedated. The ideal position for this is a sitting position (or with the head of bed

elevated). Topical anesthesia and vasoconstrictors can be applied to the nose to limit discomfort. The fiberscope is introduced into the nose and advanced into the pharynx, and then the larynx is viewed.

Sleep endoscopy is a procedure where flexible laryngoscopy is performed as a diagnostic procedure in the OR to identify anatomical obstruction in OSA patients. For this procedure, the ideal plane of anesthesia simulates a physiologic sleep state. The patient should be breathing spontaneously and will be in a supine position. Topical anesthesia and vasoconstrictors are applied to the nose; then the scope is passed through the nose into the pharynx, and the larynx is viewed. Jaw thrust is given during the exam to see if there are changes in anatomic obstruction with and without jaw thrust. The exam consists of evaluation for obstruction at the level of the nasopharynx, velopharynx, oropharynx, lateral pharyngeal walls, tongue base, supraglottis, and glottis.

Diagnostic direct laryngoscopy is performed with the child in a supine position and table turned 90°, with a small shoulder roll in place. The laryngoscope is introduced, and with a lifting motion, a thorough exam of the oropharynx, hypopharynx, and larynx is performed. If more than a brief exam is to take place, the vocal cords are anesthetized with topical lidocaine to help prevent laryngospasm. A telescope (often connected via camera to a video monitor) or rigid ventilating bronchoscope may be passed through the vocal cords to observe the trachea and major bronchi.

Microlaryngoscopy with removal/ablation of laryngeal lesions—most commonly papillomas, nodules, or polyps—is accomplished by suspending the laryngoscope from the Mayo stand or OR table, using a suspension apparatus. An operating microscope is used for bimanual manipulation of the airway with magnification. The patient continues to breathe spontaneously or is paralyzed and jet-ventilated. Papillomas may be removed with a cup forceps, microdebrider, or laser. When the laser is used, the patient's eyes and face are covered with a damp cloth. OR personnel must wear protective glasses. The microscope with the laser attached is positioned so that the laser beam passes through the laryngoscope onto the vocal folds. Alternatively, the laser may be held by the surgeon and passed through an optical fiber. Percent oxygen delivered to the patient must be 30% or less when the laser is fired due to fire risk.

Children with subglottic or tracheal stenosis may undergo microdirect laryngoscopy with dilation, either by balloon or rigid dilator.

Young infants with severe laryngomalacia may undergo a **supraglottoplasty** for relief of airway obstruction. The laryngoscope is suspended, and the laser or microlaryngeal instruments are used to remove redundant aryepiglottic fold tissue.

Usual preop diagnosis

Diagnostic laryngoscopy: hoarseness; airway obstruction; stridor; subglottic stenosis. Operative laryngoscopy: laryngeal papillomas; laryngeal nodules; laryngeal web; laryngeal polyps; subglottic hemangioma or cysts; severe laryngomalacia

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, carb loading, and postop pain management options. **See Appendix K: Pediatric ERAS, p. K-6 to K-8.**

SUMMARY OF PROCEDURE	
Position	Supine; table turned 90°; shoulder roll
Special instrumentation	± Jet ventilation; laryngoscope suspension apparatus; video equipment; operating microscope, laser
Unique considerations	Direct laryngoscopy, microdirect laryngoscopy: Potential laser precautions; patient usually not intubated; dexamethasone 0.5–1.0 mg/kg to prevent laryngeal edema; laryngeal topical lidocaine 0.4 mg/kg. An appropriately sized endotracheal tube should be available on the surgical field for immediate insertion and ventilation as needed during the procedure. Sleep endoscopy: Anesthesia should mimic physiologic sleep for accurate evaluation of upper airway obstruction in children with OSA. Supraglottoplasty: If a surgeon prefers laser ablation, a balance must be struck between adequate oxygen delivered to the patient to maintain saturations and fire hazard risk of higher percent (>30%) oxygen delivered.
Antibiotics	None
Surgical time	15–90 min
EBL	<5 mL
Postop care	Observe for airway obstruction in PACU.
Mortality	Rare
Morbidity	Laryngospasm

	Laryngeal edema Dental trauma Tracheal rupture (airway dilation)
Pain score	3–5

PATIENT POPULATION CHARACTERISTICS

Age range	Newborn+
Male:Female	1:1
Incidence	Occasional
Etiology	Papillomas: Most commonly, viral infection contracted from mother during vaginal delivery Nodules, polyps: Vocal abuse, gastropharyngeal reflux Subglottic hemangioma: Unknown Subglottic cyst: Prior intubation Laryngeal cysts, webs: Congenital malformation Laryngomalacia: Unknown Subglottic stenosis: Prolonged intubation
Associated conditions	Chronic hoarseness, stridor; GERD; FTT, prematurity

ANESTHETIC CONSIDERATIONS

(Procedures covered: Bronchoscopy; esophagoscopy; removal of foreign body; laryngoscopy; supraglottoplasty; excision of laryngeal lesions)

PREOPERATIVE

Direct laryngoscopy (DL) is performed most commonly for patients with stridor. In infants, stridor is most often 2° laryngomalacia, with vocal cord paralysis and obstructive airway lesions being less common. Patients with severe laryngomalacia may undergo supraglottoplasty. Older children may present with stridor 2° laryngeal masses or papillomatosis, for which laser excision may be performed. A careful H&P is contributory to Dx, after which flexible laryngoscopy in the otolaryngology clinic can be confirmatory.

Laryngoscopy and **rigid bronchoscopy** also are performed for the removal of airway foreign bodies (FBs). A history of choking and/or coughing while eating is usually

elicited. Children may present with agitation, wheezing, and cyanosis. This condition constitutes a true surgical emergency, and the patient should be taken to the OR as soon as possible.

Airway/respiratory	Stridor usually is worsened with crying or agitation and often is less severe during sleep.
Dental	Any loose teeth may be dislodged.
Laboratory	No routine tests indicated. In stable patients with suspected FB aspiration, CXR may be obtained.
Premedication	Because stridor often is decreased during quiet breathing and sleep, premedication with oral midazolam is usually beneficial in patients >9 mo. Children with FB aspiration generally should not be given po medications. They may benefit from small doses of iv midazolam. EMLA or ELA-max® cream may be applied 45 or 20 min (respectively) in advance to iv sites for topical anesthesia.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 10–15 mg/kg iv or po as an elixir.

INTRAOPERATIVE

Anesthetic technique

GA. Primary and backup plans for airway management during the procedure should be discussed in detail with the otolaryngologist surgeon in advance of anesthetic induction.

Induction	A standard inhalation induction with sevoflurane and O_2 ± N_2O is performed with routine monitoring. An oral airway may be necessary if upper airway obstruction occurs. IV access should be obtained as quickly as possible. Spontaneous breathing is preferred in cases where vocal cord function and airway collapse must be evaluated. If iv access is available preoperatively, propofol (2–3 mg/kg) ± ketamine (1–2 mg/kg) may be used for iv induction followed by a continuous infusion

	(see below). Glycopyrrolate (4–6 mcg/kg) may be given to reduce oral secretions. If anesthesia-assisted sleep endoscopy is to be performed at the beginning of the case, anesthetics need to be carefully titrated to attain a physiologic sleep state, with spontaneous ventilation, but minimal reactivity to endoscopic examination. Ideally, the patient will be obstructing slightly with gentle snoring, in order to help identify the site of obstruction. Currently, there is no uniform anesthetic technique or standard for achieving proper endoscopic evaluation. Studies show that propofol, volatile anesthetics, benzodiazepines, barbiturates, and opioids all result in an exaggerated amount of airway obstruction due to low muscle tone or respiratory drive suppression. Typical regimens for sleep endoscopy include gentle titration of: 1. Propofol 100–200 mcg/kg/min and remifentanil infusions 0.05–0.1 mcg/kg/min or 2. Dexmedetomidine loading dose (1–2 mcg/kg) followed by an infusion (1–2 mcg/kg/h) in combination with ketamine boluses (0.1 to 1 mg/kg titrated in to a maximum dose of 2 mg/kg. Higher cumulative doses may result in prolonged postop sedation.). After the examination is completed, anesthesia can then be deepened for subsequent procedures.
ERAS	Assess volume status (see Appendix D, p. D-1 and Appendix K, p. K-6 to K-8). Maintain normovolemia and normothermia.
Maintenance	Once an adequate level of anesthesia is achieved, topical airway anesthesia (lidocaine) is typically applied by an ENT surgeon to the vocal cords and larynx, and iv dexamethasone is often requested to minimize airway edema postoperatively. Maintenance is typically achieved with propofol (100–250 mcg/kg/min) ± remifentanil (0.1–1 mcg/kg/min) infusions and ± propofol (0.5–1 mg/kg) or ketamine (0.1–1 mg/kg) boluses titrated to effect, thereby

providing optimal anesthesia while also avoiding contamination of the OR with inhaled anesthetics. Dexmedetomidine 0.5–1 mcg/kg iv loading dose followed by 0.4–0.7 mcg/kg/h infusion may be used as an alternative to propofol. For patients in whom vocal cord function must be assessed, a gradual reduction of inhalational anesthesia or an iv anesthetic infusion should allow adequate vocal cord excursion. For certain procedures (flexible bronchoscopy/laryngoscopy, bronchoalveolar lavage), a LMA can be used for airway management; however, the LMA aperture bars should be removed to allow for passage of the endoscope.
If the patient tolerates spontaneous ventilation during the procedure, supplemental O_2 is administered with manual intermittent ventilation through an anesthesia mask, the side arm of the rigid bronchoscope, or a small ETT placed in the trachea or near the glottic opening if the patient is under suspension laryngoscopy.
Controlled ventilation can be beneficial when it is difficult to maintain adequate oxygenation/ventilation and provide an adequate level of anesthesia for an immobilized airway. For patients who are apneic or hypoventilating, manual intermittent positive pressure ventilation can be performed, but this can interfere and prolong the surgical procedure. Risks include ball-valve hyperinflation and increased difficulty in removing a FB.
Another option would be jet ventilation using a Sanders jet ventilator. Intermittent jets of 100% O_2 are delivered with a high-pressure (40–55 psi) gas source through a tube incorporated into the laryngoscope blade. As the jet is pointed toward the glottic opening, gas is entrained by the Venturi effect. Manual jet ventilation is performed, while chest excursion is observed to ensure that excessive inflating pressures and volumes are avoided.
Transnasal humidified rapid-insufflation ventilatory exchange (THRIVE) has also been successful in prolonging the apneic oxygenation time after induction.
NB: Fire hazard during laser surgery is minimal in the

	absence of a combustible material (e.g., plastic) in the field. An FiO_2 of 1.0 may, therefore, be used safely, unless a plastic ETT is in place. For selected laser procedures involving the tissues around the glottis, a metal or metal-wrapped ETT may be used. When a plastic ETT is in place, the lowest possible FiO_2 is used (O_2/air mixture) to maintain an acceptable SpO_2. During rigid bronchoscopy, ventilation is performed through a side port of the bronchoscope. Assisted, spontaneous ventilation under deep inhalational anesthesia may be maintained. Alternatively, iv anesthesia with or without muscle relaxation may be preferred, as described earlier. For airway FB cases, maintenance of spontaneous ventilation generally is preferred to avoid distal displacement of the FB. Gentle, assisted ventilation may be required, however, to ensure adequate oxygenation and ventilation.	
Emergence	A conventional ETT sometimes is placed after removal of the laryngoscope or bronchoscope, as laryngospasm following these procedures is common. Tracheal extubation is performed with the patient fully awake and following complete reversal of neuromuscular blockade, if applicable. Postop, nebulized racemic epinephrine and corticosteroids may be used to treat stridor and airway edema, and ICU admission should be considered in severe cases.	
Blood and fluid requirements	IV: 22 ga × 1 BSS @ 3–5 mL/kg/h	Blood loss is minimal.
Monitoring	Standard monitors	
Positioning	Table rotated 90° ✓ and pad pressure points ✓ eyes	Shoulder roll/neck extension for surgery Eyes covered with wet sponges or goggles when laser in use
Complications	Hypoventilation	Adjust Sanders jet; mask

	Hypoxemia	ventilation prn.
	Airway injury	2° jet ventilation, DL/bronchoscope
	Pneumothorax	
	Laryngospasm	Rx: 100% O_2, CPAP vs. manual ventilation/PEEP
	Eye injury	
	Airway fire	Remove ETT; irrigate with NS; resume ventilation with 100% O_2 when fire extinguished.

POSTOPERATIVE

Complications	Dental trauma Bleeding Eye trauma Pneumothorax	
Multimodal pain management	Acetaminophen 10 mg/kg po/iv q6h or 30–40 mg/kg pr loading dose, followed by 20 mg/kg q6h—check previous acetaminophen usage in OR. Fentanyl 1 mcg/kg iv q10min prn Hydromorphone 2 mcg/kg iv q10–20min prn Ibuprofen 10 mg/kg po q6h	Use nonopioid analgesics. Back up with bolus opioid analgesics.
ERAS	PONV protocol (see Appendix D, p. D-4)	Encourage early enteral nutrition and mobilization.
Tests	CXR	If respiratory distress or ↓ SpO_2 present

Suggested Readings

1. Best C: Paediatric airway anaesthesia. Curr Opin Anaesthesiol 2012; 25(1):38–41.
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REMOVAL OF BRANCHIAL CLEFT CYST OR

THYROGLOSSAL DUCT CYST

SURGICAL CONSIDERATIONS

Description

Branchial cleft cysts and tracts typically present in the lateral neck and thyroglossal duct cysts, in the midline. Removal consists of making an incision in the neck around the opening of the tract (if present), or over the palpable cyst, and following the tract superiorly to its origin. A **Sistrunk procedure** is performed in the case of a thyroglossal duct cyst and involves the removal of the middle section of the hyoid bone and the tract that follows up to the base of the tongue.

Usual preop diagnosis

Branchial cleft cyst; thyroglossal duct cyst

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, carb loading, and postop pain management options. Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Supine; head 180° from anesthesia; oral intubation
Incision	Horizontal neck
Antibiotics	Clindamycin 10 mg/kg or cefazolin 25 mg/kg
Surgical time	45–90 min
EBL	10–50 mL
Postop care	Routine
Mortality	Rare
Morbidity	Bleeding/neck hematoma infection Recurrence of cyst Damage to CN XI and XII
Pain score	4–6

PATIENT POPULATION CHARACTERISTICS	
Age range	Newborn–adult

Male:Female	1:1
Etiology	Congenital
Associated conditions	Branchiootorenal (BOR) syndrome

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Incision/Drainage of Deep Neck Abscess.

INCISION/DRAINAGE OF DEEP NECK ABSCESS

SURGICAL CONSIDERATIONS

Description

Children with deep neck abscesses (retropharyngeal, parapharyngeal, peritonsillar) are at risk for acute airway obstruction; therefore, the abscesses are drained on an emergent basis. Retropharyngeal and peritonsillar abscesses typically are drained through an intraoral approach and parapharyngeal abscesses, through an external neck or intraoral approach. In each case, the child must be intubated orally and placed in the supine position. The anesthesiologist or otolaryngologist who is intubating the child must be prepared for abnormal pharyngeal anatomy 2° the abscess. Care must be taken that the abscess is not ruptured in the intubation process. In most cases, the child can be extubated immediately after the abscess is drained; however, in a small number of cases, the child may need to remain intubated until the pharyngeal edema subsides.

Usual preop diagnosis

Retropharyngeal; parapharyngeal; or peritonsillar abscess

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, carb loading, and postop pain management options. **See Appendix K: Pediatric ERAS, p. K-6 to K-8.**

SUMMARY OF PROCEDURE	
Position	Supine; table turned 90°–180° oral intubation
Incision	Intraoral (retropharyngeal or peritonsillar abscess); lateral neck (parapharyngeal abscess)

Unique considerations	Acute airway obstruction can occur with induction. Care must be taken to avoid rupture of abscess on intubation; ±dexamethasone 0.5–1 mg/kg.
Antibiotics	Clindamycin 10 mg/kg
Surgical time	30–90 min
EBL	<30 mL
Postop care	May remain intubated postop
Mortality	Rare
Morbidity	Aspiration (if abscess ruptures spontaneously) Airway obstruction 2° aspiration or edema Bleeding
Pain score	5

PATIENT POPULATION CHARACTERISTICS

Age range	Most common, 6 mo–3 yr; can occur at any age
Male:Female	1:1
Incidence	Uncommon
Etiology	URI

ANESTHETIC CONSIDERATIONS

(Procedures covered: excision of branchial cleft and thyroglossal duct cyst; incision/drainage of neck abscess)

PREOPERATIVE

These patients generally are otherwise healthy children. A lymphatic malformation (cystic lymphangioma, cystic hygroma), as with other neck masses, may cause airway obstruction and difficult intubation.

Respiratory	The size and extent of the neck mass should be defined carefully in an effort to detect the potential for airway compromise and to avoid soft-tissue trauma during intubation, with consequent acute

	airway obstruction. Inspiratory stridor suggests supraglottic obstruction, while expiratory stridor is associated with subglottic/intrathoracic obstruction. If trismus is present due to pain, it may be difficult to assess the airway in the awake patient. These patients should have had prior CT/MRI imaging; scans and anesthesia records for these studies should be reviewed. **Tests:** CXR; CT/MRI
Cardiovascular	Cervical masses may be adherent to and/or cause compression of the great vessels. **Tests:** CT/MRI
Hematologic	T&C for cystic hygroma, or if a cervical mass involves great vessels or extends into the mediastinum **Tests:** Hct
Laboratory	Other tests as indicated from H&P
Premedication	If >9–12 mo and asymptomatic, midazolam (0.5–0.75 mg po) 30 min prior to arrival in OR. Avoid all premedication in patients with significant potential for airway compromise.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 10–15 mg/kg iv or po as an elixir.

INTRAOPERATIVE

Anesthetic technique

GETA

Induction	Standard pediatric induction in patients without airway compromise. When airway obstruction is present, iv access should be secured prior to mask induction, which may be done with sevoflurane in 100% O_2. As the plane of anesthesia deepens, gently assist ventilation. Consider giving atropine (0.01–0.02 mg/kg iv) prior to

	laryngoscopy. If partial airway obstruction exists, maintain spontaneous ventilation with CPAP and perform laryngoscopy at ~3 MAC of volatile agent. FOB/video laryngoscope should be available. Have full range of ETT sizes available because airway narrowing may be present. Once airway is secured, proceed with neuromuscular blockade (e.g., rocuronium 0.6–1.0 mg/kg or vecuronium 0.1 mg/kg) if needed.	
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix D, p. D-1 and Appendix K, p. K-6 to K-8). Maintain normovolemia and normothermia.	
Maintenance	Standard pediatric maintenance. Surgeon may infiltrate incision with local anesthetic. Limit lidocaine to 5 mg/kg when used without epinephrine or 7 mg/kg when used with epinephrine, bupivacaine to 2.5 mg/kg, and ropivacaine to 2.5 mg/kg. Consider volume replacement as the patient may be dehydrated.	
Emergence	Reverse neuromuscular blockade with neostigmine (0.07 mg/kg iv) and atropine (0.02 mg/kg iv). Extubate when fully awake. Discuss with surgeon local wound infiltration. PONV prophylaxis should include dexamethasone (e.g., 30 mcg/kg) and ondansetron (0.1 mg/kg up to 4 mg iv).	
Blood and fluid requirements	Minimal blood loss usually iv: 20–22 ga × 1 Great vessel involvement: IV: 20 ga × 1–2 BSS @ 3 mL/kg/h	Minimal third-space losses. Each mL blood loss can be replaced with 3 mL BSS. When great vessels are involved, place at least one iv in lower extremity. Blood loss can be quite sudden; have blood available in OR.
Monitoring	Standard monitors ± Arterial line, 22 ga	An arterial line is used when there is risk of large blood loss or periop airway compromise.

Positioning	✓ and pad pressure points ✓ eyes	
Complications	ETT dislodged/loss of airway Laryngospasm Bronchospasm Hemorrhage	ETT must be secured carefully. Liberal use of benzoin adherent. Avoid tension on ETT by circuit hoses. Hold ETT during surgeon's intraoral examination to prevent accidental extubation.

POSTOPERATIVE

Complications	Subglottic edema Upper airway obstruction from edema related to tumor resection Recurrent laryngeal nerve injury	Dexamethasone (0.5–1 mg/kg iv) and nebulized racemic epinephrine (1.25%) with mist O_2 to treat subglottic edema
Multimodal pain management	Acetaminophen 10 mg/kg po/iv q6h or 30–40 mg/kg pr loading dose, followed by 20 mg/kg q6h Morphine (0.025–0.1 mg/kg iv q2–4h)	The majority of these procedures are performed on outpatient basis (except cystic hygroma). Use nonopioid analgesics. Back up with bolus opioid analgesics.
ERAS	PONV protocol (see Appendix D, p. D-4)	Encourage early enteral nutrition and mobilization.

Suggested Readings

1. Olutoye OA, Watcha ME: Eyes, ears, nose and throat surgery. In: Gregory GA Andropoulos DB, eds. Pediatric Anesthesia, 5th edition. Wiley-Blackwell, Oxford: 2012, 777–809.
2. Rove KO, Edney JC, Brockel MA: Enhanced recovery after surgery in children promising, evidence-based multidisciplinary care. Paediatr Anaesth 2018; 28(6):482–92.

LARYNGOTRACHEAL RECONSTRUCTION, CRICOTRACHEAL RESECTION, AND LARYNGOTRACHEOPLASTY

SURGICAL CONSIDERATIONS

Description

A **laryngotracheal reconstruction** (LTR, laryngotracheoplasty) or **cricotracheal resection** (CTR) is performed in the patient with moderate-to-severe subglottic stenosis. Typically, the procedure starts with a diagnostic bronchoscopy. In most of these patients, a tracheotomy will already be present. During the procedure, the tracheotomy tube may be switched for an anode tube, which is sutured or taped to the chest. A horizontal neck incision is made over the cricoid cartilage. The strap muscles are separated in the midline, and the laryngeal cartilage and trachea are exposed. In an LTR, a vertical incision (laryngofissure) is made through the inferior portion of the thyroid cartilage, through the cricoid cartilage, and down to the tracheotomy site. Either before or after the airway is exposed, costal cartilage, auricular cartilage, or thyroid cartilage will be harvested for use as a graft. The cartilage graft is then sutured into the anterior airway, keeping the laryngofissure incision open. Sometimes, a posterior cartilage graft is necessary in a severely stenotic airway, and this is placed after making an incision through the posterior cricoid. The initial exposure for a CTR is the same as an LTR but instead of placing a cartilage graft(s), the anterior portion of the cricoid cartilage and stenotic portion of the trachea are removed and the trachea pulled superiorly and sutured to the thyroid and remaining cricoid cartilages.

In a single-stage procedure, the anode tube in the tracheostomy stoma is removed intraop before the anterior cartilaginous incisions are closed and replaced with an oral or nasal ET tube. This ETT is kept in place for 2–7 d as a stent around which the airway heals. In a two-stage procedure, the tracheotomy tube is kept in place. In this circumstance, there may be a stent superior to the tracheotomy tube, or a T-shaped tracheotomy tube may be used.

A **cricoid split** is most commonly performed in the NICU baby who fails extubation due to subglottic stenosis. Diagnostic bronchoscopy is performed; then the baby is reintubated or the bronchoscope is left in the airway, and the procedure is performed over the bronchoscope. A laryngofissure is performed but no cartilage graft placed. Typically, an ETT 1/2 size larger than the previously placed ETT is inserted.

Usual preop diagnosis

Subglottic stenosis

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, carb loading, and postop pain management options. **See Appendix K: Pediatric ERAS, p. K-6 to K-8.**

SUMMARY OF PROCEDURE	
Position	Supine, shoulder roll
Incision	Horizontal neck
Unique considerations	After the cut is made into the airway, a leak may be present, depending on position of the cuff (if present).
Antibiotics	Clindamycin 10 mg/kg, ampicillin/sulbactam 50 mg/kg
Surgical time	Laryngotracheal reconstruction (LTR, laryngotracheoplasty), cricotracheal reconstruction 1.5–4 h Cricoid split: 45 min
EBL	5–30 mL
Mortality	Rare
Morbidity	Pneumothorax Bleeding Infection Stent or ETT dislodgement Residual/recurrent subglottic stenosis
Pain score	4–6; 6–8 if costal cartilage harvested

PATIENT POPULATION CHARACTERISTICS	
Age range	Newborn to adult
Male:Female	1:1
Incidence	Rare
Etiology	ETT intubation; congenital
Associated conditions	Prematurity with prolonged NICU course

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

These procedures are performed in patients with subglottic stenosis with a lesion that is either congenital or acquired. Congenital subglottic stenosis varies with regard to the length of trachea involved and the degree of stenosis. Segmental stenosis may occur in the region of the cricoid cartilage, in the midtrachea, or just above the carina. Sx are severe retractions, especially with agitation or intercurrent URI, dyspnea, and stridor. If the stenotic segment is short and severe, excision with primary anastomosis may be performed. If the involved segment is long, tracheoplasty is usually performed.

Acquired subglottic stenosis occurs as a complication of prolonged tracheal intubation and mechanical ventilation, most commonly in premature neonates with severe lung disease (infant respiratory distress syndrome [IRDS]). The stenotic lesion usually is limited to the level of the cricoid cartilage and is treated with the cricoid split procedure. In addition to tracheal stenosis, tracheomalacia may be present.

Respiratory	Patients may be intubated and mechanically ventilated in the PICU. A variable degree of lung disease may be present; some patients may be on minimal ventilatory support, while others may require relatively high FiO_2 and/or inflating pressures. Some patients will have an indwelling tracheostomy tube that bypasses the stenotic lesion and may be cared for at home. **Tests:** As indicated from H&P
Cardiovascular	Although not common, cor pulmonale with RVH may be present 2° chronic lung disease.
Hematologic	Anemia is common, especially in infants with chronic lung disease. **Tests:** Hct
Premedication	Infants in PICU usually are receiving a regimen of sedative and analgesia drugs. These should be continued until the patient is transported to the OR, with supplemental doses given preop as needed. Tolerance may be present, and drug doses should be titrated to achieve an adequate level of sedation.

ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 10–15 mg/kg iv or po as an elixir.

INTRAOPERATIVE

Anesthetic technique

GETA

Induction	In intubated or trached patients with iv access, an iv induction is performed; otherwise, a mask induction is done with inhalation agents. Care should be taken to preserve upper airway patency, as even mild obstruction tends to exacerbate tracheal collapse. In cases of severe obstruction, iv access should be established prior to induction and may then be followed by either inhalation induction or iv induction. Following induction, tracheal intubation is performed with an ETT smaller than normal for age. In patients with severe stenosis, an ETT as small as 2.5 mm may be required. A cuffed tube is recommended, and the surgeon should be careful not to damage the cuff during the procedure. If prolonged sedation and mechanical ventilation are planned postop, central venous access should be considered.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix D, p. D-1 and Appendix K, p. K-6 to K-8). Maintain normovolemia and normothermia.
Maintenance	Plans for postop mechanical ventilation are discussed with the surgeon. In those patients for whom mechanical ventilation is planned for >24 h, high-dose opioid anesthesia can be considered (e.g., fentanyl 10–20 mcg/kg), as well as a muscle relaxant (e.g., rocuronium, if needed). A mixture of air and O_2 is used to minimize the risk of airway fire.
Emergence	The majority of patients are transported to the PICU with

	indwelling ETT and residual sedation, narcosis, and neuromuscular blockade. These patients should be transported with iv sedation (propofol, benzodiazepine, or dexmedetomidine). Emergent reintubation poses a higher risk in these patients should an accidental extubation occur.	
Blood and fluid requirements	IV: 24 or 22 ga × 1 BSS @ maintenance	Blood loss <30 mL
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Tracheal edema Injury to neck structures: Trachea Vascular structures Recurrent laryngeal nerve injury	Rx: dexamethasone (0.5–1 mg/kg)

POSTOPERATIVE

Complications	Tracheal disruption (leak)	Presents with subcutaneous emphysema of the neck, face, and chest wall
	Recurrent laryngeal nerve injury	May cause vocal cord dysfunction
Sedation/analgesia	Heavy sedation	To minimize head and neck movement and tracheal wound disruption while ETT is in place

Suggested Readings

1. Axtell AL, Mathisen DJ: Idiopathic subglottic stenosis: techniques and results.Ann Cardiothorac Surg 2018; 7(2):299–305.
2. Boardman SJ, Albert DM: Single stage and multistage pediatric laryngotrachea reconstruction. Otolaryngol Clin North Am 2008; 41:947.

CHOANAL ATRESIA REPAIR

SURGICAL CONSIDERATIONS

Description

Infants born with bilateral choanal atresia typically have severe airway distress shortly following birth because neonates are obligate nasal breathers. The distress resolves after the child is intubated or a McGovern nipple (large nipple with cross-cuts in the end) or oral airway is positioned in the oral cavity. These infants undergo primary repair of the atresia within the first few days of life. Children with unilateral choanal atresia usually do not have severe respiratory distress, and thus, surgery is often postponed until a later age.

Intranasal repair involves opening up the atretic area with choanal dilators, urethral sounds, microdebrider, or drill. Endoscopic sinus instruments are used to view the choanae and remove the posterior nasal septum. Sometimes an intranasal stent is placed. A labial approach can be used to better visualize the choanal. If a transpalatal repair is performed, a Dingman mouth gag is placed in the mouth, a palatal flap is raised, and the posterior portion of the hard palate and posterior septum is removed. A stent is positioned in the nose. The infant should be able to breathe spontaneously through the nose at completion of either procedure.

Usual preop diagnosis

Bilateral or unilateral choanal atresia

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, carb loading, and postop pain management options. **See Appendix K: Pediatric ERAS, p. K-6 to K-8.**

SUMMARY OF PROCEDURE	
Position	Supine; rotate bed 90°–180°
Incision	Intranasal or intraoral
Special instrumentation	Choanal dilators; Dingman mouth gag
Antibiotics	Clindamycin 10 mg/kg, ampicillin/sulbactam 50 mg/kg
Surgical time	30 min to 2 h

EBL	<10 mL
Postop care	Observation in PICU for respiratory distress
Mortality	Rare
Morbidity	Bleeding CSF leak Meningitis Pressure necrosis to the nasal ala and septum from stent Infection Airway obstruction if stents become malpositioned
Pain score	3–6

PATIENT POPULATION CHARACTERISTICS

Age range	Newborn–young child
Male:Female	1:1
Incidence	Rare
Etiology	Congenital
Associated conditions	Coloboma, heart disease, atresia choanae, retarded growth, genital anomalies, and ear deformities (CHARGE) association (see Anesthetic Considerations, below)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Because many neonates are nasal breathers, choanal atresia may present with cyanosis at rest, resolving with crying or placement of an oral airway. Unilateral atresia is usually asymptomatic; bilateral lesions usually → respiratory distress in the neonatal period but occasionally are asymptomatic. Although choanal atresia is most commonly an isolated anomaly, it may present as part of the CHARGE association.

Respiratory	Classic findings include cyanosis at rest, resolving with crying.

Cardiovascular	When part of the CHARGE association, cardiac defects include tetralogy of Fallot, ASD, VSD, PDA, AV canal, or right-side aortic arch.
Neurologic	When part of the CHARGE association, a variety of CNS abnormalities may be present. Hypoxia 2° airway obstruction may cause CNS impairment and Sz.
Premedication	Repair of choanal atresia usually is performed in infancy, and premedication is not indicated.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 10–15 mg/kg iv.

INTRAOPERATIVE

Anesthetic technique

GETA

Induction	Standard pediatric induction. Airway obstruction may develop during induction of anesthesia. Early placement of an oral airway is recommended to relieve airway obstruction. An oral RAE ETT is preferred, especially if a transpalatal repair is planned using a Dingman mouth retractor.
ERAS	Verify preincision antibiotics. Assess volume status (see Appendix D, p. D-1 and Appendix K, p. K-6 to K-8). Maintain normovolemia and normothermia.
Maintenance	Inhalational or iv anesthesia is maintained during the procedure. During the 1st mo of life, opioids (other than remifentanil) should be avoided generally because of the risk of postop respiratory depression. For infants undergoing repair after the first month of life, small doses of fentanyl (1–2 mcg/kg) may be given. Muscle relaxation does not need to be maintained following tracheal intubation.

Emergence	Nasal stents placed following the repair must be secure and free of secretions prior to tracheal extubation. Patients must be fully awake and capable of maintaining patency of their oropharynx in the event of postop swelling and transient obstruction of the nasopharynx.	
Blood and fluid requirements	IV: 24 or 22 ga × 1 BSS @ maintenance	Blood loss is usually <10 mL; may be greater in older infants.
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Airway obstruction Bleeding	2° obstruction or displacement of nasal stents into the oral pharynx especially in older infants

POSTOPERATIVE

Complications	See Intraop Complications, above.	
Multimodal pain management	Acetaminophen 10 mg/kg po/iv q6h or 30–40 mg/kg pr loading dose, followed by 20 mg/kg q6h	Small doses of opioid may be given iv immediately postop, with special attention to avoid respiratory depression/obstruction.
ERAS	PONV protocol (see p. D-1)	Encourage early enteral nutrition and mobilization.

Suggested Readings

1. Kwong KM: Current updates on choanal atresia. Front Pediatr 2015; 3:52.
2. Rove KO, Edney JC, Brockel MA: Enhanced recovery after surgery in children promising, evidence-based multidisciplinary care. Paediatr Anaesth 2018; 28(6):482–92.

PEDIATRIC TRACHEOSTOMY

SURGICAL CONSIDERATIONS

Description

A **tracheostomy** is performed in the infant or child with upper airway obstruction (subglottic stenosis, laryngeal web, etc.) or in the child in whom prolonged mechanical ventilation is anticipated. In most cases, the child will already be intubated and the procedure will be performed over the ETT. In selected infants, the tracheostomy can be performed with a rigid bronchoscope in the airway through which the patient is being ventilated. A midline horizontal neck incision is made just inferior to the cricoid cartilage. The dissection is carried out in the midline until the trachea is reached. In children, the tracheal incision is vertical. Stay sutures may be placed in the right and left sides of the trachea on either side of the incision to facilitate replacement of the tracheotomy tube should it become displaced. Alternatively, a formal tracheal stoma may be created by securing the skin flaps directly to the trachea. One method of formalizing the stoma is a starplasty where the tracheal incision is made in the shape of a "+" and the skin incision an "x," and the skin is sutured to the trachea. A large air leak will be present as soon as the tracheal incision is made. As the ETT or bronchoscope is being removed, a tracheostomy tube is inserted in the neck. The ventilation tubing is moved and connected to the tracheotomy tube, which is secured with neck sutures and/or ties around the neck. The starplasty has the advantage that in case the tracheotomy tube is dislodged accidentally, it can be fairly easily reinserted, even on the first postoperative day, providing an additional safety factor over the conventional approach.

Usual preop diagnosis

Ventilator dependence; subglottic stenosis

ERAS: For elective surgery, family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, carb loading, and postop pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Supine; head to anesthesia; shoulder roll; neck extended
Incision	Horizontal neck
Special	Tracheostomy hook

instrumentation	
Unique considerations	Patient is draped to allow easy access to ETT. When the trachea is opened, a large air leak may be present. On entering the airway, the ETT may be ruptured. Unlike adult tracheostomy tubes, pediatric trachs typically do not have an “inner” cannula and often do not have a cuff.
Antibiotics	Clindamycin 10 mg/kg or cefazolin 25 mg/kg
Surgical time	30 min–1 h
EBL	<10 mL
Postop care	Close observation in PICU. CXR immediately following procedure to r/o pneumothorax
Mortality	Intraop: rare. Postop 1–3%, usually 2° tracheostomy tube plugging or dislodgement
Morbidity	Pneumothorax Subcutaneous emphysema Bleeding Infection Plugging Skin abrasion around trach edges or trach ties in patient with short, chubby neck
Pain score	3–5

PATIENT POPULATION CHARACTERISTICS

Age range	Newborn to adult
Male:Female	1:1
Incidence	Uncommon
Etiology	Anatomical airway obstruction; ventilatory dependence; high, spinal cord, or head injury
Associated conditions	Prematurity; trauma

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations following Tracheostomy in Chapter 3.0, Otolaryngology.

Suggested Reading

1. Olutoye OA, Watcha ME: Eyes, ears, nose and throat surgery. In: Gregory GA Andropoulos DB, eds. Pediatric Anesthesia, 5th edition. Wiley-Blackwell, Oxford: 2012, 777–809.

CHAPTER 12.4

Pediatric Cardiovascular Surgery

SURGEONS

Katsuhide Maeda, MD, PhD
Frank L. Hanley, MD

ANESTHESIOLOGISTS

Claudia Benkwitz, MD, PhD
Lisa Wise-Faberowski, MD, MS, FAAP
Komal Kamra, MBBS, MMI
M. Gail Boltz, MD, FAAP
Chandra Ramamoorthy, MD

SURGERY FOR ATRIAL SEPTAL DEFECT (OSTIUM SECUNDUM)

SURGICAL CONSIDERATIONS

Description

Atrial septal defects (ASDs) are among the most common congenital cardiac defects ASDs vary widely in size and location and are broadly classified as **ostium secundum**, **ostium primum**, **sinus venosus**, and **coronary sinus** types (Fig. 12.4-1). Ostium secundum defects—the most common (80%)—result from an incompletely formed or fenestrated septum primum covering the fossa ovalis. An L → R shunt results in augmented pulmonary blood flow, which, if left uncorrected, may lead to RV failure, atrial arrhythmias, pulmonary HTN, and, rarely, pulmonary vascular occlusive disease (PVOD). In 1953, Gibbon successfully repaired an ASD using a pump-oxygenator and in doing so, ushered in the era of open cardiac surgery.

Secundum ASDs that fail to close spontaneously should be closed electively in early childhood to avoid long-term complications. Currently, ASD closure is performed through a minimally invasive midline partial sternotomy approach on CPB. A right anterolateral thoracotomy through the 4th intercostal space also provides satisfactory exposure and provides female patients with better cosmesis. After the initiation of CPB, cardioplegic arrest, or ventricular fibrillation, a right atriotomy is created, and the ASD is visualized.

ASD repair is performed by direct suture closure or patch closure, using autologous pericardium or prosthetic material (e.g., Gore-Tex®, Dacron™). After the repair is completed and the atriotomy is closed, standard de-airing maneuvers are performed, the aortic cross-clamp is released, and CPB is discontinued. The chest is then closed in the standard fashion.

Variant procedure or approaches

Patent foramen ovale (PFO) or ASD closure is becoming a common indication for device closure in the cardiac catheterization lab, if an adequate rim of atrial septal tissue is present to seat the device. Some have argued this approach avoids not only the risk of paradoxical embolism and stroke during surgery but also the need for sternotomy and associated prolonged recovery.

Usual preop diagnosis

ASD; ostium secundum defect; other variants

ERAS: Family preop counseling/education by the surgeon and anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, postop pain management options, physiotherapy plan, and possibility of NG tube and urinary drain postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

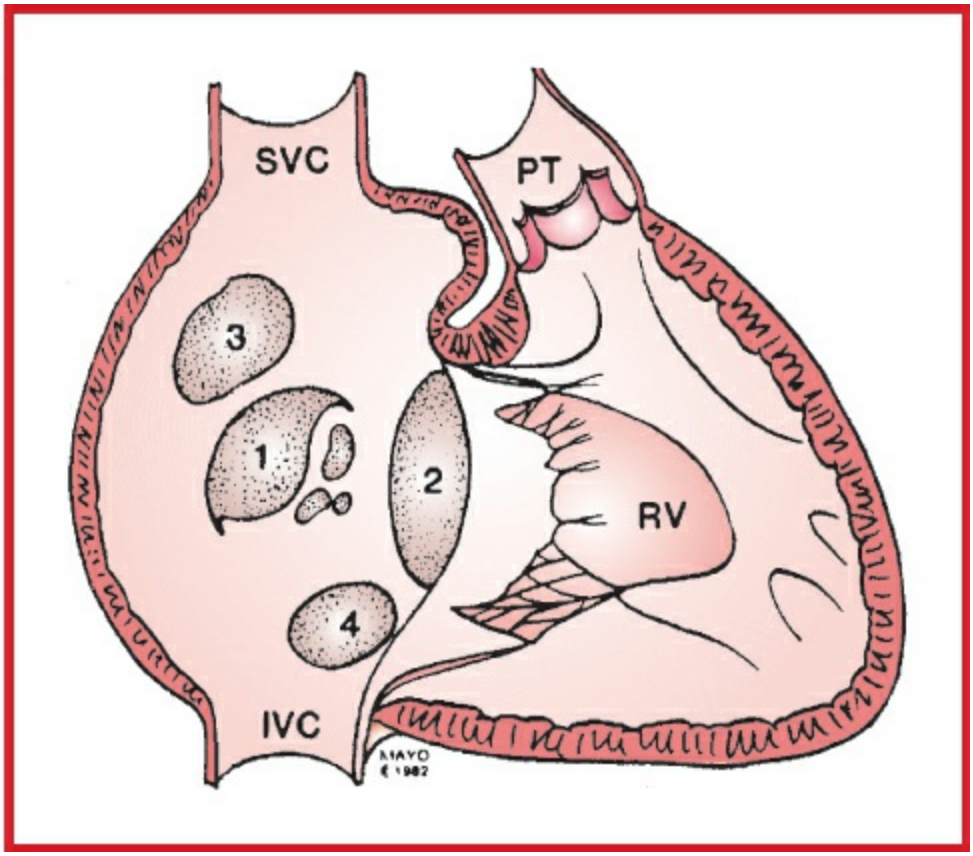

Figure 12.4-1 Location of ASDs, numbered in decreasing order of frequency. 1, secundum; 2, primum; 3, sinus venosus; 4, coronary sinus type. IVC, inferior vena cava; PT, pulmonary trunk; RV, right ventricle; SVC, superior vena cava. (Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved.)

SUMMARY OF PROCEDURE

Position	Supine or lateral decubitus (thoracotomy)
Incision	Minimally invasive midline incision with limited right median sternotomy; right anterolateral thoracotomy (4th intercostal space): Robotic-assisted total endoscopic surgery
Unique considerations	R → L shunt → systemic embolization
Antibiotics	Cefazolin 25 mg/kg q4h
Surgical time	Aortic cross-clamp or ventricular fibrillation time: 10–30 min Total: 2 h
Closing	Routine closure with chest tube in pericardial space;

considerations	temporary atrial pacing wire (older patients); possible left atrial line for monitoring
EBL	Minimal
Postop care	Extubation in OR or within first 4 h; 24-h monitoring in ICU
Mortality	Rare
Morbidity	Hemorrhage Postpericardiotomy syndrome Atrial arrhythmias
Pain score	6–8

PATIENT POPULATION CHARACTERISTICS

Age range	Neonate–adults
Male:Female	1:2
Incidence	10–15% of congenital heart defects
Etiology	Unknown; sometimes associated with syndromes such as Holt-Oram
Associated conditions	ASD may coexist with nearly any of the other recognized congenital cardiac anomalies but is more commonly associated with pulmonary stenosis (10%), partial anomalous pulmonary venous return (7%), VSD (5%), PDA (3%), and mitral stenosis (2%). ASDs are also part of other malformations, including tricuspid atresia, total anomalous pulmonary venous connection (TAPVC), and mitral atresia. When associated with tetralogy of Fallot, it is described as pentalogy of Fallot.

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Pathophysiology	Although the septum secundum ASD is the most common (~80% of all ASDs), periop management

	varies little among all types of ASDs (including ostium primum, sinus venosus, and coronary sinus types). One principal guideline in all L → R shunts is the estimation of shunt flow: Q_p:Q_s. The size of the defect and relative compliances of both ventricles are the two main factors determining the degree of shunting at the atrial level and thereby ultimately pulmonary blood flow (Q_p). Patients are generally asymptomatic until the Q_p:Q_s ratio exceeds 3.0. As the shunt flow increases, Sx of pulmonary overcirculation may develop (e.g., feeding difficulties, failure to thrive, tachypnea at rest, frequent URIs, and arrhythmias related to atrial dilatation). L → R shunt → promotes ↑ pulmonary blood flow (Q_p) → ↑ PA pressures → ↑ PVR → RV overload and RV failure. The larger the area of the defect, the greater the shunt.
Cardiovascular and respiratory	Most infants with ASDs are asymptomatic. ASDs are detected on cardiac auscultation (fixed splitting of S2) or sometimes during neurologic workup for TIAs or strokes secondary to paradoxical emboli. Depending on the degree of shunting (Q_p/Q_s), young children may have h/o frequent URIs. Cyanosis is rare and indicates shunt reversal and development of pulmonary HTN. Although almost 90% of small secundum ASDs close spontaneously in the first year of life, surgical repair is usually recommended between 3 and 5 yr of age as these patients are at risk for paradoxical embolism, stroke, bacterial endocarditis, and ultimately CHF. For some patients (depending on age, size, and location of the ASD), endovascular closure in the cath lab, or more recently with hybrid procedures, may be suitable alternatives, with both obviating the need for CPB. **Tests:** EKG: normal or RVH. CXR: cardiomegaly and ↑ pulmonary vascular markings. Echo, TEE: essential for locating and estimating size of defect, other valvular abnormalities, and identification of

	pulmonary vein anatomy. Cardiac CT may be indicated for delineation of the pulmonary veins in sinus venous ASDs because of the association with anomalous pulmonary venous return.
Laboratory	Hb/Hct; T&C
Premedication	Patients >8 mo old may benefit from midazolam 0.5–0.75 mg/kg po 20 min before induction.
ERAS	Check compliance with presurgical ERAS recommendations including NPO status. Evaluate for concurrent disease, and optimize nutritional status and hydration.

INTRAOPERATIVE

Anesthetic technique

GETA: Most of these patients are candidates for **fast-tracking**—the practice of extubating cardiac patients in the OR or within 4 h of completion of surgery. To achieve this goal, the anesthetic technique must be adjusted to allow for early extubation.

Criteria for fast-tracking include patients >4 mo of age, short CPB run, stable hemodynamic profile, minimal inotropic support, normal acid-base status, and adequate surgical hemostasis. Patients who are pacemaker dependent are not suitable candidates for fast-tracking. The use of regional techniques, caudal Duramorph® (50 mcg/kg) or hydromorphone (10–15 mcg/kg) or erector spinae plane (ESP) block w/wo catheter placement, may help to facilitate fast-tracking. Generally, patients selected for fast-tracking have undergone repair of a secundum ASD, VSD (no evidence of postop pulmonary HTN), bidirectional Glenn and Fontan procedures, or an RV → PA conduit change. For patients with a single ventricle, resumption of spontaneous ventilation decreases intrathoracic pressure, thereby increasing venous return and improving CO.

Induction	Following inhalation induction using sevoflurane (O_2/N_2O), an iv is placed and intubation facilitated with rocuronium (0.6–1 mg/kg). After ET intubation, an arterial line is placed for close BP monitoring. **Fast-track:** Inhalation induction (sevoflurane ± N_2O) is followed by placement of a PIV. Fentanyl (2–5 mcg/kg) and a muscle relaxant (e.g., rocuronium

	0.6–1 mg/kg) are administered, and the airway is secured. Subsequently, an arterial line is placed. For patients who are not candidates for regional anesthesia (e.g., parent preference, spine abnormality, bleeding disorder), intravenous techniques are used (e.g., remifentanil 0.1–0.4 mcg/kg/min). Because most patients have good myocardial function, propofol (100–200 mcg/kg/min) may also be used, often with ketamine (20–50 mcg/kg/min). Propofol may also be used after separation from CPB and in transport to the ICU, usually at a lower dose (25–75 mcg/kg/min), weaned, and discontinued just prior to extubation. **Non–fast-track:** An inhalation induction with sevoflurane ±N_2O is usually well tolerated. Then, iv access is established and intubation facilitated by muscle relaxant (rocuronium 0.6–1 mg/kg) and supplemental fentanyl. For patients who are not candidates for fast-tracking, the standard anesthetic is fentanyl 20–40 mcg/kg in divided doses with supplemental isoflurane before and during CPB. Additional midazolam (0.1–0.3 mg/kg) may be administered to reduce chance of recall and awareness. An iv induction should be used in patients with significant pulmonary HTN and/or RV failure. IV induction can be accomplished with etomidate 0.1–0.3 mg/kg or ketamine 0.5–1 mg/kg, followed by a muscle relaxant (e.g., rocuronium 1 mg/kg).
ERAS	Verify preincision antibiotics.
Maintenance	For maintenance of anesthesia, inhaled agents, iv agents, regional anesthetic, or a combination may be used. N_2O is turned off after induction to avoid expansion of any VAE. In patients with pulmonary HTN, RV failure, and/or other medical conditions requiring postop mechanical ventilation, a high-dose narcotic technique may be appropriate (e.g., fentanyl 50–150 mcg/kg ± inhalation agent).

Emergence	If the choice is made to extubate the patient receiving remifentanil in the OR, check level of paralysis and reverse as appropriate; isoflurane is terminated during skin closure, and the remifentanil is turned off last, when the dressing is applied. Extubation is performed once the patient meets standard criteria (e.g., −25 cm H_2O NIF, spontaneous ventilation, adequate SaO_2, hemodynamic stability, none or minimal inotropic support). Because remifentanil has an extremely short half-life, and in the absence of regional anesthetic, it is necessary that a long-acting opioid (e.g., hydromorphone 10–15 mcg/kg) is administered in a timely fashion to ensure postop analgesia. Propofol 25–75 mcg/kg/min ± remifentanil or dexmedetomidine (0.5–1 mcg/kg/h) may be used for transport. Extubation is then performed in the ICU. Vasodilators are usually not required for BP control. O_2, bag, mask, airway equipment, and emergency drugs should be available during transport. Discuss with surgeon local wound infiltration at conclusion of procedure. Consider iv acetaminophen (10 mg/kg). Consider PONV prophylaxis ondansetron (0.1 mg/kg) if extubation is planned and there are no concerns of QT interval prolongation.	
Blood and fluid requirements	IV: appropriate for patient's size × 1–2 LR @ TKO Blood warmer ✓ for air bubbles. T&C 1 U PRBC	**NB:** It is extremely critical to avoid iv air bubbles in all patients with intracardiac shunts. Meticulous attention must be paid to clearing the iv tubing and stopcocks of any bubbles to avoid paradoxical air embolism and possible stroke. Have blood available in the OR. Blood transfusion may be required in patients <10 kg.

Monitoring	Standard monitors Cerebral oximetry SaO_2 probes (two sites) Arterial line CVP line Urinary catheter ACT monitoring TEE	ABG, electrolytes, and Hct should be checked as needed during the procedure. Place at least two O_2 probes to ensure readings during critical times. Avoid dorsalis pedis and posterior tibial arterial lines (inaccurate 2° spasm post-CPB). Femoral arterial line may be used. Double-lumen CVP in IJ is preferable. TEE monitoring is used to assess anatomy and repair. On CPB, if the aorta is not cross-clamped, monitor for intracardiac air.
Positioning	✓ and pad pressure points ✓ eyes	
Pre-CPB	Heparinization (200–400 U/kg) ✓ ACT > 480 sec ✓ NMB ✓ UO	Confirm that antibiotics have been given 30–60 min before skin incision and repeat q4–6h per protocol. If a regional technique is used, allow for a minimum of 60 min between needle placement and heparinization.
CPB	Ventilation stopped Hypothermia ✓ sufficient analgesia/sedation ✓ adequate flow and pressure during CPB ✓ face for venous congestion ✓ ABG and ACT ✓ UO	The patient is not actively cooled for secundum ASD closure. Temperature is allowed to drift to 33°C–34°C during CPB. Supplemental fentanyl/midazolam may be handed to the perfusionist and administered directly into the CPB circuit. Bloodless procedures (clear,

	✓ blood availability	no blood prime of the CPB machine). The use of albumin (a pooled blood product) is also avoided by some. PCCs (procoagulant complex's: PEIBA, Kcentra®), fibrinogen concentrate (RiaSTAP®), etc. may be used to achieve hemostasis. Cell saver blood is often collected and sometimes used in bloodless procedures.
Transition off CPB	Rewarming ✓ sufficient analgesia/sedation	Surgeon will de-air the heart, and this maneuver is monitored with TEE.
	Vasoactive infusions started at 34°C–35°C. Flush lines. Zero transducers. Suction ETT. Resume ventilation. ✓ ABG	Observe inflation of both lungs. Turn on vaporizer. Vasoactive infusions (e.g., dopamine 3–5 mcg/kg/min) may be started but are not always necessary in uncomplicated cases.
Post-CPB	Reversal of heparin with protamine ✓ UO	1 mg of protamine will reverse 100 U of residual heparin or ~5 mg/kg of protamine.
	± Modified ultrafiltration (MUF)	MUF uses the CPB machine to remove excess water and inflammatory mediators. It has been shown to transiently ↓ postop edema and improve cardiopulmonary function. This technique is not routinely performed at all institutions. Some may use continuous ultrafiltration (CUF).

Complications	Air embolism (VAE)	Potential for paradoxical embolization
	Supraventricular dysrhythmias Heart block Ventricular dysfunction	Likely 2° atriotomy

POSTOPERATIVE

Complications	Bleeding
Tests	ABG Electrolytes; Hct CXR
Multimodal pain management	Close postop monitoring for respiratory compromise, including SaO_2, proximity to RN station, and frequent assessment Use multimodal approach emphasizing regional analgesic techniques, combined with nonopioid analgesics and opioid analgesics as needed. Consider hydromorphone PCA by RN, with basal rate of 2 mcg/kg/h, (0.002 mg/kg/h) and lockout dose of 1 mcg/kg/ (0.001 mg/kg) 15-min lockout. Acetaminophen (10 mg/kg iv q6h, 10 mg/kg po q6h once taking orals) Consider lorazepam 5–10 mcg/kg iv q6h for management of anxiolysis. If PCA is not desired due to concern of possible oversedation, consider Morphine (0.05 mg/kg q1–2h) Hydromorphone (0.005–0.01 mg/kg q1–2h)
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.

Suggested Readings

1. Chaudhary V, Chauhan S, Choudhury M, et al: Parasternal intercostal block with ropivacaine for postoperative analgesia in pediatric patients undergoing cardiac surgery: a double-blind, randomized, controlled study. J Cardiothorac Vasc Anesth 2012; 26:439–42.
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SURGERY FOR ATRIOVENTRICULAR CANAL DEFECT

SURGICAL CONSIDERATIONS

Description

Atrioventricular (A-V) canal defects constitute a spectrum of congenital cardiac anomalies stemming from the embryonic maldevelopment of endocardial cushions. This leads to the absence of septal tissue immediately above and below the level of the A-V valves and defects in the A-V valves in continuity with these septal defects. **Partial A-V canal defects** (or **ostium primum atrial septal defects**) involve the atrial septum and mitral valve, whereas **complete A-V canal defects** involve the atrial and ventricular septa and have a common atrioventricular valve. Intermediate or transitional A-V canals have varying degree of pathology between the above two common patterns. Pathophysiologically, these defects result in L → R shunting at the atrial and/or

ventricular levels, leading to pulmonary HTN and CHF. A-V valvular insufficiency is also frequently observed with these defects, contributing to the early development of CHF.

Palliative repair of A-V canal defects consists of **pulmonary artery banding** (Fig. 12.4-2) to reduce excessive pulmonary blood flow. Palliation is rare and is reserved for very small infants with complicating conditions, such as RSV and other pneumonias. **Total correction** is now performed routinely, even in neonates. Repair consists of the closure of atrial and ventricular septal defects (VSDs) with closure of the cleft in the anterior leaflet of the mitral valve and repair of associated defects, such as a patent ductus arteriosus (PDA) or secundum atrial septal defect (ASD). The septal defects may be repaired with either a **two-patch technique**, consisting of a Dacron or pericardial patch on the ventricular septum and pericardial patch on the atrial septum, or a single patch (pericardium) covering both ASDs and VSDs. A modified single-patch technique whereby the A-V valve and VSD are incorporated into a single patch is currently used by some surgeons in cases where there is a small VSD.

Partial A-V canal defects

Exposure is obtained through a standard median sternotomy. CPB is instituted with aortic cross-clamping and cardioplegic arrest. Through a right atriotomy, the mitral valve cleft is sutured. A pericardial patch is placed across the top of the ventricular septum, around the coronary sinus orifice, and along the free edge of the superior portion of the ASD. The atriotomy is closed and the aorta unclamped after de-airing. The patient is rewarmed and weaned from bypass.

Complete A-V canal defects

Following median sternotomy, CPB is instituted with aortic cross-clamping and cardioplegic arrest. In the **single-patch technique**, one patch is used to close both the ASD and VSD components. The anterior and posterior bridging leaflets often are divided and resuspended to the patch, thereby creating two separate valves. The cleft in the left A-V valve is usually closed. If A-V valve regurgitation is present, repair is undertaken. In the two-patch technique, two separate patches are used to close the ASD and VSD, and the common A-V valve is sandwiched in between the two patches. Repair of A-V valve is the same in either technique. Closure of the right atrium, de-airing, aortic unclamping, rewarming, and resuscitation of the heart are commenced, and CPB is discontinued. Closure proceeds in the standard fashion. In ~5% of patients with complete A-V canal defects, tetralogy of Fallot (TOF) or left ventricular outflow tract obstruction (LVOTO) has to be addressed surgically.

Usual preop diagnosis

A-V canal defects (complete, intermediate, or partial); endocardial cushion defects

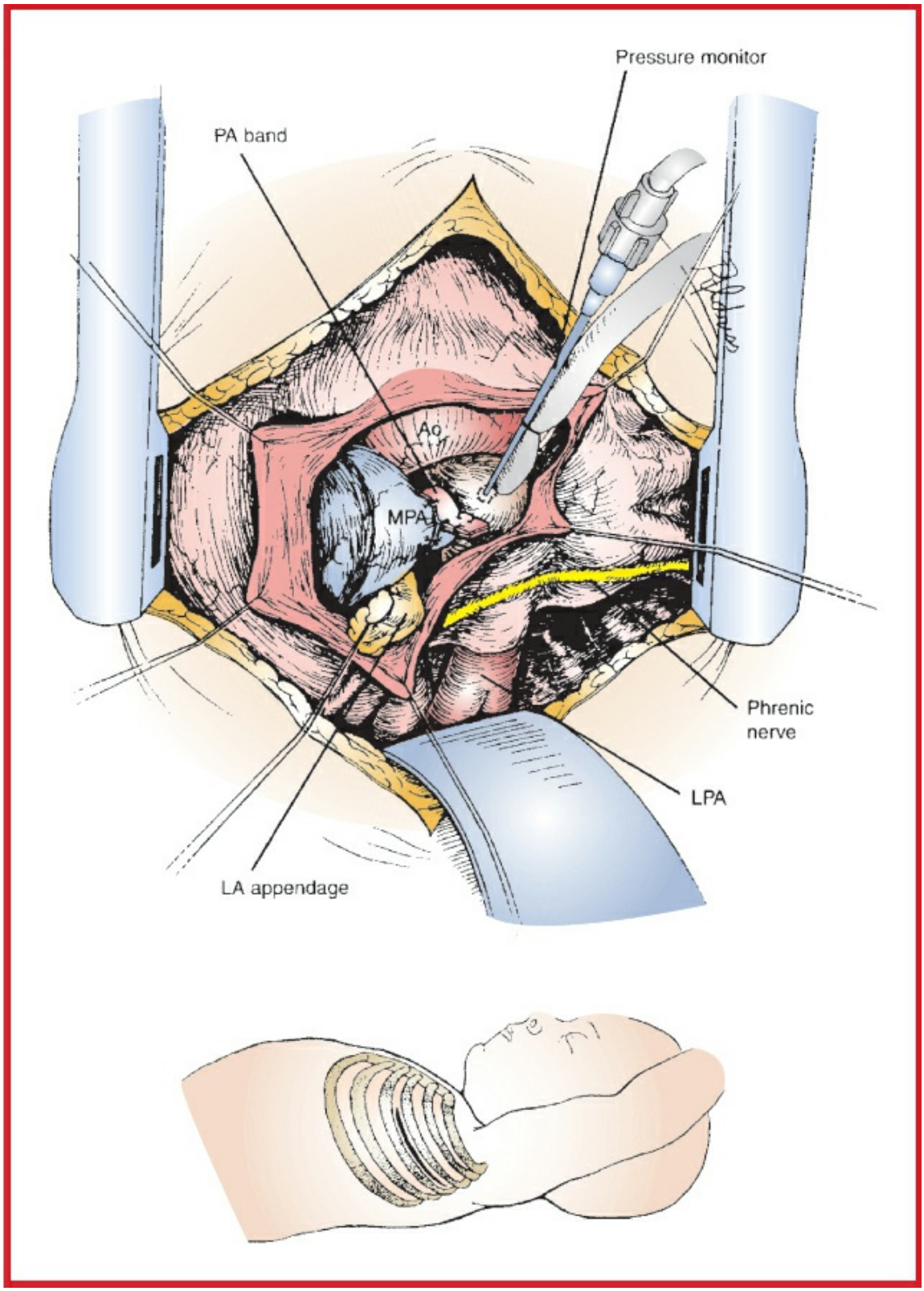

Figure 12.4-2 Placement of pulmonary artery band. PA, pulmonary artery; Ao, aorta; MPA, main pulmonary artery; LPA, left pulmonary artery; LA, left atrial. (Reproduced with permission from Kaiser LR, Kron IL, Spray TL, eds. Mastery of Cardiothoracic Surgery. Lippincott-Raven, Philadelphia: 1998.)

ERAS: Family preop counseling/education by the surgeon and anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, postop pain management options, DVT prophylaxis, physiotherapy plan, and possibility of NG tube and urinary drain postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Partial A-V Canal Defect	Complete A-V Canal Defect
Position	Supine	⇐
Incision	Median sternotomy/right anterolateral thoracotomy	Standard median sternotomy
Unique considerations	None	Repair performed through a right atriotomy; no ventriculotomies required
Antibiotics	Cefazolin 25 mg/kg q4h	⇐
Surgical time	Aortic cross-clamp: 30–40 min Total: 1.5–2 h	Aortic cross-clamp: 60–80 min Total: 2.5–3 h
Closing considerations	Chest tube in pericardial space; temporary ventricular pacing wire; possibly right or left atrial line for monitoring	⇐
EBL	Moderate	⇐
Postop care	ICU for 1–2 d, with 12- to 24-h assisted ventilation; minimal need for inotropes	1- to 3-d assisted ventilation; pulmonary HTN protocol, including hyperventilation and sedation; need for pulmonary vasodilators (e.g., NO) is uncommon; use of inotropes for

		adequate CO. Avoid excessive volume to prevent distension and mitral valve regurgitation.
Mortality	0–1%	1–2%
Morbidity	Transient heart block Atrial dysrhythmias Hemorrhage Infection	Pulmonary vasospasm Right heart dysfunction Mitral valve regurgitation Low CO Heart block/atrial dysrhythmias Residual VSD Hemorrhage
Pain score	6–10	6–8

PATIENT POPULATION CHARACTERISTICS		
Age range	1–20 yr (usually 2–3 yr)	2–6 mo (occasionally older; rarely, adults)
Male:Female	1:1	⇐
Incidence	0.5–1% of congenital heart defects	⇐
Etiology	Down syndrome: Rare, in patients with partial A-V canal defect	Commonly associated with Down syndrome (75% in patients with complete A-V canal defect)
Associated conditions	Left A-V valve insufficiency	Pulmonary HTN, left A-V valve insufficiency, minor associated cardiac anomalies (e.g., PDA or ASD); major associated anomalies (e.g., TOF, LVOTO)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Pathophysiology	A-V canal defects may be partial, transitional, or complete. The partial A-V canal has no interventricular communication and has an ostium primum ASD. There is often a cleft in the anterior leaflet of the mitral valve creating MR. The complete A-V canal has communications at both the atrial and ventricular levels with a single A-V valve that is regurgitant. The transitional AVC has a pathology in between the two ends of the spectrum. The complete A-V canal defect is further defined by the superior bridging leaflet (SBL) morphology and attachment. Rastelli types A (SBL is adherent to the LV), B (SBL is attached by an anomalous papillary muscle), and C (SBL is free floating). The degree of L → R shunting depends on the size of the defect, the pressure gradient between the chambers, and the PVR/SVR. Patients with large L → R shunts are at risk of developing pulmonary HTN, requiring early surgical correction.
Respiratory	✓ for pulmonary congestion, frequent URIs, tachypnea, diaphoresis on feeding, and FTT. Pulmonary HTN can be present in patients with partial or complete A-V canal defects. **Tests:** CXR: enlarged heart + increased pulmonary markings
Cardiovascular	Complete A-V canal → CHF and biventricular failure **Tests:** ECG: RAE, RVE; echo; rarely cardiac cath may be indicated to assess PVR.
Down syndrome	A-V canal defects account for 40% of cardiac defects in the Down syndrome patient. These patients are at risk of atlantoaxial instability (20%); therefore, avoid excessive flexion/extension of the head and neck. Additional airway considerations (subglottic stenosis, large

	tongue, hypotonia) make these patients unsuitable for fast-tracking and early extubation. Furthermore, trisomy 21 patients are more prone to developing PVOD/pulmonary HTN resulting in an increase in the PVR/SVR ratio with the possibility of developing bidirectional shunting or, as a late finding, shunt reversal (R → L).
Laboratory	See ASD.
Premedication	Midazolam 0.5–0.75 mg/kg po
ERAS	Check compliance with presurgical ERAS recommendations including NPO status. Evaluate concurrent disease, and optimize nutritional status and hydration.

INTRAOPERATIVE

Anesthetic technique

GETA

Induction	In children with small defects, minimal MR, or in the absence of PVOD, a mask induction with sevoflurane in air and O_2 is acceptable. Otherwise, an iv induction with fentanyl provides more stable hemodynamics. If the iv is in place, ketamine 1–2 mg/kg, propofol 1–2 mg/kg or fentanyl 5–10 mcg/kg, and rocuronium 1 mg/kg may be used. Verify ETT position. In children with Down syndrome, anticipate difficult airway and atlantoaxial instability. Excessive neck flexion should be avoided in this population. The non-Down partial A-V canal patients may be candidates for early extubation if the intracardiac defects are small and surgery was uncomplicated. In this case, induction and maintenance regimes should be tailored accordingly (see ASD).
ERAS	Verify preincision antibiotics.
Maintenance	Air-oxygen with volatile anesthetic and narcotics is

	the standard. In patients requiring postop mechanical ventilation, fentanyl 50–100 mcg/kg total, rocuronium prn, and midazolam (0.1–0.2 mg/kg) ± volatile agent may be used.	
Emergence	Patients undergoing repair of complete A-V canal defects are seldom suitable for fast-tracking. On conclusion of procedure, the patient is taken to CVICU, intubated, ventilated, sedated, and monitored, with emergency drugs and airway equipment immediately available.	
Blood and fluid requirements	IV: 22–24 ga × 2 LR @ TKO Blood products	
Monitoring	See ASD. TEE	TEE is used to assess left A-V valve regurgitation, valvular function, residual shunt, and ventricular function.
CPB	Management of CPB is discussed in Intraop Considerations for ASD.	In the immediate post-CPB period, TEE exam is valuable for evaluation of ventricular function and residual mitral valve regurgitation.
Transition off CPB	✓ rewarming ✓ sufficient analgesia/hypnosis ✓ vasoactive infusions started at 34°C–35°C ✓ Flush lines ✓ Zero transducers ✓ Suction ETT. ✓ Resume ventilation.	Surgeon will de-air the heart, and this maneuver is monitored with TEE. Turn on vaporizer. Vasoactive infusions may be started but are not always necessary in uncomplicated cases. Dopamine 3–5 mcg/kg/min, milrinone 0.5 mcg/kg/min Observe inflation of both lungs. In patients with PVOD, there is a significant potential for pulmonary HTN—be ready

		to assist with ventilatory measures, ± pharmacologic interventions. →NO or milrinone (greater than reduction of PVR vs. SVR).
Complications	Air embolism	Avoid air embolism in A-V canal patients (potential for shunt reversal → paradoxical embolization).
	A-V block, ventricular dysfunction	A-V block may be temporary 2° edema and/or cardioplegic arrest. Permanent injury can occur to the conduction system at the A-V node or bundle of His with repair of the VSD. Temporary atrial and ventricular pacing wires are placed.
	Persistent bleeding	
	Pulmonary HTN	Ventilatory measures for managing PHTN aim to ↓ PVR independently of SVR. A combination of hyperventilation to achieve alkalosis (pH ~7.5–7.6), high FiO_2, PaO_2 > 60 mm Hg, and low PIP/PEEP usually achieves this goal. The cerebral vasculature is more responsive to CO_2; the pulmonary vasculature is more responsive to pH. Pharmacologic measures such as inhaled NO, prostacyclins, phosphodiesterase inhibitors, as well as endothelin antagonists may be

		necessary to ↓ PVR in select patients. High PEEP or TV may ↑ intrathoracic pressure, thereby ↓ systemic venous return while at the same time ↑ RV afterload, both of which could be detrimental in the setting of pulmonary HTN. Since control of ventilation is the most reliable way to manipulate PVR, ventilatory measures represent a key concept of anesthetic management of cardiac lesions in which balancing PVR over SVR is crucial (e.g., large VSD, CAVC, truncus arteriosus).

POSTOPERATIVE

Complications	Residual VSD/ASD AV valve regurgitation	
Tests	TEE	Analysis of postrepair function is best done by TEE.
Multimodal pain management	CVICU management may include fentanyl, midazolam, and/or dexmedetomidine infusions. iv acetaminophen as appropriate	

Suggested Readings

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SURGERY FOR VENTRICULAR SEPTAL DEFECT

SURGICAL CONSIDERATIONS

Description

Ventricular septal defect (VSD) is the most common congenital cardiac anomaly. VSDs can occur anywhere in the interventricular septum (Fig. 12.4-3). One of the most common locations is the perimembranous in the region of membranous septum near the tricuspid and aortic valves. Supracristal (subarterial) defects are common in the Pacific Rim population. Muscular defects occur in the inlet, trabecular, or outlet muscular septum. A-V canal–type VSD defects are present under the septal leaflet of the tricuspid valve. Physiologically, these defects result in L → R shunting in proportion to the defect size. Untreated, this defect can cause RV volume overload and CHF in infancy and irreversible pulmonary HTN later in life. As PVR rises, shunt reversal to a R → L shunt can occur, producing hypoxemia and cyanosis; this is known as Eisenmenger syndrome and occurs in ~10% of untreated, nonrestrictive VSDs (rare). Moderate-to-large VSD that remain open >6 mo of age should be closed. Severe, intractable CHF in infants refractory to medical therapy (e.g., diuretics, digoxin) and ↑ PVR in infants >6 mo are indications for earlier VSD repair.

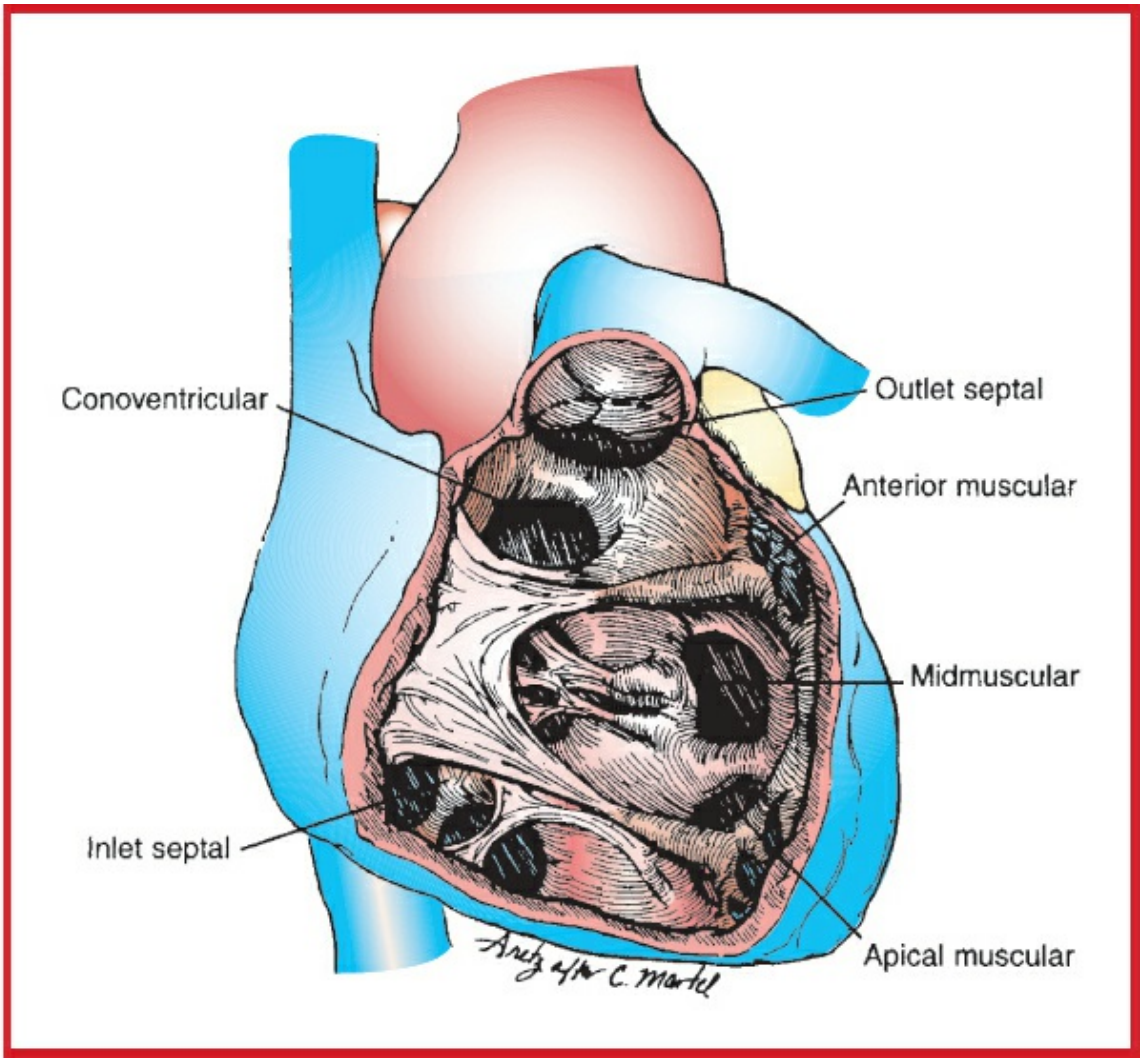

Figure 12.4-3 The right ventricular free wall has been resected to show the VSDs. conoventricular, perimembranous; outlet septal (subpulmonary), conal septal, inlet septal, A-V canal type. Muscular (trabecular) defects may be midmuscular, anterior, or apical. The penetrating bundle is closely related to the inferior margin of the conoventricular defect and diverges away from this margin into the trabecular septomarginalis beneath the muscle of Lancisi. (Reproduced with permission from Kaiser LR, Kron IL, Spray TL, eds. Mastery of Cardiothoracic Surgery. Lippincott-Raven, Philadelphia: 1998.)

Lillehei et al. performed the first successful VSD repairs using normothermic cross-circulation in 1955. Kirklin subsequently described successful VSD closure using extracorporeal circulation in 1957. VSD repair is performed now through a mediar sternotomy on CPB with bicaval cannulation. Deep hypothermia (18°C) with circulatory arrest is used in neonates <1800 g to facilitate repair. After CPB and cardioplegic arrest have been instituted, a right atriotomy is created, and the VSD is visualized by retracting the tricuspid valve leaflets. The VSD is then closed with a patch (e.g. pericardium, Gore-Tex®, Dacron™) with care being taken not to place sutures through the nearby conduction fiber bundles or the aortic valve. After the repair is completed, the atriotomy is closed, standard de-airing maneuvers are performed, the aortic cross-

clamp is released, and CPB is discontinued. The chest is then closed in the standard fashion.

Variant procedure or approaches

Supracristal defects may be more easily exposed through a pulmonary arteriotomy, while some inferiorly located muscular VSDs may be better accessed through a right ventriculotomy. Multiple VSDs or "Swiss cheese" ventricular septum can be a challenging surgical problem. Many can be closed with the approaches described above. Some may require a combined surgical and device closure. Palliative pulmonary artery banding may be required in Swiss cheese muscular VSD, with the hope that many of the VSDs may close spontaneously. At a second stage, the remaining VSDs are closed and the PA band is removed.

Usual preop diagnosis

VSD

ERAS: Family preop counseling/education by the surgeon and anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, postop pain management options, DVT prophylaxis, physiotherapy plan, and possibility of NG or chest tubes and urinary drain postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Median sternotomy
Antibiotics	Cefazolin 25 mg/kg q4h
Surgical time	Aortic cross-clamp: 15–45 min Total: 2–3 h
Closing considerations	Routine closure with chest tube in the pericardial space; temporary ventricular pacing wire; possibly right/left atrial and/or pulmonary arterial lines for monitoring
EBL	Minimal-to-moderate
Postop care	Extubation in OR or within several h; 24-h monitoring in ICU
Mortality	≤1%

Morbidity	Hemorrhage Low CO Atrial dysrhythmias Complete A-V heart block Residual shunting; tricuspid regurgitation
Pain score	6–8

PATIENT POPULATION CHARACTERISTICS

Age range	Neonate–adult
Male:Female	1:1
Incidence	20% of congenital heart defects; 2/1000 births
Associated conditions	PDA (6%); coarctation of the aorta (5%); congenital AS (2%); congenital mitral valve disease (2%); also part of other malformations, including TOF, TGA, DORV, tricuspid atresia; truncus arteriosus; others

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Pathophysiology	VSDs are classified by their location. Patients may be asymptomatic or may present with varying degrees of CHF ± pulmonary HTN, depending on the age of the patient, size of the VSD, and the flow across the VSD. Small VSDs, in which the flow is related to the size of the defect and in which there may be significant pressure gradient across the defect, are considered restrictive. These may close spontaneously in early childhood. Large VSDs in which the degree of L → R shunting is independent of the size and only determined by the PVR/SVR ratio are described as "nonrestrictive." Patients with large VSDs present with CHF and other signs of pulmonary overcirculation once their Q_p:Q_s > 2.0. Cyanosis indicates pulmonary HTN and shunt reversal (Eisenmenger syndrome).

Cardiovascular and respiratory	Similar to patients with other L → R shunting lesions (ASD, ACV). Signs and Sx of CHF and pulmonary overcirculation include tachypnea, frequent URIs, sweating during feeding, FTT, reduced exercise tolerance, and fatigue. Children with small VSDs may be asymptomatic. A holosystolic murmur may be present (particularly in restrictive defects) and can be heard best at the left lower sternal border. Cyanosis is absent unless there is R → L shunting (suggesting pulmonary HTN). **Tests:** EKG, CXR, echo. If pulmonary HTN is suspected, cardiac catheterization is performed for measurement of PA pressures. If PA pressures are elevated, O_2 and NO responsiveness are tested. VSDs may be closed surgically, via a device in the catheter (in the absence of pulmonary HTN), or with a hybrid procedural approach.
Laboratory	Hgb/Hct: electrolytes (children on diuretic, digoxin Rx), others as indicated from H&P
Premedication	Midazolam 0.5–1.0 mg/kg po may be useful.
ERAS	Check compliance with presurgical ERAS recommendations including NPO status. Evaluate concurrent disease, and optimize nutritional status and hydration.

INTRAOPERATIVE

Anesthetic technique

The anesthetic management of a patient with VSD (without pulmonary HTN and CHF) is similar to the patient with ASD (see p. 1370). These patients may be candidates for fast-tracking and early extubation. Refer to fast-tracking in ASD section. For patients with unrestrictive VSDs, avoid factors that ↓ PVR and shunt flow (i.e., high FiO_2, hyperventilation, ↓ pH). For patients who are not candidates for fast-tracking, the standard anesthetic is fentanyl 20–40 mcg/kg in divided doses with supplemental isoflurane before and during CPB. Additional midazolam (0.1–0.3 mg/kg) may be administered to prevent recall and awareness.

Blood and fluid requirements	IV: appropriate for patient size × 1–2 LR @ TKO Blood warmer T&C	Minimize administration of iv fluids. Both ventricles are volume-overloaded in large VSDs.
Monitoring	Standard monitors Arterial line	
	Surgical LA line Surgical RA/PA line (to assess for ↑ PAP)	A transthoracic LA line may be placed by the surgeon, if there is concern about postop mitral valve and LV dysfunction.
	TEE Urinary catheter ACT monitoring	In the immediate post-CPB period, TEE exam is valuable for evaluation of residual VSD and ventricular function.
Pre-CPB	See ASD.	
CPB	See ASD.	Most VSDs are closed under mild/moderate hypothermic CPB (28°C–32°C).
Transition off CPB	See ASD.	
Post-CPB	Temporary pacemaker wires	Placed in patients with conduction disturbances; pacemaker wires are placed routinely but may not be connected to a pacemaker.
	Maintenance of adequate filling pressure (LA = 5–10 mm Hg)	
	TEE Pulmonary HTN	For residual shunt and ventricular and valvular function, residual air. NO may be needed.
Complications	Residual VSD	Though usually seen on TEE, confirmation by a pulmonary

		artery blood SaO_2 >10% of the right atrial blood SaO_2 or "step up" in SaO_2 suggesting a residual left-to-right shunt
	Complete AVB	Depending on location of VSD, injury to the A-V node may occur, necessitating the use of a pacemaker; this block may be transitional or, in some cases, permanent.

POSTOPERATIVE

Complications	Persistent bleeding Heart block Ventricular dysfunction/failure Junctional ectopic tachycardia	May occur particularly after perimembranous VSD closure Especially in patients s/p ventriculotomy. For JET, evaluate for need of esmolol, amiodarone, cooling, and paralysis. Some use prophylactic dexmedetomidine gtt for sedation and antiarrhythmic purposes.
Tests	ABGs Electrolytes; Hct; coags prn CXR	
Multimodal pain management	CVICU management may include fentanyl, midazolam infusions, dexmedetomidine, and iv acetaminophen as appropriate.	

Suggested Readings

1. Backer CL, Eltayeb O, Mongé MC, et al: Shunt lesions part I: patent ductu arteriosus, atrial septal defect, ventricular septal defect, and atrioventricular septal defect. Pediatr Crit Care Med 2016; 17(8 Suppl 1):S302–9.
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4. Ross FJ, Nasr VG, Joffe D, et al: Perioperative and anesthetic considerations i atrioventricular septal defect. Semin Cardiothorac Vasc Anesth 2017; 21(3):221–8.
5. Saurav A, Kaushik M, Mahesh Alla V, et al: Comparison of percutaneous device closure versus surgical closure of peri-membranous ventricular septal defects: a systematic review and meta-analysis. Catheter Cardiovasc Interv 2015; 86(6):1048–56.

SURGERY FOR PATENT DUCTUS ARTERIOSUS

SURGICAL CONSIDERATIONS

Description

Patent ductus arteriosus (PDA) is usually located between the proximal descending thoracic aorta and the main PA. Pathophysiologically, this results in L → R shunting and augmented pulmonary blood flow, which, if left untreated, may lead to pulmonary HTN and CHF. A relatively common congenital heart anomaly, constituting 12–15% of CHDs, PDA was first successfully ligated by Gross in 1938. Early administration o indomethacin may promote ductal closure in many premature infants, obviating surgical intervention; however, this mode of therapy generally is contraindicated in the setting of renal insufficiency or intracranial bleeding.

Surgical ductal closure is indicated for significant L → R shunting and can often be performed in the NICU in neonates but in the OR for infants and children. The ductu usually can be exposed via a small, left, posterolateral thoracotomy in the 4th intercostal space or via the thoracoscopic approach. The ductus is identified and dissected with special care taken to avoid injury to the phrenic and left recurrent laryngeal nerves (Fig. 12.4-4). The ductus is interrupted with a surgical clip in neonates; in older children, the ductus is double- or triple-ligated or divided between vascular clamps, and the ends are oversewn. A small thoracostomy tube is placed, and the thoracotomy is closed. The thoracostomy tube is removed in the OR immediately after the chest is closed or a few hours later.

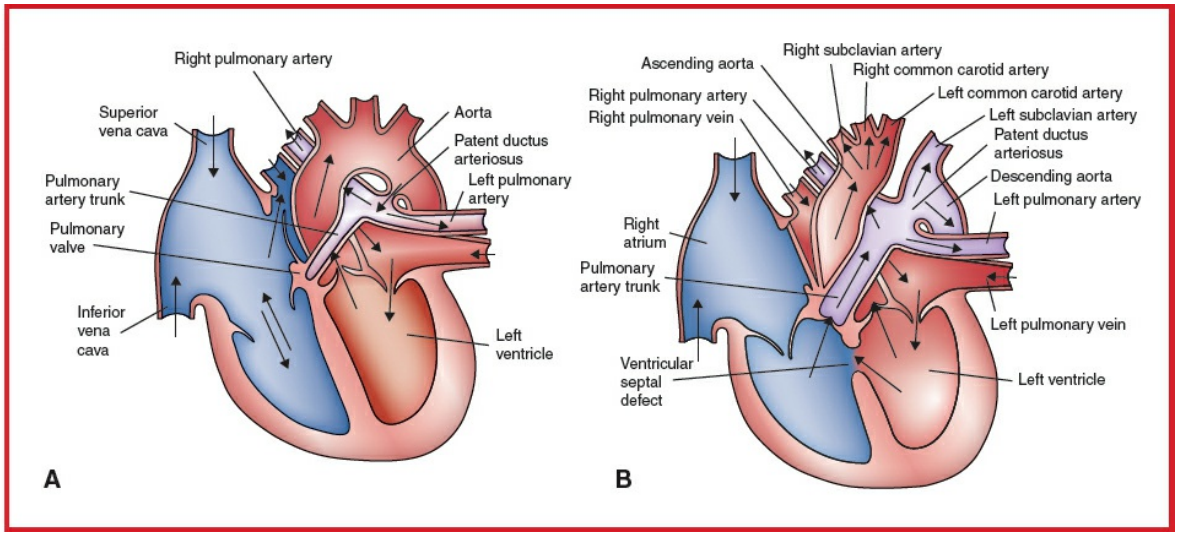

Figure 12.4-4 PDA. **A:** Ductal dependency for pulmonary blood flow in pulmonary valvular atresia. The ductus arteriosus must be open for blood to enter the pulmonary arteries; as the ductus arteriosus closes, pulmonary blood flow is lost, and the patient becomes cyanotic. **B:** Dependence on the ductus arteriosus for perfusion of the distal aorta is shown in a patient with interrupted aortic arch. Left ventricular blood (oxygenated) is able to cross the VSD and enter the PA, where it mixes with right ventricular blood. The flow is then distributed to the branch PAs and across the ductus arteriosus to the descending aorta. (Reproduced with permission from Ungerleider RM, Plunkett MD, Gaynor JW: Congenital heart disease. In: Oldham KT, Colombani PM, Foglia RP, edsSurgery of Infants and Children. Lippincott-Raven, Philadelphia: 1997.)

Variant procedure or approaches

Percutaneous coil embolization and **thoracoscopic clip ligation** are standard alternative approaches.

Usual preop diagnosis

PDA

ERAS: Family preop counseling/education by the surgeon and anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, postop pair management options, DVT prophylaxis, physiotherapy plan, and possibility of NG/ches tubes and urinary drain postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Right lateral decubitus (in case of right-sided PDA with right aortic arch, left lateral decubitus)
Incision	Small left posterolateral thoracotomy; 3rd or 4th intercostal space
Antibiotics	Cefazolin 25 mg/kg q4h

Surgical time	30–60 min
Closing considerations	Routine closure ± left thoracostomy tube
EBL	Minimal
Postop care	24-h observation in ICU; extubation in the OR or within several h
Mortality	Rare
Morbidity	Hemorrhage Recurrent laryngeal nerve injury Chylothorax
Pain score	6–8

PATIENT POPULATION CHARACTERISTICS	
Age range	1 mo–adulthood
Male:Female	1:2
Incidence	12–15% of congenital heart defects
Etiology	Failure of complete ductal closure

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Closure of a PDA in the preterm infant is done at the bedside in the NICU. These patients are intubated, mechanically ventilated, and hemodynamically unstable and may require inotropic support. The premature infant requiring surgical closure of a PDA typically presents because indomethacin Rx has failed or is contraindicated. They often have primary pulmonary disease and multisystem organ problems. In these infants, the symptoms of large L → R shunt and pulmonary overcirculation → cardiac and respiratory failure and ventilator dependence. Ductal runoff causes ↓ diastolic blood pressure, thereby compromising coronary perfusion pressure and distal organ perfusion. Older patients may be eligible for endovascular closure in the cath lab, leaving a small percentage for open surgical closure in the OR. Surgical closure may be performed with video-assisted thoracoscopy (VAT) or via thoracotomy. More recently, a hybrid approach has been applied in select patients in some centers. In older asymptomatic

patients, risk of bacterial endocarditis necessitates closure.

Cardiovascular	Clinical presentation depends on the degree of L → R shunt, which is dictated by the size of the ductus, its location, the PVR/SVR ratio, and any additional congenital cardiac abnormalities. An infant with a large ductus can present with CHF due to pulmonary overcirculation as well as with tachypnea, tachycardia, diaphoresis, failure to thrive (FTT), and hepatosplenomegaly. A continuous systolic murmur heard best at the left upper sternal border and widened pulse pressure with bounding pulses may be present. **Tests:** CXR: Normal or cardiomegaly with ↑ PA size and ↑ pulmonary vascular markings. EKG: Normal or LVH/RVH. Echo: documents patency, evaluates left-sided cardiac chamber sizes and aortic arch anatomy, and estimates size of shunt.
Laboratory	Hct; others as indicated from H&P
Premedication	Not indicated in premature infants. Midazolam 0.5–0.7 mg/kg po 20 min prior to induction for children >9 mo having routine PDA closure
ERAS	Check compliance with presurgical ERAS recommendations including NPO status. Evaluate for concurrent disease, and optimize nutritional status and hydration.

INTRAOPERATIVE

Anesthetic technique

Most children presenting for elective closure of PDA via thoracotomy are candidates for a thoracic epidural, or, in patients <10 kg, a caudal catheter can be threaded up to a thoracic level 8–10. If a neuraxial block is contraindicated or not desired, subcostal, ESP, or paravertebral blocks are reasonable alternatives for postop analgesia. In patients undergoing thoracoscopic closure, an epidural is not required. The ETT may be left above the carina, although in small patients, simple retraction of the left lung may be insufficient to expose the surgical site. If needed and tolerated by the patient, the ETT

can be briefly advanced to the R mainstem bronchus to allow better surgical visualization. In patients >25 kg, single-lung ventilation via DLT or mainstem intubation for selective ventilation of the right lung may be necessary to improve surgical access. In general, these patients are candidates for early extubation in the OR (see fast-track ir ASD).

Induction	At the bedside of the preterm infant, anesthesia can be provided with ketamine (1–2 mg/kg) or fentanyl (1–5 mcg/kg) and muscle relaxant (e.g., rocuronium 1 mg/kg iv). Small doses of fentanyl (2–5 mcg/kg) may be given for supplemental analgesia. During lateral decubitus positioning, careful attention to the airway and close monitoring of BP are necessary. Children presenting in the OR for elective operation tolerate an inhalation induction with sevoflurane in 50% N_2O + O_2. Once the patient is anesthetized, iv access is established, followed by oral intubation, with administration of a muscle relaxant (e.g., rocuronium 1 mg/kg).
ERAS	Verify preincision antibiotics.
Maintenance	In patients for whom immediate postop extubation is planned, anesthesia is maintained with isoflurane/sevoflurane in air + O_2 ± remifentanil (0.1–0.4 mcg/kg/min). Surgical retraction of the left lung, specifically if a VATS is performed, may require ↑ FiO_2 to prevent hypoxemia. Prior to lung isolation, hyperoxia and hypocarbia should be avoided to limit degree of L → R shunting.
ERAS	Discuss with surgeon local wound infiltration at conclusion of procedure. Consider iv acetaminophen (10 mg/kg).
Emergence	Older patients with an isolated PDA and no PVOD may be candidates for fast-tracking and may be extubated awake in the OR. In these cases, and if a thoracotomy has been performed, an effective regional anesthetic is particularly helpful for fast-tracking.

Epidural	Thoracic level T8-T10 preferred. For neonates <10 kg, a caudal catheter can be advanced to thoracic levels. Correct tip location should be verified either via US/Doppler or fluoroscopy. Then, an initial bolus of bupivacaine (0.25%) or ropivacaine (0.2%) at 0.3–0.5 mL/kg with either hydromorphone (5–10 mcg/kg) ± clonidine (0.5–1 mcg/kg) is administered (max 20 mL, in intermittent doses titrated to hemodynamic tolerance). Subsequently, bupivacaine or ropivacaine may either be infused or bolused at a rate of 0.2–0.4 mg/kg/h depending on the patient's age. ✓ coagulation parameters prior to placing epidural/caudal catheter.	
Blood and fluid requirements	IV: 22–24 × 1–2 Continue iv dextrose. Blood warmer	Usually, blood loss is minimal but may become significant if the ductus is torn during ligation.
	T&C ✓ for air bubbles	Have blood available for rapid transfusion. Clear air bubbles from iv tubing and stopcocks (potential bidirectional shunt → paradoxical embolism).
Monitoring	Standard monitors. ± Arterial line ± CVP line	Both blood pressure monitoring and pulse oximetry should be applied to the upper extremity, preferably the right arm (preductal) as well as the lower extremity (postductal) to detect inadvertent aortic ligation: ↓ LE pulses/pressure/perfusion. Inadvertent PA occlusion: ↓ SpO_2 + ↓ $ETCO_2$.
Positioning	✓ and pad pressure points	

	✓ eyes	
Complications	Occlusion of the aorta or PA Torn ductus → hemorrhage Residual PDA Creation of coarctation Lung trauma ± pneumothorax	✓ Echo

POSTOPERATIVE

Complications	Recurrent laryngeal nerve injury Vagus nerve injury	
Tests	Hct CXR	Other tests as indicated
Multimodal pain management	CVICU management may include fentanyl, midazolam, dexmedetomidine infusions, and iv acetaminophen as appropriate	

Suggested Readings

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4. Diaz LK: Anesthesia and postoperative analgesia in pediatric patients undergoing

cardiac surgery. Paediatr Drugs 2006; 8:223–33.
5. Garcia AV, Lukish J: Minimally invasive patent ductus arteriosus ligation. Clin Perinatol 2017; 44(4):763–71.
6. Reese J, Scott TA, Patrick SW: Changing patterns of patent ductus arteriosus surgical ligation in the United States. Semin Perinatol 2018; 42(4):253–61.

SURGERY FOR COARCTATION OF THE AORTA

SURGICAL CONSIDERATIONS

Description

Coarctation of the aorta is a congenital narrowing of the upper descending aorta, typically located at the juxtaductal region (Fig. 12.4-5). Coexisting intracardiac defects are not uncommon. Surgical repair of aortic coarctation, first performed by **Crafoord** in 1944, consisted of resection of the narrowed aortic segment, followed by an **end-to-end repair.** The same year, **Blalock** and **Park** proposed an alternative technique in which the left subclavian artery was divided distally and sutured into the descending thoracic aorta, creating a bypass. Subsequently, the use of an onlay prosthetic graft to widen the area of coarctation and the use of a **subclavian artery flap** were described by **Waldhausen**. The latter pose less risk of recoarctation later. **Prosthetic interposition tube graft repairs** have been described in patients with diffuse aortic hypoplasia. Patients with an associated intracardiac L → R shunt (e.g., VSD) may require concomitant VSD closure through median sternotomy or pulmonary artery banding following repair of the coarctation.

In infants, a left posterolateral thoracotomy approach is used. The lung is retracted anteriorly, and the pleurae are incised vertically over the aorta, along the left subclavian artery and the descending aorta. The aortic arch, all the arch branches, and the descending aorta are thoroughly mobilized. The PDA/ligamentum arteriosus is ligated and divided. Vascular clamps are placed across the aortic arch and the descending aorta. The aortic arch clamp also partially occludes the distal ascending aorta. The aortic isthmus is ligated. The coarctated segment and all ductal tissue from the descending aorta are excised. An aortotomy is made in the aortic arch (may extend on to the distal ascending aorta), and the descending aorta is anastomosed to the aortic arch. Rarely, if a subclavian flap angioplasty is performed, the distal left subclavian artery is ligated and opened longitudinally down into the aorta, across the coarctation, and into the descending aorta. The subclavian flap is then turned down and anastomosed to the descending aorta across the coarctated segment. Patch aortoplasty is performed by

creating a longitudinal aortotomy above and below the coarctation and by suturing a generously sized patch onto the defect. Following repair, the aortic cross-clamps are released, and hemostasis is secured. A pleural drainage tube is placed, followed by standard closure.

Variant procedure or approaches

In adults and older children (teens), **balloon dilatation with stent placement** in the cath lab is an acceptable alternative.

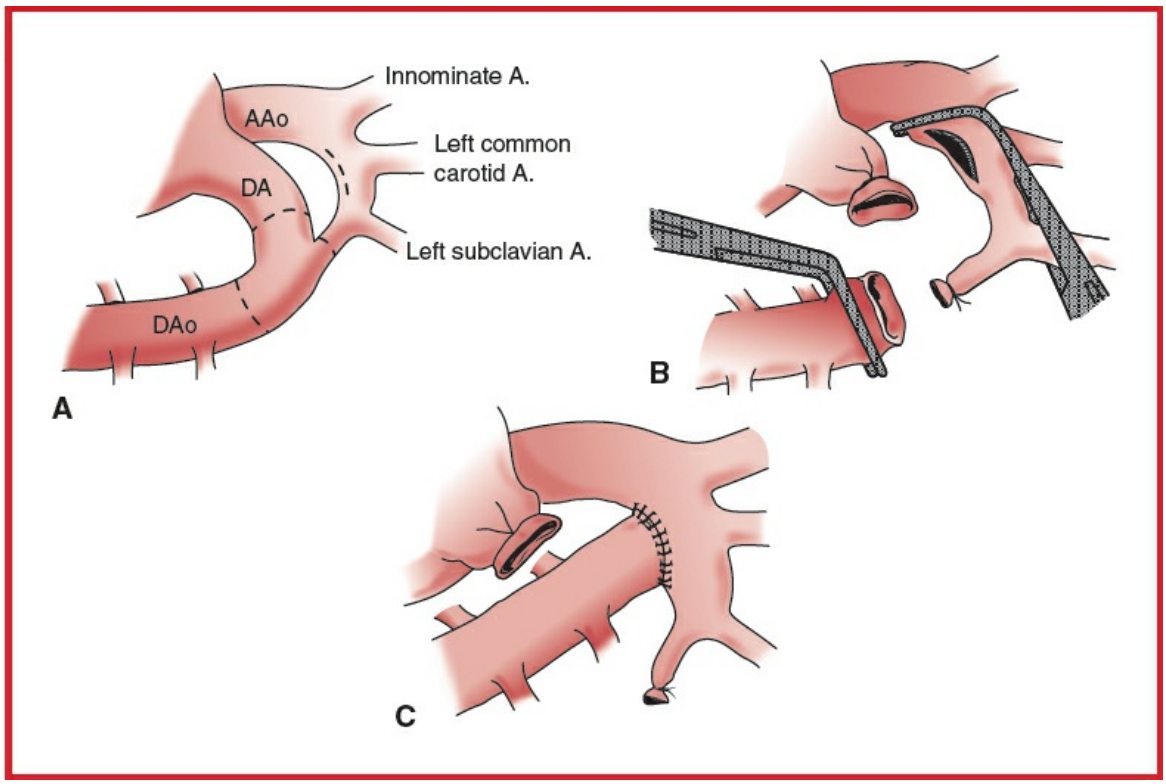


Figure 12.4-5 (Redrawn from Younoszai AK, Reddy VM, Hanley FL, et al: Intermediate term follow-up of the end-to-side aortic anastomosis for coarctation of the aorta. Ann Thorac Surg 2002; 74(5):1631–4 Copyright © 2002 The Society of Thoracic Surgeons. With permission.)

Usual preop diagnosis

Coarctation of the aorta

ERAS: Family preop counseling/education by the surgeon and anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, postop pair management options, DVT prophylaxis, physiotherapy plan, and possibility of NG/ches tubes and urinary drain postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Infant	Child or Adult
Position	Right lateral decubitus	⇐
Incision	Posterolateral left thoracotomy, 3rd–4th interspace	⇐
Unique considerations	Right upper limb arterial line. Avoid iv or arterial lines in the left arm. Mild hypothermia and surface cooling (35°C).	Collateral circulation is adequate if distal aortic MAP > 50 mm Hg. In rare cases of inadequate collateral circulation, left atrial-to-descending aorta or femoral bypass should be considered. Mild hypothermia of 35°C may be useful for spinal cord protection.
Antibiotics	Cefazolin 25–30 mg/kg q4h	⇐
Surgical time	Aortic cross-clamp: 12–20 min Total: 1–1.5 h	Aortic cross-clamp: 10–15 min Total: 2–2.5 h
Closing considerations	Thoracostomy tube	⇐
EBL	Minimal	1–2 mL/kg
Postop care	Early extubation in ICU; consider intercostal nerve block or epidural analgesia; careful control of MAP may require SNP, nicardipine, or esmolol infusion.	⇐ Tachyphylaxis has been observed with the use of SNP due to its β_2-effects on the renal vasculature.
Mortality	<1%	⇐
Morbidity	Chylothorax	⇐
	Bleeding	⇐

	Infection Paraplegia	⇐ <0.5%, though less of a risk than previously thought; some would avoid the use of epidural anesthesia or consider the use of SSEPs.
Pain score	8–10	8–10

PATIENT POPULATION CHARACTERISTICS

	Infant	Child or Adult
Age range	1 wk–1 yr	1 yr–adult
Male:Female	2:1; 1:1 for coarctations with associated defects	⇐
Incidence	5–8% of congenital heart defects	5% of congenital heart defects
Etiology	Unknown. Ductal sling may be the single most contributory factor.	⇐
Associated conditions	PDA (50%); VSD (36%); congenital mitral stenosis (7%); single ventricle (7%); TGA/VSD (7%)	Usually an isolated defect. When repaired at a later age, bicuspid aortic valve

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Pathophysiology	Coarctation is a narrowing of the aortic arch, most commonly occurring at the junction of the ductus arteriosus (juxtaductal) and distal to the left subclavian artery. The clinical presentation of the neonate or infant with coarctation depends on (a) location and degree of obstruction, (b) rate at which high-grade stenosis developed thereby affecting the

	degree of collateralization to the distal aorta, (c) patency of the ductus, (d) PVR, and (e) associated cardiac anomalies. It has been hypothesized that coarctation develops in the setting of reduced anterograde flow in the aorta, thereby providing a possible explanation why this anatomic pathology is found in the setting of left-obstructive lesions (MS, AS, HLHS, aortic arch hypoplasia) but virtually never along with right-obstructive lesions. Neonates with critical stenosis will demonstrate ductal-dependent aortic flow (R → L shunt) resulting in differential cyanosis. With the PVR initially being high and systemic RV pressure being low, LE pulses may be palpable, obscuring the diagnosis. In these patients, closure of the duct over the ensuing 4–10 d of life will result in near loss of distal perfusion leading to acidemia, gut ischemia, and cold lower extremities. If there is an associated ASD/VSD, the acute increase in LV afterload will further enhance L → R shunting and divert blood from the distal aorta. These neonates may present in shock and require prompt resuscitation and surgery. Patients with mild-to-moderate stenosis, and no associated abnormalities will be asymptomatic with upper extremity HTN and diminished lower extremity pulses.
Respiratory	**Tests:** CXR (cardiomegaly, characteristic aorta, PE)
Cardiovascular	**Neonates:** Neonates present with "critical" coarctation and are ductal-dependent. If the ductus is closing, PGE_1 administration to reopen the ductus —or to at least relax juxtaductal tissue—can be lifesaving. PGE_1 treatment may also allow time for echo assessment of associated lesions. **Infants:** Present with upper extremity hypertension and murmur. Imaging studies such as MRI or CT scan may be needed to confirm diagnosis if gradient is not well detected by echo. Four extremity blood

	pressures have been used in early detection. **Older children:** Often present with upper extremity HTN, HA, and diminished or absent femoral pulses. The indication for operation is similar to that of infants. Systemic HTN and LVH may not resolve following repair. **Tests:** Four extremity blood pressures have been used in early detection. Echo; ECG; ABG; CXR—rib notching 2° collateral vessels. (This is a late finding.) Recently, cardiac MRI or CT angio of the chest are used to confirm coarctation and other associated anomalies.
Renal	**Tests:** BUN; Cr; electrolytes
CNS	PGE_1 is associated with apnea in the newborn. Generally, the neonate is intubated once the prostaglandin infusion is started.
Laboratory	Hct; T&C
Premedication	Not appropriate in severely ill infants. Otherwise, for patients >9 mo, midazolam 0.5–0.7 mg/kg po (maximum of 20 mg). For children >25 kg, lorazepam 1–2 mg po 2 h before surgery
ERAS	Check compliance with presurgical ERAS recommendations including NPO status. Evaluate for concurrent disease, and optimize nutritional status and hydration.

INTRAOPERATIVE

Anesthetic technique

GETA: For the neonate, fast-tracking is not appropriate.

Induction	In neonates, an iv induction with fentanyl (2–5 mcg/kg) and rocuronium (0.6–1 mg/kg) is appropriate to achieve stable hemodynamic conditions. Maintain HR, preload, and contractility to maintain cardiac output. Avoid ↓ SVR and myocardial

	depression, as well as ↑ SVR, as the latter may further reduce LV cardiac output. In older patients, with only proximal systemic HTN, iv induction or inhalation induction (sevoflurane and O_2) is usually well tolerated. In most neonates, infants, and children, single-lumen ETT is sufficient. In some children, selective ventilation of the right lung with right mainstem intubation or a DLT will facilitate surgery.
ERAS	Verify preincision antibiotics.
Maintenance	An opioid technique (10–20 mcg/kg fentanyl ± volatile agent) is appropriate for critically ill neonates. Consider mild hypothermia (34°C–35°C) for CNS protection. The operation usually is via a left thoracotomy. The aortic arch, isthmus, and descending aorta are then mobilized. 100 U/kg of heparin may be given. The ductus arteriosus is ligated, and the aortic arch and descending aorta are occluded. The anesthesiologist should observe the arterial line trace closely during proximal occlusion and immediately inform the surgeon of any damping and check BP/SaO_2 in UE (right arm) and LE. If early postop extubation is planned, see fast-tracking. In neonates with critical stenosis, continuation of a PGE_1 infusion until CPB has been established may be necessary to avoid cardiovascular collapse. However, CBP is rarely used and only in extreme circumstances.
Emergence	Older infants and children, without coexisting disease, undergoing elective operation can usually be extubated in the OR. In young infants, SBP consistently >120 mm Hg should be treated, and an esmolol, nicardipine, and/or SNP infusion may need to be started in the OR. Consider propofol infusion when delayed extubation has been planned. In neonates or infants with compromised cardiac function, extubation should be delayed until their

	clinical status has improved. Dopamine or milrinone may be required. A chest tube is left in place to monitor blood loss or the appearance of a chylous effusion.	
Blood and fluid requirements	IV: appropriate for patient size × 1–2 LR @ TKO (D5 LR in neonates) Blood warmer T&C 1–2 U	As a rule, infants and children undergoing coarctation repair will not require transfusion. Infrequently, however, sudden and substantial blood loss can occur, necessitating rapid transfusion. Adequate iv access and immediate availability of blood are essential in this operation.
Monitoring	Standard monitors	
	RUE arterial line ± CVP	BP must be monitored above and below the level of coarctation. A right radial arterial line allows BP monitoring during occlusion of the aortic arch. If a percutaneous radial arterial line cannot be placed, a surgical cutdown can be performed. Alternatively, a right axillary arterial line or a direct proximal arch arterial line can be placed instead.
	BP cuffs × 2 (UE + LE)	Both upper and lower extremity cuff pressures should be monitored. A noninvasive BP below the level of the coarctation is useful to confirm postrepair equalization of upper and lower extremity BP.
	Temperature	Monitor rectal temperature

	NIRS	and maintain it below 35°C. Both cerebral and somatic sensor placement ✓ ABG, glucose, and Hct at intervals
Control of BP	Anesthetic depth	In neonates and infants, GA is usually sufficient to control BP during aortic cross-clamp; however, SNP may be necessary to control BP in some patients. Caution should be exercised to avoid ↓ ↓ BP, because ↓ aortic pressure and ↑ CSF pressure will impair spinal cord perfusion.
Aortic cross-clamping	± Heparin 100 U/kg Ductus arteriosus ligated Aorta cross-clamped × 2 ✓ arterial line for damping. Ischemia time = 10–20 min Maintain distal perfusion. Lactic acidosis → ↓ SVR + ↓BP.	Aortic cross-clamping presents an acute afterload to the LV. In preparation for release of cross-clamp, decrease or eliminate volatile anesthetic. Be prepared for volume resuscitation (blood, colloid, crystalloid) and hyperventilation. $NaHCO_3$ is frequently required (1–2 mEq/kg). ✓ ABG and treat accordingly. Cross-clamp times >30 min have been associated with spinal cord ischemia, which poses the risk of potential paralysis.
Complications	Spinal cord ischemia HTN Bleeding Hypothermia	

	Residual coarctation

POSTOPERATIVE

Complications	Paraplegia HTN Bleeding	Incidence = 0.14–0.4%. The cause is likely 2° spinal cord ischemia.
	GI bleed Abdominal pain and ileus	Occurs infrequently. Attributable to mesenteric arteritis. Neonates are at risk for GI reperfusion injury following repair. These patients are kept NPO for 12–24 h.
	Recurrent laryngeal nerve injury Phrenic nerve injury Chylous effusion Residual or recurrent coarctation	
Tests	CXR Hct ABGs	
Multimodal pain management	Per CVICU management, may include fentanyl, midazolam infusions, dexmedetomidine, iv acetaminophen as appropriate	

Suggested Readings

1. Batlivala SP, Goldstein BH: Current transcatheter approaches for the treatment o aortic coarctation in children and adults. Interv Cardiol Clin 2019; 8(1):47–58.
2. Dijkema EJ, Leiner T, Grotenhuis HB: Diagnosis, imaging and clinical managemen of aortic coarctation. Heart 2017; 103(15):1148–55.
3. McVey MJ, Farlinger CM, Van Arsdell G, et al: Anesthesia for comple cardiovascular surgery in a patient with PHACES syndrome and review of th literature. J Cardiothorac Vasc Anesth 2017; 31(3):1042–7.
4. Roeleveld PP, Zwijsen EG: Treatment strategies for paradoxical hypertensio following surgical correction of coarctation of the aorta in children. World J Pediatr Congenit Heart Surg 2017; 8(3):321–31.

SURGERY FOR TETRALOGY OF FALLOT

SURGICAL CONSIDERATIONS

Description

In **tetralogy of Fallot (TOF)**, the RV infundibulum is maldeveloped, resulting in RV outflow tract obstruction (RVOTO), a large malalignment (with overriding aorta) VSD RVH (see Fig. 12.4-6), and, occasionally, an ASD (**pentalogy of Fallot**). TOF is the most common cyanotic congenital cardiac defect. Pathophysiologically, RVOTO leads to significant R → L shunting across a nonrestrictive VSD, which, in turn, leads to inadequate pulmonary blood flow and varying degrees of cyanosis. The variation in presentation depends primarily on the severity and type of RVOTO.

Patients with TOF were first treated palliatively beginning in 1944, with the introduction of the **Blalock-Taussig** (B-T) **systemic-to-pulmonary artery shunt**. This procedure augments pulmonary blood flow and, hence, systemic oxygenation. Currently, however, most cases of TOF are treated routinely with early complete correction between 3 and 12 mo of age. Neonatal repair is performed in infants who are severely cyanotic (SaO_2 < 80%), have ductal-dependent pulmonary blood flow, or have cyanotic spells. Initial palliation with the B-T procedure is now reserved for patients with severe pulmonary arterial hypoplasia and (by some surgeons) for an anomalous left anterior descending coronary artery originating from the right coronary artery.

Surgical correction is performed through a standard median sternotomy on standard CPB with moderate hypothermia. During cooling, the modified B-T shunt, if present, is ligated and divided, followed by aortic cross-clamping, cardioplegic arrest, and topical cooling. The pulmonary valve and RVOT are accessed through a longitudinal pulmonary arteriotomy and the tricuspid valve (via a right atriotomy), respectively. RVOTO is treated as necessary by infundibular muscle resection, pulmonary valvotomy or valvectomy, and patch augmentation of the main PA or its branches. Autologous pericardium, Gore-Tex®, or other type of synthetic/biologic material may be used for patch widening of the RVOT at any level, from the RV to the PAs. The primary goal in relieving the RVOTO is to save the pulmonary valve, avoid a transcannular patch, and minimize pulmonary valve insufficiency. The VSD, accessed through the tricuspid valve, is closed with a patch (pericardium/Dacron™) in the standard fashion with care being taken to avoid injury to the bundle of His.

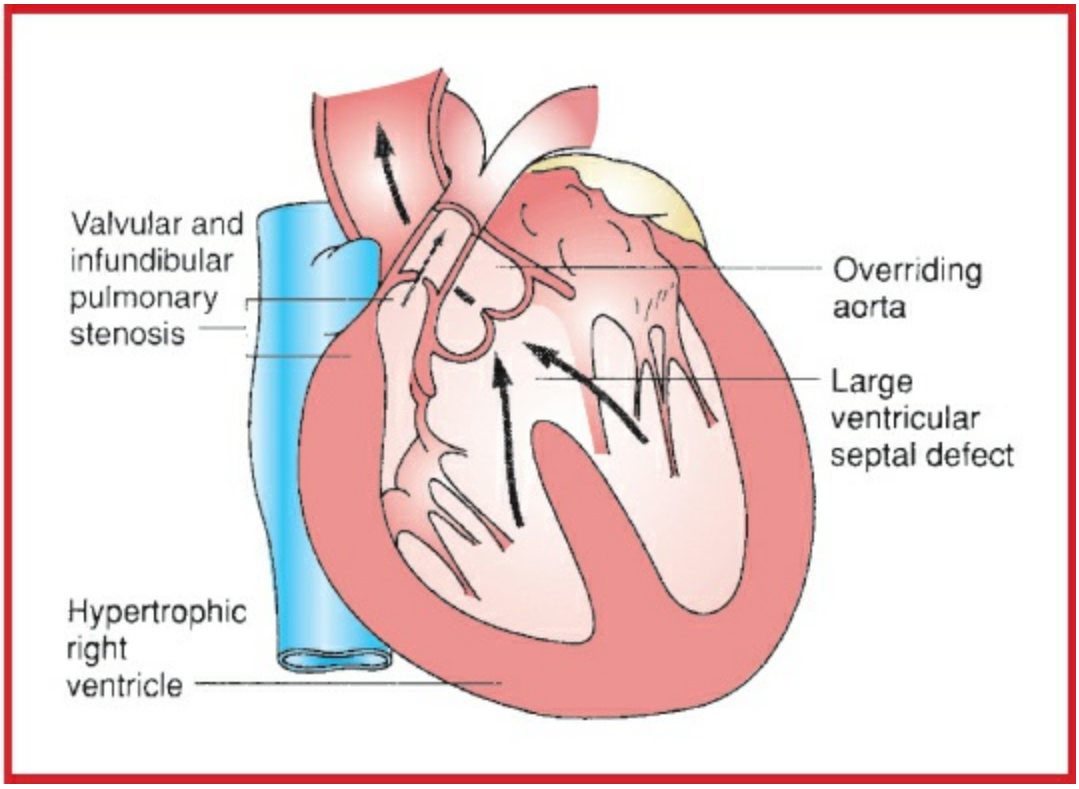


Figure 12.4-6 Anatomic features of tetralogy of Fallot. The primary morphologic abnormality, anterior and superior displacement of the infundibular septum, results in malalignment VSD, overriding the aortic valve and obstructing RV outflow. RV hypertrophy is a secondary occurrence. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al., eds.Surgery: Scientific Principles and Practice, 2nd edition. Lippincott-Raven Publishers, Philadelphia: 1997.)

Variant procedure or approaches

In patients with severe hypoplasia or atresia of the RVOT, or in patients with an anomalous origin of the LAD coronary artery from the right coronary artery, a **Rastelli procedure** is performed. This operation consists of patch closure of the VSD and reconstruction of the RVOT in which a conduit, in the form of a cryopreserved homograft or valved prosthesis, is placed between the RV and the PA.

Usual preop diagnosis

TOF; cyanotic CHD; severe cyanotic spells; failure to thrive (FTT)

ERAS: Family preop counseling/education by the surgeon and anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, postop pain management options, DVT prophylaxis, physiotherapy plan, and possibility of NG/chest tubes and urinary drain postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Neonate Repair	Infant and Adult Repair with Standard CPB
Position	Supine	⇐
Incision	Standard median sternotomy	⇐
Unique considerations	R → L shunt → systemic embolization	⇐
Antibiotics	Cefazolin 25–30 mg/kg q4h	⇐
Surgical time	Aortic cross-clamp: 30–60 min CPB: 90–120 min Total: 3–4 h	30–50 min 75–100 min 3–4 h
Closing considerations	Chest tube in pericardial (and possibly pleural) space, if opened; temporary ventricular pacing wires; routine right and left atrial lines for monitoring	⇐
EBL	Moderate	⇐
Postop care	ICU × 2–3 d. 1- to 3-d assisted ventilation; inotropes for RV dysfunction	ICU for 1–2 d
Mortality	~2%	⇐
Morbidity	Junctional tachycardia Atrial dysrhythmias Hemorrhage Infection Low CO Stroke Heart block Residual VSD	⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐

	Transient, right-sided CHF	⇐
Pain score	8–10	8–10

PATIENT POPULATION CHARACTERISTICS

Age range	Neonate–adult (usually <6 mo)
Male:Female	3:2
Incidence	10% of congenital cardiac defects
Etiology	22q11 microdeletion is seen in some patients, who also may have DiGeorge syndrome; higher than expected prevalence with older maternal age at the time of conception of affected children.
Associated conditions	A-V canal; PDA; previous systemic-to-pulmonary arterial shunt; anomalous left coronary artery from pulmonary artery (ALCAPA); metabolic acidosis (profound hypoxia); right-sided aortic arch

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Pathophysiology	TOF is the most common form of cyanotic heart disease. Its clinical presentation can vary greatly (e.g., signs of CHF, "pink TETs," profound cyanosis) reflecting its wide anatomic variations. The critical factor is the degree of RVOTO, which determines the amount of R → L shunting across the VSD. In TOF, the RVOTO usually has fixed and dynamic components. The latter can be related to RV infundibular spasm and variations in pH, $PaCO_2$, and PaO_2. The onset of hypercyanotic episodes in an infant <3 mo of age is an indication for complete surgical repair.
"TET" spells	Hypercyanotic episodes or "TET" spells: These constitute medical and surgical emergencies;

	however, they are seen less frequently due to early surgical intervention. TET spells may present in early infancy and are related to infundibular spasm resulting in ↑ R → L shunting. If untreated, these episodes can progress to unconsciousness, Sz, and death. For management of TET spells, see Table 12.4-1.
Respiratory	Infectious/asthmatic pulmonary processes will complicate preop and postop cardiopulmonary function. Optimize pulmonary function preop. **Tests:** CXR: ↓ pulmonary vascular markings
Cardiovascular	Although not typical for TOF, patients may present with CHF if left unrepaired and if there is only minimal RVOTO. An understanding of the patient's anatomic defects and their pathophysiology (e.g., is their RVOTO fixed or dynamic?) is essential for formulating the anesthetic plan. Avoid prolonged fasting to prevent profound decreases in preload on induction. **Tests:** ABG; ECG: ✓ for RVH, right axis deviation (RAD) ± complete or incomplete RBBB. CXR: ✓ heart size, "coeur en sabot" (elevation of apex 2° RVH, RAE). Cardiac cath and echo: Locate the site of pulmonary outflow obstruction, VSD, bronchopulmonary collaterals, PDA, abnormal patency of previous surgical shunts (e.g., B-T shunt). Define aortic arch anatomy, abnormal coronary or subclavian arteries, tricuspid regurgitation/aortic insufficiency (TR/AI), and ventricular function.
Hematologic	Polycythemia (typical with chronic O_2 sat <90%) produces ↑ blood viscosity and thromboembolic events. Polycythemia may also ↓ Plt + coagulopathy. Extreme polycythemia (>70 Hct) may require isovolemic hemodilution intraop. **Tests:** CBC; Plt; bleeding time; coag profile
Laboratory	Electrolytes if on diuretics; otherwise, tests as

Premedication	indicated from H&P Desirable to ↓ anxiety, avoid TET spells and facilitate separation from parents. Midazolam 0.5–1.0 mg/kg po 20 min before induction in a monitored setting.
ERAS	Check compliance with presurgical ERAS recommendations including NPO status. Evaluate for concurrent disease, and optimize nutritional status and hydration.

Table 12.4-1 Treatment for TET Spells

Treatment Modalities	Effect
1. Knee-chest position	↑ SVR
2. Abdominal compression	Simulates squatting. ↑ SVR, ↑ preload, opens RVOT
3. Volume administration	↑ preload, opens RVOT
4. O_2	Pulmonary vasodilator
5. Sodium bicarbonate	Correction of metabolic acidosis, normalizes SVR (1–2 mEq/kg)
6. Analgesia and sedation	Negative inotropy → reduced RVOT spasm. Morphine sulfate 0.05–0.1 mg/kg iv
7. Alpha-agonist (phenylephrine)	↑ SVR. Dose: 10 mcg/kg bolus and repeat. 2–5 mcg/kg/min (may not be effective in cases of severe RVOT)
8. Beta-blockers (esmolol)	Negative inotropy. Dose: 50 mcg/kg bolus. 50–300 mcg/kg/min infusion

INTRAOPERATIVE

Anesthetic technique

GETA: Patients with TOF, pulmonary atresia, and MAPCAs (major aortopulmonary collateral arteries) requiring unifocalization present a challenge for surgical and anesthetic management. Placement of a cuffed ET is necessary. Bronchial bleeding 2°

extensive surgical dissection requires frequent ETT suctioning. A significant portion of the procedure is done off-CPB, and hemodynamic instability with ST segment changes may occur during surgical dissection. Closely monitor blood loss and replace mL/mL with PRBCs. Avoid air bubbles in iv tubing/stopcocks. In older patients presenting for conduit change or revisions, massive blood loss should be anticipated.

Induction	Typically mask induction with sevoflurane, O_2 ± air. If iv in place, ketamine (1–2 mg/kg) and/or fentanyl (10 mcg/kg) with rocuronium (1 mg/kg) ± volatile agent. Avoid ↓ ↓ SVR. Aggressive volume expansion (10–15 mL/kg; 5% albumin) may be necessary. Verify ETT position. Oxygen supplementation is used judiciously as one must consider the Qp:Qs. Collaterals offer paths of least resistance in the presence of decreased PVR with high FiO_2, and blood flow through collaterals may ↓ coronary and systemic perfusion. Most of these patients present with a balanced Qp:Qs, while 25% have a QP:QS < 1.0 and may benefit from oxygen supplementation.
ERAS	Verify preincision antibiotics.
Maintenance	For patients not undergoing unifocalization (subset diagnosed with TET/PA/MAPCA), anesthesia is maintained with isoflurane or sevoflurane. Maintain preload, heart rate, and contractility and aggressively treat hypercyanosis. TET spells may occur due to surgical manipulation, especially during surgical dissection for cannulation before CPB. In that case, the surgeon can provide direct aortic compression or urgently proceed to CPB. Refer to Table 12.4-1 for treatment. For patients who are undergoing unifocalization, no anesthetic technique has so far been shown to be superior to another. TIVA techniques are preferred to preserve blood pressure (avoid diastolic runoff from MAPCAs) and maintain CO. Antifibrinolytics, such as TXA (bolus 30 mg/kg after induction, followed by 30 mg/kg by perfusionist and an infusion at 16 mg/kg/h), are

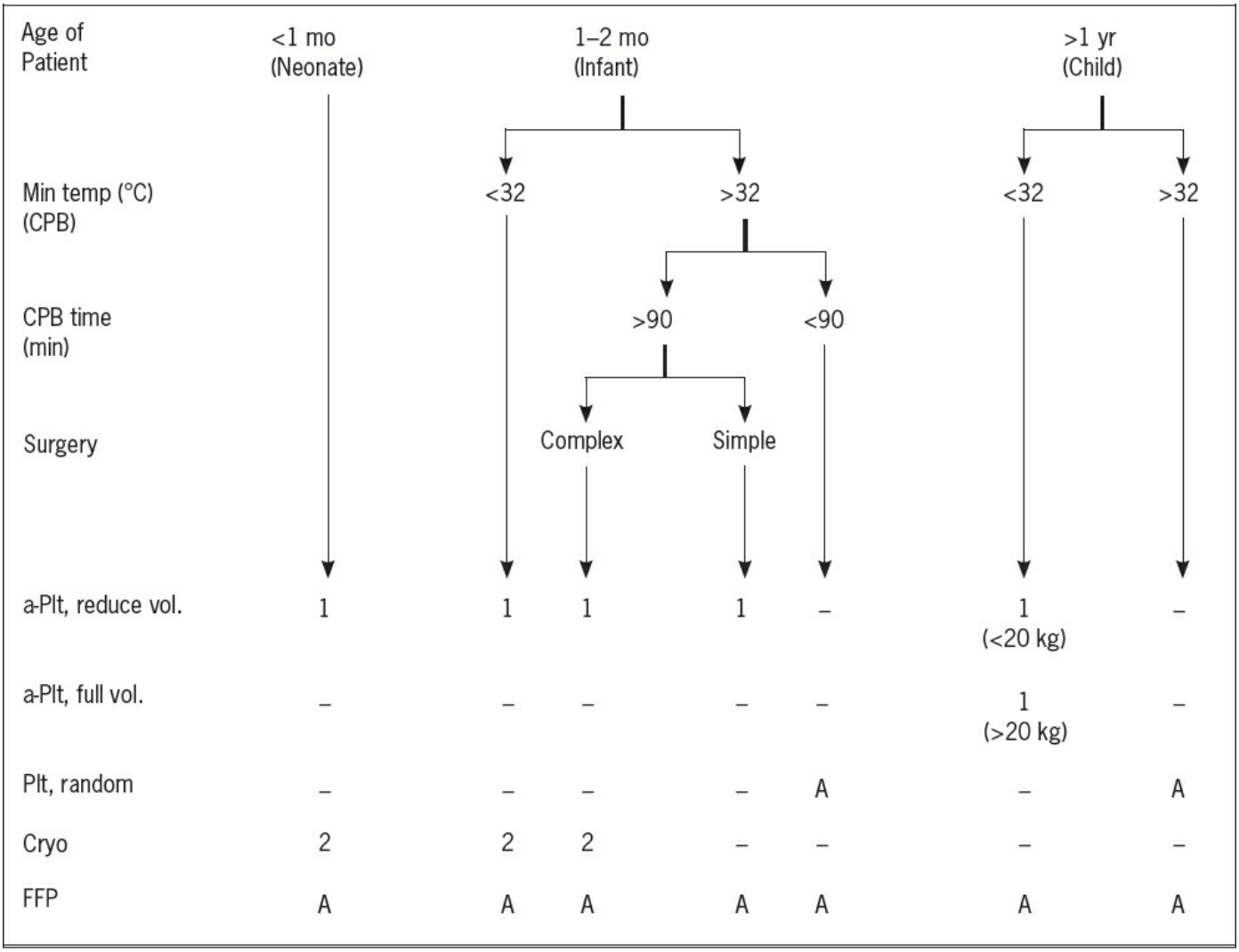
	given to all patients to reduce blood loss.	
Emergence	Patients are transported to ICU monitored, intubated, and ventilated.	
Blood and fluid requirements	IV: 22 or 24 ga as approp × 2 LR @ TKO T&C PRBC	Blood in OR before incision. For all repeat sternotomy patients, have blood available for immediate administration. Have massive transfusion system setup for older patients. FEIBA has been used to reduce post–bypass blood transfusion in an effort to minimize TRALI.
Monitoring	Standard monitors Urinary catheter Arterial line (usually radial)	Because of the length of MAPCA procedures, some prefer a femoral arterial line, as the radial A-line may dampen. However, a temporary aortic line, removed before chest closure in the OR, allows for monitoring until the radial A-line recovers. MAPCA patients require repeated catheterization for follow-up; thus, preserving the femoral vessels argues against a femoral A-line.
	CVP line	Double-lumen CVP is placed in IJ or femoral vein.
	TEE Transthoracic LA and PA line: have transducers available.	During MAPCA dissection and RVOT change with beating heart close monitoring of TEE for function and air.
Pre-CPB	Heparinization (4 mg/kg) ACT > 400 sec	In the pre-CPB period, crystalloid and/or 5% albumin is administered as

	MAP ~70 mm Hg ✓ muscle relaxation. ✓ pupils. ✓ UO.	needed to compensate for bleeding and 3rd-space losses.
CPB	Ventilation stopped Hypothermia: ~28°C–32°C Hct 30 typical during CPB ✓ adequate flow/pressure. ✓ anesthetic/NMB levels. ✓ pupils. ✓ face for venous congestion. ✓ ABG, electrolytes, UO, Hct, and ACT q30min.	Furosemide (0.5–1 mg/kg) for ↓ UO and hemoconcentration. A flow study during CPB is used for complete TOF/MAPCA repair (VSD closure and unifocalization). During the study, a separate circuit provides increasing flow with measurement of left- and right- sided pressures. If the right side remains low, the VSD is closed with a patch, thus a complete repair. During this period, ventilation with low PIP is used in order to avoid significant fluctuations in pressure measurements.
Transition off CPB	Rewarming Vasoactive infusions started at 32°C. Flush lines. TEE Zero transducers Suction ETT. Resume ventilation. Observe lung inflation. Supplement NMB and deepen anesthesia.	Surgeons de-air the heart, which can be monitored by TEE. A measurement of the RV and LV pressure ratio helps to judge adequacy of repair of the RVOTO. TEE also is used to evaluate the anatomy, the repair, and pressures.
	Rewarm to 36°C. ✓ bilateral breath sounds ✓ ABGs, electrolytes,	Infants are at risk for development of junctional ectopic tachycardia (JET). Avoid excessive warming

	and Hct (~40) ✓ ACT (>400) ✓ ECG: pacing may be necessary.	>37°C. Have amiodarone available (5–10 mg/kg load) given in 1 mg/kg aliquots, followed by 5–10 mcg/kg/min infusion. Dexmedetomidine gtt is often used for these procedures as it allows for postop sedation while offering some control of HR.
Post-CPB	Inotropic support (dopamine, milrinone, epinephrine, and $CaCl_2$) Rx pulmonary HTN (↓ PVR): FiO_2 = 1 $PaCO_2$ ~35 Early use of inhaled NO (40 ppm)	✓ RV compliance is expected. RV afterload reduction is essential, initially through ventilatory efforts: clear unobstructed ventilation; do not allow wheezing (albuterol pm); use gentle hyperventilation on 100% O_2. Inotropic support of RV also typically is used—dopamine/initially and epinephrine reserved for severe RV dysfunction. Milrinone 0.5 mcg/kg/min and $CaCl_2$ 10–20 mg/kg/h are routine in infants.
	AV sequential pacemaker (heart block not uncommon) Transthoracic PA or LA line placed to monitor hemodynamics. Reverse anticoagulation. ✓ Echo to assess for residual VSDs,	In order to minimize shear stress on the newly anastomosed vessels in TET/MAPCAs, prophylactic NO is initiated in the OR.

	residual RVOTO, and B/V function. Rx coagulopathy	See Table 12.4-2 for blood product utilization. MUF uses the CPB machine to remove excess H_2O and inflammatory mediators (↓ edema and improved cardiopulmonary function). Transport to ICU, intubated, sedated, and ventilated +/− NO.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	See Postop Complications, p. 1397.	

Table 12.4-2 Blood Product Utilization



A, available, but not in OR; a-Plt, apheresis platelets; Plt, platelets; FFP, fresh frozen plasma; Cryo, cryoprecipitate.

POSTOPERATIVE

Complications	Persistent bleeding Persistent RVOTO Dysrhythmias (JET) Residual VSDs Heart block RV dysfunction Pulmonary hemorrhage Phrenic/laryngeal nerve injury Horner syndrome Chylothorax	For neonatal repairs, a PFO may be left surgically open to allow RV decompression via a R → L intra-atrial shunt in the immediate postop period. This often will result in a ↓ systemic SaO_2. TEE will confirm the existence of interatrial shunting. This may later spontaneously close or device closure can be performed at a later time in

	Shunt thrombosis	the cath lab.
Tests	ABGs + electrolytes Coag profile CXR: ✓ line, ETT placement	Coagulation abnormalities have been demonstrated in children with cyanotic heart disease. Some centers use intraop coagulation testing (TEG, ROTEM) in select groups of patients: cyanotic disease and extensive surgical repairs.
Multimodal pain management	CVICU management iv acetaminophen as appropriate	May include fentanyl, midazolam, and/or dexmedetomidine infusions

Suggested Readings

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2. Karl TR, Stocker C: Tetralogy of Fallot and its variants. Pediatr Crit Care Med 2016; 17(8 Suppl 1):S330–6.
3. Townsley MM, Windsor J, Briston D, et al: Tetralogy of Fallot: perioperative management and analysis of outcomes. J Cardiothorac Vasc Anesth 2019; 33(2):556–65.

SURGERY FOR TOTAL ANOMALOUS PULMONARY VENOUS CONNECTION

SURGICAL CONSIDERATIONS

Description

Total anomalous pulmonary venous connection (TAPVC) is a rare congenital cardiac malformation in which the entire pulmonary venous return empties either directly into the systemic venous channels via anomalous veins or the right atrium (Fig. 12.4-7). An interatrial R → L shunt, in the form of a PFO or an ASD, is required to maintain systemic output and, hence, survival in the postnatal period. The objective of surgical correction is to redirect the entire pulmonary venous return to the left atrium.

TAPVC was first successfully repaired in 1956 by Lewis and Varco, at the University of Minnesota, by joining the pulmonary venous sinus to the left atrium and closure of the ASD. Although mortality for this lesion was initially quite high, particularly in infants with obstruction of the pulmonary veins, improvements in intraop and postop management have permitted successful correction in most neonates and infants. There are four TAPVC drainage patterns as defined by Darling et al. These include **supracardiac** (45%), **cardiac** (25%), **infradiaphragmatic** (25%), and **mixed** patterns (5%) of venous drainage. The anomalous drainage in supracardiac TAPVC is usually by a left vertical vein into the innominate vein. In cardiac TAPVC, drainage is usually into the coronary sinus and occasionally into the right atrium. In infradiaphragmatic TAPVC drainage is usually into the portal vein and may be obstructed. The mixed type consists of combinations of the other three varieties of TAPVC.

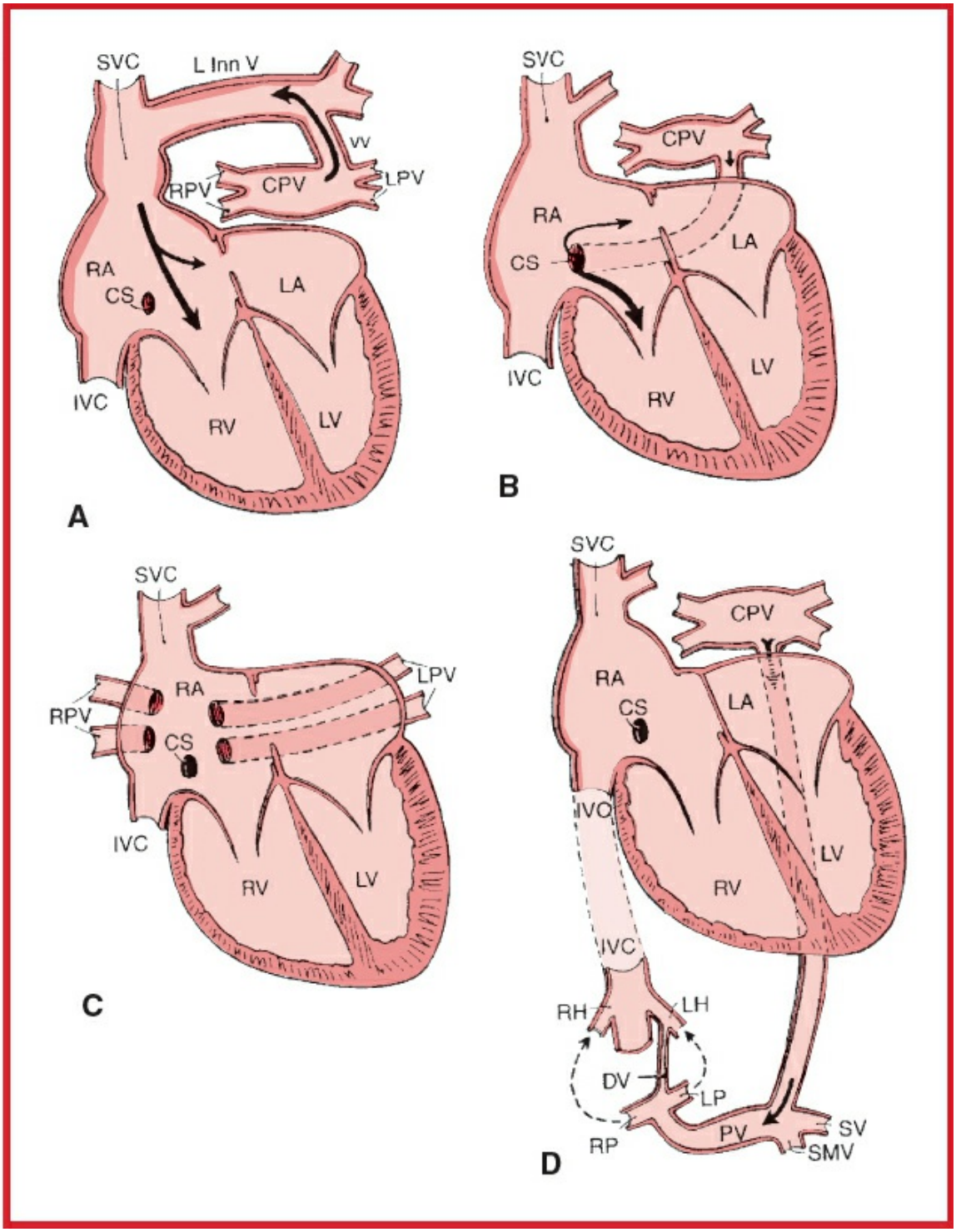

Figure 12.4-7 Common forms of TAPVC.**A:** TAPVC to the left innominate vein (L inn V) by way of a vertical vein (VV). **B:** TAPVC to coronary sinus (CS). The pulmonary veins join to form a confluence designated as the common pulmonary vein (CPV), which connects to the coronary sinus. **C:** TAPVC to right atrium (RA). The left and right pulmonary veins (LPV and RPV) usually enter the RA separately. **D:** TAPVC to the portal vein (PV). The PVs form a confluence, from which an anomalous channel arises. (Reproduced with permission from Emmanouilides GC, Allen HD, Riemenschneider TA, et al: Clinical Synopsis of Moss and Adams' Heart Disease in Infants, Children, and Adolescents Williams & Wilkins, Philadelphia: 1998.)

When pulmonary venous drainage is obstructed, patients present with cyanosis, severe pulmonary edema, pulmonary HTN, and ↓ CO. Symptomatic TAPVC is repaired at an age. Critically ill neonates with obstructed pulmonary venous return must undergo emergent correction after initial stabilization (i.e., intubation/ventilation, diuretics). Occasionally, preop ECMO may be required.

In most cases, the right and left pulmonary veins drain into a common pulmonary venous sinus, allowing for its anastomosis to the left atrium for a definitive repair. Through a standard median sternotomy, the aortic and venous cannulae are placed and CPB with cooling is initiated. The aorta is cross-clamped, immediately followed by cardioplegic arrest. The cardiac apex is lifted up, and the pulmonary veins are identified through the posterior pericardium. The left atrium is then opened transversely with extension onto the left atrial appendage, followed by the direct anastomosis of the pulmonary venous confluence to the left atrium. Finally, via a right atriotomy, the ASD or PFO is closed. The heart is de-aired, aortic cross-clamp is released, and the patient is rewarmed and separated from bypass. Successful outcomes are dependent on early and immediate correction of TAPVC with obstruction, before lung damage ensues. Other important factors include repair without residual obstruction and postop control of pulmonary HTN.

Variant procedure or approaches

Alternatively, repair of TAPVC may be accomplished through a right atriotomy and across the atrial septum, constructing the anastomosis between the pulmonary venous confluence and left atrium from within the left atrium or through a transverse sinus approach.

Usual preop diagnosis

TAPVC; total anomalous venous return; total anomalous pulmonary venous drainage—all of these ± obstruction and supracardiac, cardiac, infradiaphragmatic, or mixed types

ERAS: Time permitting, family preop counseling/education by the surgeon and anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, postop pain management options, DVT prophylaxis, physiotherapy plan, and possibility of NG/chest tubes and urinary drain postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE

Position	Supine

Incision	Standard median sternotomy
Unique considerations	Patients often require urgent or emergency surgery. Obligatory R → L shunting poses risk of systemic embolization. Myocardial preservation using blood or crystalloid cardioplegia, in addition to topical myocardial hypothermia, is used.
Antibiotics	Cefazolin 25 mg/kg q4h
Surgical time	Aortic cross-clamp: 30–60 min Circulatory arrest: occasionally, 30–45 min Total: 2–3 h
Closing considerations	A fine polyvinyl catheter inserted through the free wall of the right ventricle and advanced into the pulmonary trunk will allow monitoring for pulmonary HTN. A chest tube is inserted into the pericardial space; temporary ventricular pacing wires are placed. Left atrial lines are normally needed.
EBL	Moderate
Postop care	2–6 d of assisted ventilation, sedation, and hyperventilation; pulmonary vasodilators (NO), including isoproterenol, PGE_1, SNP; inotropes as needed for right heart dysfunction. Sometimes, if pulmonary injury is severe or pulmonary HTN is uncontrollable, ECMO may be indicated.
Mortality	2–10%, depending on presence of preop pulmonary venous obstruction and metabolic acidosis
Morbidity	Pulmonary vasospasm: 25–40% Low CO: 10% Hemorrhage: 2–3%
Pain score	8–10

PATIENT POPULATION CHARACTERISTICS

Age range	1 d–20 yr (usually <1 mo)
Male:Female	4:1 in infracardiac type; equal distribution in other

	types
Incidence	0.5–2% of congenital heart defects
Etiology	Failure of fusion of the pulmonary vein evagination (from posterior left atrium) with the pulmonary venous plexus surrounding the lung bud.
Associated conditions	PDA present in nearly all infants, within the first few weeks of life, and in about 15% of cases overall. VSD occasionally occurs (may be associated with TOF, DORV, interrupted aortic arch, and other lesions).

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Pathophysiology	In the most common form (supracardiac type), all the pulmonary venous return drains into the right atrium via a vertical vein → innominate vein → SVC. When this vein or the pulmonary confluence is stenotic or obstructed, severe pulmonary venous HTN, cyanosis, pulmonary edema, systemic/suprasystemic RV/PA pressure, and shock ensue. This is a true surgical emergency, requiring immediate intervention. Delivery of all pulmonary venous blood to the RA results in a large L → R shunt. There is total mixing of the blood in the RA, and as a result an ASD or PFO is essential for survival.
Respiratory	In patients with obstructed TAPVR, expect severe pulmonary edema and pulmonary venous HTN. **Tests:** ✓ CXR: ↑ heart size, ↑ pulmonary vascularity, "figure-of-8," or "snowman" cardiac silhouette.
Cardiovascular	Echo findings: large RV and small LA. In unobstructed patients with restrictive ASD, a balloon or blade septostomy may be necessary to improve R → L shunting. **Tests:** ✓ ECG for right axis deviation (RAD), RAE, and RVH.

Laboratory	ABG and Hct; other tests as indicated from H&P
Premedication	Generally not indicated and not necessary in severely ill infants
Transport of critically ill newborn	All critically ill neonates are intubated, are ventilated, and often are on PGE_1 and/or dopamine infusions for hemodynamic stability. To facilitate transport of these patients, notify the nurse in advance and request all drips transferred to OR syringe pumps. Maintain a dextrose-containing infusion during and after transport to ensure normoglycemia. Verify that the transport monitor has ECG, SaO_2, and invasive pressure transducers. Resuscitation medications and airway equipment must accompany the patient.
ERAS	Check compliance with presurgical ERAS recommendations including NPO status. Evaluate concurrent disease, and optimize nutritional status and hydration.

INTRAOPERATIVE

Anesthetic technique

GETA: Profound hypothermic CPB (16°C–18°C) with low flow may be required. Fo patients who weigh <3.0 kg, we prefer to use the ICU ventilator in the OR, as this allows for maximum flexibility in ventilator support.

Induction	Infants are often severely ill and come to the OR intubated and ventilated, with invasive lines and inotropic support. Verify ETT placement. Patients are subject to rapid cardiovascular decompensation. Rocuronium (1 mg/kg) is given, as is fentanyl (1–3 mcg/kg) as tolerated. Volatile agents are rarely tolerated in obstructed TAPVC.
ERAS	Verify preincision antibiotics.
Maintenance	Fentanyl (20–50 mcg/kg) in divided doses on CPB. Patients with TAPVR, especially with obstruction,

	have a highly reactive pulmonary vasculature. High opioid doses are useful to blunt increases in PVR due to surgical stimulation. However, for patients with TAPVR and venous obstruction, ventilatory interventions or pulmonary vasodilators to reduce PVR will worsen the pulmonary edema prior to repair. Placement of TEE should also be avoided as this may cause obstruction at the level of the pulmonary venous confluence.	
Emergence	Transport to ICU intubated and ventilated. If NO used in OR, must have delivery system ready for transport to ICU. There may be continued requirement for inotropic support.	
Blood and fluid requirements	IV: 22–24 ga × 2 LR @ TKO	Avoid air bubbles with R → L shunt, because they can cause systemic embolization of air.
	Continue iv dextrose in neonates. 5% albumin	✓ blood glucose. Avoid hyperglycemia, especially during profound hypothermic CPB.
	PRBC Blood warmer	Be careful with volume administration. Even small amounts of fluid in the setting of a small, noncompliant LA/LV can result in LV failure. See Table 12.4-2 for blood product utilization.
Monitoring	Standard monitors. Transthoracic LA, PA, RA lines	Severely ill infants usually present with invasive monitoring and ETT. ✓ correct placement of UAC and UVC preop.
Complications	Refractory pulmonary HTN Bleeding	Pulmonary HTN may be difficult to control. Ventilation maneuvers (e.g., ↓ $PaCO_2$;

		100% O_2), vasodilators, and deep anesthesia to ↓ PVR. NO is started for refractory pulmonary HTN; if NO (40 ppm) is unsuccessful, ECMO may be instituted. In these instances, the sternum is not closed.
	Biventricular failure	Inotropic support (dopamine, milrinone, epinephrine, calcium chloride)
	Overdose of NO → metHb	✓ metHb while on NO therapy.

POSTOPERATIVE

Complications	See above.	
Tests	ABG Hct; electrolytes; coags Methemoglobin	
	CXR TEE	To assess PV → LA anastomosis and ventricular function
Multimodal pain management	CVICU management iv acetaminophen as appropriate	May include fentanyl, midazolam, and/or dexmedetomidine infusions

Suggested Readings

1. Files MD, Morray B: Total anomalous pulmonary venous connection: preoperative anatomy, physiology, imaging, and interventional management of postoperative pulmonary venous obstruction. Semin Cardiothorac Vasc Anesth 2017; 21(2):123–31.
2. Ross FJ, Joffe D, Latham GJ: Perioperative and anesthetic considerations in tota anomalous pulmonary venous connection. Semin Cardiothorac Vasc Anesth 2017; 21(2):138–44.
3. Vanderlaan RD, Caldarone CA: Surgical approaches to total anomalous pulmonary

venous connection. Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu2018; 21:83–91.

SURGERY FOR COMPLETE TRANSPOSITION OF THE GREAT ARTERIES

SURGICAL CONSIDERATIONS

Description

D-Transposition of the great arteries (TGA) is a congenital cardiac defect in which the aorta arises from the RV and the PA arises from the LV (Fig. 12.4-8). TGA is associated with an intact ventricular septum (TGA/IVS) or a ventricular septal defec (TGA/VSD). Pathophysiologically, this discordant ventriculoarterial configuratio results in systemic and pulmonary circulations placed in a parallel (normally in series) configuration. Thus, an L → R shunt in the form of an atrial septal defect (ASD), VSD or patent ductus arteriosus (PDA) is required to permit oxygenated blood to enter the "right-sided" systemic circulation. The earliest surgical treatment for d-TGA was described by **Blalock** and **Hanlon** in 1950, in which an **atrial septectomy** was performed, improving the mixing of pulmonary and systemic blood at the atrial level. In the 1950s, a variety of partial physiologic corrections were developed in which the pulmonary veins or the venae cavae were transposed to the alternate atria. Palliative treatment was advanced by **Rashkind** description of a **balloon atrial septostomy** in 1966. More complete physiologic correction was obtained by **atrial switch** operations, described by **Senning** (used native tissue) in 1959 and **Mustard** (used prosthetic tissue) in 1963, in which systemic and pulmonary venous returns were baffled to the appropriate ventricles. Postop complications with the atrial switch operations, however, led to the development of the more "anatomic" **arterial switch** operations described by **Jatene**, **Yacoub**, and others beginning in the 1970s. By 1987, the arterial switch operation in neonates was widely accepted as the standard approach to d-TGA.

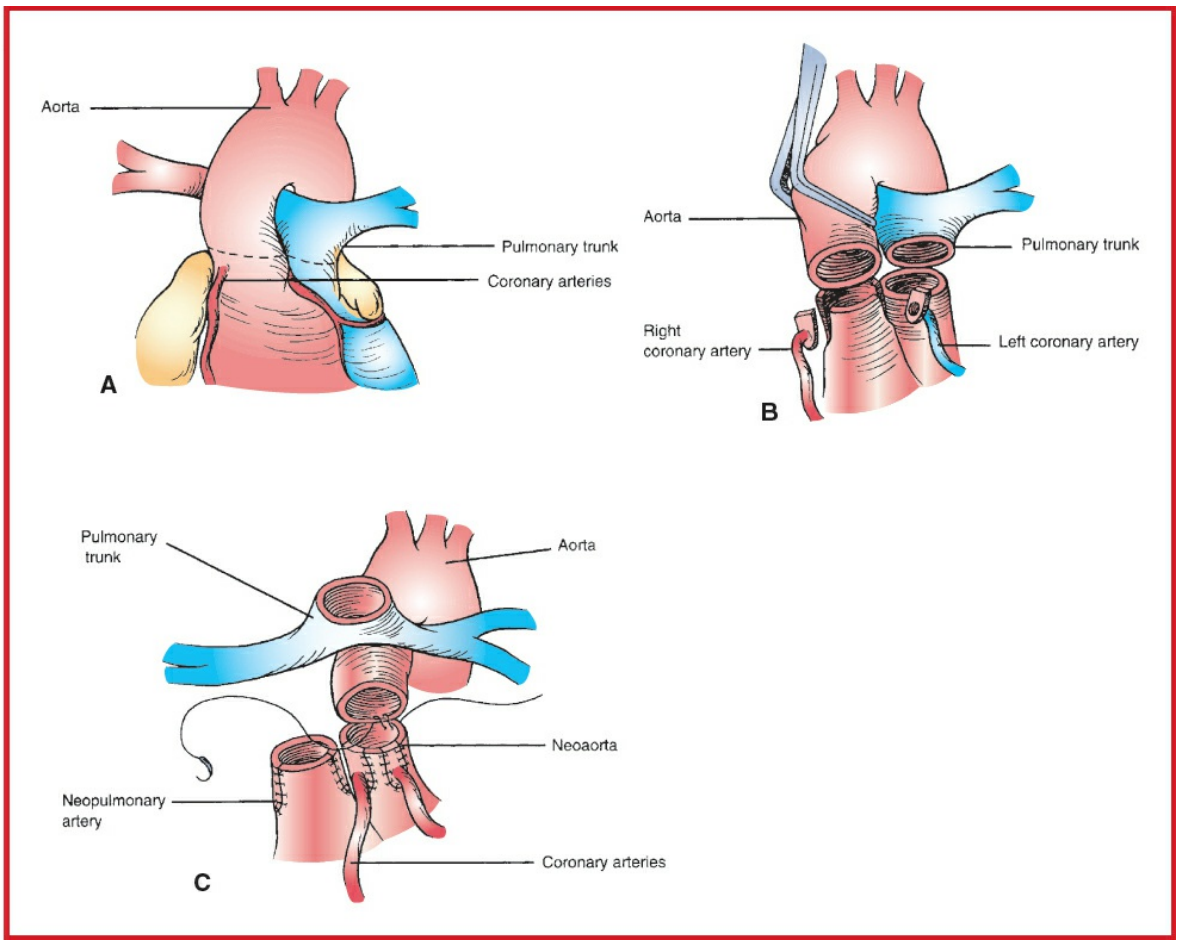

Figure 12.4-8 TGA. **A:** Typical anatomy of transposition of the great vessels, with the aorta anterior and slightly to the right of the pulmonary artery. The coronary arteries can be seen arising from the aorta. **B:** Repair is best accomplished by an arterial switch procedure in infancy. The great vessels are transected, and the coronary arteries are removed from the aorta and placed into the proximal pulmonary artery (neoaorta). **C:** The distal aorta is brought behind the pulmonary artery bifurcation (LeCompte maneuver), and the neoaorta anastomosis is completed. (Reproduced with permission from Ungerleider RM, Plunkett MD, Gaynor JW: Congenital heart disease. In: Oldham KT, Colombani PM, Foglia RP, eds. Surgery of Infants and Children. Lippincott-Raven, Philadelphia: 1997.)

Total correction is now performed routinely in the first 2 wk of life. The heart is exposed through a standard median sternotomy, and CPB is instituted. The aortic cross-clamp is applied, followed by cardioplegic arrest and induced hypothermia. The ascending aorta is transected just above the sinotubular junction and the pulmonary trunk is transected just proximal to its bifurcation. Two buttons from the "neopulmonary artery" (former aortic root) containing the origins of the left and right coronary arteries are transposed and anastomosed to the "neoaorta" (former main pulmonary trunk). The distal aortic segment is swung beneath the PA bifurcation **(LeCompte maneuver)**. Pericardial patches are used to repair the defects resulting from excision of the coronary artery buttons, and any associated ASDs and/or VSDs are repaired. The distal aortic segment is anastomosed to the neoaorta, and the distal bifurcated pulmonary artery

segment is anastomosed to the neopulmonary artery. If hypothermia has been induced, a brief period of circulatory arrest facilitates repair of the ASD and/or VSD, if present The aortic cross-clamp is removed, and rewarming is begun during the neopulmonary arterial anastomosis. CPB is then discontinued, and closure is routine.

Variant procedure or approaches

In children with TGA and VSD, additional cardiac anomalies are common. Thes include pulmonary stenosis, pulmonary atresia, straddling atrioventricular valves, hypoplasia of ventricular chambers, and coarctation or interruption of the aorta. Dynamic or structural subpulmonic obstruction is also more common in TGA and VSI than in TGA/IVS.

Rastelli procedure

The VSD is baffled to the aorta with construction of a RV → PA valved conduit and is the procedure of choice for patients with TGA/VSD and pulmonary atresia o significant valvular pulmonary stenosis. Often, the VSD may have to be enlarged tc prevent LVOT obstruction. Alternatively, in some cases, an aortic root translocation may be required.

Coronary arteries in TGA

Abnormalities in the origin and course of coronary arteries are common in TGA and, ir the past, influenced the success of surgery. A simple rule that accounts for virtually all variations is that the coronaries arise from the sinuses of Valsalva, which face the pulmonary artery, and follow the shortest route to their ultimate destination. Only a small number pose a problem in switching the great arteries.

Usual preop diagnosis

Complete TGA; transposition of the great vessels; transposition ± VSD; ASD; PDA

ERAS: Family preop counseling/education by the surgeon and anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, postop pair management options, DVT prophylaxis, physiotherapy plan, and possibility of NG/ches tubes and urinary drain postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Standard median sternotomy
Unique	Operation to be performed before LV pressure falls

considerations	substantially 2° ↓PVR
Antibiotics	Cefazolin 25 mg/kg q4h
Surgical time	Aortic cross-clamp: 45–90 min No circulatory arrest Total: 3 h
Closing considerations	Routine closure with chest tube in the pericardial space; temporary ventricular pacing wire; possible right or left atrial line for monitoring
EBL	Moderate
Postop care	1–5 d of assisted ventilation; pulmonary HTN protocol consisting of hyperventilation and sedation and use of pulmonary vasodilators; inotropes for adequate CO
Mortality	1–3%
Morbidity	Hemorrhage Atrial dysrhythmias ↓ CO Coronary artery kinking and myocardial ischemia Pulmonary HTN
Pain score	8–10

PATIENT POPULATION CHARACTERISTICS	
Age range	1–21 d; ≤3–6 mo in TGA/VSD
Male:Female	2:1; for TGA/IVS, 3.3:1
Incidence	7–8% of congenital heart defects
Etiology	Usually no associated syndromes or other noncardiac abnormalities
Associated conditions	ASD; VSD; PDA; LVOTO; pulmonary atresia; coarctation of the aorta

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Pathophysiology	In TGA, the pulmonary and systemic circulations flow in parallel, unlike the normal series circulation. Deoxygenated blood returns to the right heart and is pumped to the aorta and systemic circulation without passing through the lungs for gas exchange. The oxygenated blood returns via the pulmonary veins and recirculates through the LV back into the lungs. Survival depends on mixing of pulmonary and systemic blood at some level (PFO, ASD, VSD, PDA). With d-TGA, pulse oximetry reveals a "reversed differential cyanosis" in which the preductal SaO_2, (right hand) is lower than the postductal (foot) SaO_2. In the absence of a septal defect, a balloon atrial septostomy (Rashkind-Miller) may be required before surgery to promote mixing.
Respiratory	Some patients are maintained preop on PGE_1 (0.01–0.05 mcg/kg/min) to maintain ductal patency. PGE_1 can cause apnea; therefore, mechanical ventilation may be required. **Tests:** CXR: ✓ enlarged heart and pulmonary edema.
Cardiovascular	Number, size, and location of sites that allow for intercirculatory mixing will determine the degree of mixing (Q_p/Q_s) and thus SaO_2. In the absence of pulmonic stenosis, patients with nonrestrictive VSD have ↑ pulmonary blood flow (R → L shunt) and are at risk for developing CHF and PVOD. Marked cyanosis (PaO_2 25–40 mm Hg) is seen in patients with TGA/IVS restrictive PFO/ASD or with PS even if a large VSD may be present. **Tests:** EKG: right axis deviation (RAD) and RVH. Echo: Cardiac cath defines anatomy, coronary arteries, septal defects, PFO, PDA, bronchopulmonary collaterals, LVOT, pulmonic valve function, and pressures, including PVR and LV: RV ratio. Balloon atrial septostomy (Rashkind-Miller) may be required to improve mixing in some patients.

Laboratory	Hct; coags; lactate; other tests as indicated from H&P
Premedication	Generally not necessary in children <9 mo
Transport of critically ill newborn	All critically ill neonates are intubated, ventilated, and often on PGE_1 and/or dopamine for hemodynamic stability. To facilitate transport of these patients, notify the nurse in advance and request all drips transferred to OR syringe pumps. An air-O_2 blender should be available so the inspired O_2 concentration can be adjusted as needed. Verify that the transport monitor has EKG, SaO_2, and invasive pressure transducers. Resuscitation medications and airway equipment must accompany the patient. Patients can be transported on room air with gentle manual ventilation, taking care to avoid hyperventilation. Avoid oversedation and use of muscle relaxants before transport.
ERAS	Check compliance with presurgical ERAS recommendations including NPO status. Evaluate concurrent disease, and optimize volume status and hydration.

INTRAOPERATIVE

Anesthetic technique

GETA

Induction	Neonates with d-TGA and intact ventricular septum are placed on PGE_1 to maintain ductal patency and promote mixing of pulmonary and systemic blood. Anesthetic management is based on maintaining a balance between systemic and pulmonary blood flows. Avoid increase in PVR/SVR ratio because this will reduce intercirculatory mixing and will worsen cyanosis. Excessive pulmonary blood flow will ↓ systemic perfusion. IV induction with ketamine (1–2

	mg/kg incrementally), fentanyl (e.g., 2–15 mcg/kg incrementally), and muscle relaxant (e.g., rocuronium 1 mg/kg) is the technique of choice. Inotropic infusion and PRBC transfusion may be required to support BP.	
ERAS	Verify preincision antibiotics.	
Maintenance	For patients with inadequate intercirculatory mixing and ↓ pulmonary blood flow, treatment should include ventilation maneuvers to ↓ PVR and improve mixing. Deep GA helps to blunt reactive pulmonary HTN. Avoid ↓ HR as it causes ↓ CO in infants with limited myocardial reserve. NTG may be used to prevent coronary spasm after reimplantation, but usually coronary perfusion problems are anatomic (e.g., kink—especially during chest closure).	
Emergence	Control aortic BP and treat any coagulopathy. Monitor LA pressures closely. ✓ for myocardial ischemia, which can be 2° coronary air emboli or at the implantation site of the coronaries. Transport to ICU intubated and ventilated.	
Blood and fluid requirements	IV: 22–24 ga × 1–2 LR @ TKO Continue iv dextrose in neonates. 5% albumin Antifibrinolytics (e.g., aminocaproic acid)	Avoid air bubbles in patients with R → L and L → R shunts. See Table 12.4-2 for blood product utilization. Administer blood and products slowly with close monitoring of LAP. Overtransfusion can cause systemic HTN, LA dilation, or pulmonary edema, producing additional suture line bleeding or mitral regurgitation.
Monitoring	Standard monitors	Severely ill infants often present with invasive monitoring and mechanical ventilation. Correct

		placement of UAC and UVC should be checked preop.
	Transthoracic monitoring lines (RA, LA, or PA)	Placed routinely on Also verify position of ETT. rewarming, before weaning from CPB. These are for monitoring and administration of inotropes and other medications. The LV can be deconditioned and dysfunctional and require inotropic support (dopamine, milrinone, epinephrine, and $CaCl_2$ infusion). During weaning from CPB, it is critical to monitor LAP, as a reflection of left-sided filling, simultaneously with RA pressure monitoring.
	TEE	Abnormalities in coronary perfusion may manifest as changes in EKG rhythm and should be closely followed. TEE is useful both as a monitor of function and volume status. ECMO may be needed for severe ventricular dysfunction.
CPB	Management of CPB is discussed in Intraop Considerations for TOF.	Low flow or moderate hypothermic CPB. Cool with pH stat management (T corrected ABG). Warm on reperfusion with alpha-stat management.
Complications	Bleeding	
	LV dysfunction and failure	In patients with TGA and IVS, the LV may be inadequate to support the systemic
	Myocardial ischemia	

	Residual structural defects Dysrhythmias Pulmonary HTN Cerebral emboli (following balloon septostomy)	circulation. The LV becomes deconditioned after the PVR drops in early infancy. The LV is then unable to function as the systemic ventricle. Inotropic support (dopamine and epinephrine) and afterload reduction (e.g., SNP) may be necessary to separate from CPB. ECMO may be required for severe ventricular dysfunction.

POSTOPERATIVE

Complications	Hypothermia Bleeding Dysrhythmias Myocardial ischemia LV failure	Ischemia 2° coronary artery stenosis, stretching, spasm, or compression. Spasm can be treated with NTG and ↑ aortic pressure. If the now-anterior PA dilates (↓ PaO_2, ↑ $PaCO_2$, ↓ T, ↓ pH, excessive or too little PIP, or RV failure), the coronary arteries may be compressed. Measures to ↓ PA pressure are often essential.
Tests	ABGs; electrolytes; coag profile CXR TEE	 ✓ line, chest tube placement; ✓ for pneumothorax.
Multimodal pain management	CVICU management iv acetaminophen as appropriate	May include fentanyl, midazolam, and/or dexmedetomidine infusions.

Suggested Readings

1. Kasar T, Ayyildiz P, Tunca Sahin G, et al: Rhythm disturbances and treatment strategies in children with congenitally corrected transposition of the great arteries. Congenit Heart Dis 2018; 13(3):450–7.
2. Latham GJ, Joffe DC, Eisses MJ, et al: Anesthetic considerations and management c transposition of the great arteries. Semin Cardiothorac Vasc Anesth 2015; 19(3):233–42.
3. Lenoir M, Bouhout I, Gaudin R, et al: Outcomes of the anatomical repair in patient with congenitally corrected transposition of the great arteries: lessons learned in a high-volume centre. Eur J Cardiothorac Surg 2018; 54(3):532–8.

SURGERY FOR TRUNCUS ARTERIOSUS

SURGICAL CONSIDERATIONS

Description

Truncus arteriosus is a rare cardiac anomaly in which there is a common aortopulmonary trunk originating from the base of the heart by way of a single, semilunar valve (truncal valve). This single great artery gives rise to the pulmonary, systemic, and coronary circulations. A nonrestrictive VSD is almost always found immediately below the truncal valve. An anatomic classification scheme proposed by **Collett** and **Edwards** in 1949 describes four types of truncus. In **type I** truncus (60%), a single arterial trunk gives rise to the aorta and main PA (Fig. 12.4-9A). In **type II** truncus (20%), the right and left PAs arise separately from the posterolateral aspect of the truncus. **Type III** truncus (10%) designates cases in which the two PAs also originate from the posterior truncus, but with widely separated orifices. In **type IV** truncus (10%), the PA branches are absent with pulmonary blood flow derived from aortopulmonary collaterals. Pathophysiologically, there is significant L → R shunting at the truncal and ventricular levels, leading to unrestricted pulmonary blood flow, CHF, and pulmonary HTN. Patients become symptomatic in infancy 2° CHF when the PVR and CO ↑. Untreated, 90% of infants die within 6 mo.

The first total repairs of this congenital anomaly were reported in the early 1960s and included the insertion of **nonvalved artificial conduits** and **aortic allograft and valve conduits.** In the early and mid-1970s, repair was performed at younger ages, with abandonment of palliative banding of the PA branches. Currently, early primary repair is carried out during the first few weeks of life.

Through a median sternotomy, the truncus and PA branches are dissected, and cannulation for CPB is performed. The PAs are snared to block pulmonary flow during perfusion. Hypothermia is induced, and the aorta is cross-clamped. The PAs are separated from the main truncus, the resultant aortic defect is repaired with a patch, and a valved homograft (12–14 mm) is prepared. An end-to-end anastomosis of the distal homograft to the PA opening is performed, the VSD is closed through a right ventriculotomy, and the proximal end of the homograft is then anastomosed to the right ventriculotomy (Fig. 12.4-9B). The heart is de-aired, the aorta is unclamped, rewarming and resuscitation are performed, and CPB is discontinued.

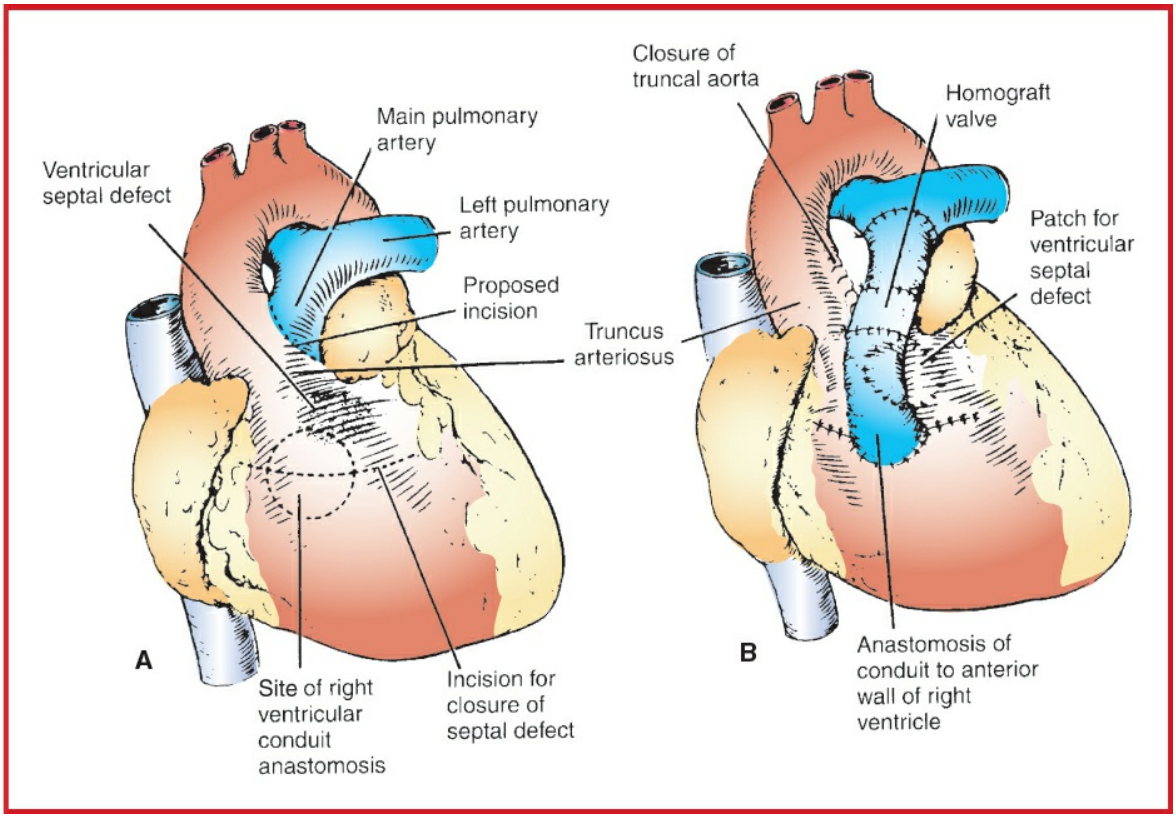

Figure 12.4-9 Truncus arteriosus. **A:** Cohen-Edwards (type I). **B:** Surgical correction involves the separation of the main PA from the truncus, VSD patch closure, and insertion of a conduit between the RV and the distal main PA. (Republished with permission of McGraw-Hill Education from Way LW: Current Surgical Diagnosis and Treatment, 10th edition. Appleton & Lange, Norwalk, Connecticut: 1994; permission conveyed through Copyright Clearance Center, Inc.)

There are several **special considerations** associated with this repair that warrant mention. The truncal valve may exhibit insufficiency, necessitating valve repair or replacement using a cryopreserved aortic or pulmonary homograft. In older infants, the PVR may be elevated, and pulmonary hypertensive crises should be anticipated. In some patients, an associated interruption of the aortic arch has to be addressed and increases the complexity of the procedure. Coronary artery abnormalities are common

in patients with truncus arteriosus and may contribute to their mortality.

Usual preop diagnosis

Truncus arteriosus (types I, II, III, IV)

ERAS: Family preop counseling/education by the surgeon and anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, postop pair management options, DVT prophylaxis, physiotherapy plan, and possibility of NG/ches tubes and urinary drain postop. Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Standard median sternotomy
Antibiotics	Cefazolin 25 mg/kg q4h
Surgical time	Aortic cross-clamp: 30–90 min Total: 2.5–3 h
Closing considerations	Routine closure with chest tube in the pericardial space; temporary ventricular pacing wire; possible right or left atrial line for monitoring
EBL	Moderate
Postop care	1–5 d of assisted ventilation; pulmonary HTN protocol consisting of hyperventilation and sedation and use of pulmonary vasodilators. Inotropes for adequate CO
Mortality	<3%
Morbidity	Hemorrhage Atrial dysrhythmias Pulmonary vasospasm Truncal valve insufficiency ↓ CO
Pain score	8–10

PATIENT POPULATION CHARACTERISTICS	
Age range	3 wk–6 mo

Male:Female	1:1
Incidence	1.7–4.6% of congenital heart defects
Etiology	No known etiology
Associated conditions	Coexisting interrupted aortic arch or coarctation with PDA (10–20%); right aortic arch (16%); mitral valve anomalies (10%); moderate-size or large ASD (10%); DiGeorge syndrome

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Pathophysiology	A single, common aortopulmonary artery, the truncus, overlies the two ventricles and VSD. Depending on the configuration, the truncus gives rise to coronary and pulmonary arteries and ascending aorta. Complete mixing of systemic and pulmonary circulations occurs at the VSD and truncal valve, resulting initially in cyanosis. After birth, as PVR decreases, significant L → R shunting occurs at the level of the VSD. This causes pulmonary blood flow and CHF. If present, truncal valve insufficiency causes ventricular dilatation and low diastolic coronary perfusion and myocardial ischemia. If untreated, 80% die of CHF in the 1st yr. Early total correction is indicated.
Airway	The facial anomalies (e.g., micrognathia) in DiGeorge syndrome may make intubation difficult.
Respiratory	Typically, these infants present with the respiratory Sx of CHF (dyspnea, tachypnea) as PVR decreases after the first few days of life as pulmonary overcirculation ensues. **Tests:** CXR: ↑ pulmonary markings and wide mediastinum
Cardiovascular	Frequently, neonates are intubated and ventilated for hemodynamic support. Arterial saturation >85%

	indicates excessive pulmonary blood flow. This may be controlled by the use of hypoxic gas mixtures (17–19% FiO_2), inspired CO_2 (3–5%), and PEEP. **Tests:** EKG, Echo: Usually diagnostic. Identifies the origin of the PA from the common trunk and the presence (subtype A) or absence (subtype B) of a VSD and evaluates truncal valve competency
Endocrine	In DiGeorge syndrome, thymic hypoplasia occurs with hypoparathyroidism and symptomatic hypocalcemia. **Tests:** ✓ Ca^{++} levels; parathyroid hormone
Premedication	Not indicated
ERAS	Check compliance with presurgical ERAS recommendations including NPO status. Evaluate for concurrent disease, and optimize volume status and hydration.

INTRAOPERATIVE

Anesthetic technique

GETA

Induction	The goal for induction is maintenance of hemodynamic stability. If not intubated prior to induction, titrate FiO_2 and ventilation to maintain oxygen saturations of 75–85%. IV induction with ketamine (1–2 mg/kg), fentanyl (2–4 mcg/kg), and muscle relaxant (e.g., rocuronium 1 mg/kg) is preferred. Keep DBP > 20 mm Hg to maintain coronary perfusion. Treat ↓ BP on induction with additional inotropes, transfusion of blood, or occlusion of a PA by the surgeon as soon as the chest is opened.
ERAS	Verify preincision antibiotics.
Maintenance	Fentanyl (20–50 mcg/kg). Rocuronium as needed ± midazolam 0.1–0.2 mg/kg ± volatile agent. FiO_2 = 0.21. Avoid hyperventilation (↓ PVR, ↑ shunt + CHF).

	PEEP may be useful to maintain PVR. The surgeon may leave a PFO to serve as a "pop-off" to preserve systemic perfusion when ↑ PVR and RV dysfunction occur. A transthoracic left atrial line is frequently placed for monitoring. In some cases, the sternum may be left open due to chest wall and mediastinal edema and the presence of the anterior RV-PA conduit (Rastelli conduit).	
Emergence	Transport to ICU intubated and ventilated with sedation infusion(s) (e.g., fentanyl) for initial postop period (2–3 d) to minimize pulmonary hypertensive crises.	
Blood and fluid requirements	See Tetralogy of Fallot (TOF).	Continue dextrose infusion in neonates. See Table 12.4-2 (p. 1396) for blood product utilization.
Infusions	Inotropic support	These patients require inotropic support (dopamine, milrinone, epinephrine, and $CaCl_2$ infusion).
Monitoring	Standard monitors + LA, RA, PA lines TEE	 Transthoracic lines TEE is helpful to assess function, truncal valve competency, RV function, and the direction of atrial shunt.
Positioning	See TOF (p. 1391).	
CPB	See TOF (p. 1391).	
Complications	Pulmonary HTN Truncal valve insufficiency Coronary artery insufficiency Residual lesion Bleeding	

	Pulmonary hypertensive crisis	Frequent in patients >1 mo old. Rx: NO, sedation, hyperventilation
	A-V block	Generally temporary, injury to conduction system unlikely because it is remote from VSD closure Occasionally, a pacemaker may be required.
	Ventricular dysfunction	May require inotropic support
	Residual lesions	Residual VSD, severe truncal valve incompetence or obstruction, obstruction of coronary flow, LVOTO
Multimodal pain management	CVICU management iv acetaminophen as appropriate	May include fentanyl, midazolam, and/or dexmedetomidine infusions

Suggested Readings

1. Martin BJ, Karamlou TB, Tabbutt S: Shunt lesions part II: anomalous pulmonar venous connections and truncus arteriosus. Pediatr Crit Care Med 2016; 17(8 Suppl 1):S310–4.
2. Naimo PS, Fricke TA, Yong MS, et al: Outcomes of truncus arteriosus repair i children: 35 years of experience from a single institution. Semin Thorac Cardiovasc Surg 2016; 28(2):500–11.
3. Parikh R, Eisses M, Latham GJ, et al: Perioperative and anesthetic considerations i truncus arteriosus. Semin Cardiothorac Vasc Anesth 2018; 22(3):285–93.

SURGERY FOR TRICUSPID ATRESIA

SURGICAL CONSIDERATIONS

Description

In tricuspid atresia, there is a developmental failure of the tricuspid valve, isolating the RA from the RV. There are three types of tricuspid atresia, based on the relationship of

the great vessels to the ventricles, otherwise known as **ventriculoarterial concordance.** Type I, the most common (60–80%), consists of normal ventriculoarterial concordance. Type II (15–25%) consists of d-transposition, and type III (3%) consists of l-transposition. In most cases of tricuspid atresia, the RV is hypoplastic, an ASD is present, and pulmonary blood flow is restricted 2° pulmonary stenosis or atresia. Together, these malformations lead to R → L shunting and varying degrees of cyanosis. Those patients with unobstructed pulmonary blood flow develop pulmonary overcirculation and CHF. Consequently, the initial palliative surgical management of this defect depends on the magnitude of pulmonary blood flow; the initial procedure may be either a modified **Blalock-Taussig systemic-to-PA shunt** or a **PA band**. The subsequent definitive surgical management consists of a bidirectional **Glenn shunt** and a modified **Fontan procedure**. Patients undergo these operations sequentially or, in rare cases, directly to the definitive Fontan operation.

The systemic-to-PA shunt, developed by **Blalock** and **Taussig** in 1944, was the first palliative treatment for this condition. Later, other shunts were introduced by **Potts** (descending aorta-to-left PA) and **Waterston** (ascending aorta-to-right PA). In 1958, Glenn described a shunt from the SVC to the right PA applied specifically to patients with tricuspid atresia. A modification of this shunt to a **bidirectional cavopulmonary anastomosis** was performed clinically by **Azzollina** in 1974 and has since gained widespread acceptance. In 1971, Fontan proposed a surgical repair for tricuspid atresia based on separation of the right and left circulations. Subsequent modifications to Fontan original operation were designed to bypass the RV and direct systemic venous return to the pulmonary circulation. The most recent modifications divert vena caval blood directly to the PA—now referred to as a **total cavopulmonary connection** (modified Fontan). In 1988, **Laks** suggested leaving a small ASD between the right and left circulations, creating a R → L shunt for the purposes of augmenting systemic CO while still maintaining adequate oxygenation.

Modified Blalock-Taussig (B-T) shunt

In neonates with tricuspid atresia or other single-ventricle variants with low pulmonary blood flow, a modified B-T shunt is the procedure of choice. The preferred approach is through a midsternotomy. The right PA and the right innominate and subclavian arteries are mobilized. The patient is heparinized, and clamps are applied on the right PA and the innominate/subclavian arteries. Arteriotomies are performed and a Gore-Tex tube graft is interposed and anastomosed to the right PA and the subclavian/innominate arteries. The size of shunt (3–4 mm) is dictated by patient size and arterial anatomy. Alternatively, the procedure can be performed via right thoracotomy or through a left thoracotomy if the morphology dictates a left-sided shunt. A midline approach can be

used for any variation of the shunt and also gives the option of using CPB in case of patient instability.

Pulmonary artery banding

In patients with tricuspid atresia or other variants of single ventricle and increased pulmonary blood flow, PA banding is performed to protect the pulmonary vascular bed, prevent pulmonary HTN, and prevent CHF. A midline sternotomy is the preferred approach. The main PA is exposed, and a 2- to 3-mm-wide strip of Silastic band is placed around the main PA and tightened to adjust the pulmonary blood flow. The goal is a SaO_2 of ~80–85%.

Bidirectional Glenn shunt

A standard median sternotomy approach is used. If concomitant intracardiac repairs are not anticipated, the bidirectional Glenn (BDG) shunt may be performed without CPB by placing a temporary shunt between the high SVC and the RA. If the patient has a preexisting Blalock-Taussig shunt on the right, it is divided after instituting CPB. A shunt on the left side may be left open, while the bidirectional Glenn shunt is created on the right. The SVC is divided, and the cardiac end is oversewn. The remaining cava end is anastomosed end to side to the superior aspect of the right PA (Fig. 12.4-10A).

Fontan procedure

Intracardiac Fontan procedures have been replaced with extracardiac Fontan. With intracardiac repair, a transposition graft between the inferior and superior venae cavae was tunneled through the right atrium. This posed the risk of atrial arrhythmias. The heart is accessed via a standard median sternotomy. Previously placed systemic-to-PA shunts are dissected and occluded prior to bypass. Bicaval cannulation and CPB with hypothermia are used. The IVC is transected at its PA junction, and a Gore-Tex tube graft is interposed end to end between the IVC and the inferior surface of the right PA. This operation, in conjunction with the previously performed bidirectional Glenn shunt, establishes a total cavopulmonary connection (Fig. 12.4-10B). After completing the anastomosis, the aortic cross-clamp is removed, the heart is rewarmed, and the patient is weaned from CPB. Fenestration of the Fontan circuit may be desirable in high-risk patients, but is generally not required in patients with tricuspid atresia and good ventricular function. Some believe the fenestration allows for maintenance of cardiac output in patients with increased. PVR at the expense of desaturation. It may also decrease venous resistance, thus decreasing the risk of PLE. The fenestration can spontaneously close or undergo device closure in the cath lab. Our current preference is to perform the Fontan procedure without using CPB.

Variant procedure or approaches

Without CPB: using the patient's own pulsatile circulation through a temporary bridge (CPB tubing) between the superior vena cava and the right atrium.

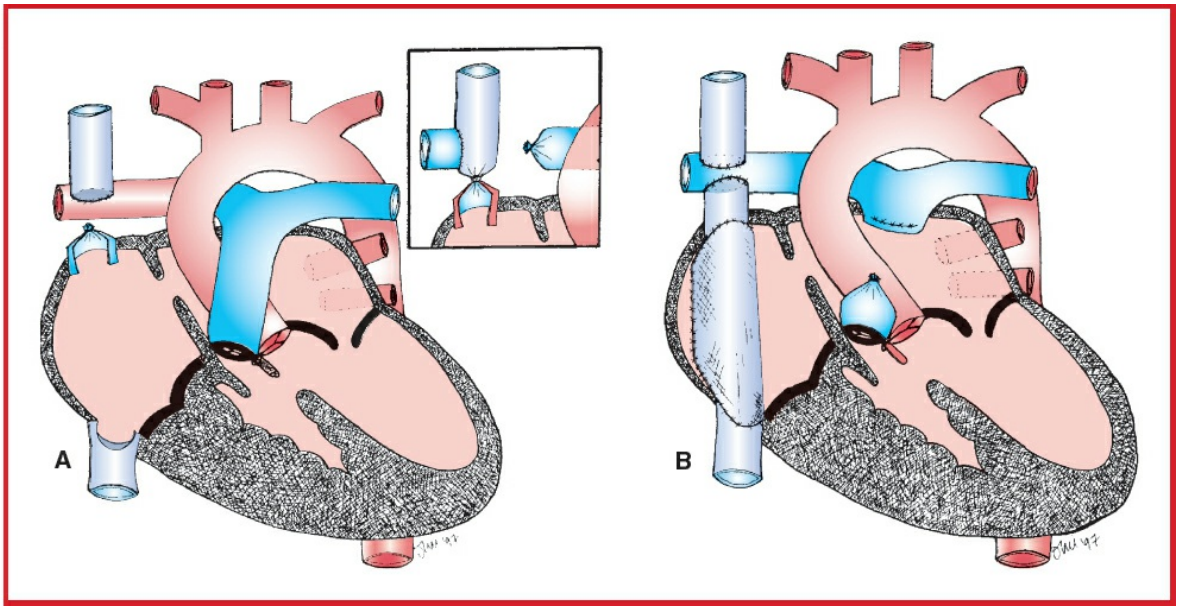

Figure 12.4-10 Surgery for tricuspid atresia. **A:** Bidirectional Glenn shunt. **Inset** shows classic unidirectional Glenn shunt. **B:** Lateral tunnel Fontan operation. (Reproduced with permission from Emmanouilides GC, Allen HD, Riemenschneider TA, et al:Clinical Synopsis of Moss and Adams' Heart Disease in Infants, Children, and Adolescents. Williams & Wilkins, Baltimore: 1998.)

An **RA → RV connection** can be performed in patients with tricuspid atresia without pulmonary obstruction and an adequately functioning RV. This is accomplished with a direct anastomosis or a valved/nonvalved conduit (e.g., aortic homograft, Dacron graft).

Usual preop diagnosis

Tricuspid atresia after B-T shunt or PA banding; univentricular heart or single ventricle after shunt or band; cyanotic congenital heart disease

ERAS: Family preop counseling/education by the surgeon and anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, postop pair management options, DVT prophylaxis, physiotherapy plan, and possibility of NG/ches tubes and urinary drain postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Bidirectional Glenn (BDG) Shunt	Cavopulmonary Fontan Procedure
Position	Supine	⇐

Incision	Standard median sternotomy	⇐
Unique considerations	Particulate or gaseous emboli from iv lines can become systemic emboli.	Areas of PA stenosis need to be repaired concomitantly.
Antibiotics	Cefazolin 25 mg/kg q4h	⇐
Surgical time	If a simple anastomosis is constructed, the aorta is not cross-clamped.	⇐
	Total: 1.5–2 h	Total: 3–4 h
Closing considerations	Chest tube in the pericardial space; temporary ventricular pacing wire; possible atrial monitoring line to assess ventricular filling pressure	Chest tube in the pericardial space; possible pleural tubes; temporary ventricular and atrial pacing wires; possible atrial line to correlate with CVP to determine the trans-pulmonary gradient
EBL	Moderate	⇐
Postop care	Cardiac ICU; early extubation to minimize positive intrathoracic pressure	ICU or early extubation; inotropes for ventricular function, including low-dose dopamine, milrinone for afterload reduction. Maintain sinus rhythm, A-V pacing, if required.
Mortality	<2%	2–4%
Morbidity	Bleeding	Pleural effusions
	Infection	–
	Atrial dysrhythmias	⇐
	↑ SVC pressure	–

	Upper extremity edema (SVC syndrome)	–
	↓ CO	⇐
	Cyanosis 2° ↓ pulmonary blood flow	–
	Pulmonary arteriovenous fistula	Protein-losing enteropathy (late)
Pain score	8–10	8–10

PATIENT POPULATION CHARACTERISTICS		
Age range	4 mo–1 yr	2–5 yr
Male:Female	1:1	⇐
Incidence	1–3% of congenital heart defects	⇐
Etiology	Unknown	⇐
Associated conditions	TGA; A-V valve insufficiency requiring repair or replacement; residual PA obstruction from previous procedures; dextrocardia; asplenia or polysplenia syndromes	

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Pathophysiology	This is characterized by the absence of the tricuspid valve and a hypoplastic RV with no communication between RA and RV. Survival in the neonatal period depends on presence of an interatrial communication. The degree of cyanosis reflects the size of the VSD and magnitude of RVOTO. Thirty percent of patients have CHF from pulmonary

	overcirculation 2° a large VSD and unobstructed RVOT and may require PA banding. Tricuspid atresia requires staged palliation, beginning with the establishment of adequate pulmonary blood flow. Patients undergo a balloon septostomy or a systemic-pulmonary artery shunt (B-T shunt) in the newborn period to augment pulmonary blood flow. Subsequently, at 3–4 mo of age, they undergo cardiac catheterization, and a palliative bidirectional Glenn shunt (SVC → PA) is performed and the B-T shunt is ligated. The Glenn shunt reduces the volume load of the systemic ventricle. Patients coming in for a BDG procedure need careful control of PVR and SVR. Any ↑ PVR 2° light anesthesia, stimulation, pain, and ventilation problems can affect the oxygen saturation by decreasing the pulmonary blood flow. These patients may also have hypoxemia due to pulmonary arterial venous AVMs. The final palliative procedure, the Fontan operation, is done between 1.5 and 3 yr of age, where the IVC is connected to the PA via an extracardiac conduit. At this stage, the patients may present with ventricular dysfunction and pulmonary hypertension. Early extubation and spontaneous ventilation should be planned in advance in patients undergoing either Glenn or Fontan procedures, since PPV and/or hypovolemia will decrease pulmonary blood flow and cardiac output resulting in reduced SaO_2 and CO.
Respiratory	Identify any infectious or asthma-related problems. Optimizing pulmonary function is imperative as the pulmonary blood flow will be supplied passively from the systemic venous return. **Tests:** CXR; SaO_2
Cardiovascular	**Tests:** EKG, Echo, cath
Laboratory	Hct; others as indicated by H&P
Premedication	Midazolam 0.5–0.75 mg/kg po 20 min before

ERAS	induction in children >9 mo old. Check compliance with presurgical ERAS recommendations including NPO status. Evaluate for concurrent disease, and optimize volume status and hydration.

INTRAOPERATIVE/POSTOPERATIVE

See intraop and postop considerations for tricuspid atresia.

Suggested Readings

1. Alsaied T, Bokma JP, Engel ME, et al: Factors associated with long-term mortality after Fontan procedures: a systematic review. Heart 2017; 103(2):104–10.
2. El Midany AAH, Mostafa EA, Mansour SA, et al: Bilateral bidirectional Glenn outcome of off-pump technique. Interact Cardiovasc Thorac Surg 2017; 25(5):745–9.
3. Lin Z, Ge H, Xue J: Comparison of extracardiac conduit and lateral tunnel fo functional single-ventricle patients: a meta-analysis. Congenit Heart Dis 2017; 12(6):711–20.
4. Viswanathan S: Thromboembolism and anticoagulation after Fontan surgery. Ann Pediatr Cardiol 2016; 9(3):236–40.

SURGERY FOR DOUBLE-OUTLET RIGHT VENTRICLE

SURGICAL CONSIDERATIONS

Description

In double-outlet right ventricle (DORV), at least 50% of both of the great arteries arise from the RV. By necessity, there is a VSD that is usually large but may in some cases be restrictive or, rarely, multiple and muscular. The VSD may be located primarily below the aorta (**DORV/subaortic VSD**; Fig. 12.4-11A), below the pulmonary valve (**DORV/subpulmonic VSD** or **Taussig-Bing DORV**; Fig. 12.4-11B), below both great vessels (doubly committed; Fig. 12.4-11C), or remote from both great vessels (noncommitted; Fig. 12.4-11D). In DORV/subaortic VSD, oxygenated LV blood is directed to the aorta, and deoxygenated systemic venous return from the RV is directed to the PA, resulting in minimal-to-no cyanosis. L → R shunting across the VSD however, leads to pulmonary overcirculation, pulmonary HTN, and CHF. In DORV/subpulmonic VSD, oxygenated LV blood is directed to the PA, and

deoxygenated systemic venous return from the RV is directed to the aorta causing pulmonary overcirculation and significant cyanosis. If early PA banding or primary correction is not performed in patients with pulmonary overcirculation, PVOD may result at an early age. In patients with some degree of pulmonary stenosis (usually infundibular), R → L shunting and cyanosis result; the natural history resembles that of patients with tetralogy of Fallot.

In 1957, Kirklin described the first repairs. In 1967, the Taussig-Bing DORV was first corrected. In recent years, management has been simplified for this variant by combining the **arterial switch operation** with an **intraventricular baffle to the pulmonary valve.** From a surgical standpoint, the anatomic variations and past attempts at correction may lead to unique intraop challenges. For example, if a previous Blalock-Taussig shunt has been performed, it needs to be controlled prior to initiating CPB. A previous pulmonary band may require removal and PA reconstruction.

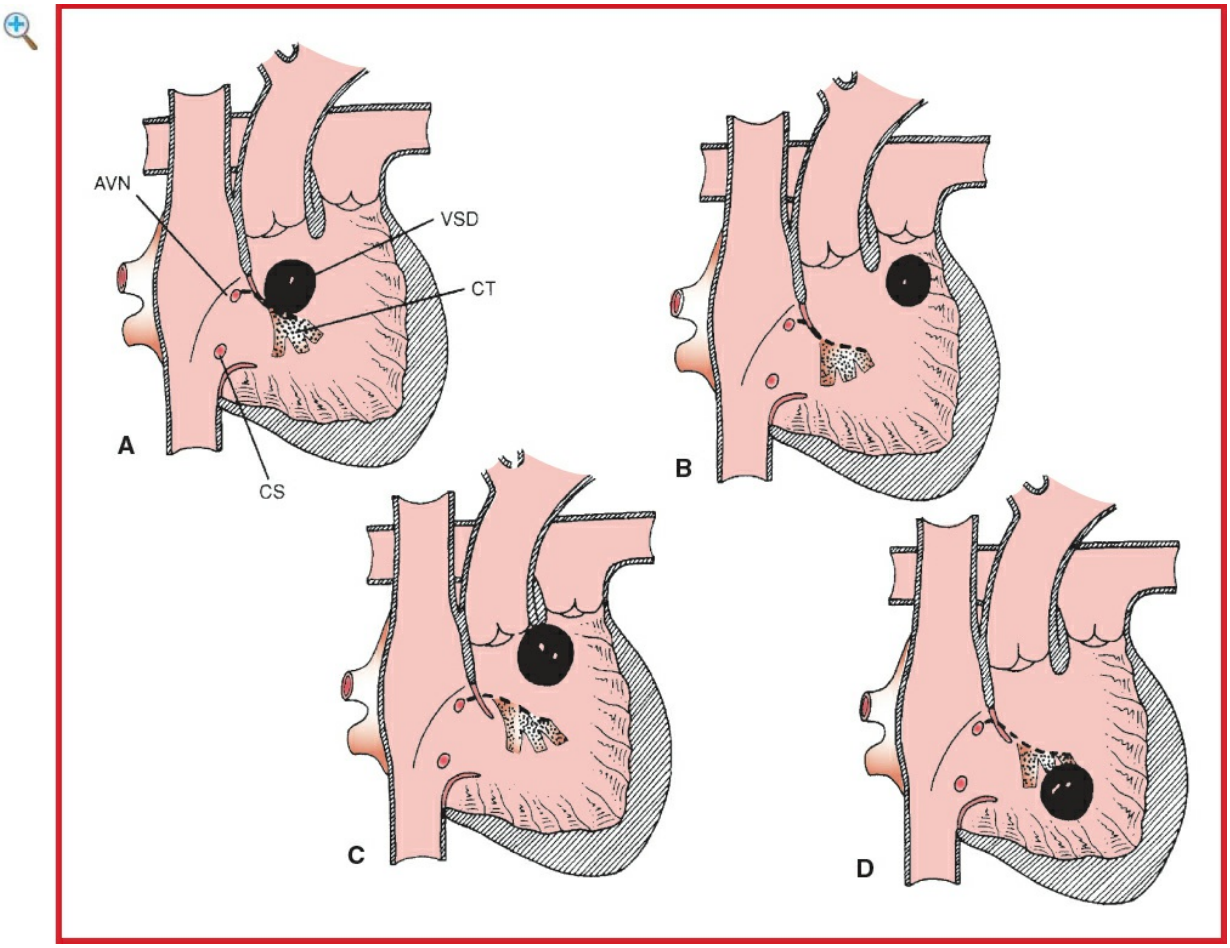

Figure 12.4-11 Types of double-outlet right ventricle classified by the relationship of the VSD to the great arteries. The location of the atrioventricular node and conduction tissue is depicted. **A:** Subaortic VSD. **B:** Subpulmonary VSD. **C:** Doubly committed VSD. **D:** Noncommitted VSD. VSD, Ventricular septal defect; AVN, atrioventricular node; CS, coronary sinus; CT, conduction tissue. (Reproduced with permission from Kaiser LR, Kron IL, Spray TL, edsMastery of Cardiothoracic Surgery. Lippincott-

Raven, Philadelphia: 1998.)

DORV/subaortic VSD generally is repaired with an **intraventricular tunnel repair**, in which LV blood from the VSD is channeled through the RV to the aorta. Through a median sternotomy, CPB is instituted, and previous shunts are ligated. The aorta is cross-clamped, and cardioplegia is administered. After performing a right atriotomy, the interior of the RV is inspected through the tricuspid valve; a right ventriculotomy may be necessary for adequate exposure. A tunnel constructed of pericardial or Dacron patch is then placed between the VSD and the subaortic infundibulum. Augmentation of the RVOT, in the form of an outflow patch or extracardiac RV → PA conduit, is often necessary if the outflow tract is obstructed or if the RVOT is encroached upon by the intraventricular tunnel. The heart is then rewarmed and resuscitated, CPB is discontinued, and standard chest closure is begun.

DORV/subpulmonic VSD (Taussig-Bing DORV) can be corrected with an arterial switch operation and VSD closure under CPB. DORV with significant pulmonary stenosis repair resembles that for the TO. DORV with doubly committed VSD is similar to DORV/subaortic VSD. DORV with uncommitted VSD poses a surgical challenge. A two-ventricle repair requires intracardiac baffles. Alternatively, a single-ventricle approach is taken.

Usual preop diagnosis

DORV ± pulmonary stenosis; s/p PA band or modified Blalock-Taussig shunt; Taussig-Bing type of DORV; CHF

ERAS: Family preop counseling/education by the surgeon and anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, postop pain management options, DVT prophylaxis, physiotherapy plan, and possibility of NG/chest tubes and urinary drain postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Standard median sternotomy
Antibiotics	Cefazolin 25 mg/kg q4h
Surgical time	Aortic cross-clamp: 30–80 min Total: 2–3.5 h
Closing	Routine closure with chest tube in the pericardial

considerations	space; temporary ventricular pacing wire; possible LA line for monitoring
EBL	Minimal
Postop care	ICU for 1–4 d of controlled ventilation; possible pulmonary HTN protocol in cases of unrestricted pulmonary blood flow
Mortality	~2%
Morbidity	Hemorrhage ↓ CO Atrial dysrhythmias RV dysrhythmias Intraventricular tunnel obstruction Baffle leakage; residual RVOTO Heart block
Pain score	8–10

PATIENT POPULATION CHARACTERISTICS

Age range	3–24 mo
Male:Female	1:1
Incidence	1–3% of congenital heart defects
Etiology	No specific correlations or associated conditions
Associated conditions	Pulmonary stenosis; complete A-V canal defect; coarctation of the aorta; interruption of the aortic arch; straddling tricuspid valve

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Pathophysiology	Both great vessels arise from the RV, and there is a single, large VSD, whose location may vary (subaortic, subpulmonic). The pathophysiology varies according to the VSD location and other concomitant cardiac anomalies, such as aortic stenosis (AS) or

pulmonary stenosis (PS). Those with subaortic VSD, in the absence of PS, present with minimal or no cyanosis but may have large L → R shunt pulmonary overcirculation, CHF, and pulmonary HTN. In infants with PS in addition to subaortic VSD, the physiology is similar to TOF with pulmonary oligemia and R → L shunt. In DORV with subpulmonic VSD, deoxygenated venous return from RV is directed to the aorta, leading to cyanosis. The oxygenated LV output is directed through the VSD into the PA, leading to pulmonary overcirculation. This physiology resembles TGA. The surgical approach may consist of VSD closure or TOF or TGA repair. DORV with subpulmonary VSD and transposition is called the Taussig-Bing anomaly.

Anesthetic management

Is dictated by specific surgical repair

Suggested Readings

1. Bharucha T, Hlavacek AM, Spicer DE, et al: How should we diagnose and differentiate hearts with double-outlet right ventricle? Cardiol Young 2017; 27(1):1–15.
2. Spaeth JP: Perioperative management of DORV. Semin Cardiothorac Vasc Anesth 2014; 18(3):281–9.
3. Yoo SJ, van Arsdell GS: 3D Printing in surgical management of double outlet right ventricle. Front Pediatr 2018; 5:289.

SURGERY FOR HYPOPLASTIC LEFT HEART SYNDROME

SURGICAL CONSIDERATIONS

Description

Hypoplastic left heart syndrome (HLHS) represents a spectrum of left-sided cardiac malformations centered around a markedly hypoplastic LV and an atretic or hypoplastic aortic valve and ascending aorta; the mitral valve is also usually hypoplastic or atretic

(Fig. 12.4-12). Consequently, the RV supports both the pulmonary and systemic circulations. The pulmonary venous return (PVR) enters the RA via an ASD, and the admixture of systemic and pulmonary venous return is delivered into the RV and main PA. Systemic flow is delivered into the aorta by way of a typically large PDA. Cyanosis, CHF, and systemic hypoperfusion result as PVR decreases and pulmonary blood flow increases at the expense of systemic blood flow.

Until the mid-to-late 1980s, patients born with this anomaly usually died within the first 2 wk of life, with survival beyond 6 wk being very rare. A palliative surgical treatment was reported by Norwood in 1983. This treatment ofHLHS comprises staged operations, with the first stage designated as the **Norwood operation**. The procedure is directed toward establishing effective CO from the RV to the systemic circulation and to support the pulmonary circulation with a systemic-to-pulmonary arterial shunt. An adequate atrial septal communication is essential.

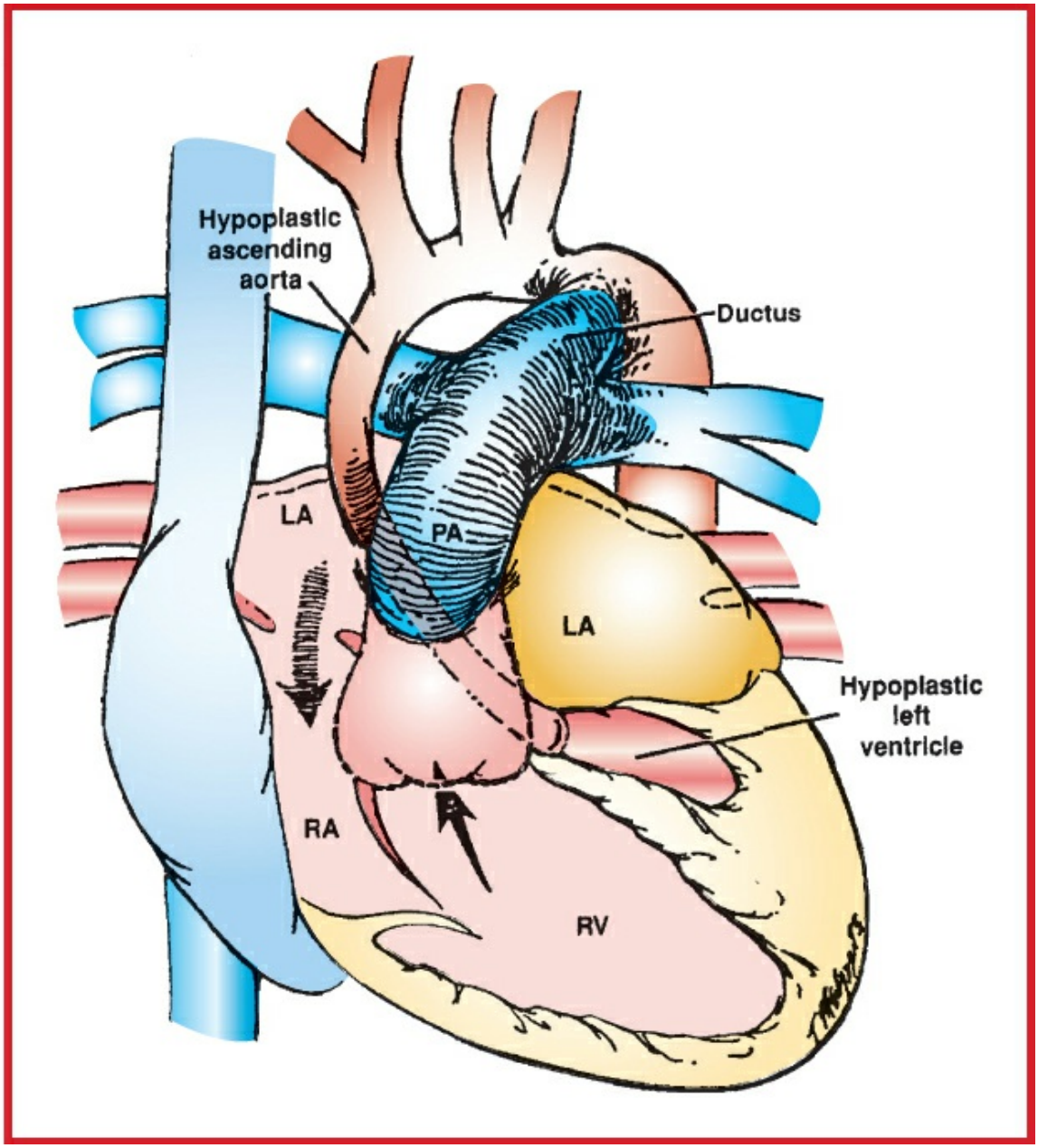

Figure 12.4-12 The anatomic features of hypoplastic left heart syndrome. The right atrium (RA), right ventricle (RV), and main pulmonary artery (PA) are larger than in neonates with normal circulation. LA, left atrium. (Reproduced with permission from Kaiser LR, Kron IL, Spray TL, edsMastery of Cardiothoracic Surgery. Lippincott-Raven, Philadelphia: 1998.)

Stage I (Norwood)

A midline sternotomy approach is used. The innominate artery (alternatively, the main PA or ascending aorta, if it is of adequate size) and RA appendage are cannulated, and CPB with cooling is instituted. The arch vessels and proximal descending thoracic aorta are dissected. Deep hypothermia with low-flow CPB technique is used. During arch reconstruction, cerebral blood flow is maintained, although many surgeons prefer total circulatory arrest. The ductus arteriosus is then divided, and the pulmonary end is

oversewn. Next, the main PA is divided, and the distal PA is oversewn. An aortotomy is created, extending from the interior aspect of the aortic arch through the lateral aspect of the ascending aorta to the level of the transected pulmonary trunk. The entire aortic arch complex is then augmented, creating a "neoaorta" from the proximal portion of the transected main PA, which is anastomosed to the ascending aorta and arch. A cryopreserved homograft patch is used to facilitate the repair. The RA is opened, and the atrial septum is excised to maximize the size of the interatrial communication. The heart is de-aired, and rewarming is started with full CPB. If circulatory arrest was used the cannulae are reinserted, and rewarming begins. Finally, a B-T systemic-to-PA shunt is created to provide pulmonary blood flow. The patient is weaned from CPB, a pericardial drainage tube is placed, and the chest is closed in standard fashion.

Currently, a modification of the Norwood, the Sano procedure, is strongly advocated by Japanese surgeons and is being adopted by many surgeons worldwide, including the United States. This involves abandoning the modified B-T shunt in favor of RV-PA shunt ± valve. This modification eliminates the diastolic runoff and preserves coronary blood flow. The major advantage is a stable early postop course. The long-term implications of right ventriculotomy in a systemic RV are not known at the present time. However, the objective of both procedures is to provide pulsatile systemic blood flow to the pulmonary circulation.

Stage II (bidirectional Glenn procedure)

As the PVR normally falls in the weeks after the first-stage operation, excessive pulmonary blood flow from the B-T shunt may → RV volume overload and CHF. The second-stage procedure for HLHS is intended to reduce the volume load on the single ventricle while maintaining adequate pulmonary blood flow. This operation consists of a bidirectional cavopulmonary (Glenn) shunt and usually is performed in children 4–6 mo old. Unlike the stage I shunt procedures, pulmonary blood flow is now nonpulsatile and passive and dependent on PVR. This interstage procedure is necessary to reduce the single-ventricle volume load that can come with the stage I and III procedures as it functions as the only systemic ventricle.

Stage III (Fontan procedure)

The third and final stages of the Norwood procedure usually are performed about 6–12 mo after the second stage and consist of the completion of the Fontan procedure. It is designed to divide the systemic venous return from the pulmonary venous return by establishing continuity from the IVC to the confluence of the PA and SVC.

Usual preop diagnosis

HLHS; mitral and aortic atresia

ERAS: Family preop counseling/education by the surgeon and anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, postop pair management options, DVT prophylaxis, physiotherapy plan, and possibility of NG/ches tubes and urinary drain postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Standard median sternotomy
Unique considerations	Deep hypothermia (<18°C) ± circulatory arrest; manipulation of PVR and SVR, both preop and postop, is extremely important, with the FiO_2 and ventilation being crucial in regulating pulmonary blood flow. For very high pulmonary blood flows and SaO_2 >85%, consider the addition of N_2 to lower the FiO_2 to <20%; use of afterload reduction to manipulate SVR and ↓ ventricular work.
Antibiotics	Cefazolin 25 mg/kg q4h
Surgical time	Aortic cross-clamp: 30–60 min Circulatory arrest (if used): 30–45 min Total: 2.5–3.5 h
Closing considerations	Sternum often left open, with chest tube in the pericardial space, with closure delayed until POD 2–4; temporary ventricular pacing wire; possible left atrial line for monitoring
EBL	Minimal-to-moderate
Postop care	2–7 h of controlled ventilation; moderate need for inotropic drugs; balancing PVR and SVR to optimize pulmonary blood flow and systemic CO
Mortality	10–20%
Morbidity	Hemorrhage Infection ↓ CO

	RV dysfunction Inadequate/excessive pulmonary blood flow Tricuspid regurgitation
Pain score	8–10

PATIENT POPULATION CHARACTERISTICS

Age range	5–30 d
Male:Female	2:1
Incidence	3–5% of congenital heart defects
Etiology	Often associated with genetic disorders, but no single associated defect
Associated conditions	CNS defects (29%); microencephaly (25–27%); VSD (5%); TGA

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Pathophysiology	HLHS is characterized by a hypoplastic or atretic aortic and mitral valves associated with hypoplasia of the LV, ascending aorta, and aortic arch. Pulmonary venous return enters the LA and then passes into the RA via an ASD or the PFO. Rarely, pulmonary venous return is via TAPVC to the RA. The systemic circulation is supplied entirely through the ductus arteriosus. Perfusion of the ascending aorta, coronary arteries, and transverse arch is retrograde via the ductus. Maintenance of adequate systemic perfusion relies on ductal patency and is achieved with continuous administration of PGE_1. Maintaining ↑ PVR by ↓ FiO_2 to 0.17–0.20 (less common now), or by adding CO_2 to breathing gas mixture, may be necessary. As the ductus closes, the systemic perfusion is compromised, thus leading to ischemia, acidosis, and eventually death. Survival is dependent

	on maintaining ductal patency and adequacy of mixing at the atrial level and a balance between PVR and SVR to ensure adequate pulmonary and systemic perfusion.
Cardiovascular	**Tests:** EKG; RAE/RVH; echo, assessment of tricuspid or common A-V valve regurgitation. Severe TR is a contraindication for first-stage repair.
Neurologic	Preop head ultrasound to r/o intracranial pathology (e.g., hemorrhage). Periop neurologic monitoring, including cerebral oximeter, is recommended (e.g., both hemispheres and flank to assess somatic oxygenation).
Laboratory	BUN; Cr; Hgb/Hct; Plt count
Premedication	Not indicated.
Transport to OR	See Transport of the Critically Ill Newborn (6th ed. p. 1400).
ERAS	Check compliance with presurgical ERAS recommendations including NPO status. Evaluate concurrent disease, and optimize volume status and hydration.

INTRAOPERATIVE

Anesthetic technique

GETA

Induction	On arrival in the OR, monitors are applied and ventilation should be adjusted to maintain arterial SaO_2 = 75–85%. Avoid hyperventilation (↑ pulmonary blood flow). Arterial SaO_2 >85% will cause systemic hypoperfusion. See Truncus Arteriosus.
ERAS	Verify preincision antibiotics.
Maintenance	Fentanyl (20–40 mcg/kg) with muscle relaxant (rocuronium 1 mg/kg) in divided doses on CPB.

	Volatile anesthetics on CPB. Midazolam (0.1–0.2 mg/kg) as tolerated	
Emergence	Transport to ICU intubated, ventilated, and monitored.	
Blood and fluid requirements	See Tetralogy of Fallot (p. 1391).	Blood loss can be due largely to dilutional coagulopathy and multiple suture lines.
Infusions	See Truncus Arteriosus (p. 1407).	
Monitoring	See Truncus Arteriosus (p. 1407).	
CPB	See TGA (p. 1402).	
Transition off CPB and Post-CPB	See TOF (p. 1391).	After stage I (Norwood) surgical repair, the blood flow continues to be supplied in a parallel fashion from the single ventricle. A small homograft conduit may be placed from the RV to PA (Kishimoto/Sano modification) instead of the traditional modified B-T shunt. This prevents the diastolic runoff of the B-T shunt and improves coronary perfusion. Optimal PaO_2 30–50 mm Hg with MAP 40–50 mm Hg.

POSTOPERATIVE

Complications	Bleeding Pulmonary overcirculation Myocardial dysfunction and failure Aortic arch obstruction Pulmonary HTN CNS injury
Multimodal pain management	CVICU management may include

	fentanyl, midazolam, and/or dexmedetomidine infusions. IV acetaminophen as appropriate

Suggested Readings

1. Oberhuber RD, Huemer S, Mair R, et al: Cognitive development of school-ag hypoplastic left heart syndrome survivors: a single center study. Pediatr Cardiol 2017; 38(6):1089–96.
2. Ohye RG, Schranz D, D'Udekem Y: Current therapy for hypoplastic left hear syndrome and related single ventricle lesions. Circulation 2016; 134(17):1265–79.
3. Roeleveld PP, Axelrod DM, Klugman D, et al: Hypoplastic left heart syndrome: fron fetus to fontan. Cardiol Young 2018; 28(11):1275–88.

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2. Fang ZA, Ghelani SJ, Koutsogiannaki S, et al: Validation of a mathematical model o bidirectional Glenn circulation with aortopulmonary collaterals and the implications for QP/QS calculation. J Cardiothorac Vasc Anesth 2018; 32:395–401.
3. Franklin SW, Szlam F, Fernandez JD, et al: Optimizing thrombin generation with 4- factor prothrombin complex concentrates in neonatal plasma after cardiopulmonary bypass. Anesth Analg 2016; 122:935–42.
4. Fudulu DP, Schadenberg A, Gibbison B, et al: Corticosteroids and other anti- inflammatory strategies in pediatric heart surgery: a national survey of practice. World J Pediatr Congenit Heart Surg 2018; 9:289–93.
5. Gleich S, Latham GJ, Joffe DC, et al.: Perioperative and anesthetic considerations i pulmonary atresia with intact ventricular septum. Semin Cardiothorac Vasc Anesth 2018; 22(3):256–64.
6. Holtby HM: Anesthetic considerations for neonates undergoing modified Blalock- Taussig shunt and variations. Paediatr Anaesth 2014; 24:114–9.
7. Varghese J, Kutty S, Bisselou Moukagna KS, et al: Five-year experience wit immediate extubation after arterial switch operations for transposition of great arteries. Eur J Cardiothorac Surg 2017; 51:728–34.

CHAPTER 12.5

Pediatric General Surgery

SURGEONS

Jordan S. Taylor, MD
James Wall, MD, MSE, FACS

ANESTHESIOLOGISTS

Andrew J. Giustini, MD, PhD
Rebecca E. Claure, MD
Brenda Golianu, MD

RESECTION OF CYSTIC HYGROMA, BRANCHIAL CLEFT CYST, THYROGLOSSAL DUCT CYST, OR OTHER CERVICAL MASS

SURGICAL CONSIDERATIONS

Description

Common lesions requiring dissection in the neck and floor of the mouth include branchial cleft remnants, thyroglossal duct remnants, vascular malformations (hemangiomas), lymphatic malformations (cystic hygromas), and infected or enlarged lymph nodes refractory to antibiotic therapy.

Surgical approach

Ideally, an acutely inflamed node (typically Staphylococcus aureus) usually is incised and drained; a chronically infected node (e.g., catscratch disease, atypical TB) or an enlarged node (lymphoma) is excised. Remnants of the first and second (rarely third) branchial clefts are lateral masses found and excised from the parotid region anterior to the ear, sometimes extending to the external auditory canal, or the anterior border of the sternocleidomastoid muscle, sometimes extending through the carotid bifurcation to the tonsillar fossa, respectively. Thyroglossal duct remnants are midline lesions that involve the central portion of the hyoid bone and may extend up to the base of the tongue. When acutely infected and unresponsive to a course of antibiotics, they can be drained; when quiescent, thyroglossal duct remnants are excised. Occasionally, it is advantageous for the anesthesiologist to digitally depress the tongue near the foramen cecum to help the surgeon know when the dissection approaches this structure. Vascular and lymphatic malformations may overlap; they tend to be lateral and are sometimes extensive. Significant blood loss may result, and resection may involve tedious dissection of neurovascular structures, including the carotid sheath, brachial plexus, sympathetic chain, phrenic nerve, and cranial nerves V, VII, X, XI, and XII.

Transaxillary subcutaneous **endoscopic surgery** allows an alternate approach to resecting select lesions. This approach involves using tiny incisions placed in the ipsilateral axilla through which endoscopic ports are placed and tunneled under the skin to the neck, aided by carbon dioxide insufflation, to resect benign lesions using laparoscopic tools. This approach is not widely practiced; however, it appears to be safe and effective for a wide variety of lesions, including thyroid and parathyroid lesions. It completely avoids a neck incision, which can be cosmetically unappealing.

Usual preop diagnosis

Cystic hygroma; branchial cleft cyst/fistula; thyroglossal duct cyst; atypical mycobacterial adenitis

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care and pain management options, description of antimicrobial prophylaxis, skin preparation, and possible need for transfusion. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Lateral Lesions (Branchial Cleft Remnant Lymph Node, Vascular + Lymphatic Malformations)	Midline Lesions (Thyroglossal Duct Remnants)
Position	Neck extended, turned to contralateral side	Neck extended
Incision	Oblique	Transverse
Special instrumentation	Facial nerve monitor; nerve stimulator	None
Unique considerations	Nerve testing	None
Antibiotics	Cefazolin 30 mg/kg iv	⇐
Surgical time	1–6 h	1 h
EBL	5–20 mL/kg	<5 mL/kg
Postop care	PICU; airway monitoring	None
Mortality	<2%	<1%
Morbidity	Airway compromise	⇐
	Fluid accumulation	⇐
	Infection	⇐
Pain score	3–4	3–4

PATIENT POPULATION CHARACTERISTICS

Age range	Newborn–school age
Male:Female	1:1
Incidence	Common
Etiology	Developmental anomaly; mycobacteria
Associated conditions	Hygroma-mediastinal airway involvement; branchial cleft

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

These patients generally are otherwise healthy children. Cervical masses, including cystic hygroma (cystic lymphangioma), may cause airway obstruction and difficult intubation (also see EXIT Procedures).

Respiratory	The size and extent of the cervical mass should be defined carefully in an effort to detect the potential for airway compromise. Inspiratory stridor suggests supraglottic obstruction, whereas expiratory stridor is associated with subglottic/intrathoracic obstruction. If these patients have had prior CT/MRI imaging, these records, including prior anesthesia records, should be reviewed. **Tests:** CXR ± CT/MRI scans
Cardiovascular	Cervical masses may be adherent to and/or cause compression of the great vessels. **Tests:** CT/MRI scans
Hematologic	**Tests:** For cystic hygroma, or if a cervical mass involves great vessels or extends into the mediastinum, T&C and Hct
Laboratory	Other tests as indicated from H&P
Premedication	If patient >7–9 mo and asymptomatic, consider midazolam (0.5 mg/kg po) 30 min prior to arrival in OR. Use premedication cautiously in patients with potential airway compromise.

ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Evaluate for concurrent disease, nutritional status, and hydration.

INTRAOPERATIVE

Anesthetic technique

GETA with pediatric circuit; OR temperature 75°F–80°F; forced-air warmer on OR table; maintain SpO_2 between 92% and 94% to minimize retinopathy in premature infants at risk.

Induction	Standard pediatric induction in patients without airway compromise. IV access should be secured before induction when airway compromise is present or suspected. Mask induction with sevoflurane in 100% O_2. As plane of anesthesia deepens, gently assist ventilation. (Keep PIP < 20 cm H_2O.) Prior to laryngoscopy, consider atropine (0.02 mg/kg) if <1 mo old to prevent vagal response. If difficult airway is anticipated, proceed with difficult airway algorithm. If partial airway obstruction exists, maintain spontaneous ventilation and perform laryngoscopy under deep anesthesia (e.g., ~2 MAC of volatile agent). FOB should be available. Have full range of ETT sizes available because airway narrowing may be present. Once the airway is secured, proceed with NMB (e.g., rocuronium 0.6 mg/kg iv or vecuronium 0.1 mg/kg iv), unless monitoring facial nerve function.
ERAS	Verify preincision antibiotics. Assess volume status. Discuss with surgeon local wound infiltration at conclusion of procedure. Consider iv acetaminophen (10 mg/kg for patients <1 yr old or 15 mg/kg for older patients with maximum dose of 650 mg). Consider PONV prophylaxis with iv ondansetron (0.1 mg/kg).

Maintenance	Standard pediatric maintenance. Surgeon may infiltrate incision with local anesthetic. Limit bupivacaine to 2.5 mg/kg (maximum: 10 mL of 0.25% bupivacaine). Supplement inhalation anesthetic with small doses of fentanyl (e.g., 1–2 mcg/kg), hydromorphone (0.005–0.01 mg/kg), or morphine (0.05–0.1 mcg/kg).	
Emergence	If NDMR was used, reverse neuromuscular blockade with sugammadex (2–4 mg/kg) or with a combination of neostigmine (0.07 mg/kg) and glycopyrrolate (0.01 mg/kg). Do not attempt reversal with neostigmine and glycopyrrolate until first twitch of TOF has returned. Confirm air leak around ETT and extubate when fully awake.	
Blood and fluid requirements	Minimal blood loss usually IV: 20–22 ga × 1; 2nd large iv if great vessel involvement BSS @ maintenance (see p. D-3)	Minimal 3rd-space losses. Each mL blood loss can be replaced with 3-mL BSS or 1-mL albumin 5%. If great vessels are involved, place at least one iv in lower extremity. Blood loss can be quite sudden; have blood available in OR.
Monitoring	Standard monitors ± Arterial line (22 ga)	An arterial line is used when there is risk of large blood loss or to assist management of ventilation.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	ETT dislodged/loss of airway Laryngospasm Bronchospasm	ETT must be carefully secured. Liberal use of benzoin. Avoid tension on ETT by circuit hoses. Hold

	Hemorrhage	ETT during surgeon's intraoral examination.

POSTOPERATIVE

Complications	Subglottic edema Upper airway obstruction from edema related to tumor resection Recurrent laryngeal nerve injury	Dexamethasone (0.5 mg/kg) and nebulized racemic epinephrine (2.25%) with mist O_2 Close postop monitoring for respiratory compromise, including SaO_2, proximity to RN station, and frequent postop assessment
Multimodal pain management	Use multimodal approach emphasizing regional analgesic techniques, combined with nonopioid analgesics and opioid analgesics as needed. Local infiltration by surgeon Consider hydromorphone PCA by RN, with basal rate of 1 mcg/kg/h (0.001 mg/kg/h) and bolus dose of 2 mcg/kg/ (0.002 mg/kg) q10min lockout. Acetaminophen (10–15 mg/kg iv q6h, 10–15 mg/kg po q6h once taking orals). In infants younger than 1 yr old, use 10 mg/kg of acetaminophen po or iv. Maximum is 650 mg acetaminophen/dose for patients >42 kg. Consider lorazepam 5–10 mcg/kg iv q6h for management of anxiolysis. If PCA is not desired due to concern of possible oversedation, consider: Morphine (0.05–0.1 mg/kg q2–4h) Hydromorphone (0.005–0.01 mg/kg q1–4h)	
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.	

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anomalies. Semin Pediatr Surg 2006; 15(2):70–5.
3. Gross E, Sichel JY: Congenital neck lesions. Surg Clin North Am 2006; 86(2):383–92.
4. Kolomvos N, Theologie-Lygidakis N, Tzerbos F, et al: Surgical treatment of oral and facial soft tissue cystic lesions in children: a retrospective analysis of 60 consecutive cases with literature review. J Craniomaxillofac Surg 2014; 42(5):392–6.
5. Rao KS, Shenoy T: Anesthetic management of a large cystic hygroma in a newborn. Anesth Essays Res 2015; 9(2):270–2.
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ESOPHAGUS—FOREIGN BODY REMOVAL AND DILATION

SURGICAL CONSIDERATIONS

Description

Flexible, diagnostic **esophagogastroduodenoscopy**—a common procedure in pediatrics—usually is performed under GA or heavy sedation in an endoscopy suite or special procedure area. **Rigid esophagoscopy** usually is performed for therapeutic indications such as removal of a foreign body (FB), dilation of an esophageal stricture, or injection of varices. The procedure is similar for each diagnosis and generally is performed with ET intubation. FB removal is normally a very short procedure, whereas dilation and variceal injection can be prolonged and may require multiple insertions/removals of the endoscope. Compression of the trachea distal to the ETT by the rigid esophagoscope may occur. **Radial balloon dilation**, which involves less shear stress than repeatedly passing a bougie catheter, is becoming a popular method of dilation. This is done under endoscopic and fluoroscopic guidance and is accompanied by a very low rate of complications. Functional luminal imaging probes are relatively new, but utilize impedance measurements to enable precise dilation without radiation exposure.

Usual preop diagnosis

Esophageal FB; stricture; esophageal varices

ERAS: For elective procedures, family preop counseling by the

surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Supine, head to the side for rigid esophagoscopy
Special instrumentation	Rigid esophagoscopes; forceps; dilators
Unique considerations	Esophagoscope may obstruct airway; dilation may perforate esophagus.
Surgical time	5 min–2 h
Closing considerations	Be prepared for abrupt ending
EBL	<5 mL/kg
Postop care	Airway support
Mortality	<5%
Morbidity	Esophageal perforation: 2–5%
Pain score	2–3

PATIENT POPULATION CHARACTERISTICS	
Age range	Newborn–school age
Male:Female	1:1
Incidence	1/1000
Etiology	Varices—portal HTN; FB—possible stricture
Associated conditions	Esophageal atresia—stricture; portal HTN—varices

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Esophagoscopy for FB removal is usually performed in healthy infants and toddlers,

although it can occur in any age group. All of these patients should be treated with full-stomach precautions, and additional imaging may be necessary to evaluate for multiple FBs.

Esophageal dilation is usually performed in three distinct patient populations: (a) those with prior tracheoesophageal fistula (TEF) repair, (b) those with prior ingestion of a caustic substance, and (c) those with skin and connective tissue diseases (e.g., epidermolysis bullosa [EB]).

Respiratory	Patients with TEF may have residual BPD, chronic lung disease, or subglottic stenosis. Check anesthesia records for ETT size used. Those with prior caustic ingestion and pulmonary aspiration may have resultant chemical pneumonitis and/or fibrosis. Patients with EB may have limited mouth opening and may have a difficult airway or require special care regarding placing and securing of ETT. See discussion of EB considerations in Chapter 13.2 Non-OR anesthesia, pediatric endoscopy. **Tests:** CXR, if clinically indicated
Cardiovascular	There may be persistent congenital cardiac anomalies in the TEF patient. **Tests:** EKG, echo as indicated. Cardiology consultation, as needed.
Laboratory	No routine lab analyses are required.
Premedication	For esophageal dilation, patient preference is extremely important because some patients have undergone this procedure several times. For FB removal, iv access is usually recommended before induction, though a mask induction may be selected by the anesthesiologist as well. Use premedication cautiously in patients with potential airway compromise.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Optimizing duration of NPO status must be balanced with potential risk of perforation due to continued FB

	presence. Evaluate for concurrent disease.

INTRAOPERATIVE

Anesthetic technique

GETA, using a pediatric circuit. Room temperature should be maintained at 75°F–80°F. Forced-air warmer may be used.

Induction	If the patient is presenting for dilation alone and has no evidence to suggest reflux or retained food in the esophagus, a standard inhalation or iv induction may be performed. Rapid-sequence induction is usually appropriate for FB removal. Prior to laryngoscopy, consider atropine (0.02 mg/kg) if <1 mo old to prevent vagal response. Preoxygenate for 2–3 min. Apply cricoid pressure. Propofol (2–3 mg/kg) followed by succinylcholine (1–2 mg/kg). Rocuronium (1 mg/kg) may be used if longer procedure is anticipated. Intubate the trachea with age-appropriate ETT. If succinylcholine was used, consider additional neuromuscular blockade if needed subsequently.
ERAS	Verify preincision antibiotics. Assess volume status, and potential for airway compromise. Consider iv acetaminophen (10 mg/kg for patients <1 yr old and 15 mg/kg for older patients with a maximum dose of 650 mg). Consider PONV prophylaxis with iv ondansetron (0.1 mg/kg).
Maintenance	Maintain anesthesia with volatile agent/N_2O/O_2 and opioids (iv morphine 0.05–0.1 mg/kg, iv hydromorphone 0.005–0.01 mg/kg, or iv fentanyl 1–2 mcg/kg), or TIVA technique with remifentanil 0.05–0.2 mcg/kg/min and propofol 100–250 mcg/kg/min is usually effective. The addition of small doses of ketamine can add respiratory and cardiovascular stability, but may delay emergence. Ensure adequate

	depth of anesthesia to prevent movement during rigid bronchoscopy; consider neuromuscular blockade.	
Emergence	Extubate when fully awake. If NDMR was used, reverse neuromuscular blockade with sugammadex (2–4 mg/kg) or with a combination of neostigmine (0.07 mg/kg) and glycopyrrolate (0.01 mg/kg). Do not attempt reversal with neostigmine and glycopyrrolate until first twitch of TOF has returned.	
Blood and fluid requirements	IV: 20–22 ga × 1 BSS @ maintenance	
Monitoring	Standard monitors Peripheral nerve stimulator	
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Esophageal perforation Aspiration Accidental extubation Stridor 2° subglottic edema	Esophageal perforation, more common with rigid esophagoscopy, may lead to pneumothorax (R > L).

POSTOPERATIVE

Complications	Residual neuromuscular blockade Pneumothorax, esophageal perforation	
Multimodal pain management	Minimal postop pain	Consider iv/po acetaminophen (10 mg/kg for patients <1 yr old or 15 mg/kg for older patients with a maximum dose of 650 mg) q6h. If patient reports marked substernal discomfort, suspect esophageal perforation.
Tests	None. CXR may be considered if there is concern	

	about possible residual FB or possible pneumothorax.
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.

Suggested Readings

1. Bakan M, Topuz U, Umutoglu T, et al: Remifentanil-based total intravenous anesthesia for pediatric rigid bronchoscopy: comparison of adjuvant propofol and ketamine. Clinics (Sao Paulo) 2014; 69(6):372–77.
2. Gercek A, Ay B, Dogan V, et al: Esophageal balloon dilation in children: prospective analysis of hemodynamic changes and complications during general anesthesia. J Clin Anesth 2007; 19:286–89.
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ACHALASIA, HELLER MYOTOMY, PERORAL ENDOSCOPIC MYOTOMY (POEM), AND ADVANCED ENDOSCOPIC SURGERIES

SURGICAL CONSIDERATIONS

Description

Achalasia is a rare disorder of the esophagus characterized by increased tone of the lower esophageal sphincter (LES), failure of relaxation of the LES, and loss of norma peristalsis of the distal portion of the esophagus. Pediatric patients often present with

dysphagia to solids and liquids (sequentially), weight loss, and regurgitation. Diagnosis in children is often delayed because the presenting symptoms are misinterpreted as more common conditions like GERD and failure to thrive. If symptoms have been present for a long period of time, an esophagram may show the classic "bird's-beak" appearance with proximal dilation and distal narrowing. Esophageal manometry is essential for identifying the increased resting pressure in the LES, abnormal peristalsis, and failure of the LES to relax after swallowing.

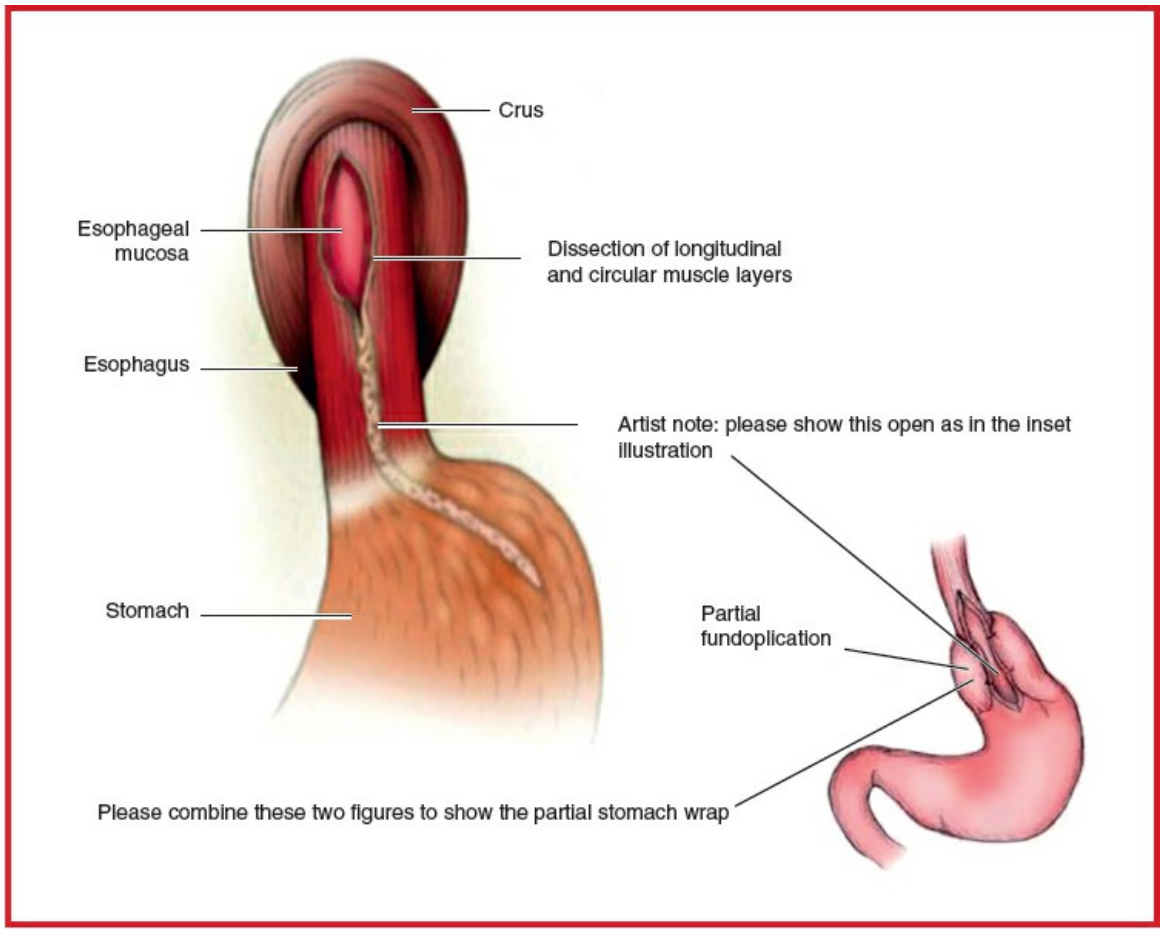

Figure 12.5-1 Heller myotomy.

Surgical approach

There are various subtypes of achalasia; type II is characterized by increased pressure throughout the esophagus and is the most responsive to surgical intervention. Surgery is aimed at reducing the elevated resting pressure of the LES; typically this is achieved by either graded dilation or laparoscopic esophageal myotomy with fundoplication. The **Heller myotomy** is typically done through four or five laparoscopic incisions. The longitudinal and circular muscle fibers of the distal esophagus and stomach are carefully divided. Complete dissection of the GE junction may be necessary to ensure adequate myotomy proximal to the GE junction; the goal is extension of the myotomy 5 cm above

the LES, in addition to the 2–3 cm onto the stomach (see Fig. 12.5-1).

Endoscopy is performed after the myotomy to inspect the esophageal mucosa for any tears. To reduce esophageal reflux, a fundoplication may be performed consisting of a partial stomach wrap, either anterior or posterior (Dor or Toupe).

Variant procedures or approaches

Peroral endoscopic myotomy (POEM) as a treatment for achalasia has gained wide acceptance in the adult population and is becoming a more frequent alternative treatment for children with achalasia. It should only be done by an advanced endoscopic surgeon with adequate training. Beginning ~10 cm from the GE junction, a lift is made in the submucosa with indigo carmine. The mucosotomy is made above where the myotomy is made to offset any potential full-thickness defect in the esophagus. A 1–2-cm mucosotomy is made at that level on the right side of the esophagus; the endoscope is tunneled to at least 2 cm past the GE junction in the submucosal plane. The myotomy is performed using the triangle knife from 5 cm above the LES to the 2–3 cm onto the stomach; the circular muscle fibers are divided while the longitudinal muscles remain intact. The mucosotomy is closed at the conclusion with endoscopic clips.

Usual preop diagnosis

Achalasia; GERD

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Heller Myotomy with Anterior Fundoplication	POEM
Position	Supine	⇐
Incision	Four to five laparoscopic ports	Endoscopic
Special instrumentation	Endoscope	CO_2 gas
Unique considerations	Liquid diet for 2 d prior due to high rate of retained esophageal	⇐

	material	
Antibiotics	Cefazolin 30 mg/kg iv	⇐
Surgical time	2 h	1 h
Closing considerations	None	NA
EBL	<5 mL	⇐
Postop care	NPO for 24 h, 2 wk full liquid diet, 6 mo PPI	⇐
Mortality	<0.01%	⇐
Morbidity	Duodenal perforation	Duodenal perforation
	Incomplete myotomy	Incomplete myotomy
	Wrap failure	GERD
	Hiatal hernia	
Pain score	3–6	1–3

PATIENT POPULATION CHARACTERISTICS	
Age range	5 yr–adult
Male:Female	~1.25:1
Incidence	0.1/100,000
Etiology	Abnormal relaxation of the lower esophageal sphincter and dysmotility of the esophageal body
Associated conditions	Trisomy 21, Trypanosoma cruzi

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Achalasia is a condition of abnormal esophageal motility and increased pressure at the LES. There is often a delay in the diagnosis because the symptoms are easily misinterpreted. Patients may have dilated proximal esophagus and be at increased risk for aspiration.

Respiratory	Increased risk for aspiration 2° esophageal dysmotility **Tests:** CXR, barium esophagram
Gastrointestinal	Liquid diet for 2 d prior to procedure; dilated esophagus
Laboratory	Hct; T&C
Premedication	Consider 0.5 mg/kg po midazolam (maximum 20 mg) or 0.05–0.1 mg/kg iv midazolam (maximum 2 mg).
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Optimizing duration of NPO status must be balanced with potential risk of perforation due to continued FB presence. Evaluate for concurrent disease.

INTRAOPERATIVE

Anesthetic technique

GETA, forced-air warmer; maintain OR temperature at 75°F–80°F.

Induction	IV catheter should be placed prior to induction. Preoxygenate 2–3 min. Rapid-sequence induction with cricoid pressure should be performed, using propofol (2–3 mg/kg) or succinylcholine (1–2 mg/kg iv) or rocuronium (1 mg/kg). Confirm BS after insufflation (if laparoscopic).
ERAS	Verify preincision antibiotics. Assess volume status and potential for airway compromise. Consider iv acetaminophen (10–15 mg/kg, maximum dose 650 mg). Consider PONV prophylaxis with iv ondansetron (0.1 mg/kg).
Maintenance	Volatile agent and air/O_2. Maintain muscle relaxation. If laparoscopic, surgeon should infiltrate wound sites with bupivacaine 0.25%.
Emergence	If NDMR was used, reverse neuromuscular blockade with sugammadex (2–4 mg/kg) or with a combination of neostigmine (0.07 mg/kg) and

	glycopyrrolate (0.01 mg/kg). Do not attempt reversal with neostigmine and glycopyrrolate until first twitch of TOF has returned. Endoscopic suction should be used prior to extubation.	
Blood and fluid requirements	Minimal blood loss IV: 18 or 20 ga × 1 BSS @ maintenance	
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Hypoxia ↓ BP	DDX: Movement of the ETT; obstruction of ETT by kinking or secretion; pneumothorax Blood loss; tension pneumothorax; ↓ venous return 2° ↑ intra-abdominal pressure (if laparoscopic)

POSTOPERATIVE

Complications	Esophageal perforation Pneumothorax Aspiration
Multimodal pain management	Acetaminophen 10–15 mg/kg iv q6h, maximum dose of 650 mg Ketorolac (0.5 mg/kg iv up to 15 mg q6 × 24–72 h) This procedure typically has modest postop pain.
Tests	CXR
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.

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REPAIR OF TRACHEOESOPHAGEAL FISTULA AND ESOPHAGEAL ATRESIA

SURGICAL CONSIDERATIONS

Description

The majority of infants with tracheoesophageal fistulae (TEF) have an associated esophageal atresia (EA), as shown in Figure 12.5-2 (type C). The Dx is made presumptively when an NG tube cannot be advanced past 8–13 cm and gas is present in the stomach. The complications of aspiration (gastric contents come up the fistula into the trachea) and GI distension compromising respiration (from passage of air down the fistula into the intestines) are diminished by repair within a few days of birth. Primary repair without gastrostomy is routine. The absence of stomach and bowel gas suggests a pure EA without fistula (type A). A staged procedure—initial gastrostomy with deferred EA repair—may be used in babies <1 kg, those with pure EA, or those with more critical associated anomalies.

Surgical approach

All cases with TEF should begin with rigid bronchoscopy while the patient is spontaneously breathing. Bronchoscopy allows identification of the level of the TEF and detection of a second fistula and rules out a tracheoesophageal cleft that would be managed differently. The operation is performed in left-lateral decubitus position through a 4th interspace right thoracotomy. Preop echo is advised to look for cardiac anomalies and confirm a normal left-sided aortic arch. In the case of a right-sided arch (10%), most surgeons approach the fistula through a left thoracotomy. Debate continues on whether the best approach is retropleural or transpleural. The former is slower, but it may diminish the chances of empyema if the esophageal anastomosis leaks.

Another approach is thoracoscopy. There is now extensive experience with this

approach, and it is proven to be a safe and effective method of repair in children, even those with complex congenital heart disease. It is performed using three or four trocars in the modified (prone) left-lateral decubitus position, causing the lung to drop forward as 5 mm Hg capnothorax is achieved. Dividing the azygous vein is often necessary to find the subjacent fistula, branching off the posterior aspect of the trachea (type C). The right bronchus, aorta, and (rarely) left bronchus may be mistaken for this structure. Division of the fistula may dramatically improve ventilation; until this moment, it is sometimes necessary to operate in short 3–5-min bursts, relaxing the lung and mediastinal retraction for 1–2 min when saturations descend to critical levels. Afterward, the proximal fistula is located with the assistance from the anesthesiologist advancing the oroesophageal tube and then is dissected upward into the root of the neck to achieve sufficient length for anastomosis. After the posterior wall of the anastomosis is complete, some surgeons will ask for the NG tube to be replaced by a small (5 or 6 Fr) feeding tube, which is advanced into the stomach, separating the anterior from posterior esophageal wall during closure and permitting enteric feeds during the customary 1 wk before an esophagram is performed. This tube must be fixed in place because it has a tendency to become dislodged. Because neck hyperextension can place significant tension on the anastomosis, postop reintubation with direct laryngoscopy is to be avoided. When the length of native esophagus is too short, even after lengthening maneuvers, both ends can be tied to the prevertebral fascia or attached to monofilament sutures and brought tangentially out of the back skin (Foker). If the esophagus is affixed to the prevertebral fascia, reoperation occurs months later after the esophagus elongates relative to the vertebral bodies. If it is still not of sufficient length, it is replaced with the stomach or bowel. If the surgeon has elected for the **Foker procedure**, the esophagus is stretched daily over a 1–2-wk period prior to the surgery to provide sufficient length for a secondary anastomosis. A chest tube is usually left in place.

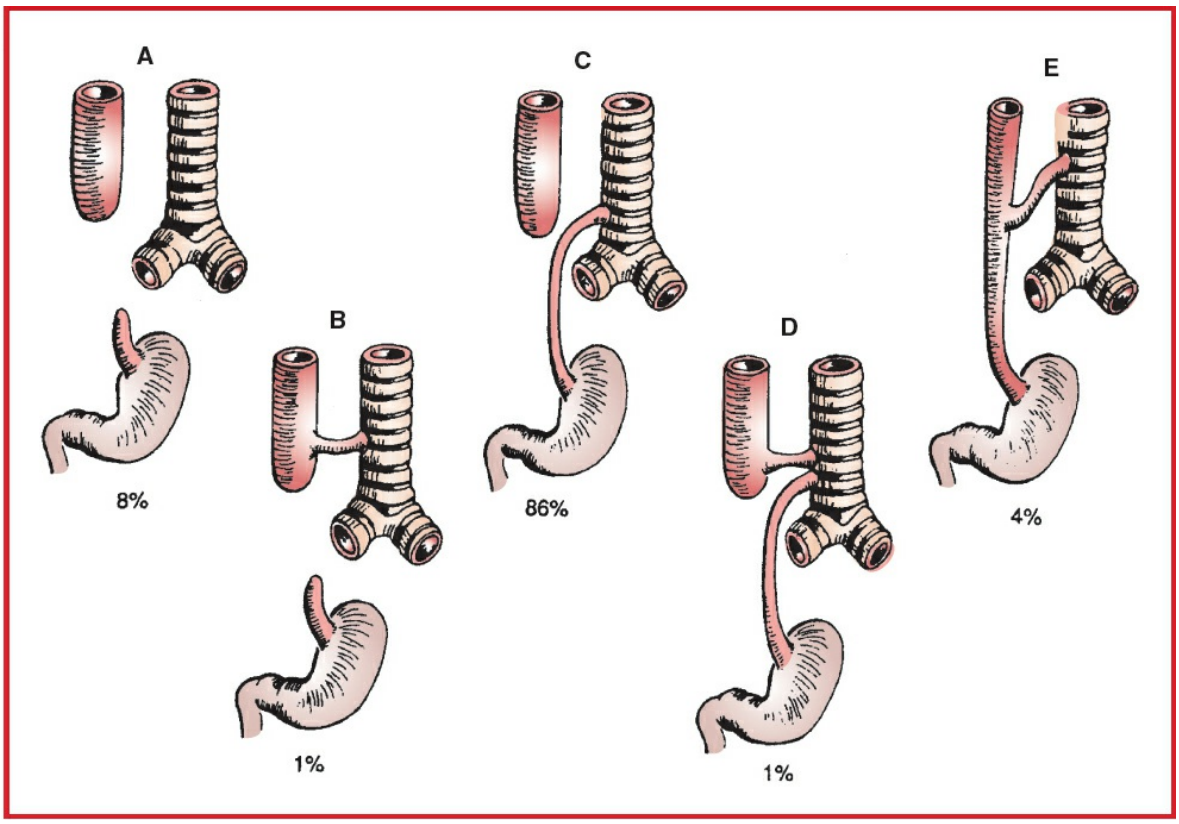

Figure 12.5-2 Types of esophageal atresia. **A:** Pure esophageal atresia. **B:** Proximal fistula. **C:** Esophageal atresia, distal fistula. **D:** Proximal and distal fistula. **E:** Pure tracheoesophageal fistula. (Redrawn from Ravitch MM, et al., eds:Pediatric Surgery, Vol. 1, 3rd edition. Year Book Medical Publishers, Chicago: 1979. Copyright © 1979 Elsevier. With permission.)

Variant procedures or approaches

Pure EA without fistula (type A) often involves a long gap—the initial operation is a feeding G-tube along the lesser gastric curve, followed by definitive operation months later or the **Foker procedure**. A pure fistula without EA (type E)
is usually diagnosed later in life and often occurs in the neck; it is repaired through a cervical incision by dividing the fistula and oversewing both the esophageal and tracheal sides.

Usual preop diagnosis

EA; TEF

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care and pain management options, description of antimicrobial prophylaxis, skin preparation, and possible need for transfusion. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Primary Repair	Gastrostomy
Position	Lateral	Supine
Incision	Posterolateral thoracotomy (side opposite aortic arch)	LUQ
Special instrumentation	NG tube in the upper pouch	G-tube
Unique considerations	Loss of ventilation via fistula; lung compression	May be done under local anesthesia
Antibiotics	Preop: ampicillin 25 mg/kg iv + gentamicin 2.5 mg/kg iv	⇐
Surgical time	2–4 h	1 h
Closing considerations	Extubation favored	Local anesthetic; wound infiltration
EBL	10 mL/kg	5 mL/kg
Postop care	NICU; humidified mist; avoid CPAP and neck hyperextension.	⇐
Mortality	1–20%, depending on associated anomalies	5%
Morbidity	Stricture: 20–40%	—
	Leak: 10–20%	—
	Aspiration	⇐
	Atelectasis	—
	Stridor	—
	GERD	—
	Tracheomalacia	—
Pain score	7–8	3–4

PATIENT POPULATION CHARACTERISTICS

Age range	Days–weeks

Male:Female	1:1
Incidence	1 in 4000 births
Etiology	Unknown
Associated conditions	Vertebral, anal, TEF, renal (or radial) anomalies (VATER association); vertebral, anal, cardiac, TEF, renal, limb anomalies (VACTERL association); trisomies 13 and 18; hydrocephalus

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

EA and TEF usually are detected in the first day of life, although TEF without atresia may be difficult to diagnose until the patient experiences recurrent pneumonia, cyanosis associated with feeding, or abdominal distension. The fistula is usually at the distal trachea near the carina. Because of the risk of pulmonary aspiration, initial gastrostomy may be performed in babies <1 kg. Conditions frequently associated with TEF include prematurity (30–40%) and congenital anomalies such as cardiac (20–35%), including ASD, VSD, TOF, and AV canal, genitourinary disorders (15–24%), GI disorders (16-24%, including duodenal or ileal atresia, malrotation, and imperforate anus), skeletal anomalies (13–18%), central nervous system disorders (10%), mediastinal disorders (8%), and chromosomal disorders (5.5%). The term VACTERL association (vertebral anal, cardiac, tracheoesophageal, renal, limb) refers to this group of anomalies, which may occur in varying combinations.

Preop, the following interventions are recommended to minimize risk of aspiration: avoid feeding, upright positioning, and intermittent suctioning of the upper pouch via a NG tube.

Respiratory	The upper esophageal pouch should be suctioned to minimize aspiration. Respiratory distress may be present due to lung immaturity if preterm, or aspiration pneumonitis, and may require preop intubation and mechanical ventilation. Single-lung ventilation is typically not tolerated in small babies, and necessary surgical working space can be created by regulated pneumothorax for

	thoracoscopy or retraction for open surgery. **Tests:** CXR, ABG
Cardiovascular	Associated cardiac abnormalities include VSD, PDA, tetralogy of Fallot, ASD, and coarctation of the aorta. At risk for pulmonary HTN with R → L shunt. In ductal-dependent patients, maintain prostaglandin infusion (PGE_1). **Tests:** Echo
Gastrointestinal	Associated GI anomalies may occur (e.g., imperforate anus, midgut malrotation, duodenal atresia, pyloric stenosis).
Musculoskeletal	Musculoskeletal anomalies are usually of little anesthetic significance, except for possible C-spine involvement.
Hematologic	For the first 2–3 mo of life, the O_2-carrying capacity of blood is increased because of the presence of fetal Hb with its ↓ sensitivity to 2,3-DPG. A shift to the right of the O_2 sat curve results in ↑ O_2-Hb affinity. As a result, tissue oxygenation may be reduced, especially with anemia (Hb < 12 g/dL @ <2–3 mo). Although TEF repair is not usually associated with significant blood loss, a T&C is indicated. Patients should be well hydrated and should have adequate urine output. **Tests:** Hct; T&C; others as indicated from H&P
Laboratory	Serum electrolytes, ABG, blood glucose, to determine metabolic state
Premedication	Usually none. Use premedication cautiously in patients with potential airway compromise. Premedication is usually not needed.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Evaluate for concurrent disease, and optimize nutritional status and hydration. Discuss plans for regional anesthesia, epidural, erector spinae plane catheter, or local infiltration by surgeon. Postop care

	in neonatal intensive care.

INTRAOPERATIVE

Anesthetic technique

GETA for thoracoscopy, using a pediatric circuit. Warm room to 75°F–80°F and use forced-air warmer. If thoracotomy is planned, the child is otherwise healthy, and extubation is planned within 48 h, consider placing an epidural catheter via caudal route after the airway is secured and the child is anesthetized. If surgical incision permits, an erector spinae plane catheter may also be considered. Patients with large fistulae may need awake gastrostomy or a Fogarty catheter placed via the gastrostomy, in conjunction with FOB, to occlude the distal end of the fistula. Alternatively, the Fogarty catheter car be used to occlude the proximal end of the fistula via the trachea.

Induction	Atropine (0.02 mg/kg iv in children <1 mo) may be given before induction to ablate vagal response to laryngoscopy. Traditionally, spontaneous ventilation and awake intubation have been advocated to minimize gastric distension; however, most cases will do well with iv induction and this is now the most common approach. IV induction may be performed with care during ventilation to minimize PIP and potential inflation of the stomach. Advance ETT to right mainstem and withdraw until bilateral breath sounds are present. Rotate ETT so the bevel faces posteriorly to prevent intubation of the fistula. If rigid bronchoscopy is performed after induction, ETT is ideally placed 1 cm below where fistula was visualized. This can be technically difficult as the tube can migrate into the fistula or the fistula can often be located near the carina, in which case intubation above the fistula is necessary. Always have a flexible pediatric bronchoscope available to verify placement of ETT and site of TEF. Keep air leak around ETT to a minimum (leak at 18–35 cm H_2O) to minimize alterations in ventilation 2° changes in chest and pulmonary compliance. The depth of the TEF should be noted on the initial rigid

	bronchoscopy. This depth guides ETT placement intraop and any postop attempts at reintubation, which can be catastrophic if the ETT is advanced through the fistula repair.
ERAS	Verify preincision antibiotics. Assess volume status. Consider caudal epidural catheter or erector spinae catheter.
Maintenance	Standard maintenance with inhalational anesthetic, TIVA, or combination. Avoid high FiO_2 if possible in premature neonates at risk for retinopathy. Use air/O_2 mixture for ventilation to maintain O_2 sat between 95% and 100%. Use low PIPs to avoid gastric distension by gases passing through fistula. Careful adjustment of ventilation will be necessary during surgical retraction of the lung or during insufflation if procedure is done thoracoscopically. Manual ventilation may be helpful. If the patient is not tolerating manipulation by the surgeon, brief breaks may be necessary to restore ventilation and oxygenation. Increased $PaCO_2$ and increased ventilation pressures may be more of a challenge with the thoracoscopic technique and may require intermittent manual ventilation to assess pulmonary compliance. Muscle relaxation (rocuronium 0.6 mg/kg iv, vecuronium 0.1 mg/kg iv) is usually necessary. If epidural or erector spinae plane catheter is used, GA drug requirements will be reduced. Frequent tracheal suctioning may be needed.
Emergence	Patients usually remain intubated postop. The decision to extubate should be made cautiously, as reintubation runs a serious risk of compromising the new anastomosis. Opioid-sparing techniques, thoracoscopic surgery, or the use of regional anesthesia may facilitate earlier extubation.
Blood and fluid	Blood loss usually Continue dextrose-

requirements	minimal IV: 22–24 ga × 2 BSS (maintenance) 5% albumin	containing solution from NICU. Replace 3rd-space losses (6–8 mL/kg/h) with BSS. Replace blood loss with 5% albumin mL for mL; maintain Hct > 35%.
Monitoring	Standard monitors Arterial line (24 ga)	ABG, Hct, and glucose q60min. Consider preductal, postductal SaO_2 in premature neonates or those with cardiac lesions.
Positioning	✓ and pad pressure points ✓ eyes Axillary roll	The patient is turned to the left-lateral decubitus position for a right thoracotomy. Monitor breath sounds in the dependent lung. Consider using FOB to recheck tube position.
Complications	Hypothermia Metabolic acidosis Hypoxemia Aspiration/gastric insufflation Pneumothorax Mucus plug	 Migration of ETT above the fistula may lead to gastric insufflation and difficult ventilation. Typically in ETT or large bronchi

POSTOPERATIVE

Complications	Apnea/hypoventilation Pneumothorax Tracheal leak	Maintenance of normothermia lessens the incidence of apnea, hypoventilation, and metabolic acidosis.

	Recurrent laryngeal nerve injury Pneumonia	Close postop monitoring in ICU
Multimodal pain management	Patients usually remain intubated and sedated to protect the fragile anastomosis. Use multimodal approach emphasizing regional analgesic techniques, combined with nonopioid analgesics and opioid analgesics as needed. Local infiltration (by surgeon) or regional/neuraxial anesthesia (epidural catheter or erector spinae plane catheter) can be helpful to minimize sedation if early extubation is planned. Consider hydromorphone PCA by RN, with basal rate of 1 mcg/kg/h (0.001 mg/kg/h) and bolus dose of 2 mcg/kg (0.002 mg/kg) with a 15-min lockout. Acetaminophen (10 mg/kg iv q6h; change to 10 mg/kg po q6h once taking orals). If iv acetaminophen is not available, pr delivery method can be used—20 mg/kg pr q6h; one-time dose perioperatively 30–40 mg/kg pr. Consider lorazepam 5–10 mcg/kg iv q6h for anxiolysis. If PCA is not desired due to concern of possible oversedation, consider Morphine (0.05–0.1 mg/kg q4h) Hydromorphone (0.005–0.01 mg/kg q2–4h)	
Tests	ABG; Hct; glucose; chest x-ray	
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.	

Suggested Readings

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7. Tollinche LE, Chawla M, Lee EW, et al: Collaborating with interventiona pulmonology in managing a massive tracheoesophageal fistula that extends from cricoid to carina: a case report. JA Clin Rep 2017; 3(1):62.

MEDIASTINAL MASS—BIOPSY OR RESECTION

SURGICAL CONSIDERATIONS

Description

Mass lesions in the mediastinum are classified as anterior, middle, and posterior, based on their relationship to the heart, which occupies the middle mediastinum. **Anterior tumors** include lymphomas, thyroid tumors, teratomas, and thymomas. Large lymphomas and, less commonly, teratomas or metastatic germ cell tumors may cause **anterior mediastinal mass syndrome** and/or **SVC compression** Preop preparation includes a rigid bronchoscope, plans to advance the ETT into a mainstem bronchus, and consideration of the need to rapidly roll the patient to the prone position. These masses are often approached through a **3rd-rib anterior mediastinotomy (Chamberlain procedure)** or thoracoscopically. For patients with compromised airway, light sedation and core-needle biopsy after appropriate imaging (e.g., MRI or CT scan) are preferable. **Middle mediastinal tumors** include esophageal duplications, bronchogenic cysts, lymphangiomas and variants, pericardial cysts, and lymph nodes. They are typically approached through a 5th intercostal space posterolateral thoracotomy or thoracoscopically. **Posterior mediastinal lesions** are usually neurogenic tumors and, less commonly, neuroenteric cysts (Fig. 12.5-3). The former may communicate with the spinal cord through the intervertebral foramina, giving them the appearance of central narrowing ("dumbbell tumor"). They usually arise from the sympathetic ganglia. When high in the chest, excision of these lesions may cause Horner syndrome. They are

approached thoracoscopically or via posterolateral thoracotomy.

Surgical approach

The potential for blood loss and airway compromise must always be anticipated when operating on chest lesions adjacent to the great vessels and tracheobronchial tree. When SVC or anterior mediastinal mass syndromes are suspected, they may be confirmed clinically and should be discussed among surgeon, anesthesiologist, and oncologist. **Thoracoscopy** is the gold standard for biopsy. In the absence of an adequate workspace, a minithoracotomy may be necessary, but an adequate sample for diagnostic purposes can typically be achieved with core needle biopsy. For resection, thoracotomy or median sternotomy is performed based on location of the tumor. A chest tube is typically left in place after resection or biopsy to drain the pleural space and ensure lung expansion postop.

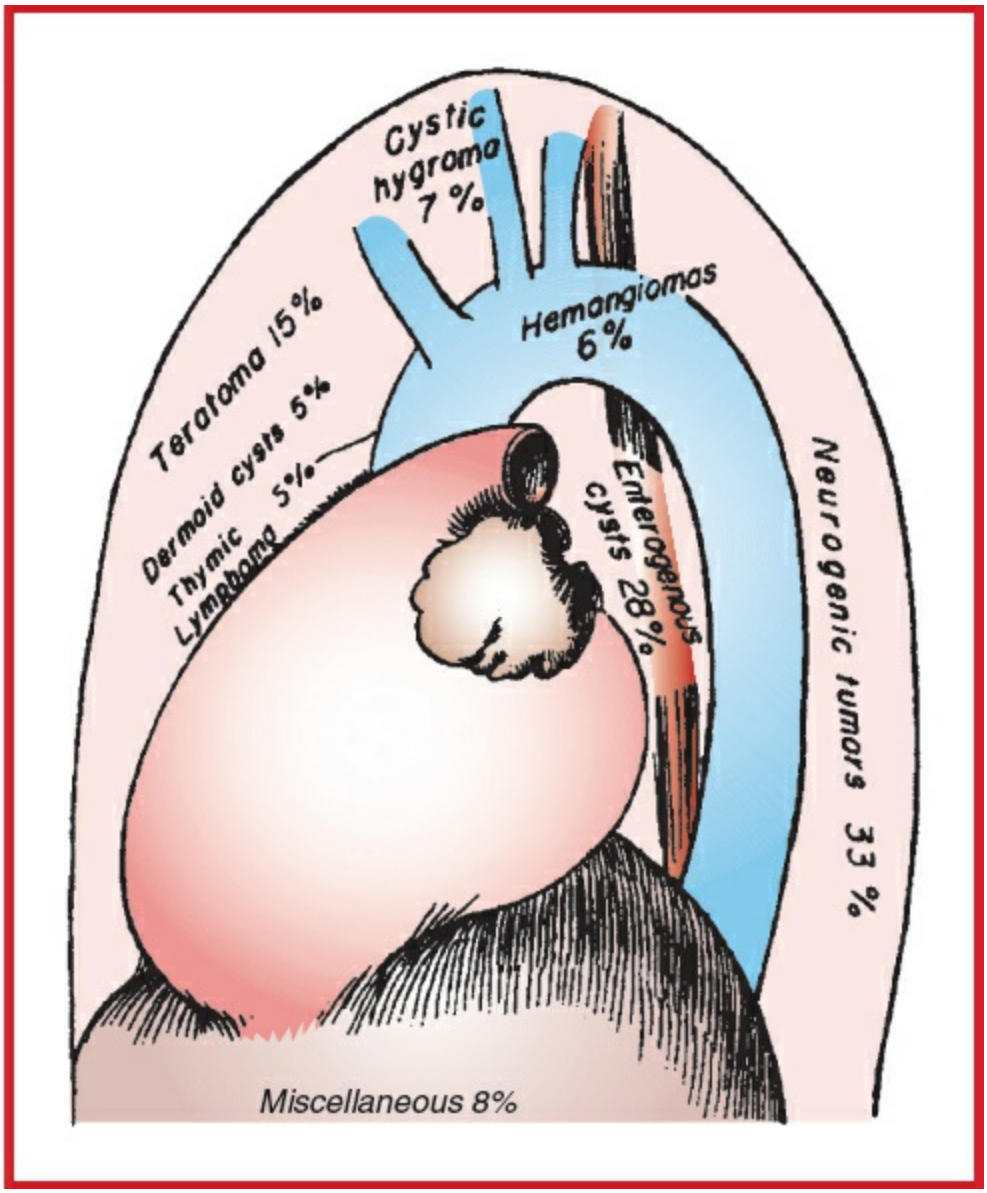

Figure 12.5-3 Distribution of mediastinal cysts and tumors. (Reprinted from Welch KJ:Pediatric Surgery, 4th edition. Year Book Medical Publishers, Chicago: 1986. Copyright © 1986 Elsevier. With permission.)

Variant procedure

In the past, it was a dictum that at least 1 cm^3 of tumor was needed for architecture to diagnose and classify lymphomas. In the age of histochemistry and chromosomal studies, this is less true. Sometimes the diagnosis can be made on bone marrow aspirate, pleural effusion aspirate, or a needle biopsy. These alternatives should be considered when large anterior mediastinal masses are encountered. Endoscopic ultrasound-guided needle biopsy is an accepted technique for lesions near the esophagus. A new technique of transesophageal endoscopic surgery has been used for excision of mediastinal lymph nodes and masses.

Usual preop diagnosis

Neuroblastoma; teratoma; duplication cyst of foregut; mediastinal mass (lymphoma)

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care and pain management options, description of antimicrobial prophylaxis, skin preparation, and possible need for transfusion. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Lateral Thoracotomy	Median Sternotomy
Position	Lateral	Supine or semirecumbent
Incision	Posterolateral	Median, parasternal
Special instrumentation	None	Bronchoscope; ± CPB
Unique considerations	Airway or cardiovascular collapse after induction in anterior mediastinal masses	⇐
Antibiotics	Preop: ampicillin 25 mg/kg iv + gentamicin 2.5 mg/kg iv; intraop: cephalosporin irrigation (1 g/500 mL NS)	⇐

Surgical time	2–4 h	1–4 h
Closing considerations	Lung inflation; intercostal block; epidural catheter	⇐
EBL	10–30 mL/kg	10–50 mL/kg
Postop care	Aggressive respiratory therapy; analgesia	⇐
Mortality	<5%, except symptomatic anterior masses	⇐
Morbidity	Atelectasis/respiratory	⇐
	Cardiovascular collapse with anterior masses	⇐
Pain score	7–8	6–7

PATIENT POPULATION CHARACTERISTICS	
Age range	Newborn–teens
Male:Female	1:1
Incidence	1/5000
Etiology	Unknown
Associated conditions	Cervical or axillary cystic hygroma; hemangioma; SVC syndrome

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

The clinical presentation of a mediastinal mass is often nonspecific in an otherwise healthy child. Often, a routine CXR (for some incidental Sx) will show the presence o an anterior mediastinal mass. These patients may suffer acute cardiorespiratory compromise on induction of anesthesia. A careful preop workup is essential. The presence of orthopnea, dyspnea, use of accessory muscles of ventilation, or upper body edema may indicate compression of the trachea and/or great vessels and increase risk of anesthesia-related complications. Radiologic evaluation, including CXR, CT or MRI and echo, will be essential in guiding treatment plan.

For large masses, consider rigid bronchoscopy and/or CPB standby. If severity o symptoms and size of tumor preclude anesthesia, possible options include preop radiation therapy or steroids. Both of these therapies aim to decrease tumor mass and relieve airway obstruction, but can interfere with accurate histologic diagnosis.

Current practice is to obtain a diagnostic biopsy under local or light sedation, due to concern for airway compromise. Treatment is then initiated to decrease tumor burden. Patients may return after treatment for resection of residual tumor.

Respiratory	Respiratory Sx (e.g., dyspnea, cough, stridor, wheezing) are extremely important. Note that, when mild airway compromise is present in the awake patient, this can portend a total obstruction when the patient is anesthetized or after muscle relaxation. The ability to lie supine without respiratory compromise should be determined, but does not guarantee adequate air exchange after receiving sedation or anesthesia. Tracheal and bronchial compression from the tumor may be positional. **Tests:** CXR; chest CT/MRI; echocardiogram; supine-sitting flow/volume loops can be useful for evaluating location and extent of airway obstruction in patients who are cooperative, typically those >5 yr; oxygen saturation or ABG is indicated if symptomatic.
Cardiovascular	May include SVC syndrome (e.g., venous engorgement of the head and neck, edema of the upper body). Other Sx and signs may include syncope and headaches (↑ ICP) made worse in the supine position, JVD, and papilledema. Cardiac insufficiency may occur due to tumor compression. **NB:** In severely symptomatic patients or large mediastinal masses, consider necessity for cardiopulmonary fem-fem bypass standby. **Tests:** Echo

Laboratory	Electrolytes; CBC; If resection, T&C for 2–4 U, depending on body weight and tumor size; other tests as indicated from H&P
Premedication	Use premedication cautiously in patients with potential airway compromise. Premedication is usually contraindicated in patients with mediastinal masses, especially in anterior mediastinal masses or symptomatic masses. Consider nonpharmacologic interventions to decrease anxiety.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Optimize nutritional status and hydration. Discuss planned approach with surgeon, as well as optimal location for planned procedure (preferably in an OR), contingency plans, and plans for postop care. Ideally, a discussion of the plan for a patient with a mediastinal mass should include the anesthesiologist, surgeon, oncologist, and intensivist.

INTRAOPERATIVE

Anesthetic technique

GETA using pediatric circle. OR temperature 75°F–80°F; forced-air warmer

Induction	For diagnostic biopsy, the usual practice is light sedation with ketamine/midazolam and/or dexmedetomidine/midazolam, with generous infiltration of local anesthetic by the surgeons. If patient has undergone treatment and the tumor has decreased significantly in size, decreasing the risk for airway compromise, a standard iv induction is appropriate. An iv is mandatory. If SVC syndrome is present, it is important to have iv access in the lower extremity. An awake FOB and intubation in the sitting position may be necessary. A mask induction with sevoflurane/O_2 in the semi-Fowler (reclining) position may also be performed. Intubation should be performed with preservation of spontaneous

	ventilation. Have a small stylet ETT available in the event of tracheal compression. Use muscle relaxants with caution because the change from spontaneous to positive pressure ventilation may not be tolerated and may lead to obstruction. Be prepared for obstruction distal to ETT. If obstruction occurs, gently pushing a smaller ETT into the R mainstream bronchus may alleviate obstruction. Rigid bronchoscopy/one-lung ventilation may be needed. **NB:** Surgeon must be present (with rigid bronchoscope immediately available) in the event of acute airway obstruction on induction. If obstruction is unabated, options include median sternotomy and femoral access for CPB. **NB:** A simple positional change (e.g., supine to lateral, prone, or sitting) may relieve cardiorespiratory collapse.
ERAS	Verify preincision antibiotics. Assess volume status. Consider iv acetaminophen (10 mg/kg for infants <1 yr old or 15 mg/kg for older children, maximum 650 mg). Consider PONV prophylaxis with iv ondansetron (0.1 mg/kg). Do not use any steroids intraop unless first discussed with surgeon and oncologist since steroids may make accurate diagnosis of biopsies difficult or impossible and may require patient to undergo higher-risk chemotherapy in the future.
Maintenance	Spontaneous ventilation/assisted ventilation with volatile agent and 100% O_2 may be appropriate. Supplemental epidural analgesia may be administered if a major resection is planned as opposed to a small incision for biopsy. Have surgeon infiltrate wound with local anesthetic to reduce volatile anesthetic and opiate requirements.
Emergence	If NDMR was used, reverse neuromuscular blockade with sugammadex (2–4 mg/kg) or with a combination of neostigmine (0.07 mg/kg) and

	glycopyrrolate (0.01 mg/kg). Do not attempt reversal with neostigmine and glycopyrrolate until first twitch of TOF has returned. Confirm air leak around ETT (with cuff deflated). Have all emergency airway equipment available and surgeon present. Patient should be fully awake before extubation.	
Blood and fluid requirements	Usually minimal blood loss IV: 18–24 ga × 2, depending on age BSS @ maintenance T&C for major resections	If mediastinoscopy is performed, sudden blood loss from torn great vessel may occur.
Monitoring	Standard monitors ± Arterial line	Esophageal or precordial stethoscope, if available, is earliest monitor of airway obstruction. Preop A-line may be indicated in patients with large masses or in symptomatic patients.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Cardio/respiratory failure Loss of airway Hypotension	If obstruction worsens acutely, be prepared to change to lateral decubitus or prone position, which may help alleviate tracheal, bronchial compression, and cardiovascular collapse. These cases require great attention to detail. All efforts must be made to maintain spontaneous ventilation. Preparations must be

made for resuscitation.

POSTOPERATIVE

Complications	Respiratory failure Pneumothorax	Anesthesiologist must be readily available in the PACU to manage acute airway problems.
Multimodal pain management	Ketorolac 0.5 mg/kg (up to 30 mg) iv q6h × 24 h Acetaminophen iv or po 10 mg/kg q6h for infants <1 yr old or 15 mg/kg q6h for older children with a maximum dose of 650 mg q6h Epidural analgesia	Cervical biopsy/mediastinoscopy has minimal postop pain and can be effectively treated with NSAID and local anesthetic infiltration. Use opiates cautiously.
Tests	Hct, ABG, CXR, as clinically indicated	
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.	

Suggested Readings

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NEONATAL LUNG RESECTION

SURGICAL CONSIDERATIONS

Description

Neonatal lung resection is performed for a few disorders relatively unique to children, including congenital pulmonary airway malformations (CPAMs); sequestrations (intralobar 75%, extralobar 25%); congenital lobar overdistension (CLO, formerly called "emphysema"); and congenital pulmonary cysts (Fig. 12.5-4). Many lesions are asymptomatic; they are diagnosed by antenatal ultrasound or later when a CXR is performed for other reasons. CPAMs may compromise respiration, develop infections, and have a small but real risk of malignant degeneration. Sequestrations have little long-term risk, but they are frequently fed by a large systemic artery of near-aortic caliber (often from below the diaphragm) with independent venous drainage back into the vena cava, causing significant L → R shunting. CLO resection is performed when the volume of ineffective, dilated lung compresses adjacent functioning lobes, compromising their function; this condition is worsened by positive pressure ventilation. The key therapy is surgical—opening the hemithorax enables an oversized lobe to herniate through the incision, decompressing the functioning lung beneath. Most resections are performed on a ventilated lung because it is difficult to selectively intubate small airways.

Surgical approach

Patients undergoing lateral thoracotomy through the 4th, 5th, or 6th intercostal space benefit from preop placement of an epidural catheter. In some institutions, thoracoscopic resection may be performed. Significant blood loss is possible, though infrequent. Often, ventilation improves when the aberrant lung segment is removed. A large CPAM, intralobar sequestration, or CLO usually requires formal **lobectomy**. Smaller CPAMs, pulmonary cysts, and extralobar sequestrations are treated with lesser resections. A chest tube usually is left in place at the end of the case to drain the pleural cavity and promote lung expansion.

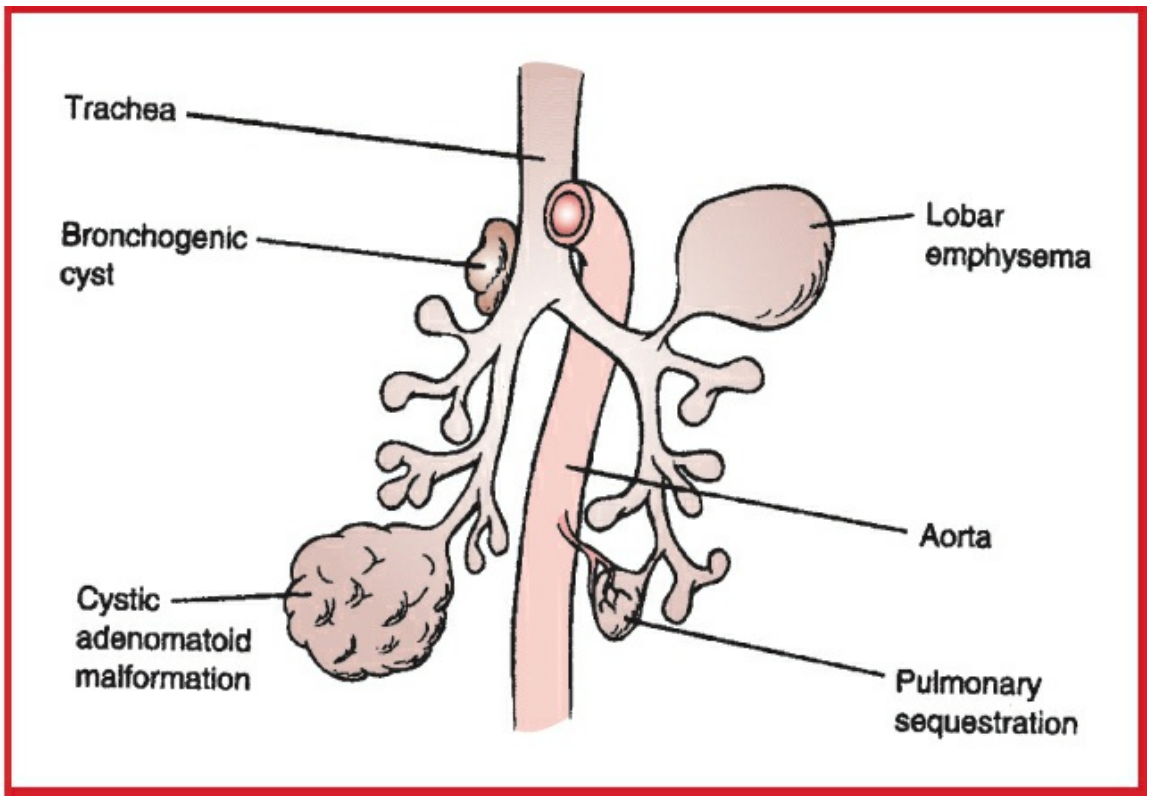

Figure 12.5-4 Classic developmental abnormalities of the tracheobronchial tree. (Reproduced from Oldham KT, Colombani PM, Foglia RP Surgery of Infants and Children Lippincott-Raven, 1997. After Haller JA Jr, Golladay ES, Pickard LR, et al: Surgical management of lung bud anomalies: lobar emphysema, bronchogenic cyst, cystic adenomatoid malformation, and intralobar pulmonary sequestration. Ann Thorac Surg 1979; 28:34(1):34. Copyright © 1979 The Society of Thoracic Surgeons. With permission.)

Variant procedures or approaches

Thoracoscopic lobectomy is increasingly the technique of choice for lung resections. It can be performed safely and effectively and avoids the morbidity and poor cosmesis of a thoracotomy. Upper-lobe resections can be technically more challenging, but are still possible with thoracoscopy. Insufflation of the hemithorax with 7 mm Hg carbon dioxide can aid in lung collapse. Some argue for observation of asymptomatic low-risk cystic lung lesions, but the criteria for observation are yet to be rigorously studied.

Usual preop diagnosis

CPAM; sequestration; CLO; pulmonary cysts; congenital diaphragmatic hernia pneumothorax

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care and pain management options, description of antimicrobial prophylaxis, skin preparation, and possible need for transfusion. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Thoracotomy	Thoracoscopy
Position	Lateral decubitus	⇐
Incision	Lateral thoracotomy	⇐
Special instrumentation	Pediatric rib retractor	4 mm 30° scope
Unique considerations	Rapid thoracotomy improves ventilation in CLO. Aggressive high-pressure ventilation should be avoided.	Controlled pneumothorax creates working space but can increase CO_2 through absorption.
Antibiotics	Cefazolin 30 mg/kg (25 mg/kg in neonates)	⇐
Surgical time	2 h	2–3 h
Closing considerations	Extubation preferable and aided by epidural catheter	Extubation preferable, intercostal block, epidural unnecessary
EBL	10 mL/kg	5 mL
Postop care	NICU	NICU/PICU
Mortality	<5%	<2%
Morbidity	Bleeding Air leak Atelectasis Pneumothorax	⇐
Pain score	7–8	4–5

PATIENT POPULATION CHARACTERISTICS

Age range	Days–weeks
Male:Female	1:1
Incidence	1/5000 live births
	Bronchopulmonary foregut maldifferentiation

Etiology	
Associated conditions	**Extralobar sequestration** may occur below the diaphragm. **Sequestrations** may be associated with high-output heart failure and diaphragmatic hernia. **CCAM** may cause hydrops fetalis and fetal death. Intermediate forms of sequestration and CCAM exist.

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

In general, children have significantly decreased respiratory reserve compared with adults because:

1. FRC is closer to RV in children, thereby making airway closure more likely.
2. O_2 consumption is higher (6–8 mL/kg/min vs. 3 mL/kg/min).
3. In adults, the decubitus position increases blood flow to the ventilated, dependent lung while decreasing perfusion to the operated nondependent lung. In children, the nondependent lung may actually receive greater perfusion than the dependent lung, which may be due to a more compliant chest wall in infants and young children.

Premedication	None usually needed. In older infants >7–9 mo, consider midazolam 0.5 mg/kg po with maximum of 20 mg or 0.05–0.1 mg/kg iv with maximum of 2 mg. If airway obstruction or severe pulmonary disease is present, use premedication judiciously.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Optimize nutritional status and hydration.

INTRAOPERATIVE

Anesthetic technique

GETA, forced-air warmer; OR warmed to 75°F–80°F; use warming pad on OR table and warm iv fluids. Consider epidural if thoracotomy.

Induction	Either inhalation or iv induction may be performed.

	(For OLV, see below.) The trachea is intubated. An arterial line is indicated for children having a thoracotomy and for VATS in patients with significant lung disease. A CVP is generally not required if iv access is adequate.
ERAS	Verify preincision antibiotics. Assess volume status. Consider thoracic epidural catheter, paravertebral catheter, erector spinae plane catheter, or intercostal nerve block. Consider iv acetaminophen 10 mg/kg.
One-lung ventilation (OLV) in pediatric patients	OLV is used to allow deflation of the operative lung, which is especially useful during VATS. Alternatively, the surgeon may insufflate CO_2 to compress the operative lung. OLV also isolates the lungs to help prevent contamination of the nonoperative lung with blood or purulent fluid from the operative lung. The **three techniques for OLV** in infants and children include the following: Use of a **single-lumen tube:** a single-lumen tube is advanced into the mainstem bronchus of the nonoperative lung. FOB may be placed through ETT to confirm placement. Disadvantages: may obstruct upper-lobe bronchus; cannot suction operative lung; may not have complete collapse of operative lung. Use of a **bronchial blocker:** For placing blocker OUTSIDE the ETT—The operative lung is intubated with ETT, guide wire passed through ETT, and BB advanced over guide wire; the second smaller ETT is placed in the trachea, alongside the BB. BB also can be advanced under direct visualization with FOB guidance via ETT. For placing blocker THROUGH ETT, multiport adapters allow oxygenation while positioning. Disadvantages: requires small ETT, FOB, or fluoroscopy. If bronchial blocker is not available, consider balloon-tipped Fogarty catheter. Care must be taken to not place a bronchial blocker too deep in a small infant as it can be inadvertently incorporated into the surgical closure of the bronchus. Use of a **double-lumen tube (DLT):** Can be placed

	for older children (see Table 12.5-1 for approximate sizes). (See Lobectomy, Pneumonectomy, for details.)	
Maintenance	Standard maintenance. Muscle relaxation is appropriate. Inhalation agent or TIVA may be used; 100% O_2 or O_2/air mixture; N_2O is avoided. Fentanyl 2–5 mcg/kg or other iv opioid should be given if epidural is not in place.	
Emergence	In most cases, the patient can be extubated at the end of surgery. If NDMR was used, reverse neuromuscular blockade with sugammadex (2–4 mg/kg) or with a combination of neostigmine (0.07 mg/kg) and glycopyrrolate (0.01 mg/kg). Do not attempt reversal with neostigmine and glycopyrrolate until first twitch of TOF has returned. An OG tube should be placed before and suctioned prior to extubation. Ensure ability to oxygenate and ventilate adequately before extubation.	
Blood and fluid requirements	IV: 20–22 ga × 2 BSS @ maintenance	Potential for moderate blood loss. Transfuse to maintain Hct > 23. If >2 mo of age; dextrose-containing solutions are not required.
Monitoring	Standard monitors ± Arterial line (22 ga) Foley catheter	For thoracotomy, ABG, Hct, and glucose should be evaluated as clinically indicated; UO should be monitored and kept at 1 mL/kg/h.
Positioning	✓ and pad pressure points ✓ eyes.	
Complications	Hypoxia Hypercarbia	DDX: Movement of ETT or BB, bronchospasm; obstruction of ETT by kinking or secretions; pre-

	↓ BP	existing disease Permissible during OLV (40–50 mm Hg) to minimize barotrauma Blood loss; hypovolemia; ↓ venous return 2° ↑ intrathoracic pressure

Table 12.5-1 Tube Selection for OLV in Children

Age (yr)	ETT (Inner Diameter)	Fogarty Catheter	Bronchial Blocker	Univent Tube	DLT (Fr)
0.5–1	3.5–4.0	3	2*		
1–2	4.0–4.5	4	3*		
2–4	4.5–5.0	4	5†		
4–6	5.0–5.5	5	5†		
6–8	5.5–6	6	5†	3.5	
8–10	6.0 cuffed	6	5†	3.5	26
10–12	6.5 cuffed	6	5†	4.5	26–28
12–14	6.5–7.0 cuffed	6	5†	4.5	32
14–16	7.0 cuffed	7	5,7†	6.0	35
16–18	7.0–8.0 cuffed	7	7,9†	7.0	35–37

*Edwards Lifescience, LLC. Irvine, CA.
†Cook Critical Care, Inc., Bloomington, IN.

POSTOPERATIVE

Complications	Atelectasis Hypoventilation Hypoxia Pneumothorax	Supplemental O_2 Check breath sounds, chest wall motion, and CXR. May require chest tube.
Multimodal pain management	Thoracic epidural Ketorolac 0.5 mg/kg iv	Lumbar (or caudal if <8 kg and <1 yr) epidural catheter may be placed and threaded up to

	q6h × 48–72 h in children older than 6 mo Acetaminophen iv or po 10 mg/kg q6h for infants <1 yr old or 15 mg/kg q6h for older children	thoracic levels. (NB—1st dilate space with NS prior to threading catheter; ultrasound guidance may also be used to guide placement.) Max 15 mg/dose, if needed to enhance analgesia Maximum dose of 650 mg q6h
Tests	Hct, ABG, CXR	
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.	

Suggested Readings

1. Dinesh K: Single lung ventilation in pediatric anesthesia. Anesthesiol Clin North Am 2005; 23:693–708.
2. McJadyen G, Budac S, Richards M, et al: Anesthesia for thoracic surgery. In Gregory GA, Andropoulos DB, eds.Gregory's Pediatric Anesthesia, 5th edition. Wiley-Blackwell Pub, West Sussex, UK: 2012, 576–80, 583.
3. Rothenberg SS, Albanese CT: Experience with 144 consecutive pediatric thoracoscopic lobectomies. J Laparoendosc Adv Surg Tech A 2007; 17(3):339–41.
4. Templeton TW, Templeton LB, Lawrence AE, et al: An initial experience with an Extraluminal EZ-Blocker®: a new alternative for 1-lung ventilation in pediatric patients. Paediatr Anaesth 2018; 28(4):347–51.

DRAINAGE OF EMPYEMA

SURGICAL CONSIDERATIONS

Description

Most empyemas occur in otherwise healthy children when a necrotizing pneumonia causes a parapneumonic effusion that becomes infected. The infected fluid (empyema) has the tendency to become solid over days to weeks. It compresses the surrounding

lung and responds poorly to antibiotics because it is remote from the circulatory system. Three phases of empyema are recognized, and the key variable determining outcome is fibrin. The early or **exudative phase** occurs when the effusion becomes purulent—liquid pus without fibrin can be successfully treated with a chest tube if it is recognized early (uncommon). The second phase, **fibrinopurulent**, occurs over the next days as thick strands of infected fibrin replace exudative fluid. It is the most common phase and is most expeditiously treated by **thoracoscopic ± open empyemectomy**. The last phase, **organized**, occurs when all exudate has been replaced by thick, infected fibrin, compressing the lung and adhering to both visceral and parietal pleurae. Fortunately, this stage is rare in children; tedious **thoracoscopic decortication** may be successful, but often **thoracotomy** is required and the blood loss can be extensive. Some previously common organisms (e.g., Haemophilus influenzae) are decreasing with the advent of pediatric vaccines; Streptococcus pneumonia, S. aureus, and Streptococcus pyogenes remain common pathogens, joined more recently by gram-negative rods. Significant bleeding is not uncommon, and bronchopleural fistulae, if not already present, may occur when the dead lung adheres to debrided overlying fibrin.

Surgical approach

Ipsilateral long-term venous access (peripherally inserted central or subclavian catheter) is placed before or during surgery. In larger children, a BB may protect the healthy lung from pus, which may extrude from the infected side into the trachea during operation. A **two- or three-port thoracoscopic technique** is most common, aided by hermetic trocars used with 5 mm Hg intrathoracic pressure (unless a bronchopleural fistula exists). The first port is placed into a preexisting chest tube site or the largest known pocket of pus/fibrin observed on preop imaging. Gradually, this space is enlarged until the remaining ports can be inserted under direct vision. As fibrin and pus are removed, the trapped lung is liberated, and the procedure continues somewhat tediously until the entire lung is free and most fibrin is removed. One or two large-bore chest tubes are placed at the end of the procedure.

The alternate approach is placement of one or more pigtail chest tubes and flushing the chest cavity with a fibrinolytic agent (e.g., tissue plasminogen activator). This has gained popularity with recent positive results and it is often the first-line approach.

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care and pain management options, description of antimicrobial prophylaxis, skin preparation, and possible need for transfusion. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Thoracoscopic	Thoracotomy
Position	Contralateral decubitus	⇐
Incision	Three ports	5th interspace
Special instrumentation	Suction irrigator; chest tube	Rib retractor; suction; chest tube
Unique considerations	5 mm Hg capnothorax	—
Antibiotics	Cefuroxime (25 mg/kg) and clindamycin (10 mg/kg)	⇐
Surgical time	1.5 h	2 h
Closing considerations	Local anesthetic	± Epidural catheter
EBL	10–20 mL/kg	⇐
Postop care	May be septic for 24 h	⇐
	Extubation ideal	⇐
Mortality	<5%	<10% when used for advanced disease
Morbidity	Air leak	⇐
	Bleeding	⇐
	Sepsis	⇐
	Atelectasis	⇐
	Pneumatocele	⇐
Pain score	3–4	7–8

PATIENT POPULATION CHARACTERISTICS

Age range	1–17 yr
Male:Female	1:1

Incidence	1/150 pneumonias
Etiology	Bacteria-infected pleural effusion
Associated conditions	Chronic granulomatous disease (uncommon)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Neonatal Lung Resection for guidelines for OLV.

Suggested Readings

1. Choudry DK: Single lung ventilation in pediatric anesthesia. Anesthesiol Clin North Am 2005; 23:693–708.
2. Fuller MK, Helmrath MA: Thoracic empyema, application of video-assisted thoracic surgery and its current management. Curr Opin Pediatr 2007; 19(3):328–32.
3. Golianu B, Hammer GB: Pediatric thoracic anesthesia. Curr Opin Anaesthesiol 2005; 18(1):5–11.
4. McJadyen G, Budac S, Richards M, et al: Anesthesia for thoracic surgery. In Gregory GA, Andropoulos DB, eds. Gregory's Pediatric Anesthesia, 5th edition. Wiley-Blackwell Pub, West Sussex, UK: 2012, 584–5.

REPAIR OF PECTUS EXCAVATUM/CARINATUM

SURGICAL CONSIDERATIONS

Description

Pectus excavatum ("funnel chest") is a sternochondral deformity more common in boys and of greater frequency than pectus carinatum ("pigeon chest"). Both may be associated with scoliosis, spontaneous pneumothorax, and Marfan syndrome. Severe excavatum lesions may be associated with significant cardiorespiratory compromise. It may be associated with pain, though often the impetus for repair is for cosmetic reasons. The timing of repair is variable. Some surgeons prefer performing the surgery at a younger age (5–6 yr) because of the ease and decreased bleeding, whereas others prefer waiting until adolescence to prevent possible recurrence during puberty.

Surgical approach

The classic **Ravitch** approach involves an omega-shaped chest incision in the supine position. The pectus muscles are detached from the sternum, and 3–5 pairs of

costochondral cartilages are resected, leaving the perichondrium for subsequent cartilage regeneration (Fig. 12.5-5). A transverse osteotomy of the upper sternum corrects its appearance. In some excavatum patients, a metal bar or "strut" may be placed beneath the sternum but on top of the ribs. If used, the strut is removed 2 yr later in a short operation through a small lateral incision. Hemovac drains are placed beneath the skin to trap bleeding from cut bony surfaces; chest tube(s) is placed if the pleura or pericardium is violated. Significant blood loss from cut surfaces of bones and cartilage can occur in older patients.

A newer approach (**Nuss procedure**) is now widely practiced (Fig. 12.5-6). This involves placement of a curvilinear stainless steel bar (pectus bar) via lateral axillary incisions through the rib space under thoracoscopic guidance beneath the sternum at the point of maximal sternal depression. The bar travels through both hemithoraces anterior to the heart and lungs; when "flipped" 180°, it exerts powerful forces backward on the ribs and forward on the sternum. Sometimes, fixation devices must be added to the ribs to keep the bar from "flipping back" into original position. A chest tube is not always necessary; however, very significant pain results, optimally treated with a multimodal approach, including an epidural catheter. The rapid change of chest wall shape has also caused thoracic outlet syndrome. The downside of both the Ravitch and Nuss procedures is that they try to instantaneously reverse years of bone malformation. A very new approach in the process of FDA approval seeks to reverse PE slowly through the use of magnetic force. A magnet is implanted in the retrosternal space, and a complimentary magnetic brace is worn regularly to slowly force the sternum back into normal position.

Usual preop diagnosis

Pectus excavatum; carinatum

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care and pain management options, description of antimicrobial prophylaxis, skin preparation, and possible need for transfusion. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

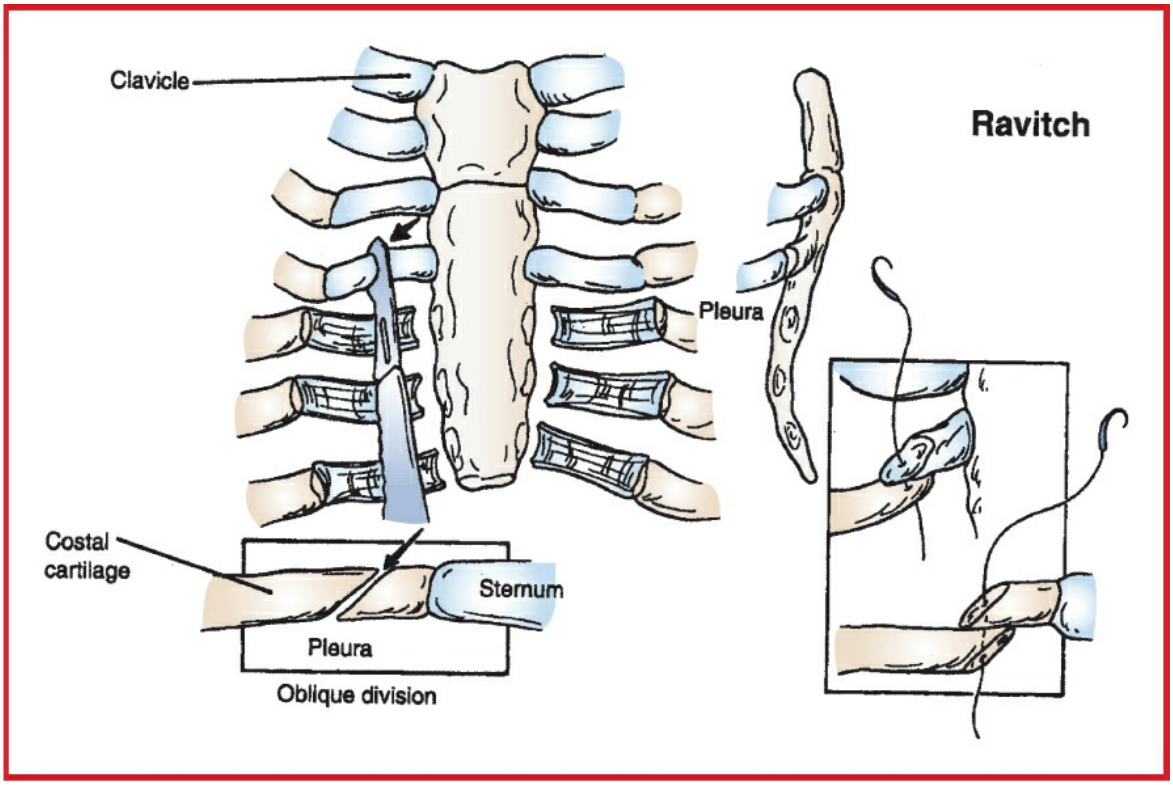

Figure 12.5-5 Ravitch approach: The costal cartilage immediately above the most cephalad abnormal costal cartilage is divided obliquely from medial to lateral, as shown. This is often at the level of the second costal cartilage, at the manubrial-sternal junction. The divided normal costal cartilages are allowed to overlap, the medial portion being anterior and the lateral being posterior. Suture fixation of the transected cartilage provides immobilization, ensuring sternal support at this level **(inset)**. (Reproduced with permission from Oldham KT, Colombani PM, Foglia RPSurgery of Infants and Children Lippincott-Raven, Philadelphia: 1997.)

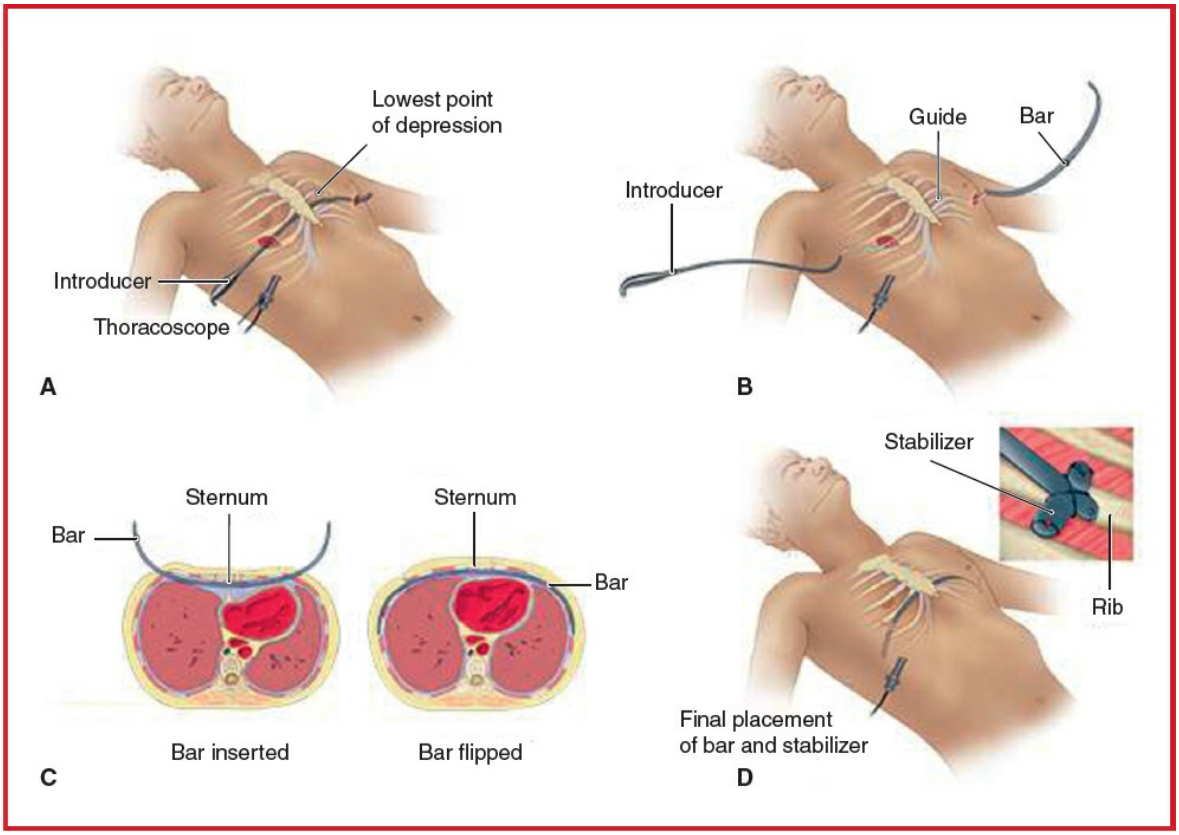

Figure 12.5-6 Nuss procedure.

SUMMARY OF PROCEDURES

	Ravitch	Nuss
Position	Supine	⇐, R side slightly elevated
Incision	Omega, chest	Two right axillae, one left axilla
Special instrumentation	Periosteal elevators; sternal saw; possible strut	Steel bar; bar bender; stabilizers
Unique considerations	Heart and lungs beneath	Cosmetically superior
Antibiotics	Cefazolin 30 mg/kg (25 mg/kg in neonates)	⇐
Surgical time	~3 h	≤1 h
Closing considerations	Extubate; epidural, if possible	Epidural very important

EBL	10–20 mL/kg	<5 mL/kg
Postop care	Drains out 1–3 d → home 5 d	→ home 5 d
Mortality	<2%	⇐
Morbidity	Bleeding	⇐
	Recurrence	Bar "flips"
	Pneumothorax	Thoracic outlet syndrome
	Cardiac injury	⇐
Pain score	5–6	8–9

PATIENT POPULATION CHARACTERISTICS

Age range	5 yr–adolescent
Male:Female	5–9:1
Incidence	1/400–1000 excavatum; 1/1500 carinatum
Etiology	Relationship with reactive airway disease
Associated conditions	Marfan syndrome (5%); mitral valve prolapse (5%)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Pectus excavatum, a condition in which there is concave depression of the lower sternum, may be associated with CHD and restrictive lung disease in severe cases. Usually, however, the deformity is primarily cosmetic, and the patient is asymptomatic. Surgery usually occurs between 12 and 15 yr of age. **Pectus carinatum** (a convex lower sternum) usually is repaired for cosmetic reasons only and usually during the teenage years. Both pectus conditions may be associated with connective tissue disorders (e.g., Marfan, Ehlers-Danlos); therefore, CHD may be present.

Respiratory	Restrictive lung disease 2° chest wall deformity may be present in severe deformities. If patient has exercise limitations, there is a need to differentiate between cardiac and pulmonary components.

	Tests: CXR: AP, lateral; PFTs; ABG, if symptomatic, SaO_2
Cardiovascular	In both conditions, CHD should be investigated if present. Pulmonary HTN may be 2° pulmonary overcirculation (e.g., VSD) or chronic hypoxemia. **Tests:** ECG; echo
Laboratory	Hct; T&C
Premedication	Consider 0.5 mg/kg po midazolam (maximum 20 mg) or 0.05–0.1 mg/kg iv midazolam (maximum 2 mg).
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Evaluate for concurrent disease. Discuss with surgeon possible epidural catheter, paravertebral catheter, or erector spinae plane catheter.

INTRAOPERATIVE

Anesthetic technique

GETA, forced-air warmer; maintain OR temperature at 75°F–80°F.

Induction	IV or mask induction. With restrictive lung disease, there is ↓ FRC, which will shorten the time to alveolar equilibration for the volatile anesthetics; institute early manual hyperventilation. Tracheal intubation, facilitated by neuromuscular blockade (rocuronium 1 mg/kg, vecuronium 0.1 mg/kg). Use appropriately sized ETT.
ERAS	Verify preincision antibiotics. Assess volume status. Consider thoracic epidural catheter, paravertebral catheter, or erector spinae plane catheter. Consider iv acetaminophen 10–15 mg/kg (maximum 650 mg).
Maintenance	Standard maintenance with inhalational anesthetic, TIVA, or combination. Insertion of thoracic epidural catheter will provide for supplemental anesthesia and treatment of postop pain and is highly recommended. Postoperative infusions will usually

	contain a mixture of ropivicaine/clonidine and hydromorphone (see Appendix D, p. D-3 and Appendix E, p. E-1). If no epidural is placed, bolus with long-acting iv opioid (morphine 0.1 mg/kg, hydromorphone 10 mcg/kg) for postop pain control, and titrate to effect.	
Emergence	Plan for extubation in OR. If NDMR was used, reverse neuromuscular blockade with sugammadex (2–4 mg/kg) or with a combination of neostigmine (0.07 mg/kg) and glycopyrrolate (0.01 mg/kg). Do not attempt reversal with neostigmine and glycopyrrolate until first twitch of TOF has returned.	
Blood and fluid requirements	Usually minimal blood and 3rd-space losses IV: 18 or 20 ga × 1 LR @ 3–5 cc/h	
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes	Elbow padding to avoid ulnar nerve compression Careful positioning to avoid nerve compression
Complications	Pneumothorax Atelectasis	

POSTOPERATIVE

Complications	Respiratory insufficiency	
	Pneumothorax Nerve injury related to positioning	2° splinting, preexisting restrictive pulmonary disease
Multimodal pain management	Epidural (thoracic) or PCA	Standard epidural infusion. Ketorolac (0.5 mg/kg iv q6h × 24–72 h), if needed, in addition to the above measures (see Appendix E)

	Acetaminophen 10–15 mg/kg q6h	Maximum 650 mg q6h
	Ketorolac 0.5 mg/kg iv × 24–72 h	Maximum 15 mg per dose
Tests	Hct, ABG, CXR	
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.	

Suggested Readings

1. Hammer GB: Anesthesia for thoracic surgery. In: Davis PJ, Cladis FP, eds.Smith's Anesthesia for Infants and Children, 9th edition. Elsevier Publishing, Philadelphia: 2017, 773–88.
2. Nuss D, Kelly RE Jr: Indications and technique of Nuss procedure for pectu excavatum. Thorac Surg Clin 2010; 20(4):583–97.
3. Obermeyer RJ, Goretsky MJ: Chest wall deformities in pediatric surgery.Surg Clin North Am 2012; 92(3):669–84.

ESOPHAGEAL REPLACEMENT, COLON INTERPOSITION

SURGICAL CONSIDERATIONS

Description

Esophageal replacement in children usually is performed for caustic stricture or esophageal atresia (EA) refractory to other therapy (Fig. 12.5-7). Caustic esophageal strictures—usually in toddlers following lye ingestion—are becoming less common; esophageal replacement is indicated after failed attempts at balloon dilation (BD). Patients with EA may have a primary replacement for known long-gap atresia (type A) or will have a secondary replacement after failed attempts at anastomosis (all types). There is no good long-term esophageal replacement; segments of the colon, stomach, or (rarely) jejunum are the best surrogates.

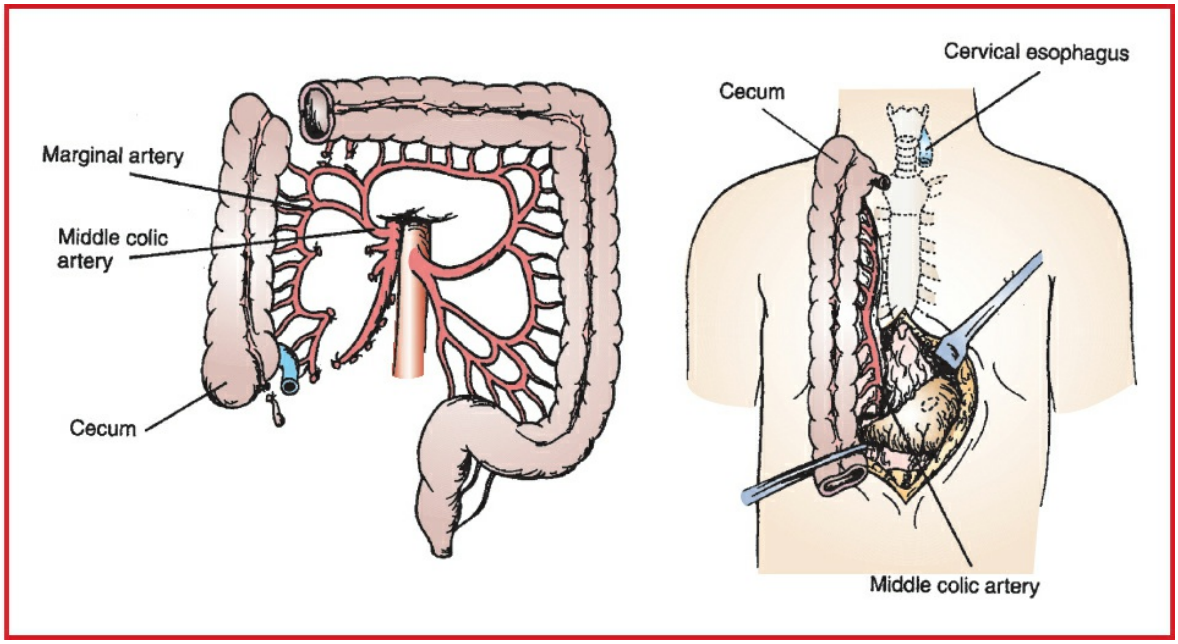

Figure 12.5-7 Esophageal replacement using a right colon interposition in a retrosternal position. (Reproduced with permission from Oldham KT, Colombani PM, Foglia RPSurgery of Infants and Children. Lippincott-Raven, Philadelphia: 1997.)

Surgical approach

Depending on anatomy and surgeon preference, the **distal anastomosis** occurs in the abdomen and/or chest; the **proximal anastomosis** occurs in the chest or neck. Position changes with redraping may be required, depending on the selection of incisions. The esophageal substitute usually is brought through the bed of the esophagus with small risks to the pulmonary vessels, recurrent laryngeal nerves, and brachiocephalic vein. The **retrosternal approach** may be safer but is less optimal in children because of long-term problems with obstruction and emptying.

Variant procedures or approaches

The colon is the most frequent substitute, with the transverse colon attached to either the R colon (isoperistaltic) or L colon (reverse peristaltic) being used. When the stomach is used, it may be pulled up entirely from the abdomen through the chest with **gastroesophageal anastomosis** in the neck **(Orringer)**; alternatively, a **gastric tube** of greater curve (common) or lesser curve maybe constructed for cervical or thoracic anastomosis. The small bowel is used only when other substitutes are inappropriate because an additional microvascular anastomosis is needed for graft survival.

Usual preop diagnosis

EA; caustic stricture

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting

NPO duration, optimizing nutritional status, postop care and pain management options, description of antimicrobial prophylaxis, skin preparation, and possible need for transfusion. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE

Position	Supine, tilted; or supine, ± lateral
Incision	Abdominal and cervical ± thoracotomy
Special instrumentation	Bougie (upper esophagus)
Antibiotics	Preop: ampicillin 25 mg/kg iv + gentamicin 2.5 mg/kg iv
Surgical time	3–5 h (4–6 h with position change)
EBL	20–40 mL/kg
Postop care	PICU
Mortality	<5%
Morbidity	Respiratory failure Anastomotic leak Sepsis Stricture
Pain score	7–8

PATIENT POPULATION CHARACTERISTICS

Age range	1–5 yr
Male:Female	2:1
Incidence	~200/yr in the United States
Etiology	Caustic ingestion; EA
Associated conditions	Caustic stricture; imperforate anus; VACTERL association

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

These patients usually are children presenting with a Hx of caustic substance ingestion and subsequent development of esophageal stricture. They frequently have undergone multiple esophageal dilations under GA. Previous anesthesia records should be obtained. Preop, these patients are admitted for bowel prep and, consequently, may be hypovolemic.

Gastrointestinal	Varying degrees of esophageal reflux may be present. Preop H_2-blocker administration may be appropriate (e.g., ranitidine 1.0 mg/kg iv). If a gastrostomy is present, it should be vented. **Tests:** Electrolytes
Hematologic	Anemia due to poor nutrition **Tests:** CBC; T&C
Laboratory	Other tests as indicated from H&P
Premedication	Consider 0.5 mg/kg po midazolam (maximum 20 mg) or 0.05–0.1 mg/kg iv midazolam (maximum 2 mg).
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Evaluate for concurrent disease. Discuss with surgeon possible epidural catheter, paravertebral catheter, or erector spinae plane catheter.

INTRAOPERATIVE

Anesthetic technique

GETA, forced-air warmer; heating pad on OR table. Warm room to 75°F–80°F. An epidural catheter (for intraop and postop pain management) may be placed once the child is anesthetized and airway is secured.

Induction	IV induction is preferred. If reflux concerns present, preoxygenate for 2–3 min and perform rapid-sequence induction and intubation with cricoid pressure. Use appropriately sized ETT. Continue neuromuscular blockade with vecuronium (0.1 mg/kg) or rocuronium (0.6 mg/kg).

ERAS	Verify preincision antibiotics. Assess volume status. Consider thoracic epidural catheter, paravertebral catheter, or erector spinae plane catheter. Consider iv acetaminophen 10–15 mg/kg (maximum 650 mg).	
Maintenance	Use air/O_2/isoflurane. Avoid N_2O to minimize increase in bowel air and possible pneumothorax related to surgical dissection, use NMB with TOF monitoring, and dose epidural catheter as needed (see Appendix D, p. D-4 and Appendix E, p. E-1).	
Emergence	Possible extubation in OR vs. postop intubation. If NDMR was used and the plan is to extubate in OR, reverse neuromuscular blockade with sugammadex (2–4 mg/kg) or with a combination of neostigmine (0.07 mg/kg) and glycopyrrolate (0.01 mg/kg). Do not attempt reversal with neostigmine and glycopyrrolate until first twitch of TOF has returned.	
Blood and fluid requirements	Blood loss moderate IV: 22 ga × 2 BSS @ ~10 mL/kg/h	Replace 3rd-space losses with BSS (~10 mL/kg/h). Replace blood loss mL for mL with albumin 5%. Transfuse to maintain Hct > 22.
Monitoring	Standard monitors CVP: 4 Fr DL or 5 Fr TL, or PICC for postop TPN ± Arterial line (22 ga) Foley catheter	Marked pulse pressure variation with ventilation is a sensitive indicator of hypovolemia. ABG/Hct prn.
Positioning	Shoulder roll ✓ and pad pressure points ✓ eyes	Beware of tracheal extubation with head extension. If necessary, reconfirm ETT position with laryngoscopy.
Complications	Hypoventilation	Suprasternal dissection

	Hypothermia Pneumothorax Dysrhythmias Aspiration	involves traction on the trachea and recurrent laryngeal nerve. Mediastinal pull-through may damage great vessels and → pneumothorax, manipulation-induced dysrhythmias, and impaired chest wall compliance.

POSTOPERATIVE

Complications	Hypoventilation Pneumothorax Recurrent laryngeal nerve injury Mediastinitis	Inadequately treated pain → hypoventilation.
Multimodal pain management	Epidural analgesia (see Appendix E). Acetaminophen (10–15 mg/kg iv/po q6h, maximum 650 mg per dose) Ketorolac (0.5 mg/kg iv up to 15 mg q6h × 24–72 h)	
Tests	Hct, ABG, CXR	
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.	

Suggested Readings

1. Brooks MR, Golianu B: Perioperative management in children with chronic pain Paediatr Anaesth 2016; 26(8):794–806. doi:10.1111/pan.12948.
2. Loukogeorgakis SP, Pierro A: Replacement surgery for esophageal atresia. Eur J Pediatr Surg 2013; 23(3):182–90.

REPAIR OF CONGENITAL DIAPHRAGMATIC

HERNIA

SURGICAL CONSIDERATIONS

Description

Posterolateral congenital diaphragmatic hernia (CDH; Bochdalek hernia) remains a potentially lethal anomaly due to pulmonary HTN, pulmonary hypoplasia, and associated cardiac dysfunction. In utero Dx allows for delivery at (ideally) or transport to a tertiary center with sophisticated ventilatory support techniques. Early NG tube placement is important to minimize distension of the intrathoracic viscera. Surgery transiently worsens pulmonary HTN and may cause "persistent fetal circulation," in which the fetal circulation reopens to shunt blood around the lungs, causing further hypoxemia, hypercarbia, and acidosis—all stimuli for further pulmonary HTN. Thus, in the sickest newborns, surgery is delayed until after cardiorespiratory stabilization, with the following supportive measures: low-pressure, high-frequency ventilation; passive hypercapnia; oscillating or jet ventilation; NO; and even ECMO, which is becoming less common with the success of the former methods. When ECMO (with anticoagulation) is used, diaphragm repair may be performed at different times: **early during ECMO** (less swelling, more bleeding), **late during ECMO** (more swelling, ability to "come off" if bleeding), or **after ECMO** (less bleeding, less swelling, little recourse if surgery worsens ventilation). When the intestines are reduced from the chest, there is sometimes insufficient room in the abdomen, in which case, an abdominal silo is placed transiently.

Surgical approach

Left-sided lesions (Fig. 12.5-8) are seven times more frequent than right; repair is traditionally performed through a subcostal incision, but increasingly a laparoscopic or thoracoscopic approach is being utilized. In children with significant hypercarbia and/or pulmonary hypertension, insufflation with carbon dioxide may not be tolerated, precluding a laparoscopic approach. However, infants are surprisingly resilient to intrathoracic insufflation and respiratory acidosis can be effectively managed with hyperventilation.

Small defects cause few ventilation problems and are closed primarily. Larger defects are associated with more challenging ventilation and require prosthetic mesh augmentation. Recurrent defects may be approached through the abdomen or chest and sometimes require transfer of muscle flaps (interior oblique). Unless ECMO is used, a chest tube is not always necessary. Prognosis is determined by severity of associated cardiac lesions or other associated anomalies. Another reliable predictor of severity

(and mortality) is the presence of liver herniation.

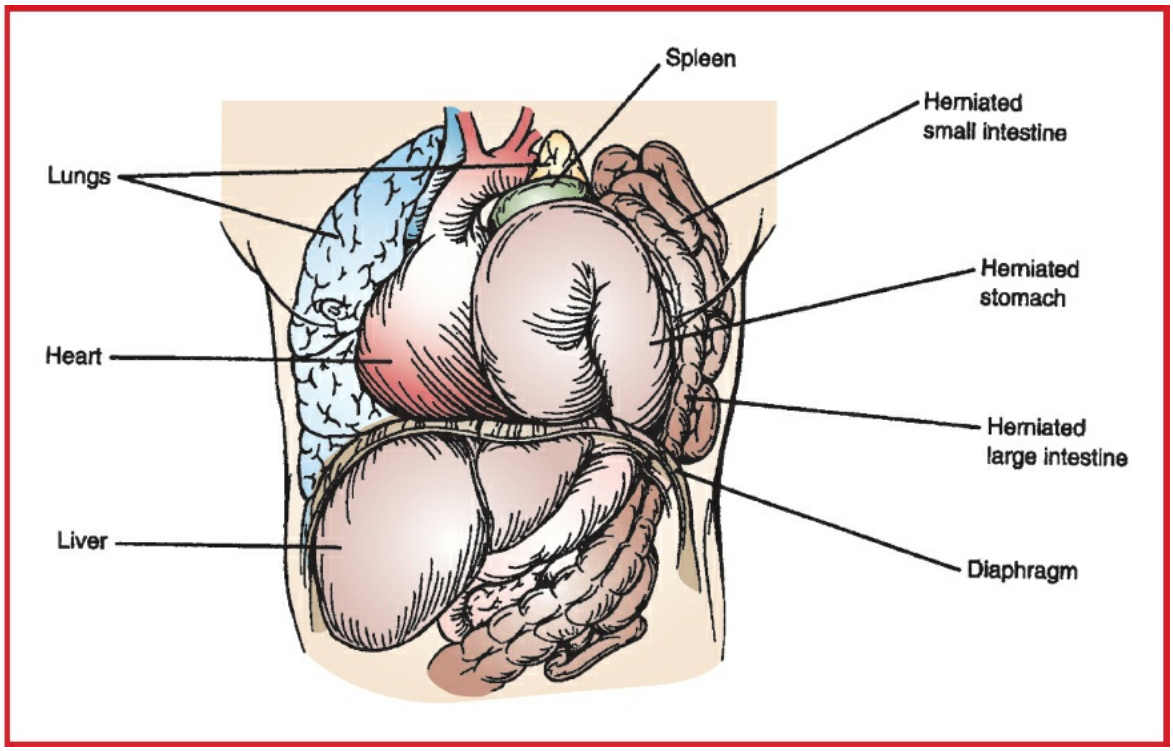

Figure 12.5-8 Left-sided congenital diaphragmatic hernia demonstrating translocation of the abdominal viscera into the left hemothorax and displacement of the mediastinum to the contralateral side. (Reproduced with permission from Oldham KT, Colombani PM, Foglia RPSurgery of Infants and Children. Lippincott-Raven, Philadelphia: 1997.)

Variant procedure

In utero therapies for CDH, including tracheal occlusion, have not been shown to improve survival. Although the defect commonly originates in the posterolateral diaphragm (Bochdalek), less common retrosternal defects (Morgagni) present later in life without the same degree of cardiorespiratory compromise.

Usual preop diagnosis

Diaphragmatic hernia; Bochdalek hernia (posterolateral diaphragm)

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care and pain management options, description of antimicrobial prophylaxis, skin preparation, and possible need for transfusion. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE

Position	Supine (lateral for thoracic approach)

Incision	Subcostal (posterolateral for thoracic approach)
Special instrumentation	Pre- and postductal arterial monitors
Unique considerations	Reactive pulmonary vasculature
Antibiotics	Preop: ampicillin 25 mg/kg iv + gentamicin 2.5 mg/kg iv
Surgical time	1–2 h
Closing considerations	Assess for changes in ventilation (e.g., PIP, pre- and postductal ABG).
EBL	5–10 mL/kg
Postop care	Paralysis maintained, high level of paralysis needed on ECMO; hyperventilation; fentanyl infusion @ 2–5 mcg/kg/min
Mortality	15–50% without ECMO 25–30% with ECMO 7% if liver below diaphragm 65% if liver above diaphragm
Morbidity	Pulmonary HTN Respiratory failure Sepsis Intestinal obstruction/dysfunction
Pain score	6–7 (7–8 for thoracic approach)

PATIENT POPULATION CHARACTERISTICS

Age range	Newborn–wk or mo
Male:Female	1–2:1
Incidence	1 in 4000
Etiology	Unknown
Associated conditions	Malrotation (40–100%); congenital heart disease (23%—VSD, ASD, PDA, TOF); renal anomalies (rare); esophageal atresia (rare); CNS abnormalities

	(e.g., myelomeningocele, hydrocephalus) (rare)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

These infants present with varying degrees of respiratory distress. Surgery is performed after the child has been stabilized medically. The majority are already mechanically ventilated, sedated, and paralyzed in the NICU prior to anesthesia consultation. Some infants may be on ECMO. The anesthesiologist needs to be aware of the distinction between early and late diaphragmatic hernias. Late herniations (occurring near or even after delivery) are associated with mature, well-developed lungs and minimal problems with ventilation. These babies often can be extubated in the early postop period, facilitated by epidural analgesia. CDH is frequently associated with other congenital abnormalities, including chromosomal abnormalities, CHD.

Respiratory	The lung on the affected side is variably hypoplastic, and the lung on the contralateral side may be compressed and also may be hypoplastic. Pulmonary hypoplasia is most severe in patients with early herniation and may be minimal in cases of late (even postnatal) herniation. The prognosis is correlated with magnitude of pulmonary hypoplasia. Mediastinal shift may prevent normal development of the contralateral lung. Thickening arterial smooth muscle can increase PA pressures, leading to R → L shunting. Persistent pulmonary HTN and progressive hypoxemia may be present. Nitric oxide may be indicated to ↓ PVR. **Tests:** CXR; ABG
Cardiovascular	Associated congenital heart defects are common and should be addressed prior to repair. R → L shunting may occur at the level of PDA or preductally (e.g., PFO). The degree of R → L shunting may be dramatically increased by pulmonary vasoconstriction (2° ↓ PO_2, ↑ PCO_2, ↑ pH, ↑ sympathetic tone) → severe systemic hypoxemia. ↓ CO 2° persistent pulmonary HTN and hypoxemia will lead to

	metabolic acidosis. **Tests:** CXR; ABG; echo
Neurologic	Myelomeningocele and/or hydrocephalus may be present. Repeated bouts of hypoxemia predispose to intraventricular hemorrhage (IVH) in preterm infant. These areas of hemorrhage have loss of cerebral autoregulation, and BP increases are directly transmitted to the microvasculature, with ↑ risk of recurrent hemorrhage and edema. **Tests:** Head ultrasound
Hematologic	Hct should be maintained at 35%. HbF has ↑ affinity for O_2 and ↓ sensitivity to 2,3-DPG. This will aggravate cellular hypoxia. Confirm that vitamin K was administered at birth. **Tests:** CBC; T&C; PT; PTT
Metabolic	Dextrose supplementation is needed due to negligible glycogen stores in neonate. In patients with CHF, diuretic administration leads to ↓ K^+. **Tests:** Electrolytes; glucose; BUN; Cr
Gastrointestinal	Constant NG/OG suction. Gastric distension will worsen ventilation.
Laboratory	Other tests as indicated from H&P
Premedication	None required
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Evaluate for concurrent disease.

INTRAOPERATIVE

Anesthetic technique

GETA, using a pediatric circle. Forced-air warmer. Warm room to 75°F–80°F. Maintain body temperature as close to 37°F if possible. Use pressure-limited ventilation (PIP < 30 cm H_2O). Continue NO if administered preop. Consider use o NICU ventilator, particularly if high RR (>30/min) is required.

Induction	Transported from NICU to OR by anesthesia team. If

	infant is already intubated, confirm paralysis prior to transport to lessen the risk of patient movement and inadvertent extubation. Transport with full monitoring (ECG, pulse oximetry, arterial pressure tracing). Have airway equipment available (Miller 1 laryngoscope blade, ET 3.0–3.5 with stylets, neonatal mask). Resuscitation drugs (e.g., epinephrine 1 and 10 mcg/mL) should be drawn up. Prior to any further anesthetic administration, re-establish all monitoring in OR. For nonintubated patients, rapid-sequence induction is appropriate. Atropine (0.02 mg/kg iv) may be given prior to induction to counteract bradycardia. If necessary to mask ventilate, avoid high inflation pressures, as this may further dilate the stomach. Place an OG tube prior to induction. Avoid N_2O and maintain PIPs as low as possible. For patients with late herniations and healthy lungs, consider caudal epidural catheter ↑advanced to thoracic space instead of iv opioids and early extubation (OR or NICU). If surgery is performed on ECMO, give high-dose iv opioids (may be given in ECMO circuit) and muscle relaxant.
ERAS	Verify preincision antibiotics. Assess volume status. Consider iv acetaminophen 10 mg/kg for multimodal analgesia if liver function tests are normal.
Maintenance	Opioid-based anesthetic (e.g. fentanyl 10–25 mcg/kg iv total), if no epidural in place, with isoflurane supplementation. Ventilate with air/O_2 to maintain SaO_2 95–100%, as measured by preductal ABGs/pulse oximetry. Avoid hypoxia, acidosis, and hypothermia, which will ↑ pulmonary vasoconstriction. Keep CO_2 slightly ↑ (permissive hypercapnia). Continue neuromuscular blockade with rocuronium or vecuronium. May need to momentarily

	pause surgery to restore adequate oxygenation and ventilation.	
Emergence	Transport back to NICU with full monitoring, airway equipment, and drugs.	
Blood and fluid requirements	Blood loss minimal IV: 22–24 ga × 2 BSS @ 4 mL/kg/h maintenance	These infants are fluid-restricted in NICU. Continue dextrose-containing solution from NICU. If umbilical venous line is not present, dopamine may be infused via peripheral iv with dextrose solution serving as the carrier fluid. In emergency, BSS, albumin 5%, and PRBCs (Hct < 50%) may be given via umbilical artery line.
Monitoring	Standard monitors Right-side precordial stethoscope	Contralateral pneumothorax is detected using a right axillary precordial stethoscope.
	Arterial line (umbilical or radial—24 ga); if possible, right hand (preductal) ± Umbilical vein line	ABG, Hct, glucose q30–60min
	Preductal and postductal pulse oximetry	Changes in pre- and postductal SaO_2 ↑ provide early warning of R→L shunt/pulmonary HTN. L hand postductal SaO_2 will drop with R→L shunt.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Pneumothorax Hypoventilation	With acute deterioration in SaO_2, pneumothorax

	Hypothermia Metabolic acidosis R → L shunting CHF	on the unaffected side is likely. Do not attempt to expand lungs vigorously. Hypoplasia, not atelectasis, is the primary problem. Keep PIP < 30 cm H_2O, if possible.

POSTOPERATIVE

Complications	Same as Intraop Complications, above	Severely affected neonates will usually have been stabilized on high-frequency jet ventilation or ECMO. The goal is to schedule semielective surgery when the neonate is medically stable. In case of acute deterioration in the OR, discuss with NICU criteria for initiation of HFJV or ECMO for infants whose oxygenation continues to worsen. Postop, these neonates go through a "honeymoon period" of up to 24 h, after which they may develop ↑ pulmonary HTN and deteriorate clinically.
Multimodal pain management	Fentanyl (0.5–2.0 mcg/kg/h iv) Hydromorphone (0.010 mg/kg) Acetaminophen	Tachyphylaxis can develop in 24–48 h. Acetaminophen if liver function tests are normal: 10 mg/kg q6h iv/po. If iv is unavailable, consider 20 mg/kg pr while NPO.

	Epidural analgesia
Tests	CXR, ABG, Hct, glucose, electrolytes
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.

Suggested Readings

1. Becmeur F, Reinberg O, Dimitriu C, et al: Thoracoscopic repair of congenital diaphragmatic hernia in children. Semin Pediatr Surg 2007; 16(4):238–44.
2. Brett CM, Davis PJ: Anesthesia for general surgery in the neonate. In: Davis PJ, Cladis FP eds. Smith's Anesthesia for Infants and Children, 9th edition. Elsevier Publishing, Philadelphia: 2017, 586–97.
3. Ellinas H, Seefelder C: Congenital diaphragmatic hernia repair in neonates: is thoracoscopy feasible? Paediatr Anaesth 2010; 20(10):967–9.
4. Hedrick HL: Management of prenatally diagnosed congenital diaphragmatic hernia. Semin Pediatr Surg 2013; 22(1):37–43.
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PYLOROMYOTOMY FOR PYLORIC STENOSIS

SURGICAL CONSIDERATIONS

Description

Pyloric stenosis due to idiopathic hypertrophy of the muscular layers of the antrum and pylorus occurs in infants from 1 to 3 mo of age, causing projectile vomiting with subsequent dehydration and metabolic alkalosis. Surgical division of the hypertrophied fibers—**pyloromyotomy**—is the treatment of choice (Fig. 12.5-9). Preop hydration and electrolyte replacement are becoming less frequently needed, as early Dx by ultrasound becomes more common. Aspiration of food or barium contrast is avoided by NG suction.

Surgical approach

The operation is performed through either a RUQ, periumbilical, or three laparoscopic incisions. The RUQ incision is now less utilized, whereas laparoscopic approach in experienced hands can be performed very quickly and effectively. With the open approach, the serosa and hypertrophic muscle of the pylorus are divided with a scalpel handle or Benson spreader. With the laparoscopic approach, a combination of sharp

division of the muscular fibers followed by blunt retraction is used to perform the myotomy. The anesthesiologist is typically asked to instill 40–60 cc of saline or air by orogastric tube into the stomach so that leaks can be detected. Careful inspection for a mucosal tear will avoid a subsequent leak, the most common serious complication. Mucosal injury is treated by a simple repair or by closing the entire myotomy and creating a new one at an alternate site.

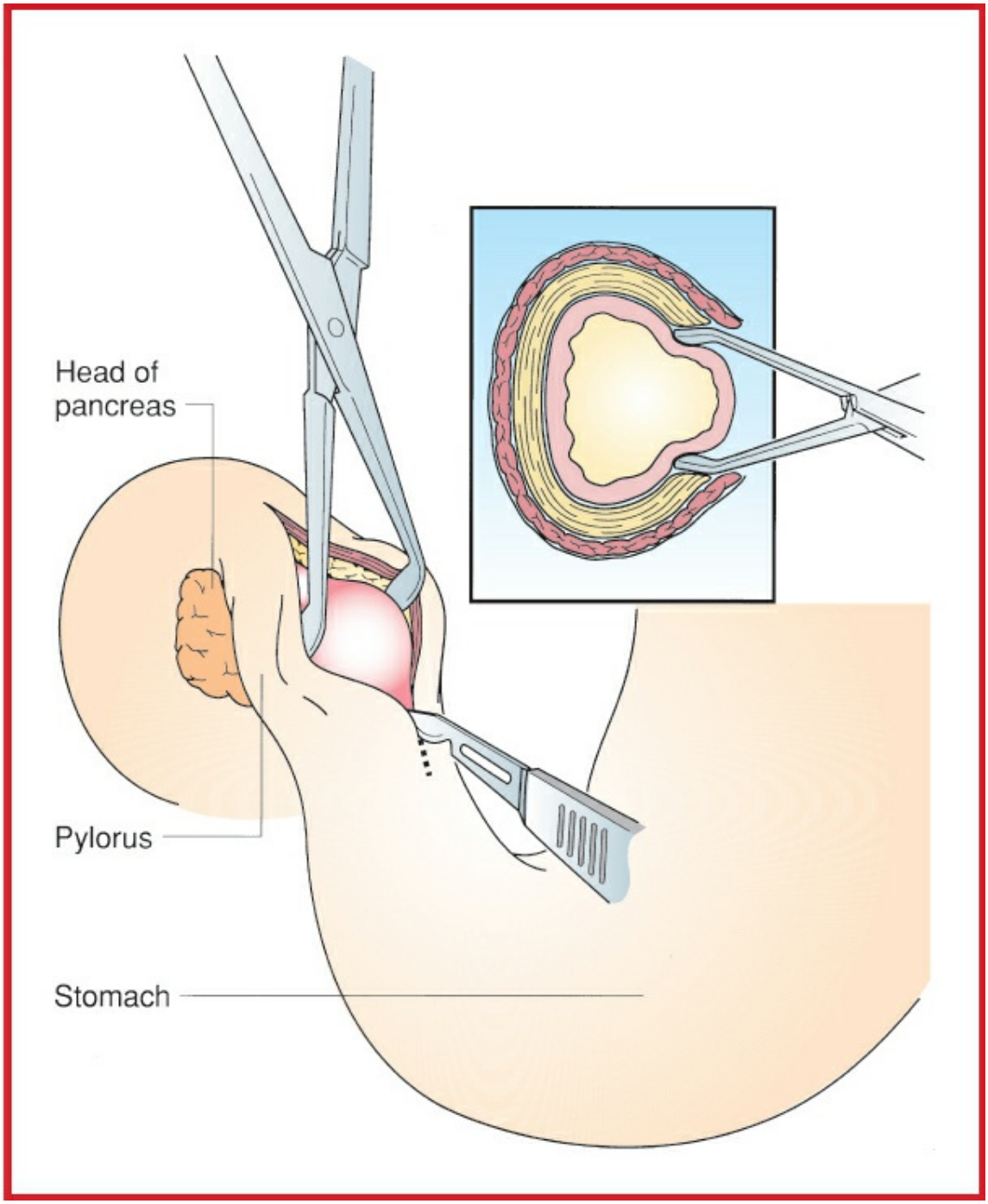

Figure 12.5-9 Ramstedt pyloromyotomy for infantile hypertrophic pyloric stenosis. The cross-sectional view shows herniation of the submucosa into the myotomy site, indicative of an adequate myotomy. (Reproduced with permission from Sato TT, Oldham KT: Pediatric abdomen. In: Greenfield LJ,

Mulholland MW, Oldham KT, et al., eds. Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Usual preop diagnosis

Pyloric stenosis; gastroenteritis; GERD

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care and pain management options, description of antimicrobial prophylaxis, skin preparation, and possible need for transfusion. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Transverse; RUQ; periumbilical, or three laparoscopic ports
Special instrumentation	Benson pyloric spreader; arthrotome (laparoscopy)
Intraop antibiotics	Cefazolin 30 mg/kg iv
Surgical time	0.5–1 h
EBL	<5 mL/kg
Postop care	Cardiac/apnea monitoring
Mortality	0.3%
Morbidity	Duodenal perforation Incomplete myotomy with recurrent vomiting Dehiscence Hernia
Pain score	4–5

PATIENT POPULATION CHARACTERISTICS	
Age range	1–12 wk
Male:Female	4:1
Incidence	3/1000 births

Etiology	Unknown
Associated conditions	Has occurred following repair of other congenital anomalies, such as esophageal atresia, omphalocele

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients with pyloric stenosis are usually term infants that present in the first month of life with dehydration 2° intractable vomiting. While in the past these infants usually presented with moderate to severe dehydration, diagnosis by ultrasound has led to earlier intervention, thereby minimizing the degree of electrolyte imbalance. Correction of volume deficit and metabolic abnormalities is the first line of treatment. Surgery should proceed only after patients are medically stabilized, adequate urine output is ensured, and metabolic alkalosis is corrected. These procedures are usually done with laparoscopy.

Cardiovascular	Mild-to-moderate dehydration is common and deficit should be replaced with NS over ~12 h. **Tests:** Urinary Cl > 20 mEq/L or plasma Cl > 100 mEq/L, when fluid volume restored
Metabolic	Protracted vomiting → dehydration with hypochloremic hypokalemic metabolic alkalosis. In severe cases, a metabolic acidosis may be present. Up to 30% of infants may be hyperkalemic. ↓ K^+ should be treated once alkalemia is resolved and UO is confirmed. **Tests:** ABGs; electrolytes; Ca^{++}; glucose
Gastrointestinal	Full-stomach precautions. Prior to induction, it is necessary to pass an OG tube several times to adequately decompress the stomach.
Laboratory	Hct; other tests as indicated from H&P
Premedication	None required
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Evaluate for concurrent disease. Ensure that electrolyte derangements are corrected prior to

	surgery. Obtain iv access, and ensure patient is adequately hydrated.

INTRAOPERATIVE

Anesthetic technique

GETA, forced-air warmer. Warm OR to 75°F–80° F. Maintain body temperature close to 37°C.

Induction	An iv catheter should be in place prior to induction for preop fluid management. Decompress the stomach with NG or OG tube. Atropine (0.02 mg/kg iv) may be given before stomach decompression to prevent bradycardia. Preoxygenate 2–3 min. Rapid-sequence induction with cricoid pressure should be performed, using propofol (2–3 mg/kg) or succinylcholine (1–2 mg/kg iv) or rocuronium (1 mg/kg). Use awake laryngoscopy if difficulty with intubation is anticipated. Intubate the trachea with an appropriately sized tube, usually 3.0-mm cuffed ETT or 3.5-mm uncuffed ETT. Air leak should be between 20 and 30 cm H_2O pressure. If succinylcholine is used, further NMB with rocuronium (0.6 mg/kg) or vecuronium (0.1 mg/kg) will be necessary. Laparoscopic technique and insufflation may displace the diaphragm and carina cephalad, leading to right mainstem intubation. Confirm BS after insufflation.
ERAS	Verify preincision antibiotics. Assess volume status.
Maintenance	Volatile agent and air/O_2 or N_2O/O_2. Avoid opioids to lessen risk of postop apnea due to tendency to hypoventilate due to previous metabolic alkalosis. Maintain muscle relaxation. Surgeon should infiltrate wound sites with bupivacaine 0.25% (with epinephrine 1:200,000)—not to exceed 2.5 mg/kg (1 mL/kg), for postop pain relief. Rectal acetaminophen 30 mg/kg can be administered.

Emergence	If NDMR was used, reverse neuromuscular blockade with sugammadex (2–4 mg/kg) or with a combination of neostigmine (0.07 mg/kg) and glycopyrrolate (0.01 mg/kg). Do not attempt reversal with neostigmine and glycopyrrolate until first twitch of TOF has returned. Prior to extubation, suction stomach contents via NG/OG tube. Extubate when fully awake.	
Blood and fluid requirements	Minimal blood loss IV: 22 ga × 1 BSS @ maintenance	Minimal 3rd-space loss
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Aspiration	

POSTOPERATIVE

Complications	Apnea	Pulse oximetry/apnea monitor × 24 h. Previous metabolic alkalosis decreases sensitivity to respiratory acidosis predisposing to hypoventilation and apnea. This may be exacerbated by administration of opioids. Differential diagnoses of apnea include hypoglycemia and hypothermia.
	Hypoglycemia (rare)	Rx for hypoglycemia: dextrose 0.5 g/kg iv

	Dehydration and electrolyte derangements	For child with severe dehydration and electrolyte abnormalities, ICU admission may be necessary.
Multimodal pain management	Acetaminophen (10 mg/kg po/iv q6h; 20 mg/kg pr q6h prn when NPO if iv unavailable) Avoid opioids	
Tests	None routinely indicated	
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.	

Suggested Readings

1. Liu LM, Pang LM: Neonatal surgical emergencies.Anesthesiol Clin North Am2001; 19(2):265–8.
2. Schwartz D, Connelly NR, Manikantan P, et al: Hyperkalemia and pyloric stenosis Anesth Analg 2003; 97:355–7.
3. Vegunta RK, Woodland JH, Rawlings AL, et al: Practice makes perfect: progressive improvement of laparoscopic pyloromyotomy results, with experience. J Laparoendosc Adv Surg Tech A 2008; 18(1): 152–6.
4. Williams RK, Lauro HV, Davis PJ: Anesthesia for general and urologic surgery. In Davis PJ, Cladis FP eds.Smith's Anesthesia for Infants and Children, 9th edition. Elsevier Publishing, Philadelphia: 2017, 795–7.

ABDOMINAL TUMOR: RESECTION OF NEUROBLASTOMA, WILMS TUMOR, AND HEPATIC TUMORS

SURGICAL CONSIDERATIONS

Description

Pediatric abdominal tumors occur most commonly in children 1–4 yr old, may be massive, and usually arise from the sympathetic chain (including adrenal gland), kidney, or liver. Neuroblastoma and Wilms tumors are the most common; hepatic tumors (including hemangiomas) are less common but can be uniquely challenging. Because they originate in sympathetic tissue, many neuroblastomas produce catecholamines; however, these rarely have hemodynamic consequences.

Surgical approach

At first operation for very large neuroblastomas and hepatoblastomas, a central line is placed and tumors are biopsied; definitive resection usually follows chemotherapy and/or radiation therapy. Small neuroblastomas, small hepatoblastomas, and even large Wilms tumors (without vascular extension or bilateral involvement) may be excised primarily. The principles of operation for these tumors are similar, beginning with a generous incision—transverse, midline, or thoracoabdominal, depending on tumor location and surgeon preference. The incision may be extended into the chest if control of the suprahepatic vena cava is necessary. Mobilization of the tumor from adjacent structures may precede vascular control when the latter is difficult to obtain early, as is often the case. Tumors encasing vessels may be divided to preserve end-organ blood supply. Neuroblastomas tend to invade
local structures. Wilms tumors and hepatoblastomas tend to push aside adjacent structures. Wilms tumors are bilateral in 10–15% of cases and are prone to vascular extension into the renal vein, IVC, and (rarely) right atrium. Major hepatic resections are sometimes required for hemangiomas that cause CHF or thrombocytopenia (Kasabach-Merritt syndrome).

Laparoscopic assistance is limited generally to biopsy of these lesions for tissue diagnosis. Some hepatoblastomas may be amenable to laparoscopic liver resection. Small, localized neuroblastomas and posterior mediastinal neural crest lesions are quite amenable to laparoscopic or thoracoscopic resection.

Usual preop diagnosis

Neuroblastoma; Wilms tumor; hepatoblastoma

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review/optimization of nutritional status, postop care and pair management options, description of antimicrobial prophylaxis, skin preparation, and possible need for transfusion. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Neuroblastoma	Wilms Tumor	Hepatic Resections
Position	Supine, 15° lift	⇐	⇐
Incision	Transverse, possible thoracic extension (Fig. 12.5-10)	⇐	⇐
Special instrumentation	None	Bypass instruments	CUSA; laser; argon beam coagulator
Unique considerations	Rarely, hormonally active; may wrap blood vessels	Atrial tumor; IVC may be obstructed →↓ ↓ CO.	Possible CHF; Plt trapping
Antibiotics	Cefotaxime 25 mg/kg	⇐	⇐
Surgical time	3–6 h	⇐	⇐
Closing considerations	None	⇐	Hypoglycemia
EBL	20–50 mL/kg	⇐	20–100 mL/kg
Postop care	PICU; epidural is ideal.	± PICU	PICU
Mortality	<5%	⇐	⇐
Morbidity	Intestinal obstruction: 10%	⇐	—

	Postop respiratory atelectasis	⇐	⇐ Hypoglycemia: 10% Bile leak: 5–10%
Pain score	7–8	7–8	7–8

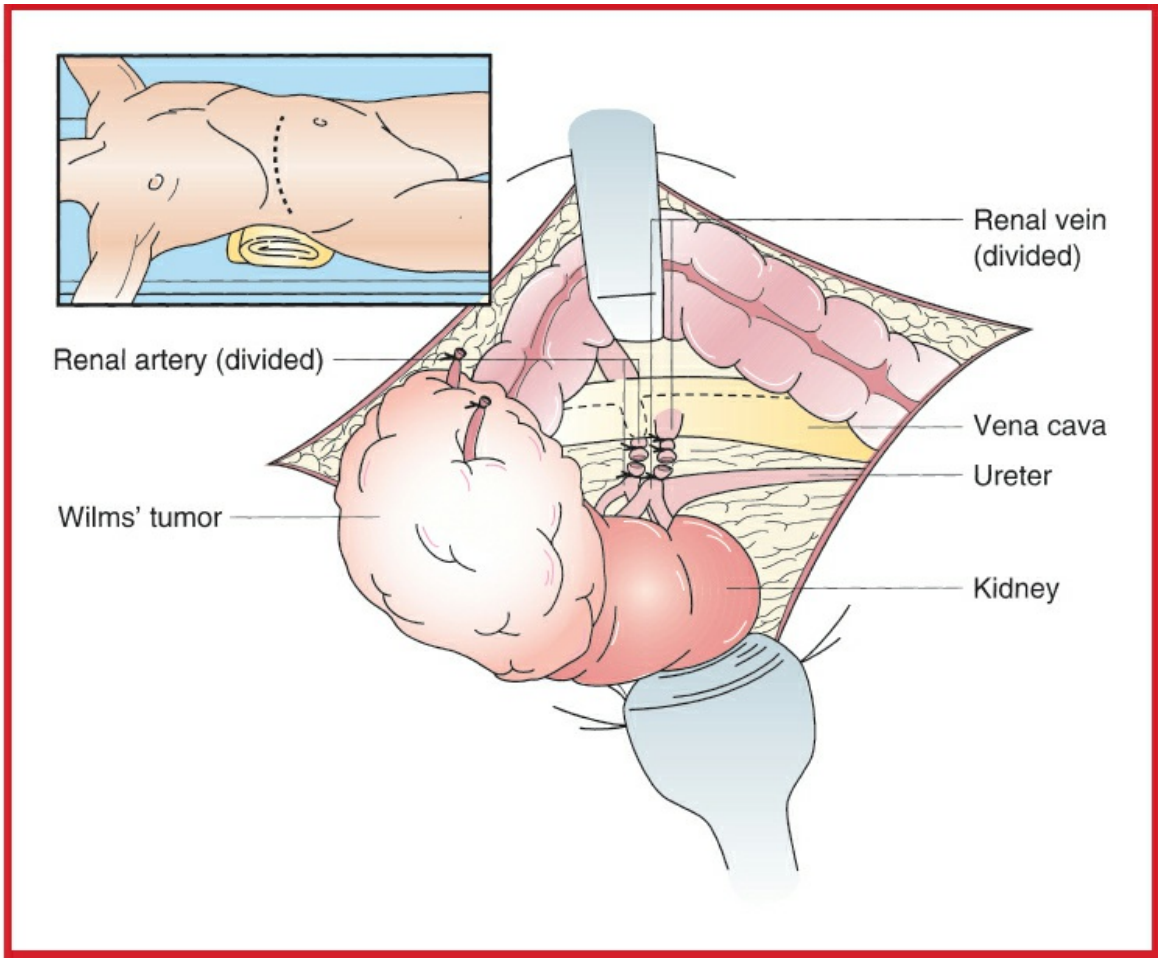

Figure 12.5-10 Operative approach to resection of a right renal Wilms tumor. **Inset** shows transverse incision. (Reproduced with permission from Laquaglia MP: Childhood tumors. In: Greenfield LJ, Mulholland MW, Oldham KT, et al., eds. Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

PATIENT POPULATION CHARACTERISTICS

	Neuroblastoma	Wilms Tumor	Hepatic Resections
Age range	Few months–	⇐	⇐

	school age		
Male:Female	1:1	⇐	⇐
Incidence	1/10,000	<1/10,000	⇐
Etiology	Unknown	⇐	⇐
Associated conditions		Beckwith-Wiedemann; neurofibromatosis; aniridia 1%; hemihypertrophy 2%; GU abnormalities 5%	

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Neuroblastoma, Wilms tumor (nephroblastoma), and hepatic tumors commonly present as abdominal masses in infants and children <4 yr old. Symptoms and signs at presentation depend on size and location of the tumor and any metastases. Neuroblastomas are usually associated with increased circulating and urinary catecholamines, though usually not clinically significant. While hypertension is rare, tumor manipulation may result in sudden release of catecholamines. Elevated catecholamines may be suspected if the following Sx exist: flushing, diaphoresis, palpitations, and hypertension.

The majority of patients with Wilms tumor has HTN due to increased renin activity and may be on antihypertensive medications.

Respiratory	There may be respiratory compromise (as a result of a large abdominal mass pushing up on the diaphragm), which may worsen in the supine position. Wilms tumor commonly metastasizes to the lungs. **Tests:** CXR, if indicated from H&P
Cardiovascular	↑ BP is associated with Wilms tumor and rarely with neuroblastoma; volume status should be assessed carefully. Tumor bulk may impede venous return by

	occluding the IVC. Wilms tumor may extend through the IVC into the right atrium. These patients may have received chemotherapy, e.g., Adriamycin or doxorubicin, which is associated with cardiac toxicity (most commonly at doses >200 mg/m^2). Cardiology consultation may be appropriate. **Tests:** Echocardiogram
Renal	Wilms tumor may present with hematuria and other GU anomalies such as horseshoe kidney, duplication of urinary tract, and aplastic or hypoplastic kidneys. Renal function is usually normal unless both kidneys are affected. **Tests:** BUN; Cr
Endocrine	Neuroblastomas are associated with ↑ catecholamine production. Preop adrenergic blockade (as would be required for a pheochromocytoma) is usually not necessary. **Tests:** Urine VMA and HVA
Gastrointestinal	Intestinal compression from tumor may ↑ risk of gastric aspiration. Persistent, watery diarrhea (→ hypovolemia, ↓ K^+) is associated with neuroblastoma 2° VIP secretion. **Tests:** Electrolytes
Hematologic	Severe anemia and thrombocytopenia may be present. Blood should be available because of possible massive intraop blood loss. **Tests:** CBC; T&C. ✓ availability of parental/directed donor blood, if requested. ✓ PT, PTT.
Laboratory	Other tests as indicated from H&P
Premedication	Consider 0.5 mg/kg po midazolam (maximum 20 mg) or 0.05–0.1 mg/kg iv midazolam (maximum 2 mg) for patients >9 mo.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Evaluate for concurrent disease. Discuss with surgeon possible epidural catheter.

INTRAOPERATIVE

Anesthetic technique

Combined epidural/GETA, warm OR to 75°F–80°F; warm all iv fluids.

Induction	IV catheter insertion before induction may be preferable. Access above the diaphragm, such as an upper extremity or EJ site, is preferred due to possible tumor invasion of IVC or need for IVC cross-clamping. A modified rapid-sequence induction is recommended in those patients with a large intra-abdominal mass compressing the GI tract. Otherwise, standard pediatric induction is appropriate.
ERAS	Verify preincision antibiotics. Assess volume status. Consider epidural catheter or discuss with surgeon local wound infiltration at conclusion of procedure. Consider iv acetaminophen (10 mg/kg for patients <1 mo old or 15 mg/kg for older patients). Consider PONV prophylaxis with iv ondansetron (0.1 mg/kg).
Maintenance	Standard maintenance. Muscle relaxation is appropriate. HTN associated with tumor manipulation can be treated with SNP (0.5–2.0 mcg/kg/min) or esmolol (50–150 mcg/kg/min).
Emergence	In most instances, patient can be extubated at the end of surgery. If NDMR was used, reverse neuromuscular blockade with sugammadex (2–4 mg/kg) or with a combination of neostigmine (0.07 mg/kg) and glycopyrrolate (0.01 mg/kg). Do not attempt reversal with neostigmine and glycopyrrolate until first twitch of TOF has returned. Suction NG tube and confirm air leak around ETT before extubation. If there is no air leak, consider laryngeal edema and need for continued intubation.
Blood and fluid	Potential for large Tumor resection may be

requirements	blood loss/moderate 3rd-space loss IV: 18–20 ga × 1–2 BSS @ maintenance 5% albumin may be useful to replace 3rd-space losses (8–10 mL/kg/h).	associated with massive blood loss, especially with IVC or renal vein involvement. Avoid placement of iv catheters in lower extremities. Transfuse to maintain Hct > 23. If >1 mo of age, dextrose-containing solutions are not required.
Monitoring	Standard monitors Arterial line: 22 ga ± CVP line: (subclavian or IJ) confirm position by CXR	ABG, Hct, and blood glucose should be measured regularly. CVP measurement may be useful to evaluate fluid status. Monitor UO and keep at 1 mL/kg/h.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Hypotension HTN	↓ BP 2° blood loss or following tumor removal due to decreased catecholamines.
	PE	↑ BP 2° tumor or adrenal manipulation 2° tumor embolization usually from IVC →↓ BP
	Hypothermia	
	Hypoventilation	Abdominal retractors and packing will interfere with ventilation.

POSTOPERATIVE

Complications	Atelectasis Hypoventilation	
Multimodal Pain	Epidural optimal	See p. E-5 for dosing

management	Hydromorphone or morphine PCA schedule. Morphine (0.05–0.1 mg/kg q1–2) Hydromorphone (0.005–0.01 mg/kg q1–2h) Acetaminophen (10 for <1 yr old or 15 mg/kg for older patients with max of 650 mg iv/po q6h or 20 mg/kg pr q6h prn)
Tests	Hct, ABG, CXR
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.

Suggested Readings

1. Kako H, Taghon T, Veneziano G, et al: Severe intraoperative hypertension after induction of anesthesia in a child with a neuroblastoma. J Anesth 2013; 27:464–67.
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LAPAROTOMY FOR INTESTINAL PERFORATION

AND NECROTIZING ENTEROCOLITIS

SURGICAL CONSIDERATIONS

Description

Necrotizing enterocolitis (NEC) is an ischemic/inflammatory condition of the entire G tract, most commonly affecting the terminal ileum, occurring in stressed, premature infants, often after feeding with formula. It may resolve with conservative management (NPO, antibiotics, NG suction) or progress to necrosis and perforation, treated by resection and stoma formation or drainage procedure, depending on patient weight and surgeon preference. Isolated ileal perforation—occurring without precedent pneumatosis intestinalis—may be a different disease entity; it is sometimes treated by primary repair. Infants with NEC may be septic, thrombocytopenic, and coagulopathic, with organ dysfunction related to prematurity, and have marginal ventilation. Despite expeditious surgery, several blood volumes may be lost and hypothermia may develop. Unstable infants may have surgery performed in the NICU.

Surgical approach

If not already present, central venous access is established at the time of surgery. A transverse laparotomy incision enables inspection of all intestines; dead bowel is resected, a proximal stoma is created in the healthy bowel, and a distal mucous fistula is created to protect potentially viable bowel. Less commonly, a **Hartmann pouch** is created (distal intestine remains inside without stoma). When proximal bowel is of intermediate viability, a second-look operation is wise.

Variant procedures or approaches

Placement of peritoneal drain. The procedure involves placement of a RLQ Penrose drain into the abdominal cavity as a bedside procedure. It is quick, relatively easy, and attended by little bleeding or hypothermia. Between 60% and 80% of drained children subsequently will require laparotomy.

Usual preop diagnosis

Perforated NEC

ERAS: Time permitting, family preop counseling by the surgeon/anesthesiologist should include review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Resection	Drainage
Position	Supine	⇐
Incision	Transverse	RLQ
Special instrumentation	None	Penrose drains
Unique considerations	Temperature support	⇐
Antibiotics	Ampicillin 50 mg/kg + gentamicin 2.5 mg/kg + clindamycin 10 mg/kg iv preop	⇐
Surgical time	1–2.5 h	0.5 h
EBL	10–100 mL/kg	1–2 mL/kg
Postop care	NICU	⇐
Mortality	20–25%	16–20%
Morbidity	Respiratory failure Sepsis Stricture Intracranial hemorrhage	⇐
Pain score	6–7	3–4

PATIENT POPULATION CHARACTERISTICS

Age range	Newborn–weeks
Male:Female	>1:1
Incidence	5–8% NICU admissions
Etiology	Multifactorial, including intestinal ischemia; bacterial colonization; perinatal stress; immaturity; hypoxia; hyperosmolar feeding; splanchnic ischemia
Associated conditions	Prematurity (80–90%); respiratory distress; PDA

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Most (80–90%) of these patients are premature infants (<36-wk gestational age) presenting with sepsis. Severity of symptoms, complications, and mortality are inversely related to gestational age. Respiratory distress syndrome (RDS) is often present 2° prematurity of the lungs, and pulmonary insufficiency is likely present. In addition to sepsis, significant 3rd-space losses contribute to hypovolemia and metabolic acidosis. If the patient is extremely unstable, consider peritoneal drainage or surgical intervention at the bedside in the NICU.

Respiratory	Premature infants are at risk for RDS. These infants are usually on mechanical ventilation with ↑ FiO_2 prior to surgery. They also are at ↑ risk for hypoventilation, hypercapnia, and hypoxemia. Enlarged abdomen may compromise respiratory function. ✓ ventilator settings and recent ABG in preparation for OR mechanical ventilation. Consider need for NICU ventilator in OR. **Tests:** CXR; ABG
Cardiovascular	Likely hemodynamic instability 2° to sepsis and/or underresuscitation. Inotropes (e.g., dopamine 5–10 mcg/kg/min) may be required to maintain adequate CO. Associated cardiac anomalies (e.g., VSD, PDA) can lead to CHF, further complicating fluid management. Pulmonary overcirculation and intrinsic pulmonary disease contribute to pulmonary HTN. **Tests:** CXR; ABG; echo
Neurologic	Intraventricular hemorrhage (IVH) may be 2° to prematurity or birth asphyxia. These hemorrhagic regions have impaired autoregulation, and wide variations in BP (20–30 mm Hg) can aggravate ischemia/hemorrhage. In addition, these patients may have a seizure disorder. **Tests:** Head ultrasound, if indicated from H&P
Renal	Presence of PDA and previous Rx with NSAID can

	lead to impaired renal perfusion and clearance. Aggravating factors are aminoglycoside antibiotics, sepsis, and CHF. **Tests:** BUN; Cr
Metabolic	Metabolic acidosis 2° to sepsis and/or CHF will further worsen myocardial function. Neonates have minimal glycogen stores and are more prone to hypoglycemia. **Tests:** ABG; Ca^{++}; glucose; electrolytes
Hematologic	DIC, and associated thrombocytopenia and anemia may be present. **Tests:** CBC, PT, PTT, fibrinogen, availability of irradiated, washed RBCs or freshest PRBC
Laboratory	Others as indicated from H&P
Premedication	None required
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Evaluate for concurrent disease.

INTRAOPERATIVE

Anesthetic technique

GETA, using a pediatric circle. Warm OR to 75°F–80°F. Forced-air warmer and warming pad on OR table. Use air/O_2 mixture for ventilation and maintain SpO_2 between 92% and 94% (PaO_2 < 70 mm Hg) to minimize risk of retinopathy. Avoid high concentrations of O_2 if possible. Consider use of NICU ventilator if patient requires ↑ RR or ↑ PIPs. Epidural catheter insertion is not recommended in the presence of sepsis.

Induction	These patients usually are intubated. If not, intubate with full-stomach precautions. Suction the stomach. Atropine 0.02 mg/kg iv may be given before laryngoscopy to prevent bradycardia. Preoxygenate for 3 min. Miller 0/1 blade. Apply cricoid pressure until airway is secured. ETT should have leak at 18–35 cm H_2O pressure.
ERAS	Verify preincision antibiotics. Assess volume status.

	Consider iv acetaminophen 10 mg/kg if liver function tests are normal.	
Maintenance	Low-dose volatile agent supplemented with fentanyl, titrated for hemodynamic stability (10–30 mcg/kg). Avoid N_2O. Muscle relaxation required. Inotropes (dopamine 3–5 mcg/kg/min and epi 0.05–0.2 mcg/kg/min) may be needed to maintain hemodynamic stability and perfusion. Neonates may be underresuscitated upon arrival from NICU. 3rd-space losses are usually significant. Treat hypotension with volume before increasing pressor support. Maintain Hct > 35%. Albumin 5% (10 mL/kg iv). PRBC 10 mL/kg, FFP Plt 10 mL/kg.	
Emergence	Postop ventilation generally required. Transport to NICU with full monitoring (pulse oximetry, ECG, arterial line). Have laryngoscope and appropriately sized mask and ETT available. Extra volume (albumin 5% in 20 mL syringes) may be needed during transport.	
Blood and fluid requirements	Anticipate moderate-to-large blood and fluid losses. IV: 22–24 ga × 2 (or 1 + CVP)	Neonates may be underresuscitated upon arrival from NICU. 3rd-space losses are usually significant. Rx: ↑ BP with volume before increasing dopamine. Maintain Hct > 35%. Albumin 5% (10 mL/kg iv) boluses as needed. Crystalloid/colloid > 100 mL/kg total not uncommon. Hct, glucose, Ca^{++}, ABG, Plt count, PT/PTT, electrolytes q30–60min. i-Stat if available. Check ionized serum Ca^{++} frequently (q30 min while transfusing). Citrate is present in blood and blood products,

		especially FFP, and binds serum Ca^{++}. Neonatal liver has limited ability to clear citrate, and neonatal heart is especially dependent on ionized Ca^{++}.
	Continue dextrose-containing solution from NICU to avoid hypoglycemia. Warm fluids.	Because of the potentially large blood loss/kg, ensure that blood replacement is available in the room and that additional factor replacement is available on call.
Monitoring	Standard monitors A-line pref. preductal (RUE) ± CVP line	CVP line is not as important as arterial line for intraop care, but may be useful for administering inotropic drugs.
Positioning	✓ eyes ✓ pad pressure points	
Complications	Hypothermia	
	Metabolic acidosis Hypovolemia	Aggressive volume replacement and maintaining normothermia will prevent or ameliorate metabolic acidosis. Bicarbonate replacement = base deficit × wt (kg) × 0.3.
	Hyperkalemia 2° blood products	Minimized by requesting that newest blood available be sent up. If irradiated, it may need to be washed (check w/ blood bank for policy).
	Pneumothorax	↓ SaO_2, ↑ PIPs. ✓ for mucus plugging or mainstem intubation.

	Hypocalcemia	Frequent blood sampling is necessary. Rx: $CaCl_2$ (10 mg/kg iv) in dilute solution via CVP line or Ca gluconate (30 mg/kg iv) via peripheral line.
	Hypoglycemia	Continue 10% dextrose infusion from NICU.

POSTOPERATIVE

Complications	Hypovolemia due to blood loss and 3rd spacing Metabolic acidosis Sepsis Pulmonary edema Retinopathy of prematurity (ROP)
Multimodal pain management	Morphine (0.05–0.10 mg/kg iv) or hydromorphone 0/005–0.01 mg/kg q1–2h prn or via continuous infusion for initial 24–48 h. If liver function tests are normal, consider iv acetaminophen 10 mg/kg q6h.
Tests	CBC, electrolytes, Ca^{++}, glucose, ABG, CXR if central line placed
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function. Depending on the extent of the bowel resected, some patients may require long-term total peripheral nutrition.

Suggested Readings

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2. Gregory GA: Anesthesia for premature infants. In: Gregory GA, Andropoulos DB eds. Gregory's Pediatric Anesthesia, 5th edition. Wiley-Blackwell Pub, West Sussex, UK: 2012, 480–96.

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REPAIR OF BILIARY ATRESIA AND CHOLEDOCHAL CYSTS

SURGICAL CONSIDERATIONS

Description

"Biliary atresia" is a misnomer, because the pathology seems to be an ascending progressive fibrosis of the biliary tree ultimately manifesting as intrahepatic bridging fibrosis and cirrhosis. The obstruction develops postnatally, typically in an otherwise healthy 4- to 6-wk-old girl, though it may be confused with neonatal hepatitis or with the cholestasis seen in sick neonates fed intravenously. Preop studies often are not diagnostic. There is some time pressure for diagnosis and surgery because several studies have shown worse outcomes if the procedure is delayed beyond 8–10 wk of age. Even if the Kasai is not successful in long term, it can be an important bridge that allows infants to grow, improving outcomes of subsequent liver transplantation. **Todani** classified choledochal cysts into five types. The first type is the most common: a fusiform ballooning of the extrahepatic bile ducts often involving the gallbladder. Cysts are prone to bile stasis, obstruction, and malignant conversion in adulthood. Some are detected when they become symptomatic, whereas others are detected on antenatal ultrasound.

Surgical approach

Following preop administration of vitamin K, operation for biliary atresia begins either through a transverse RUQ incision or laparoscopically for liver biopsy and operative cholangiography. Ascent of contrast into the liver and descent into the duodenum occur in up to 20% of cases, which excludes biliary atresia and will terminate the operation. Failure to establish patency of the biliary tree is indication to extend the incision to excise the gallbladder and extrahepatic biliary tree. In doing so, the portal vein and hepatic artery are skeletonized up to the base of the liver (called the portal or hepatic "plate"; Fig. 12.5-11). This region is excised (attended by some bleeding) in the hope that bile will drain from the liver above into a Roux-en-Y loop of jejunum, which is sewn to the undersurface of the liver (**portoenterostomy** or **Kasai procedure**). There is currently little support for early liver transplantation.

Choledochal cyst resection involves a smaller incision, possible cholangiogram, and dissection similar to the Kasai procedure, but only to a level above the cyst (frequently, the bifurcation of the hepatic ducts). Liver biopsy is not always required, and cirrhosis is uncommon. Bleeding may result when an inflamed cyst is adherent to the portal vein or hepatic artery. The distal end of the cyst is ligated, the body of it excised, and the proximal bile duct (usually the common hepatic duct) sewn to a Roux-en-Y limb of jejunum. Kasai can be performed laparoscopically with or without robotic assistance. However, concerns have been raised about the effectiveness of biliary drainage when performed laparoscopically.

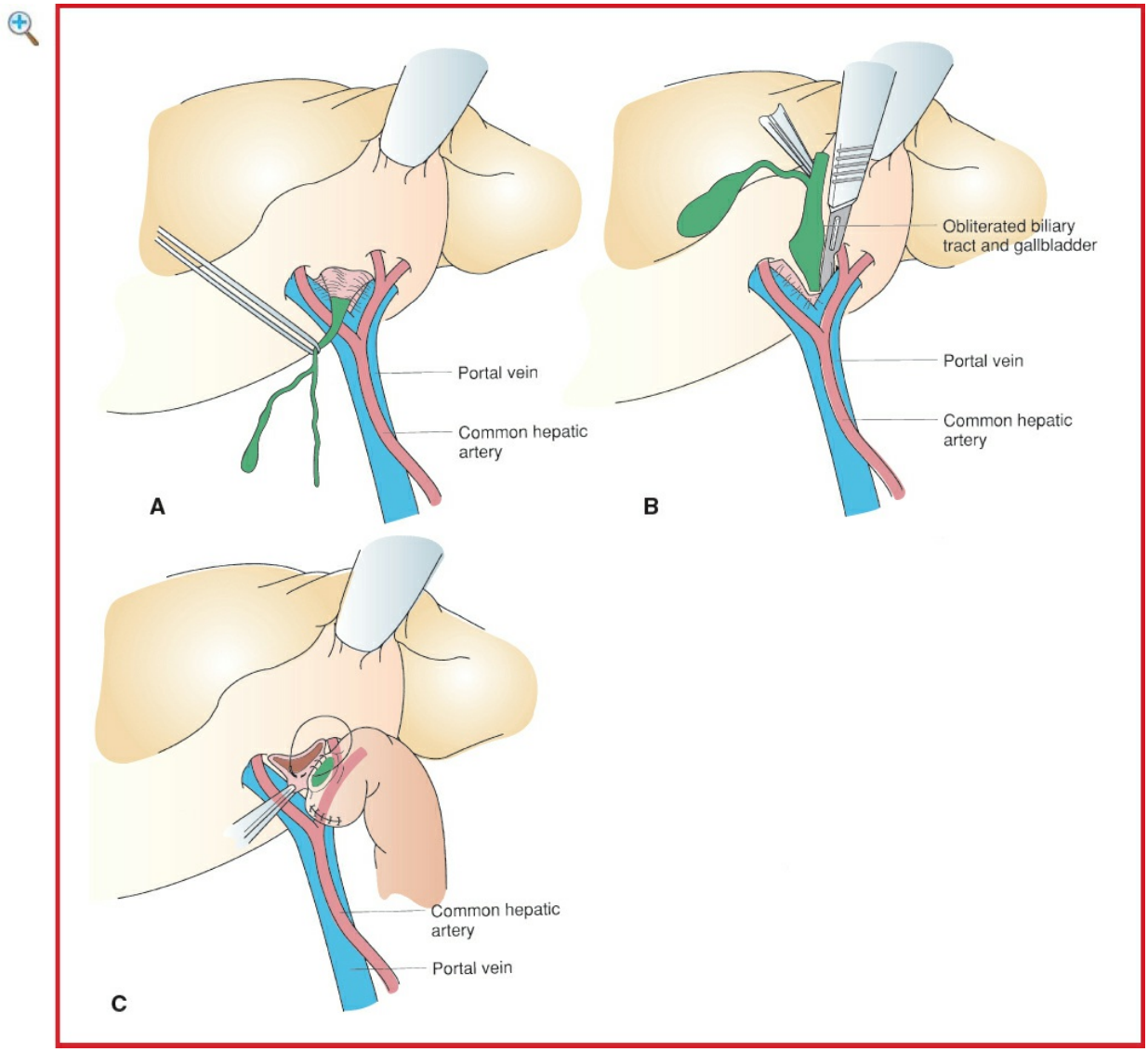

Figure 12.5-11 The essential features of the portoenterostomy for biliary atresia include appropriate mobilization **(A)** and transection **(B)** of the fibrous biliary tract remnant. **C:** Creation of a Roux-en-Y jejunal conduit with biliary enteric anastomosis completes the procedure. (Reproduced with permission from Sato TT, Oldham KT: Pediatric abdomen. In: Greenfield LJ, Mulholland MW, Oldham KT, et al., eds. Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Variant procedures

Infant ERCP has been reported as an alternative to intraop cholangiogram for the definitive diagnosis of biliary atresia. However, most centers do not have the expertise to perform endoscopic cholangiograms in infants.

Usual preop diagnosis

Biliary atresia; choledochal cyst; obstructive jaundice

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care and pain management options, description of antimicrobial prophylaxis, skin preparation, and possible need for transfusion. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Upper transverse chevron; right transverse for cholangiogram
Special instrumentation	Cholangiography equipment
Unique considerations	Cholangiogram, if gallbladder patent
Antibiotics	Preop: ampicillin 25 mg/kg iv + gentamicin 2.5 mg/kg iv Intraop: cephalosporin irrigation (1 g/500 mL NS)
Surgical time	4–6 h (1–2 h if cholangiography/biopsy only)
EBL	5–10 mL/kg
Postop care	PICU
Mortality	<5%
Morbidity	Bile leak: 10–15% Obstruction: 10% Sepsis: 5–10% Respiratory failure: 5%
Pain score	7–8 (4–5 for cholangiogram)

PATIENT POPULATION CHARACTERISTICS	
Age range	6–12 wk
Male:Female	>1:1
Incidence	1/15,000 births
Etiology	Viral; autoimmune
Associated conditions	NB: Asplenia syndrome (5–10%); polysplenia (5–10%)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Biliary atresia is a postnatal inflammatory disorder of the hepatobiliary tree resulting in fibrosis, cirrhosis, and obstructive jaundice. The Kasai procedure is indicated if the diagnosis of biliary atresia is made in the first 2–3 mo of life. If the Kasai procedure is unsuccessful, the patient may require a liver transplant.

Gastrointestinal	Hepatic function preserved initially (i.e., normal albumin synthesis). Cholestatic jaundice usually present. There may be impaired elimination of drugs, particularly NMBs. Glucose homeostasis is usually normal.
Hematologic	Anemia 2° chronic disease. Impaired vitamin K absorption 2° lack of bile salts. Elevated PT will variably correct with vitamin K administration (phytonadione 1 mg im/iv given during the week before surgery). Have FFP available if PT not corrected after vitamin K. **Tests:** PT; PTT; CBC; T&C
Laboratory	Electrolytes: BUN, Cr, LFTs, albumin, bilirubin, direct and indirect, glucose, others as indicated from H&P. Confirm availability of blood products (PRBCs, FFP).
Premedication	None required
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status.

	Evaluate for concurrent disease. Discuss with surgeon possible caudal epidural.

INTRAOPERATIVE

Anesthetic technique

GETA/caudal. Warm OR to 75°F–80°F; use forced-air warmer, warming pad on OR table. (Remember, majority of heat loss is radiant.)

Induction	Mask induction is appropriate if no iv in place. NMB (e.g., rocuronium 0.6–1 mg/kg or cisatracurium 0.1–0.2 mg/kg) to facilitate tracheal intubation, using appropriately sized ETT (usually 3.0–3.5 cuffed ETT; with leak at 18–35 cm H_2O). If coagulation factors are normal, consider caudal catheter, and advance to thoracic position. Preservative-free NS may be used to dilate the epidural space. Position may be confirmed with ultrasound.	
ERAS	Verify preincision antibiotics. Assess volume status. Consider caudal epidural or discuss with surgeon local wound infiltration at conclusion of procedure.	
Maintenance	Sevoflurane or isoflurane/air/O_2; no N_2O, to avoid bowel distension. Continue muscle relaxant to facilitate abdominal closure.	
Emergence	Patient is usually extubated in OR and transported to PACU or, in the case of prolonged surgery and/or significant blood loss, to PICU. If NDMR was used, reverse neuromuscular blockade with sugammadex (2–4 mg/kg) or with a combination of neostigmine (0.07 mg/kg) and glycopyrrolate (0.01 mg/kg). Do not attempt reversal with neostigmine and glycopyrrolate until first twitch of TOF has returned.	
Blood and fluid requirements	Moderate blood loss IV: 22 ga × 1–2 BSS @ 10 mL/kg/h Albumin 5%	Potential for large 3rd-space losses. Plan 10 mL/kg/h of BSS for replacement, and be prepared for sudden

		blood loss. Use albumin 5% or BSS to replace blood loss.
Monitoring	Standard monitors Urinary catheter NG tube ± Arterial line (22–24 ga)	Hct, blood glucose, ±ABG p.m. Maintain UO of 1 mL/kg/h. The presence of ↑ ↑ BP variations with respiration is a useful indicator of hypovolemia.
Positioning	✓ padding—heels, elbows, occiput ✓ eyes	
Complications	Hypothermia Hypovolemia Hypoventilation Metabolic acidosis	In upper abdominal surgery, the retractors and abdominal packing may limit diaphragmatic excursion, thus requiring higher PIP to adequately ventilate the patient. Need ETT leak (PIP) >20 cm H_2O to ensure ability to adequately ventilate. ETT position may also change with packing, resulting in R mainstem intubation, requiring repositioning.

POSTOPERATIVE

Complications	Hypovolemia Atelectasis Cholangitis	3rd-space losses continue in the immediate postop period.
Multimodal pain management	Fentanyl 1–2 mcg/kg iv q1h prn Morphine (0.05–0.1 mg/kg iv q2–4h prn)	Caudal analgesia if catheter in place. Bupivacaine dose should be limited to 2.5 mg/kg for single dose

	Hydromorphone (0.005–0.01 mg/kg q1h iv)	administration (maximum 25 mg). Hourly infusions should not exceed 0.3mg/kg/hr 2° decreased hepatic clearance and serum protein-binding capacity.
Tests	Hct, ABG	
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.	

Suggested Readings

1. Dutta S, Woo RK, Albanese CT: Minimal access portoenterostomy: advantages and disadvantages of standard laparoscopic and robotic techniques. J Laparoendosc Adv Surg Tech A 2007; 17(2):258–64.
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REPAIR OF ABDOMINAL WALL DEFECTS: OMPHALOCELE/GASTROSCHISIS

SURGICAL CONSIDERATIONS

Description

Omphalocele is a herniation of the bowel and sometimes viscera into an enlarged umbilical cord that may be categorized as small (<2 cm, sometimes called a "hernia of the cord"), medium (2–5-cm defect); or giant (>6 cm and containing the liver). The larger the defect, the more difficult the repair secondary to lack of the skin and muscle; primary repair is virtually never possible for giant defects. Omphaloceles are associated with genetic defects (trisomy 21) and may be part of other syndromes (e.g., OEIS, pentalogy of Cantrell, which includes cardiac defects). The surprisingly tough membrane of the umbilical cord protects the intestines from exposure to amniotic fluid. **Gastroschisis** is not associated with chromosomal anomalies or syndromes. It involves a 1–2-cm defect to the right of the umbilicus, through which the bowel, and sometimes the stomach or gonads, extrude and are exposed to the sclerosing effects of amniotic fluid, causing variable degrees of "peel" (bowel wall thickening).

Surgical approach

Central venous catheter placement precedes or accompanies the initial operation for gastroschisis as postop parenteral nutrition is required in almost all cases. Enlargement of the defect is sometimes necessary to permit visceral reduction, provided there is sufficient space in the abdominal cavity. If there is not sufficient space, reduction can cause bowel ischemia and respiratory compromise. Some surgeons will use a maximal transduced bladder or stomach pressure of 20 mm Hg or maximal PIP of 35 mm Hg as an indicator that primary repair may potentially lead to abdominal compartment syndrome. In this case, a prosthetic abdominal wall of Silastic is created or a preformed device is placed, creating a "silo." In the NICU, the silo is gradually reduced in size over 3–10 d, whereupon the abdomen is closed primarily (Fig. 12.5-12). Small- and medium-sized omphaloceles are treated similarly. Return of intestinal function will typically take 3–7 d for omphaloceles and 1–4 wk for gastroschisis.

Variant procedures or approaches

Sutureless approaches to both gastroschisis and omphalocele are emerging and can be an effective means of closing these defects with outstanding cosmetic results. For giant omphalocele, sclerosing solutions (silver sulfasalazine, tincture of mercurochrome) are applied to cause epithelialization. The omphalocele is thus effectively converted into a

ventral hernia. Months to years later, the ventral hernia can be closed without undue respiratory or bowel compromise. Alternatively compression wraps applied around the abdomen work to reduce bowel content over a period of months. The remaining fascial defect decreases in size until it resembles an umbilical hernia, which may close spontaneously or require minor surgical closure later. With gastroschisis, sutured closure of the fascial defect is unnecessary. In cases where the bowel can be primarily reduced, the remnant umbilical cord is used as a biologic dressing over the defect, and a large plastic dressing is applied (e.g., Tegaderm™). The defect closes spontaneously over the ensuing weeks, and reepithelialization occurs as bowel function returns. For irreducible bowel, a silo is applied and sequential reduction is performed. After the bowel is reduced completely, a plastic dressing with absorbant nonstick gauze is applied, and spontaneous closure ensues. Cosmetic results of the sutureless approaches are typically superior to suture closure, and there is never a concern for high ventilation pressures.

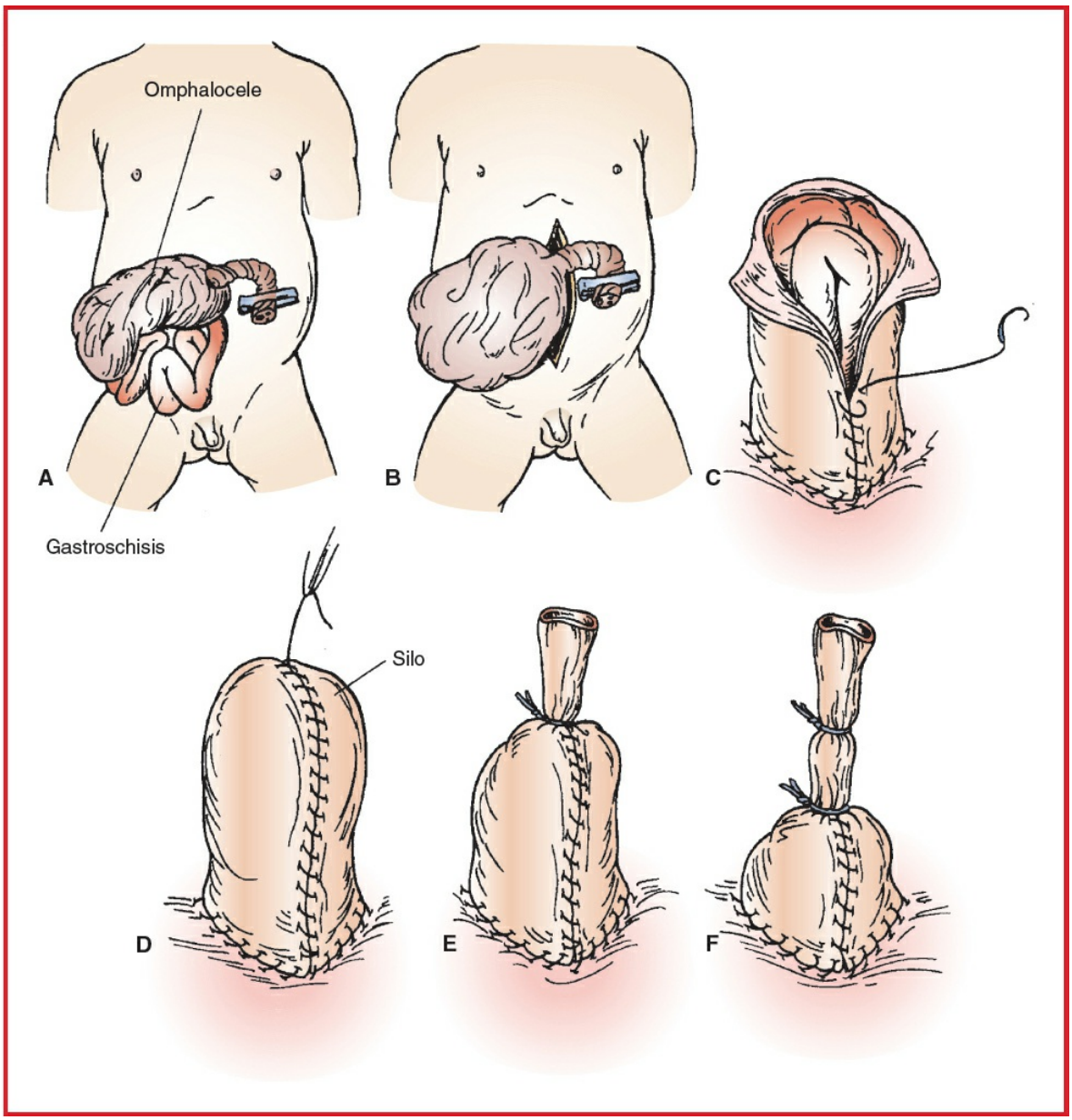

Figure 12.5-12 Management of gastroschisis and omphalocele (both shown together). **A:** Gastroschisis defect. **B:** Extension of opening with midline incision (optional). **C:** Use of silo if primary closure is not possible. **D:** Finished silo. **E, F:** Staged ligation of silo with reduction of silo contents into abdominal cavity proper. (Reproduced with permission from Oldham KT, Colombani PM, Foglia RP Surgery of Infants and Children. Lippincott-Raven, Philadelphia: 1997.)

Usual preop diagnosis

Omphalocele; gastroschisis; pentalogy of Cantrell (diaphragm, abdominal wall, pericardium, heart, lower sternum)

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE

Position	Supine
Incision	Midline
Special instrumentation	None; for staged repair, reinforced Silastic sheeting or premade (Bentec) silo
Antibiotics	Preop: ampicillin 25 mg/kg iv + gentamicin 2.5 mg/kg iv
Surgical time	2 h
Closing considerations	Assess respiratory and cardiovascular function after muscle closure by PIP, ABG, and MAP. Impaired ventilation and venous return will result from overaggressive attempts at closure.
EBL	5–10 mL/kg
Postop care	Assisted ventilation; volume resuscitation as needed (gastroschisis)
Mortality	Omphalocele: 28% Gastroschisis: 15–23%
Morbidity	Respiratory failure Intestinal ischemia/obstruction Infection
Pain score	5–6 (primary); 4–5 (staged repair)

PATIENT POPULATION CHARACTERISTICS

Age range	Newborn
Male:Female	1:1
Incidence	1/3000–1/10,000 live births
Etiology	Unknown
Associated conditions	Gastroschisis: malrotation, intestinal atresia—usually not associated with chromosomal abnormalities or syndromes Omphalocele: cardiac, renal anomalies

	Trisomy 13, 18, 21 Beckwith-Wiedemann syndrome (hypoglycemia, macroglossia) Pentalogy of Cantrell: omphalocele, sternal, diaphragmatic, pericardial, cardiac anomalies Exstrophy cloaca: omphalocele, exstrophy bladder, imperforate anus

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Newborns with omphalocele/gastroschisis may present for urgent surgery. The large exposed surface area of abdominal contents allows substantial evaporative heat and fluid losses. Omphalocele is associated with other congenital anomalies (e.g., VSD Beckwith-Wiedemann syndrome [infantile gigantism, macroglossia, hypoglycemia]; see above list). The majority of these patients should be medically stabilized in the nursery before coming to the OR.

Respiratory	If premature (<36-wk gestational age), infant is at ↑ risk for RDS and respiratory insufficiency. **Tests:** CXR; ABG
Cardiovascular	With omphalocele, there is a 20% incidence of cardiac anomalies (VSD, PDA). **Tests:** Echo for omphalocele or if murmur is found
Gastrointestinal	Intestinal atresia may be present. Hypovolemia from evaporative loss and underresuscitation likely; check for evidence of dehydration, urine output, and ABG. Full-stomach precautions.
Endocrine	Beckwith-Wiedemann associated with hypoglycemia (term infant glucose should be >36 mg/dL). **Tests:** Glucose; electrolytes
Laboratory	CBC; T&C; PT; PTT; UA; ABG
Premedication	None required
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status.

	Evaluate for concurrent disease.

INTRAOPERATIVE

Anesthetic technique

GETA, warm OR to 75°F–80°F; forced-air warmer, warming pad on OR table (Remember, majority of heat loss is radiant.)

Induction	Atropine (0.02 mg/kg iv) may be given before induction to ablate vagal response to laryngoscopy. Pass an OG tube to decompress the stomach. Ensure adequate intravascular volume status (capillary refill <2 sec; warm, pink extremities). Preoxygenate with 100% O_2 for 2–3 min prior to rapid-sequence intubation. Propofol (2–3 mg/kg) and rocuronium (1.2 mg/kg) or succinylcholine (1–2 mg/kg) iv are administered to facilitate tracheal intubation. Use appropriately sized ETT to keep air leak at 18–35 cm H_2O. Lower-pressure air leak may make ventilation difficult if primary closure of abdomen is accompanied by significant rise in intra-abdominal pressure. For small defects, place an epidural catheter inserted via the caudal after intubation. If positioning for the epidural catheter insertion is difficult, do not proceed; use iv fentanyl, morphine, or hydromorphone for pain management.
ERAS	Verify preincision antibiotics. Assess volume status. Discuss with surgeon local wound infiltration at conclusion of procedure. Consider iv acetaminophen 10 mg/kg.
Maintenance	Avoid high FiO_2. Use air/O_2 mixture for ventilation to maintain O_2 sat 95–100% and PaO_2 < 100. If no epidural is placed, then use a primarily narcotic-based technique with fentanyl (10–25 mcg/kg iv total) and low-dose sevoflurane as needed. Note initial PIP prior to abdominal closure. Maintain neuromuscular blockade to facilitate abdominal closure. If an epidural catheter is available, dose

	with local anesthetic and opiate to supplement inhalation/iv agent.	
Emergence	Remain intubated postop unless the defect is very small. An epidural catheter may also be placed at the end of procedure if defect is small and early extubation is planned. Transport to NICU on 100% O_2.	
Blood and fluid requirements	Marked 3rd-space fluid loss Minimal to moderate blood loss IV: 22–24 ga × 1–2, upper extremities BSS @ 4 mL/kg/h	Continue dextrose-containing solution from NICU. Replace 3rd-space losses (10–15+ mL/kg/h). Replace blood loss with albumin 5% and/or blood mL for mL. Maintain Hct > 30%. Lower extremities are usually edematous due to abdominal venous and lymphatic compression.
Monitoring	Standard monitors Arterial line (24-ga radial)	ABG pre- and postabdominal closure. Hct, glucose, electrolytes q60min. CVP; reserve 1 lumen for postop TPN.
	± CVP/Broviac planned Urinary catheter	Respiratory variation on arterial wave form is a sensitive indicator of hypovolemia.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Hypothermia Hypovolemia	If intragastric pressure is >20 mm Hg and

	Respiratory insufficiency/hypoventilation Atelectasis Volume overload/pulmonary edema Abdominal compartment syndrome	CVP increases by 4 mm Hg with initial primary closure, it should be converted to a staged repair. Raised abdominal pressure will cause an acute restrictive ventilatory defect and promote abdominal visceral ischemia.

POSTOPERATIVE

Complications	Bowel ischemia/necrosis Peritonitis Sepsis/metabolic acidosis Pneumothorax	Respiratory insufficiency due to raised abdominal pressure; may require release of repair and converting to a staged repair
Multimodal pain management	Continuous epidural or iv opioid infusion per NICU. Acetaminophen 10 mg/kg iv q6h if liver function tests normal	
Tests	ABG, Hct, glucose, electrolytes, Ca^{++}	UO maintained at >0.5 mL/kg/h
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.	

Suggested Readings

1. Brett CM, Davis PJ: Anesthesia for general surgery in the neonate. In: Davis PJ, Cladis FP, eds. Smith's Anesthesia for Infants and Children, 9th edition. Elsevier Publishing, Philadelphia: 2017, 582–6.
2. Lee SL, Beyer TD, Kim SS, et al: Initial nonoperative management and delaye closure for treatment of giant omphaloceles. J Pediatr Surg 2006; 41(11):1846–9.

3. Liu LM, Pang LM: Neonatal surgical emergencies.Anesthesiol Clin North Am2001; 19(2):276–7.
4. Mhamane R, Dave N, Garasia M: Delayed primary repair of giant omphalocele anesthesia challenges. Paediatr Anaesth 2012; 22(9):935–6.
5. Morton NS, Fairgrieve R, Moores A, et al: Anesthesia for the full-term and ex premature infants. In: Gregory GA, Andropoulos DB, eds.Gregory's Pediatric Anesthesia, 5th edition. Wiley-Blackwell, West Sussex, UK: 2012, 503–6.

PULL-THROUGH FOR HIRSCHSPRUNG DISEASE

SURGICAL CONSIDERATIONS

Description

Congenital aganglionosis, called **Hirschsprung disease** (HD), begins at the dentate line of the anus and extends proximally for a variable distance. It produces functional obstruction because the involved bowel is tonically contracted. The "transition zone" to ganglionic bowel occurs in the distal colon in 80% of cases; in 10%, it occurs in the small bowel. Sx range from mild-to-severe constipation, sometimes complicated by toxic enterocolitis. When severe, it may be life-threatening and mandates a rapid **loop colostomy**. Three classical operations (**Swenson**, **Soave**, **Duhamel**) and a newer perineal one-stage pull-through (**POOP**) were developed to remove or bypass the affected bowel (Fig. 12.5-13). Today, classic three-stage operations are being reduced to one or two stages, often assisted by laparoscopy.

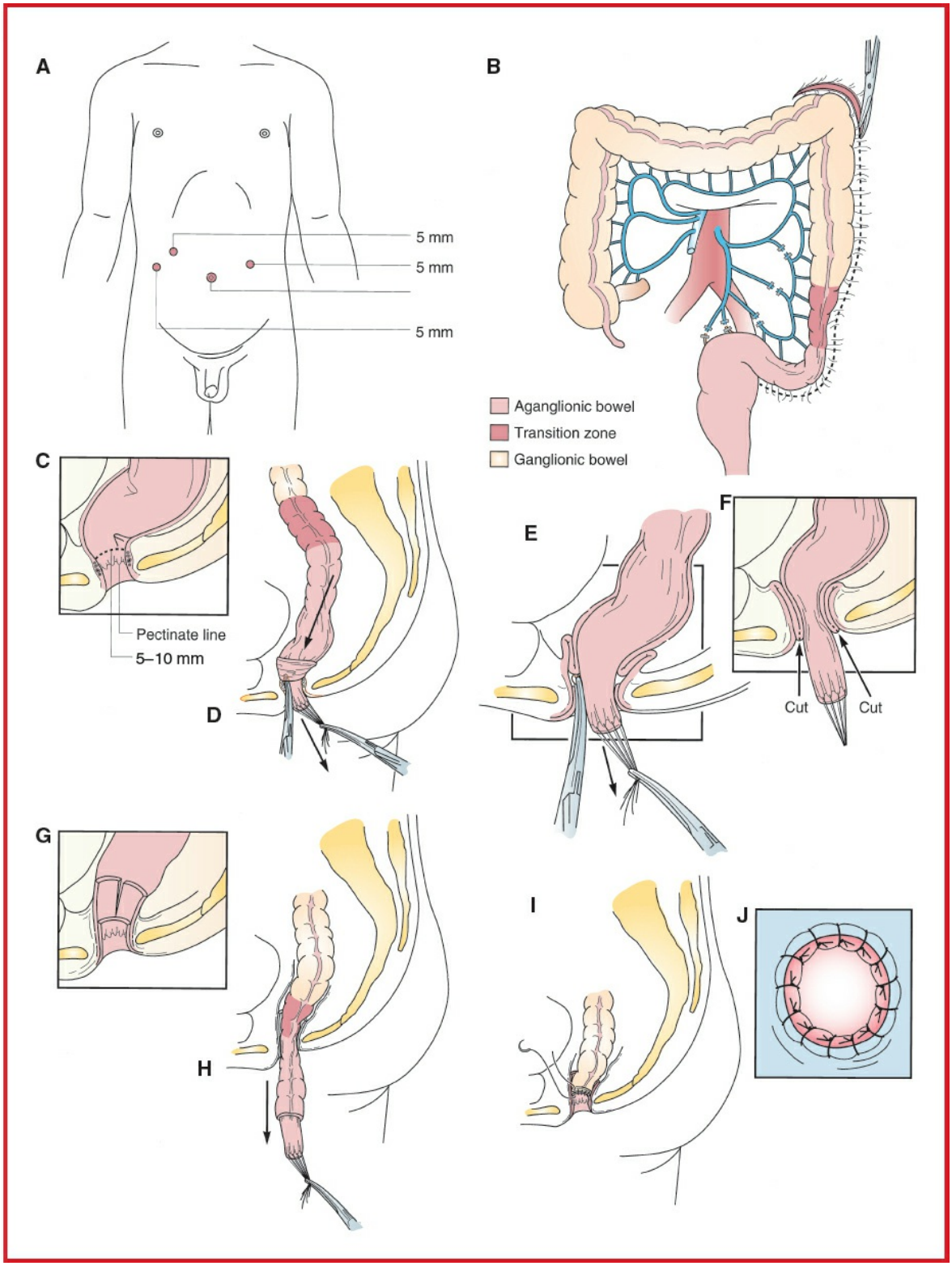

Figure 12.5-13 Laparoscopically assisted pull-through for Hirschsprung disease. **A:** Sites for operative trocar placement. **B:** Division of the colon and rectal mesentery with mobilization of proximal colon. **C:** Circumferential incision in rectal mucosa 5–10 mm cephalad to the pectinate line. **D:** Mucosal traction sutures to facilitate further dissection from rectal muscular cuff. **E:** Transanal submucosal dissection is continued cephalad to meet the caudal extent of the transperitoneal rectal dissection. **F:** Circumferential incisions of rectal muscular cuff. **G:** Rectal muscular cuff is split posteriorly to accommodate the pull-through segment (segment is not shown here). **H:** The rectum and sigmoid colon are pulled through the

rectal muscular cuff to the anastomotic sites. **I:** The colon is transected at appropriate site with confirmation of ganglion cells by frozen section. **J:** Transanal, end-to-end single-layer colorectal anastomosis. (Reproduced with permission from Sato TT, Oldham KT: Pediatric abdomen. In: Greenfield LJ, Mulholland MW, Oldham KT, et al., eds.Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Surgical approach

Initial diagnosis is with contrast enema, followed by a transanal rectal biopsy to demonstrate absence of ganglion cells. Standard surgical approach in a neonatally diagnosed Hirschsprung disease is now a **one-stage neonatal repair**, using a Soave or Swenson procedure, which avoids a colostomy and may be performed via a circumanal incision. Laparoscopy or umbilical incision is used to biopsy the colon to determine the transition zone. Once ganglionated bowel is identified on frozen section, it is pulled down to the anus by the transanal approach.

A more traditional approach is to biopsy through a LLQ incision initially, bringing out a loop ("leveling") colostomy above the transition zone, identified using frozen sections. Subsequent definitive repair is performed when the child is larger in one stage (or two if a protective proximal stoma needs subsequent closure). Positioning depends on the approach chosen; some surgeons prefer a lower-body antibacterial preparation; others position the child in lithotomy position and prepare the abdomen and perineum. Positioning neonates transversely across an operating table rotated 90° affords good surgical access to the perineum and anesthesia access to the head. Significant bleeding is infrequent; operative time often is determined by the delay for frozen sections, which are challenging for most pediatric pathologists. Where skilled pediatric pathologists are unavailable, some surgeons will perform a RUQ transverse colostomy in the hope that the transition zone is distal to it. This is a significantly faster procedure, followed by permanent sections on which ganglia are more easily identified; it is inadequate in 10–20% of "long-segment" patients.

Usual preop diagnosis

Hirschsprung disease; congenital aganglionosis; congenital megacolon

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Preliminary Colostomy	Pull-Through

Position	Supine	Supine → lithotomy
Incision	LLQ transverse	Low transverse
Special instrumentation	None	Staplers
Unique considerations	Frozen section to confirm ganglion cells	No monitors or iv lower extremity; frozen sections
Antibiotics	Preop: ampicillin 25 mg/kg iv + gentamicin 2.5 mg/kg iv	⇐
Surgical time	1–1.5 h	1–2 h (POOP) 3–4 h (Duhamel, Swenson, Soave)
Closing considerations	None	Reprep/drape
EBL	<5 mL/kg	5–10 mL/kg
Postop care	Cardiac/apnea monitor	PICU
Mortality	With enterocolitis: 10% Without enterocolitis: 0–2%	<5%
Morbidity	Prolapse Stricture Hernia	Anastomotic leak: 5% Wound infection: 4% Pelvic abscess: 3%
Pain score	4	6–7

PATIENT POPULATION CHARACTERISTICS

Age range	Newborn–18 mo (normally)	1 yr
Male:Female	4:1	⇐
Incidence	1/5000	⇐
Etiology	Unknown	⇐

Associated conditions	Trisomy 21 (5%); GU anomalies (<5%); neurofibromatoses ⇐

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Children with Hirschsprung disease (congenital aganglionosis) may have had prior colostomies and may present for colorectal reanastomosis. They may be mildly malnourished, but otherwise healthy.

GI	Diarrhea may be present with associated malabsorption state. **Tests:** Electrolytes
Laboratory	Hct; T&C
Premedication	Consider 0.5 mg/kg po midazolam (maximum 20 mg) or 0.05–0.1 mg/kg iv midazolam (maximum 2 mg) for patients >9 mo.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Evaluate for concurrent disease.

INTRAOPERATIVE

Anesthetic technique

Combined epidural/GETA, warm OR to 75°F–80°F; forced-air warmer.

Induction	Mask induction, unless iv is already in place. Keep air leak around ETT to 18–35 cm H_2O. For more involved procedure, consider placement of epidural catheter.
ERAS	Verify preincision antibiotics. Assess volume status. Consider epidural catheter or discuss with surgeon local wound infiltration at conclusion of procedure. Consider iv acetaminophen 10 mg/kg for

	multimodal pain control and 0.1 mg/kg iv ondansetron for PONV prophylaxis.	
Maintenance	Low-dose volatile agent and air/O_2 with muscle relaxation for majority of cases. Epidural anesthesia provides the majority of analgesia, but not the required degree of muscle relaxation. Supplemental muscle relaxants (e.g., rocuronium 0.1 mg/kg or vecuronium 0.1 mg/kg) are necessary.	
Emergence	The goal is to extubate at the end of the case. If NDMR was used, reverse neuromuscular blockade with sugammadex (2–4 mg/kg) or with a combination of neostigmine (0.07 mg/kg) and glycopyrrolate (0.01 mg/kg). Do not attempt reversal with neostigmine and glycopyrrolate until first twitch of TOF has returned.	
Blood and fluid requirements	Mild blood loss IV: 20–22 ga × 1–2 in upper extremities LR @ 10 mL/kg/h	These cases are usually not associated with large blood losses. Use 5% albumin for rapid volume expansion, if needed. As a result of bowel prep, patient may require 10–20 mL/kg iv of LR to offset volume deficit. Neonates should have supplemental glucose infusion.
Monitoring	Standard monitors Urinary catheter ± Arterial line (22 ga)	Maintain UO @ 1 mL/kg/h.
Positioning	✓ padding, particularly over the lateral fibular head (common peroneal nerve) ✓ eyes	
Complications	Hypothermia Hypovolemia	Majority of heat loss is radiant (skin), but

		potential for large-volume shifts mandates warming fluids.

POSTOPERATIVE

Complications	Hypothermia Hypovolemia	
Multimodal pain management	Continuous epidural Morphine (0.05–0.1 mg/kg q1–2h) Hydromorphone (0.005–0.01 mg/kg q1–2h) Acetaminophen (10 mg/kg iv/po q6h)	Ropivacaine or bupivacaine ± hydromorphone, and clonidine will provide analgesia for 8–16 h.
Tests	Hct if significant blood loss	
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.	

Suggested Readings

1. Georgeson KE, Robertson DJ: Laparoscopic-assisted approaches for the definitive surgery for Hirschsprung's disease. Semin Pediatr Surg 2004; 13(4):256–62.
2. Tannuri AC, Tannuri U, Romao RL: Transanal endorectal pull-through in children with Hirschsprung's disease—technical refinements and comparison of results with the Duhamel procedure. J Pediatr Surg 2009; 44(4):767–72.
3. Williams RK, Lauro HV, Davis PJ: Anesthesia for general and urologic surgery. In Davis PJ, Cladis FP, eds.Smith's Anesthesia for Infants and Children, 9th edition. Elsevier Publishing, Philadelphia: 2017, 797–9.

PULL-THROUGH FOR IMPERFORATE ANUS AND CLOACA

SURGICAL CONSIDERATIONS

Description

Imperforate anus anomalies are classified as **high** or **low**, depending on whether the distal rectum ends above or below the levator muscle. Usually, the rectum terminates as a "fistula" entering the perineum or pelvic structures anterior to the external anal sphincter. Rarely, the rectum ends blindly, often associated with trisomy 21. If the fistula terminates on the perineum, it is called a "perineal fistula" or "anterior anus." In girls, it often terminates inside the fourchette but outside the hymen, called a "vestibular" fistula. Fistulae to the vagina or uterus are rare; when they occur, they may be in conjunction with urethral anomalies. This combined structure—including the rectum, vagina, and urethra—is called a "cloaca." In boys, the fistula often ends in the urethra, occasionally the prostate, and rarely the bladder neck.

Surgical approach

At birth, associated conditions (e.g., VACTERL syndrome) are excluded while one waits 24 h for the appearance of meconium through a sometimes-hard-to-see perineal fistula. The operation is then performed according to the estimated site of the fistula. Low lesions are dilated or repaired; high lesions are treated with a divided RLQ or loop colostomy. Definitive repair of high lesions occurs after several months following contrast studies. This operation—called a **posterior sagittal anorectoplasty (PSARP)** or **Pena procedure**—is performed in the prone jackknife position. If the fistula is high, it occasionally will be necessary to turn the patient over for abdominal mobilization of the sigmoid colon.

Laparoscopic approaches are quickly replacing the PSARP, especially for high lesions. High lesions are also amenable to early **laparoscopic mobilization and pull-through**. This can be done with low fistulae as well, but dissection of the common wall between the urethra and fistula must be performed with care.

Usual preop diagnosis

Imperforate anus

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care and pain management options, and possible need for transfusion. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Low Lesions	High Lesions
Position	Supine, lithotomy	Prone, possible turn to spine or lithotomy

Incision	Midline perineal	Midline sacral, transverse abdominal
Special instrumentation	Muscle stimulator	⇐ + Urethral sound; vaginal pack
Unique considerations	None	Pressure points; prone position
Antibiotics	Preop: ampicillin 25 mg/kg iv + gentamicin 2.5 mg/kg iv	⇐
Surgical time	1–1.5 h	3–6 h
EBL	<5 mL/kg	5–10 mL/kg
Postop care	Apnea monitor if neonate	
Mortality	20%, due to associated anomalies	≤40%, due to associated anomalies
Morbidity	Anal stenosis: 5–10% Mucosal prolapse: 5%	⇐ Intestinal obstruction: 5–10% Neurogenic bladder: <5% Urethral stricture: 1–3%
Pain score	3–4	5–6

PATIENT POPULATION CHARACTERISTICS

Age range	Newborn–6 mo	12–18 mo
Male:Female	1.5:1	⇐
Incidence	1/5000	⇐
Etiology	Unknown	⇐
Associated conditions	CHD (common); esophageal atresia (15%); GU anomalies; sacral/spinal cord anomalies; VATER association	⇐

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Definitive repair is performed via the sacral and/or perineal route at ~12 mo. Children with rectal or anal agenesis without fistula will have had colostomies in newborn period. Other anomalies (e.g., VATER association VATER/VACTERL, vertebral anomalies, anal agenesis, cardiac defects, tracheoesophageal fistula [TEF]), esophageal atresia (EA) and/or renal or radial bone abnormalities may be present.

Respiratory	If VATER association is present, ✓ cervical spine. Avoid extreme head flexion. If prior TEF repair, concerns as previously noted in Anesthetic Considerations for Repair of Tracheoesophageal Fistula/Esophageal Atresia. **Tests:** CXR; cervical spine film
Cardiovascular	Patients with VATER association have a 20% incidence of CHD (e.g., VSD). Obtain echocardiogram and, if needed, cardiology consultation preop. **Tests**: Echo
Gastrointestinal	Colostomy may be present; thus, anesthesia records may be available for review.
Renal	Renal abnormalities may be present. **Tests:** BUN; Cr; electrolytes
Musculoskeletal	Radial bone deformities may be present.
Laboratory	Hct; T&C (✓ parental/directed donor blood availability.)
Premedication	If >9 mo, consider midazolam (0.5 mg/kg po) 30 min prior to arrival in OR. Consider 0.5 mg/kg po midazolam (maximum 20 mg) or 0.05–0.1 mg/kg iv midazolam (maximum 2 mg) for patients >9 mo.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Evaluate for concurrent disease. Discuss with surgeon possible epidural catheter.

INTRAOPERATIVE

Anesthetic technique

Combined epidural/GETA, warm OR to 75°F–80°F; heating pad on OR table.

Induction	Standard pediatric induction. Secure iv access and administer muscle relaxant (e.g., rocuronium 0.5–1 mg/kg or vecuronium 0.1 mg/kg) to facilitate ET intubation. Maintain air leak at >18–35 cm H_2O. Lumbar epidural catheter should be inserted after induction.	
ERAS	Verify preincision antibiotics. Assess volume status. Consider epidural or discuss with surgeon local wound infiltration at conclusion of procedure. Consider iv acetaminophen (10 mg/kg) for multimodal pain control and 0.1 mg/kg iv ondansetron for PONV prophylaxis.	
Maintenance	Volatile agent/air/O_2 with epidural analgesia (2 cc ropivacaine 0.2% or bupivacaine 0.25%), or morphine (0.1 mg/kg iv), hydromorphone (10–15 mcg/kg iv), or fentanyl (2–5 mcg/kg iv). Maintain neuromuscular blockade as surgically indicated.	
Emergence	Usually extubated at the end of the case. If NDMR was used, reverse neuromuscular blockade with sugammadex (2–4 mg/kg) or with a combination of neostigmine (0.07 mg/kg) and glycopyrrolate (0.01 mg/kg). Do not attempt reversal with neostigmine and glycopyrrolate until first twitch of TOF has returned. Ability to flex hips is a sign of adequate reversal.	
Blood and fluid requirements	Moderate blood/3rd-space losses IV: 20–22 ga × 2 BSS @ maintenance	Place ivs in the upper extremities because positioning of legs may impede venous flow. 3rd-space losses ~5

		mL/kg/h. Neonates should have supplemental glucose infusion.
Monitoring	Standard monitors Urinary catheter ± 24-ga radial arterial line	Maintain UO @ 0.5–1 mL/kg/h. Marked arterial waveform variation with ventilation is a sensitive indicator of hypovolemia. ABG/Hct/glucose prn.
Positioning	✓ and pad pressure points ✓ eyes	Patient may be turned during procedure.
Complications	Metabolic acidosis Hypovolemia →↓ BP Hypothermia	Mild metabolic acidosis may occur with significant bleeding or when 3rd-space losses are replaced with bicarbonate-deficient fluids (NS, albumin 5%, PRBCs).

POSTOPERATIVE

Complications	Subglottic edema Respiratory depression 2° to opiates	
Multimodal pain management	Continuous epidural analgesia Fentanyl (1–2 mg/kg iv q1h prn) Morphine (0.05–0.1 mg/kg iv q1–4h) Hydromorphone (0.002 mg/kg iv q1h) Acetaminophen 10	Aggressive pain management warranted

	mg/kg iv/po q6h
Tests	Hct, ABG, electrolytes
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.

Suggested Readings

1. Boric K, Dosenovic S, Jelicic Kadic A, et al: Interventions for postoperative pain in children: an overview of systematic reviews. Paediatr Anaesth 2017; 27(9):893–904.
2. Brett CM, Davis PJ: Anesthesia for general surgery in the neonate. In: Davis PJ, Cladis FP, eds. Smith's Anesthesia for Infants and Children, 9th edition. Elsevier Publishing, Philadelphia: 2017, 611–2.
3. Sydorak RM, Albanese CT: Laparoscopic repair of high imperforate anus.Semin Pediatr Surg 2002; 11(4):217–25.

REPAIR OF INGUINAL AND UMBILICAL HERNIAS AND HYDROCELE

SURGICAL CONSIDERATIONS

Description

Inguinal hernia repair (**herniorrhaphy**) and its variant, **hydrocele repair**, are the most frequently performed operations in pediatric surgery. Most pediatric hernias are indirect; they occur when the processus vaginalis (a small pouch of peritoneum dragged down to the scrotum during gonadal descent) fails to obliterate. Infants, particularly the premature, are more likely than toddlers to develop bilateral and incarcerated hernias. Hydroceles are variants in abnormal obliteration of the processus vaginalis. Communicating hydroceles have a smaller neck and derive their name because this neck is so small that only intraperitoneal fluid, not bowel, can pass through it. Noncommunicating hydroceles have a completely obliterated proximal neck without communication to the peritoneal cavity. Noncommunicating hydroceles can resolve spontaneously during the first 2 yr of life; hydroceles that fail to resolve are typically communicating and repaired after 2 yr. Hydroceles can be diagnosed on physical exam as "communicating" when they empty/fill with postural change. Umbilical hernias have a tendency to close over the first 5 yr of life (~95%) and are repaired when large (>2 cm) or persistent. Complications of hernia/hydrocele repair include damage to the vas

deferens or testicular vessels, metachronous contralateral hernias (~10%) if just one side is repaired initially, and a very low incidence of infertility when bilateral repairs are undertaken. Bleeding, if any, is minor, recurrence uncommon (≤1%), and bowel resection is rarely necessary, even when a hernia is incarcerated. Overnight admission for apnea monitoring is suggested in premature children (≤54–60 wk corrected age). **Hydrocele repair** complications are similar to those of herniorrhaphy. **Umbilical hernia repairs** have very few complications. Acetaminophen pr or iv at the beginning of the procedure aids postop pain management.

Surgical approach

Inguinal hernias and hydroceles are repaired through a lower-lateral abdominal skin crease incision (more recently, laparoscopically), permitting separation of the sac from spermatic cord structures, followed by high ligation ± distal fenestration (in hydroceles). Umbilical hernia repair is performed through a transverse incision in the infraumbilical skinfold, through which the sac is resected from the undersurface of the skin and healthy fascial edges are closed.

Usual preop diagnosis

Inguinal hernia; umbilical hernia; hydrocele

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Inguinal	Umbilical
Position	Supine	⇐
Incision	Inguinal, bilateral	Infraumbilical
Unique considerations	Prematurity	Abdominal compression if hernia large
Antibiotics	None	⇐
Surgical time	40 min	⇐
Closing considerations	Nerve block, caudal	Umbilical block
EBL	5 mL/kg	⇐

Postop care	Apnea monitor; hospitalization for premature infants	None
Mortality	<1%	⇐
Morbidity	Apnea Recurrence	None
Pain score	3–5	3–5

PATIENT POPULATION CHARACTERISTICS		
Age range	Premature–adolescent	>2 yr
Male:Female	5:1	N/A
Incidence	1–2%	1%
Etiology	Patent processus vaginalis	Persistent umbilical defect
Associated conditions	Gonadal dysgenesis (rare)	None

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Hernia repair is most commonly performed in otherwise healthy infants in the first 2 yr of life, often on an outpatient basis. It is also performed on premature infants (<37-wk gestational age at birth). Premature infants are particularly prone to inguinal hernias. Postop apnea can occur in infants ≤60 wk postconceptual age, particularly if the infant was premature, has neurologic disease or anemia, or required intensive care in the early neonatal period. Infants ≤ 60-wk postconception usually require overnight admission for monitoring (postop apnea and ↓ HR).

Respiratory	Bronchopulmonary dysplasia (BPD), tracheomalacia, and subglottic stenosis are consequences of prolonged mechanical ventilation and immature lungs at birth. ✓ prior NICU Hx. ↓ FRC and ↑ PVR make infants with BPD more susceptible to hypoxia. They may require supplemental nasal O_2 on a chronic basis, have immature respiratory centers, and may exhibit paradoxical apneic/bradycardic episodes in

	response to hypoxemia. **Tests:** CXR
Cardiovascular	Prior PDA ligation is possible. These patients may be on diuretic therapy for intrinsic lung disease (e.g., BPD) with resultant decreased intravascular volume. **Tests:** CXR; electrolytes
Neurologic	Premature infants may be prone to seizure disorders. **Tests:** Anticonvulsant levels
Hematologic	Anemia is common at ~3 mo of age (physiologic nadir) and increases risk of postop apnea.
Tests	Hct; PT; PTT; Plt, as indicated from H&P
Laboratory	Other tests as indicated from H&P
Premedication	If appropriate (e.g., infants > 9 mo), midazolam (0.5 mg/kg po; maximum 20 mg) 30 min prior to arrival in OR or 0.05–0.1 mg/kg iv midazolam (maximum 2 mg).
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Evaluate for concurrent disease.

INTRAOPERATIVE

Anesthetic technique

Typically, GETA or LMA (± caudal [especially for bilateral repair] or ilioinguinal/iliohypogastric block [for single-sided repair]). An alternative in ex-preterm infants at high risk for postop apnea is spinal anesthesia without GA, though this is practiced more rarely. Warm OR to 75°F–80°F and use a forced-air warmer.

Induction	Mask induction in children with sevoflurane/N_2O/O_2. Secure iv. If appropriate, position the child for placement of caudal anesthetic: ropivacaine 0.2% or bupivacaine 0.25% ± epinephrine 1:200,000 @ 1 mL/kg (max 10 cc). If the child is otherwise healthy and >18 mo old, proceed with LMA; otherwise, tracheal intubation is preferred. If premature, consider

	atropine 0.02 mg/kg iv prior to intubation to prevent bradycardia. Intubation may be facilitated with rocuronium (0.6–1.2 mg/kg) or vecuronium (0.1 mg/kg).	
ERAS	Verify preincision antibiotics. Assess volume status. Consider caudal (bilateral surgery) or ilioinguinal/iliohypogastric block (unilateral surgery). Consider iv acetaminophen (10–15 mg/kg) for multimodal pain control and iv ondansetron (0.1 mg/kg) for PONV prophylaxis.	
Maintenance	Standard pediatric inhalational anesthetic is appropriate. With caudal anesthetic or nerve block, decrease the amount of volatile anesthetic and avoid or reduce opiates. If LMA and spontaneous ventilation are used, deepen anesthetic to 2 MAC of inhalational agents at incision to minimize risk of laryngospasm. Caudal onset time 10–15 min.	
Emergence	If NDMR was used, reverse neuromuscular blockade with sugammadex (2–4 mg/kg) or with a combination of neostigmine (0.07 mg/kg) and glycopyrrolate (0.01 mg/kg). Do not attempt reversal with neostigmine and glycopyrrolate until first twitch of TOF has returned. Extubate only when fully awake. LMA may be removed deep and oral airway is placed.	
Blood and fluid requirements	Negligible blood loss IV: 22–24 ga × 1 BSS @ maintenance	Infants receiving diuretics will require 10–20 mL/kg iv of BSS to avoid ↓ BP 2° volatile anesthetics. In children <1 mo old, use dextrose-containing iv solution (e.g., D10W for maintenance, LR for

		replacement fluids).
Monitoring	Standard monitors	Premature infants may become hypoglycemic. ✓ blood glucose during surgery.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Laryngospasm	
	Bronchospasm Local anesthetic toxicity Hypothermia Hypoglycemia	Rx bronchospasm: albuterol inhaler, mist, mask, deepen anesthesia

POSTOPERATIVE

Complications	Apnea/bradycardia Subglottic edema	Can ↓ incidence of apnea/bradycardia by administering caffeine (10 mg/kg iv) intraop or in NICU/PACU
Multimodal pain management	Field block Ketorolac 0.5 mg/kg iv q6h Acetaminophen (10 mg/kg po/iv q6h prn, 20 mg/kg pr q6h prn)	If no caudal is used, a field block (bupivacaine 0.25% 2–3 mL) at the end of surgery reduces pain in the immediate postop period. It is usually performed by the surgeon.
Tests/monitoring	Apnea monitor and pulse oximeter for 12–18 h for term infants ≤44 wk; premature infants ≤60 wk	Caffeine is no substitute for monitoring and attentive parents/nurses.
ERAS	Encourage early enteral nutrition and patient	

mobilization as appropriate.
Assess for appropriate return of bowel function.

Suggested Readings

1. Laituri CA, Gareey CL, Peiters B, et al: Overnight observation in former prematur infants undergoing inguinal hernia repair. J Pediatr Surg 2012; 47(1):217–20.
2. Williams RK, Lauro HV, Davis PJ: Anesthesia for general and urologic surgery. In Davis PJ, Cladis FP, eds.Smith's Anesthesia for Infants and Children, 9th edition. Elsevier Publishing, Philadelphia: 2017, 792–5.

SURGERY FOR THE UNDESCENDED TESTICLE

SURGICAL CONSIDERATIONS

Description

Also called "cryptorchidism," this occurs when a testicle fails to follow the usual pattern of descent. Testicles begin in fetal life just inferior to the kidney and, through differential growth, migrate to the base of the ipsilateral hemiscrotum, attached there by the gubernaculum. Problems occur when testicular descent does not occur, occurs partially, or occurs incorrectly. Testicles that are found in the abdomen, inguinal canal, perineum, thigh, suprapubic fat, or contralateral scrotum may be associated with subsequent problems, including infertility and malignant degeneration. Transposition and fixation of the testicles into their normal location (**orchidopexy**) does not eliminate these problems; rather, it places the testicle in a position where it can be more easily evaluated and may mitigate the progressive infertility thought to occur when testicles remain outside the scrotum. Because testicular descent can occur early in life, orchiopexy is usually performed around 9–12 mo of age.

Surgical approach

The operation begins in a similar fashion to a hernia repair, as 95% of cryptorchid testes have an associated hernia sac. One exception is if the testicle is thought to be **intra-abdominal**. In this circumstance, many surgeons will begin with a laparoscopic abdominal examination, using the vas deferens and testicular vessels to locate the testis. If it is high in the abdomen, it may be brought immediately to the perineum (difficult if the testicular vessels are short), or a two-step **Fowler-Stevens** approach is undertaken. In this approach, the gubernacular vessels supplying the inferior pole of the testis are encouraged to hypertrophy by division of the spermatic vessels, and the testicle is left in the abdomen near the internal ring. At a second operation ~6 mo later, the testicle is

brought down, much as in the primary operation following hernia repair. This involves creation of a passage down to the base of the ipsilateral hemiscrotum, through which the testicle is advanced as far as the vas deferens permits. The tough outer layer of the testicle—the tunica albuginea—is then attached to the scrotum in a subcutaneous pocket outside the dartos fascia to discourage migration back up to a high location. There is scant blood loss; however, there is a small risk to testicular viability. Small, high, abnormal testes with short vessels and vas associated with poor gubernacular vessels are deemed better removed than left in a high location where malignant degeneration might go undetected. A caudal block may be preferable to injection of local anesthesia at multiple sites.

Usual preop diagnosis

Undescended testicle; cryptorchidism

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Orchidopexy	First of a Two-Stage Repair
Position	Supine	⇐
Incision	Lower groin crease	Laparoscopic or open
Special instrumentation	–	One to three ports if laparoscopic
Unique considerations	Length of vas and vessels	Length of vas deferens
Antibiotics	None	⇐
Surgical time	1–1.5 h	30 min
EBL	<5 mL/kg	⇐
Postop care	Home	⇐
Mortality	<1%	⇐
Morbidity	Bleeding Orchiectomy	⇐

Pain score	4–5	2–3

PATIENT POPULATION CHARACTERISTICS

Age range	18–24 mo
Incidence	1/2000 births
Etiology	Unknown
Associated conditions	Prematurity; gastroschisis; intersex anomaly; Turner syndrome (potential for airway, cardiac, and renal problems)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pediatric Urology and Inguinoscrotal Procedures.

Suggested Readings

1. Thorup J, Haugen S, Kollin C, et al: Surgical treatment of undescended testes.Acta Paediatr 2007; 96(5):631–7.
2. Williams RK, Lauro HV, Davis PJ: Anesthesia for general and urologic surgery. In Davis PJ, Cladis FP, eds.Smith's Anesthesia for Infants and Children, 9th edition. Elsevier Publishing, Philadelphia: 2017, 809–10.

RESECTION OF SACROCOCCYGEAL TERATOMA

SURGICAL CONSIDERATIONS

Description

Occasionally during gestation, a group of cells composing all three germ layers segregates and begins autonomous development as a teratoma. When this occurs just anterior to the coccyx, the tumor may remain small and local, or grow up into the abdomen or down into the peritoneum, attaining sizes as large as the child itself. Although a few centers attempt fetal surgery for very large lesions, in most hospitals, the child is delivered by the appropriate route (cesarean delivery for large external lesions), and the mass is addressed in the neonatal period or whenever it is diagnosed thereafter. Most (though not all) sacrococcygeal teratomas (SCTs) are initially benign; however, they may soon transform into malignancy beginning at 2 mo of age.

Surgical approach

Small teratomas are approached prone from the rectum; larger ones, with high blood flow, may first have an intra-abdominal procedure to ligate feeding vessels and mobilize the tumor. Once prone, a V-shaped incision is created down to the posterior aspect of the anteriorly displaced anus. Surgical principles of dissection include avoiding entry into the rectum (a colostomy is rarely necessary); meticulous hemostasis, including ligation of the median sacral artery; and removal of the coccyx, from which the tumor arises and may recur. At the end of the procedure, the levator muscles are brought together, and the anus is suspended from the presacral fascia. Bleeding can be massive, and adjacent structures (bowel, bladder, and presacral nerve plexus) are distorted and prone to injury.

Usual preop diagnosis

Sacrococcygeal teratoma

Differential diagnosis

May appear similar to meningomyelocele

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, pain management options, and possible need for transfusion. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE

Position	Prone, sometimes preceded by supine
Incision	Perineal chevron, sometimes preceded by transverse abdominal
Special instrumentation	Hegar dilators
Unique considerations	Intra-abdominal blood supply
Antibiotics	Ampicillin 25 mg/kg and gentamicin 2.5 mg/kg
Surgical time	2–5 h
Closing considerations	Extubation depends on duration and blood loss.
EBL	20–80 mL/kg
Postop care	NICU, prone
Mortality	Fetal, due to hydrops and high flow state; <10% neonatal
Morbidity	Bleeding Colostomy Pelvic nerve damage → bowel and bladder dysfunction Recurrence and/or malignant degeneration

PATIENT POPULATION CHARACTERISTICS

Age range	1–2 mo
Male:Female	1:1
Incidence	1/15,000 births
Etiology	Unknown
Associated conditions	Constipation; heart failure; Currarino triad (sacral agenesis abnormalities, anorectal malformations, presacral mass); malignant degeneration

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Sacrococcygeal teratoma is a rare tumor of infancy. Sometimes diagnosed prenatally, it also can present as late as 18–24 mo. Patients may present with urinary obstruction by the tumor mass; lower extremity pain, numbness, or weakness; or bowel obstruction. ~10% may have a sacral anomaly or myelomeningocele.

Respiratory	There may be respiratory compromise as a result of a large abdominal mass pushing up on the abdominal contents and the diaphragm. **Tests:** CXR, if indicated from H&P
Cardiovascular	Sacrococcygeal teratoma may be associated with high-output cardiac failure due to AV fistulae within the tumor. Consultation with a cardiologist may be appropriate. **Tests:** ECG; echo may be necessary.
Renal	Postrenal obstruction may compromise renal function. **Tests:** BUN; Cr
Gastrointestinal	Intestinal compression by the tumor may cause ↑ risk of gastric aspiration. **Tests:** Electrolytes
Hematologic	This tumor may be associated with coagulopathy. **Tests:** PT; PTT; INR
Laboratory	Other tests as indicated from H&P
Premedication	Patients >9 mo may benefit from midazolam (0.5 mg/kg) po 30 min before surgery. If iv is present, iv midazolam 0.05–0.1 mg/kg may be used (e.g., for 10 kg child, 0.5–1 mg midazolam). Consider 0.5 mg/kg po midazolam (maximum 20 mg) or 0.05–0.1 mg/kg iv midazolam (maximum 2 mg) for patients >9 mo.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Evaluate for concurrent disease.

INTRAOPERATIVE

Anesthetic technique

GETA, using a pediatric circuit; warm OR to 75°F–80°F; warm all iv fluids. Due t risk of coagulopathy and the possibility of spine malformations, epidural catheter usually is not considered.

Induction	Usually an inhalation induction. If an iv is present, then an iv induction is performed. A modified rapid-sequence induction is recommended in those patients with a large intra-abdominal mass compressing the GI tract. Otherwise, standard pediatric induction is appropriate. The appropriate size for the ETT is one that will allow a small leak around the tube when positive pressure is applied (18–35 cm H_2O).
ERAS	Verify preincision antibiotics. Assess volume status. Consider iv acetaminophen 10 mg/kg for multimodal pain control and ondansetron iv 0.1 mg/kg for PONV prophylaxis.
Maintenance	Standard maintenance. Muscle relaxation is appropriate.
Emergence	Depending on blood loss and fluid requirements, the patient may need to remain intubated at the end of the procedure. If extubation is elected, suction NG and confirm air leak around ETT before extubation. If there is no air leak, consider laryngeal edema and the need for continued intubation. If NDMR was used, reverse neuromuscular blockade with sugammadex (2–4 mg/kg) or with a combination of neostigmine (0.07 mg/kg) and glycopyrrolate (0.01 mg/kg). Do not attempt reversal with neostigmine and glycopyrrolate until first twitch of TOF has returned.
Blood and fluid	Potential for massive Tumor resection may be

requirements	blood loss. IV: Two large-bore iv catheters (e.g., 20–22 ga)	associated with massive blood loss, due to large pelvic venous bed, AV fistula, and coagulopathy. Close monitoring of Hct is necessary, along with correction of acidosis and Ca^{++} replacement.
Monitoring	Standard monitor ± Central line Arterial line (22 ga)	

POSTOPERATIVE

Complications	Bleeding Coagulopathy Hypoventilation Laryngeal edema	PICU is usually required. Maintain normothermia; correct metabolic acidosis. Postop ventilation is usually required due to potential risk of hypoventilation and laryngeal edema. Serial Hct may help detect postop hemorrhage.
Multimodal pain management	Fentanyl 1 mcg/kg/h iv Morphine (0.05–0.1 mg/kg iv q1–2h) Hydromorphone (0.005–0.01 mg/kg iv q1–2h) Acetaminophen (10 mg/kg iv/po q6h; 20 mg/kg pr q6h prn)	Approximate doses; titration required. Ketorolac likely not indicated due to risk of postop bleeding, possible compromise of renal function
Tests	ABG, Hct, PT/PTT	
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate	

return of bowel function.

Suggested Readings

1. Brett CM, Davis PJ: Anesthesia for general surgery in the neonate. In: Davis P. Cladis FP, eds. Smith's Anesthesia for Infants and Children, 9th edition. Elsevier Publishing, Philadelphia: 2017, 614–6.
2. Cowles RA, Stolar CJ, Kandel JJ, et al: Preoperative angiography with embolizatio and radiofrequency ablation as novel adjuncts to safe surgical resection of a large, vascular sacrococcygeal teratoma. Pediatr Surg Int 2006; 22(6):554–6.

ANESTHESIA FOR MINIMALLY INVASIVE SURGERY IN PEDIATRIC PATIENTS

Gregory B. Hammer

In recent years, there has been a significant increase in the practice of minimally invasive surgery in pediatric patients. Specific considerations for these surgeries (as in adult patients) include the effects of pneumoperitoneum on respiratory and cardiac function. ↑ abdominal pressure → ↓ diaphragmatic excursion, ↑ atelectasis, and V/Q mismatch. ↑ CO_2 levels can be difficult to control with mechanical ventilation; thus, manual ventilation may be necessary. There is risk of pneumothorax and pneumomediastinum. Use of Trendelenburg position further decreases FRC and lung compliance and increases the work of breathing. Cephalad movement of the carina may cause endobronchial intubation. Venous return may be impaired, causing ↓ CO. These effects are most pronounced in children <6 mo old. These children also may be at risk for reversal of L → R shunts through a patent foramen ovale (PFO) or ductus arteriosus.

Minimally invasive procedures that are frequently performed in pediatrics include appendectomy, pyloric stenosis, hernia repair, Nissen fundoplication, cholecystectomy, splenectomy, laparoscopically assisted bowel resection, thoracoscopy (VATS), and congenital diaphragmatic hernia repair. The general principles for anesthesia for minimally invasive surgery in pediatric patients are as follows:

PREOPERATIVE

1. Be vigilant about respiratory and cardiac function. Note baseline lung function (SaO_2, CXR, ABG); ✓ for any cardiac defects (e.g., L → R shunt, ↓ CO).
2. Epidural is usually not placed for laparoscopy or thoracoscopy, but it should be

considered at the end of the procedure if the decision is made to do open surgery or for large resections. Consider need for PT/PTT if significant bleeding or if preop health status indicates (e.g., oncology PT, malnutrition, renal/liver dysfunction).

3. Blood should be available for major cases including VATS for empyema. Although there usually is little blood loss with minimally invasive surgery, the potential for large-vessel disruption exists.
4. ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options.

Premedication	Consider 0.5 mg/kg po midazolam (maximum 20 mg) or 0.05–0.1 mg/kg iv midazolam (maximum 2 mg) for patients >9 mo.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Evaluate for concurrent disease.

INTRAOPERATIVE

Anesthetic technique

GETA; forced-air warmer; warm OR to 70°F–75°F; warm iv fluids.

Induction	Inhalation induction using sevoflurane, N_2O, followed by iv placement. If patient is at risk for aspiration, rapid-sequence induction is appropriate. For ET intubation in children, a cuffed tube may be used, with the cuff inflated to attain a leak at 18–30 cm H_2O. A cuffed tube is usually 1/2 size smaller than the corresponding uncuffed tube for age. If OLV is required, see Anesthetic Considerations for Pediatric Thoracic Surgery, for placement. Note the distance of the end of ETT from the carina. As abdominal girth is increased during CO_2 insufflation, it is common for the tube to advance to an endobronchial position.
ERAS	Verify preincision antibiotics. Assess volume status.

	Consider iv acetaminophen (10 for patients <1 yr old or 15 mg/kg for patients >1 yr old with maximum dose 650 mg) for multimodal pain control and 0.1 mg/kg iv ondansetron for PONV prophylaxis.	
Maintenance	Standard maintenance. Muscle relaxation is appropriate. An OG tube is placed to empty the stomach of any residual premedication and excess air introduced during PPV. Continued communication between the anesthesiologist and surgeon is essential. Pay attention to changes in positioning (e.g., Trendelenburg), intra-abdominal pressure (n1 = 15 cm H_2O), airway pressures, and BP. Recheck that BS = after insufflation, as cephalad movement of diaphragm may lead to endobronchial intubation.	
Emergence	In most cases, the patient can be extubated at the end of surgery. If NDMR was used, reverse neuromuscular blockade with sugammadex (2–4 mg/kg) or with a combination of neostigmine (0.07 mg/kg) and glycopyrrolate (0.01 mg/kg). Do not attempt reversal with neostigmine and glycopyrrolate until first twitch of TOF has returned.	
Blood and fluid requirements	IV: 22–20-ga catheter × 1 BSS maintenance fluids	Potential for 3rd space and blood loss, especially with VATS surgery for empyema
Monitoring	Standard monitors ± Arterial line Urinary catheter	Consider arterial line if patient has significant cardiac or respiratory compromise.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	↑ CO_2 (40–50 mm Hg)	

	(common) ↑ PIP (common) Subcutaneous crepitus (moderately common)	
	Endobronchial intubation(common) Difficult ventilating (common) Hypovolemia	2° Trendelenburg position, ↑ abdominal girth. In thoracoscopy, if SLV is used, it may be necessary to raise the lung and ventilate transiently. → ↓ CO. Rx: crystalloid or albumin 10–20 mL/kg.
	Pneumothorax	CO_2 embolus (rare)
	Pneumomediastinum (rare)	
	Inadvertent cannulation of the vessel (rare)	

POSTOPERATIVE

Complications	Respiratory function impairment Bleeding Residual subcutaneous CO_2 Pneumothorax	Respiratory function may still be significantly impaired in the postop period and should be monitored closely.
Multimodal pain management	Ketorolac 0.5 mg/kg iv q6h, maximum 15 mg Morphine (0.05–0.1 mg/kg iv q1–2h) Hydromorphone (0.005–0.01 mg/kg iv q1–2h) Acetaminophen (10 mg/kg for patients <1 yr old or 15 mg/kg for	If there is significant intraop bleeding, avoid ketorolac for 24 h postop, and verify with surgical team before starting.

	patients >1 yr old po/iv q6h). Maximum acetaminophen dose of 650 mg q6h
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.

Suggested Readings

1. Hammer GB: Anesthesia for thoracic surgery. In: Davis PJ, Cladis FP, eds.Smith's Anesthesia for Infants and Children, 9th edition. Elsevier Publishing, Philadelphia: 2017, 774.
2. Williams RK, Lauro HV, Davis PJ: Anesthesia for general and urologic surgery. In Davis PJ, Cladis FP, eds.Smith's Anesthesia for Infants and Children, 9th edition. Elsevier Publishing, Philadelphia: 2017, 789–92.

EX UTERO INTRAPARTUM TREATMENT (EXIT) PROCEDURE

SURGICAL CONSIDERATIONS

Description

The EXIT (ex utero intrapartum treatment) strategy was developed as a means of establishing an airway after iatrogenic occlusion of the fetal trachea to promote lung growth for fetuses with severe congenital diaphragmatic hernia (CDH). The EXIT strategy can be viewed as a "half" delivery in which a **hysterotomy** is performed, only the head and shoulders are "delivered," and uterine relaxation is maintained by high concentrations of an inhalational anesthetic and intravenous tocolytics, ensuring the maintenance of uteroplacental blood flow and gas exchange. Using this strategy, operations as long as 3 h on uteroplacental "bypass" have been performed without significant maternal bleeding and uterine contraction. It provides time to perform procedures such as direct laryngoscopy, bronchoscopy, tracheotomy, arterial and venous access, administration of surfactant, resection of neck or lung masses, and cannulation for ECMO (extracorporeal membrane oxygenation) support, thereby converting a potential emergent crisis into a controlled situation.

Surgical technique

A successful EXIT procedure is a carefully orchestrated event in which all members of the OR team have specific roles and responsibilities. The scrubbed personnel consist of two pediatric/fetal surgeons, a maternofetal medicine specialist/obstetrician, a pediatric anesthesiologist, a neonatologist, and other specialists as indicated, with appropriate nurses and techs as needed. Unlike the EXIT procedure, a conventional cesarean delivery makes no attempt to prevent bleeding from the hysterotomy because hemostasis is achieved by return of uterine tone following the relatively rapid delivery of the fetus. Because of the significant hemorrhage from a conventional hysterotomy, the EXIT procedure is carried out using a **hemostatic uterine stapling device** (US Surgical CS 57, US Surgical/Tyco, Norwalk, CT). First, a low transverse skin crease incision is used. The decision to use a Mallard versus Pfannenstiel fascial incision is determined by uterine size (e.g., presence/absence polyhydramnios) and placental position. If the operation is performed in the late third trimester and the placenta is posterior or fundic, the lower uterine segment can be opened and the uterus left in situ. An anterior or previa placenta often necessitates moving the uterus out of the abdomen/pelvis. The hysterotomy in this situation is not in the lower uterine segment. Intraop ultrasonography is critical to map placental position. If polyhydramnios is present, amnioreduction is performed to avoid underestimation of the proximity of the placental edge to the hysterotomy. Two applications of the uterine stapler are usually necessary for an adequate opening. Bleeding often occurs where staple lines fail to intersect and is easily controlled with suture ligation. Only the necessary fetal parts are delivered in order to maintain uterine volume and avoid vigorous contractions and placental separation. A **sterile pulse oximeter** is attached to the palm of the fetal hand. It is covered with foil and Tegaderm tape to prevent aberrant readings due to the operating room lights. The long oximeter cord is passed across the field to the anesthesiologist. The fetal eyes are covered with a warm wet laparotomy pad. The fetus is continuously bathed in warm saline. Care is taken not to manipulate or unnecessarily expose the umbilical cord to avoid spasm of the vessels. Sterile instruments that need to be available include a laryngoscope with at least two different sized blades and extra bulbs (batteries are not sterilized and are inserted separately), two sizes of a rigid bronchoscope, a light cord, various endotracheal (some with surfactant adapters) and tracheostomy tubes, endotracheal tube stylettes, a hand bag device with a manometer and sterile tubing that is passed off the field to an oxygen source, a sterile neonatal stethoscope, and a sterile syringe filled with surfactant (if necessary). IV access is obtained if possible. Alternatively, a mixture of fentanyl and an NMB agent such as rocuronium, vecuronium, or pancuronium can be administered im (deltoid) to the fetus immediately after the hysterotomy. After the airway is obtained and secured, the umbilical cord is clamped

and divided and the child taken to the resuscitation table by the neonatologist. The placenta is delivered and the uterus closed in the standard fashion. Oxytocin is administered immediately prior to clamping the umbilical cord to enhance uterine tone.

Indications

Clinical situations in which the fetal airway or cardiovascular well-being is significantly threatened by conventional cesarean or vaginal delivery are candidates for the EXIT strategy. Some examples are:

- Intrinsic laryngotracheal anomalies resulting in congenital high airway obstruction syndrome (CHAOS): laryngeal web/atresia/cyst/stenosis, and trachea stenosis/atresia
- Extrinsic airway compression: cervical teratoma/lymphangioma (may or may not result in CHAOS)
- Epignathus
- Severe hydrops from a cystic adenomatoid malformation of the lung after a 32-wk gestation
- EXIT to ECMO for severe CDH with congenital heart disease
- Delivery of thoraco-omphalopagus twins
- Delivery of twins discordant for a potentially obstructing neck lesion

ERAS: Preop counseling by the surgeon/anesthesiologist should include limiting maternal NPO duration, review of nutritional status, postop care, pain management options, and possible need for transfusion. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	L uterine displacement
Incision	Low transverse
Special instructions	Fetal monitoring
Unique considerations	Need to maintain uterine relaxation
Child	Monitor for fetal hypoxia and bradycardia.
Antibiotics	Cefazolin 2 g iv
Surgical time	2 h
Closing	Extubation

considerations	
Postoperative care	Variable—moderate
Mortality	Rare
Morbidity	Risk of hemorrhage

STERILE EQUIPMENT (ON SURGICAL FIELD)	
ETT	3.0 cuffed; 2.5, 3.0, 3.5 uncuffed, and available stylets
Laryngoscopes and blades	Miller 0,1 Wis-Hipple 1,1.5
LMA	1, 1.5
Suction catheters	6 Fr, 8 Fr
Other	Mask, capnograph tubing, oral airways, umbilical tape, Steri-Strips, stethoscope

NONSTERILE EQUIPMENT READILY AVAILABLE	
Fiber-optic bronchoscope	Appropriate size for neonatal airway
Ambu bag	
Additional oxygen source	

Maternal risks and outcomes

The most serious and immediate maternal risk during the EXIT procedure is **intraop hemorrhage**. This may result from **uterine atony** and can be minimized by decreasing the concentration of the inhalational anesthetic and administering oxytocin before umbilical cord ligation. This, in combination with the hemostatic uterine stapling device, has kept the average maternal blood loss well within the accepted range for traditional cesarean delivery. In addition, **placental injury** may occur during hysterotomy, resulting in hemorrhage. This has occurred in the setting of polyhydramnios, in which the edge of the placenta was compressed, obscuring it from view by the ultrasonographer. It is advisable to perform intraop amnioreduction in cases with severe polyhydramnios with a potentially nearby placenta before performing an EXIT procedure to allow better placental visualization. In one study, the short-term

maternal outcomes after 34 EXIT procedures were compared to those from 52 nonlaboring patients who underwent nonemergent primary cesarean delivery of singleton fetuses. The rates of chorioamnionitis and endometritis and the postop hematocrit and hospital stays were similar between groups. The incidence of **wound infection** was increased in those undergoing EXIT procedure (15%) compared to controls (2%).

Lower uterine segment transverse hysterotomy is preferred for the EXIT procedure as it allows the possibility of future vaginal delivery. However, a low anterior placenta or an extremely large neck mass may make this incision impossible. In such cases, a classical hysterotomy is necessary, which would preclude future vaginal deliveries because of the risk of uterine rupture during labor. Thus, all pregnant women should be counseled that cesarean delivery may be required for all future pregnancies and that there is an increased risk of abnormal placentation with subsequent pregnancies.

ANESTHETIC CONSIDERATIONS

The features that distinguish the EXIT procedure from a conventional cesarean delivery are, in large part, due to the anesthetic management. Of paramount importance is the uterine relaxation achieved with an inhalational agent, most commonly isoflurane. Isoflurane has been administered in concentrations up to 2.5% to completely anesthetize the fetus to allow fetal laryngoscopy, bronchoscopy, tracheostomy, or tumor resection. Preservation of uteroplacental gas exchange with high concentrations of maternal isoflurane is well tolerated by the fetus for EXIT procedures lasting up to 180 min. Careful attention to the maintenance of maternal systemic blood pressure, often with the use of phenylephrine and ephedrine, is essential to safely use the high concentration of isoflurane required for uterine relaxation. Intraop fluid administration is kept to an absolute minimum 2° the postop predisposition to maternal pulmonary edema while on tocolytic agents. Occasionally, additional uterine relaxation is required, even when the end-tidal isoflurane concentration is ≥2.5%. This suggests that extensive manipulation of the uterus (e.g., forward displacement of the uterus to perform a posterior hysterotomy because of an anterior placenta) may stimulate the uterus to contract, even if high concentrations of isoflurane are used. For this situation, the intraop use of nitroglycerine provides excellent temporary uterine relaxation and is well tolerated. Pulmonary edema does not occur as a result of intraop intermittent dosing of nitroglycerine when it is used as an adjunct for uterine relaxation.

PREOPERATIVE

Conduct a rigorous preop evaluation of the mother, including CV history; evaluate all fetal anomalies in question. The most common indication for an EXIT procedure is the presence of a prenatally diagnosed neck mass, which is anticipated to result in severe airway obstruction following birth; severe micrognathia and mandibular hypoplasia may also require this approach. Preoperative consultation and coordination between treating providers are necessary.

Full-stomach precautions	Pretreatment with Bicitra® 30 mL po, ranitidine 50 mg iv
Positioning	Left uterine displacement
Premedication	Due to need for rapid-sequence induction and potential effects in the fetus, consider nonpharmacologic anxiolysis.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Evaluate for concurrent disease.

INTRAOPERATIVE

Anesthetic technique

GETA, rapid-sequence induction. The primary goal is to maintain complete uterine relaxation, to support maternofetal gas exchange, and to ensure fetal oxygenation. Uterine blood flow is not autoregulated, but directly related to MAP.

Maintain blood pressure with phenylephrine and ephedrine as necessary. Maintain fluid resuscitation to moderate due to propensity of pulmonary edema while on tocolytic agents. Use high concentration of isoflurane or sevoflurane to maintain uterine relaxation. Nitroglycerin can also be used to facilitate relaxation. Intrauterine infusion with normal saline may be necessary to preserve uterine volume and prevent separation of the placenta.

Induction	Rapid-sequence induction, with propofol and succinylcholine
ERAS	Verify preincision antibiotics. Assess volume status.
Maintenance	Volatile agent at high concentration to maintain uterine relaxation. Propofol (150–250

	mcg/kg/min) and remifentanil (0.2–0.5 mcg/kg/min) may help reduce uterine contractility in a dose-dependent manner and thereby reduce the need for large quantities of volatile anesthesia. With uterine exposure, reduce propofol to 50–75 mcg/kg/min.	
Special considerations	Coordination is necessary between maternal anesthesia team, surgical team, and pediatric anesthesia regarding cord clamping and delivery. The cord is clamped, volatile agent immediately discontinued, and N_2O continued, fentanyl and midazolam are given; oxytocin bolus and continuous infusion of oxytocin are titrated to uterine response. Once hemostasis is achieved, and uterine tone is restored, anesthetic agents are restarted.	
Care of fetus/neonate	Infant: delivery of the fetal head and upper extremity. Commence fetal monitoring with fetal scalp electrode, O_2 sat monitoring (normal SaO_2—65–75%). If possible, place iv catheter. Alternatively, additional anesthetic can be administered im via deltoid muscle (fentanyl 2–3 mcg/kg; rocuronium 0.5–1 mg/kg or vecuronium 0.1 mg/kg). After the airway is secured, the cord is clamped and delivery completed. Once the airway is secured, O_2 sat should increase to >90%. If unable to secure, consider surgical intervention. Secure ETT with umbilical tape, Steri-Strips. Secure iv access if not obtained previously. Hemodynamic management may include resuscitation with iv fluids and transfusion. Transfer to NICU unless further immediate surgical intervention is needed.	
Emergence	Usually extubated	
Blood and fluid requirements	Moderate blood loss IV: 16–18 ga × 1–2	Blood products available in the room due to potential for

		hemorrhage; cautious BSS administration due to potential for pulmonary edema related to the use of tocolytics
Monitoring	Standard monitors A-line	CVP to guide fluid resuscitation
Positioning	L uterine displacement	
Complications	Maternal hemorrhage Uterine atony	

POSTOPERATIVE

Complications (maternal)	Hemorrhage	✓ H/H regularly (e.g., 30 min for the 1st h); transfuse as necessary.
	Pulmonary edema	2° overly aggressive resuscitation, prolonged use of NTG
Complications (neonate)	Hypovolemia Respiratory compromise	2° fetal hemorrhage via the umbilical cord 2° aspiration, overresuscitation-ventilatory support as necessary
Tests	CXR to verify ETT position	
Multimodal pain management	Maternal Neonate	Patient-controlled analgesia Fentanyl 1–2 mcg/kg iv q1h prn Morphine (0.05–0.1 mg/kg iv q1–2h) Hydromorphone (0.005–0.01 mg/kg iv q1–2h)

	Acetaminophen 10 mg/kg iv q6h; 20 mg/kg pr q6h
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.

Suggested Readings

1. Dinges E, Heier J, Delgado C, et al: Multimodal general anesthesia approach for E Utero Intrapartum Therapy (EXIT) procedures: two case reports.Int J Obstet Anesth 2019; 38:142–145. doi: 10.1016/j.ijoa.2018.08.009.
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PEDIATRIC BARIATRIC SURGERY

Description

Childhood obesity, defined by the U.S. Centers for Disease Control and Prevention as a BMI above the 95th percentile for age, is pandemic in the United States, with rates up to 18% for adolescents aged 12–19. Adolescent bariatric surgery has been shown to both improve the quality of life and significantly decrease the comorbidities of obesity including obstructive sleep apnea (OSA), hypertension, type 2 diabetes, nonalcoholic fatty liver disease, pseudotumor cerebri, joint disease, and depression. There are two fundamental strategies to accomplish weight loss through surgery. The first approach is **restriction** in which the stomach volume is reduced to physically limit the amount of food that can be consumed comfortably at a given time. The second approach is **malabsorption** in which a given amount of intestine is bypassed to decrease absorptive capacity for nutrients.

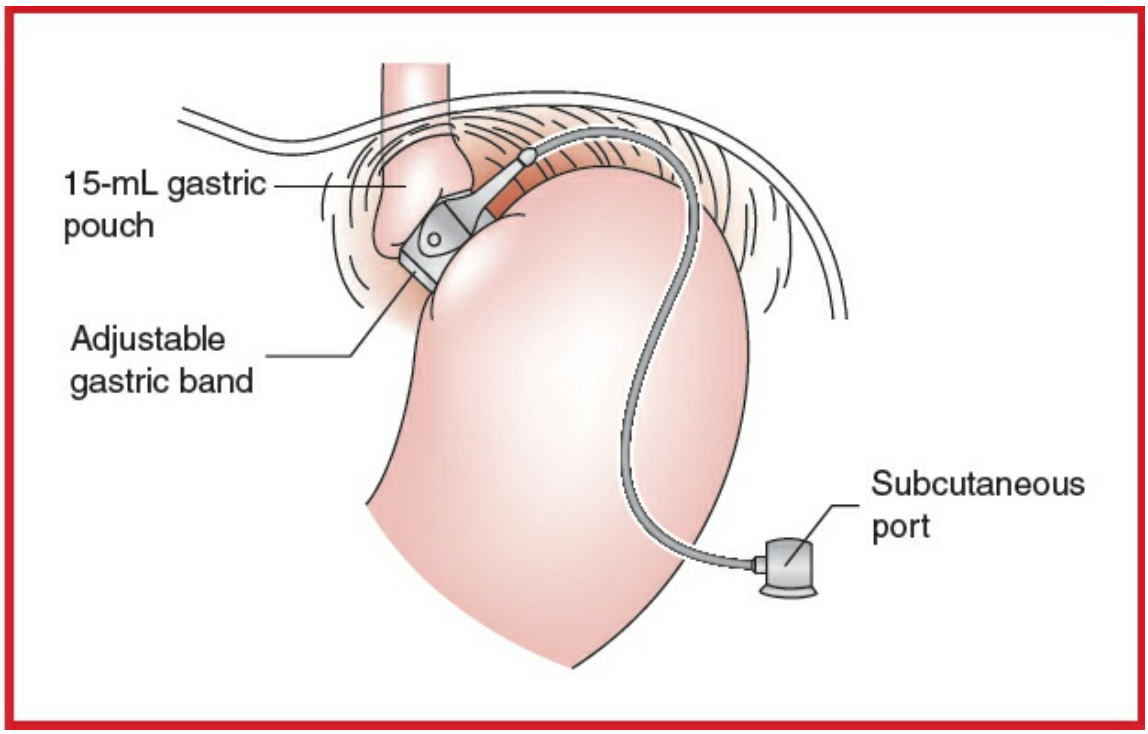

Figure 12.5-14 Gastric band approach.

Surgical approach

Prior to any consideration of surgical intervention, pediatric patients with obesity must be assessed by a multidisciplinary team including pediatricians, psychologists, social workers, physical therapists, and nutritionists. Nonsurgical weight loss options should be thoroughly investigated and exhausted prior to offering surgery.

The three most commonly performed procedures for obesity in the adolescent population are gastric band, sleeve gastrectomy, and Roux-en-Y gastric bypass. The **gastric band** (Fig. 12.5-14) is an adjustable device surgically placed around the stomach just distal to the GE junction. The procedure is generally done laparoscopically. An access port is placed in the subcutaneous tissue of the abdomen. The device variably compresses the stomach and restricts intake. **Sleeve gastrectomy** (Fig. 12.5-15) is performed by resecting the bulk of gastric tissue along the greater curvature leaving a small tubular stomach resulting in restriction and some malabsorption. The procedure is generally performed with laparoscopic staplers using a bougie (34–40 Fr) or endoscope in the stomach to guide the sizing of the resection. Finally, the **Roux-en-Y gastric bypass** (Fig. 12.5-16) involves division of the stomach leaving a small gastric pouch and creation of separate alimentary and pancreaticobiliary limbs of the intestine that delay the mixing of nutrients and pancreaticobiliary secretions, thus limiting absorption. Again, the preferred approach is laparoscopic. Perioperative complications associated with obesity must be considered in the

management of bariatric patients. Increased risk of thromboembolic disease and wound infection warrants prophylaxis. OSA and hypercapnia warrant postop monitoring.

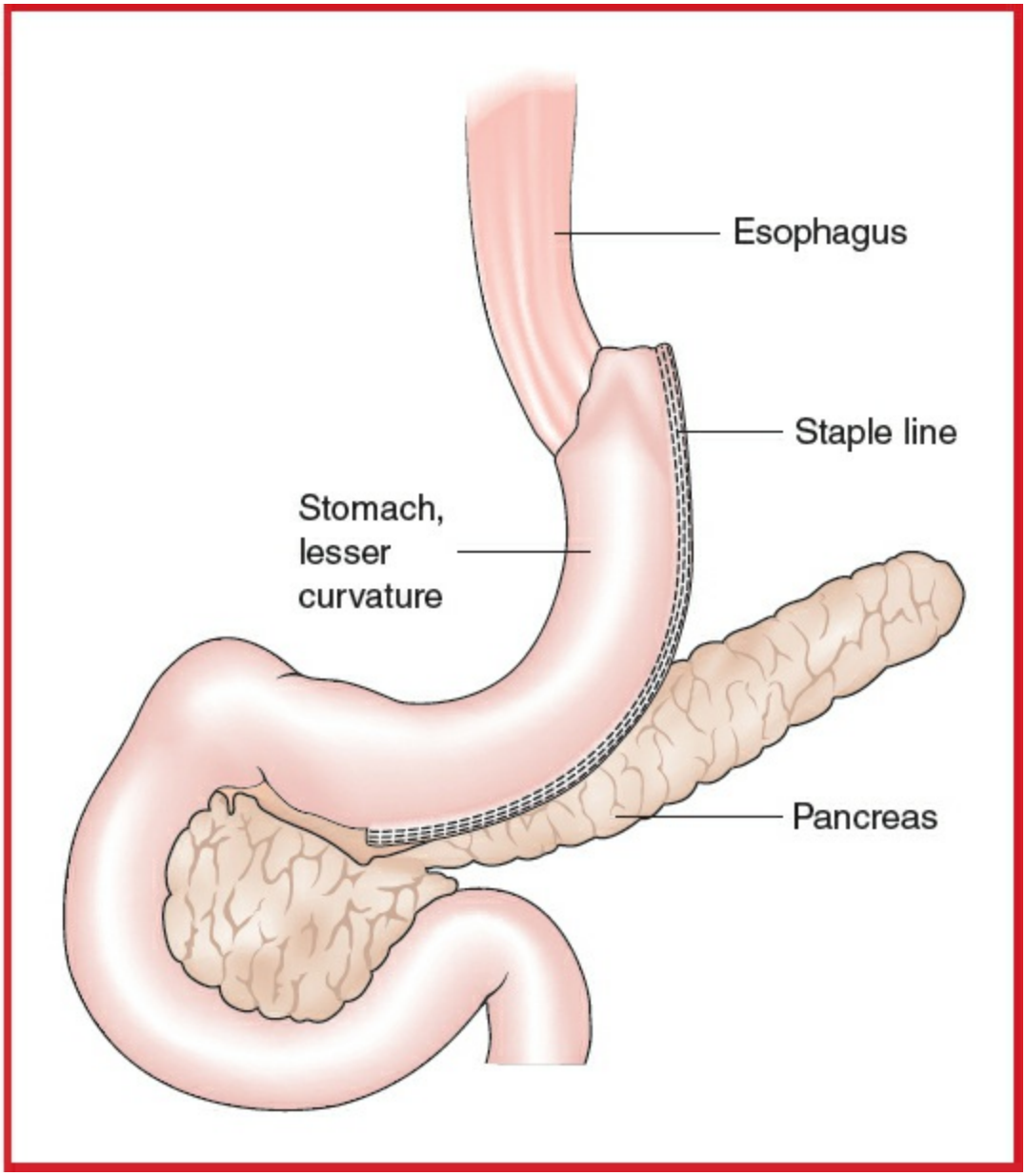

Figure 12.5-15 Sleeve gastrectomy.

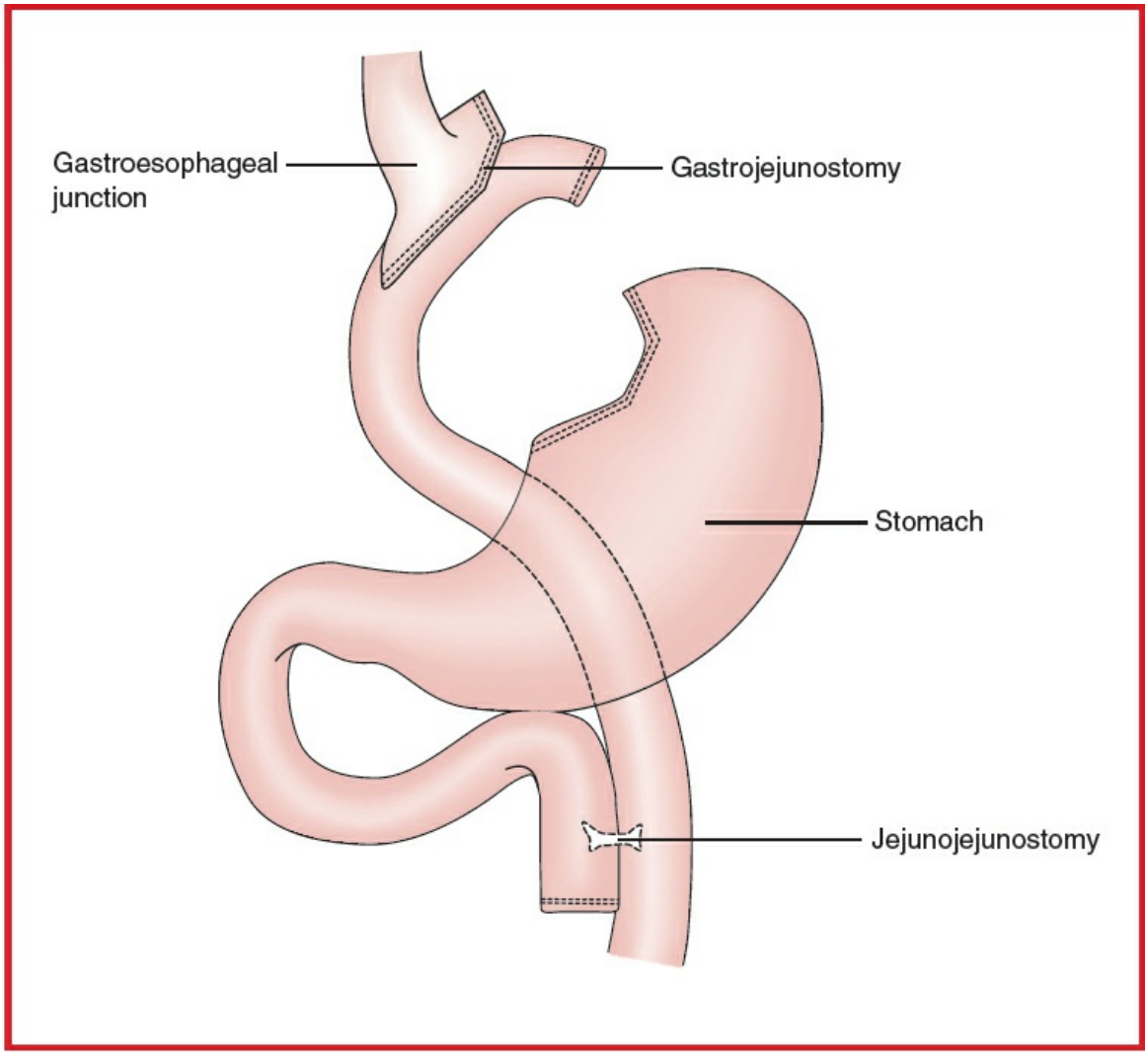

Figure 12.5-16 Roux-en-Y gastric bypass.

Variant procedures or approaches

A number of emerging endoscopic bariatric technologies aim to reduce the morbidity and mortality of existing techniques. Intragastric balloons and duodenal sleeves are promising but investigational at this time.

Usual preop diagnosis

Pediatric obesity (BMI > 50 or BMI > 45 with comorbid conditions). Majo comorbidities include OSA, type 2 diabetes, and pseudotumor cerebri.

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Roux-en-Y Gastric Bypass	Sleeve Gastrectomy/Gastric Band
Position	Supine on bariatric OR table with legs separated	⇐
Incision	Five laparoscopic ports	Four laparoscopic ports
Special instrumentation	Long laparoscopic ports	⇐
Unique considerations	DVT prophylaxis	⇐
Antibiotics	Cefoxitin 2 g	⇐
Surgical time	2–4 h	1–2 h
EBL	5–50 mL	5–50 mL
Postop care	Apnea monitoring	⇐
	± UGI to evaluate for leak	
Mortality	<1%	<0.5%
Morbidity	↓ PaO_2, ↑ $PaCO_2$ DVT PE Anastomotic leak	⇐
Pain score	5–6	4–5
Age range	Adolescents	
Male:Female	1:1	
Incidence	1:6	
Etiology	Diet and sedentary lifestyle	
Associated conditions	Obstructive sleep apnea, hypertension, diabetes, joint disease, depression	

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Morbid obesity, with a BMI > 40%, is associated with multiple comorbidities, including OSA, HTN, type 2 diabetes, fatty liver disease, and, in extreme cases pulmonary hypertension. A multidisciplinary evaluation must be performed prior to scheduling surgery, and a thorough preop evaluation is warranted, including review of medications, associated comorbidities, review of previous anesthetics, airway examination, and discussion of perioperative anesthesia plan. Also, include a review of any dieting strategies, especially medications taken for weight loss, as these may result in decreased response to vasopressors intraop. Patients with obesity may present challenges in iv placement and airway management. Postop pain management starts in the preop period with instruction in use of the incentive spirometer, visual analogue scale, and PCA if appropriate. A bariatric bed must be ordered preop.

Respiratory

Adipose tissue is metabolically active, leading to ↑ O_2 consumption and increased work of breathing. Increased mass of the thoracic wall → ↑ resistance, ↓ compliance, and a restrictive breathing pattern. In addition, ↑ abdominal pressure → atelectasis and ↑ closing volume. Obese patients also frequently suffer from OSA. Adolescent patients may have an increased response to hypoxia and relatively decreased response to hypercapnia. With increasing age, sensitivity to increased levels of CO_2 is diminished, and $PaCO_2$ rises further. These changes predispose the obese patient to hypoventilation, hypoxemia, and hypercarbia. In addition, changes to the airway related to increased adiposity of the face and neck may make mask ventilation and intubation difficult. Closely review previous anesthetic records.

Nighttime hypoxemia and hypercarbia are frequently seen in obese patients. A sleep study helps to document severity of apneic episodes. Number and severity of apnea and hypopnea episodes (apnea, >10 sec of no airflow; hypopnea, >50% reduction of airflow, associated with ↓ O_2 sat > 4%). Symptoms include snoring, daytime sleepiness, headaches, and difficulty concentrating. Treatment is usually a BiPAP mask. Close monitoring is needed in the postop period, as administration of opioids may exacerbate symptoms, leading to further hypoxemia and hypercarbia.

Tests: CXR, baseline SaO_2, sleep study, documenting hypoxemia while asleep

Cardiovascular

Because cardiac output rises proportionately with weight, obesity in both children and adults is frequently associated with hypertension and possibly LVH. Even normotensive patients have increased preload and afterload, ↑ PAP, and elevated left and right heart stroke volume. Symptoms of pulmonary HTN (dyspnea on exertion, fatigue, syncope

baseline hypoxemia) should be elicited and ECG obtained in symptomatic patients.

Tests: ECG, echo if indicated

Gastrointestinal

Obese patients have higher intra-abdominal pressures and may be at increased risk of aspiration. Studies have shown that acidity and volume do not statistically differ from nonobese patients. The presence of diabetes or gastroparesis increases risk of aspiration. Fatty liver disease may be present, frequently indicated by a rise in ALT. Increased volume of distribution may necessitate higher initial doses of anesthetic induction agents, especially lipid-soluble agents such as propofol.

Tests: Chem 23

Renal

Increased RBF and GFR may necessitate increased doses of renally cleared medications.

Premedication

Premedication should be used with caution, as obese patients are at increased risk of hypoventilation and hypoxemia. Midazolam 1–2 mg iv may be given if needed, with constant monitoring. Preop medications are continued, with the exception of ACE inhibitors, which are held the night prior to surgery, to minimize risk of intraop hypotension.

INTRAOPERATIVE

Induction	Assuming a reassuring airway examination and history, a rapid-sequence induction with preoxygenation and cricoid pressure, followed by propofol 2–2.5 mg/kg (TBW) and succinylcholine 1 mg/kg TBW, is the safest way to secure the airway. If history of difficult intubation exits, or examination is suggestive of difficult airway, consider awake FOI, using topical anesthesia, midazolam iv, and remifentanil infusion (0.05–1 mcg/kg/min) or dexmedetomidine infusion (0.2–0.7 mcg/kg/h). Positioning should include the use of a ramp to facilitate neck extension. This allows alignment of

	laryngeal, pharyngeal, and oral axes and promotes optimal visualization of the airway with laryngoscopy.
ERAS	Verify preincision antibiotics. Assess volume status. Consider iv acetaminophen (10–15 mg/kg to a maximum of 650 mg) for multimodal pain control and 0.1 mg/kg (maximum of 4 mg) iv ondansetron for PONV prophylaxis.
Maintenance	Propofol 200 mcg/kg/min combined with low-dose sevoflurane or desflurane; rocuronium for NMB (after recovery of NM function following succinylcholine). Use opioids cautiously, as may lead to increased sedation on awakening. Suggest loading with hydromorphone 10 mcg/kg TBW, followed by remifentanil infusion 0.5–1 mcg/kg/min. Ketorolac 0.5 mg/kg iv may reduce opioid requirement.
Emergence	Extubate awake. NG tube suction prior to extubation. Caution in immediate postop period, as patient may have ↓ ventilatory drive with ↓ responsiveness to hypoxemia and hypercarbia. Cautiously titrate opioids. If NDMR was used, reverse neuromuscular blockade with sugammadex (2–4 mg/kg) or with a combination of neostigmine (0.07 mg/kg with a maximum of 5 mg) and glycopyrrolate (0.01 mg/kg with a maximum of 1 mg). Do not attempt reversal with neostigmine and glycopyrrolate until first twitch of TOF has returned.

POSTOPERATIVE

Complications	Hypoxia, hypercarbia, apnea, airway obstruction	Close monitoring, supplemental O_2 if needed, relatively small frequent opioid dosing
	Difficult postop ambulation	Assistance with ambulation, including physical, occupational therapy—

		additional doses of opioid should be utilized around ambulation sessions.
	DVT/PE	DVT and PE prevention—ambulation, compression stockings while in bed, subcutaneous heparin—discuss with surgical team.
Multimodal pain management	PCA may be used, with cautious dosing regimens (e.g., hydromorphone—no basal rate, 1–2 mcg/kg bolus dose with a maximum starting dose of 200 mcg q10min). Ketorolac 0.5 mg iv q6h may be used with caution, after checking renal function and coordinating with surgical team to ensure there are no concerns regarding possible postop bleeding. Acetaminophen 10–15 mg/kg iv q6h should be continued postop (maximum of 650 mg per dose). Postop monitoring is essential. Supplemental O_2 may be necessary via nasal cannula. Please see Appendix E: Multimodal Pediatric Postoperative Pain Management, p. E-1.	
ERAS	Encourage early enteral nutrition and patient mobilization as appropriate. Assess for appropriate return of bowel function.	

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CHAPTER 12.6

Pediatric Urology

SURGEONS

Andrew J. Sun, MD
Hsi-Yang Wu, MD

ANESTHESIOLOGIST

Radhamangalam J. Ramamurthi, MD, FRCA

KIDNEY AND UPPER URINARY TRACT OPERATIONS

SURGICAL CONSIDERATIONS

Description

With the increase in perinatal ultrasonographic detection of renal masses and hydronephrosis, pediatric kidney and upper urinary tract surgeries have become increasingly common. Children come to surgery at an earlier age, leading to a lower incidence of renal dysfunction.

Nephrectomy

Nephrectomy is most commonly performed to remove poorly or nonfunctioning kidneys secondary to congenital anomalies such as ureteropelvic junction (UPJ) obstruction or end-stage reflux nephropathy. Tumor nephrectomy is uncommon in children (with the exception of Wilms tumors). Multicystic dysplastic kidneys (MCDK) were removed in the past but currently are only removed if they become symptomatic or increase in size, as they have a benign course. Most often, a subcostal incision is used in children as it affords excellent renal exposure with less pain and risk of wound complications.

For benign processes, a flank/subcostal incision is commonly used, and careful

positioning of the patient is crucial. The ultimate goal is to have the patient in a 30°–45° flank up position on the respective side. However, failure to properly stabilize and secure the patient to the OR table can cause devastating consequences; therefore, efforts must be coordinated to properly position the patient. A rolled sheet or gel pad should be positioned beneath the dependent axilla, elevating the thorax to avoid brachial plexus neuropraxia. The dependent lower extremity is flexed at the hip and knee, while the overlying leg is kept straight. Padding is placed between the knees. In older children, in this lateral flank position, the kidney rest at the break of the table may be elevated to increase the distance between the rib and iliac crest, thus increasing exposure of the kidney. Attention is needed by the anesthesiologist during positioning, including care of the ETT, padding of pressure points, application of wide tape to secure patient safely, and repositioning of leads. After the patient is positioned, a transverse incision is made below the 11th or 12th rib. The peritoneum is reflected, and surgery remains retroperitoneal if possible. The ureter is dissected to the hilum, and the vessels are ligated. The kidney is excised, and the wound is closed.

A dorsal lumbotomy (incision parallel to the paraspinous muscle group) is an additional option for benign indications and is performed with the patient in the prone or lateral position. This has an advantage of being a muscle-splitting, rather than a muscle-cutting, incision and, as such, is associated with less postoperative pain. Abdominal padding may be added to raise the lumbodorsal area, and care should be taken to ensure complete pulmonary expansion in this position.

For Wilms tumor nephrectomies, a chevron incision is recommended as maximum exposure of the renal vessels, aorta, and vena cava is needed and retroperitoneal lymph nodes need to be dissected (Fig 12.6-1). In general, minimally invasive approaches are not recommended for Wilms tumor by the Children's Oncology Group.

Regardless of the position, a urethral catheter is usually placed and positioned for dependent drainage with care taken to avoid obstructing the tubing. In this way, the anesthesiologist may measure urinary output, though urinary extravasation may occur within the surgical site depending on the operation.

In routine open surgery of the kidney and renal pelvis, use of intraoperative local anesthesia (infiltration of local anesthetic in the surgical incision) and higher dosage of nonopioid pain medications (acetaminophen) appear to decrease pain intensity during the first postoperative day. Continuous epidural or caudal catheters can be effective for postoperative pain management but may result in urinary retention.

Usual preop diagnosis

MCDK; Wilms tumor; nonfunctioning kidney; dysplastic kidney; UPJ obstruction

Partial nephrectomy

Partial nephrectomies are usually performed for a poorly functioning or nonfunctioning upper pole of a duplicated system. Ectopic ureters and ureteroceles are frequently the cause of lost function. Again, these benign indications can be approached through either a lumbodorsal or a flank incision. If the upper pole is obstructed but functional, a **pyeloureterostomy** from the upper pole ureter to the pelvis of the lower pole may be performed to salvage as much functioning parenchyma as possible. Partial nephrectomies may be performed for bilateral Wilms tumor or other renal masses through a chevron incision as described above. Blood should be immediately available in these cases as there is a risk of significant blood loss. Urine output should be watched closely and the patient resuscitated as needed. Blood loss is attempted to be minimized by clamping of the renal vessels but comes at the risk of renal ischemia and free radical–mediated tissue injury upon reperfusion. For this reason, the surgeon will often apply an iced slush to the renal fossa to cool the kidney prior to clamping the renal vessels. Administration of 20% intravenous mannitol around this time is often done to help scavenge free radicals. An increasing number of partial nephrectomies are being done robotically for benign diagnoses.

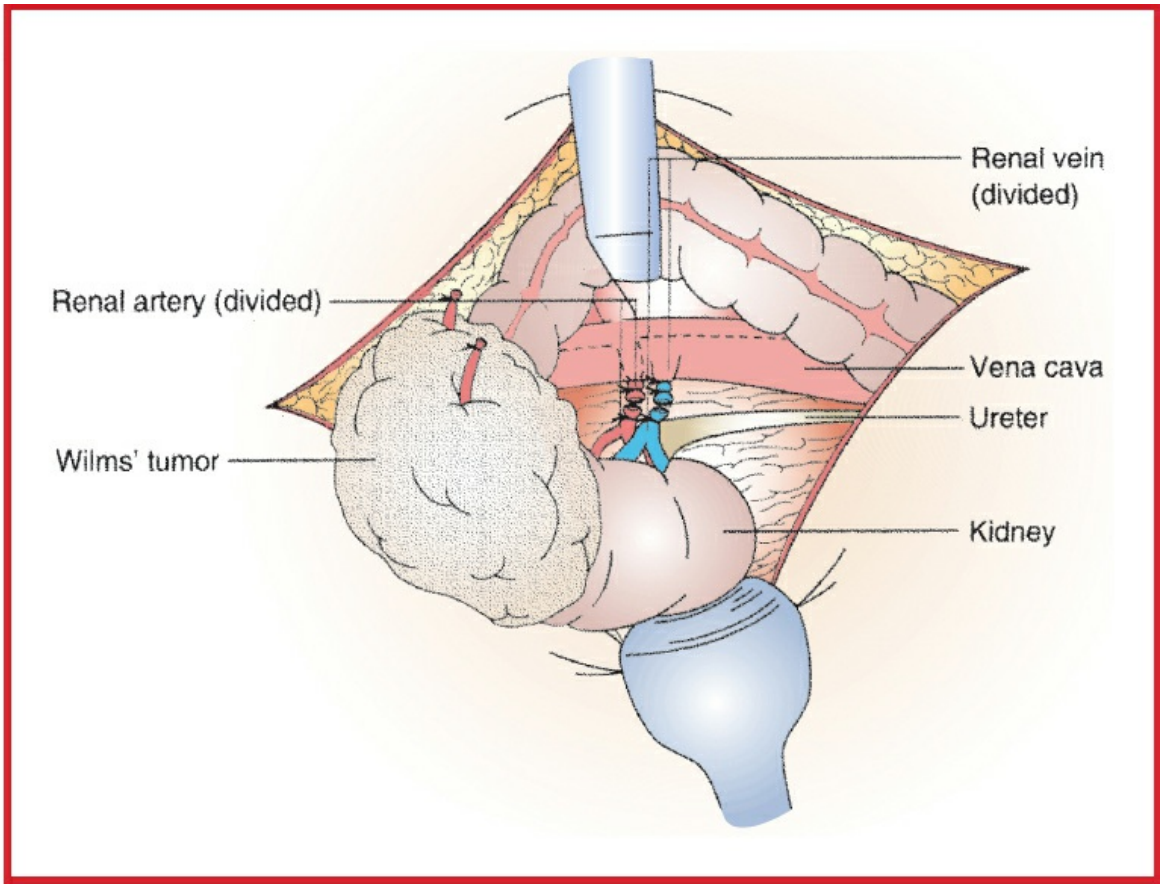

Figure 12.6-1 Anatomy for nephrectomy. (Reproduced with permission from Greenfield LJ, Mulholland MW, Oldham KT, et al. eds.: Surgery: Scientific Principles and Practice, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Usual preop diagnosis

Nonfunctioning pole of a duplex system; ureterocele; ectopic ureter; bilateral Wilms tumor; angiomyolipoma (common in patients with tuberous sclerosis)

Nephroureterectomy

Nephroureterectomy is performed for the upper pole of a duplex system that is obstructed due to an ureterocele or ectopic ureter. After the nephrectomy/partial nephrectomy is performed through one of the aforementioned approaches, the ureter is dissected as low as possible (usually to the level of the iliac vessels). The ureteral stump is left open if there is no vesicoureteral reflux and tied off if there is reflux. If indicated, distal ureterectomy can be performed via a second lower abdominal incision (typically a Pfannenstiel incision). If the initial incision was done in the prone position, the patient may need to be repositioned supine.

Usual preop diagnosis

Nonfunctioning upper pole of a duplex system; ureterocele; ectopic ureter

Pyeloplasty

Fetal hydronephrosis is detected in ~1 in every 300 pregnancies. Pyeloplasty to correct congenital obstruction of the UPJ is one of the most common pediatric upper urinary tract surgical procedures. The hydronephrotic kidney usually is exposed through either a dorsal lumbotomy or a subcostal flank incision. The patient may be in a prone or modified lateral decubitus position (see details related to subcostal or lumbodorsal incision previously described). In most instances, the operation is performed entirely retroperitoneally with exposure of the upper ureter and renal pelvis. The abnormal UPJ is excised, followed by an end-to-end anastomosis (**dismembered pyeloplasty** or **Anderson-Hynes pyeloplasty**). If the renal pelvis is intrarenal and dependent drainage is not possible via a conventional pyeloplasty, a **ureterocalicostomy** may be performed by removing an area of thin renal parenchyma and anastomosing the ureter to a lower pole calyx. At the conclusion of the procedure, a perirenal Penrose drain is often placed near the anastomosis, and, depending on surgeon preference, a ureteral stent or nephrostomy tube may be used. A urethral catheter is usually left after the procedure. An increasing proportion of these procedures are being performed using a robotic approach as detailed later. A major difference between these is that a robotic approach requires intraperitoneal access, while open approaches are usually extraperitoneal.

Usual preop diagnosis

Fetal hydronephrosis 2° UPJ obstruction; hydronephrosis with a decrease in kidney function and/or flank pain

Transureteroureterostomy (TUU)

This is a rare procedure, in which a ureter is anastomosed to the contralateral ureter. It is used when there is problematic drainage of a distal ureter into the bladder. It is sometimes required to salvage a failed reimplantation or to reroute a conduit-type diversion to an orthotopic neobladder or augmented native bladder. This technique can also be used to provide drainage in cases of distal ureteral trauma. A midline or Pfannenstiel incision is used, and the peritoneum is entered. The ureters are dissected, and the affected ureter is retroperitonealized and brought to the contralateral side anterior to the great vessels. It is anastomosed to the contralateral ureter end to side with absorbable suture. If required, the recipient ureter is then reimplanted into the neobladder or augmented bladder.

Usual preop diagnosis

Failed ureteral reimplant; modification of urinary diversion; distal ureteral trauma

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Nephrectomy/Pyeloplasty	Nephroureterectomy	TUU
Position	Supine/flank/prone	Supine/flank	Supine
Incision	Dorsal lumbotomy; subcostal; flank; chevron	Subcostal; flank; second incision: Pfannenstiel	Midline or Pfannenstiel
Antibiotics	1st- or 2nd-generation cephalosporin; aminoglycoside + clindamycin	⇐	⇐
Surgical time	2.5–4.5 h	3–4 h (repositioning may be required)	⇐
EBL	Minimal; if partial	Minimal	⇐

	nephrectomy, 300 mL		
Mortality	<1%	⇐	⇐
Morbidity	Bleeding: <5%	⇐	⇐
	Infection: <5%	⇐	⇐
	Ileus: <5%	⇐	⇐
			Urinary fistula: <5%
Pain score	Flank: 10 Subcostal: 10 Midline/chevron: 10 Lumbotomy: 5	10	10

PATIENT POPULATION CHARACTERISTICS

	Ureteroceles	MCDK*	UPJ Obstruction	Wilms Tumor
Age range	Pediatric	Neonates	Neonates, children	Children (average, 4 yr)
Male:Female	1:4	M > F	M > F	M < F in the United States
Incidence	1:2000	⇐	1:500 birth	1:100,000
Etiology	Congenital	⇐	⇐	Genetic: WT1 gene
Associated conditions	UPJ; VUR; duplicated collecting system	⇐	VUR*; renal insufficiency	Hemihypertrophy, aniridia, HTN, Beckwith-Wiedemann syndrome

*MCDK, multicystic dysplastic kidney; VUR, vesicoureteral reflux.

Suggested Readings

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ANESTHETIC CONSIDERATIONS

PREOPERATIVE

In infants and children, most upper urinary tract surgical procedures are performed to preserve or restore renal function. Patients may present with renal function that varies from minimally abnormal, requiring little or no modification of anesthetic plan, to end-stage renal disease (ESRD) with its associated abnormalities, including hypoproteinemia, chronic anemia, and serum electrolyte disturbances. A careful preop workup is required to determine the presence or absence of abnormal physiologic factors that will affect anesthesia management. For most cases, the workup will have been performed by the patient's physicians before surgery and will provide the rationale for the surgical procedure. Such nonspecific findings as anorexia, headache, nausea, fatigue, alterations in urine output, and the presence of edema will alert the clinician to the likelihood of renal failure.

Renal abnormalities often are present as one component of a congenital malformation syndrome (e.g., polycystic kidneys, cerebrohepatorenal syndrome). In formulating the anesthetic plan, drugs eliminated by the kidney (e.g., pancuronium, meperidine) should be avoided.

Respiratory	An evaluation of pulmonary function, including auscultation of the lungs, may indicate the presence of pulmonary edema (uremic lung) or a pleural effusion. **Tests:** ABG; CXR; SaO_2
Cardiovascular	HTN is commonly seen in these patients, who may be taking antihypertensive medications and diuretics. In severe cases, CHF or pulmonary edema may be present, necessitating the use of cardioactive drugs and diuretics to optimize the patient's clinical condition before surgery. Timing discontinuation of medication around the procedure is crucial. For example, ACE inhibitors need to be stopped at least 12–24 h before surgery under anesthesia. **Tests:** ABG; CXR; digitalis level; electrolytes
Renal	In cases requiring unilateral urinary tract surgery, the opposite kidney is usually normal. In the presence of renal insufficiency, a detailed evaluation of renal function is essential. Chronic metabolic acidosis may

	be present 2° poor kidney function, electrolyte abnormalities (↑ K^+, ↓ Ca^{++}, ↑ or ↓ Na), hypovolemia, hypervolemia, and/or poor tissue perfusion. Children with ESRD will have been dialyzed before surgery. Preop K^+ <6 mEq/L is usually safe. These patients may have an AV fistula, which must be protected during surgery (padded, no BP cuff). More commonly, a double-lumen central venous catheter will have been placed for hemodialysis (e.g., permacath). **Tests:** UA; UO; serum electrolytes; BUN; Cr; total protein; A/G ratio; ABG
Gastrointestinal	Renal failure is associated with increased incidence of delayed gastric emptying and gastroesophageal reflux. Modified rapid-sequence induction should be considered.
Hematologic	Anemia, bone marrow depression, and coagulopathies are common in patients with poor renal function, particularly platelet dysfunction. An Hct of 20–23% is not uncommon and is often well tolerated. Transfusion needs to be considered against the possibility of sensitization of immune system prior to possible renal transplant. **Tests:** Hb/Hct, PT/PTT; Plt count
Medications	Patients with ESRD will be taking many medications, which may influence the anesthetic plan. For example, chronic steroid therapy → Cushing facies and glycosuria; therefore, ✓ blood sugar and ✓ airway. Patients taking digitalis or diuretics → ↓ K^+→ arrhythmias. Aminoglycosides → prolongation of neuromuscular blockade. If possible, avoid renal toxic drugs in patients with renal insufficiency (e.g., NSAIDs, aminoglycosides).
Premedication	Standard preop medication if renal function is normal. Patients with ESRD may have increased sensitivity to sedatives; doses should be titrated carefully to effect. Avoid long-lasting sedative

ERAS	medications. Check compliance with presurgical ERAS recommendations (see above) including NPO status. Evaluate for concurrent disease, nutritional status, and hydration. Consider preop acetaminophen 10–15 mg/kg iv or po as an elixir.

INTRAOPERATIVE

Anesthetic technique

GETA ± epidural: (Platelet dysfunction should be assumed in ESRD and the risk/benefit of epidural placement carefully weighed.) Warm OR to 70°F–75°F; use warming pad on OR table and/or forced-air warming.

Induction	Mask induction is preferable, unless iv is already in place. If an indwelling permacath is to be accessed, heparin should be aspirated from the lumen before use. Routine use of dialysis catheters is discouraged due to the need for strict sterile technique in handling of the catheter to avoid line infection. Succinylcholine should not be used with renal failure patients due to risk of K^+ release in borderline hyperkalemic patients. In the presence of renal insufficiency, antibiotics (e.g., aminoglycosides) may interfere with the metabolism of muscle relaxants and prolong their effect and may further compromise renal function. Tracheal intubation, facilitated by an NMR (e.g., rocuronium 0.6–1 mg/kg or cisatracurium 0.2–0.3 mg/kg), is appropriate in patients with renal insufficiency. In appropriate patients (normal coags and no platelet dysfunction), epidural anesthesia with bupivacaine may reduce anesthetic requirements and provide postop analgesia (**NB:** local anesthetic clearance may be impaired in ESRD). Maintain muscle relaxation with rocuronium or cisatracurium.
ERAS	Verify preincision antibiotics. Assess volume status (see p. D-1). Maintain normovolemia and normothermia.
Maintenance	Standard pediatric maintenance. Moderate hyperventilation may be beneficial ($\rightarrow \downarrow K^+ + \uparrow$ pH).

Emergence	Reverse neuromuscular blockade with neostigmine and glycopyrrolate or atropine. Discuss with surgeon local wound infiltration. PONV prophylaxis should include dexamethasone (e.g., 30 mcg/kg) and ondansetron (0.1 mg/kg up to 4 mg iv).	
Blood and fluid requirements	IV × 1 in upper extremities BSS @ (maintenance): 4 mL/kg/h (1–10 kg) +2 mL/kg/h (11–20 kg) +1 mL/kg/h (>20 kg)	Usually minimal blood loss; however, renal surgery may be associated with ↑ blood loss. Transfuse with whole blood or PRBCs as needed to maintain an adequate Hct, based on physiologic response (usually 25–30%). If K^+ is high and patient has ESRD, use freshest PRBC or washed PRBC to minimize the K^+ load. Minimal iv flush should be administered in the presence of oliguric renal insufficiency. Fluids in excess can lead to pulmonary edema especially in an aneuric patient. Avoid K^+ containing crystalloid infusions. See Zero Balance Fluid Management, Appendix K, p. K-2.
Monitoring	Standard monitors ± Arterial line	Consider placing an arterial line in patients with significant renal failure particularly for those patients with poorly controlled HTN as they may exhibit marked hypotension or BP variability after induction; ✓ serum electrolytes and ABG frequently.

Positioning	✓ and pad pressure points ✓ eyes	✓ eyes frequently if prone or flank positions are used.
Complications	Peripheral nerve injury Eye trauma Hemorrhage Dysrhythmia Indigo carmine administration may lead to ↑ BP, ↓ HR, ↓ BP, and bronchospasm.	

POSTOPERATIVE

Complications	Hypovolemia Anemia Hypothermia Electrolyte abnormalities Coagulopathy Metabolic/respiratory acidosis	
Multimodal pain management	Acetaminophen	In renal failure, reduce analgesic doses by 50% to minimize cumulative effects. Use nonopioid analgesics. Back up with bolus opioid analgesics.
	Opioids via PCA/epidural catheter with mixture of local anesthetic—ropivacaine 0.1%, hydromorphone 3 mcg/mL, +/− clonidine 0.1–0.2 mcg/mL	Note: morphine metabolites morphine-6-glucuronide (analgesic) and morphine-3-glucuronide (antanalgesic) are renally excreted and accumulates in patients with renal failure. It is therefore preferred to use hydromorphone. For patients without renal failure, epidural or caudal catheters can be effective for postop pain management but may result

		in urinary retention. Peripheral nerve blockade (e.g., transversus abdominis plane block, TAP), quadratus lumborum plane block, and ilioinguinal and iliohypogastric blocks avoid this issue. Single-shot caudal may also be used for minor procedures. (See discussion in surgical section on p. 1521.)
ERAS	PONV protocol (see Appendix D, p. D-4)	Encourage early enteral nutrition, catheter removal, and ambulation as appropriate.
Tests	As indicated	

Suggested Readings

1. Hobai IA: Atrioventricular block induced by indigo carmine. Can J Anaesth 2008; 55(10):717–8.
2. Lee WJ, Jang HS: Cardiac arrest from intravenous indigo carmine during laparoscopic surgery. A case report. Korean J Anesthesiol 2012; 62(1):87–90.
3. Rove KO, Edney JC, Brockel MA: Enhanced recovery after surgery in children: promising, evidence-based multidisciplinary care. Paediatr Anaesth 2018; 28(6):482–92.

PERCUTANEOUS STONE PROCEDURES

SURGICAL CONSIDERATIONS

Description

Whenever possible, the management of urologic stone disease is done endoscopically as procedures are shorter, patients have less pain, and potential complications tend to be less morbid. However, due to stone size, stone location, or patient anatomy, sometimes these modalities can fail. When this occurs and a stone must be treated, such

as in cases of infection or obstruction, percutaneous procedures are required. These include **percutaneous nephrolithotomy (PCNL)** and **open pyelolithotomy**.

Every child with renal calculi should undergo metabolic evaluation. Renal function should be checked preop. GA is usually required due to limited patient cooperation in the pediatric population and need for precise positioning. Moderate pain may be expected and should be treated with opioid therapy. Ketorolac should not be used due to potential renal effects.

Percutaneous nephrolithotomy (PCNL)

Patients undergoing PCNL can be admitted to the hospital the day before the procedure so that a nephrostomy tube can be placed by interventional radiology. Those who advocate prior nephrostomy placement feel that there is less bleeding when the stone procedure is done the following day. Some surgeons prefer to obtain their own access using a spinal needle and fluoroscopy during the case. Prior to starting the case, the anesthesiologist should ensure that blood is immediately available, as accessing the renal pelvis has the risk of disrupting intrarenal vasculature. After induction of general anesthesia, patients are placed in prone position with special care taken to ensure all extremities are secure and pressure points adequately padded. Access to the renal pelvis is obtained and the tract is dilated with a balloon. A sheath is then left in place to allow for placement of a nephroscope into the renal pelvis. The stone is then fragmented using either a laser or other device, and fragments extracted. In contrast to other endoscopic procedures, which tend to be short and without exposed vasculature, PCNL carries a risk of fluid absorption toxicity ("TUR syndrome"). Depending on the fluid used, there is a risk of hyponatremia in addition to volume overload. Both the surgical and anesthesia teams should be aware of the volume and type of fluid being used for the procedure. Related to this, it is imperative that fluids used are warmed to prevent hypothermia during the operation. After this operation, patients are often left with a nephrostomy tube and ureteral stent. Patients typically admitted to the hospital for 1–2 d postoperatively.

Usual preop diagnosis

Renal calculus

Open pyelolithotomy

The approach for an open pyelolithotomy is identical to that used for a pyeloplasty (described above). Once renal exposure has been obtained, a small incision is made in the renal pelvis and the stone manually removed. Postoperative considerations, including potential uses of a ureteral stent, nephrostomy tube, and Penrose drain, are

similar. Patients tend to be admitted for 2–3 d after this procedure.

Usual preop diagnosis

Renal calculus

Suggested Readings

1. Bowen DK, Tasian GE: Pediatric stone disease.Urol Clin North Am 2018; 45(4):539–50.
2. D'Addessi A, Bongiovanni L, Sasso F, et al: Extracorporeal shockwave lithotripsy in pediatrics. J Endourol 2008; 22(1):1–12.

TRANSURETHRAL PROCEDURES

SURGICAL CONSIDERATIONS

Description

Transurethral procedures are not as common in children as they are in adults; however, the instrumentation, general principles, and considerations are similar. The most common pediatric endoscopic procedures are **cystoscopy** and **vaginoscopy**, primarily as diagnostic procedures; **removal of** indwelling ureteral stents; transurethral incision of urethral stricture, for congenital lesions or complications of urethral surgery; **transurethral incision of posterior urethral valves** (PUV);**transurethral incision of ureterocele; subureteric injection for vesicoureteral reflux; endoscopic injections for urinary incontinence; placement of ureteral stents; and ureteroscopy (commonly with lithotripsy for treatment of stones)**. As described above, fluid absorption toxicity is rarely seen with these procedures in children.

The positioning and techniques are identical to those in the adult. Careful attention to positioning is required when the pediatric patient is placed in the lithotomy position. For smaller children, this involves the frog leg position at the distal end of the bed rather than stirrups. The patient can remain supine if a flexible cystoscope is used. The most frequent neurologic complication from lithotomy position may be injury to the common peroneal nerve → foot drop and sensory deficit. After the patient is positioned, a lubricated cystoscope or resectoscope (7–18 Fr) is introduced through the urethra. In infants, PUV may be resected using a small cutting electrode or a laser, whereas a resectoscope is used in older children. With the advent of prenatal ultrasonography, PUV (often seen with hydronephrosis and azotemia) are usually resected in the neonatal period.

Ureteral stents or bladder stones are removed using forceps or other tools, after crushing or pulverization with a laser if necessary. Eye protection may be worn by operating room staff if a laser is used. Occasionally, when ureteral stents are placed/removed, an intraoperative retrograde pyelogram is performed to evaluate the upper tract collection system. During cystoscopy, localization of the ureteral orifices may be difficult due to inflammation, prior bladder surgery, or congenital ectopia. The anesthesiologist may be asked to administer intravenous fluorescein, methylene blue, or indigo carmine, which will filter through the kidneys and produce colored urine to assist with locating the ureteral orifices. Indigo carmine specifically has potential effects of ↑ BP by increasing afterload and causing reflex bradycardia. Fluorescein carries a risk of bronchospasm/pulmonary edema in patients with allergies or asthma and can rarely cause hypotension. Methylene blue may cause CNS depression, methemoglobinemia in patients with G6PD-deficiency, and serotonin syndrome in patients taking antidepressants.

As noted before, stone surgical procedures are typically done using the most minimally invasive technique, such as extracorporeal shock wave lithotripsy (ESWL)**and ureteroscopy**. Often, these procedures require fluoroscopy, which may bring with it both equipment considerations (fluorocompatible moving tables) and positioning requirements to allow C-arm placement.

For pain control, aside from opioids in the immediate postoperative period, lidocaine gel may be injected transurethrally at the completion of the transurethral procedure to avoid postoperative urethral irritation. Some surgeons administer phenazopyridine (Pyridium) to decrease catheter irritation. Finally, if a catheter is left, an antimuscarinic may be given to decrease bladder spasms (oxybutynin).

Cystoscopy/Cystolitholapaxy

Positioning for these procedures is typically done in lithotomy position. After induction of general anesthesia, a cystoscope is inserted and the urethra/bladder visualized. Depending on the procedure, a range of instruments may be used to biopsy, remove, or obliterate lesions, foreign bodies, or stones. If lasers are used, eye protection may be used by operating room staff. Most lasers have a very short working distance so the risk of ocular injury is small. Pure cystoscopic procedures tend to be fairly short, with the majority requiring <1 h. Paralysis is not always required. Depending on the procedure performed, a Foley catheter may or may not be left at the end of the procedure.

Usual preop diagnosis

Intravesical foreign body (ureteral stent); bladder calculus; bladder outlet obstruction;

urethral stricture; ureterocele; hematuria; urethral/vaginal mass; posterior urethral valves, urogenital sinus

ESWL (extracorporeal shock wave lithotripsy)

This procedure utilizes ultrasound to break the stone from outside the body. The child is placed in a supine position on a special bed. The need for general anesthesia or sedation is still required to reduce movement as this procedure requires aiming the burst in three dimensions but may depend on the child's age, the extent of stone burden, and the kind of extracorporeal lithotripter being used. Usually general anesthesia with endotracheal intubation in young children is required.

Usual preop diagnosis

Nephrolithiasis, ureterolithiasis

Ureteroscopy and laser lithotripsy

Positioning for this procedure requires lithotomy. Paralysis is needed for upper tract instrumentation as patient movement such as a cough could cause ureteral perforation, especially when using the semirigid ureteroscope. Lasers are frequently used for these procedures. After the stone is fragmented and removed, a stent is often left to prevent obstruction from ureteral edema or fragments. In some cases, the stent may be left with a string attached that will exit the urethra and be visible outside of the body. These strings should be not manipulated except to allow for stent removal at a later date. It is important to know that ureteral access in children is tenuous, and it is not uncommon (especially for untreated ureteroscopy patients) that the scope or access sheath will not be accommodated by the ureter. In these cases, only a ureteral stent will be placed and remain in place to allow the ureter to passively dilate up in size, with plan for another attempt at ureteroscopy 1–2 wk later. Thus, large doses of paralytics should not be given until ureteral access is established, as, if only a stent is placed, the procedure will be quite short.

Usual preop diagnosis

Nephrolithiasis, ureterolithiasis

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Cystourethroscopy,

	Cystolitholapaxy	ESWL	Ureteroscopy
Position	Lithotomy	Supine	Lithotomy
Incision	None	None	⇐
Antibiotics	Aminoglycoside ± ampicillin; 1st- or 2nd-generation cephalosporin; amoxicillin/clavulanate	None	Aminoglycoside ± ampicillin; 1st- or 2nd-generation cephalosporin; amoxicillin/clavulana
Surgical time	Cystoscopy: 10 min Transurethral procedure: 0.5–1 h	1 h	1–2 h
EBL	Minimal	None	⇐
Postop care	PACU; basic catheter management, with oral Pyridium in the PACU for bladder analgesia	PACU → home	⇐
Mortality	<1%	<1%	⇐
Morbidity	Bleeding Urethral stricture Infection Overdistension in augmented bladder	Sepsis <1% Hematoma <1%	Pyelonephritis <5% Ureteral perforation <5%
Special considerations	Use of cautery, fluoroscopy, PUV (prematurity or azotemia), and possible fluid reabsorption. Children with an obstructing ureterocele and	Hematoma <1%; risk of residual stone fragments causing obstruction/pain	Ureteral perforation <5%; often will have indwelling ureteral stent postop

	pyelonephrosis may be at risk for urosepsis and should have close hemodynamic monitoring.		
Pain score	2	2	2

PATIENT POPULATION CHARACTERISTICS

	Cystourethroscopy, Cystolitholapaxy	ESWL, Ureteroscopy
Age range	0–18 yr	Toddler and older
Incidence	1/1000–1/5000	Dependent on age group; rising
Male:Female	Posterior urethral valves, strictures: male only Ureterocele, 1:6 Vesicoureteral reflux, 1:4	Female > male
Etiology	Posterior urethral valves; vesicoureteral reflux; intravesical foreign body; bladder calculus; bladder outlet obstruction; urethral stricture; ureterocele	Metabolic abnormality or urogenital malformation with impaired drainage of the upper tract
Associated conditions	Spina bifida; paraplegia/quadriplegia; repeat cystoscopies; strictures; bladder stones; latex allergy	Obesity, diabetes, hypertension, Dent disease, primary hyperoxaluria, Lesch-Nyhan syndrome; urogenital malformation

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Transurethral Procedures, Open Bladder Procedures Penile Surgery, and Genital Procedures.

Suggested Readings

1. Hernandez JD, Ellison JS, Lendvay TS: Current trends, evaluation, and management of pediatric nephrolithiasis. JAMA Pediatr 2015; 169(10):964–70. doi:10.1001/jamapediatrics.2015.1419.
2. Schneck FX, Ost MC: Surgical management of pediatric stone disease. In:Campbell-Walsh Urology, 11th edition. Elsevier, Philadelphia: 2016, 3102–20.e3.
3. Warner MA: Lower extremity neuropathies associated with lithotomy positions. Anesthesiology 2000; 93:938–42.

SIMPLE OPEN BLADDER OPERATIONS

SURGICAL CONSIDERATIONS

Description

Open bladder operations commonly performed on children include **ureteral reimplantation** for correction of vesicoureteral reflux, obstructive megaureters, or ureterocele; **vesicostomy creation or closure (Blocksom)**; and **bladder neck reconstruction**.

Ureteral reimplantation

Vesicoureteral reflux (VUR) is one of the most common abnormalities of the urinary tract in children and is present in about 25–50% of children who get UTIs. Although VUR resolves spontaneously in many children, there are a number of indications for correction of VUR. These include high-grade VUR, progressive VUR and renal scarring, failure to resolve within several years, other bladder surgery, breakthrough UTIs, and poor medical compliance.

Ureteral reimplantations can be performed using different approaches to the bladder (e.g., extravesical, intravesical, or a combined approach); however, these different approaches require a similar exposure and abdominal incision. In general, these are extraperitoneal rather than intraperitoneal operations. Initially, cystoscopy may be performed to plan a potentially complex reimplantation (e.g., duplex systems, ectopia, or periureteral diverticula). A suprapubic (Pfannenstiel) incision (Fig. 12.6-2) is usually made, the fascia is opened (may either be muscle cutting or splitting incision; in the latter, the fascia may be opened vertically), and the bladder is exposed. Sufficient muscle relaxation is required to enable the surgeon to place a self-retaining retractor to expose the bladder. The anesthesiologist also may be asked to limit N_2O to decrease the amount of peritoneal contents bulging toward the bladder and surgical field. The bladder is then opened (intravesical approach), and the ureteral reimplantation(s) is

performed. Alternatively, the bladder is mobilized to expose the posterolateral ureter, which is then reimplanted (extravesical approach). When required, ureteral stents are placed in the bladder and removed cystoscopically 1 mo later. A Penrose drain may be left in place, which is either brought through the incision or through a separate skin puncture.

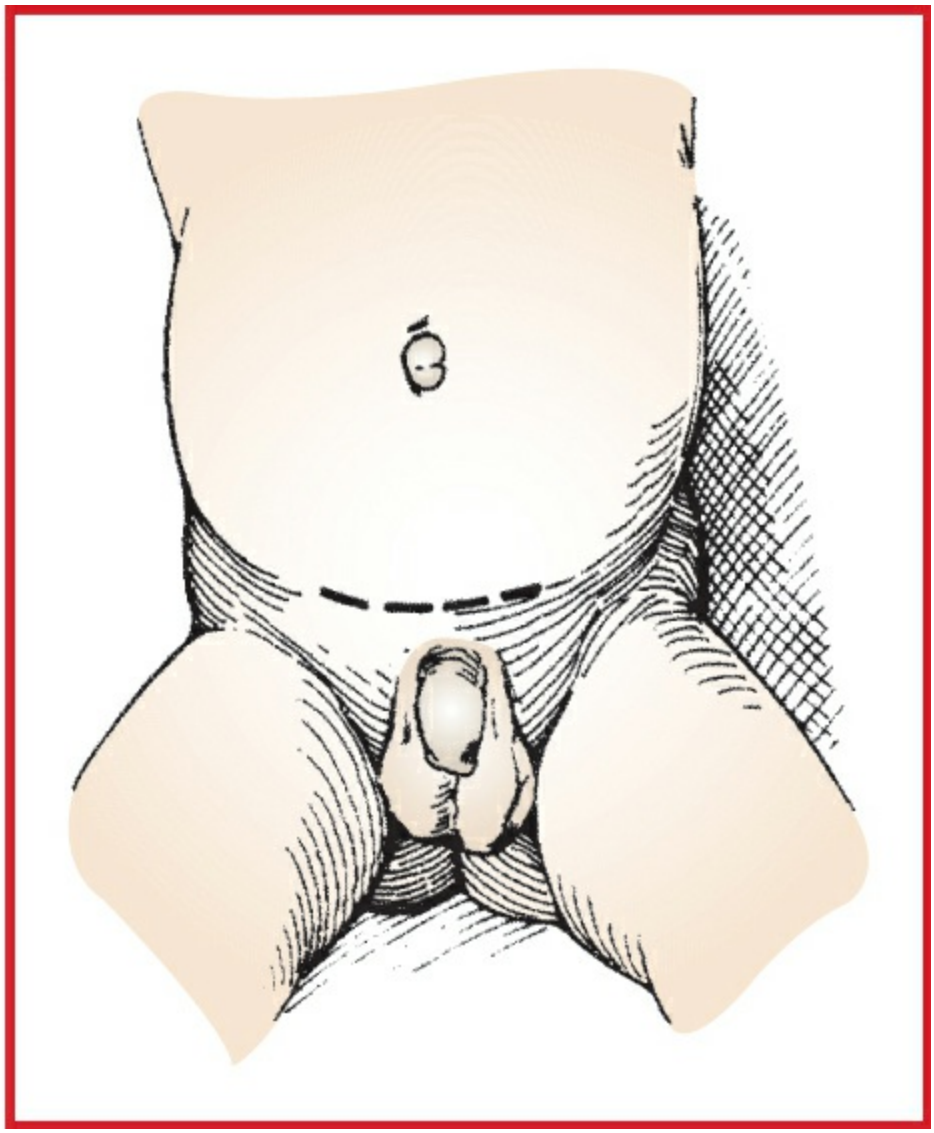

Figure 12.6-2 A Pfannenstiel incision in Langer lines is a low transverse incision that provides good access to the bladder and other pelvic organs and good cosmesis. (Reprinted from Hinman F:Atlas of Pediatric Urologic Surgery, 2nd edition. WB Saunders, Philadelphia: 2009. Copyright © 2009 Elsevier. With permission.)

Obstructive megaureters and ureteroceles are other conditions that may require ureteral reimplantation. The abdominal exposure and indications do not differ significantly from ureteral reimplantation for VUR; however, tailoring of the ureter by reducing its caliber by excising redundant tissue or plication may be necessary. Reconstruction of the bladder neck also may be required if an ureterocele extends distally through the bladder

outlet.

Regional anesthesia techniques—specifically caudal or epidural analgesia—have gained popularity for these procedures. They have been shown to decrease postoperative pain medication requirements. However, as the patient usually leaves the hospital within 48 h, long-term epidural or caudal anesthesia is usually not required. As there may be increased risk of urinary retention following neuraxial anesthesia, a urethral catheter is usually left in place postoperatively. The diagnosis of urinary retention may be difficult to make following bladder surgery, and catheterization trauma may occur. However, an indwelling catheter may cause increased discomfort from bladder spasms and irritation. Intravesical lidocaine gel may alleviate some bladder irritation, though oral oxybutynin and Pyridium may be considered as well. Without a catheter, children usually void spontaneously within 6–9 h after surgery. For these reasons, the surgeon's preference on whether an indwelling urethral catheter will be left at the conclusion of the procedure should be elicited at the beginning of the case and considered in the selection of a regional block.

Usual preop diagnosis

VUR; obstructive megaureter; ureterocele

Vesicostomy

Infants and very young children may require reliable bladder drainage and decompression until definitive bladder or urethral surgery (e.g., spina bifida failing intermittent catheterization). A vesicostomy accomplishes this by allowing urine to flow continuously from a small, lower abdominal vesicocutaneous fistula. In this procedure, the patient is placed supine, and a 2-cm transverse incision is made halfway between the umbilicus and the pubis, and the bladder is dissected extraperitoneally to expose the dome. The bladder is opened at the dome (urachus) and is anastomosed to the abdominal skin with absorbable sutures, creating a small fistula. Closure of a vesicostomy is likewise done in a supine position and involves excision of the fistula tract and subsequent closure of the bladder and skin.

Usual preop diagnosis

Posterior urethral valves; severe VUR; neurovesicular dysfunction (as seen in spina bifida); prune belly syndrome

Bladder neck operations

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options.

See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Reimplantation	Vesicostomy
Position	Supine	⇐
Incision	Pfannenstiel or low midline extraperitoneal	⇐
Unique considerations	None	⇐
Antibiotics	1st- or 2nd-generation cephalosporin; aminoglycoside + clindamycin	⇐
Surgical time	1.5 h	45 min
EBL	Minimal	⇐
Postop care	PACU; ± urethral catheter ± stents. Anticholinergics for bladder spasms. Older children may benefit from epidural anesthesia.	PACU; ± vesicostomy catheter
Mortality	<1%	⇐
Morbidity	Infection: <3%	⇐
	Bleeding: <3%	⇐
	Urinary retention: Unilateral: <5% Bilateral: 8–10%	—
	Ureteral obstruction	
	Persistent reflux	
Pain score	7	4

PATIENT POPULATION CHARACTERISTICS

Age range	1 mo–teenage	⇐
Male:Female	1:4	1:1
Incidence	1%	⇐

Etiology	Unknown	Congenital
Associated conditions	UTI; renal failure	⇐

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Transurethral Procedures, Open Bladder Procedures Penile Surgery, and Genital Procedures.

Suggested Readings

1. Hinman's Atlas of Pediatric Urologic Surgery, 2nd edition. Elsevier/Saunders, Philadelphia: 2009.
2. Khoury AE, Bägli DJ: Vesicoureteral reflux. In:Campbell-Walsh Urology, 11th edition. Elsevier, Philadelphia: 2016, 3134–72.e7.
3. Merguerian PA, Sulters PA, Tang E, et al: Efficacy of continuous epidural analgesia versus single dose caudal analgesia in children after intravesical ureteroneocystostomy. J Urol 2004; 172(4 pt 2):1621–5.

COMPLEX OPEN BLADDER OPERATIONS

SURGICAL CONSIDERATIONS

Description

A variety of pathologies may be associated with a need for complex bladder reconstruction or augmentation. These include conditions associated with severe congenital malformations, such as epispadias and bladder exstrophy, and those associated with neurogenic bladder, such as spina bifida, cerebral palsy, and spinal cord injury. In regard to severe congenital malformations, these often require multiple-staged procedures with the ultimate goal being a continent bladder of adequate capacity. Specific procedures are highly patient dependent and may involve work on the bladder neck, urethra, and ureters. In regard to neurogenic bladders, a main concern is the failure of bladder storage and/or compliance, leading to urinary incontinence, high voiding pressures, and upper tract deterioration. In these cases and also when infectious or fibrotic processes have caused a reduction in bladder capacity, the patient may be a candidate for **bladder augmentation** with the native intestine, colon, stomach, or ureter (in the case of significant ureteral dilation). A **continent catheterizable stoma** may be performed at the same time due to the frequent need for catheterization subsequent to the procedure. Patients with limited mobility who require urethral catheterization can also

opt for the placement of a continent catheterizable stoma using the appendix or ileum. This may be done as a separate procedure with or without augmentation. In both groups, patients have often had many operations, and the operative team needs to consider possible latex sensitivity (see Appendix G: Special Considerations for Latex Allergy, p. G-1).

In some cases of severe malformations that cannot be corrected or severe urinary incontinence, bladder augmentation and stoma formation are combined with closure of the bladder neck or insertion of an **artificial urethral sphincter**.

Patients with neurogenic bowel may become dehydrated more easily during bowel preparation prior to surgery. Although traditionally mechanical and antibiotic bowel preparation for 1–2 d prior to surgery was recommended, growing evidence in the general surgery literature suggests that bowel preparation does not reduce wound infections or anastomotic leaks and may actually increase ileus rates. Ultimately, the use of bowel preparation is surgeon dependent. Anesthesiologists should be aware of the length and extent of preop bowel preparation in case the patient has become dehydrated or suffered electrolyte imbalances due to this process. Special consideration should be made for patients who have ventriculoperitoneal (VP) shunts. Typically care is made to sequester the shunt in sterile fashion, keeping it away from any spillage from bowel segments.

Bladder neck reconstruction

These procedures usually are required in patients with severe anomalies, such as exstrophy, or severe incontinence due to an incompetent bladder neck. These are complex procedures, with dissection often difficult. The approach to the bladder is similar to that of ureteral reimplantation, using a lower abdominal (Pfannenstiel) incision (Fig. 12.6-2). The space of Retzius is dissected bluntly and the anterior bladder wall and pubic bone are exposed. The bladder is opened and the bladder neck dissected and reconstructed. Various techniques to tubularize the anterior bladder wall, elongate the urethra, and increase outlet resistance may be used. Bilateral ureteral reimplantation and bladder neck suspension can be performed at the same time. These procedures are variable in length but tend to be quite long given their complexity and may require more than 4 h to complete. One special consideration is latex allergy (see Appendix G).

Usual preop diagnosis

Exstrophy/epispadias complex; spina bifida; neurogenic bladder; incontinence; bladder neck malformation

Bladder augmentation

Bladder augmentation is usually performed on children with a small capacity bladder, resulting from congenital abnormalities or fibrosis with poor compliance. Cystoscopy may or may not be performed at the same time. The patient is usually in supine position, and the operation may be performed through a lower midline due to the need to harvest a bowel segment. If laparoscopic bowel harvest is planned, then a Pfannenstiel incision can be used for the augmentation. The bowel and bladder are mobilized, with wide intraperitoneal exposure, leading to potentially large insensible losses in children. The relevant bowel segment is harvested, and the remaining native bowel is reanastomosed across the defect in the standard stapled or hand-sewn fashion. The "patch" of bowel segment is then sewn onto the bladder using running absorbable suture to minimize risk of future bladder calculi. At the end of the procedure, a suprapubic tube is placed to decompress the bladder and allow irrigation of mucus produced by the bowel segments. In the past, nasogastric decompression was maintained until return of bowel function. Some surgeons will ask for the tube to be removed at the end of the procedure. Perioperative antibiotics are usually continued for a minimum of 3 d.

As a special consideration, with larger numbers of patients undergoing bladder augmentation, perforation is not uncommon. Extraperitoneal bladder perforation of a normal bladder may be managed with drainage alone, but perforation of an augmented bladder is almost always managed operatively because the perforation is considered to be intraperitoneal and involves a higher risk of subsequent infection or abscess.

Usual preop diagnosis

Spinal cord injury, spina bifida, exstrophy, cerebral palsy; urinary incontinence; bladder tuberculosis, schistosomiasis, interstitial cystitis

Continent catheterizable stoma (Mitrofanoff appendicovesicostomy or Monti tube)

In the case of a child who needs lifetime catheterization, a continent catheterizable abdominal stoma is often preferred due to its greater ease of catheterization, particularly for children with motor impairment. Use of the appendix as a flap-valve conduit between the bladder and the abdominal wall was first described by Mitrofanoff in 1980. Operative setup is similar to that of a bladder augmentation. After amputation of the appendix, the base is brought through the abdominal wall to form a stoma at the umbilicus. The tip of the appendix is amputated to create a tube, and a small submucosal trough is made in the posterolateral bladder. An indwelling catheter is placed in the channel to maintain patency immediately postoperatively. Other catheterizable continent stomas may be constructed from short segments of the reconfigured ileum (Monti).

Usual preop diagnosis

Spina bifida, spinal cord injury, or cerebral palsy with neurogenic bladder; urinary retention or urinary incontinence, limited mobility

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Bladder Augmentation	Continent Catheterizable Stoma	Bladder Neck Reconstruction
Position	Supine	⇐	⇐
Incision	Lower midline incision, intraperitoneal	⇐	Pfannenstiel or low midline, extraperitoneal
Special instrumentation	Catheter in bladder/suprapubic tube, possibly NG tube	Catheter in bladder/suprapubic tube, possibly NG tube, catheter in stoma	Dependent on procedure
Unique considerations	Spina bifida pts may have latex allergy.	Pts with chronic catheterization may have infected urine; treat with preop antibacterial irrigation and culture-specific antibiotics.	Spina bifida pts may have latex allergy.
Antibiotics	2nd- or 3rd-generation cephalosporin; aminoglycoside + clindamycin	⇐	Cefazolin 30 mg/kg q4h; aminoglycoside + clindamycin
Surgical time	3.5 h	4.5 h (with augmentation) or 1.5 h (without	2 h

		augmentation)	
EBL	100 mL	⇐	200 mL
Postop care	PACU → ward	⇐	⇐
Mortality	<1%	⇐	⇐
Morbidity	Electrolyte abnormalities, growth retardation (>50%) Bladder calculi (10–50%) Rupture of augmented bladder (5–10%) Small bowel obstruction (3%) Bladder cancer (1%)	Stomal stenosis (30–40%)	Infection: <3% Bleeding: <3% Urinary retention: <5%
Pain score	10	10	7

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Transurethral Procedures, Open Bladder Procedures Penile Surgery, and Genital Procedures.

Suggested Readings

1. Adams MC, Joseph DB, Thomas JC: Urinary tract reconstruction in children. In Campbell-Walsh Urology, 11th edition. Elsevier, Philadelphia: 2016, 3330–67.e10.
2. Gilbert SM, Hensle TW: Metabolic consequences and long-term complications o enterocystoplasty in children: a review. J Urol 2005; 173(4):1080–6.
3. Hinman F, Baskin LS: Introduction to catheterizable channels. In:Hinman's Atlas of Pediatric Urologic Surgery, 2nd edition. Elsevier/Saunders, Philadelphia: 2009, 471.

PENILE SURGERY

SURGICAL CONSIDERATIONS

Description

Pediatric penile operations usually correct congenital urethral abnormalities or involve circumcision. The most common surgical operation performed in the United States, **circumcision**, consists of the excision of the preputial skin to expose the glans. It can be performed for religious, ethnic, social, or medical reasons (e.g., phimosis or recurrent balanitis).

Circumcision

Freehand circumcision involves using two incisions to remove a sleeve of penile skin to fully expose the glans. Various clamps (Gomco, Mogen, etc.) can be used to circumcise in the newborn period. Most circumcisions performed in the operating room on older children or those with penile skin anomalies will be freehand excisions. Regarding analgesia, even in the neonate, a penile block is recommended for this procedure. In older children being circumcised, both caudal and penile blocks can offer a similar duration of anesthesia (4–8 h). However, school-aged children may be bothered more by leg numbness and inability to void from the caudal block.

Usual preop diagnosis

Phimosis, balanitis, family preference for circumcision

Hypospadias

Hypospadias is an abnormal opening of the urethral meatus, resulting from incomplete development of the urethra. The defect can be located anywhere from the corona of the glans to the perineum. Accordingly, surgical correction can require limited reconstruction as in the **meatal advancement glanuloplasty (MAGPI)** procedure or extensive dissection and reconstruction requiring 3–4 h of surgery. Although most pediatric urologists perform a one-stage reconstruction for the majority of hypospadias, some more extensive cases may require a two-staged repair. Options for single-staged repairs include a **tubularized incised plate (TIP)**, an **onlay flap** using the preputial skin, and rarely an **onlay graft** using harvested tissue from another location. An artificial erection is obtained by infusion of normal saline into the corpora to judge need for and adequacy of repair. This may cause significant fluid absorption in a small child.

The surgeon may choose not to use a urethral catheter in distal hypospadias repairs and some midshaft repairs. In such cases, caudal anesthesia should be avoided due to risk of urinary retention and risks of surgical complications relating to the need for postoperative catheterization. A **penile nerve block** may be helpful in such cases, with care given to avoid a penile hematoma, disruption of penile anatomy, or disruption of blood flow to the dorsal penis. Should a penile nerve block be performed, the use of

1% lidocaine with 1:100,000 epinephrine is done at the discretion of the surgeon. In all cases, postoperative urethral instrumentation should be avoided, as catheterization of the newly formed urethra could disrupt the repair. Catheters, when placed, are usually secured by stitching to the glans penis. Often at the conclusion of the surgery, the surgeon may require an additional 3–5 min of anesthesia to properly apply dressings to protect the hypospadias repair.

If repair of postop fistulae or other complication is done, buccal mucosa may be needed to create a new urethra, which would require access to the patient's mouth for harvesting of the buccal mucosa.

Of special concern to anesthesiologists, an association between use of caudal blocks and hypospadias repair complications (i.e., fistula formation) has been described. Several series have documented this association, but did not control for the severity of the hypospadias itself, which is known to be an independent risk factor for complications. Indeed, the only retrospective study controlling for this found that only hypospadias severity, and not the type of anesthetic block, was a risk factor for complications after repair. It is possible that caudal blocks are utilized more frequently in more complex repairs, as operative times are longer, most patients are left with a urethral catheter, and more pain is anticipated. Further, the biologic mechanism for how a caudal block would impact hypospadias complications remains unclear. While awaiting further well-designed prospective RCT studies to clarify the causality of the observed association in the retrospective studies, we continue to believe that caudal blocks are appropriate for hypospadias repairs.

Usual preop diagnosis

Hypospadias ± chordee; fistula repair; epispadias repair; penile torsion; concealed penis

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Circumcision	Hypospadias
Position	Supine	⇐
Incision	Circumferential penile	⇐ + ventral penis

Special instrumentation	None	Optical magnification, possibly microscope
Unique considerations	1% lidocaine ±1:100,000 epinephrine for hemostasis	Tourniquet; injectable NS for artificial erection; 1% lidocaine ± 1:100,000 epinephrine. If a catheter is placed, liberal iv fluids may be given.
Antibiotics	None	Surgeon dependent
Surgical time	30 min	1.5–4 h
EBL	Minimal	<50 mL
Postop care	Outpatient	Outpatient or ward ± urethral catheter
Mortality	<1%	⇐
Morbidity	Infection: 2%	⇐
	Hematoma: 2%	⇐
		Urethrocutaneous fistula (5–20%), urethral stricture, urethral diverticulum
Pain score	2	5

PATIENT POPULATION CHARACTERISTICS		
Age range	Neonates–children	>4 mo
Incidence	61%	1:300
Etiology	Acquired	Congenital
Associated conditions	Infection	Cryptorchidism; inguinal hernia; bifid scrotum

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Transurethral Procedures, Open Bladder Procedures Penile Surgery, and Genital Procedures.

Suggested Readings

1. Braga LH, Jegatheeswaran K, McGrath M, et al: Cause and effect versus confoundin

—is there a true association between caudal blocks and tubularized incised plate repair complications? J Urol 2017; 197(3):845–51.
2. Efe E, Resim S, Bulut BB, et al: Successful treatment with enoxaparin of glan ischemia due to local anesthesia after circumcision. Pediatrics 2013; 13(2):e608–11.
3. Hinman F, Baskin LS: Introduction to hypospadias repair. In:Hinman's Atlas of Pediatric Urologic Surgery, 2nd edition. Elsevier/Saunders, Philadelphia: 2009, 653–61.
4. Polaner DM, Almenrader N, Vemulakonda V: Caudal analgesia, hypospadias, and urethrocutaneous fistula: does association mean causality? Paediatr Anaesth 2017; 27(7):676–7.
5. Snodgrass WT, Bush NC: Hypospadias. In:Campbell-Walsh Urology, 11th edition. Elsevier, Philadelphia: 2016, 3399–429.e2.
6. Taicher BM, Rauth JS, Eck JB, et al: The association between caudal anesthesia and increased risk of postoperative surgical complications in boys undergoing hypospadias repair. Paediatr Anaesth 2017; 27(7):688–94.
7. Weksler N, Atias I, Klein M, et al: Is penile block better than caudal epidural block for post-circumcision analgesia? J Anesth 2005; 19(1):36–9.

GENITAL PROCEDURES (CLITOROPLASTY, VAGINOPLASTY, URETHROPLASTY)

SURGICAL CONSIDERATIONS

Description

Masses of the introitus include urethral prolapse, prolapsed ectopic ureterocele, and rhabdomyosarcoma. Genitoplasty is usually performed in female patients with abnormal genitalia, such as ambiguous genitalia resulting from abnormal steroidogenesis (congenital adrenal hyperplasia [CAH], danazol exposure), a urogenital sinus, or cloacal anomalies.

Urethral prolapse repair

With the patient in lithotomy position, a simple circumferential incision is made at the junction between the prolapsed mucosa and the urethral meatus. The prolapsed tissue is excised, and an end-to-end anastomosis is performed with absorbable suture. Introital rhabdomyosarcoma often requires open or transurethral biopsy of the mass and is subsequently treated with chemotherapy in most cases.

Usual preop diagnosis

Urethral prolapse, urethral mass (e.g., introital rhabdomyosarcoma)

Vaginoplasty/clitoroplasty

These procedures are performed in patients with ambiguous genitalia and are usually associated with hormonal imbalance (CAH). In the past, this surgery was performed urgently in neonates for gender assignment reasons. However, there is controversy regarding the medical necessity for early surgery versus waiting for puberty to allow the child to decide. It is imperative that stress dose mineralocorticoid and glucocorticoid (steroid) replacement is given prior to the start of any procedure. The initial procedure usually requires reduction of the enlarged clitoris and reconstruction of the labioscrotal folds. With the patient in a lithotomy position, skin incisions are made to allow partial resection of the corporal bodies and glans with nerve sparing. Periclitoral skin flaps are used to reconstruct the clitoris and labial folds. Vaginoplasty is performed through a perineal approach by creating an urethrovaginal septum. The vagina usually can be pulled into its normal position between the urethra and rectum and anastomosed to perineal skin flaps using absorbable sutures. Vaginoplasty can be performed with clitoroplasty in an infant. If performed later in life (puberty), a vaginoplasty with complex flaps and bowel interposition is necessary. If a long, complicated intra-abdominal procedure is anticipated, an abdominoperineal approach is used. During some of these procedures, a loop of sigmoid colon or ileum is isolated, along with its mesentery, and is brought through the perineal incision. It is then anastomosed proximally to the vagina and distally to skin flaps. Additionally, these procedures may be used for **gender reassignment** if masculinization of the ambiguous genitalia in a genotypic male is not possible.

Usual preop diagnosis

Ambiguous genitalia; CAH; cloacal exstrophy; urogenital sinus persistence; danazol exposure

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Lithotomy
Incision	Perineal or abdominoperineal
Special instrumentation	Loupes (magnification)

Position	Lithotomy
Unique considerations	Steroid replacement may be necessary (CAH)
Antibiotics	1st- or 2nd-generation cephalosporin; aminoglycoside + clindamycin
Surgical time	2–4 h
EBL	10–15 mL
Postop care	± Urethral catheter
Mortality	<1%
Morbidity	Infection: <5% Bleeding: <5% Flap necrosis: <5%
Pain score	6

PATIENT POPULATION CHARACTERISTICS	
Age range	Clitoroplasty, 3–6 mo; vaginoplasty, puberty
Incidence	1:30,000 births (ambiguous genitalia)
Etiology	Congenital
Associated conditions	Hypothalamic-pituitary axis suppression; adrenal hyperplasia; steroid replacement therapy

Suggested Readings

1. Hinman F, Baskin LS: Vaginoplasty. In: Hinman's Atlas of Pediatric Urologic Surgery, 2nd edition. Elsevier/Saunders, Philadelphia: 2009, 807–14.
2. Rink RC: Surgical management of disorders of sex development and cloacal and anorectal malformations. In: Campbell-Walsh Urology, 11th edition. Elsevier, Philadelphia: 2016, 3498–520.e3.

ANESTHETIC CONSIDERATIONS FOR TRANSURETHRAL PROCEDURES, OPEN BLADDER PROCEDURES, PENILE SURGERY, AND GENITAL PROCEDURES

PREOPERATIVE

Typically, infants and children presenting for these procedures are otherwise healthy, with some notable exceptions. **Vesicoureteral reflux** may be associated with renal dysplasia and HTN. The**prune belly (Eagle-Barrett) syndrome** includes dystrophic abdominal musculature, requiring an evaluation of pulmonary function. **Bladder and cloacal exstrophy** may be accompanied by a spinal cord abnormality (e.g., tethered cord, spina bifida). Congenital cardiac anomalies may be present, and an evaluation should be performed prior to surgery.

Pediatric urology patients with lower urinary tract dysfunction and underlying neurologic disorders (e.g., myelomeningocele) and exstrophy are at risk for developing latex allergy as a result of repeated urethral catheterizations or surgical procedures.

Circumcision and hypospadias repair are most commonly performed in the first 2 yr of life in otherwise healthy children.

Respiratory	Prune belly syndrome: pulmonary function may be decreased. ✓ for Hx of respiratory compromise. Postop ventilatory support may be necessary. ✓ adequate reversal of NMB and force of cough. **Tests:** CXR; others as indicated from H&P
Renal	Renal anomalies may be present as part of a congenital malformation complex. **Tests:** As indicated from H&P
Endocrine	Surgeries for genital disorders usually are performed to reshape anatomic abnormalities 2° congenital endocrine disorders. Ambiguous genitalia are associated with congenital adrenal abnormalities. They are usually detected in the 1st mo of life and may lead to severe salt-losing crises with ↑ Na^+ and ↓ K^+. The electrolyte status of these patients must be evaluated in the preop period. Treatment consists of steroid replacement. **Tests:** Electrolytes; blood sugar
Premedication	If >7–9 mo of age, consider midazolam premedication (0.5 mg/kg) po or 0.1–0.2 mg/kg iv. Avoid long-lasting sedative medications.

ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Evaluate for concurrent disease, nutritional status, and hydration. Consider preop acetaminophen 10–15 mg/kg iv or po as an elixir.

INTRAOPERATIVE

Anesthetic technique

GA (ETT or LMA) using a pediatric circle. A combined technique with epidural or caudal anesthesia is often used. For small children, warm OR to 70°F–75°F. Use warming pad and/or forced air warming on OR table.

Induction	For patients <5–10 yr, standard mask induction with sevoflurane/N_2O/O_2. Older patients may agree to standard iv induction, facilitated by the use of topical local anesthetic cream or patch. For open-bladder and complex genital procedures, an indwelling epidural catheter for intraop and postop pain relief is recommended.
ERAS	Verify preincision antibiotics. Assess volume status. Discuss with surgeon local wound infiltration at conclusion of procedure. Consider iv acetaminophen (10 mg/kg for patients <1 yr old or 15 mg/kg for older patients with maximum dose of 650 mg). Consider PONV prophylaxis with iv ondansetron (0.1 mg/kg) Maintain normovolemia and normothermia.
Maintenance	Standard pediatric maintenance. With epidural anesthesia, volatile and/or iv anesthetic requirements are reduced.
Emergence	Typically, no special considerations. Carefully evaluate patient for adequate ventilation prior to extubation in those with prune belly syndrome. Discuss with surgeon local wound infiltration. PONV prophylaxis should include dexamethasone (e.g., 30 mcg/kg) and ondansetron (0.1 mg/kg up to 4 mg iv).

Blood and fluid requirements	Minimal blood loss IV: 22 or 24 ga × 1 BSS @ (maintenance): 4 mL/kg/h (1–10 kg) +2 mL/kg/h (11–20 kg) +1 mL/kg/h (>20 kg)	Complex cases may be associated with significant blood loss and require transfusion with whole blood or PRBC. See Zero Balance Fluid Management, Appendix K, p. K-2.
Monitoring	Standard monitors ± Arterial line	Place arterial line for measurement of arterial gases or to ✓ Hct and blood glucose if significant blood loss or long case is anticipated, in patients with concurrent renal dysfunction.
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Nerve damage	In lower extremities, ✓ if padding is insufficient with lithotomy position.

POSTOPERATIVE

Complications	Prune belly: hypoventilation Adrenogenital syndrome: adrenal insufficiency	Assisted ventilation may be required.
Multimodal pain management	Acetaminophen Epidural or PCA analgesia IV opioids	Use nonopioid analgesics. Back up with bolus opioid analgesics. Ditropan or ketorolac will ↓ bladder spasm. Ketorolac → renal insufficiency. Do not use if renal function is abnormal.
ERAS	PONV protocol (see p. D-1)	Encourage early enteral nutrition, catheter removal,

and mobilization as appropriate.

Suggested Readings

1. Hammer G, Hall S, Davis PJ: Anesthesia for general abdominal, thoracic, urologic and bariatric surgery. In: Davis P, Cladis F, Motoyama EK, eds. Smith's Anesthesia for Infants and Children, 8th edition. Elsevier Mosby, Philadelphia: 2011, 778–82.
2. Hansen TG, Henneberg SW, Lerman J: General abdominal and urologic surgery. In Cote CJ, Lerman J, Anderson BJ, eds.A Practice of Anesthesia in Infants and Children, 6th edition. Elsevier, Inc., Philadelphia: 2018, 680–6.
3. Rove KO, Edney JC, Brockel MA: Enhanced recovery after surgery in children promising, evidence-based multidisciplinary care. Paediatr Anaesth 2018; 28(6):482–92.

INGUINOSCROTAL PROCEDURES

SURGICAL CONSIDERATIONS

Description

Undescended testis (cryptorchidism), hydrocele, and inguinal hernia are common in pediatric urology, and surgery is usually performed on an outpatient basis. Testicular torsion is one of the few true pediatric urologic emergencies because testicular infarction will occur within hours of the torsion. Testicular tumors in children, accounting for 1–2% of all pediatric solid tumors, are more frequently benign than those in adults and represent the main indication for **radical or simple orchiectomy** in children.

Orchiopexy

A nonpalpable testis may warrant diagnostic laparoscopy as the initial procedure, with subsequent laparoscopic or open abdominal orchiopexy versus orchiectomy if the testicle is found to be intra-abdominal (detailed under Laparoscopic and Robotic Procedures). 20% of nonpalpable testes become palpable after induction of anesthesia. Orchiopexy for a palpable undescended testis is performed through a small inguinal incision. Here, the external oblique fascia is opened, exposing the inguinal canal. The testis is localized, and the cord is dissected to gain adequate length for scrotal fixation, without torsion or tension. If the testicle is high and adequate inguinal mobilization is not possible, dissection into the retroperitoneum may be required. The scrotal pouch is created by making a skin incision two-thirds the way down the scrotum and then by

blunt dissection between the skin and dartos muscle. The testis is fixed into this pouch with suture.

Both ilioinguinal nerve block and caudal analgesia appear to be equally effective in management of postorchiopexy pain, but parents should be counseled on the risk of postoperative urinary retention with a caudal block. When a preoperative inguinal block is considered, this should be discussed with the surgeon. Alternatively, the block may be performed at the end of the procedure or the wound irrigated with 0.25% bupivacaine. The total dose of bupivacaine to be used for irrigation should be discussed with the anesthesiologist and should not exceed 3 mg/kg. Both of the above methods provide excellent postoperative analgesia and facilitate early discharge from the surgical recovery unit.

Usual preop diagnosis

Cryptorchidism; nonpalpable testis

Testicular torsion

Testicular torsion is a pediatric urologic emergency. There is no definitive diagnostic imaging study and the diagnosis is primarily clinical, although ultrasound with Doppler scans of the testis can be useful. At times, symptoms of testicular torsion may be indistinguishable from epididymitis or torsion of the testicular appendages (embryonic remnants). Once in the operating room, the testis is delivered through a scrotal incision, examined, detorsed, and assessed for viability. If the testis is nonviable, a **simple scrotal orchiectomy** is performed. If the testicle is viable, it is fixed in a **scrotal dartos pouch**, often using a three-point suture fixation. The contralateral testis is fixed in a similar fashion, usually through a second scrotal incision. A torsion of a testicular appendage usually is treated medically with pain control and anti-inflammatory agents. If this condition is discovered at surgical exploration, the diseased tissue is excised, the testis is reinserted into the scrotum, and the wound is closed. It should be noted that neonatal (antenatal) or perinatal torsion may require an orchiopexy in the newborn period. If the diagnosis is unclear, if there is concern for a testicular mass, and/or if there is an associated hydrocele or hernia, this operation may be performed through an inguinal incision.

Usual preop diagnosis

Testicular torsion; torsion of the testicular appendage

Hydrocelectomy–inguinal hernia repair

This procedure is performed through an inguinal incision, with subsequent dissection of the inguinal canal. The patent processus vaginalis is carefully dissected from the cord

structures, the peritoneal sac is ligated at the level of the internal inguinal ring, and the wound is closed after evacuation of the hydrocele liquid. (Also see Repair of Inguinal and Umbilical Hernias, Hydrocele.)

Usual preop diagnosis

Hydrocele; inguinal hernia

Radical orchiectomy

Although simple orchiectomy is performed through a scrotal incision, radical orchiectomy (used when testicular cancer is suspected) is performed through an inguinal incision. The external oblique fascia is opened, and the spermatic cord is isolated and clamped at the level of the internal ring. The testis is delivered through the incision and examined. If the testis is felt to contain malignancy, the cord is ligated and divided at the level of the internal inguinal ring. If there is uncertainty in the diagnosis, a biopsy can be performed.

Usual preop diagnosis

Testicular mass

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Hydrocelectomy, Hernia Repair	Orchiopexy, Orchiectomy
Position	Supine	⇐
Incision	Inguinal/scrotal	⇐ + Can be extended to reach retroperitoneum ± laparoscopic exploration
Antibiotics	None	⇐
Surgical time	1 h	⇐
EBL	Minimal	⇐
Postop care	PACU → home	⇐
Mortality	<1%	⇐

Morbidity	Infection: 1–2% Recurrence: 1%	Testicular atrophy: 7%
Pain score	5	5

PATIENT POPULATION CHARACTERISTICS		
Age range	1 yr–puberty	Cryptorchidism: 1–2 yr Torsion: 0–18 yr
Incidence	1–4%	Cryptorchidism: 3% Torsion: 1:4000
Etiology	Congenital	⇐

Suggested Readings

1. Barthold JS, Hagerty JA: Etiology, diagnosis, and management of the undescended testis. In: Campbell-Walsh Urology, 11th edition. Elsevier, Philadelphia: 2016, 3430–52.e9.
2. Hinman F, Baskin LS: Reduction of testicular torsion. In: Hinman's Atlas of Pediatric Urologic Surgery, 2nd edition. Elsevier/Saunders, Philadelphia: 2009, 619–623.
3. Hinman F, Baskin LS: Inguinal hernia repair. In: Hinman's Atlas of Pediatric Urologic Surgery, 2nd edition. Elsevier/Saunders, Philadelphia: 2009, 629–633.

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Orchiopexy, orchiectomy, hydrocelectomy, and hernia repair are performed most commonly in otherwise healthy children.

Renal	With phimosis, there may be Hx of UTIs. Possible pyelonephritis. Hematuria requires GU workup. **Tests:** UA; renal function (BUN, Cr), as clinically indicated
Laboratory	Hct; others as indicated from H&P
Premedication	If >7–9 mo of age, consider midazolam (0.5 mg/kg po) before induction. Avoid long-lasting sedative medications.
ERAS	Check compliance with presurgical ERAS

	recommendations (see above) including NPO status. Evaluate for concurrent disease, nutritional status, and hydration. Consider preop acetaminophen 10–15 mg/kg iv or po as an elixir.

INTRAOPERATIVE

Anesthetic technique

GETA or LMA/mask anesthetic, using a pediatric circle (consider using humidified and warmed gases for infants). A combined technique with caudal anesthesia often is used for nonendoscopic procedures. For small children, warm OR to 70°F–75°F. Use warming pad and/or forced-air warming on OR table.

Induction	In younger patients, mask induction is customary before iv placement. If the surgical procedure will be >30 min, tracheal intubation or LMA is preferred. Intermediate-acting NMR (e.g., rocuronium, 0.6 mg/kg iv) is administered to facilitate tracheal intubation. If appropriate, caudal anesthesia can be obtained using ropivacaine 0.2% and bupivacaine 0.125 or 0.25% ± epinephrine 1: 200,000, 1 mL/kg up to 10 mL total. Test dose of 0.1 mL/kg for maximum of 3 mL should be given after a negative aspiration through the catheter or needle. If a catheter is used, and additional 0.8 mL should be injected to account for the dead space of the catheter. A positive test dose, in contrast to adults epidural test dose, could be indicated by an increase in HR, a decrease in HR, a decrease in BP, or ST-T wave changes. The caudal local anesthetic dose should be fractionated with frequent aspirations. The addition of clonidine (1–2 mcg/kg) to the caudal block intensifies and prolongs the analgesia, with minimal sedation. Acetaminophen 30–40 mg/kg PR or 10 mg/kg iv over 30 min may be given following intubation.
ERAS	Verify preincision antibiotics. Assess volume status. Discuss with surgeon local wound infiltration at conclusion of procedure. Consider iv acetaminophen (10 mg/kg for patients <1 yr

	old or 15 mg/kg for older patients with maximum dose of 650 mg). Consider PONV prophylaxis with iv ondansetron (0.1 mg/kg). Maintain normovolemia and normothermia.	
Maintenance	Standard pediatric maintenance. If no regional block is performed, at least 2 MAC anesthesia is required prior to skin incision to prevent laryngospasm in nonintubated patients. Caudal anesthesia can be used to provide the majority of analgesia in nonendoscopic procedures.	
Emergence	If neuromuscular blockade is used, reverse with neostigmine (0.07 mg/kg iv) and atropine (0.02 mg/kg iv) or glycopyrrolate (0.01 mg/kg iv). Extubate when patient is fully awake or deep. Discuss with surgeon local wound infiltration. PONV prophylaxis should include dexamethasone (e.g., 30 mcg/kg) and ondansetron (0.1 mg/kg up to 4 mg iv).	
Blood and fluid requirements	Negligible blood loss IV: 20–22 ga × 1 BSS @ maintenance	Pediatric maintenance: 4 mL/kg/h (0–10 kg) +2 mL/kg/h (11–20 kg) +1 mL/kg/h (>20 kg) See Zero Balance Fluid Management, Appendix K, p. K-2.
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes	Ocular compression/corneal abrasion may occur with oversized mask.
Complications	Laryngospasm	Rx: 100% O_2, jaw thrust, positive pressure. If iv is present, first deepen the level of anesthesia with propofol. If necessary, administer succinylcholine (1–2 mg/kg iv) in addition to atropine (0.02 mg/kg iv). If no iv, give succinylcholine 3 mg/kg im and atropine 0.02 mg/kg im.

	Intravascular local anesthetic administration	Epinephrine in caudal anesthetic (to detect intravascular administration) does not significantly prolong analgesia.

POSTOPERATIVE

Complications	Bleeding	
Multimodal pain management	Caudal or regional block Acetaminophen (10–20 mg po/iv and 10 mg q6h prn; alternatively 30–40 mg pr on first dose, followed by 20 mg pr q6h prn)	Optimal analgesia and presence of parents in PACU will minimize child's agitation/movement/crying. Use nonopioid analgesics. Back up with bolus opioid analgesics.
ERAS	PONV protocol (see p. D-1)	Encourage early enteral nutrition, catheter removal, and mobilization as appropriate.

Suggested Readings

1. Barthold JS: Abnormalities of the testis and scrotum and their surgical management. In: Wein A, et al., eds. Campbell-Walsh Urology, 10th edition. Elsevier, Philadelphia: 2012, 3557–96.
2. Fernandes ML, Pires KC, Tiburcio MA, et al: Caudal bupivacaine supplemented with morphine or clonidine, or supplemented with morphine plus clonidine in children undergoing infra-umbilical urological and genital procedures: a prospective, randomized and double-blind study. J Anesth 2012; 26(2):213–8.
3. Jagannathan N, Sohn L, Sawardekar A, et al: Unilateral groin surgery in children will the addition of an ultrasound-guided ilioinguinal nerve block enhance the duration of analgesia of a single-shot caudal block? Paediatr Anaesth 2009; 19(9):892–8.
4. Polaner DM, Taenzer AH, Walker BJ, et al: Pediatric regional anesthesia network (PRAN): a multi-institutional study of the use and incidence of complications of pediatric regional anesthesia. Anesth Analg 2012; 115(6):1353–64.
5. Rove KO, Edney JC, Brockel MA: Enhanced recovery after surgery in children: promising, evidence-based multidisciplinary care. Paediatr Anaesth 2018;

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5. Tobias JD: Caudal epidural block: a review of test dosing and recognition of systemic injection in children. Anesth Analg 2011; 93(5):1156–61.

LAPAROSCOPIC AND ROBOTIC PROCEDURES

SURGICAL CONSIDERATIONS

Description

Laparoscopy and robot-assisted laparoscopic techniques are used more frequently by pediatric urologists. Complexity and duration of procedures range from basic laparoscopy to locate an impalpable testis (**diagnostic laparoscopy** with subsequent **laparoscopic orchiopexy**) to robotic-assisted **partial nephrectomy** for a nonfunctional renal moiety. Additional procedures that have gained popularity using a minimally invasive approach include **nephrectomy, nephroureterectomy, adrenalectomy, pyeloplasty**, and **varicocelectomy**.

In both basic laparoscopy and robot-assisted laparoscopy, pneumoperitoneum is created by insufflating CO_2 (to a pressure of 12–16 mm Hg) either through the Veress needle technique or after trocar insertion in the peritoneal cavity through a small, 1-cm periumbilical incision under direct vision **(Hasson technique)**. Respiratory pressures on the ventilator must be watched closely, as insufflation can be released quickly should the need arise. Urine output should be monitored, as pneumoperitoneum may depress renal blood flow and function. Other trocars (sizes range from 2 to 15 mm) are then inserted as necessary, under direct laparoscopic vision whenever possible, avoiding abdominal wall vessels and internal organs. The specific placement of ports and patient position (typically supine or flank) is dependent on the procedure.

Advantages to the use of the robot include improved 3D visualization and instrument control compared to traditional laparoscopy. Though the data are limited, there is increasing evidence that robotic surgery may afford decreased postop pain, shorter hospital stays, and decreased blood loss. However, ~20–45 min of robot setup time should be calculated into the time under anesthesia. Additionally, issues with port placement, difficulty anatomy due to smaller patient size, and positioning of the robot itself all contribute to a highly variable operative time. It is important for there to be regular communication between the surgical and anesthesia teams about the expected duration, as this may change throughout the procedure. Adequate leg padding and securing of the patient to the bed during these procedures is of paramount importance,

for both ease of the surgery as well as patient safety during the procedure. A test roll of the table should occur prior to the start of the procedure to ensure the patient is secure. Once docked, the robot takes up a significant amount of space in the operating room and may make access to the patient during the case difficult. Lines should be checked and confirmed to be working well prior to the start of the procedure.

Diagnostic laparoscopy with potential orchiopexy or orchiectomy

Performed for an impalpable testis, if diagnostic laparoscopy reveals blind ending vessels, confirming the absence of a testis, the procedure is terminated relatively quickly, and no further incisions are made. **Large doses of paralytics should not be given until it is confirmed with the surgical team that the procedure will need to proceed beyond the initial diagnostic laparoscopy**. An inguinal testis remnant usually indicates either antenatal testicular ischemia or torsion. If the vessels are seen to enter the inguinal ring, laparoscopy is concluded and inguinal exploration is performed. If the testis is located intra-abdominally, it is evaluated for size and location to determine whether to proceed to **orchiectomy** versus a one- or two-stage (**Fowler Stevens**) **orchiopexy**. Laparoscopic orchiectomy or **gonadectomy** may be performed in intersex situations for a dysgenetic (streak) gonad, for a nonviable gonad, or for a gonad in which minimal cord length exists. If adequate cord length permits, laparoscopic ligation of the gonadal vessels is done, and the testis is placed into a scrotal pouch (**dartos pouch**) in one stage. If there is inadequate cord length, the gonadal vessels are still ligated, but the patient will require a future second-stage Fowler Stevens operation to bring the testicle into the scrotum once adequate collateral vasculature has been allowed to develop intra-abdominally. In other situations, **laparoscopic or open dissection** of testicular vessels on a peritoneal pedicle in the retroperitoneum may be performed. It should be noted that the robot is not typically used in this procedure.

Usual preop diagnosis

Nonpalpable testis; cryptorchidism

Varicocele ligation

Using a transperitoneal approach, identical to that of the approach for diagnostic laparoscopy, the spermatic veins are isolated from the abdominal wall and are ligated with metallic clips to reduce the varicocele. Use of a robot is typically not required for this procedure. The primary complications from this procedure are hydrocele and varicocele recurrence.

Usual preop diagnosis

Varicocele

Renal surgery (nephrectomy [including partial], nephroureterectomy, pyeloplasty)

Patients are typically placed in the lateral-decubitus position with the target kidney up, though partial lateral-decubitus, prone, or supine positioning may be used in some cases. Flexion of the operating table may be requested to help facilitate access to the kidney. Initial and subsequent port placement is variable but is performed using the aforementioned principles. If used, the robot will typically approach the side of the table the patient's back is facing (if in the lateral-decubitus position). For supine and prone cases, the robot will be at the foot of the bed. The approach to the kidney is typically transperitoneal, though purely retroperitoneal approaches have been described. After sufficient insufflation, mobilization of the colon is done (if required) and the kidney dissection is performed.

In a nephrectomy, the hilar vessels are ligated with metallic clips. The kidney is then retrieved through the 10-mm port by morcellating it or the incision can be dilated or elongated. Nephroureterectomy is performed in a similar manner, except that the ureter is dissected down to its insertion into the bladder where it is excised with a small cuff of bladder tissue. The resulting incision in the bladder is closed using two layers of suture. For partial nephrectomies, blood should be immediately available in these as there is a risk of significant blood loss. Blood loss is attempted to be minimized by clamping of the renal vessels but comes at the risk of renal ischemia and free radical–mediated tissue injury upon reperfusion. Administration of 20% intravenous mannitol around this time is often done to help scavenge free radicals, as ice slush cannot be used in a laparoscopic approach. Urine output should be watched closely and the patient resuscitated as needed. Once the affected area of the kidney is removed, it is placed in a bag and retrieved through the 10-mm port.

Prior to a pyeloplasty, some surgeons will place a ureteral stent at the start of the case, which may require the patient to start in lithotomy and later be repositioned. The stent assists with ureteral identification during the case. After initial entry, port placement, and kidney dissection, the pyeloplasty is carried out using the same principles as open pyeloplasty. This includes dismembering the ureter from the renal pelvis, spatulation of the ureter, and careful reassembly of the ureteropelvic unit. The patient is usually left with a ureteral stent at the end of the case. Whether surgery is performed intra- or extraperitoneal, laparoscopic/robotic surgery with CO_2 insufflation is associated with potentially significant systemic hemodynamic changes in children, as previously described.

Usual preop diagnosis

UPJ obstruction; infected or nonfunctioning kidney; HTN; multicystic or dysplastic kidney; protein-losing nephropathy in ESRD; renal mass

Vesicoureteral reimplantation

This procedure is typically done using robotic assistance. After initial cystoscopy to determine that there is adequate bladder size for a robotic procedure, the patient is placed in a supine position with legs splayed. This procedure may be performed intravesically but more commonly is done extravesically/intraperitoneal (**Lich-Gregoir**). In both cases, a urethral catheter and at times ureteral stent(s) are left in place postoperatively. If an extravesical approach is selected, the initial port is placed in the umbilicus and two robotic working ports are placed laterally. The robot is then docked, coming in from the direction of the patient's feet, and the patient is dropped into the Trendelenburg position, to improve exposure of the pelvic organs. The ureter is then dissected down to where it meets the bladder and a detrusorrhaphy is performed. If an intravesical approach is selected, an initial port is placed through a midline incision one-third of the way from the umbilicus to the pubis. The bladder is entered, and a balloon trocar is placed through a cystotomy into the bladder, followed by two robotic working ports. The ureteral reimplantation is then performed. Primary complications following robotic ureteral reimplant include urine leak, transient ureteral obstruction, and persistent reflux.

Usual preop diagnosis

Vesicoureteral reflux

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Undescended Testis/Varicocele	Renal Surgery	Ureteral Reimplant
Position	Supine; 15° Trendelenburg	Lateral decubitus	Supine, legs splayed, Trendelenburg
Incision	5–10-mm umbilical port + one or two additional ports	Four ports usually necessary	12-mm umbilical port and 5–8-mm working ports

			× 2
Special instrumentation	Bladder catheterization, NG tube	⇐	Cystoscopy, bladder catheterization
Unique considerations	Secure child firmly to avoid movement with table tilting. Intra-abdominal pressure = 14–16 mm Hg. Lower pressure may be needed if pulmonary mechanics are compromised. Urethral catheter commonly placed.	⇐	
Antibiotics	Cefazolin 30 mg/kg q4h	1st- or 2nd-generation cephalosporin; aminoglycoside + clindamycin	As necessary per preop urine culture
Surgical time	30 min–1 h	2.5 h (nephrectomy) to 4 h (pyeloplasty)	3–5 h
EBL	Minimal	⇐	⇐
Postop care	PACU → home	PACU → ward	PACU → ward
Mortality	<1%	⇐	⇐
Morbidity	Overall: 0.6–5%	⇐	⇐
	Trocar misplacement: bowel perforation	⇐	⇐
	Vascular/organ thermal injury from electrocautery	⇐	⇐
	CO_2 embolus	⇐	⇐

	Grounding pad thermal injury	⇐	⇐
	Trocar site bleeding, trocar hernia	⇐	⇐
	Varicocele only: recurrent varicocele (1–11%), hydrocele (1–5%)	Bleeding = 5%	Recurrent reflux, transient ureteral obstruction, urine leak
Pain score	2	4	4

PATIENT POPULATION CHARACTERISTICS	
Age range	10 mo–18 yr
Male:Female	Male (cryptorchidism)
Incidence	3% of newborn boys
Etiology	Congenital
Associated conditions	Renal insufficiency

Suggested Readings

1. Gundeti MS: Pediatric Robotic and Reconstructive Urology: A Comprehensive Guide. John Wiley & Sons, Chichester, UK: 2012.
2. Hinman F, Baskin LS: Laparoscopic techniques in children. In: Hinman's Atlas of Pediatric Urologic Surgery, 2nd edition. Elsevier/Saunders, Philadelphia: 2009, 71–2.
3. Hinman F, Baskin LS: Laparoscopic orchiopexy techniques. In: Hinman's Atlas of Pediatric Urologic Surgery, 2nd edition. Elsevier/Saunders, Philadelphia: 2009, 597–606.
4. Hinman F, Baskin LS: Laparoscopic varicocelectomy. In: Hinman's Atlas of Pediatric Urologic Surgery, 2nd edition. Elsevier/Saunders, Philadelphia: 2009, 649–50.

ANESTHETIC CONSIDERATIONS

(See also Anesthetic Considerations, p. 1528.)

During mask induction, care should be taken to avoid excessive positive pressure with consequent insufflation of the stomach. An OGT should be placed immediately after induction and intubation to remove air from the stomach, decreasing the risk of gastric puncture with placement of trocars and improving surgical view during procedure. Creation of a pneumoperitoneum as part of a laparoscopic procedure impairs ventilation and can restrict venous return. The use of Trendelenburg and lithotomy positions can further compromise respiratory function. Anesthetic considerations for pediatric patients undergoing laparoscopic procedures are further considered in Chapter 12.5. Severely limited patient access in robotic-assisted surgery makes it difficult to respond to the patient. A practice trial maneuvering the cumbersome robotic equipment should be performed to ensure rapid access to the patient in case of emergency. Care should be taken not to move the operating room table after the robotic arm/instruments are placed to avoid patient injury.

Suggested Readings

1. Carr MC, Casale P: Anomalies and surgery of the ureter in children. In: Wein A, et al., eds. Campbell-Walsh Urology, 10th edition. Elsevier Saunders, Philadelphia: 2012, 3212–35.
2. Mariano ER, Furukawa L, Woo RK, et al: Anesthetic concerns for robot-assisted laparoscopy in an infant. Anesth Analg 2004; 9(6):1665–7.
3. Peters CA: Robotically assisted surgery in pediatric urology. Urol Clin N Am 2007; 31(4):743–52.
4. Sweeney DD, Smaldone MC, Docimio SG: Minimally invasive surgery for urologic disease in children. Nat Clin Pract Urol 2007; 4(1):26–38.

CHAPTER 12.7

Pediatric Orthopedic Surgery

SURGEONS

Amy L. Ladd, MD
Matthew B. Burn, MD
James G. Gamble, MD, PhD

ANESTHESIOLOGISTS

Genevieve D'Souza, MD
Brenda Golianu, MD
Radhamangalam J. Ramamurthi, MD, FRCA

PERCUTANEOUS PINNING OF DISPLACED SUPRACONDYLAR HUMERUS FRACTURE

SURGICAL CONSIDERATIONS

Description

Supracondylar fractures of the **distal humerus** are the most common elbow fractures in children and the most common pediatric fractures requiring reduction under general anesthesia (GA). They have a justifiable reputation for complications because of the close proximity to neurovascular structures with a reported incidence of 2–11% for brachial artery injury and 12–20% for nerve injury (anterior interosseous branch of the median nerve, ulnar nerve, or radial nerve palsies). The most serious potential complication is a compartment syndrome of the forearm, which **requires emergent surgery** for reduction and fasciotomy.

The vast majority of these injuries result from falling on an outstretched arm (FOOSH) with the elbow **extended**—an extremely common childhood event. The Gartland

classification is used to guide treatment with type 1 fractures being minimally displaced and usually stable. They can be managed with a splint alone. Most supracondylar fractures are either type 2, **partially displaced**, or type 3, completely displaced fractures, and require GA for **closed reduction and percutaneous pinning (CRPP)**. They can also be classified based on the direction of displacement of the distal fragment into flexion and extension types. Extension-type supracondylar fractures are significantly more common, but flexion-type fractures are more likely to require open reduction.

Documentation of the neurovascular examination is mandatory upon initial evaluation, immediately before anesthesia and upon awakening postop. When a patient presents to the emergency department, if the neurovascular status is normal, and if the patient has eaten recently, it may be safe to wait for 6–12 h with continued monitoring of the neurovascular status. Reduction is obtained by a combination of traction and manipulation. Complete muscular relaxation is essential during the reduction maneuver. Usually, two 0.062-inch smooth Kirschner wires are inserted across the fracture site using intraoperative fluoroscopy. Many surgeons prefer to use the intensifier screen as a platform, thus requiring the patient to be at the edge of the OR table. Occasionally, the fracture cannot be reduced closed, and an open reduction is necessary. In that case, the arm is reprepped, and an incision is made to openly visualize and reduce the fracture. The same type of smooth pin fixation is then used (Fig. 12.7-1). Following the pinning, either a splint or well-padded bivalve cast is applied before the patient is awakened.

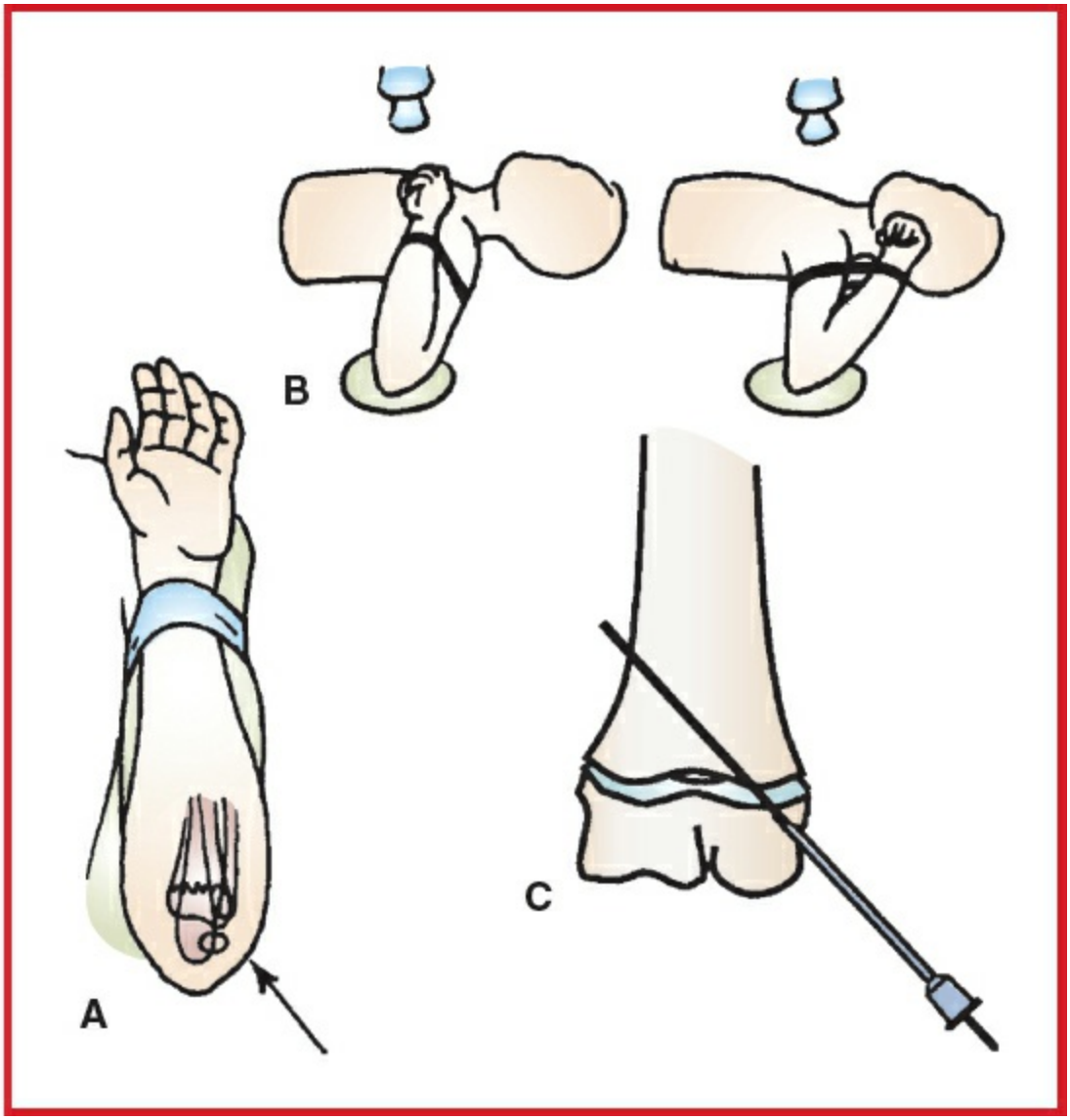

Figure 12.7-1 Percutaneous pinning of supracondylar humerus fracture. **A:** The fracture is manually reduced and held with elbow flexed. **B:** Fracture reduction is assessed with I.I. **C:** The fracture is stabilized with percutaneous K-wires. (Reproduced with permission from Chapman MW:Chapman's Orthopaedic Surgery, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Usual preop diagnosis

Supracondylar fracture of the elbow

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

Percutaneous Pinning	Open Reduction

Position	Usually supine, occasionally prone or lateral	⇐
Incision	None	1″ lateral
Special instrumentation	Power drill, intraop fluoroscopy	⇐
Unique considerations	Full stomach; impending compartment syndrome	⇐
Antibiotics	Usually none	Cefazolin 25 mg/kg
Surgical time	30–60 min	30–90 min
Closing considerations	Cast or splint	⇐
EBL	Minimal	⇐
Postop care	PACU → room; close neurovascular monitoring	⇐
Mortality	Rare	⇐
Morbidity	Late angular deformity, especially cubitus varus: 10%	⇐
	Nerve palsy (typically anterior interosseous [median], ulnar or radial nerve) from the fracture itself: 7–12%	⇐
	Compartment syndrome (Volkmann contracture): <0.5% (some degree of vascular spasm or loss of radial pulse much more common)	⇐
	Stiffness, myositis ossificans	⇐
	Vascular injury	⇐
	Ipsilateral fracture	⇐
Pain score	3–5	3–6

PATIENT POPULATION CHARACTERISTICS

Age range	3–10 yr with peak age range of 5–8 yr
Male:Female	1.6:1
Incidence	Frequent
Etiology	Trauma, usually a fall
Associated conditions	Usually normal, healthy child

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Upper-Extremity Procedures.

Suggested Readings

1. Franklin CC, Skaggs DL: Approach to the pediatric supracondylar humeral fracture with neurovascular compromise. Instr Course Lect 2013; 62:429–33.
2. Georgopoulos G, Carry P, Pan Z, et al: The efficacy of intra-articular injections for pain control following the closed reduction and percutaneous pinning of pediatric supracondylar humeral fractures: a randomized controlled trial. J Bone Joint Surg Am 2012; 94:1633–42.
3. Mehan ST, May CD, Kocher MS: Operative management of displaced flexion supracondylar humerus fractures in children. J Pediatr Orthop 2007; 27:551–6.
4. Mehlman CT, Strub WM, Roy DR, et al: The effect of surgical timing on the perioperative complications of treatment of supracondylar humeral fractures in children. J Bone Joint Surg Am 2001; 83A(3):323–7.
5. Mulpuri K, Wilkins K: The treatment of displaced supracondylar humerus fractures: evidence-based guideline. J Pediatr Orthop 2012; 32(Suppl 2):143–52.
6. Ramesh P, Avadhani A, Shetty AP, et al: Management of acute 'pink pulseless' hand in pediatric supracondylar fractures of the humerus. J Pediatr Orthop B 2011; 20(3):124–8.
7. Saglam Y, Tunali O, Akgul T, et al: Mid-term results of pediatric vascular injured supracondylar humerus fractures and surgical approach. J Pediatr Orthop B 2014; 23(6):572–8.

CLOSED OR OPEN REDUCTION OF DISPLACED LATERAL CONDYLE HUMERUS FRACTURE

SURGICAL CONSIDERATIONS

Description

Lateral condylar fractures of the distal humerus are second only to supracondylar fractures in frequency. Initial radiographs of lateral condyle fractures can look deceptively normal; however, because these fractures cross the physis (growth plate) and enter the articular surface, they require anatomic reduction to restore joint surface congruity and to avoid a premature physeal arrest. In addition, the elbow may be unstable and dislocate if the fracture extends into the trochlea of the humerus. Accurate and stable reduction minimizes the risk of nonunion, a well-known complication resulting from unsuspected rotation of the fracture fragment and by traction forces of the extensor muscles attaching to this condyle. Unlike supracondylar fractures, neurovascular complications are rare with lateral condyle fractures.

Although minimally displaced fractures can be treated with a cast, 60% of lateral condyle fractures are displaced and require manipulation and pinning. Casting without manipulation, and thus requiring no anesthesia, is indicated for stable fractures that are displaced <2 mm. Nonoperative treatment is associated with a high risk (up to 15%) of subsequent displacement despite immobilization. More significant displacement (>2 mm) is an indication for operative treatment, which requires GA. Stable fractures with 2–4-mm displacement can be treated with **CRPP** under fluoroscopic control. **Open reduction and pinning** is necessary for fractures that are unstable, rotated, or displaced more than 4 mm. Screw fixation is gaining popularity, but pinning remains the gold standard. Muscular relaxation is advantageous when performing either a closed or open reduction of the fracture. A sterile tourniquet is used for cases requiring open reduction.

Usual preop diagnosis

Displaced lateral condyle humerus fracture

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, postop care, and pain management options. **See Appendix K: Pediatric ERAS, p. K-6 to K-8.**

SUMMARY OF PROCEDURES

	Closed Reduction/Pinning	Open Reduction/Pinning
Position	Supine	⇐
Incision	None	1–2″ lateral
Instrumentation	Power drill, fluoroscopy	⇐

Unique considerations	None	⇐
Antibiotics	Usually none	Cefazolin 25 mg/kg
Surgical time	30–60 min	45–90 min
Closing considerations	Cast or splint	⇐
EBL	Negligible	⇐
Postoperative care	PACU → room	⇐
Mortality	Rare	⇐
Morbidity	Delayed or nonunion	⇐
	Cubitus valgus (more common) or varus	⇐
	Lateral condylar overgrowth	⇐
	Physeal arrest	⇐
	Osteonecrosis of lateral trochlea	⇐
	Ulnar nerve palsy	⇐
		Avascular necrosis of trochlea
Pain score	3–5	3–6

PATIENT POPULATION CHARACTERISTICS

Age range	5–10 yr; average = 6 yr
Incidence	15% of all elbow fractures; more common in summer
Etiology	Trauma
Associated conditions	Usually normal, healthy child

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Upper-Extremity Procedures.

Suggested Readings

1. Beathy JH: Fractures of the lateral humeral condyle are the second most frequen elbow fracture in children. J Orthop Trauma 2010; 24:434–8.
2. Gilbert SR, MacLennan PA, Schlitz RS, et al: Screw versus pin fixation with ope reduction of pediatric lateral condyle fractures. J Pediatr Orthop B 2016; 25(2):148–52.
3. Knapik DM, Gilmore A, Liu RW: Conservative management of minimally displace (≤2 mm) fractures of the lateral humeral condyle in pediatric patients: a systematic review. J Pediatr Orthop 2017; 37(2):e83–7.
4. Launay F, Leet AI, Jacopin S, et al: Lateral humeral condyle fractures in children: a comparison of two approaches to treatment. J Pediatr Orthop 2004; 24:385–91.
5. Song KS, Water PM: Lateral condyle humerus fractures: which one should we fix?J Pediatr Orthop 2012; 32 (Suppl 1):S5–9.

ASPIRATION AND INJECTION OF UNICAMERAL BONE CYST

SURGICAL CONSIDERATIONS

Description

Unicameral bone cysts (UBCs) are benign lesions typically located centrally in the metaphyseal regions of long bones, in skeletally immature patients, and most commonly in the proximal humerus. The cyst is rarely a source of pain until presentation (typically after a fracture). The benign radiographic appearance allows clinicians to follow most lesions without the need for surgical biopsy. Surgical care is indicated when the UBC is of sufficient size and location to cause mechanical weakening of the bone and predispose to a pathologic fracture. The goals of surgical care are to confirm the diagnosis of UBC and to reestablish the mechanical integrity of the bone. Diagnosis of a UBC is made by percutaneous aspiration of the lesion, using a standard 16- to 18-gauge spinal needle under GA. Fluoroscopic guidance facilitates needle placement. The presence of clear, straw-colored fluid confirms diagnosis of UBC. An alternative diagnosis, such as aneurysmal bone cyst, is more likely if frank blood is aspirated. If the lesion contains no fluid, it may be a nonossifying fibroma. Open biopsy may be necessary if the diagnosis is unclear.

Multiple treatment options are described in the literature, but most cases can be treated

adequately with percutaneous aspiration and injection of the cavity with a substance to promote new bone formation. **The surgeon may inject radiopaque dye to verify that the entire cavity is contiguous.** If the cystic cavity is loculated by bony trabecula, a **curette** or **percutaneous Kirschner** wire is used to convert the lesion into a unicompartmental space, so the subsequent injection will easily access the entire lesion. Scraping the inner cyst walls also helps to disrupt the cyst lining and is thought to improve the chance of filling in the cavity. The final surgical step is to introduce a second "venting" needle into the cyst to allow lavage with sterile saline, followed by injection of the cavity. Historically, methylprednisolone has been used, but more recent evidence suggests a higher success rate when autologous bone marrow is injected. Injectable allograft bone preparations also can supplement the bone marrow injection. Care must be taken to avoid aspirating from the first needle after the second has been placed, to avoid intraosseous air embolism.

Usual preop diagnosis

Unicameral bone cyst

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, postop care, and pain management options. **See Appendix K: Pediatric ERAS, p. K-6 to K-8.**

SUMMARY OF PROCEDURES

	Percutaneous	Open
Position	Supine	⇐
Incision	None	Length of cyst
Instrumentation	Spinal needles, Kirschner wires, intraoperative fluoroscopy	Curettes
Unique considerations	Risk of air embolus	Additional time for intraop pathology evaluation
Antibiotics	Usually none	Cefazolin 25 mg/kg
Surgical time	30–60 min	60–90 min
Closing considerations	None	Cast or splint
EBL	Minimal	⇐

Postop care	PACU → room	PACU → room/home
Mortality	Rare	⇐
Morbidity	Infection	⇐
	Iatrogenic fracture	⇐
	Growth arrest: rare	⇐
Pain score	0–2	3–6

PATIENT POPULATION CHARACTERISTICS

Age range	3–14 yr; rarely found in adults (<15%)
Male:Female	1:3
Incidence	20% of benign bone lesions; most common location is the proximal humerus (67%), followed by the proximal femur (15%).
Etiology	Unknown. Venous obstruction → fluid transudate containing high levels of interleukin-1 and interleukin-6, which stimulate osteoclasts
Associated conditions	Usually normal, healthy child. Initial presentation typically follows a pathologic fracture.

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Upper-Extremity Procedures.

Suggested Readings

1. Alvarez RG, Arnold JM: Arthroscopic assistance in minimally invasive curettage and bone grafting of a calcaneal unicameral bone cyst. Foot Ankle Int 2007; 28:1198–9.
2. Pretell-Mazzini J, Murphy RF, Kushare I, et al: Unicameral bone cysts: genera characteristics and management controversies. J Am Acad Orthop Surg 2014; 22(5):295–303.
3. Rougraff BT, Kling TJ: Treatment of active unicameral bone cysts with percutaneous injection of demineralized bone matrix and autogenous bone marrow. J Bone Joint Surg 2002; 84A(6):921–9.

RELEASE FOR TORTICOLLIS

SURGICAL CONSIDERATIONS

Description

Congenital muscular torticollis is a painless tilting of the head due to unilateral contracture of the sternocleidomastoid muscle. The head tilts toward the involved side and rotates toward the opposite side (a "cock-robin" posture such that the chin points to the opposite side). It is associated with breech and difficult deliveries, as well as other musculoskeletal disorders, such as metatarsus adductus, hip dysplasia, and talipes equinovarus. Multiple theories regarding the etiology of congenital muscular torticollis have been proposed, including fibrosis of the sternocleidomastoid muscle following a peripartum intramuscular bleed, fibrosis resulting from a compartment syndrome of the sternocleidomastoid muscle, intrauterine crowding, and a primary myopathy of the sternocleidomastoid muscle. Eighty percent of cases of torticollis are a result of this congenital contracture of the sternocleidomastoid muscle. Less common etiologies—such as congenital cervical spine malformations (e.g., Klippel-Feil syndrome), neurologic disorders, a cranial or cervical neoplasm, inflammatory conditions (e.g., Grisel syndrome), or an ocular dysfunction—should also be excluded. Congenital muscular torticollis is seen more frequently on the right side (i.e., tilting to the right and turned to the left). The majority (50–70%) will resolve spontaneously within the first year of life with minimal residual deficit. However, in the remainder, persistent torticollis will lead to skull and facial deformities (plagiocephaly). If the child sleeps prone, he or she will usually lie with the affected side down, resulting in flattening of the face on that side. If the child sleeps supine, flattening of the contralateral skull occurs. This plagiocephaly will become permanent if the torticollis persists and is left untreated.

Initial treatment includes physical therapy with stretching of the sternocleidomastoid muscle. For children <1 yr of age, a program of stretching is recommended and will resolve 90% of cases. After 2 yr of age, nonoperative treatment is not likely to be effective. Children with persistent torticollis and an unacceptable amount of facial asymmetry should be treated surgically before 3 yr of age. However, some improvement in facial asymmetry has been reported in children treated surgically up to 8 yr of age.

Surgical options include a unipolar release, a bipolar release, a middle-third transection, or a complete resection. Unipolar release involves division of the distal insertion of the sternocleidomastoid muscle and usually is performed for a mild deformity. For more extensive involvement, bipolar release is usually performed. This

procedure entails division of both the insertion and origin of the sternocleidomastoid muscle. Z-plasty of the clavicular head or transfer of the clavicular head to the sternal head may be done to maintain a more normal cosmetic contour of the neck. Potential surgical complications include injury to the spinal accessory nerve, jugular veins, carotid vessels, and the facial nerve. Postop, patients are encouraged to perform simple stretching exercises, but they will often require bracing to maintain the corrected alignment.

Usual preop diagnosis

Congenital muscular torticollis

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Unipolar	Bipolar
Position	Supine	⇐
Incision	Transverse, 1.5 cm superior to the sternum and clavicle over muscle insertion	⇐ + 1 cm distal to mastoid process behind the ear at muscle origin
Unique considerations	Plagiocephaly	⇐
Antibiotics	Cefazolin 25 mg/kg	⇐
Surgical time	30 min	45 min
EBL	Minimal	⇐
Postoperative care	PACU → room/home	⇐
Mortality	Rare	⇐
Morbidity	Hypertrophic scar	⇐
	Loss of normal muscle contour	⇐
		Spinal accessory nerve injury

Pain score	3–5	3–5

PATIENT POPULATION CHARACTERISTICS	
Age range	Onset at birth, surgery after age 1 yr
Male:Female	1:1
Incidence	1/500
Etiology	Fibrosis of the sternocleidomastoid; possible intrauterine or perinatal muscle compartment syndrome
Associated conditions	Usually normal, healthy child; hip dysplasia in 20%

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Upper-Extremity Procedures.

Suggested Readings

1. Lepetsos P, Anastasopoulos PP, Leonidou A, et al: Surgical management of congenital torticollis in children older than 7 years with an average 10-year follow-up. J Pediatr Orthop B 2017; 26(6):580–4.
2. Shim JS, Noh KC, Park SJ: Treatment of congenital muscular torticollis in patient older than 8 years. J Pediatr Orthop 2004; 24:683–8.
3. Suhr MC, Oledzka M: Considerations and intervention in congenital muscula torticollis. Curr Opin Pediatr 2015; 27(1):75–81.
4. Von Heideken J, Green DW, Burke SW, et al: The relationship betweer developmental dysplasia of the hip and congenital muscular torticollis. J Pediatr Orthop 2006; 26:805–8.

POLLICIZATION OF A FINGER

SURGICAL CONSIDERATIONS

Description

Pollicization is indicated in the infant with congenital absence or hypoplasia of the thumb. It is a technically demanding procedure that involves conversion of an adjacent functional finger (usually the index finger) into a useful thumb. The components of the

donor finger, including the bones, tendons, nerves, and vascular supply, are used to form a functional thumb and thenar mass (Fig. 12.7-2). Tendon transfers are performed to substitute for the absent or hypoplastic thenar muscles. These patients often have other associated congenital malformations, which should be ruled out prior to surgery. The organs that are commonly involved include the vertebrae, anus, heart, trachea, esophagus, kidneys, hematopoietic system, and lower limbs. Commonly associated genetic syndromes include Holt-Oram syndrome (cardiac septal defects and radial deficiency), TAR syndrome (thrombocytopenia with absent radius), and Fanconi anemia (aplastic anemia).

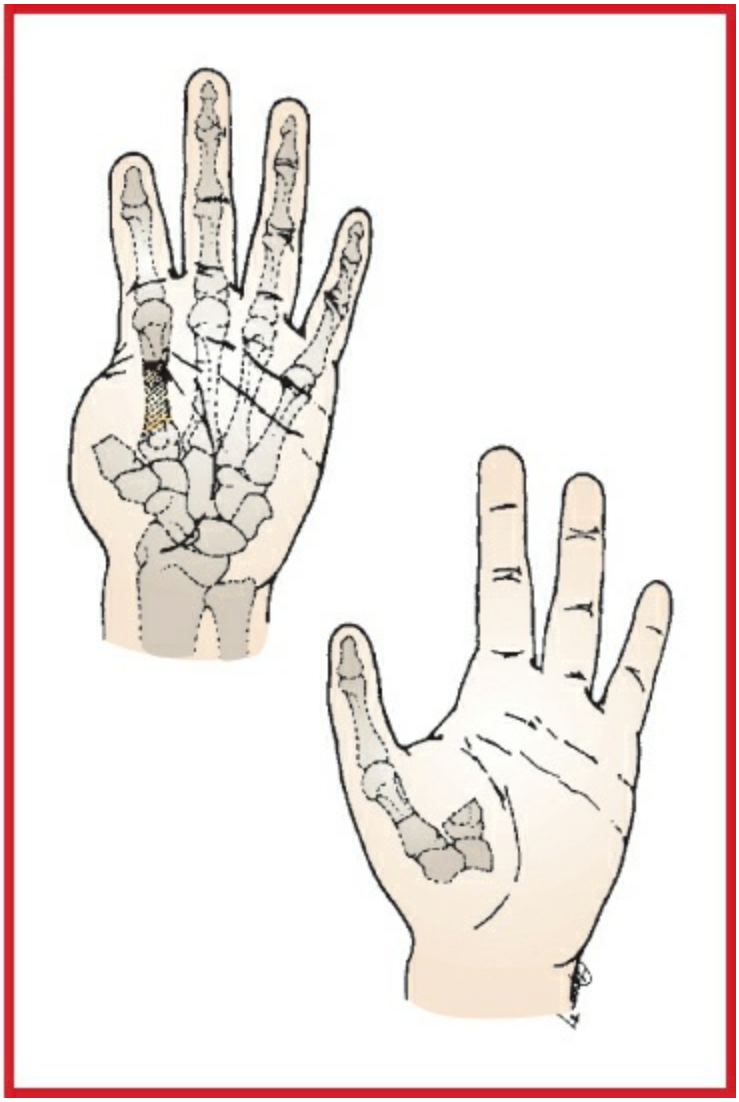

Figure 12.7-2 Pollicization of a finger. (Reproduced with permission from Chapman MW:Chapman's Orthopaedic Surgery, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Variant procedure or approaches

There are several different surgical techniques, which share the basic transposition and

rotation of the finger to the thumb position.

Usual preop diagnosis

Aplastic thumb; hypoplastic thumb; radial club hand; radial longitudinal deficiency

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, physical therapy, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Supine, with arm extended on hand surgery table
Incision	Multiple incisions on the hand
Special instrumentation	Pneumatic tourniquet; magnification loupes
Antibiotics	Cefazolin 25 mg/kg (children)
Surgical time	3–4 h
Tourniquet	100 mm Hg above systolic; max time = 120 min
Closing considerations	Complex skin flaps are necessary. A plaster splint is placed while the patient is still anesthetized.
EBL	Minimal; performed under tourniquet control
Postop care	PACU → overnight admission for observation or perfusion to the transposed finger
Mortality	Minimal
Morbidity	Ischemia (loss of digit): Rare Skin flap necrosis: Moderately common
Pain score	1–2

PATIENT POPULATION CHARACTERISTICS	
Age range	1–2 yr is ideal time for surgery. Procedure should be done before patient begins school.
Male:Female	1:1
Incidence	Overall, about 1/20,000 live births require a variant of

	this procedure.
Etiology	Unknown; also associated with thalidomide ingestion
Associated conditions	Associated with congenital anomalies of the upper extremity, esophagus, spine, and lower extremities Absence of radius (radial club hand), common Various forms of syndactylies, common Abnormalities of the hematopoietic system (Fanconi syndrome), cardiovascular system (ASDs in Holt-Oram syndrome), spine, and GI system, along with hypothyroidism, are frequently associated.

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Upper-Extremity Procedures.

Suggested Readings

1. Colen DL, Lin IC, Levin LS, et al: Radial longitudinal deficiency: recer developments, controversies, and an evidence-based guide to treatment. J Hand Surg Am 2017; 42(7):546–63.
2. Soldado F, Zlotolow DA, Kozin SH: Thumb hypoplasia.J Hand Surg Am 2013; 38(7):1435–44.

SYNDACTYLY REPAIR

SURGICAL CONSIDERATIONS

Description

Syndactyly refers to congenital failure of separation of two or more fingers. If the connection extends to the end of the digits, it is defined as “complete” syndactyly. Otherwise, it is defined as “incomplete” syndactyly. It can also be broken down into “simple” or “complex” based on whether the connection involves soft tissue alone or soft tissue and bone, respectively. Complex syndactyly often includes fusion of adjacent phalanges or interposition of accessory phalanges, with frequent abnormalities of the neurovascular structures. Surgical treatment is typically recommended to allow independent digital function as well as for aesthetic reasons. The timing of surgery is determined on an individual patient basis, but is usually recommended prior to 18 mo of age to prevent detriments in hand development.

Syndactyly release and reconstruction involves creation of a dorsal, proximally based skin flap to recreate the web. Zigzag dorsal and palmar incisions are created by starting distally and moving proximally. The digital nerve and arteries are dissected proximally as far as possible. Due to concern for vascular insufficiency, both sides of a digit at the same time are not released at the same time. Primary closure is almost never possible, and supplemental full-thickness skin grafts harvested from the groin are often required to complete the closure. It is not always possible to save all the bony elements. Patients with conditions such as Apert syndrome must undergo careful preoperative evaluation of their airway.

Usual preop diagnosis

Syndactyly of fingers; bifid finger, thumb/finger

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, postop care, and pain management options. **See Appendix K: Pediatric ERAS, p. K-6 to K-8.**

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Zigzag between digits; skin graft donor site from groin
Special instrumentation	Magnification loupes are always necessary. Tourniquet is mandatory.
Unique considerations	Groin skin often taken for graft closure
Antibiotics	Usually none
Surgical time	2–4 h
Closing considerations	Above-the-elbow cast or splint to keep incision away from the mouth and other hand of the infant or child
EBL	20 mL
Postop care	PACU → home, if simple syndactyly
Mortality	None associated with procedure
Position	Supine
Morbidity	Digital necrosis Partial slough of flaps or skin graft requiring revision

	Scarring and some stiffness of fingers "Web creep" (distal migration of the webspace) Angulatory deformities late, occasionally depending on degree of involvement of the skeleton and joint
Pain score	1–3

PATIENT POPULATION CHARACTERISTICS	
Age range	6 mo–5 yr
Male:Female	2:1
Incidence	1/2000 births (the most common significant congenital hand anomaly)
Etiology	Family Hx (10–40%); failure of differentiation in the 6th–8th wk of intrauterine life
Associated conditions	Polydactyly, accessory phalanges; Apert syndrome; Poland syndrome

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Upper-Extremity Procedures.

Suggested Readings

1. Chang J, Danton TK, Ladd AL, et al: Reconstruction of the hand in Apert's syndrome a simplified approach. Plast Reconstr Surg 2002; 109(2):465–70.
2. Little KJ, Cornwall R: Congenital anomalies of the hand—principles of management Orthop Clin North Am 2016; 47(1):153–68.
3. Oda T, Pushman AG, Chung KC: Treatment of common congenital hand condition Plast Reconstr Surg 2012; 126:121e–33e.
4. Smith GD: Congenital hand anomalies and reconstruction.Br J Hosp Med (Lond) 2012; 73:203–9.

ANESTHETIC CONSIDERATIONS FOR UPPER-EXTREMITY PROCEDURES

(Procedures covered: percutaneous pinning; displaced supracondylar humerus fracture; closed/open reduction; displaced lateral condylar humerus fracture; aspiration/injection unicameral/bone cyst; torticollis release; pollicization of the finger; syndactyly release)

PREOPERATIVE

The majority of children presenting for repair of upper-extremity fractures are otherwise healthy. Most of these patients present for repair of a traumatic injury; thus, the preop workup is routine. Some arm procedures, such as repair of a compound fracture, require immediate attention and necessitate emergency surgery and full-stomach considerations. Some upper-extremity procedures such as pollicization of a finger may be needed in patients suffering from other congenital anomalies or syndromes; thus, a detailed preoperative evaluation is needed.

Laboratory	Tests as indicated from H&P
Premedication	Standard premedication. Avoid long-lasting sedative medications.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 10–15 mg/kg iv or po as an elixir.

INTRAOPERATIVE

Anesthetic technique

GETA or LMA because children rarely tolerate regional anesthesia alone. In the older patient, regional anesthesia may be appropriate and can reduce the risk of aspiration pneumonitis associated with GA in the patient with a full stomach. A combined technique offers the advantages of reduced anesthetic requirements and postop pain relief; however, regional anesthesia is relatively contraindicated in patients with neurovascular compromise.

General anesthesia

Induction	Standard induction except in acute trauma patients, where rapid-sequence induction is appropriate
ERAS	Verify preincision antibiotics. Assess volume status (see p. K-6). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance
Emergence	Management of emergence and extubation should be

	routine, except in difficult airway cases, which require awake extubation. Skin closure is frequently followed by application of a splint; patient should remain anesthetized during splinting procedure. Discuss with surgeon local wound infiltration. PONV prophylaxis may include dexamethasone (e.g., 30 mcg/kg) and ondansetron (0.1 mg/kg up to 4 mg iv).

Regional anesthesia

Ultrasound guidance

Ultrasound-guided nerve block techniques are increasingly used in pediatric anesthesia. The use of ultrasonography increases the ability to position the needle as close to the nerve as possible avoiding inadvertent trauma to the adjacent structures. Direct visualization also helps in optimizing the volume and distribution of the local anesthetic, thus improving the safety and efficacy of the block.

Anesthetics and doses	See Table 12.7-1.
Interscalene block	Performed at level of C6 to minimize risk of pneumothorax. The phrenic nerve lies anterior to the brachial plexus and is frequently blocked by anterior spread of LA, leading to hemidiaphragm paralysis. This is usually well tolerated; however, care must be taken in patients with respiratory compromise. Temporary Horner syndrome may result from LA migration to sympathetic chain. Major complications (e.g., total spinal or pneumothorax) resulting from interscalene block are very rare; therefore, this technique is suitable for outpatients. Interscalene block is contraindicated in patients with contralateral recurrent laryngeal nerve palsy.
Supraclavicular block	Ultrasound guidance has enhanced the safety of supraclavicular approach to supraclavicular block. The trunks and divisions of the brachial plexus run very close to the subclavian artery as it travels over the first rib. This block ensures complete anesthesia of the upper extremity with the exception of the upper medial aspect

	of the axilla, which is supplied by the intercostobrachial nerves. Complications such as hemothorax and pneumothorax can be reduced by careful in-plane approach under ultrasound.
Infraclavicular block	The infraclavicular approach to brachial plexus block has the advantage of blocking the axillary and musculocutaneous nerves. The coracoid approach is shown to be safer than the classical approach. Use of ultrasonography increases the efficacy and safety of this block.
Axillary block	The medial aspect of the upper arm is innervated by the intercostobrachial nerve (T2) and requires a separate subcutaneous field block in the axilla, especially when a tourniquet is used. The musculocutaneous nerve, which takes off from the brachial plexus high up in the axilla, can also be missed by the traditional axillary block. This nerve can easily be identified in the upper part of the arm in the belly of coracobrachialis muscle, under ultrasound guidance. This block is needed to prevent tourniquet pain and to provide analgesia in the distribution of lateral cutaneous nerve of forearm, a branch of musculocutaneous nerve.
Supplemental sedation	Supplemental sedation may be accomplished with use of propofol by continuous infusion (50–150 mcg/kg/min).
Blood and fluid requirements	Minimal blood loss IV: 22 ga × 1 BSS @ 4-2-1 rule maintenance IV catheter should be placed in the nonoperated extremity.
Monitoring	Standard monitors.
Positioning	✓ and pad pressure points ✓ eyes
Interscalene block complications	Total spinal Epidural anesthesia IV injection (Sz/dysrhythmias) Resuscitative equipment, including airway management tools, and intralipid should be immediately available. Dose

	Stellate ganglion block (Horner syndrome) Laryngeal nerve block Phrenic nerve block Pneumothorax	of 20% intralipid: 1.5 mL/kg repeat × 2 max 3 mL/kg; infusion rate 0.25 mL/kg/min.
Supraclavicular block complications	Hematoma, hemothorax, pneumothorax, phrenic nerve block	In-plane ultrasound guidance has improved the safety of this block.
Infraclavicular block complications	Hematoma Pneumothorax Inadvertent intravascular injection	The coracoid approach has reduced risk of complications.
Axillary block complications	Inadequate block Intravascular injection Peripheral nerve damage Axillary hematoma Axillary artery thrombosis Pneumothorax	Very small doses of local anesthetic can cause CNS toxicity if reverse flow occurs during an intra-arterial injection. Axillary thrombosis and pneumothorax are extremely rare.

Table 12.7-1 Maximum Recommended Doses of Anesthetics for Regional Anesthesia

Drug	mg/kg (*with Epinephrine)	Duration (min)
Lidocaine	5 (*7)	45–180
Bupivacaine	2.5 (*3)	180–600
Ropivacaine	3	180–600
Tetracaine	1.5	180–600
2-Chloroprocaine	8 (*10)	30–60
Procaine	8 (*10)	60–90

POSTOPERATIVE

Multimodal pain management	PCA. Regional block	Combined regional-GA provides excellent postop

		pain management. Emphasize nonopioid analgesics. Back up with bolus opioid analgesics.
ERAS	PONV protocol (see p. D-1)	Encourage early enteral nutrition and mobilization.
Tests	None routinely indicated	

Suggested Readings

1. Marhofer P, Greher M, Kapral S: Ultrasound guidance in regional anaesthesia.Br J Anaesth 2005; 94(1):7–17.
2. Marhofer P, Invani G, Suresh S, et al: Everyday regional anesthesia in children Pediatr Anesth 2012; 22(10):995–1001.
3. Marhofer P, Sitzwohl C, Greher M, et al: Ultrasound guidance for infraclavicular brachial plexus anesthesia in children. Anaesthesia 2004; 59:642–6.
4. Rove KO, Edney JC, Brockel MA: Enhanced recovery after surgery in children promising, evidence-based multidisciplinary care. Paediatr Anaesth 2018; 28(6):482–92.
5. Surech S, Wheeler M: Practical pediatric regional anesthesia. Anesthesiol Clin North Am 2002; 20(1):83–113.

POSTERIOR SPINAL INSTRUMENTATION AND FUSION

SURGICAL CONSIDERATIONS

Description

Posterior spinal instrumentation refers to implanted metal rods affixed to the spine to correct and internally splint the deformed spine. Originally designed for scoliosis, posterior spinal instrumentation is commonly performed simultaneously with **spinal fusion** for a variety of diagnoses, including fracture, tumor, degenerative changes, and developmental spinal deformity. Hook-rod systems became popular in the mid-1980s and are still used by spine surgeons. Today, the most common form of spine fixation involves pedicle screws (introduced in the 1990s) that allow greater control of the vertebra for improved stability and, if needed, improved correction of deformity.

Regardless of the surgeon's choice of instrumentation, the spine is most commonly

approached by an extensive midline posterior incision (although anterior and lateral approaches are described), in which a subperiosteal exposure (typically T2-T5 down to L1-L4) is used to elevate all the paraspinous muscles as far laterally as the tips of the transverse processes. Instrumentation (pedicle screws and/or hooks) is placed on both the concave and convex sides of the spine (Fig. 12.7-3). These points of fixation are joined to two contoured rods running parallel to the spine on either side. With linked fixation in place, the correction can begin (in the case of scoliosis or spinal deformity) by compressing along the convex surfaces and distracting along the concave surfaces. Postoperatively, some spine surgeons advise the use of a TLSO brace for the initial months following surgery.

Sublaminar wire loops (Fig. 12.7-4) are commonly used instead of the hook-rod method of spinal instrumentation when treating neuromuscular spinal deformity (e.g., cerebral palsy, muscular dystrophy, myelomeningocele, or spinal muscular atrophy). This alternative construct provides more points of fixation to the spine and eliminates the need for postop bracing. When a large degree of pelvic obliquity is a component of the patient's deformity, the instrumentation often is extended into the iliac wings (Fig. 12.7-5).

One of the most prominent fears in the minds of patients and their parents undergoing elective spine surgery are neurologic deficits. Intraoperative neuromonitoring is designed for early detection of impending spinal cord damage. **Somatosensory evoked potentials** (SSEPs) and **motor evoked potentials** (MEPs) are used routinely in high-volume spinal deformity correction centers. MEPs may offer more utility as they monitor the motor tracts in the anterior spinal cord, which is at higher risk of ischemia during spine surgery (especially during deformity correction). Close coordination among the surgeon, spinal cord monitoring personnel, and anesthesiologist is necessary to properly recognize adverse intraop spinal events and to minimize the occurrence of false-positive findings. Many spine surgeons also request that an intraop wake-up test be performed to further verify spinal cord function.

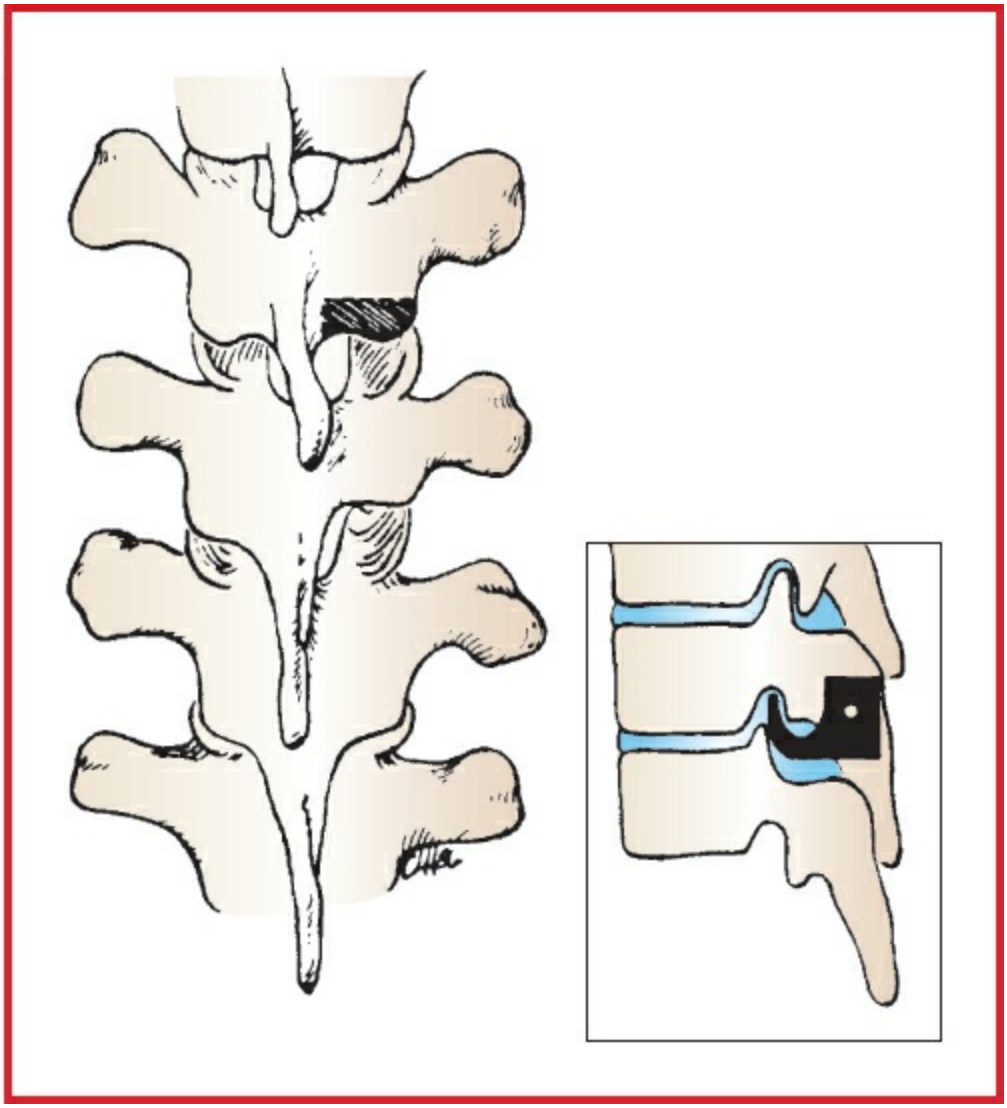

Figure 12.7-3 Placement of a standard pedicle hook, in a hood-rod device. (Reproduced with permission from Chapman MW:Operative Orthopaedics, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Usual preop diagnosis

Scoliosis (usually idiopathic or neuromuscular); kyphosis (increased round back); reconstruction for tumor, trauma, or other

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, physical therapy, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

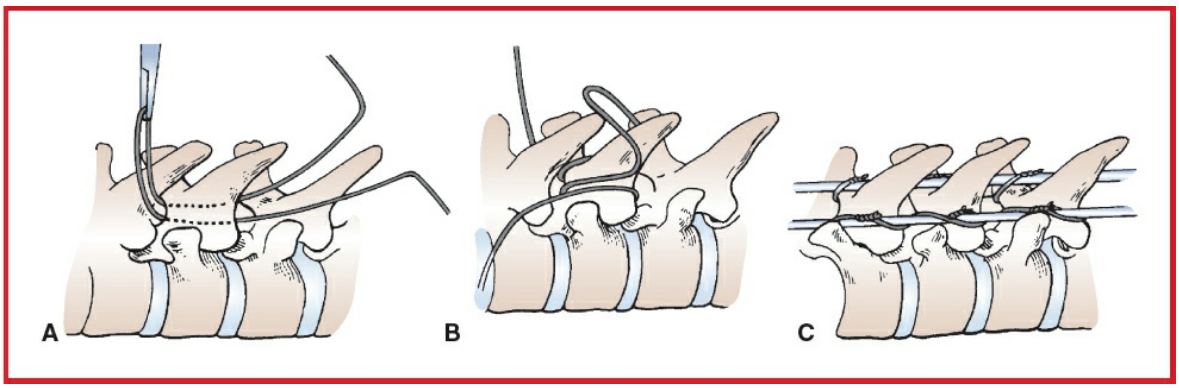

Figure 12.7-4 An example of passing and attaching sublaminar wires. (Reproduced with permission from Chapman MW:Operative Orthopaedics, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

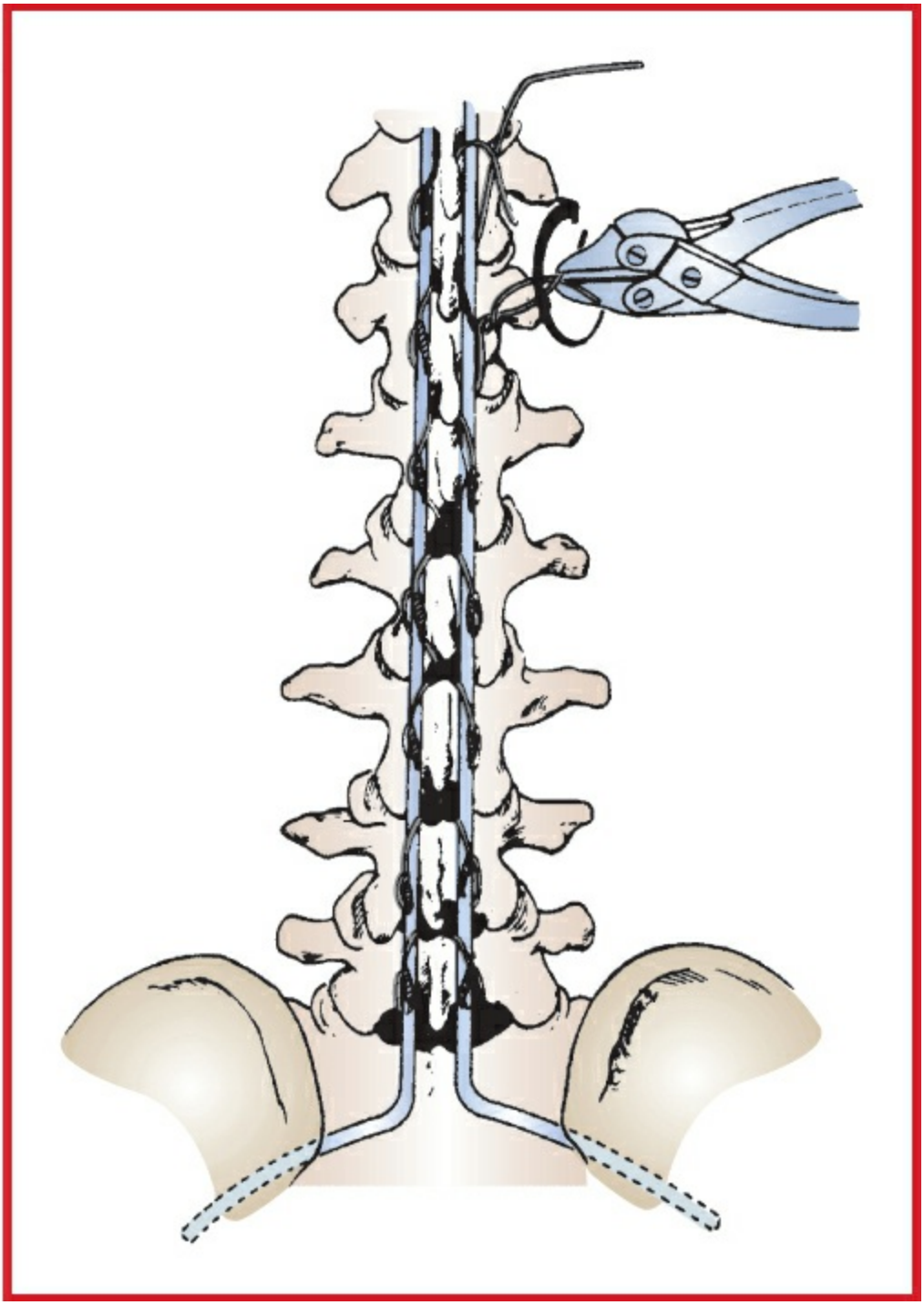

Figure 12.7-5 Positioning rods in the pelvis; sublaminar wires being tightened. (Reproduced with permission from Chapman MW:Operative Orthopaedics, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

SUMMARY OF PROCEDURE

Position	Prone (on spinal frame or bolsters); avoid abdominal, elbow, and ocular compression.
Incision	Posterior midline; optional separate iliac crest bone graft

Special instrumentation	Rods, hooks, pedicle screws, wires
Unique considerations	"Wake-up" test and/or SSEPs; induced ↓ BP is often requested; prolonged prone positioning places brachial plexus and ulnar nerve at risk.
Antibiotics	Cefazolin 25 mg/kg iv
Surgical time	2–6 h
Closing considerations	Greatest blood loss typically toward the end of procedure. Avoid hypotension after instrumentation is implanted.
EBL	1200–3000 mL
Postop care	ICU: 1–2 d
Mortality	0–0.5%
Morbidity	Acute ileus: very common Genitourinary infection: 5–7% Hematoma, massive bleeding: 1–5% Pneumothorax, pneumonia, atelectasis: 1–5% Hook dislodgement requiring reoperation: 0–2% Wound infection: 0–2% Superior mesenteric artery syndrome: 0–1% Thromboembolism: <1% Spinal cord injury and/or root injury: 0.6% Delayed: Pseudarthrosis: 0–5% Late rod fracture: 0–5% Progression of spinal deformity: 0–2%
Pain score	7–9

PATIENT POPULATION CHARACTERISTICS

Age range	Usually 8–40 yr
Male:Female	1:5
Incidence	1–2/10,000

Etiology	Idiopathic (50–75%); neuromuscular (20–30%); associated with syndromes such as osteochondral dystrophies, osteogenesis imperfecta, etc. (5%); congenital scoliosis (2–5%)
Associated conditions	Neuromuscular: Friedreich ataxia (myocarditis and other cardiovascular anomalies; sudden death) Myelomeningocele (latex allergy, chronic UTI, hydrocephalus) Muscular dystrophy (muscle weakness, cardiomyopathy, dysrhythmias, succinylcholine → prolonged muscle contraction, ↑ sensitivity to respiratory depressant effect of barbiturates, opiates, and benzodiazepines) Cerebral palsy (GERD, ↓ airway protective reflexes, ↑ postop pulmonary complications, malnourishment, Sz, medication may interfere with Plt function) Higher incidence of MH Connective tissue disease: Ehlers-Danlos and Marfan syndromes (avoid ↑ BP → aortic dissection; ↑ risk of pneumothorax). Osteogenesis imperfecta (position and intubate with great care) Congenital osteochondral dystrophies

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Spinal Reconstruction and Fusion.

Suggested Readings

1. Abu-Kishk I, Kozer E, Hod-Feins R, et al: Pediatric scoliosis surgery—i postoperative intensive care unit admission really necessary? Paediatr Anaesth 2013; 23:271–7.
2. Auerbach JD, Lonner BS, Antonacci MD, et al: Perioperative outcomes an complications related to teaching residents and fellows in scoliosis surgery. Spine 2008; 33(10):1113–8.
3. Borgeat A, Blumenthal S: Postoperative pain management following scoliosis surgery. Curr Opin Anaesthesiol 2008; 21(3):313–6.
4. Heller KD, Wirtz DC, Siebert CH, et al: Spinal stabilization in Duchenne muscula

dystrophy: principles of treatment and record of 31 operative treated cases. J Pediatr Orthop 2001; 10(1):18–24.
5. Mathieseen O, Dahl B, Thomsen BA, et al: A comprehensive multimodal pain treatment reduce opioid consumption after multilevel spine surgery. Eur Spine J 2013; 22(9):2089–96.
6. Neira VM, Ghaffari K, Bulusu S, et al. Diagnostic accuracy of neuromonitoring for identification of new neurologic deficits in pediatric spinal fusion surgery. Anesth Analg 2016; 123(6):1556–66.
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8. Thomson JD, Banta JV: Scoliosis in cerebral palsy: an overview and recent results.J Pediatr Orthop 2001; 10(1):6–9.

ANTERIOR SPINAL FUSION FOR SCOLIOSIS

SURGICAL CONSIDERATIONS

Description

Anterior spinal fusion is performed through a transthoracic and/or retroperitoneal approach to the vertebral bodies, in which the intervertebral discs are removed and a bone graft is placed between the vertebral bodies. The disc removal ("release") loosens the spine and allows greater deformity correction than posterior-only procedures. Often, no instrumentation is used anteriorly when the anterior fusion is performed as a first stage to a "front-and-back" fusion. (In such cases, posterior spinal instrumentation is subsequently implanted to correct the spinal deformity.) Anterior spinal instrumentation is performed when a posterior spinal fusion is not needed (e.g., idiopathic thoracolumbar or lumbar scoliosis).

When **instrumentation of the anterior spine** is performed, the surgical approach is through a flank incision and then through a rib bed on the convex side of the curve (usually the 10th rib). The retroperitoneal plane is entered and developed by blunt dissection behind the transversus abdominis muscle. The pleural cavity is entered, and the diaphragm usually must be divided circumferentially near its costal origin and around posteriorly to the spine. The prevertebral areolar plane is then entered, and the segmental vessels to each vertebral body are clipped or cauterized in the midline. The psoas muscle is elevated off the lateral aspects of the vertebral bodies. Each disc in the fusion area (usually 3–5 discs) is excised back to the posterior longitudinal ligament.

Next, vertebral screws are inserted transversely across the appropriate bodies and joined at their heads by a rod (Figs. 12.7-6 and 12.7-7). Bone graft (typically from the rib harvested during the surgical approach) is placed within each discectomy level. A chest tube is placed before closure of the thoracic cavity.

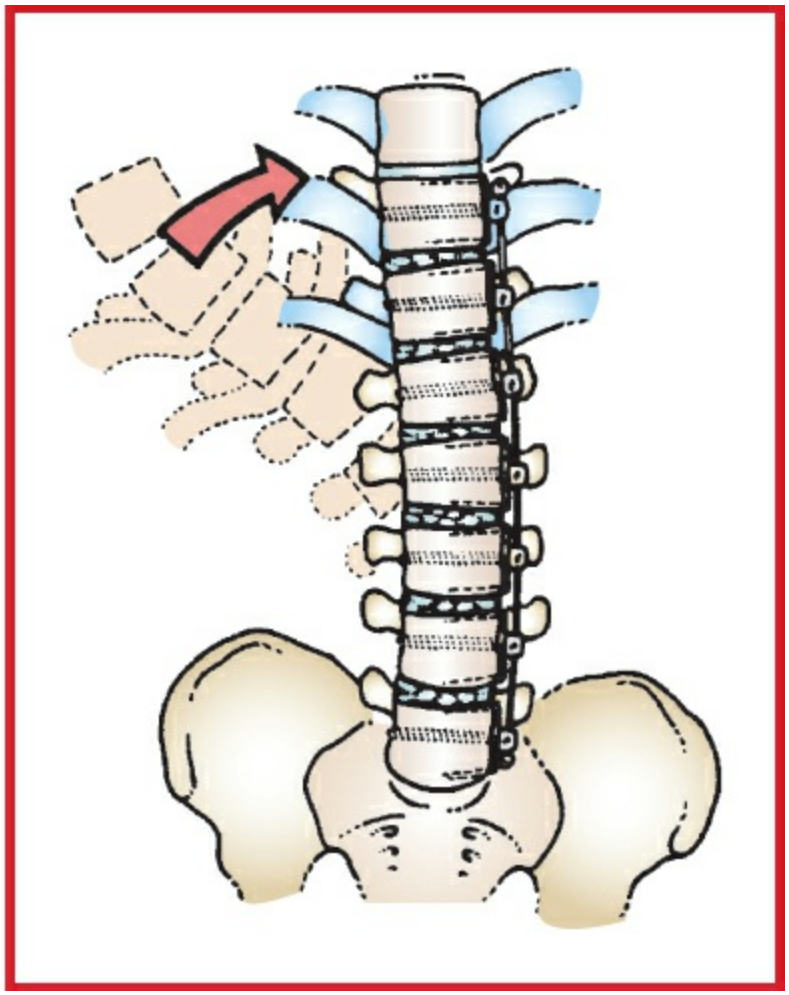

Figure 12.7-6 Dwyer instrumentation used to make spinal correction. (Reprinted from Crenshaw AH, ed: Campbell's Operative Orthopaedics, 8th edition. Mosby-Year Book, St. Louis: 1992. Copyright © 1992 Elsevier. With permission.)

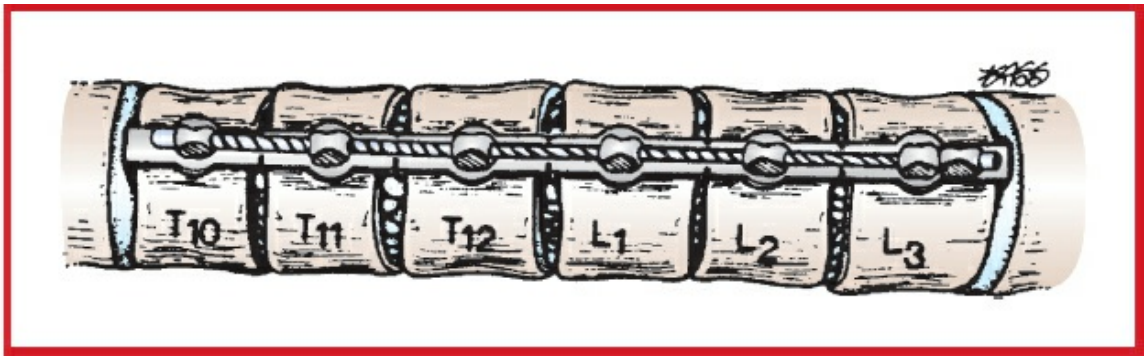

Figure 12.7-7 Instrumentation from T10-L3 (Zielke). (Reproduced with permission from Chapman MW: Chapman's Orthopaedic Surgery, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Usual preop diagnosis

Idiopathic or neuromuscular scoliosis

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, physical therapy, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Fusion with Instrumentation	Release (No Instrumentation)
Position	Full lateral decubitus (Fig. 12.7-8)	⇐
Incision	Flank: over the rib at top vertebra in the curve (usually T9-T11)	⇐
Special instrumentation	Screws, staples, rods	None
Unique considerations	Flex OR table at thoracolumbar junction until disc removal and deformity correction. Procedure often followed by posterior spinal fusion. Proximity of great vessels → potential for major bleeding. Patients with neuromuscular scoliosis often have poor generalized nutrition. SSEP/MEP is often used to monitor spinal cord function.	⇐ Uninstrumented release is always followed by posterior spinal fusion with instrumentation.
Antibiotics	Cefazolin 25 mg/kg iv	⇐
Surgical time	3–4 h	2–3 h
Closing considerations	Chest tube always used; hypotension, if used electively, must be reversed before closure.	⇐
EBL	500–2000 mL	250–2000 mL
Postop care	ICU 1–2 d	⇐
Mortality	0–2%, depending on underlying	⇐

	conditions	
Morbidity	Overall: 30%, depending on underlying condition	20%
	Ileus and atelectasis: ~50%	⇐
	UTI: 10–25% (common in spina bifida)	⇐
	Minor transient root weakness or paresthesia: 10–20%	1–5%
	Partial sympathectomy: common	⇐
	Late kyphosis above instrumentation: 5–10%	—
	Nonunion and hardware failure: 5%	—
	Massive blood loss: 2–5%	⇐
	Respiratory failure: 1–2%	⇐
	Pneumonia: 1%	⇐
	Paraplegia (acute anterior spinal artery syndrome): <1%	⇐
	Thromboembolism: rare (<5% in children)	⇐
Pain score	5–8	4–7

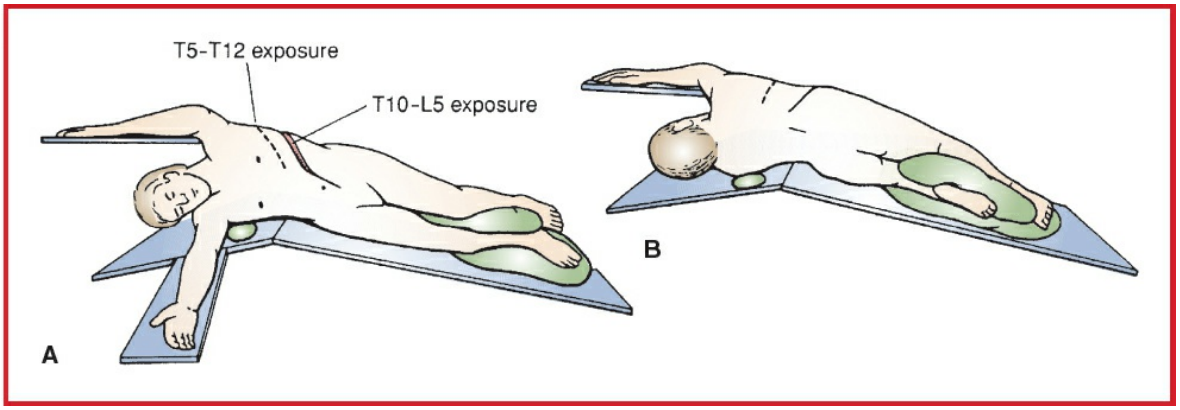

Figure 12.7-8 Lateral decubitus position (diagrammatic) for anterior spinal procedures: **(A)** anterior view; **(B)** posterior view. Roll is placed under axilla to minimize axillary artery compression. Skin incision for exposure of T5-T12 is shown with the dotted line. (Reproduced with permission from Chapman MW: Chapman's Orthopaedic Surgery, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

PATIENT POPULATION CHARACTERISTICS	
Age range	5–35 yr
Male:Female	Idiopathic: 1:10 Neuromuscular: 1:1
Incidence	<1/10,000
Etiology	Idiopathic scoliosis; neuromuscular disease (especially cerebral palsy, spina bifida, polio, myopathies, muscular dystrophies); other genetic bone dysplasias; Marfan syndrome
Associated conditions	See Associated Conditions for Posterior Spinal Instrumentation and Fusion.

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Spinal Reconstruction and Fusion.

Suggested Readings

1. Betz RR, Shufflebarger H: Anterior versus posterior instrumentation for the correction of thoracic idiopathic scoliosis. Spine 2001; 26(9):1095–100.
2. Mac-Thiong JM, Asghar J, Parent S, et al: Posterior convex release and interbody fusion for thoracic scoliosis: technical note. J Neurosurg Spine 2016; 25(3):357–65.
3. Rumalla K, Yarbrough CK, Pugely AJ, et al: Spinal fusion for pediatric neuromuscular scoliosis: national trends, complications, and in-hospital outcomes. J Neurosurg Spine 2016; 25(4):500–8.
4. Rusy LM, Hainsworth KR, Nelson TJ, et al: Gabapentin use in pediatric spinal fusion patients: a randomized, double-blind, controlled trial. Anesth Analg 2010; 110(5):1393–8.

PELVIC OSTEOTOMY

SURGICAL CONSIDERATIONS

Description

Pelvic osteotomy is used to improve coverage of the femoral head in cases of developmental hip dysplasia. Besides immediately increasing coverage, the osteotomy can stimulate the growth of a shallow acetabulum. It is frequently performed in

conjunction with open reduction and occasionally with femoral osteotomy. The surgical approach is made along the iliac crest, exposing the external (gluteal) surface of the iliac bone and sometimes the internal (iliac) surface as well. The pelvic osteotomy is performed just above the acetabulum and sometimes through the pubis and ischium, depending on the direction of rotation and reorientation desired. Pelvic osteotomies either reorient an intact acetabular hyaline cartilage surface or are designed as salvage procedures to enlarge the acetabulum by fibrocartilage metaplasia (see next section, Acetabular Augmentation and Chiari). **Salter innominate osteotomy** is the classic reorientation osteotomy, in which a complete cut of the supra-acetabular iliac bone allows rotation through the symphysis pubis. **Pemberton operation** is a slightly more difficult incomplete iliac osteotomy, rotating on the triradius cartilage (Fig. 12.7-9), which is at the center of the acetabulum in young children. The **Steel, "Dial,"** or **Eppright osteotomies** are the most difficult reorientation procedures. In each, the acetabulum is freed totally from any bony contact with the remainder of the pelvis and rotated into better position.

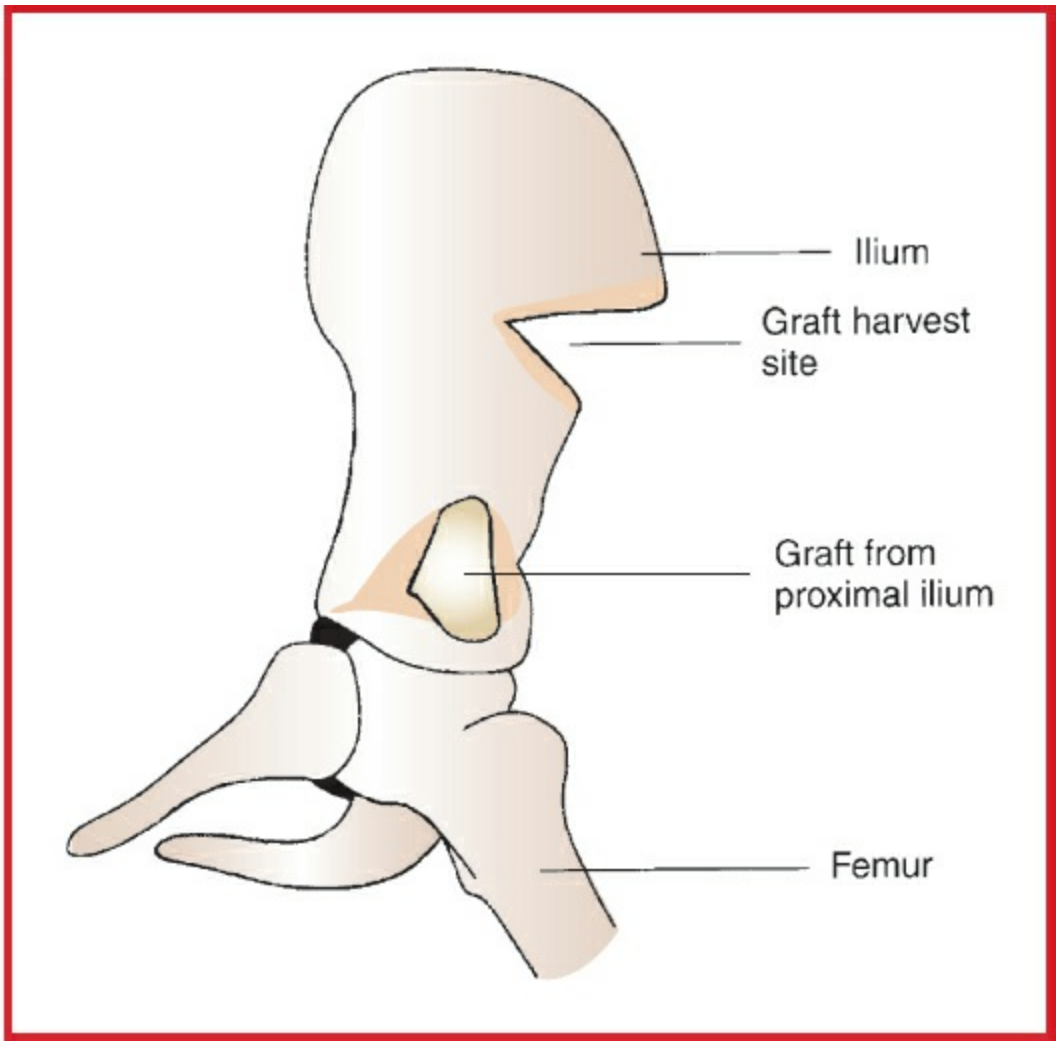

Figure 12.7-9 Pemberton osteotomy: A triangular graft is cut from the proximal ilium, and the graft is

carefully wedged into the osteotomy site. (Reproduced with permission from Chapman MW:Chapman's Orthopaedic Surgery, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Usual preop diagnosis

Acetabular dysplasia due to congenital or developmental hip dislocation

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, physical therapy, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Salter	Pemberton	Steel, Dial
Position	Supine or slightly lateral	⇐	⇐
Incision	Oblique or longitudinal anterior hip	⇐	⇐
Special instrumentation	Steinmann pins	Special curved, custom osteotomes	Steinmann pins
Unique considerations	Frequently follows previous unsuccessful open hip surgery	⇐	⇐ + additional ischial incision
Antibiotics	Usually cefazolin 25 mg/kg iv	⇐	⇐
Surgical time	1.5–2 h	2–3 h	2–4 h
Closing considerations	Hip spica	⇐	⇐
EBL	100–300 mL	⇐	200–600 mL
Postop care	PACU → room; care as needed for spica cast	⇐	⇐
Mortality	Minimal	⇐	⇐

Morbidity	Avascular necrosis of the hip: 5–6%	—	—
	Persistent hip subluxation: 5%	⇐	⇐
	Infection: 1%	⇐	⇐
	Sciatic or perineal palsy: <0.1%	⇐	⇐
	Excess bleeding from superior gluteal artery: Rare	⇐	Occasional
	Ileus: Rare	⇐	Occasional
Pain score	2–5	2–5	3–6

PATIENT POPULATION CHARACTERISTICS			
Age range	18 mo–6 yr, if dislocated 18 mo–10 yr, if only subluxated	18 mo–7 yr	12 yr
Male:Female	1:2	⇐	⇐
Incidence	1/10,000	1/10,000	1/10,000
Etiology	Congenital and/or developmental hip dysplasia: 98% Perthes disease: 1%	⇐	⇐
Associated conditions	Torticollis: <1%	⇐	⇐
	Other joint contractures in cases of neuromuscular dislocation: <1%	⇐	⇐

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities.

Suggested Readings

1. Dezateux C, Rosendahl K: Developmental dysplasia of the hip.Lancet 2007; 369(9572):1541–52.
2. Murphy RF, Kim YJ: Surgical management of pediatric developmental dysplasia of the hip. J Am Acad Orthop Surg 2016; 24(9):615–24.
3. Pogliacomi F, De Filippo M, Costantino C, et al: 2006: the value of pelvic and femoral osteotomies in hip surgery. Acta Biomed 2007; 78(1):60–70.

ACETABULAR AUGMENTATION (SHELF) AND CHIARI OSTEOTOMY

SURGICAL CONSIDERATIONS

Description

Acetabular augmentation is a “salvage” procedure used to deepen the hip socket when a realignment osteotomy of the pelvis and/or femur would not adequately cover the femoral head. This is accomplished by securing strips of cortical cancellous bone graft onto the proximal surface of the hip capsule. The surgical approach is anterior to the hip, elevating the gluteal muscles subperiosteally from the outer surface of the ilium. The reflected head of the rectus femoris tendon is elevated, and a domed-shaped slot is created just above the capsular attachment to the ilium. Abundant cortical cancellous strips of bone graft are then harvested from the upper two-thirds of the outer wall of the ilium. These bone grafts have a natural curve and lie on the convexity of the hip capsule. No internal fixation, other than suture repair, is used to hold the bone graft in place. This creates a large bony augmentation (shelf) over the uncovered femoral capsule.

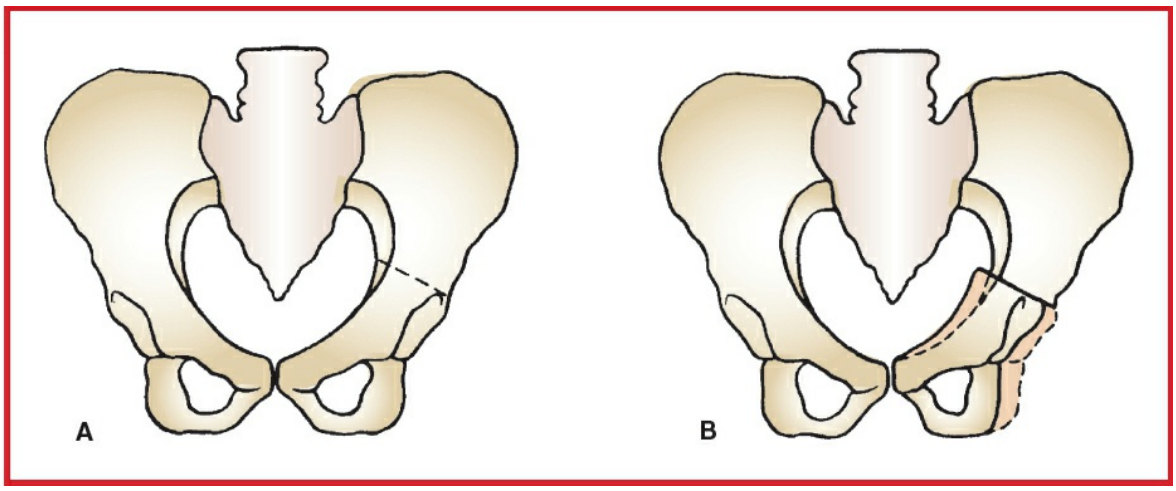

Figure 12.7-10 Chiari osteotomy. **A:** Line of osteotomy. **B:** Completed osteotomy. (Reprinted from Crenshaw AH, ed: Campbell's Operative Orthopaedics, 8th edition. Mosby-Year Book, St. Louis: 1992. Copyright © 1992 Elsevier. With permission.)

Variant procedure or approaches

The bone graft may be taken as a large, sculpted, solitary, cortical cancellous strut or wedge, or more commonly, as curved "shavings" anchored in a dome-shaped slot just above the hip capsule. In the **Chiari procedure**, a complete dome-shaped osteotomy allows lateral displacement of the ilium just above the proximal hip capsule (Fig. 12.7-10). The line of the osteotomy corresponds more or less with the slot of the shelf procedure. In either case, the result is abundant bony coverage over the hip capsule, which undergoes metaplasia into fibrocartilage.

Usual preop diagnosis

Acetabular dysplasia (shallow socket) due to congenital hip dislocation or developmental neurologic subluxation

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, physical therapy, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Acetabular Augmentation	Chiari Osteotomy
Position	Supine or slightly tilted up (reverse Trendelenburg's)	⇐ or lateral decubitus
Incision	Oblique or longitudinal; anterior hip region	⇐

Special instrumentation	Usually no internal fixation; I.I. or intraop x-ray	Two large screws or pins; I.I. or intraop x-ray
Antibiotics	Cefazolin 25 mg/kg iv	⇐
Surgical time	1.5–3 h	⇐
Closing considerations	Unilateral or 1.5 spica cast mandatory	Spica cast (optional)
EBL	100–500 mL	200–800 mL
Postop care	PACU → room. Care as necessary for cast	⇐
Mortality	Minimal	⇐
Morbidity	Lateral-femoral cutaneous nerve dysfunction: 30–50% Infection: 1%	Sciatic or peroneal palsy: 2% Possible need for later C-section: Rare
Pain score	4–6	4–6

PATIENT POPULATION CHARACTERISTICS

Age range	6–35 yr
Male:Female	1:1.5
Incidence	<1/10,000 in general population; in neuromuscular population (e.g., cerebral palsy, poliomyelitis residuals): 5–10%
Etiology	Neuromuscular hip subluxation with shallow acetabulum; residual shallow acetabulum (poor coverage from congenitally dislocated hip)
Associated conditions	Cerebral palsy; polio; spina bifida; myopathy; congenital atrophies; Charcot-Marie-Tooth disease

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities.

Suggested Readings

1. Fong HC, Lu W, Li YH, et al: Chiari osteotomy and shelf augmentation in the treatment of hip dysplasia. J Pediatr Orthop 2000; 20(6):740–4.
2. Ito H, Tanino H, Yamanaka Y, et al: The Chiari pelvic osteotomy for patients with dysplastic hips and poor joint congruency: long-term follow-up. J Bone Joint Surg Br 2011; 93(6):726–31.
3. Piontek T, Szulc A, Gowacki M, et al: Distant outcomes of the Chiari osteotomy 30 years follow up evaluation. Orthop Traumatol Rehabil 2006; 8(1):16–23.

OBER FASCIOTOMY AND YOUNT-OBER RELEASE

SURGICAL CONSIDERATIONS

Description

Ober fasciotomy is performed to release flexion, abduction, and external rotation contracture at the hip. This contracture usually occurs as a result of profound flaccid paralysis and prolonged positioning in a so-called frog position of 90° flexion, abduction, and lateral rotation at the hips. This results in tightening of the iliotibial (IT) band (the greatly thickened lateral aspect of the fascia lata) and related structures. The operation is performed through an anterolateral incision just distal to the iliac crest. All of the fascial investments of the tensor, sartorius, and, at times, the rectus femoris and gluteus medius and minimus are divided while preserving any normal-appearing muscle fibers. The limb is stretched into progressively more adduction and extension, until a neutral position can be obtained. The **Yount procedure** is added when the knee also is contracted in a flexed mode due to tightness of the IT band. The Yount procedure consists of further resection of a segment of the IT band and a lateral intermuscular septum through a separate distal midlateral longitudinal incision just above the knee. An oblique segment of the IT band and septum are removed and not repaired.

Usual preop diagnosis

Flaccid paralysis and "frog"-type contracture due to poliomyelitis, myelomeningocele, or myopathy

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, physical therapy, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Ober Fasciotomy	Yount-Ober Release
Position	Supine; both legs must be prepped and draped to well above the iliac crest area for intraop stretching.	⇐
Incision	Oblique iliac crest	Midlateral longitudinal above knee joint, ~10 cm
Unique considerations	Patients with sensory and motor loss have a tendency to get pressure sores.	⇐
Antibiotics	Usually none	⇐
Surgical time	1 h/side	30 min/side
Closing considerations	Bilateral above-knee casts	⇐
EBL	<150 mL	<50 mL
Postop care	PACU → room; extensive physical therapy program of stretching exercises. Myopathic patients are at risk for postop respiratory compromise.	⇐
Mortality	Minimal	⇐
Morbidity	Hematoma: ~1%	⇐
	Fracture of atrophied bone postop: <1%	⇐
	Infection <1%	⇐
	Pressure sores from positioning or casts: <1%	⇐
Pain score	3–4	3–4

PATIENT POPULATION CHARACTERISTICS

Age range	2–15 yr
Male:Female	1:1
Incidence	Extremely rare in children born in the United States; however, polio is seen commonly in southeast Asian and Latin American immigrants.
Etiology	Polio; myelomeningocele; myopathy or dystrophy
Associated conditions	Other contractures; incontinence; pressure sores in myelomeningocele

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities.

Suggested Readings

1. Irwin CE: The iliotibial band, its role in producing deformity in poliomyelitis.J Bone Joint Surg 1949; 31:141–52.
2. Ober FR: The role of the iliotibial band and fascia lata as a factor in the causation o low-back disabilities and sciatica. J Bone Joint Surg 1936; 18:105–19.

HIP, OPEN REDUCTION, AND FEMORAL SHORTENING

SURGICAL CONSIDERATIONS

Description

Open reduction of the hip replaces a dislocated femoral head into the anatomic acetabulum, at times after an unsuccessful attempt to reduce the hip by closed means. A developmental dislocation presents with a more normal acetabulum and occurs around birth or later. A teratologic congenital dislocation of the hip occurs early in utero and, as a result, has a high-riding dislocation with a poorly developed acetabulum, presenting much more difficulty in obtaining and maintaining reduction. The most common surgical approach is through an extended anterior incision. The hip capsule is exposed circumferentially, after division and tagging of the origins of the rectus, femoris, and sartorius muscles and retraction of the tensor and gluteal muscles. The iliopsoas tendon is either lengthened or divided. The capsule is opened in an oblique

fashion, the ligamentum teres is excised, and any obstacle to reduction is removed. The femoral head is replaced in the socket, and the capsule is repaired in a "vest-over-pants" imbrication, with the hip reduced under direct visualization (Fig. 12.7-11). A medial approach through the adductor region can be used in very young children (<18 mo) but does not allow a capsular repair. If femoral shortening is necessary, the surgical excision is either extended anterolaterally or a separate lateral incision is made longitudinally over the proximal femur.

Variant procedure or approaches

Most children <2 yr old can simply have the hip repositioned (back into the socket)—closed or open—and subsequently have normal hip development. In older children, especially with a high dislocation, a segment of the femur is removed subtrochanterically to allow reduction without pressure (thus allowing "descent" of the femoral head). If the acetabulum is very shallow, a pelvic osteotomy may be added (see Pelvic Osteotomy).

Usual preop diagnosis

Developmental dislocation of the hip; teratologic congenital dislocation of the hip

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

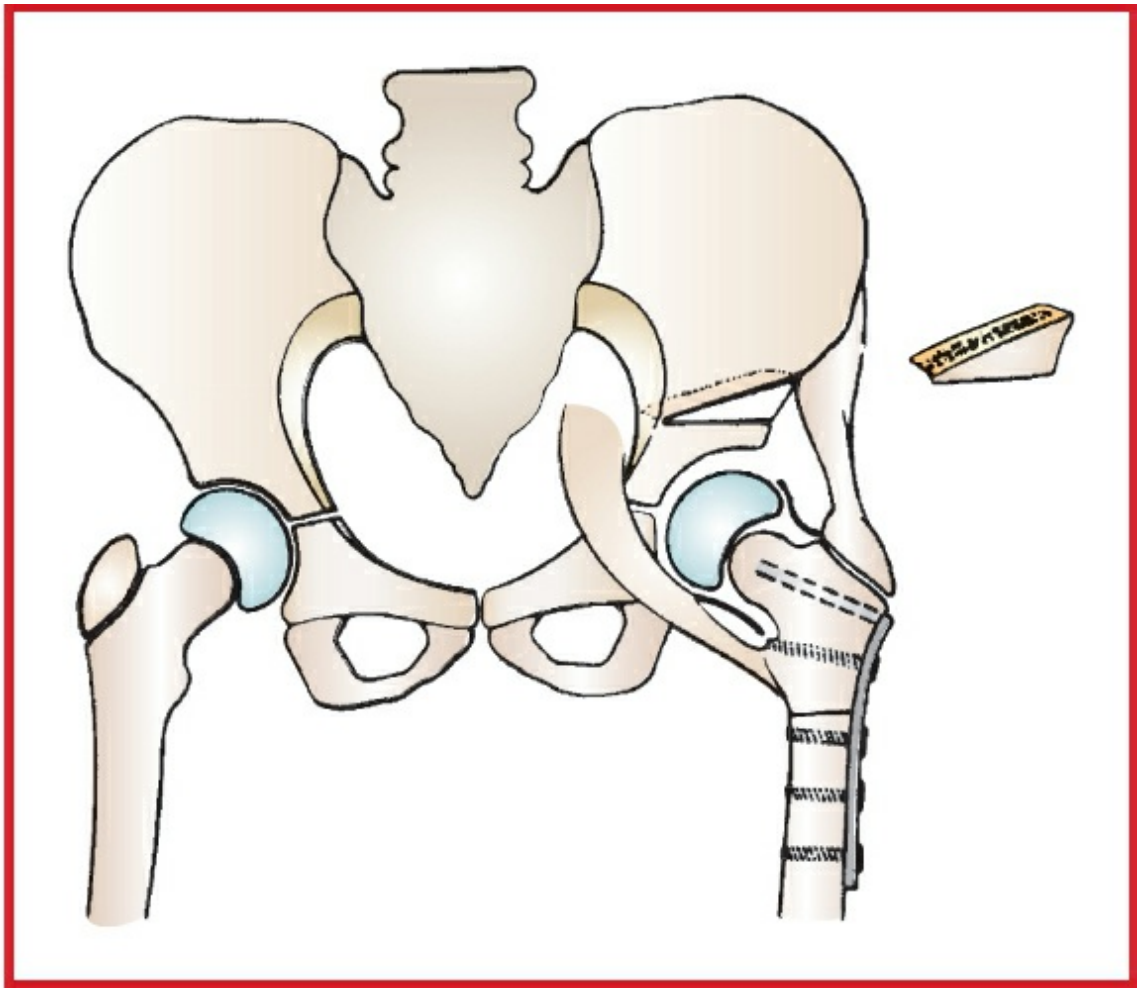

Figure 12.7-11 Open reduction with femoral shortening. (Reprinted from Crenshaw AH, ed: Campbell's Operative Orthopaedics, 8th edition. Mosby-Year Book, St. Louis: 1992. Copyright © 1992 Elsevier. With permission.)

SUMMARY OF PROCEDURES

	Open Reduction	Open Reduction + Femoral Shortening
Position	Supine	⇐
Incision	Oblique ("bikini") along the iliac crest or medial longitudinal over the joint	⇐ + anterolateral thigh over the joint
Special instrumentation	None	Plates and screws
Unique considerations	Preliminary arthrogram and, often, attempted closed reduction. I.I. are	⇐

	used.	
Antibiotics	Usually cefazolin 25 mg/kg iv	⇐
Surgical time	1.5–3 h	2–4 h
Closing considerations	Hip spica cast is applied on child's spica frame. **NB:** Do not wake patient until the last radiograph is taken, in case cast has to be reapplied.	⇐
EBL	<100 mL	100–400 mL
Postop care	PACU → room; care as necessary for spica cast	⇐
Mortality	Minimal	⇐
Morbidity	Avascular necrosis of femoral head	⇐
	Stiffness and late arthritis	⇐
	Limb-length discrepancy	⇐
	Marked scrotal or labial swelling: temporary	⇐
	Redislocation	⇐
	Infection	⇐
Pain score	2–4	3–5

PATIENT POPULATION CHARACTERISTICS

Age range	Closed reduction: 3 mo–3 yr Open reduction: 6 mo–10 yr Open reduction femoral shortening: 2–14 yr
Male:Female	1:5 (approximate)
Incidence	1:10,000
Etiology	Genetic background; breech presentation; firstborn girl
Associated	Arthrogryposis; Larsen disease; myelomeningocele;

conditions	chromosomal anomalies; congenital torticollis; cerebral palsy

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities.

Suggested Readings

1. Farsetti P, Caterini R, Potenza V, et al: Developmental dislocation of the hip successfully treated by preoperative traction and medial open reduction: a 22-year mean followup. Clin Orthop Relat Res 2015; 473(8):2658–69.
2. Hogan KA, Blake M, Gross RH: Subtrochanteric valgus osteotomy for chronicall dislocated, painful spastic hips. Surgical technique. J Bone Joint Surg 2007; 89(Suppl 2):226–31.
3. Kothari A, Grammatopoulos G, Hopewell S, et al: How does bony surgery affec results of anterior open reduction in walking-age children with developmental hip dysplasia? Clin Orthop Relat Res 2016; 474(5):1199–208.

ADDUCTOR RELEASE OR TRANSFER AND PSOAS RELEASE

SURGICAL CONSIDERATIONS

Description

Neuromuscular diseases (most often cerebral palsy) can cause spasticity throughout the body. At the hip, long-term spasticity can lead to adduction (adductors) and flexion (iliopsoas) contractures. The goal of surgical intervention varies based on the functional demands of the child (i.e., whether they are ambulatory or whether they need help with hygiene), but the general goal is to slightly weaken the hip adductors/flexors to allow greater motion. The same releases performed in cerebral palsy are often utilized in the treatment of other causes of hip contracture due to developmental hip dislocation, juvenile arthritis, etc.

The patient is positioned supine and the hip is abducted and externally rotated. Using a medial groin incision, the adductor tendons (adductor longus, adductor brevis, and gracilis) are isolated and divided with electrocautery. Using the same incision and in nonambulatory patients, the iliopsoas (hip flexor) tendon is located and divided at its

insertion onto the lesser trochanter. If less flexor lengthening is desired (i.e., ambulatory patients), the iliopsoas can be fractionally lengthened close to the pelvic brim. Variations of these procedures exist. In the classic **Banks** and **Green** procedure, the anterior branch of the obturator nerve is divided on the surface of the adductor brevis leading to more permanent adductor weakness. This procedure has lost popularity as the denervated muscles can undergo denervation fibrosis resulting in recurrent contracture. Some surgeons transfer the now released adductor longus and gracilis muscles to the ischium (posterior/lateral to the former origin) to convert the hip adductors into hip extensors by altering their direction of pull. At the end of the procedure, a long leg and/or spica cast is applied under anesthesia.

Usual preop diagnosis

Adduction and flexion contracture of the hip with subluxation due to cerebral palsy, acquired encephalopathy, or progressive neurologic disorder

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, physical therapy, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Adductor Release	Adductor Transfer	Psoas Release
Position	Supine	Supine or lithotomy	⇐
Incision	Medial proximal groin, longitudinal or transverse	Transverse medial groin	Anterior groin
Unique considerations	Frequently bilateral; often poor hygiene, especially if severe contracture; proximity to the perineum	⇐	⇐
Antibiotics	± cefazolin 25 mg/kg iv	⇐	⇐
Surgical time	1 h	1.5 h	1 h
Closing considerations	Bilateral leg casts or double spica cast	⇐	⇐

EBL	<100 mL	⇐	⇐
Postop care	PACU → room; care as necessary for spica cast	⇐	⇐
Mortality	Minimal	⇐	⇐
Morbidity	Hematoma, drainage	—	—
	Infection: <1%	⇐	⇐
	Recurrence of adduction deformity		
Pain score	2–4	2–4	2–4

PATIENT POPULATION CHARACTERISTICS	
Age range	2–20 yr
Male:Female	1:1
Incidence	0 in general population; 30% of cerebral palsy patients (0.6–5.9/1000)
Etiology	Cerebral palsy (90%); slowly progressive degenerative neurologic conditions (8–10%); head injury and drowning (1–2%)
Associated conditions	Multiple other contractures; GERD; poor general nutrition; developmental delay

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities.

Suggested Readings

1. Aversano MW, Sheikh Taha AM, Mundluru S, et al: What's new in the orthopaedic treatment of cerebral palsy. J Pediatr Orthop 2017; 37(3):210–6.
2. El Hage S, Rachkidi R, Noun Z, et al: Is percutaneous adductor tenotomy as effective and safe as the open procedure? J Pediatr Orthop 2010; 30:485–8.
3. Presedo A, Oh CW, Dabney KW, et al: Soft-tissue releases to treat spastic hip subluxation in children with cerebral palsy. J Bone Joint Surg 2005; 87:832–41.
4. Reimers J, Poulsen S: Adductor transfer versus tenotomy for stability of the hip in spastic cerebral palsy. J Pediatr Orthop 1984; 4(1):52–4.

PINNING OF SLIPPED CAPITAL FEMORAL EPIPHYSIS

SURGICAL CONSIDERATIONS

Description

During rapid growth period, the shearing stress of the body weight on the hip joint may cause the femoral head (capital epiphysis) to gradually (over weeks to months) slide posteriorly and inferiorly relative to the femoral neck by shearing through the "physis" or growth plate—termed **slipped capital femoral epiphysis (SCFE)**. Although most SCFE present with chronic symptoms (85%), patients can also present after mild trauma (fracture through the growth plate). This can occur unilaterally or bilaterally. The most common treatments are percutaneous **in situ pinning** (without reduction) or **modified Dunn procedure** (with open reduction), which are used to prevent further slipping of the epiphysis on the growth plate. Using intraop fluoroscopy for guidance, usually one (occasionally two) cannulated screw is placed percutaneously through the anterolateral aspect of the femoral neck into the femoral head epiphysis. Historically, pins (rather than screws) were used for fixation, but there was a high rate of pin complications (i.e., migration to be intra-articular with chondral damage).

Variant procedure or approaches

After the physis is closed, if there is severe residual deformity, a corrective osteotomy is performed in the trochanteric region (see Proximal Femoral Osteotomy, Southwick Procedure). If the surgeon believes that it is not possible to place a screw from the neck to the head (i.e., slip is too severe), **open epiphysiodesis with bone grafting** is an option. This is performed through an anterolateral groin incision, where the hip capsule is opened widely, and the growth plate is curetted before placing bone graft (usually harvested from the iliac crest) across it (linking the femoral head/neck). A body spica cast is frequently needed.

Usual preop diagnosis

Acute or chronic SCFE

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Pinning of SCFE	Variant Open Epiphysiodesis
Position	Supine	⇐
Incision	Short, proximal thigh or stab incision	Anterolateral groin
Special instrumentation	Guide wires; cannulated screws; I.I.; fracture table	I.I. (recommended)
Unique considerations	Frequently bilateral (≤20%); often obese	⇐
Antibiotics	Cefazolin 25 mg/kg up to 1–2 g iv	⇐
Surgical time	0.5–2 h	1–3 h
Closing considerations	None	Frequently needs spica cast
EBL	Negligible	200–500 mL
Postop care	PACU → room	Body spica cast, occasionally
Mortality	Minimal	⇐
Morbidity	Unsuspected pin penetration: ≤37%	⇐
	Avascular necrosis: ≤33% (in acute slip cases)	⇐
	Chondrolysis, hip stiffness: 1–28%	⇐
	Fracture after pin removal: <1%	⇐
	Infection: <1%	
Pain score	2–3	2–3

PATIENT POPULATION CHARACTERISTICS

Age range	10–16 yr
Male:Female	2–3:1
Incidence	1–3/100,000 (higher in African Americans)

Etiology	Excessive loading of the growth plate (obesity or increased angle of inclination of the physis) Insufficient tensile strength of collagen and proteoglycans around the femoral neck Increased thickness of the physis as from excessive growth hormone, hypogonadism, hypothyroidism, hyperparathyroidism, renal osteodystrophy, almost any other significant endocrinopathy Radiation therapy
Associated conditions	Obesity; endocrinopathies; renal osteodystrophy

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities.

Suggested Readings

1. Castillo C, Mendez M: Slipped capital femoral epiphysis: a review for pediatricians Pediatr Ann 2018; 47(9):e377–80.
2. Davis RL II, Samora WP III, Persinger F, et al: Treatment of unstable versus stabl slipped capital femoral epiphysis using the modified Dunn procedure. J Pediatr Orthop 2018; 38(1):3–8.
3. Novais EN, Millis MB: Slipped capital femoral epiphysis: prevalence, pathogenesis and natural history. Clin Orthop Relat Res 2012; 470:3432–8.
4. Sucato DJ: Approach to the hip for SCFE: the North American perspectiveJ Pediatr Orthop 2018; 38(Suppl 1):S5–12.

FLEXIBLE INTRAMEDULLARY NAILING OF LONG-BONE FRACTURES

SURGICAL CONSIDERATIONS

Description

Stabilization of long-bone fractures with flexible nails is used in both the upper and lower extremities. These implants can be placed through small incisions and allow the surgeon to take advantage of its elastic memory to exert balanced dynamic force to hold

the reduction. As a result, immobilization (splinting or casting) and prolonged immobility are often unnecessary. For femur fractures, in comparison to standard rigid nails used in older children and adults for the femur, the entry site for flexible nails is distal to the femoral neck and does not risk the blood supply to the femoral head.

This technique can be utilized for femur, tibia, radius, ulna, and humerus fractures. The child is placed supine on either a radiolucent operating table (or fracture table for the lower extremity) to allow intraoperative fluoroscopy. Closed reduction is attempted, but with the surgeon proceeding with an open reduction if it fails. After the fracture is aligned, a small incision is made and dissection is carried down to the periosteum where a small hole is made in the cortex. This hole allows the flexible nail to enter the medullary canal and be passed either retrograde or anterograde across the fracture site while being contoured by the surgeon. No intramedullary reaming is performed before nail insertion. Intraop imaging is used to assess for rotational and angular stability and for possible rare need for cast application.

Usual preop diagnosis

Fracture

ERAS: Family preop counseling by the surgeon/anesthesiologist should include: limiting NPO duration, review of nutritional status, postop care, and pain management options (Fig. 12.7-12). See Appendix K: Pediatric ERAS, p. K-6 to K-8.

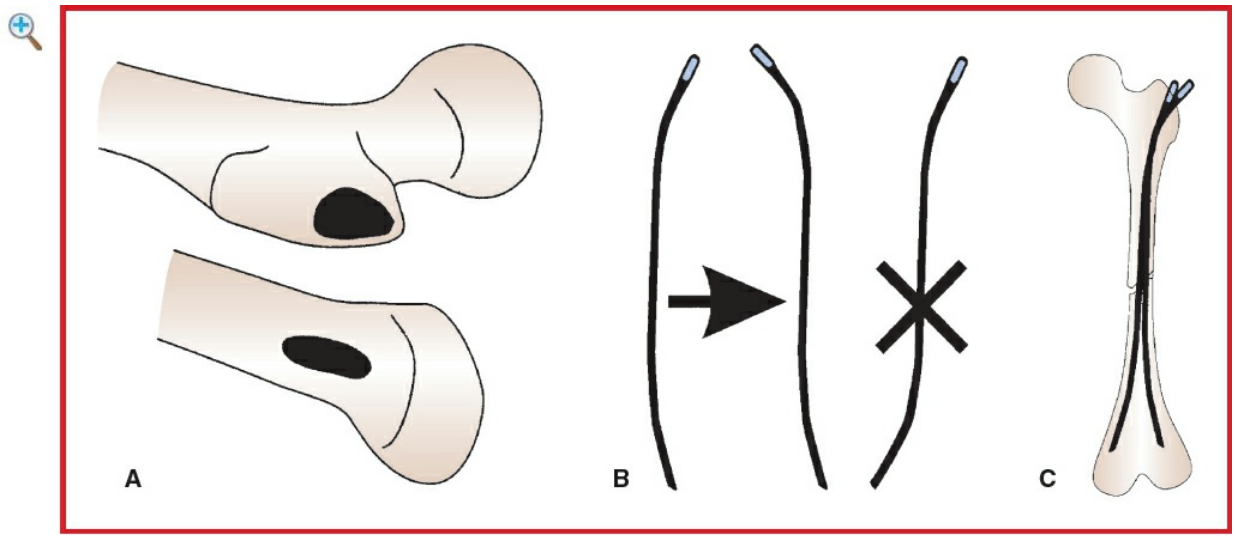

Figure 12.7-12 Intramedullary nailing. **A:** Nail entry site through the greater trochanter (antegrade) or distal metaphysic (retrograde). **B:** Nails are contoured before insertion. **C:** Fracture stabilized with two antegrade nails. (Reproduced with permission from Chapman MW: Chapman's Orthopaedic Surgery, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

SUMMARY OF PROCEDURES

	Closed Reduction	Open Reduction
Position	Supine; radiolucent table; may be performed on fracture table if femoral	⇐
Incision	2–3 cm at entry site for each nail	Incision at fracture site and 2–3 cm at entry site for each nail
Instrumentation	Intramedullary nails, power drill, I.I.	⇐
Unique considerations	Blood loss from fracture; muscle relaxation may be necessary to obtain reduction.	⇐
Antibiotics	Cefazolin 25 mg/kg	⇐
Surgical time	45–60 min	60–90 min
Closing considerations	May supplement with cast	⇐
EBL	Minimal	50–200 mL
Postoperative care	PACU → room	⇐
Mortality	Rare, except in multitrauma	⇐
Morbidity	Nonunion, malunion	⇐
	Shortening	⇐
	Infection	⇐
	Painful instrumentation	⇐
Pain score	4–7	4–7

PATIENT POPULATION CHARACTERISTICS

Age range	6–14 yr
Male:Female	2.6:1

Incidence	19/100,000 for femoral shaft
Etiology	Trauma
Associated conditions	Usually normal, healthy child

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities.

Suggested Readings

1. Kelly DM: Flexible intramedullary nailing of pediatric humeral fractures: indications, techniques, and tips. J Pediatr Orthop 2016; 36(Suppl 1):S49–55.
2. Kocher MS, Sink EL, Blasier RD, et al: Treatment of pediatric diaphyseal femur fractures. J Am Acad Orthop Surg 2009; 17:718–25.
3. Rathjen KE, Riccio AI, De La Garza D: Stainless steel flexible intramedullary fixation of unstable femoral shaft fractures in children. J Pediatr Orthop 2007; 27:432–41.

PROXIMAL FEMORAL OSTEOTOMY

SURGICAL CONSIDERATIONS

Description

Femoral osteotomies are performed in the inter- or subtrochanteric region to redirect the femoral head more superiorly (valgus) or inferiorly (varus) and/or for rotational correction of excessive rotational deformities (anteversion or retroversion). The usual surgical approach is direct lateral over the proximal femoral shaft (just distal of the greater trochanter). The deep fascia is split, and the underlying vastus muscle is elevated subperiosteally to expose the femoral shaft. The osteotomy site is confirmed with fluoroscopy before being cut using a power saw. This creates two free fragments that are realigned prior to applying fixation, which is commonly achieved with plate/screws.

Variant procedure or approaches

Different named plates (e.g., AO blade, Coventry screw, Richards screw, Wagner) may be used to affix the proximal to the distal femoral segments. In the case of a chronic

superior hip dislocation (i.e., developmental dysplasia of the hip), a 1- to 4-cm segment of femur may be removed to allow soft tissue relaxation and descent of the femoral head into the socket. Most proximal femoral osteotomies are performed in the subtrochanteric area, but some are performed in the intertrochanteric or base of the neck (**Kramer compensating**). The **Southwick osteotomy** is an example of a more complicated subtrochanteric osteotomy, which allows correction in three directions (varus, lateral rotation, and extension).

Usual preop diagnosis

Developmental hip subluxation; excessive hip anteversion; residual deformity from Perthes disease; coxa vara; SCFE; residual deformity

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, physical therapy, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Varus Derotation Osteotomy + Plate and Screws	Southwick or Kramer
Position	Supine	⇐
Incision	Lateral thigh or, occasionally, long anterior thigh	⇐
Special instrumentation	Plate and screws; power drill and saw; I.I.	Plate and screws; power drill and saw; I.I.
Unique considerations	Fracture or radiolucent table	⇐
Antibiotics	± Cefazolin 25 mg/kg iv	⇐
Surgical time	1.5–2.5 h	2–4 h
Closing considerations	Spica cast, frequently	Spica cast, occasionally
EBL	250–750 mL	500–1000 mL
Postop care	PACU → room. Spica cast Non–weight bearing ~6 wk; no full	⇐

	weight bearing, 3 mo	
Mortality	Minimal	⇐
Morbidity	Persistent hip dysplasia: 5–20% (depending on etiology)	⇐
	Excess blood loss from a perforating branch of the profunda femoris: <1%	⇐
	Infection: <1%	⇐
	Loss of fixation, instrument failure: <1%	⇐
	Nonunion: <1%	⇐
	Persistent hip stiffness: <1%	⇐
	Avascular necrosis: rare	⇐
Pain score	6–8	6–8

PATIENT POPULATION CHARACTERISTICS

Age range	2–21 yr
Male:Female	1:1
Incidence	Depending on Dx
Etiology	Coxa varum, coxa valgum due to muscle imbalance; hip dislocation; excessive medial femoral torsion (anteversion); osteochondrodystrophies (dwarfing syndromes); Perthes disease; SCFE
Associated conditions	Cerebral palsy; myelomeningocele, neuromyopathies; congenital hip dislocation; occasionally, hypothyroidism as a cause of SCFE

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities.

Suggested Readings

1. Aprato A, Leunig M, Massé A, et al: Instability of the hip after anatomical re· alignment in patients with a slipped capital femoral epiphysis. Bone Joint J 2017; 99-B(1):16–21.
2. Koyonos L, Slenker N, Cohen S: Complications in brief: osteotomy for lowe extremity malalignment. Clin Orthop Relat Res 2012; 470:3630–6.
3. Park KW, Shah IP, Ramanathan AK, et al: Proximal femoral osteotomy in Legg Calvé-Perthes disease using a monolateral external fixator: surgical technique, outcome, and complications. J Pediatr Orthop B 2017; 26(4):329–35.
4. Raney EM, Grogan DP, Hurley ME, et al: The role of proximal femoral valgu osteotomy in Legg-Calve-Perthes disease. Orthopedics 2002; 25(5):513–7.

EPIPHYSIODESIS

SURGICAL CONSIDERATIONS

Description

Epiphysiodesis is performed in skeletally immature adolescents with a significant leg-length discrepancy (anisomelia) to modify the growth in either the ipsilateral or contralateral lower extremity. The timing of the procedure is critical and is based on the child's bone age (growth remaining) and the amount of length discrepancy (between the two lower extremities).

At the precise age determined by these methods, the epiphysiodesis procedure can be completed (most commonly at the distal femoral and proximal tibial physes) using multiple available options for modulating growth at the physis, including bone blocks, drilling, staples, and small two-hole plates ("eight plates"). The original techniques described by **Phemister** (Fig. 12.7-13), **White**, and **Stubbins** involved removing a ¾″–1¼″ square or rectangular block of bone from the center of the physis using a box chisel, which was rotated 90° or 180° and reinserted to create a bone bridge across the physis. Another option for permanent closure is **physeal drilling**, which can be accomplished percutaneously using fluoroscopic guidance. **Blount** described the use of stout, reinforced staples bridging over the physis (using a tension band–type mechanism) inserted medially and laterally at the knee through small incisions (1″). This procedure causes compression of the physis to prevent growth. Another similar technique that has become popular recently is the use of small two-hole plates ("eight plates"). Both of these techniques provide the theoretical advantage of being reversible (i.e., resumption of growth after hardware removal) if overcorrection is found with follow-up.

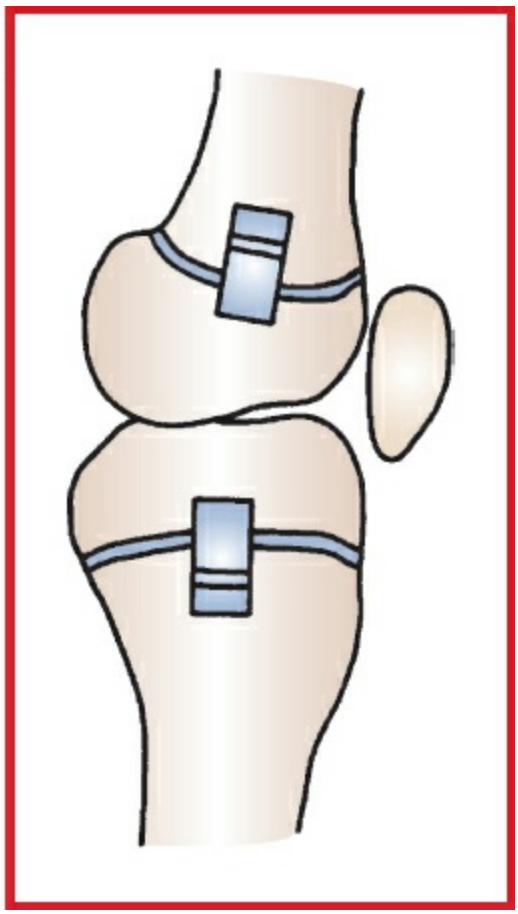

Figure 12.7-13 Phemister method of epiphysiodesis (block of bone reversed and then reinserted to form osseous bar). (Reproduced with permission from Chapman MW:Chapman's Orthopaedic Surgery, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Usual preop diagnosis

Limb-length discrepancies of 2–5 cm in adolescents (willing to accept a slight diminution in adult stature)

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Open Epiphysiodesis	Percutaneous Epiphysiodesis	Epiphyseal Stapling
Position	Supine, with tourniquet	Supine	Supine, with tourniquet
Incision	3–4-cm longitudinal	1 cm, same	4–5 cm, same

	incision, medial and laterally centered incisions over distal femoral and/or proximal tibial epiphysis	area as open epiphysiodesis	area as open epiphysiodesis
Special instrumentation	Box chisel	Drill point and sleeve	Heavy, reinforced staples
Unique considerations	Tourniquet used	I.I. mandatory; tourniquet (optional)	⇐
Antibiotics	± Cefazolin 25 mg/kg iv	⇐	⇐
Surgical time	1 h	⇐	⇐
Closing considerations	Cylinder cast or knee immobilizer	⇐	⇐
EBL	<50 mL	⇐	⇐
Postop care	PACU → room; crutches for comfort	⇐	⇐
Mortality	Minimal	⇐	⇐
Morbidity	Under- or overcorrection with regard to length: 5–10%	⇐	⇐
	Wound problems: <5%	⇐	⇐
	Asymmetric growth arrest → valgus or varus deformity: 2–5%	⇐	⇐
	Anterior or lateral compartment syndrome: 1%	—	—
	Fracture: 1%	—	—
	Peroneal palsy: <1%	—	—

Pain score	3–5	2–3	3–5

PATIENT POPULATION CHARACTERISTICS

Age range	9–14 yr (adolescents, usually healthy with limb-length discrepancy 2–6 cm)
Male:Female	1:1
Incidence	<1/1000
Etiology	Idiopathic hemihypertrophy; neurologic (e.g., polio, hemiplegia); congenital deformities of the lower extremities (e.g., congenitally short femur, fibular hemimelia); osteomyelitis; development of tumorous conditions (e.g., enchondromatosis); traumatic growth plate injuries occurring near puberty; epiphyseal problems related to the hip (slipped epiphysis, sequelae of Perthes disease); Klippel-Trenaunay-Weber syndrome
Associated conditions	Other contractures in neurologic conditions (e.g., polio); neurofibromatosis, AV fistulae; Wilms tumor (rare)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities.

Suggested Readings

1. Bayhan IA, Karatas AF, Rogers KJ, et al: Comparing percutaneous physeal epiphysiodesis and eight-plate epiphysiodesis for the treatment of limb length discrepancy. J Pediatr Orthop 2017; 37(5):323–7.
2. Kemnitz S, Moens P, Fabry G: Percutaneous epiphysiodesis for leg length discrepancy. J Pediatr Orthop 2003; 12(1):69–71.
3. Lawing C, Margalit A, Ukwuani G, et al: Predicting late follow-up and understanding its consequences in growth modulation for pediatric lower limb deformities. J Pediatr Orthop 2019; 39(6):295–301. doi: 10.1097/BPO.0000000000000951.
4. Waseem M, Fischer J, Paton RW: Partial percutaneous epiphysiodesis in patients with congenital abnormalities of the growth plates. J Pediatr Orthop B 2004; 13:39–42.

SOFIELD PROCEDURE

SURGICAL CONSIDERATIONS

Description

Long-bone deformities are common in certain conditions, such as osteogenesis imperfecta. These can be corrected using a **Sofield procedure** (fragmentation rodding) in an attempt to reduce recurrent fractures, to allow bracing, and/or to aid ambulation. These types of procedures are needed less frequently in the upper extremities.

The procedure involves exposure of at least one end of the long bone (to insert fixation) and exposure of a varying amount of the long bone shaft (to allow multiple osteotomies to be created). If the deformity is severe, the entire shaft is exposed via a longitudinal incision, usually laterally. By creating multiple osteotomies (usually 2–4), a curved/deformed bone can be manipulated piecemeal (similar to a "shish kebab") to allow a straight intramedullary rod to traverse all of the segments.

Variant procedure or approaches

As these surgeries are done on children with growing bone, the bone can continue to elongate beyond the end of the intramedullary rod in some cases. The unsupported portion of the bone will be liable to fracture and to developing a new deformity—often requiring revision surgery. To address this, **Bailey** and **Dubow** developed an elongating (or growing) rod system that telescopes (similar to a car radio antenna) within the bone to allow for some growth. The surgical technique for insertion of the rod is, however, identical to any fragmentation rodding, except that both ends of the bone must be exposed. Similar elongation can be accomplished with a **Fassier-Duval** rod without requiring exposure of both bone ends.

Usual preop diagnosis

Osteogenesis imperfecta; fibrous dysplasia (occasionally); rickets; congenital pseudarthrosis of the tibia

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, physical therapy, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE

Position	Supine

Incision	Lateral for femur; anterolateral for tibia
Special instrumentation	± fluoroscopy (I.I.) table
Unique considerations	Tendency to hyperthermia; other bones may fracture in more severe cases, even as a result of a BP cuff. If dentinogenesis imperfecta is present, extreme care should be taken during intubation to prevent tooth trauma. In these patients, neck motion is often limited.
Antibiotics	Cefazolin 25 mg/kg iv
Surgical time	1–1.5 h/tibia; 1.5–2.5 h/femur (often done sequentially on the same day)
Closing considerations	Double spica cast if the femur is rodded.
EBL	Depending on patient age and size, as well as use of a tourniquet for the femur, 50–250 mL; for the tibia, 50–100 mL
Postop care	PACU → room; avoid trauma to the mouth or other bones in PACU.
Mortality	<1% (usually related to severe restrictive lung disease, in the most severely involved cases)
Morbidity	Intraop hyperthermia: common Intraop fracture of other bones Late rod migration: common Late refracture: common Nonunion: rare Exuberant callus simulating osteosarcoma: rare Infection: <1% of rodding Radial nerve palsy (in cases of the humerus or radius rodding)
Pain score	2–3 (It is surprising how little discomfort these children have, especially the 2nd or 3rd time a bone is rodded.)

PATIENT POPULATION CHARACTERISTICS

Age range	2–25 yr
Male:Female	1:1
Incidence	1/20,000 (osteogenesis imperfecta); other etiologies much less common
Etiology	Congenital (hereditary deficit in collagen synthesis), most commonly as autosomal dominant or spontaneous mutation: all cases
Associated conditions	Dentinogenesis imperfecta; diminished vital capacity due to associated kyphoscoliosis ↓ hearing due to otosclerosis and impingement of the 8th cranial nerve; pelvic distortion causing chronic constipation; basilar impression and other C-spine abnormalities causing brainstem compression or even hydrocephalus (rare)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities.

Suggested Readings

1. Azzam KA, Rush ET, Burke BR, et al: Mid-term results of femoral and tibial osteotomies and fassier-duval nailing in children with osteogenesis imperfecta. J Pediatr Orthop 2018; 38(6):331–6.
2. Gamble JG, Strudwick WJ, Rinsky LA, et al: Complications of intramedullary rods in osteogenesis imperfecta: Bailey-Dubow rods versus non-elongating rods. J Pediatr Orthop 1988; 8(6):645–9.
3. Scollan JP, Jauregui JJ, Jacobsen CM, et al: The outcomes of nonelongating intramedullary fixation of the lower extremity for pediatric osteogenesis imperfecta patients: a meta-analysis. J Pediatr Orthop 2017; 37(5):e313–6.

LIMB LENGTHENING

SURGICAL CONSIDERATIONS

Description

Limb lengthening usually is performed in the lower extremity for congenital or acquired

leg-length discrepancies of at least 5 cm. Lesser discrepancies are dealt with by bone shortening or epiphysiodesis of the longer extremity. The basic principles include (a) application of an adjustable, external fixator; (b) "low-energy," transverse bone cut (osteotomy without the use of a power saw) through a small, longitudinal incision over the involved bone; (c) preservation of the periosteal sleeve; (d) gradual lengthening, usually 1 mm/d in fractional adjustments; and (e) when the desired limb length is obtained, either using bone graft and plate acutely or leaving until the bone gap fills in and stabilizes (average 38 d/cm gained).

Limb lengthening dates back to the early 1900s, but it fell into disfavor because of the high rate of major complications. **Wagner** improved the technique by introducing a simplified, unilateral, large-pin fixator, but performed the osteotomy in the midshaft and began lengthening immediately (Fig. 12.7-14). The patient is followed radiographically to allow modification of the lengthening speed (mm/d), pin care and/or exchange, and revision of the external fixator alignment if needed. This technique usually requires a bone graft and later plating as a second operation to obtain healing. **DeBastiani** used a similar large-pin fixator (**Orthofix**) but performed the osteotomy more toward the end of the bone in the metaphysis and waited 1 wk before beginning lengthening. Spontaneous healing was commonly achieved without bone grafting. **Ilizarov** introduced a more complex, but more adaptable (i.e., changing translation, angulation, and/or rotation during treatment), small-pin transfixation system with a circular fixator. This alternate fixator is used in a similar fashion with an osteotomy within the metaphysis to create a site of healing callus, which is stretched (callotasis) to gain length. When the desired additional length is reached (usually between 4 and 10 cm), the distraction is stopped and the callus is allowed to consolidate (heal) into the bone. Recently, some authors have shown good results with the addition of an intramedullary nail as an internal guide while the distraction is produced with an external fixator.

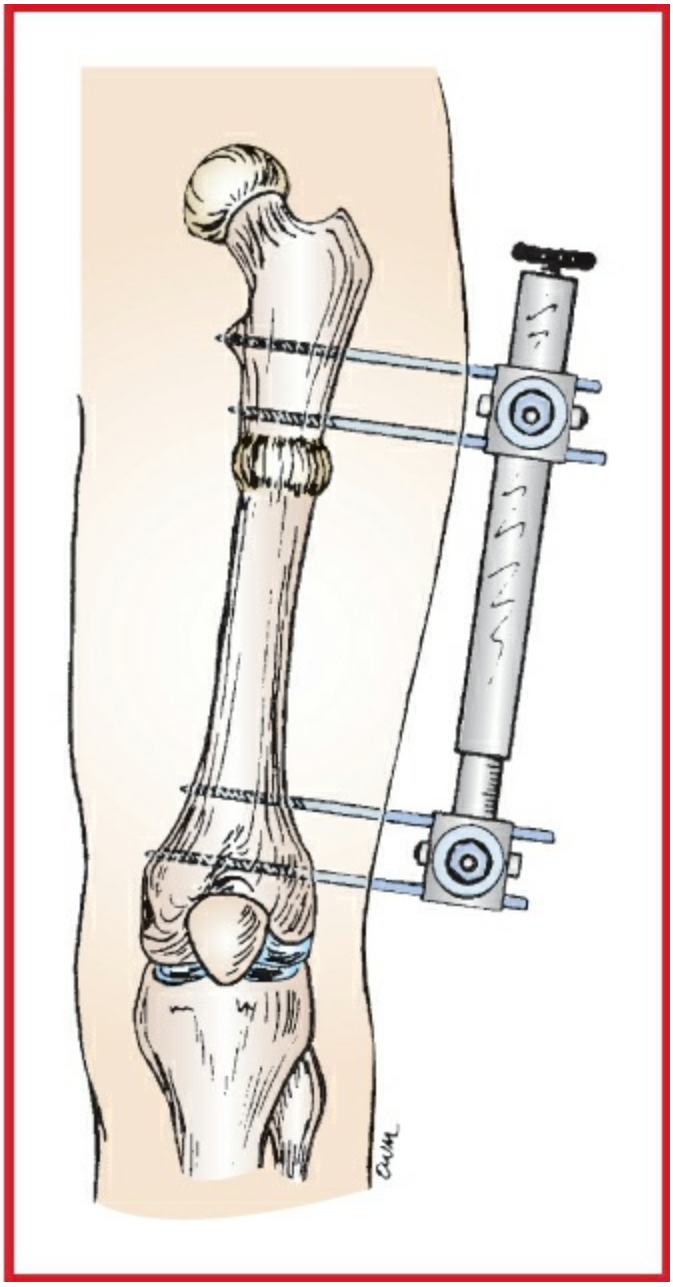

Figure 12.7-14 Wagner apparatus for leg lengthening. (Reproduced with permission from Chapman MW, ed: Operative Orthopaedics, 2nd edition. J. B. Lippincott, Philadelphia: 1993.)

Usual preop diagnosis

Congenital or acquired anisomelia (limb-length discrepancy) due to overgrowth or growth retardation >5 cm

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, physical therapy, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Wagner	Orthofix	Ilizarov
Position	Supine	⇐	⇐
Incision	Longitudinal midshaft	Longitudinal proximal shaft (metaphyseal)	⇐
Special instrumentation	I.I.; Wagner device (Fig. 12.7-14); large bone pins	I.I.; Orthofix device; large bone pins	Ilizarov frame ("Erector set"); multiple 1.5–1.8 mm small-diameter wires
Unique considerations	Acute lengthening may cause ↑ BP.	—	Frame should be prepped prior to surgery because of "fiddle factor."
Antibiotics	Cefazolin 25 mg/kg iv	⇐	⇐
Surgical time	1–2 h	⇐	2–4 h
EBL	<100 mL	⇐	⇐
Postop care	PACU → room; early initiation of physical therapy and/or CPM machine	⇐	⇐
Mortality	Minimal	⇐	⇐
Morbidity	While the device remains in place, at least one of the following complications is		

	usual; frequently, several occur before healing is complete:		
	• Joint stiffness or localized pin infection: Very common (50% temporary)	⇐	⇐
	• Edema, swelling, pressure sores: Common	⇐	⇐
	• Joint subluxation: Common	⇐	⇐
	• Psychological decompensation due to pain: Common	⇐	⇐
	• Premature consolidation: Common	⇐	⇐
	• Skin necrosis: Common	⇐	⇐
	• Wound infection: Common	⇐	⇐
	• Localized osteomyelitis: Common	⇐	⇐
	• Axial deviation of the bone: Common	⇐	⇐
	• Delayed union, nonunion, late fracture: Common	⇐	⇐
	• Pin penetration of a vessel or nerve: Rare	⇐	⇐
	• Compartment syndrome: Rare	⇐	⇐
	• Student atrophy: Rare	⇐	⇐
Pain score	7–8	7–8	7–8

PATIENT POPULATION CHARACTERISTICS

Age range	10–30 yr
Male:Female	1:1

Incidence	Dependent on underlying Dx (common in polio)
Etiology	Congenital deficiencies of the lower extremities (e.g., proximal focal femoral deficiency, congenitally short femur, fibular hemimelia); osteomyelitis, traumatic growth plate injury, fracture; asymmetric neurologic conditions (e.g., polio or cerebral palsy); congenital hemihypertrophy
Associated conditions	Hip and knee contractures; in cases of polio, other deformities, and weaknesses; AVM; congenital or developmental hip dislocation

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities.

Suggested Readings

1. Friend L, Widmann RF: Advances in management of limb length discrepancy and lower limb deformity. Curr Opin Pediatr 2008; 20(1):46–51.
2. Gordon JE, Manske MC, Lewis TR, et al: Femoral lengthening over a pediatric femoral nail: results and complications. J Pediatr Orthop 2013; 33(7):730–6.
3. Hamdy RC, Bernstein M, Fragomen AT, et al: What's new in limb lengthening and deformity correction. J Bone Joint Surg Am 2017; 99(16):1408–14.

PATELLAR REALIGNMENT

SURGICAL CONSIDERATIONS

Description

Patellar realignment encompasses over 100 procedures designed to prevent lateral subluxation and dislocation of the patella. These disorders include a spectrum of malalignments of the patella, ranging from simple excess lateral tilt, recurrent partial subluxation, and recurrent episodic dislocation to irreducible chronic dislocation. As such, the surgical procedures also encompass a spectrum of complexities, depending on the degree of instability. Nowadays, an arthroscopic inspection often is performed first. The basic principles of the repair include both proximal and distal realignments. **Proximal realignment** includes (a) lateral release, which is the division of the

contracted lateral patellar retinacular joint capsule and other tight lateral tissue, the first step in all surgical repair; (b) medial tightening, including reefing and/or advancement of the medial capsule and vastus medialis muscle insertion; and (c) distal realignment, consisting of redirection of the patellar tendon more medially (and sometimes more anteriorly).

Variant procedure or approaches

Arthroscopic or open lateral release is the simplest and first-step procedure. It may be sufficient when there is only subluxation and not true dislocation, and it has the advantage of being an outpatient procedure. For frank dislocation, an open "proximal realignment" also includes the medial tautening. If this is not sufficient to hold the patella centralized and if the patient has open epiphyses (<16 yr), the lateral half of the patellar tendon may be released (distal realignment) and reattached medially (**Roux-Goldthwait**), or the patella may be held medially by tenodesing the semitendinosus tendon to it. In skeletally mature patients, the bony insertion of the patellar tendon is osteotomized and transferred medially (**Trillat**) or anteromedially (**Maquet**). The **Hauser procedure** of distal and medial transfer of the tibial tubercle has had a very poor long-term outcome and is seldom performed.

Usual preop diagnosis

Lateral patellar subluxation; recurrent dislocation; congenital or chronic lateral patellar dislocation

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, postop care, and pain management options. **See Appendix K: Pediatric ERAS, p. K-6 to K-8.**

SUMMARY OF PROCEDURES

	Proximal Realignment	Trillat	Maquet
Position	Supine, with tourniquet	⇐	⇐
Incision	Anterior transverse or longitudinal or oblique, about the knee, or arthroscopic	Anterior longitudinal	Transverse or oblique
Special instrumentation	None	Single bone screw	⇐

Unique considerations	Tourniquet	⇐	May use iliac or bank bone graft
Antibiotics	Optional, cefazolin 25 mg/kg iv	Usually, cefazolin 25 mg/kg iv	⇐
Surgical time	1.5 h	1–2 h	⇐
Closing considerations	Cylinder cast	⇐	Skin closure may be difficult, depending on elevation of tibial tubercle.
Postop care	PACU → home, if arthroscopic	PACU → room	⇐
EBL	<100 mL	⇐	⇐
Mortality	Minimal	⇐	⇐
Morbidity	Recurrence: 5–10%	⇐	⇐
	Late stiffness or ↑ knee pain: 5%	⇐	⇐
	Superficial wound dehiscence or infection: ≤5%	<5%	≤5%
	Anterior compartment syndrome of the leg (Hauser procedure): 1–5%	⇐	⇐
	Deep infection: 1–2%	⇐	⇐
	Peroneal palsy: <1%	⇐	⇐
Pain score	4–6	4–6	4–6

PATIENT POPULATION CHARACTERISTICS

Age range	2–20 yr (most commonly, 13–20 yr)
Male:Female	1:3

Incidence	Subluxation: very common Recurrent dislocation: rare Congenital dislocation: very rare
Etiology	Generalized ligamentous laxity; familial tendency; congenital hypoplasia at a lateral femoral condyle; abnormal attachment or contracture of the IT band; medial femoral torsion or genu valgum; trauma
Associated conditions	Diffuse hyperlaxity syndromes (Ehlers-Danlos, Marfan's, etc.); nail patella syndrome (hypoplastic nails and dislocated radial heads, as well as hypoplastic patellae)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities.

Suggested Readings

1. Hennrikus W, Pylawka T: Patellofemoral instability in skeletally immature athletes. Instr Course Lect 2012; 62:445–53.
2. Hohn E, Pandya NK: Does the utilization of allograft tissue in medial patellofemoral ligament reconstruction in pediatric and adolescent patients restore patellar stability? Clin Orthop Relat Res 2017; 475(6):1563–9.
3. Mulford JS, Wakeley CJ, Eldridge JD: Assessment and management of chronic patellofemoral instability. J Bone Joint Surg Br 2007; 89(6):709–16.
4. Nelitz M, Dreyhaupt J, Reichel H, et al: Anatomic reconstruction of the medial patellofemoral ligament in children and adolescents with open growth plates: surgical technique and clinical outcome. Am J Sports Med 2013; 41:58–63.
5. Popkin CA, Bayomy AF, Trupia EP, et al: Patellar instability in the skeletally immature. Curr Rev Musculoskelet Med 2018; 11(2):172–81.
6. Spindler KP: Reconstruction of the medial patellofemoral ligament was effective for traumatic patellar dislocation. J Bone Joint Surg Am 2012; 94:2093.

TENDON TRANSFER, LENGTHENING (POSTERIOR TIBIAL)

SURGICAL CONSIDERATIONS

Description

Extremity tendons may be lengthened (for contracture) or transferred to change the muscle force vector and compensate for paralysis or paresis of other muscle groups. Originally used for the treatment of poliomyelitis sequelae, these lengthenings and transfers are now used for a variety of deformities due to more common neuromuscular disorders, such as cerebral palsy, muscular dystrophies, Charcot-Marie-Tooth disease, and traumatic nerve palsies. Basic principles are that the muscles to be transferred should be at least grade 4/5 strength and that the loss of normal function should be well compensated. The posterior tibial muscle (PTM) is a representative example, but many extremity muscles have one or more described lengthenings or transfers. Tendon transfer procedures frequently are combined with other transfers or fusions.

For moderate spastic ankle varus, the simplest procedure, **PTM lengthening**, is accomplished by an intramuscular myotendinous "slide." This refers to simply cutting the tendinous fibers well within the distal muscle belly and leaving a small gap in the tendon while the surrounding muscle fibers remain intact. An alternative for spastic varus is the **split posterior tibial transfer** of the PTM. Four short, 2- to 3-cm incisions are used to expose and dissect half of the posterior tibia tendon at its insertion on the navicular. Then, half of the tendon is passed proximally up its sheath to a second incision just posterior to the distal tibial shaft medially. The freed half tendon is passed laterally to the peroneal tendon sheath just distal to the lateral malleolus, where, through a final incision, the tendon is anastomosed to the peroneus brevis.

For complete flaccid foot drop (e.g., peroneal nerve palsy), the entire posterior tibial tendon is transferred. First, it is detached at its medial insertion, delivered proximally at the distal tibia posteriorly, passed **anteriorly** through a window in the interosseous membrane, and then subcutaneously passed to the middorsal surface of the foot, where it is fixed into the middle cuneiform by a pullout stitch.

Usual preop diagnosis

Flaccid or spastic developmental deformity, such as varus or valgus foot neuromuscular disease

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, postop care, physical therapy, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Lengthening	Split Transfer	Anterior Transfer
Position	Supine	⇐	⇐
Incision	Longitudinal posteromedial calf	Medial foot; posteromedial calf; lateral ankle; lateral foot	Medial foot; posteromedial calf; anterior ankle; dorsal foot
Special instrumentation	None	Tendon passer	Pullout suture; buttons
Unique considerations	Underlying neurologic disease Usually added to other procedures (e.g., Achilles tendon lengthenings)	⇐	⇐
Antibiotics	Usually none	⇐	⇐
Surgical time	30 min	1 h	⇐
Closing considerations	Below-knee cast	⇐	⇐
EBL	<20 mL	<50 mL	⇐
Postop care	PACU or room	⇐	⇐
Mortality	Rare	⇐	⇐
Morbidity	Over- or undercorrection Hematoma Drainage: <1%	⇐ ⇐ ⇐	⇐ ⇐ ⇐
Pain score	1–3	3–4	3–4

PATIENT POPULATION CHARACTERISTICS

Age range	3–30 yr
Male:Female	1:1
Incidence	Dependent on Dx

Etiology	Poliomyelitis; cerebral palsy, spina bifida; traumatic peroneal nerve injury; neuropathies, myopathies (e.g., Charcot-Marie-Tooth disease)
Associated conditions	Multiple other contractures

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities.

Suggested Readings

1. Shane AM, Reeves CL, Cameron JD, et al: Posterior tibial tendon transfer. Clin Podiatr Med Surg 2016; 33(1):29–40.
2. Shen PC, Chou SH, Chen JC, et al: An innovative anchoring technique for anterio transfer of the tibialis posterior tendon. J Foot Ankle Surg 2017; 56(3):478–83.

TRIPLE ARTHRODESIS AND GRICE PROCEDURE (EXTRA-ARTICULAR SUBTALAR ARTHRODESIS)

SURGICAL CONSIDERATIONS

Description

Triple arthrodesis is used to realign the hind foot of skeletally mature patients with significant fixed or flexible deformities of multiple etiologies. The technique involves denuding three cartilaginous surfaces of the hindfoot (talonavicular, talocalcaneal (subtalar), and calcaneocuboid joints) to expose the underlying bone. This is mainly performed through an oblique incision over the lateral side of the sinus tarsi incision, but an additional short medial incision over the talonavicular joint can be added. Supple (passively correctable) deformities can be easily corrected prior to arthrodesis, but correction of fixed deformities is more difficult and often requires resection of bone wedges based on the alignment (valgus, varus, planus, cavus, etc.). After correction of the deformity (and preparation of the surfaces), internal fixation (screws or staples) is placed to maintain the reduction and allow arthrodesis. Postoperative immobilization is required with a short leg cast.

Variant procedure or approaches

Because the triple arthrodesis removes growth cartilage, it is unsuitable in growing children (<12–14 yr). **Grice** developed an **extra-articular subtalar fusion** (initially for postpoliomyelitis deformity) that can be performed as early as age 2–3 to improve planovalgus foot alignment. This procedure is accomplished through the same lateral sinus tarsi incision and involves placing a block of autologous bone graft (harvested from the tibia, fibula, or iliac crest) between the talus and calcaneus to push the alignment away from a valgus hindfoot without violating the cartilage.

Usual preop diagnosis

Varus or cavovarus foot deformities; severe valgus or equinovalgus

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, physical therapy, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURES

	Triple Arthrodesis	Grice Procedure
Position	Supine, slightly tilted up on the operative side	⇐
Incision	2" oblique over the sinus tarsi; optional medial incision	⇐
Special instrumentation	Pins, screws, or rods	Pin or screw
Unique considerations	Intraop x-ray to confirm pin position	Iliac or tibial autologous graft
Antibiotics	Usually, cefazolin 25 mg/kg iv up to 2 g	Cefazolin 25 mg/kg iv up to 2 g
Surgical time	1–2 h	1–5 h
Closing considerations	Above-the-knee cast	⇐
EBL	<100 mL	<50 mL
Postop care	PACU → room	⇐
Mortality	Rare	⇐

Morbidity	Superficial skin slough	⇐
	Superficial infection	⇐
	Nonunion of at least one arthrodesis site (usually talonavicular)	⇐
	Aseptic necrosis of the talus: rare	⇐
Pain score	6–8	4–5

PATIENT POPULATION CHARACTERISTICS

Age range	>12 yr (triple arthrodesis); 3–10 yr (Grice)
Male:Female	1:1
Incidence	<1% (depends on diagnosis and severity of deformity)
Etiology	Neuromuscular imbalance (most cases); congenital malformations (e.g., coalitions, severe pes planus); incompletely treated or overcorrected clubfoot; postfracture of calcaneus or talus
Associated conditions	Poliomyelitis; cerebral palsy (↑ GERD, ↓ airway protective reflexes, ↑ postop pulmonary complications); myelomeningocele; Charcot-Marie-Tooth disease (↑ sensitivity to muscle relaxants); congenital tarsal coalition

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities.

Suggested Readings

1. Front NL, Grassbaugh JA, Baird G, et al: Triple arthrodesis with lateral column lengthening for the treatment of planovalgus deformity. J Pediatr Orthop 2011; 31:773–82.
2. Güven M, Tokyay A, Akman B, et al: Modified Grice-Green subtalar arthrodesis performed using a partial fibular graft yields satisfactory results in patients with cerebral palsy. J Pediatr Orthop B 2016; 25(2):119–25.
3. Masrouha KZ, Morcuende JA: Relapse after tibialis anterior tendon transfer in idiopathic clubfoot treated by the Ponseti method. J Pediatr Orthop 2012; 32:81–4.

4. Trehan SK, Ihekweazu UN, Root L: Long-term outcomes of triple arthrodesis i cerebral palsy patients. J Pediatr Orthop 2015; 35(7):751–5.

SURGICAL CORRECTION OF CLUBFOOT

SURGICAL CONSIDERATIONS

Description

Due to the success of the manipulation/casting followed by an Achilles tenotomy (**Ponseti technique**), surgery for clubfoot has been less commonly performed. However, resistance to nonsurgical management is an indication for open release. The orthopedic literature is replete with reports of varying techniques for surgical correction of resistant clubfoot. Turco popularized the one-stage surgical correction of resistant (uncorrected by casting) clubfoot (talipes equinovarus) in 1971. The four components of the deformity are (a) hindfoot equinus (back of the heel is up), (b) hindfoot varus (rolled inwardly), (c) midfoot cavus, and (d) forefoot adductus (medial deviation). Beyond this, however, there exists considerable disagreement as to the pathologic anatomy, ideal skin incision, position, and which structures to release. Most surgeons vary the degree of release in proportion to the degree of deformity, often performing release of the same deep structures through totally different skin incisions. The most important structures released include the entire posterior capsule of the ankle and subtalar joint; capsule of the subtalar, talonavicular, and calcaneocuboid joints; Achilles tendon, posterior tibial tendon, and usually the toe flexors; and origin of the abductor, halluces, and plantar fascia. The navicular is repositioned on the talus and usually held with a small pin.

Variant procedure or approaches

Turco procedure is essentially a posteromedial procedure only and is performed through one incision on the medial aspect of the foot. Crawford described a much more extensile approach through an incision (**Cincinnati**) that runs from anteromedial, around the back of the tendo Achilles, and then anterolateral to the calcaneocuboid joint. This approach is also used by McKay, Simons, and others for a more complete release. I there is severe equinus deformity, however, the incision is difficult to close posteriorly after correction of the equinus (stretching the posterior skin). **Carroll** accomplishes much the same correction using a separate medial and posterolateral incision.

Usual preop diagnosis

Resistant idiopathic clubfoot; secondary clubfoot due to paralysis

ERAS: **Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, postop care, physical therapy, and pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.**

SUMMARY OF PROCEDURES

	Turco	Cincinnati/McKay/Simons	Carroll
Position	Supine	Prone or supine	Supine
Incision	Straight medial foot	Transverse from the navicular bone medially posteriorly across the heel cord and then laterally to the cuboid	Medial zigza and posterolater longitudinal
Special instrumentation	Usually loupe magnification; small K-wires to hold reduction	⇐	⇐
Unique considerations	Tourniquet mandatory and often bilateral	⇐	⇐
Antibiotics	Cefazolin 25 mg/kg iv	⇐	⇐
Surgical time	1–2 h/foot	⇐	⇐
Closing considerations	Well-padded, loose-fitting, above-the-knee cast × 10–14 d	⇐	⇐
EBL	<30 mL	⇐	⇐
Postop care	PACU → room	⇐	⇐
Mortality	Rare	⇐	⇐
Morbidity	Mild, persistent deformity: very common	⇐	⇐
	Hematoma: 2%	⇐	⇐

	Superficial infection: 1–2%	⇐	⇐
	Avascular necrosis	⇐	⇐
	Overcorrection valgus, planus	⇐	⇐
	Pressure changes of the navicula	⇐	⇐
	Wound dehiscence or necrosis	⇐	⇐
	Transection of posterior tibial nerve or artery branch: Rare (except in patients who have had multiple operations)		
Pain score	2–5	2–5	2–5

PATIENT POPULATION CHARACTERISTICS

Age range	3 mo–6 yr
Male:Female	2:1 (idiopathic type)
Incidence	1.2/10,000 live births (idiopathic type)
Etiology	Genetic or hereditary effects; neuromuscular defects of the calf muscles; primary defect of formation of the talus and/or other tarsal bones; shortened ligaments and muscles
Associated conditions	Arthrogryposis (difficult intubation; ±VSD, other CHD); Larsen syndrome (difficult intubation, ± ↑ ICP);

	Freeman-Sheldon syndrome (difficult intubation); osteochondral dystrophies (e.g., diastrophic dwarfism); spinal dysraphism; tethered spinal cord; congenital constricting bands; poliomyelitis

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities.

Suggested Readings

1. Cummings RJ, Davidson RS, Armstrong PF, et al: Congenital clubfoot.J Bone Joint Surg 2002; 84A(2):290–308.
2. Duffy CM, Salazar JJ, Humphreys L, et al: Surgical versus Ponseti approach for the management of CTEV: a comparative study. J Pediatr Orthop 2013; 33:326–32.
3. Verma A, Mehtani A, Sural S, et al: Management of idiopathic clubfoot in toddlers by Ponseti's method. J Pediatr Orthop B 2012; 21:79–84.

ANESTHETIC CONSIDERATIONS FOR PEDIATRIC ORTHOPEDIC SURGERY OF THE PELVIS AND LOWER EXTREMITIES

(Procedures covered: pelvic osteotomy; acetabular augmentation and Chiari osteotomy; Ober fasciotomy; Yount Ober release; hip, open reduction; adductor release and/or transfer; psoas release; pinning of SCFE; femoral osteotomy; epiphysiodesis; Sofield procedure; limb lengthening; tendon transfer or lengthening; triple arthrodesis, Grice procedure; correction of clubfoot)

PREOPERATIVE

Children undergoing orthopedic procedures of the lower extremities typically fall into two groups: (a) posttrauma but otherwise healthy and (b) those with a variety of chronic medical problems, including cerebral palsy, congenital hip dislocation, limb deformities, osteogenesis imperfecta, juvenile rheumatoid arthritis, epidermolysis bullosa (EB), and various myopathies and muscular dystrophies. The anesthesiologist should review the anesthetic implications of these various syndromes or diseases (see Table 12.7-2). Many of these patients will have cardiac, respiratory, endocrine, and metabolic derangements, as well as airway abnormalities that may affect anesthetic management. In addition, the surgical procedures may run the gamut from a simple syndactyly repair of the toes with little blood loss to pelvic osteotomies (in small

children) with blood loss approaching the patients' blood volume. Many patients with SCFE are obese and require anesthetic techniques that minimize the risk of aspiration.

Table 12.7-2 Preop Anesthesia Considerations for Pediatric Orthopedic Diseases

Condition	Special Anesthetic Considerations
Achondroplasia	± Unstable spine: preop neuro and ortho exams are critical. Careful positioning is necessary; prevent compression of cervicomedullary junction by placing a bolster under the shoulders. Difficult iv access. ± GERD 2° obesity. Anticipate difficult mask fit and intubation. Possible choanal stenosis/narrow nasopharynx; may preclude nasal airway/nasal intubation and placement of NG tube. Smaller ETTs are needed. ± Restrictive lung disease and chronic respiratory infections common.
Apert syndrome	C-spine fusion and small nasopharynx. Hypoplastic maxilla, prominent mandible/cleft palate. Difficult laryngoscopy and ET intubation. ± Tracheal stenosis/abnormal tracheal cartilage. Possible choanal stenosis/atresia; may preclude nasal airway, nasal ETT, and NG tube placement. Difficult vascular access. ± Craniosynostosis → ↑ ICP. ± CHD.
Arthrogryposis	Poor cervical mobility; TMJ ankylosis; possibility of difficult intubation. iv access and positioning difficult 2° flexion or contracture deformity. 10% incidence of CHD
Cerebral palsy	Communication difficulties. Scoliosis → restrictive lung disease. ± GERD. ↑ sensitivity to succinylcholine. ↑ resistance to NMRs. MAC decreased. Contractures → restricted access for examination and positioning. ± Latex allergy. Difficult iv access.
Juvenile rheumatoid arthritis	Poor cervical mobility; TMJ ankylosis; possibility of difficult intubation. ± Restrictive pulmonary disease. ± Restrictive pericarditis and tamponade
Klippel-Feil syndrome	Limited C-spine mobility → difficult intubation. Impaired renal drug excretion.

Marfan syndrome	Atlantoaxial instability: evaluate C-spine before laryngoscopy. Care in positioning is needed. May require larger than normal doses of spinal epidural anesthesia 2° height. Aortic dilation → aortic insufficiency ± aortic dissection/aneurysm. Avoid ↑ BP. Anticipate difficult intubation 2° narrow palate. Lung cysts → pneumothorax.
Muscular dystrophy	Possible cardiomyopathy: Avoid cardiac depressant drugs. ↑ sensitivity to muscle relaxants. MH susceptibility. ↓ gastric emptying and weak laryngeal reflexes. Avoid succinylcholine. May have MVR and cardiac conduction abnormalities. May require postop ventilation.
Myopathies	Avoid all muscle relaxants and respiratory depressants. Postop ventilation may be necessary.
Osteogenesis imperfecta	Bones fracture easily (e.g., with BP cuff): Use extreme care in positioning and intubation. Hypermetabolic fever may occur during anesthesia. Plt dysfunction: difficult airway. Use atropine with caution as it may exacerbate pyrexia. CHD may require antibiotic prophylaxis. ± Difficult airway. ± Restrictive lung disease. Deafness may make communication difficult.
Septic arthritis	Infection/systemic toxicity slows gastric emptying; requires rapid-sequence intubation (Appendix B, p. B-5). Dehydration 2° ↑ T and ↓ fluid intake → hypovolemia/hemodynamic instability. Rx: adequate fluid resuscitation with balanced salt solution.

Patients with neuromuscular disorders (e.g., cerebral palsy, spina bifida, muscular dystrophy) presenting for orthopedic procedures pose special challenges for the anesthesiologist. Other syndromes and chronic conditions with orthopedic manifestations include osteogenesis imperfecta, juvenile rheumatoid arthritis, and EB. The anesthesiologist should review and understand the anesthetic implications of these various syndromes.

Respiratory	Patient's preop activity level is a good indication for baseline respiratory function. Careful assessment is necessary as associated anomalies may affect the

	airway or lungs. Chronic otitis 2° eustachian tube dysfunction is common. Postpone surgery (~2–3 wk) if Sx of acute URI (e.g., runny nose, fever, sore throat, cough) are present. **Tests:** As indicated from H&P; CXR
Cardiovascular	Some pediatric patients with congenital musculoskeletal anomalies presenting for orthopedic procedures have coexisting cardiovascular anomalies. Preop review of patient's H&P is essential. Patients should not be accepted for orthopedic surgery and anesthesia until they are in the best possible physical and emotional condition. For children with CHD or who require cardiac medication, it is advisable to consult with a pediatric cardiologist before surgery. If taking ACE inhibitors, hold AM of surgery, as it may lead to intractable intraop hypotension. ***NB:** The consequences of VAE may be disastrous (e.g., cerebral or myocardial embolization) in patients with R → L shunt lesions. All iv lines, injection ports, and syringes must be air free. **Tests:** Hct; baseline SaO_2; CXR, echo, and EKG as needed
Neurologic	For patients with cerebral palsy presenting for orthopedic surgery, preop understanding of their intellectual functional capacity is necessary. Information about patient's behavioral or intellectual abilities is usually best obtained from parents or guardian. If patient is on seizure-control medication, it is recommended that the medication be continued until surgery. All patients who require Ober fasciotomy or Yount release will have profound weakness of lower extremities, if not of the entire body. Must be careful in the choice of muscle relaxant (generally avoid depolarizing agents). Many patients with muscular dystrophy present for repeated orthopedic procedures. Patients with congenital muscular dystrophy (especially

	Duchenne's or Becker's) can have significant associated cardiac dysfunction. A pediatric cardiologist should be involved in the preanesthetic evaluation of their LV function, size, LV ejection fraction, shortening fraction, and echo exam. It is important to note that asymptomatic carriers of these X-linked muscular dystrophies can have associated echo and EKG abnormalities.
Hematologic	Complications of blood loss remain a major anesthetic consideration in pelvic osteotomies, especially in small children or those who have ↑ bleeding 2° osteogenic bone or bleeding disorders. There is no hard-and-fast rule for an acceptable amount of blood loss before transfusion therapy begins; each case must be individualized. Patients who need ↑ O_2-carrying capacity (e.g., congenital heart disease, sickle cell anemia [SSA], have evidence of V/Q mismatch from preexisting pulmonary disease) will require transfusion at lower levels of blood loss than otherwise healthy children. Blood transfusion therapy must be considered after the loss of 15–20% of the patient's total blood volume. Predonation is limited by age, size, and level of cooperation with blood-collecting techniques. Careful hemodilution can be helpful. Albumin may help to avoid tissue swelling and facilitate early extubation. Cell salvaging can introduce both intracellular and surgical debris back into circulation but may avoid heterologous transfusion.
Laboratory	Tests as indicated from H&P
Premedication	Premedication for separation anxiety (e.g., midazolam) and facilitating induction. Care must be taken if premedication is used in patients with respiratory or cardiac dysfunction. Dosage must be individualized. Children with valvular disease, prosthetic valves, and/or most forms of CHD, as well

	as post–cardiac-correction patients, should receive antibiotics for bacterial endocarditis prophylaxis preop. Avoid long-lasting sedative medications.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Multimodal analgesia is recommended for surgeries with potential for significant postop pain. Preop pregabalin 2 mg/kg and celecoxib 2–4 mg/kg po may be administered as part of multimodal analgesia regimen. Consider use of regional anesthesia and discuss options with family. Consider preop acetaminophen 10–15 mg/kg iv or po as an elixir.

INTRAOPERATIVE

Anesthetic technique

As indicated in the preop considerations, these patient populations cover a wide spectrum, from fit and healthy children to those suffering from a variety of clinical syndromes with airway and cardiorespiratory problems. Thus, anesthesia needs to be tailored to the individual patient. Some older children may benefit from regional anesthesia with sedation. Some may do well with a combined regional/GA technique, whereas still others with difficult airways may require awake FOB. The following sections address some of these concerns.

Induction	**Otherwise healthy:** Standard pediatric (<12 yr) or adult induction. **Difficult airway:** A mask induction and FOL during spontaneous respiration should be considered. Alternatives include the use of LMA/intubating LMA, video laryngoscope, FOL or light wand stylet, retrograde wire intubation, and tracheostomy. **Muscle abnormalities:** These patients may be very sensitive to muscle relaxants, have gastric hypomotility, and be predisposed to MH. Induction should be accomplished by nontriggering agents (e.g., propofol 1–2 mg/kg and rocuronium 0.5–1

	mg/kg) if necessary for intubation. Succinylcholine usually is contraindicated in these patients. Dantrolene must be available, but it need not be administered prophylactically. A study of MH patients showed that 32 out of 89 had preexisting musculoskeletal abnormalities. **Cardiorespiratory compromise**: Inhalational induction, when administered cautiously, may be used safely in this group of patients. Intramuscular (e.g., ketamine 4–8 mg/kg im) inductions are usually safe and effective in neonates and infants with severe cardiac disease.
ERAS	Verify preincision antibiotics. Assess volume status (see p. K-6). Maintain normovolemia and normothermia.
Maintenance	**Otherwise healthy:** Standard pediatric maintenance **Muscle abnormalities:** Maintenance of anesthesia with a nontriggering agent (e.g., N_2O, opiates) and short-acting NMRs is prudent. A peripheral nerve stimulator should be used to monitor muscle relaxation, as the effects of muscle relaxants may be unexpectedly prolonged. **Cardiorespiratory compromise:** The maintenance of anesthesia in this group most commonly is accomplished by use of inhalational agents, additional narcotics, or other iv agents, depending on patient tolerance and postop plans for ventilatory management.
Emergence	**Otherwise healthy:** If a muscle relaxant is used, reverse with neostigmine (0.07 mg/kg) and glycopyrrolate (0.01 mg/kg iv) or edrophonium (0.5 mg/kg) and atropine (0.015 mg/kg iv). Make sure patient is awake and able to protect airway. A vital capacity of >15 mL/kg is considered an adequate sign of recovery of respiratory reserve. **Muscle abnormalities:** Anticipate postop

	respiratory impairment. Suction airway carefully. The response to neostigmine is unpredictable and may precipitate myotonia. Continued postop mechanical ventilation may be required. **Cardiorespiratory compromise:** Tourniquet release may cause significant. ↓ CO and ↓ BP, requiring temporary inotropic support. Otherwise, emergence as in other patients. Discuss with surgeon local wound infiltration. PONV prophylaxis may include dexamethasone (e.g., 30 mcg/kg) and ondansetron (0.1 mg/kg up to 4 mg iv).

Regional anesthesia

Used in patients undergoing lower extremity surgery

Caudal epidural	In young children, the epidural space can be reached easily by the caudal epidural approach, with less risk of dural puncture than with thoracic or lumbar epidural approaches. There is minimal risk of cord injury at the level of the sacrococcygeal ligament. The dural sac, however, can extend to the level of the third or fourth sacral vertebra in the newborn; therefore, care must be taken to avoid an inadvertent intrathecal injection. Bupivacaine provides reliable, long-lasting anesthesia and postop analgesia when given via the caudal epidural route. Bupivacaine 0.25% (or ropivacaine 0.2%) with epinephrine 1:200,000 (1 mL/kg) provides 3–6 h of analgesia for all procedures below the umbilicus. In infants (<2.5 kg), a more dilute solution is used (0.125% or 0.175%), and the volume can be increased to remain below the toxic dose range (2.5 mg/kg). Intraop anesthesia with bupivacaine 0.25% with epinephrine 1:200,000 is given as a bolus with volumes determined by level desired (0.05 mL/kg/segment, not to exceed 1 mL/kg). Preservative-free clonidine (1–2 mcg/kg) as an additive to bupivacaine caudal anesthesia has been shown to increase the efficacy and duration of the analgesia but may also cause some postop sedation.

	Lower doses (1 mcg/kg) are preferred.	
Continuous epidural infusion	Use ropivacaine 0.1–0.125% at a rate of 0.1 mL/kg/h in patients <5 yr; thereafter, patients may require 0.05–0.15 mL/kg/h. Maximum hourly dose not to exceed 0.5 mg/kg/h of ropivacaine. Usually requires postop Foley catheter.	
Peripheral nerve blocks	Use of ultrasonography helps to improve the efficacy and safety of these blocks. Femoral, obturator, and lateral cutaneous nerve of the thigh can be blocked by doing a lumbar plexus block at the level of the L4 vertebra or by doing a 3-in-1 block at the groin. Sciatic nerve can be blocked in the posterior thigh at the apex of the popliteal fossa. Saphenous/sciatic or femoral/sciatic combinations can provide excellent analgesia for distal extremity surgeries. If used in combination, these blocks can provide excellent postop analgesia for most of the lower limb procedures with minimal side effects. Catheters can be left in place for providing continuous postop analgesia. With the availability of safer and less-expensive programmable pumps, most of the blocks can be done even for outpatient procedures, and the children can be sent home with elastomeric pump (e.g., On-Q®) pump infusions.	
Blood and fluid requirements	IV: 22 ga or greater × 1–2 BSS (at maintenance) 4 mL/kg/h: 0–10 kg + 2 mL/kg/h: 11–20 kg + 1 mL/kg/h: >20 kg (e.g., 25 kg = 65 mL/h) Warm fluids for long cases.	There may be rapid fluid shifts in pediatric patients undergoing orthopedic procedures. Close monitoring and adequate fluid replacement will ensure hemodynamic stability. In hip or pelvis surgery, blood loss may be substantial, and adequate iv access is important, as blood transfusion may be required.
Control of blood loss	Tourniquet: 120-min limit	Use of pneumatic tourniquets has become common practice

		in peripheral orthopedic procedures. They reduce intraop blood loss; however, they cause pain and, upon removal, release products of anaerobic metabolism.
Monitoring	Standard monitors. ± Arterial line ± CVP line Temperature	Most pediatric patients presenting for extremity surgery do not require invasive monitoring. An arterial or CVP line may be helpful, depending on patient's medical condition, length of surgery, and anticipated blood loss.
Positioning	✓ and pad pressure points ✓ eyes	Patients with osteogenesis imperfecta or osteoporosis are at risk for fractures and joint dislocations and require special care in positioning.
Complications	MH	Early Sx of MH include hypercapnia, tachycardia, tachypnea, unstable BP, dysrhythmias, cyanotic mottling of the skin, rapid rise in T (1°/15 min), discolored urine, metabolic acidosis, respiratory acidosis, hyperkalemia, and myoglobinuria. Rx: stop surgery and anesthesia immediately; hyperventilate with 100% O_2; activated charcoal filters can be used to remove residual anesthetic gases from the breathing circuit; administer dantrolene sodium iv (starting dose = 1–

		2 mg/kg q5–10min; maximum cumulative dose = 10 mg/kg) by rapid infusion. Procainamide (15 mg/kg) over 15 min may be required for dysrhythmias. Initiate cooling; correct acidosis and hyperkalemia. Maintain UO of at least 2 mL/kg/h. Monitor patient in ICU until danger of subsequent episodes is over (24 h).

POSTOPERATIVE

Complications	MH Respiratory insufficiency	For MH considerations, see above.
Multimodal pain management	PCA Parenteral opioids Spinal opioids Regional/epidural catheter, local anesthetic and opioid infusions	Backup with bolus opioid analgesics.
ERAS	PONV protocol (see p. D-1)	Encourage early enteral nutrition and mobilization.

Suggested Readings

1. Aydogan MS, Korkmaz MF, Ozgul U, et al: Pain, fentanyl consumption, and deliriun in adolescents after scoliosis surgery: dexmedetomidine vs midazolam. Pediatr Anesth 2013; 23:446–52.
2. Frizzell KH, Cavanaugh PK, Herman MJ: Pediatric perioperative pain managemen Orthop Clin North Am 2017; 48(4):467–80.
3. Marhover P, Ivani G, Suresh S, et al: Everyday regional anesthesia in children Paediatr Anaesth 2012; 22(10):995–1001.
4. Miller DJ, Nelson SE, Shah AS, et al: Outpatient pediatric orthopedic surgery Orthop Clin North Am 2018; 49(1):55–62.
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(PRAN): a multi-institutional study of the use and incidence of complications o pediatric regional anesthesia. Anesth Analg 2012; 115(6):1353–64.
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7. Rove KO, Edney JC, Brockel MA: Enhanced recovery after surgery in childre promising, evidence-based multidisciplinary care. Paediatr Anaesth 2018; 28(6):482–92.
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SURGERY FOR EPIDERMOLYSIS BULLOSA

SURGICAL CONSIDERATIONS

Description

EB is a disabling inherited condition affecting the skin and submucosa leading to recurrent skin blistering due to impaired epidermal and dermoepidermal adhesion. Recessive dystrophic EB is the most common type requiring surgical treatment. Children develop lesions associated with minimal trauma, which most commonly result in contractures of the hands and feet, mouth, and esophagus. Special care is required in handling patients with EB because minor trauma from iv or EKG lead placement ca cause severe blistering. Hand surgery typically required opening up the contracted fingers by removing the cocoon of epidermis. The defects are grafted with full-thickness skin grafts, typically taken from the abdomen. Following sedation or anesthesia, the affected extremity is gently sponged with dilute chlorhexidine solution. A tourniquet is not applied because it is typically not required. A wrist block is administered by the surgeon. The cocoon of scar tissue is removed, the fingers are manipulated to expose the defects, and a full-thickness skin graft is harvested. Generous Bactroban ointment and nonadhesive dressings are placed on the hand, and a well-padded cast is applied at the end of the procedure. Adhesive tape is avoided throughout the procedure.

Usual preop diagnosis

EB

ERAS: Family preop counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop care, and pai

management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	As necessary to relieve skin contractures on the hands
Antibiotics	Cefazolin 20–40 mg/kg iv up to 2 g
Surgical time	1–2 h. Positioning, iv placement, and sedation/anesthesia are time consuming, often longer than the procedure itself.
EBL	<100 mL
Postop care	PACU → home. Return in 2 wk for intraop removal of cast, dressing change, and first splint application. Splinting and special gloves are the mainstay of postop treatment.
Mortality	None associated with the procedure
Morbidity	Trauma from positioning and monitoring → new blisters
Pain score	7–9 (similar to second-degree burns)

PATIENT POPULATION CHARACTERISTICS	
Age range	1–20 yr; older patients with precancerous or cancerous hand lesions
Male:Female	2–3:1
Incidence	Extremely rare
Etiology	Inherited
Associated conditions	Malnutrition; esophageal strictures; generalized skin contractures; malignant transformation of skin lesions

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

EB is a heterogenous group of rare hereditary disorders characterized by blister formation in the skin in response to minor trauma, friction, or pressure. The most minor form of EB is EB simplex, in which the blisters heal without scarring. The junctiona form often is diagnosed at birth, with blisters caused by the physical trauma of delivery.

These patients develop severe scarring and have a short life expectancy. Patients with the recessive dystrophic form may have strictures of the oropharynx, larynx, and esophagus. Patients may be on long-term corticosteroid treatment. Periop hydrocortisone treatment may be required to compensate for adrenal suppression.

Airway	A careful airway evaluation is essential because these patients may have a difficult airway 2° mucous membrane and skin involvement in the area of the oropharynx, face, and neck. Patients with EB also may have limited mouth opening and neck movement as the result of scarring and contractures. Poor dentition: ✓ for loose teeth.
Skin	Because of the fragility of the skin and mucous membranes in patients with EB, the anesthetic plan should be designed to minimize trauma to the skin and mucous membranes. Friction and shearing forces, not direct pressure, are responsible for new bullae and wound formation.
Gastrointestinal	The most common sites of involvement are the oropharynx, esophagus, and anus. Dysphagia, esophageal stricture, and constipation are common and are the major causes of morbidity, nutritional deficiencies, and growth retardation. Esophageal dilation, insertion of NG feeding tubes, gastrostomy, and colonic interposition have been performed in patients with EB. Esophageal stricture increases the risk of regurgitation and aspiration, and precautions to avoid aspiration should be taken.
Musculoskeletal	Skin lesions can be painful, and some patients will be on chronic opiate medication for pain management.
Hematologic	Chronic blood loss from denuded skin can → anemia and hypoalbuminemia. **Test:** CBC
Laboratory	Other tests as indicated from H&P
Premedication	Adequate premedication is essential to minimize movement during induction. An orally administered

	combination of midazolam (0.6 mg/kg) and ketamine (3.5 mg/kg) facilitates the atraumatic placement of iv lines in the OR. Glycopyrrolate 0.01 mg/kg can be given as antisialagogue. EMLA cream can be applied without adhesive dressing. Avoid long-lasting sedative medications.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Evaluate for concurrent disease, nutritional status, and hydration. Consider preop acetaminophen 10–15 mg/kg iv or po as an elixir.

INTRAOPERATIVE

Patients are placed on sheepskin to cushion pressure points. The following should be available: Albolene liquefying cleanser, Surg-O-Flex® (flexible tubular bandage), Vaseline gauze, Zeroform®, Kerlix®, Webril®, cotton umbilical tape, Mepitel® dressing, and Coban® wrap. No adhesive tape is used. Adhesive portions of EKG leads and electrocautery dispersion plates are removed; the leads and plates are secured to the patient, using Webril® or Surg-O-Flex®. Water-based gels pads (3M Defib pads 2346N) are applied directly to the patient's skin and then the EKG or grounding pads applied over the water-based gel pad.

BP cuff must be applied over multiple layers of cotton padding. Carefully trim the adhesive off the pulse oximetry probe, wrap around the palm or finger, and wrap Coban® around the probe. Alternatively, use adult clip-on probe. Anesthesia masks, ETTs, temperature probes, and all attached monitoring equipment are lubricated with Albolene. Venipuncture can be difficult, and the iv lines will need to be secured with Vaseline gauze and Coban®.

Anesthetic technique

GETA is the preferred method of anesthesia when upper airway manipulation is required or airway protection is compromised. Anticipate difficult airway. Planned FOL is safer than DL. Use smaller ETT to avoid formation of laryngeal bullae. ETT and laryngoscope blade, if used, should be well lubricated. Smaller-than-normal LMA has been used, with the shaft and cuff lubricated. Secure tube with umbilical tape. The safety of GETA, however, is not well documented in junctional EB patients, where columnar epithelium can be involved. Succinylcholine should be used with caution due to potential ↑ K^+ 2° muscle atrophy, although it has been used safely in many instances.

NMRs prolong duration of action 2° ↓ muscle mass and changes in volume of distribution 2° hypoalbuminemia, which results from ill health and poor nutritional status due to high metabolic demands.

IV anesthesia

Ketamine has been utilized for patients with EB undergoing surgical procedures. For anesthesia, use a loading dose of midazolam 0.1–0.2 mg/kg with ketamine 0.25–0.5 mg/kg, followed by a continuous infusion of ketamine (1 mg/kg/h) and midazolam (0.1 mg/kg/h). Glycopyrrolate can be used as an antisialagogue in these patients. Alternatively, propofol (50–100 mg/kg/h) with remifentanil (0.05–0.1 mcg/kg/h) or dexmedetomidine (0.4–0.7 mcg/kg/h) infusions may be used. Titrate medications according to patient's response to surgical stimulation.

Inhalation anesthesia

Inhalation anesthesia may also be performed in cases of difficult iv access and low risk of aspiration.

Local anesthesia

Deep local anesthetic infiltration may be used.

Regional anesthesia

In some patients with EB, regional anesthesia techniques allow maintenance of airway patency, involve minimal epidermal/dermal damage, and can offer prolonged postop pain relief. Brachial plexus anesthesia, epidural anesthesia, and spinal anesthesia have been used successfully in patients with EB.

Emergence	Adequate postop analgesia and parental presence in the PACU may help prevent excessive struggling and skin trauma during emergence and recovery. Plastic O_2 delivery masks should be avoided as they have sharp edges. Avoid rectal route for pain management, as it may cause perianal trauma and blistering. Acetaminophen, ketorolac, and opioids can be used for postop analgesia. PONV should be avoided by using combination antiemetic therapy. Pruritus, a common side effect of opiates, should be treated promptly. Discuss with surgeon local wound infiltration. PONV prophylaxis should include dexamethasone (e.g., 30 mcg/kg) and ondansetron

(0.1 mg/kg up to 4 mg iv).

Suggested Readings

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CHAPTER 12.8

Surgery for Craniofacial Malformations

SURGEON
Stephen A. Schendel, MD, DDS, FACS

ANESTHESIOLOGISTS
Nai Yi Sun, MD
Rita Agarwal, MD, FAAP, FASA
Louise K. Furukawa, MD

SURGICAL CORRECTION OF CRANIOSYNOSTOSIS

SURGICAL CONSIDERATIONS

Description

Premature fusion of cranial sutures, or **craniosynostosis**, causes various well-recognized patterns of cranial vault and facial deformities. Abnormal skull growth occurs perpendicular to the fused sutures. Craniosynostosis can occur as an isolated abnormality or as part of a syndrome. Crouzon, Apert, Saethre-Chotzen, Carpenter, Muenke, and Pfeiffer syndromes are the six most common syndromes associated with craniosynostosis. Single or multiple sutures can be involved, the most common being the sagittal suture. This condition is called **scaphocephaly**, in which the cranial vault is bitemporally narrow, with anteroposterior (AP) elongation. **Anterior or posterior plagiocephaly** involves a single coronal suture or lambdoid suture and is characterized by flattening of the forehead on the affected side. **Oxycephaly** ("tower-head deformity") involves bilateral coronal sutures, with a flat, high forehead, whereas **brachycephaly** also involves the cranial base sutures and results in bitemporal bulging, midfacial hypoplasia, an anterior open bite, and hypertelorism. These patients may have severe

sleep apnea and can pose a challenge for airway management. **Trigonocephaly** (triangular head shape; Fig. 12.8-1), with a keel-shaped forehead and hypoteloric tendency, involves the metopic suture.

Surgical correction of these craniofacial anomalies requires a combined plastic surgery and neurosurgery team approach involving the release or resection of the affected suture and simultaneous correction of the asymmetric skull by **bone-flap repositioning or advancement.** Fronto-orbital abnormalities are addressed with **bifrontal craniotomy** and **forehead advancement**, along with advancement of the supraorbital bar (**fronto-orbital advancement**; Fig. 12.8-2). For example, in plagiocephaly, because of the unilateral coronal synostosis, the frontal bone is retruded, and the superior orbital rim is elevated and retruded on this side. Craniectomy is performed, the forehead is removed, the involved coronal suture is resected, and the supraorbital bar is cut above the orbit and down to the lateral orbital wall across the midline. The bar is bent, advanced on the involved side—sometimes up to 1.5 cm—and fixed in this position. Additional bone strips are taken from the posterior cranium and split for use as graft material; the other bone pieces are replaced and fixed with wires, suture, or resorbable plates. Another approach that is being utilized more commonly in infants <12 mo of age is endoscopic repair, followed by postop helmet therapy for up to 6 mo, to allow the skull to mold and grow properly. This approach has been shown to reduce blood loss and decrease surgical time and length of stay and is more successful in younger infants (aged 2–3 mo), single-suture repairs, and in nonsyndromic patients. Clinical outcomes are similar but dependent on compliance with helmet wearing.

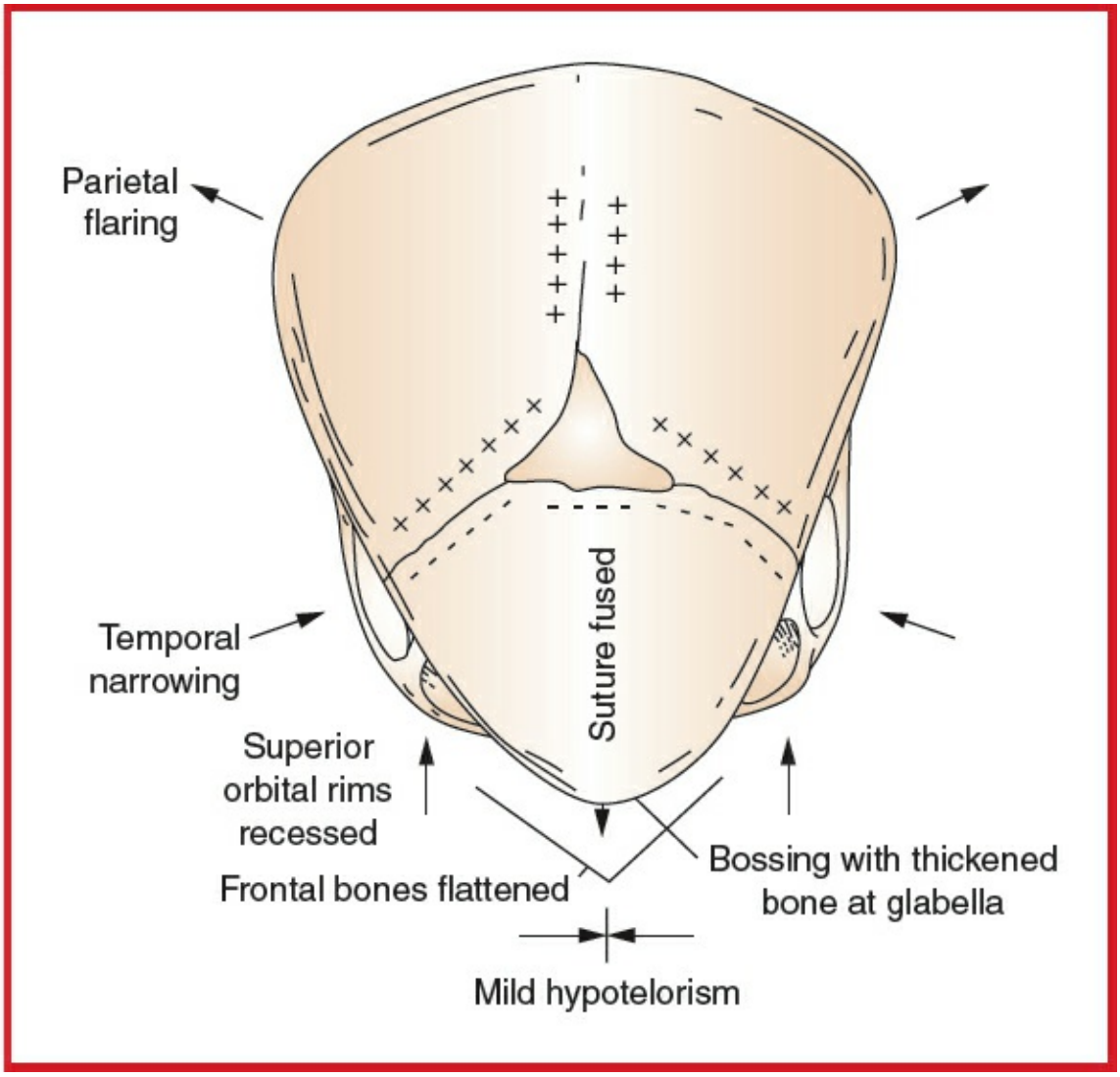

Figure 12.8-1 Skull shape abnormalities in metopic synostosis: Regions of reduced bone deposition (---). Regions of compensatory increased bone deposition (+++). (From Shaffrey ME, Persing JA, Delashaw JD, et al: Surgical treatment of metopic synostosis.Neurosurg Clin N Am1991; 2(3):621–27. Reprinted with permission from John A Persing, MD.)

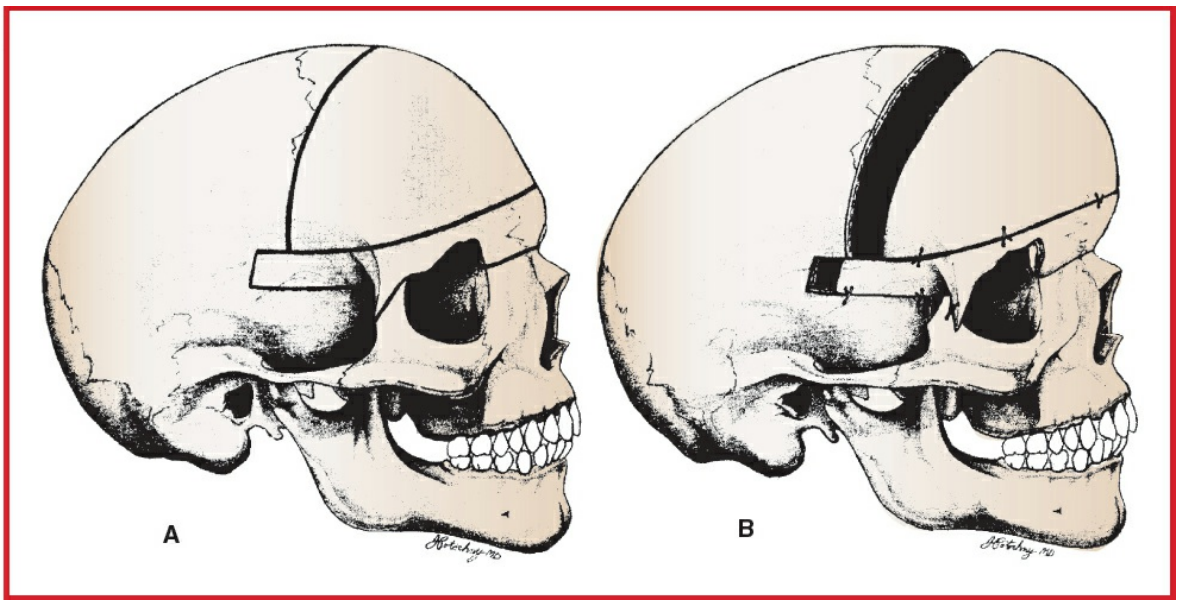

Figure 12.8-2 Fronto-orbital advancement. **A:** Lines of osteotomy for forehead and supraorbital bar advancement. **B:** Fronto-orbital advancement in a tongue-in-groove manner and fixation with wires. (Reproduced with permission from Aston SJ, Beasley RW, Thorne CH, eds.Grabb and Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

Patient positioning, type of headrest, and incision all vary, depending on location of the suture abnormality. If the deformity is mostly posterior (e.g., a sagittal or plagiocephaly case), a prone approach with biparietal or midsagittal incision can be used and may be done endoscopically in the younger infant. Resection of the involved suture and **barrel staving** of the cranium, with grafting for reshaping, works well. Reconstruction as above usually is accomplished at ~3–6 mo of age. Brain mass doubles in size the first 6 mo and triples by 3 yr of age, when ~80% of the brain growth is completed. Brain growth is the driving force for cranial vault growth. All procedures are extradural. Dural tears, if they occur, are repaired to prevent CSF leak and CNS infection.

In syndromic patients, their cranial synostosis deformity is repaired in a manner similar to the procedures described above. Repairs are usually carried out before the age of 12 mo, with a view to midfacial advancement of the primary dentition at maturity either by **LeFort III or by monobloc advancement with or without distraction.** (See Major Secondary Craniofacial Surgical Procedures.)

Postsurgical orthopedic distraction devices can be used to encourage midfacial growth and are commonly used in posterior vault expansion. The syndromic cases may require repeat craniotomy and reshaping at a young age if signs of ↑ ICP appear. Other synostotic cases also should be monitored for ↑ ICP and the need for urgent secondary craniotomy. Marchac and Renier detected ↑ ICP in 13% of single-suture synostosis and 42% of multisuture synostosis. ↑ ICP may increase the risk of dural breach during

craniotomy 2° cranial bone resorption and thinning.

Blood loss can be significant at first incision through the vessel-rich scalp. Raney clips are applied immediately to minimize blood loss. In anticipation of major blood loss, transfusion is often started with the first incision. Severe life-threatening blood loss can occur if the sagittal sinus is breached, and neurosurgical repair must be accomplished quickly. The use of tranexamic acid or aminocaproic acid has been shown to reduce blood loss. Elevation of the bone flaps usually causes diffuse bleeding, which is stopped easily with irrigated bipolar cautery and thrombin-soaked sponges. It is useful to have the patient in the reverse Trendelenburg position from the start. Diffuse bleeding at the cut bone edges and over the bone surfaces can be further controlled with bone wax. Focal bleeding from around the orbit and in the temporal fossa region subperiosteally also can be controlled with bone wax, and positioning in reverse Trendelenburg position. Open vessels, sinuses, and bony edges increase the risk of venous air embolism (VAE). A LeFort/monobloc component to the surgery increases blood loss, especially during the initial mobilization of the facial segment. Injection of local anesthetic with epinephrine, and/or on sponge packs for concurrent application of pressure, will help to control the diffuse mucosal bleeding. Moderate deliberate controlled hypotension is also paramount. Electrocautery and Ligaclips may be necessary for larger vessels (e.g., descending palatine pedicles).

Variant procedure or approaches

In older children (>2 yr), split cranial bone grafts may be required to correct defects caused by bone-flap advancement. Excision of skull segments is commonly accompanied by rigid fixation.

Usual preop diagnosis

Craniosynostosis (sagittal, coronal, metopic, lambdoid); syndromes such as Apert and Crouzon syndromes; ↑ ICP

ERAS: Preop family counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, postop pain management options, possibility of lines, and urinary catheter postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE

Position	Usually supine; prone for correction of lambdoidal suture synostosis or posterior sagittal synostosis. If entire cranial vault reshaping (multiple sutures), special padded

	occipital-cheek headrest, because pin fixation is not safe until >2 yr
Incision	Usually bicoronal, biparietal, Meisterschnitt, midsagittal
Special instrumentation	Horseshoe headrest, usually pediatric; occasionally Gardner tongs; Midas Rex craniotomy; resorbable plates and screws
Unique considerations	Control of ICP; spinal drain may be placed; have blood in room; VAE risk.
Antibiotics	Cefazolin 30 mg/kg q3h, or vancomycin 10–15 mg/kg q6h, and cefotaxime 25–50 mg/kg q6h for oropharyngeal contamination or following dural tears
Surgical time	2–6 h
Closing considerations	Blood loss with Raney clip removal. Full head-wrap dressing causes head/neck movement → bucking.
EBL	200–800 mL; may be formidable
Postop care	ICU: 1–2 d in some institutions (further transfusion often necessary in the first 24 h to replace drain losses)
Mortality	0.6–1.6%
Morbidity	Major complications: 14.3% Bone infection: 3–7% Meningitis CSF leak: 4.5% ↑ ICP Air embolus: <1% Blindness: <1% Massive bleeding: <1% Venous thrombosis Neurologic injury: rare
Pain score	4

PATIENT POPULATION CHARACTERISTICS

Age range	2–24 mo (primary correction)
	1:1

Male:Female	
Incidence	Nonsyndromic: 1/10,000 births (most sporadic; few familial patterns) Crouzon syndrome (OSA common): 1/25,000 Apert syndrome (OSA common): 1/100,000
Etiology	Idiopathic; however, some are associated with specific genetic conditions (e.g., Crouzon and Apert syndromes). Other cases may be 2° ↓ brain growth.
Associated conditions	Hydrocephalus; ↑ ICP; mental retardation; airway problems; ocular abnormalities; exotropia (29% Crouzon or Apert syndrome); lagophthalmos; exorbitism

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients may have craniofacial anomalies—particularly Apert and Crouzon syndromes—which are associated with midface hypoplasia, obstructive sleep apnea, and in some cases difficult intubation. Apert syndrome may also be associated with congenital cardiac anomalies. Hence, detailed preop evaluation is necessary. Children with single-suture craniosynostosis are usually healthy. Surgery is often performed between 3 and 6 mo of age, preferably when the infant weighs >5 kg.

Respiratory	Patients with long-standing upper airway obstruction due to choanal atresia, mandibular and maxillary hypoplasia, or other causes may have chronic hypoventilation and hypoxia and may experience episodes of apnea. If the patient has Sx of acute URI, delay elective surgery at least 2 wk. The presence of fever, cough, and abnormal chest auscultation necessitates surgical cancellation and pediatric consultation. **Tests:** As indicated from H&P
Airway	Be aware of other congenital anomalies affecting the patient's airway, such as Apert, Klippel-Feil, Goldenhar, Pierre Robin, Treacher Collins, and

	Crouzon syndromes. Review any previous anesthetic records to gain insights into appropriate airway management (e.g., video laryngoscope or FOI may be necessary). Consider elective tracheostomy under local anesthesia in patients with severe airway abnormalities.
Cardiovascular	Consider the coexistence of congenital cardiopulmonary anomalies, particularly in patients with Apert syndrome (autosomal dominant trait, craniosynostosis, midface hypoplasia, syndactyly of hands and feet, ASD, and VSD). Preop evaluation of a patient with a known or suspected heart defect should include thorough H&P, ECG, Hct, baseline O_2 sat, and echocardiogram. For children with Sx of cardiac dysfunction or those requiring cardiac medication, it is advisable to consult with a pediatric cardiologist to optimize the patient's condition before surgery. **Tests:** Preop EKG indicated for patients with CHD, CXR, and echo; others as indicated from H&P
Neurologic	If only the sagittal suture is involved, ICP is usually normal. If more than one suture is involved, brain growth may be impaired, the patient may be developmentally delayed, and intracranial HTN may be present. Older patients presenting for repair are more likely to show signs and symptoms of elevated ICP. Syndromic craniosynostosis often has associated hydrocephalus.
Hematologic	Surgery in early infancy (<9 mo) is common; thus, allowable blood loss is small; blood transfusion usually is required. **Tests:** Hct; PT; PTT; T&C blood
Laboratory	Other tests as indicated from H&P
Premedication	Patients >9–10 mo old may benefit from premedication with midazolam (0.5 mg/kg po). Antibiotic prophylaxis for CHD may be warranted.

	Consult latest AHA guidelines.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 15 mg/kg po (2–12 yo).

INTRAOPERATIVE

Anesthetic technique

GETA: Anticipate possible difficult airway. Heat OR to 78°–80°. Forced-air warmer. Heat all fluids to body temperature.

Induction	Surgery for craniectomies is extradural. Either mask induction with N_2O and inhalational agent or iv induction is suitable for the infant with a normal airway. If ICP is suspected to be elevated, consider mild hyperventilation after loss of consciousness. For a difficult airway, intubation may be facilitated by using video laryngoscope or FOI while patient is anesthetized and spontaneously ventilating. In rare situations, tracheostomy, under sedation and local anesthesia, may be necessary. Consider suturing ETT to prevent accidental extubation in prone cases, as unsutured endotracheal tubes can slip through tape due to pooling of oral or nasal secretions.
ERAS	Verify preincision antibiotics. Assess volume status (see p. D-1). Maintain normovolemia. Avoid hypothermia.
Maintenance	Maintenance anesthesia with inhalational agent or balanced (iv) anesthesia and long-acting muscle relaxant should be adequate. Surgery may be prolonged. Control of ICP may be necessary (see below). A remifentanil infusion 0.1–0.2 mcg/kg/min provides profound intraop analgesia and BP control and allows for rapid awakening.
Emergence	Prompt awakening to allow neurologic evaluation is an important goal. Excessive facial edema due to prolonged surgery or high blood loss requiring large-volume fluid replacement, particularly in patients with preoperative

	sleep apnea, may require the patient to remain intubated postoperatively. Check for presence of air leak around ETT in patients with significant facial edema to determine readiness for extubation.	
Blood and fluid requirements	Anticipate large blood loss. IV× 2 (as large as possible) LR @: 4 mL/kg/h—0–10 kg +2 mL/kg/h—11–20 kg +1 mL/kg/h— >20 kg (e.g., 25 kg = 65 mL/h) Warm all fluids. Humidify gases.	Have 1–2 U PRBC or whole blood available in the room. Consider splitting PRBC into aliquots preop to minimize donor exposure. Use freshest compatible PRBC available for infants to minimize risk of hyperkalemia. Consider antifibrinolytics such as tranexamic acid (loading dose 50 mg/kg, followed by infusion of 5 mg/kg/h) or aminocaproic acid to decrease intraop blood loss and blood transfusion needs. Use LR for replacing deficit, maintenance, and third-space fluid loss. Replace blood loss with colloid and PRBC mL for mL. Warm all fluids administered. Significant blood loss begins with scalp incision; allowable blood loss is small so that it is important to begin transfusion early before hypovolemia occurs. Estimation of intraop blood loss may be difficult because of significant loss of blood onto surgical drapes and gowns. EBV for an infant in this age group is 80 mL/kg. Monitor for signs of coagulopathy and transfuse

		FFP and cryoprecipitate platelets as needed. Avoid NS (acidosis, ↑ bleeding) in children <5 yr. Beware of ↑ K^+ and ↓ Ca^{++} associated with massive transfusion.
Control of ICP	Hyperventilation Osmotic diuretic Loop diuretic	In some cases, it may be desirable to ↓ ICP. This can be accomplished by ↑ ventilation ($PaCO_2$ = 25–30 mm Hg), diuretics (furosemide 0.5–1 mg/kg iv), and/or mannitol (0.25–1 g/kg iv).
Monitoring	Standard monitors (Appendix D, p. D-1) + Arterial line ± CVP line ± Precordial Doppler ± Urinary catheter	Arterial cannulation for BP, monitoring of ABG, Hct, electrolytes, etc., ↑ K^+ and ↓ Ca^{++} are most common following transfusion with whole blood or FFP. VAE has been reported during craniectomies in infants; hence, a precordial Doppler and CVP line will be helpful. CVP may be particularly helpful in the infant with marginal cardiovascular status for volume assessment and drug administration. Close attention to $ETCO_2$ and, if available, ETN_2 monitoring is useful. If VAE is suspected, the surgical field should be flooded and the head lowered immediately. CVP may be particularly helpful in the infant with

		marginal cardiovascular status for volume assessment and drug administration and if peripheral iv access is limited. Precordial or esophageal stethoscope is useful in cases where the patient is turned 180° or in cases of marginal pulmonary function.
Positioning	✓ and pad pressure points ✓ eyes	Positioning depends on surgical approach; most are performed with patient supine. The head-up position is commonly used to help decrease venous pressure and blood loss.
Complications	Oculocardiac reflex (OCR) → ↓↓ HR and ↓↓ BP VAE	Notify surgeons. If it does not resolve, give atropine 0.02 mg/kg iv (minimum 0.1 mg). Be prepared to make prompt Dx of VAE (↓ $ETCO_2$, change in Doppler sounds, ↑ ETN_2, ↓ O_2 sat, ↓ BP, ↑ HR) and Rx: notify surgeons, flood wound, ± head down, aspirate CVP, ± vasopressors. Minimizing head-up position, avoiding hypovolemia, and introducing PEEP can help to prevent VAE.

POSTOPERATIVE

Complications	Hypovolemia with ↓ BP Hypothermia	Inadequate volume replacement may result in ↓ BP and acidosis. ✓ Hct to

		establish need for further fluid or blood therapy. Coagulopathy may develop postop; check coags to establish need for blood component therapy.
	Airway complications	Excessive facial edema, history of a marginal airway preoperatively, or severe obstructive sleep apnea with sensitivity to opioids may necessitate maintenance of a secure airway postop.
Multimodal pain management	If intubated, fentanyl and midazolam infusions per ICU protocol Postextubation, consider: Acetaminophen 10 mg/kg iv q6h ATC Lorazepam 0.01 mg/kg iv q6h ATC Hydromorphone RN controlled analgesia 1 mcg/kg continuous and 2 mcg/kg q10min lockout for breakthrough pain. Alternatively: Fentanyl 1 mcg/kg iv Morphine 0.05–0.1 mg/kg iv q2–3h prn Hydromorphone 0.005–0.01 mg/kg iv q2–4h Hydrocodone/acetaminophen elixir (Hycet) 0.15 mg/kg po q6h	
Tests	Follow up Hct postop	Transfuse to keep Hct ≥ 30%.

Suggested Readings

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MAJOR SECONDARY CRANIOFACIAL SURGICAL PROCEDURES

SURGICAL CONSIDERATIONS

Description

These procedures usually are performed on children ≥5 yr. There are two basic approaches. The first involves advancement of the upper face and frontal bone, frequently described as a **monobloc** (Fig. 12.8-3) or **frontofacial advancement**. Occasionally, a LeFort III osteotomy and advancement may be performed depending on the anatomy. The second variation, called **facial bipartition** or **periorbital osteotomy**, is for correction of telorbitism (widely spaced eyes), usually accomplished by a combined extra- and intracranial approach, using both plastic and neurosurgery teams.

Variant procedure or approaches

Many different variations of the above-named procedures can be performed; however, from an anesthetic standpoint, they are not significantly different. The use of **cranial bone grafts** and **rigid fixation** have shortened these somewhat lengthy procedures. Other bone grafts, however, from ribs and iliac crest, are occasionally required. These procedures frequently last ≥6 h, and blood loss can be very heavy. Reconstruction of the forehead and orbital area following a tumor excision, for example, uses a similar

approach but requires additional bone grafts. The use of external or internal distraction devices has eliminated the need for bone grafts and decreased associated complications including infection.

Usual preop diagnosis

Craniofacial malformations; craniofacial deformities; telorbitism or hypertelorism; craniofacial dysostosis

ERAS: Preop family counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, postop pain management options, and possibility of lines and urinary catheter postop. **See Appendix K: Pediatric ERAS, p. K-6 to K-8.**

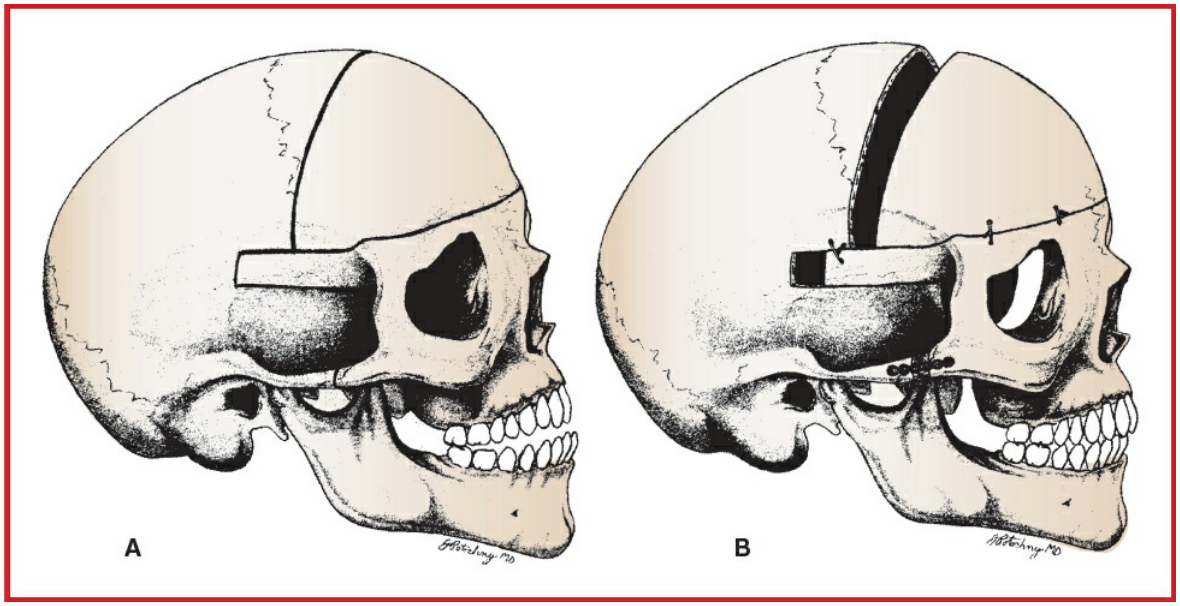

Figure 12.8-3 Monobloc advancement. **A:** Lines of osteotomy for monobloc osteotomy. **B:** Advancement of midface, orbits, and frontal bone and stabilization with bone grafts and miniplates. (Reproduced with permission from Aston SJ, Beasley RW, Thorne CH, eds:Grabb and Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

SUMMARY OF PROCEDURES

	Monobloc/Frontofacial Advancement	Facial Bipartition, Periorbital Osteotomies
Position	Supine	⇐
Incision	Bicoronal, oral	Bicoronal, infraorbital
Special	Horseshoe headrest, usually	⇐

instrumentation	pediatric; disimpaction forceps; Midas Rex craniotomy; resorbable plates and screws; mini-/microtitanium plates and screws; ± distraction device to supplant bone grafting and rigid fixation	
Unique considerations	Control of ICP: spinal drain may be placed, hyperventilation. Blood in room for anticipated transfusion.	⇐
Antibiotics	Cefazolin 30 mg/kg q8h or vancomycin 10–15 mg/kg q6h and cefotaxime 25–50 mg/kg q6h for oropharyngeal contamination and following dural tears	⇐
Surgical time	4–10 h	⇐
Closing considerations	Blood loss with Rainey clip removal for suturing. Full head-wrap dressing → head/neck movement with awakening.	⇐
EBL	400–800 mL; may be formidable	⇐
Postop care	ICU: 1–2 d; monitor Hct.	⇐
Mortality	0.6–1.6%	⇐
Morbidity	Major complications: 14.3% Bone infection: 3–7% Meningitis Infection rates higher if: Adults rather than children (10×) Longer OR times and longer hospital stay Tracheostomy Foreign body (plates/screws/other alloplast)	⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐ ⇐

	Anterior fossa entered Large dead space (e.g., in adult nongrowing brain) CSF leak: 4.5% ↑ ICP Air embolus: <1% Blindness: <1% Massive bleeding: <1% Venous thrombosis Neurologic injury: Rare	⇐ ⇐ ⇐ ⇐ ⇐ ⇐
Pain score	6	6

PATIENT POPULATION CHARACTERISTICS

Age range	3–20 yr
Male:Female	1:1
Incidence	Crouzon syndrome: 1/25,000 Apert syndrome: 1/100,000
Etiology	Congenital (80%); occasionally trauma or tumor (20%)
Associated conditions	Depends greatly on the syndrome or disease entity. See Craniosynostosis.

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Craniofacial syndromes often are associated with maxillofacial deformities, mandibular abnormalities, and challenging airway management.

Respiratory	Patients with long-standing upper airway obstruction due to choanal atresia, mandibular and maxillary hypoplasia, etc. may have chronic hypoventilation and hypoxia and may have apnea episodes. If Sx of acute URI, delay elective surgery at least 2 wk. The presence of fever, cough, and abnormal chest auscultation necessitates surgical cancellation and pediatric consultation.

	Tests: As indicated from H&P
Airway	Be aware of other congenital anomalies affecting the airway, such as Apert, Goldenhar, Klippel-Feil, Pierre Robin, Treacher Collins, and Crouzon syndromes. Review any previous anesthetic records for insights into airway management (e.g., need for video laryngoscope or FOI). Consider elective tracheostomy under local anesthesia in patients with severe airway abnormalities.
Cardiovascular	Incidence of CHD is increased in patients with craniofacial abnormalities. Preop evaluation of patient with known or suspected heart defect should include H&P, ECG, Hct, and baseline O_2 sat. For children with Sx of cardiac dysfunction or those requiring cardiac medication, it is advisable to consult with a pediatric cardiologist to optimize patient's condition before surgery. **Tests:** Preop ECG, echocardiogram, CXR indicated for patients with CHD; others as indicated from H&P
Neurologic	Neurologic deficits, if any, should be documented preop.
Laboratory	Hb/Hct; therapeutic drug levels for patients taking anticonvulsants
Premedication	Premedication is helpful for patients > 1 yr—oral midazolam 0.5–0.75 mg/kg or oral ketamine 6 mg/kg about 30–60 min before induction.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss postop pain management. Consider preop acetaminophen 15 mg/kg po (2–12 yo).

INTRAOPERATIVE

Anesthetic technique

GETA, with special consideration given to associated CHD, pulmonary, and airway problems.

Induction	In an otherwise healthy patient, inhalational induction with subsequent placement of iv lines is appropriate. Muscle relaxants facilitate intubation but should be used only when adequate mask ventilation can be ensured. An oral RAE ETT is useful for this procedure and should be secured carefully in place. Suturing in place is often warranted. Intubation in a patient with airway abnormalities may be facilitated by using an FOI or GlideScope™ with patient spontaneously ventilating. In rare situations, tracheostomy, under sedation and local anesthesia, may be necessary.	
Maintenance	Standard pediatric maintenance. Consider use of remifentanil infusion (0.1–0.2 mcg/kg/min) for supplemental analgesia and to facilitate rapid awakening.	
Emergence	Extubate the trachea when patient is awake and protective airway reflexes have returned if appropriate. These patients often require postop intubation and ventilation.	
Blood and fluid requirements	Anticipate large blood loss. IV: 18 ga × 1–2 BSS @: 4 mL/kg/h—0–10 kg +2 mL/kg/h—11–20 kg +1 mL/kg/h—>20 kg (e.g., 25 kg = 65 mL/h) Warm fluids.	The goal of intraop fluid therapy is to replace preop deficits, intraop fluid, electrolyte, and blood losses while providing maintenance fluids. Half of the calculated deficit (hours fasting × hourly maintenance fluid requirement) generally is replaced during the first hour of anesthesia and the balance over the next 1–2 h. Surgical manipulation of tissue will cause 'third-space' fluid loss proportional to the degree of surgical trauma and tissue exposure. It may range from 0 to 10 mL/kg/h.

Control of blood loss	Deliberate ↓ BP is rarely necessary.	Deliberate ↓ BP can be accomplished by use of SNP, esmolol, clevidipine, or potent inhalational agents titrated to effect (MAP 50–60 mm Hg).
Monitoring	Standard monitors Arterial line ± CVP line	Arterial line is essential for monitoring BP during deliberate ↓ BP and for ABGs and blood chemistries.
Control of ICP	Hyperventilation Mannitol Loop diuretics CSF drainage (>1 yr)	For some procedures, it is essential to reduce intracranial volume to facilitate surgical access. If prolonged brain retraction is required, postop cerebral edema may ensue. ↓ ICP by ↑ ventilation ($PaCO_2$ = 25–30 mm Hg), and diuretics (e.g. furosemide 0.5–1 mg/kg iv).
Positioning	✓ and pad pressure points ✓ eyes	Positioning the head above the heart facilitates venous drainage but also increases the incidence of VAE. Do not hyperextend or hyperflex the head and neck. Flexion of the neck will move the ETT downward (mainstem intubation); extension will move the ETT upward (cuff leak).
Complications	Displacement of ETT Oculocardiac reflex (OCR)→ ↓ ↓ HR, ↓ BP	Discuss with surgeon prevention of displacement by prior suturing of ETT to alveolar ridge. Notify surgeon. If necessary,

		Rx: atropine 0.02 mg/kg.
	VAE Major blood loss	VAE should be suspected if sudden ↑ ETN_2, ↓ $ETCO_2$, ↓ O_2 sat, ↓ BP, and ↑ HR occur. Notify surgeon, flood surgical field, d/c N_2O, and support patient hemodynamically.

POSTOPERATIVE

Complications	↑ ADH secretion Diabetes insipidus (see Appendix D, p. D-1)	SIADH or DI may follow brain manipulation and may require pharmacologic intervention for Rx.
	Cerebral edema	Cerebral edema may → ↑ ICP (headache, N/V, ↓ mental status, etc.).
	Pneumothorax Bleeding	Pneumothorax (Sx = ↑ respiratory rate, wheezing, ↑ BP, ↓ CO, ↓ O_2 sat) may occur 2° rib resection for bone graft. ✓ CXR.
Multimodal pain management	Regional anesthesia	Regional anesthesia may be considered (infraorbital block for cleft lip, scalp blocks for frontofacial advancement).
	Nonopiate	Acetaminophen 10 mg/kg iv q6h
	Opiate	Lorazepam 0.01 mg/kg iv q6h Consider RN controlled analgesia with hydromorphone 1 mcg/kg continuous and 2 mcg/kg q8 lockout for breakthrough pain. Alternatively: Fentanyl 1 mcg/kg iv

		Morphine 0.05–0.1 mg/kg iv q2–3h prn Hydromorphone 0.005–0.01 mg/kg iv q2–4h Hydrocodone/acetaminophen elixir (Hycet) 0.15 mg/kg po q6h
Tests	Hct	

Suggested Readings

1. Bradley JP, Gabbey JS, Taub PJ, et al: Monobloc advancement by distractio osteogenesis decreases morbidity and relapse. Plast Reconstr Surg 2006; 118(7):1585–97.
2. Cladis F, Grunwaldt L, Losee J: Anesthesia for plastic surgery. In: Davis PJ, Cladi FP, Motoyama EK, eds. Smith's Anesthesia for Infants and Children, 9th edition. Elsevier, Philadelphia: 2017, 843–52.
3. Fearon JA, Cook TK, Herbert M: Effects of hypotensive anesthesia on bloo transfusion rates in craniosynostosis corrections. Plast Reconstr Surg 2014;133(5):1133–6.
4. Nargozian C: The airway in patients with craniofacial abnormalities. Paediatr Anaesth 2004;14(1):53–9.
5. Suresh S, Voronov P: Head and neck blocks for infants, children and adolescents. Pediatr Anesth 2012; (22):81–7.

CLEFT LIP REPAIR—UNILATERAL/BILATERAL

SURGICAL CONSIDERATIONS

Description

Cleft lip may be either unilateral or bilateral and associated frequently with clefts of the alveolus and palate. Surgical repair involves the design and execution of geometric flaps on the medial and lateral sides of the cleft and primary repair of the cleft nasal deformity. The most common unilateral technique is the **rotation advancement flap of Millard** (Fig. 12.8-4). Multiple bilateral lip repairs have been described, some repairing both sides simultaneously and some one side at a time (Fig. 12.8-5). Technique depends on the amount of prolabial and lateral element tissue available. Recently, **primary nasal repair** has been coupled with these bilateral procedures.

These nasal repairs involve extensive mobilization of the alar cartilages and transfer of tissue up into the cleft nasal vestibule and floor, with nasal stents often placed. All of these factors can decrease or occlude nasal airway breathing. Although only a minority of neonates has been found to be true obligatory nasal breathers, this should be kept in mind for those postop patients with respiratory distress.

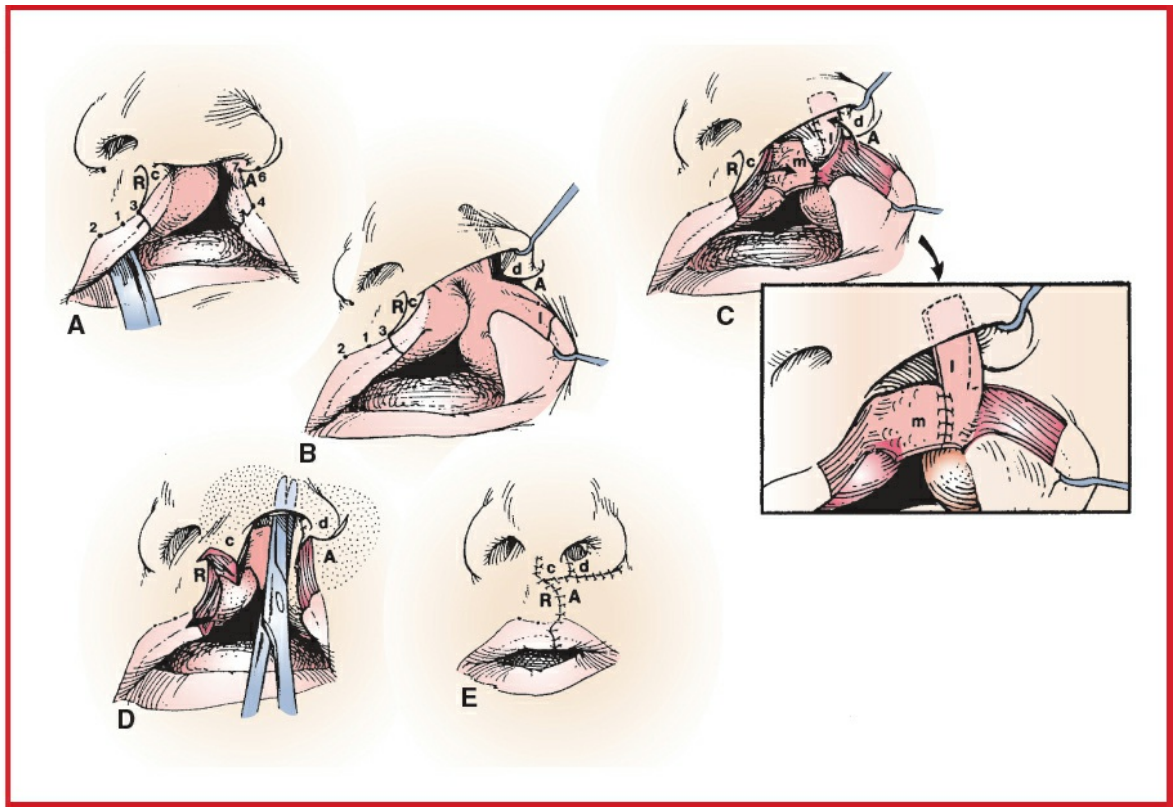

Figure 12.8-4 Step-by-step unilateral complete cleft rotation advancement: m, medial mucosal flap; l, lateral mucosal flap. (Reproduced with permission from Aston SJ, Beasley RW, Thorne CH, eds:Grabb and Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

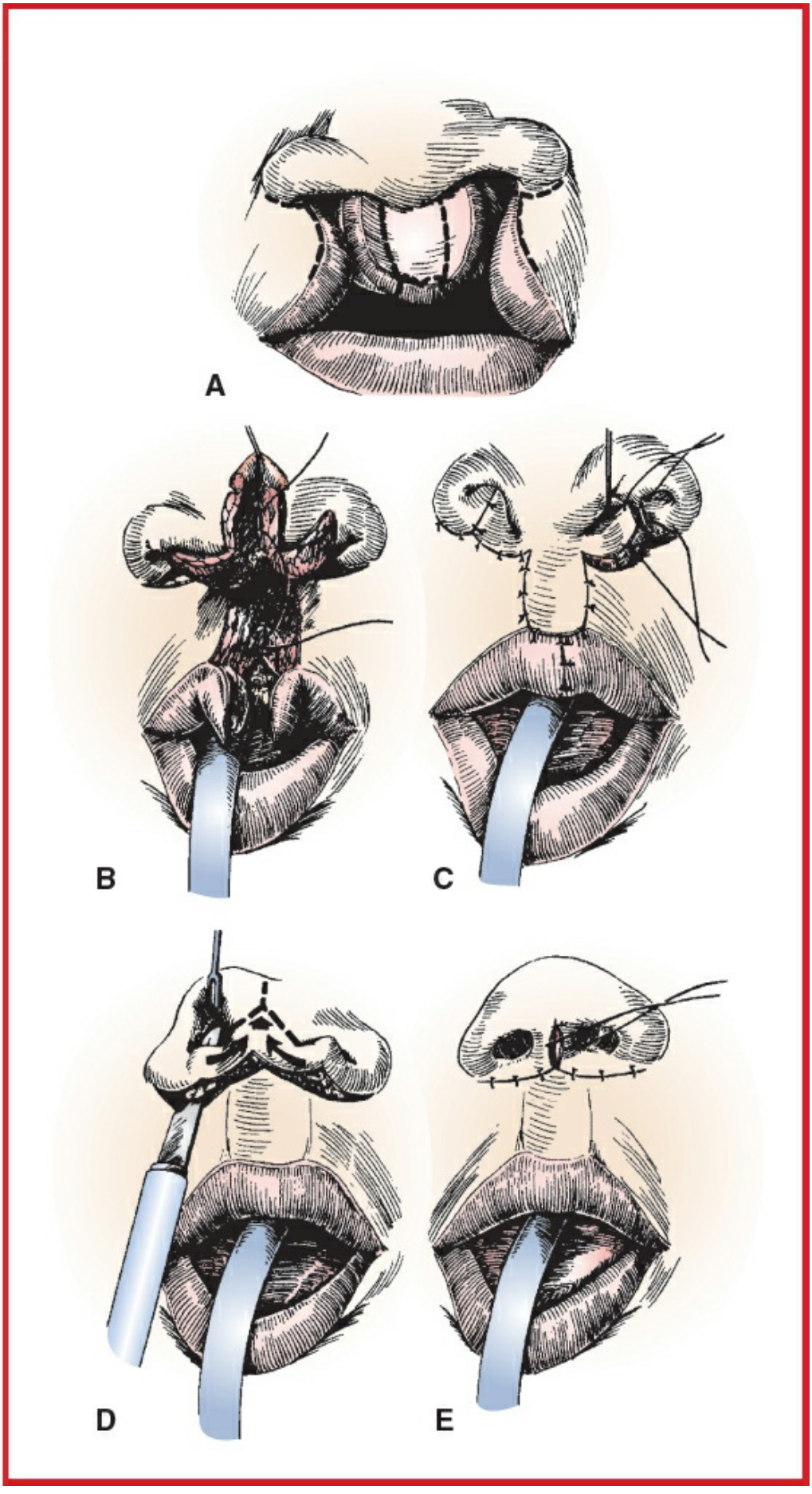
A
B
C
D
E

Figure 12.8-5 Banked fork-flap procedure. In the first stage **(A–C)**, bilateral straight line repairs are done after the prolabium is divided vertically into three forks. The central limb is used to construct the center of the lip. The lateral forks are "banked" at the alar bases for later use in constructing a columella. At the second stage **(D–E)**, bipedicle flaps from the nasal floor, which include the banked forks, are used in combination with a membranous septum incision to elongate the columella and increase tip projection. (Reproduced with permission from Aston SJ, Beasley RW, Thorne CH, eds:Grabb and Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997. After Millard DR Jr: Closure of bilateral cleft lip and elongation of columella by two operations at infancy. Plast Reconstr Surg 1971; 47:324–31.)

Variant procedure or approaches

Other approaches commonly performed are those of the **Davies-** or **Tennison**-type (Z-plasty) lip repairs (Fig. 12.8-6). In large clefts, a lip adhesion may be performed as an initial stage several months before the actual definitive correction of the cleft lip. This procedure basically involves creating a wound on either side and suturing the muscles, mucosa, and skin together. The procedure itself is very short (~45 min). **Presurgical orthopedic devices** may be placed and manipulated, instead of a lip adhesion, to bring a wide, bony cleft into better opposition for a tension-free complete repair. These are custom-fitted and may be fixed with pins to the palate. They are removed in the OR at time of repair.

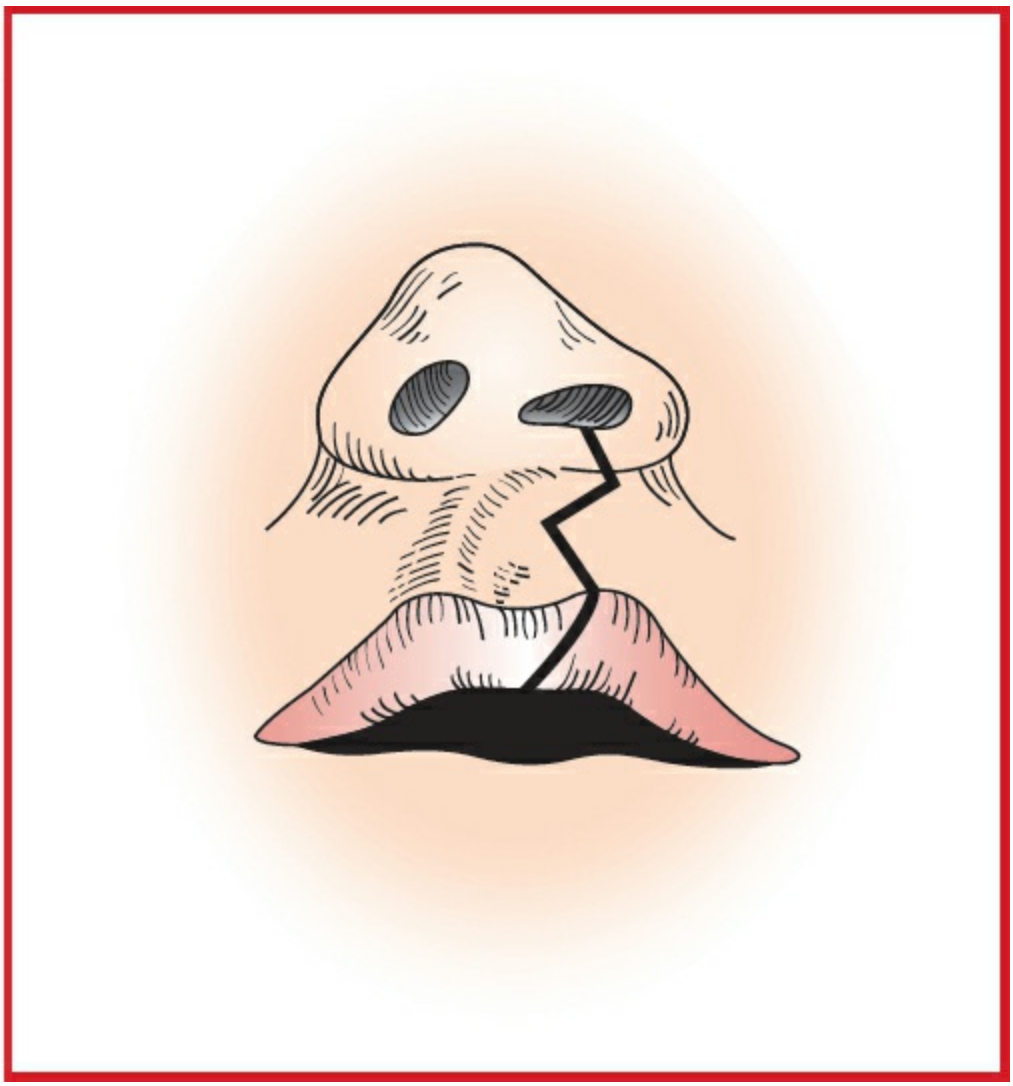

Figure 12.8-6 Z-plasty closure of the lip. (Reprinted from McCarthy JG, edPlastic surgery: cleft lip and palate, and craniofacial, Volume 4, 1st edition. Copyright © 1990 Elsevier. With permission.)

Usual preop diagnosis

Cleft lip/palate

ERAS: Preop family counseling by the surgeon/anesthesiologist should include continuing limiting NPO duration, review of nutritional status, carb loading, and postop pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE

Position	Supine; table rotated either 90° or 180°, with oral RAE or reinforced tube toward chin; patient's head at the edge of head of bed; shoulder roll; neck extended; entire face exposed; scleral shields

Incision	Medial and lateral cleft margins into the nose and in the maxillary vestibule on the cleft side
Special instrumentation	Throat pack (**NB:** ✓ removal before extubation); oral RAE or anode tube
Unique considerations	Local anesthesia with epinephrine is injected **after** lip and nose markings are complete. Pediatric patients should wake up in a calm state because undue crying may place excessive tension on the repair. Immediate elbow restraints for children × 2 wk.
Antibiotics	Cefazolin 30 mg/kg iv
Surgical time	1.5 h (bilateral usually ½ h longer) Lip adhesion: 45 min
Closing considerations	Nasal stent; swelling and ointment may occlude nasal airway; smooth emergence is important.
EBL	5–10 mL (higher with palatoplasty)
Postop care	Elbow restraints × 2 wk; PACU → room overnight → home POD 1
Mortality	Minimal
Morbidity	Infection Wound breakdown Hypertrophic scars
Pain score	4

PATIENT POPULATION CHARACTERISTICS

Age range	1 wk–6 mo
Male:Female	2:1—cleft lip and palate. Isolated cleft palate is more common in females.
Incidence	1/750 for Caucasians; more common in Asians; less in African Americans. Left cleft is more common than right; both are more common than bilateral, in the ratio of 6:3:1.
Etiology	Multifactorial, including both genetic and environmental

	aspects
Associated conditions	Associated anomalies are seen in ~29% of cleft lip cases and may include major chromosomal deletions and/or duplications, along with possible severe mental retardation and CHD.

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lip and Nose Surgery.

Suggested Readings

1. Arosarena OA: Cleft lip and palate. Otolaryngol Clin North Am 2007; 40(1):27–60.
2. Gatti GL, Freda N, Giacomina A, et al: Cleft lip and palate repair.J Craniofac Surg 2017; 28(8):1918–24.
3. Liao YF, Hsieh YJ, Chen IJ, et al: Comparative outcomes of two nasoalveolar molding techniques for unilateral cleft nose deformity. Plast Reconstr Surg 2012; 130(6):1289–95.
4. Schendel SA: Unilateral cleft lip repair–state of the art.Cleft Palate-Craniofac J 2000; 37(4):335–41.

PALATOPLASTY

SURGICAL CONSIDERATIONS

Description

Cleft palate can be seen as either an isolated condition or in conjunction with clefting of the lip. The mildest form of cleft palate is the submucous or occult cleft, in which there is no visible cleft but, rather, a nonunion of the soft-palate muscles. This is followed by the incomplete soft-palate cleft and, finally, the complete cleft, which includes soft and hard palates and may extend through the alveolar portion of the maxilla. Special attention needs to be taken in cleft palate repair in children with Pierre Robin syndrome. In spite of delayed closure, 30% of these children develop respiratory distress following one-stage palatal repair. This usually resolves in a few days. Some of these children, however, have an extremely reduced airway secondary to the small mandible and will need other procedures to increase the airway including jaw distraction. In fact, all children with cleft lip and palate demonstrate reduced volume of the oropharyngeal airway. Repair involves mobilizing the lateral soft tissue and moving it toward the midline to close the cleft and elongate the palate, if necessary. The most important goal

of cleft palate repair is the attainment of normal speech. Children with unrepaired or inadequately repaired clefts develop nasal-sounding speech patterns termed rhinolalia. Cleft palate repair, therefore, usually is done when the child is 9–18 mo old, before consequential speech development. In addition to closing the cleft itself, an important goal of palate repair is normal anatomic approximation of the levator palati muscles, which are responsible for oronasal valving in speech and swallowing. The cleft palate is closed by elevating the mucoperiosteum from the underlying bones and approximating it in the midline (**von Langenbeck technique**; Fig. 12.8-7) or using a V-Y type of retrodisplacement and closure (**Wardill-Kilner technique**). In either method, the levator muscles are specifically dissected and the levator sling is reconstructed. A layered closure usually is accomplished, including repositioning of the uvular muscles.

There are several different approaches to the muscle reconstruction in the soft palate, generally termed **intravelar veloplasties.** Z-plasty of the soft palate, also called a **Furlow procedure** (Fig. 12.8-8), has been used to lengthen the palate and reorient the palatal muscles across the cleft. The other procedures basically involve direct closure of the muscles and a pushback to lengthen the palate.

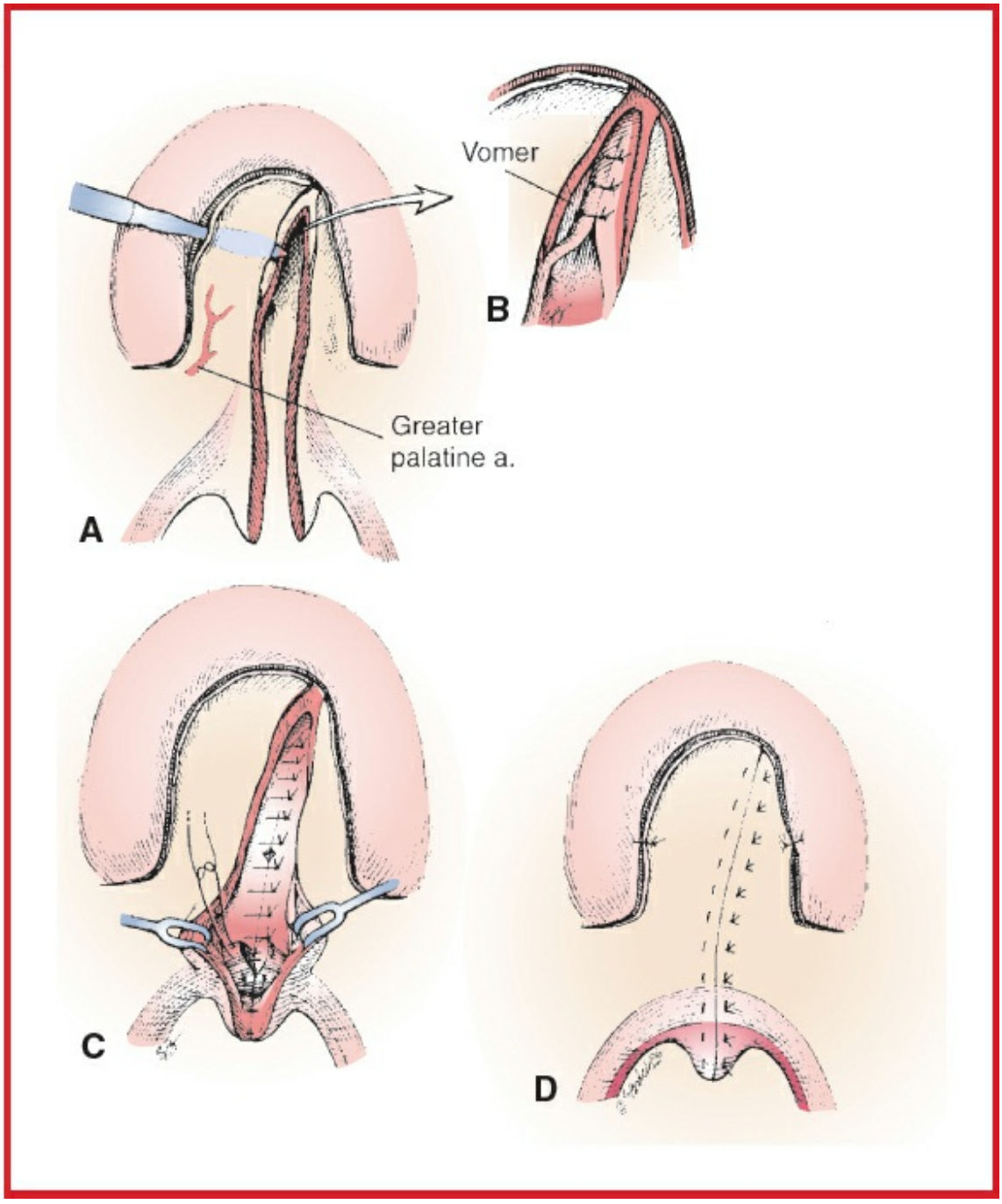

Figure 12.8-7 Palatoplasty technique. **A:** Cleft palate closure after healing of gingivoperiosteoplasty at 11–12 mo of age. Bilateral, unipedicled mucoperiosteal flaps, based on the greater palatine arteries, are elevated. **B:** Anteriorly, the nasal floor is repaired by suturing the vomerine mucosa to the nasal mucosa on the cleft side. **C:** The levator muscles are dissected free from the oral and nasal mucosa and released from the posterior edge of the hard palate. The levator muscles are approximated to each other in the midline. **D:** The oral mucosa is reapproximated in the midline with interrupted horizontal mattress sutures. (Reproduced with permission from Aston SJ, Beasley RW, Thorne CH, eds:Grabb and Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

Usual preop diagnosis

Cleft palate

ERAS: **Preop family counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, and postop pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.**

SUMMARY OF PROCEDURE	
Position	Supine; table rotated 90°–180° with oral RAE tube extending down the midline of the lower jaw and taped to the chin
Incision	Edges of the cleft palate and, possibly, the alveolar and pterygomandibular raphe areas
Special instrumentation	Dingman mouth gag (when setting the gag, communication between surgeon and anesthetist allows ETT compression to be noted early); usually, a headlight; oropharyngeal pack
Unique considerations	The gag may be released intermittently to allow reperfusion of the tongue; each manipulation may affect the ETT. Minimal-to-moderate amount of blood in the oropharynx at end of procedure should be carefully suctioned. Also, there may be some respiratory difficulties on emergence. Traction with a tongue suture often proves helpful in restoring patient's airway (maintained 24 h). Usually, oral or nasopharyngeal airways should not be placed in children.
Antibiotics	Cefazolin 30 mg/kg q5–6h (up to 1 g) × 5 d
Surgical time	1–1.5 h
Closing considerations	Child should not wake up crying and hypertensive. Tongue suture may be placed before extubation. **NB:** Dingman gag will stick to the ETT; therefore, holding the tube with a forceps deep in the oropharynx and careful removal of the gag avoid accidental extubation.
EBL	50 mL
Postop care	Elbow restraints; PACU → room; → home next day. OG tube is placed, suctioned, and removed.
Mortality	Rare

Morbidity	Recurrent bleeding (requiring early return to OR): Rare Hematoma under palate Dehiscence of palate
Pain score	4

PATIENT POPULATION CHARACTERISTICS

Age range	6–18 mo
Male:Female	1:3 (isolated cleft palate)
Incidence	1/1000
Etiology	Failure of fusion of the palatal shelves from anterior to posterior. (It can be due to a persistent high-tongue position in utero; increased facial width; reduced facial mesenchyme and/or drugs such as steroids, anticonvulsants, and benzodiazepines; or infection.)
Associated conditions	Multiple associated conditions. Most common is the Pierre Robin syndrome, in which cleft palate is found in association with glossoptosis and a micrognathic retruded mandible. These children frequently have airway obstruction and, even at an older age, may have sleep apnea. Other associations include Klippel-Feil syndrome, Treacher Collins syndrome, CHD, chronic URI, chronic otitis media, and subglottic stenosis.

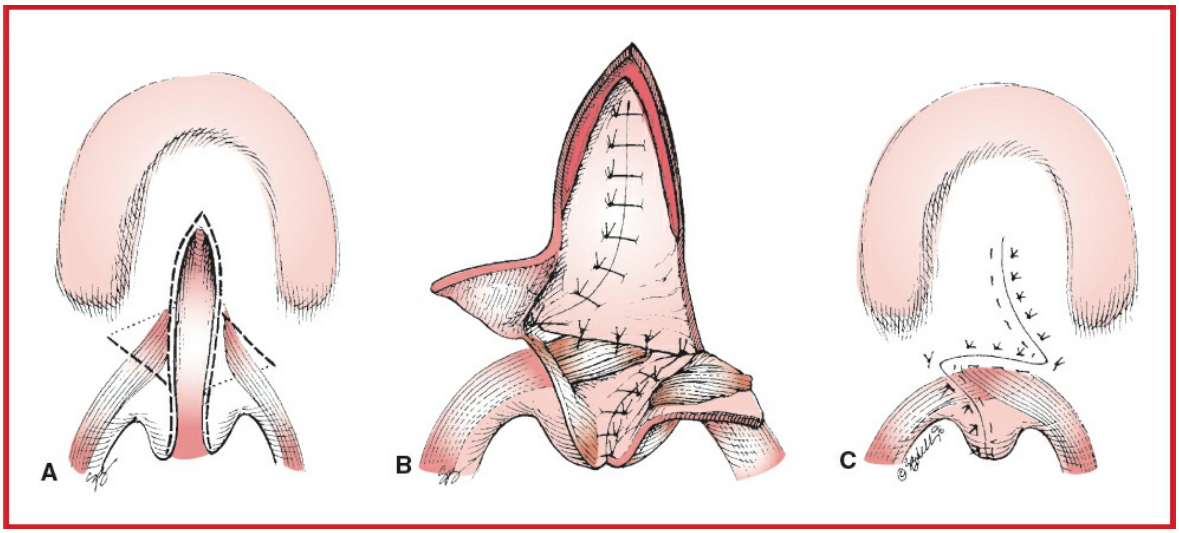

Figure 12.8-8 Double opposing Z-plasty closure of an isolated cleft palate. **A:** Design of the incisions. **B:** Muscle included in the posteriorly based flap. **C:** Final result with recreation of the levator sling. (Reproduced with permission from Aston SJ, Beasley RW, Thorne CH, edsGrabb and Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lip and Nose Surgery.

Suggested Reading

1. Gatti GL, Freda N, Giacomina A, et al: Cleft lip and palate repair.J Craniofac Surg 2017; 28(8):1918–24.

PHARYNGOPLASTY

SURGICAL CONSIDERATIONS

Description

Following the initial repair of palatal clefts, some children or young adults demonstrate continued hypernasal speech patterns, a condition called "velopharyngeal incompetence." This can be 2° a short soft palate, a large nasopharynx, or a soft palate that has inadequate movement either 2° scarring or due to neurogenic problems. The typical repair would be a palatal Z-plasty or superiorly based **pharyngeal flap** (Fig. 12.8-9) to the soft palate. The pharyngeal flap can cause later airway management problems especially with nasoendotracheal intubation.

Variant procedure or approaches

The **Jackson modification of the Orticochea flap** uses the posterior tonsillar pillars, which consist of the palatopharyngeus muscle and overlying mucosa, to create a competent oronasal sphincter (Fig. 12.8-10). The flaps are based superiorly and repositioned horizontally to meet above and behind the soft palate. Although they act to augment the posterior pharyngeal wall, they are also intended to maintain their innervation and, therefore, augment sphincter activity. A posterior pharyngeal wall implant also may be placed. Obstructive sleep apnea may be caused by these procedures and may make airway management difficult.

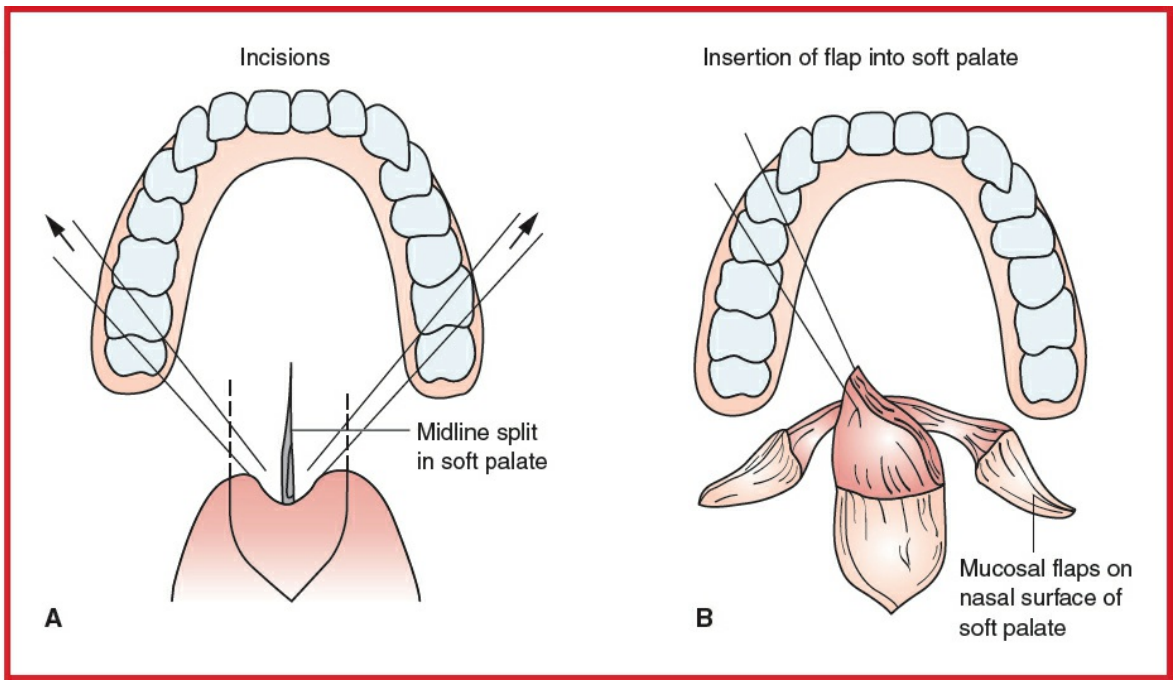

Figure 12.8-9 A and B: Pharyngeal flap, superiorly based. (Reprinted from Booth PW, Schendel SA, Hausamen J-E, eds:Maxillofacial Surgery, Vol. 1, 1st edition. Churchill Livingstone, Edinburgh: 1999. Copyright © 1999 Elsevier. With permission.)

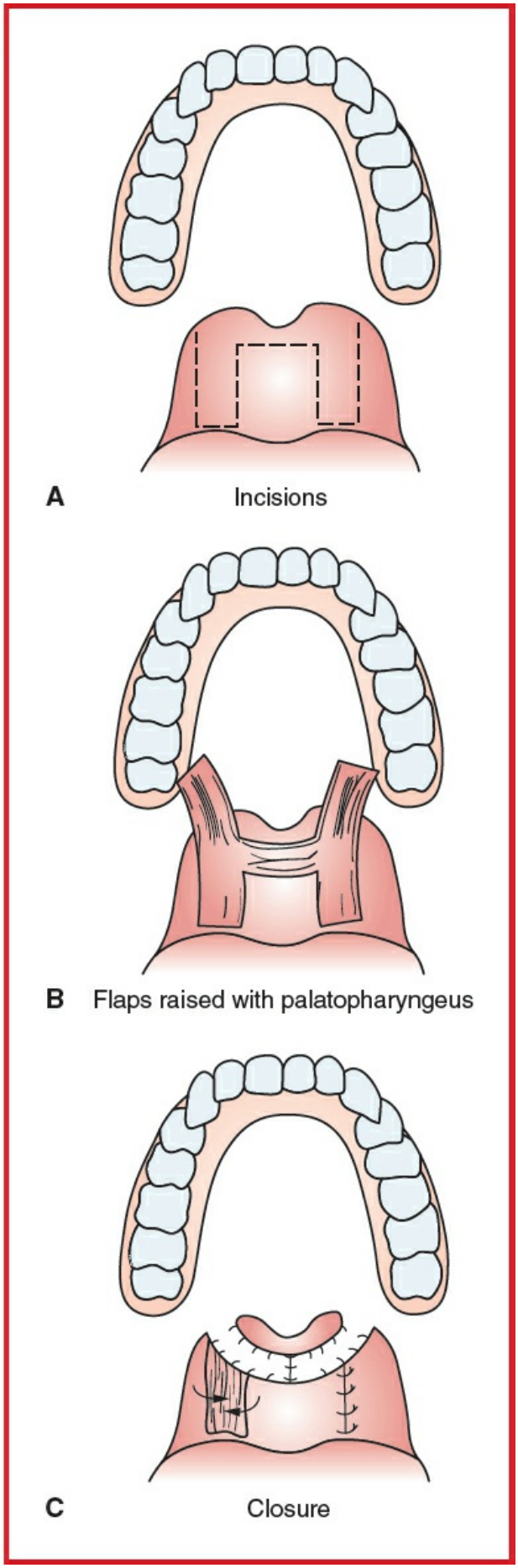
A
Incisions
B
Flaps raised with palatopharyngeus
C
Closure

Figure 12.8-10 A-C: Sphincter pharyngoplasty. (Reprinted from Booth PW, Schendel SA, Hausamen J-E, eds: Maxillofacial Surgery, Vol. 1, 1st edition. Churchill Livingstone, Edinburgh: 1999. Copyright © 1999 Elsevier. With permission.)

Usual preop diagnosis

Velopharyngeal incompetence

ERAS: Preop family counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, and postop pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Supine, table rotated 90° or 180°; oral RAE tube extending down the midline chin and taped in position
Incision	Involves incisions in soft and hard palates and in the posterior pharyngeal wall
Special instrumentation	Dingman mouth gag (caution with removal and manipulation regarding ETT); headlight
Unique considerations	Avoid oral or nasopharyngeal airways or nasal suctioning.
Antibiotics + other meds	Cefazolin 30 mg/kg q4h (up to 2 g) × 3 d; periop steroids, depending on preop airway
Surgical time	1–1.5 h
Closing considerations	Pediatric patients should not become hypertensive (↑ bleeding). There will be some nasopharyngeal drainage; thorough oral suctioning is important.
EBL	50–100 mL
Postop care	Avoid postop oral or nasopharyngeal airways or nasal suctioning. Be aware of possible occlusion of nasopharynx with flap and bleeding. Tongue suture can be placed for 24 h.
Mortality	Rare
Morbidity	Recurrent bleeding

	Hematoma under palate Dehiscence of palate Nasopharyngeal obstruction Secondary sleep apnea
Pain score	4

PATIENT POPULATION CHARACTERISTICS

Age range	3–11 yr most common
Male:Female	1:1
Incidence	~15% of children undergoing cleft palate repair will need some type of secondary palatal lengthening procedure after 3 yr.
Etiology	Short and scarred palate; neurogenic palate; palate-to-pharyngeal ratio that is too small
Associated conditions	Sleep apnea; Pierre Robin syndrome, with glossoptosis and micrognathia. Treacher Collins syndrome; microtia with craniofacial malformation; subglottic stenosis; CHD. Of special interest: some patients with cleft palate may have **velocardiofacial syndrome**. These children may have **medially displaced internal carotid arteries**, placing these major arteries in harm's way during dissection along the posterior pharyngeal wall.

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lip and Nose Surgery.

Suggested Readings

1. Ettinger RE, Oppenheimer AJ, Lau D, et al: Obstructive sleep apnea after dynami sphincter pharyngoplasty. J Craniofac Surg 2012; 23(7 Suppl 1):S32–4.
2. Naran S, Ford M, Losee JE: What's new in cleft palate and velopharyngea dysfunction management? Plast Reconstr Surg 2017; 139(6):1343e–55e.
3. Ruda JM, Krakovitz P, Rose AS: A review of the evaluation and management o velopharyngeal insufficiency in children. Otolaryngol Clin North Am 2012; 45(3):653–69.
4. Also see Suggested Readings for Cleft Lip, p. 1612.

ALVEOLAR CLEFT REPAIR WITH BONE GRAFT

SURGICAL CONSIDERATIONS

Description

Alveolar cleft occurs as both bony and soft-tissue defects in the alveolar portion of the maxilla in the position of the lateral incisor tooth; thus, an oral/nasal fistula exists with this deformity. The size of the cleft is variable; it may be unilateral or bilateral and is associated with cleft lip and palate. The alveolar segments are often collapsed such that orthodontic expansion is required before bone graft and repair. These devices are maintained to stabilize the graft in situ for a 3-mo healing period. The surgical procedure involves raising mucosal-gingival-periosteal flaps, advancing them, and performing a layered closure, starting with the nasal floor and working toward the oral cavity. A bone graft is placed in between these two layers to consolidate the upper arch. Cancellous bone usually is taken from the iliac crest or corticocancellous bone from the outer table of the skull. Other materials may be used but more controlled studies are needed to ascertain the long-term results.

Most commonly, the bone is harvested from the ilium. This can be accomplished via limited access and a trephine or via an open technique, depending on the amount of bone required. This portion of the procedure, especially by open technique, can add 50–100 mL of blood loss. Most nasal and lip revision surgery should be put off until the alveolus is reconstructed because this is the base on which the lip and nose sit.

Variant procedure or approaches

In young children, the alveolar cleft procedure may be performed without the use of bone grafts at the time of lip or hard palate closure (**gingivoalveoloplasty**, Fig. 12.8-11) with the hope that preop alignment of the clefted alveolus, and periosteal creation of new bone will fill the bony defect and allow subsequent normal tooth eruption. This is not always complete, and some of these children will need later bone grafting at age 7–8 yr, before eruption of the permanent canine teeth.

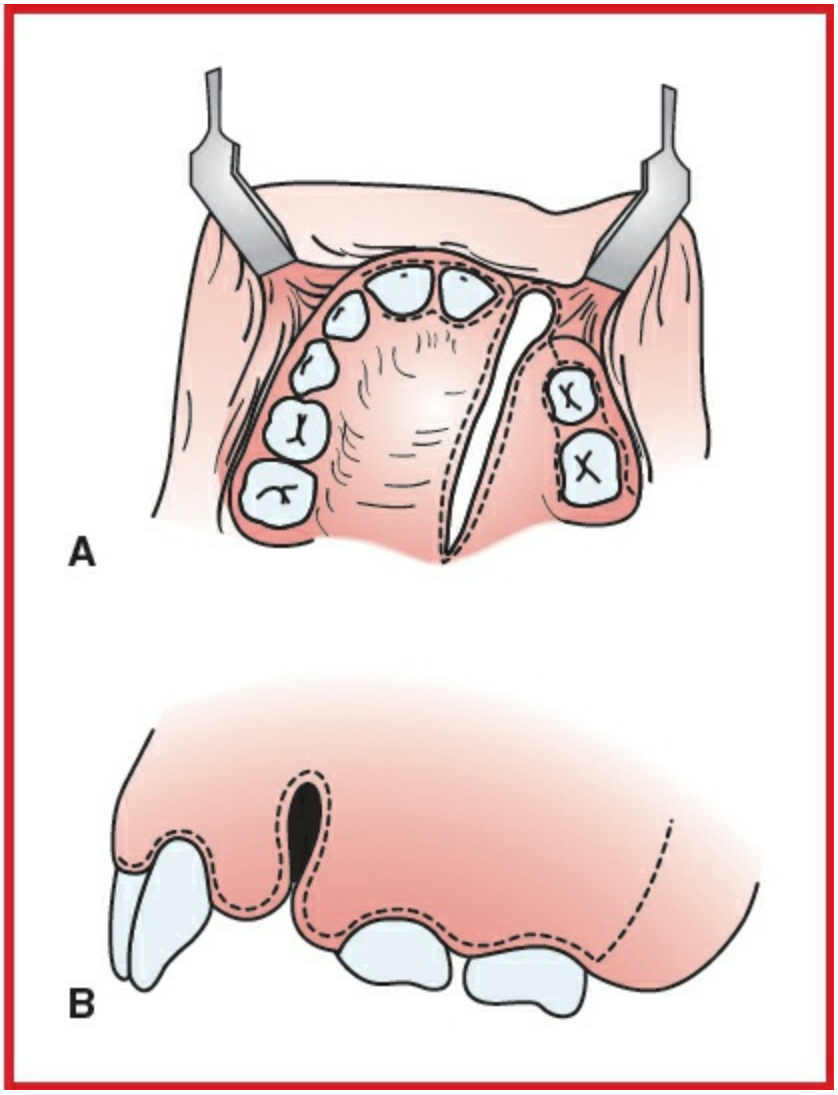

Figure 12.8-11 Gingivoalveoloplasty (GAP). Gingival and mucosal incisions are shown on the palate **(A)** and vestibular **(B)** surfaces, extending along the cleft borders. (Reprinted from Booth PW, Schendel SA, Hausamen J-E, eds:Maxillofacial Surgery, Vol. 1, 1st edition. Churchill Livingstone, Edinburgh: 1999. Copyright © 1999 Elsevier. With permission.)

Usual preop diagnosis

Congenital alveolar cleft

ERAS: Preop family counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, and postop pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE

Position	Supine; table rotated 90°–180° ± roll under hip (bone harvest)

Incision	Oral, with the addition of iliac crest incision or scalp incision, either parasagittal or coronal
Special instrumentation	Throat pack; Dingman mouth gag; headlight. Two instrument setups are used, to prevent cross-contamination from oral to iliac surgical sites.
Unique considerations	Important to ensure that the hip iliac crest bone graft site is on the opposite side from the anesthesiologist if the table is rotated only 90°. Midline oral RAE tube to chin. Care when manipulating Dingman, as it sticks to ETT
Antibiotics	Cefazolin 30 mg/kg (up to 1 g) iv preop
Surgical time	1.5–2.5 h
Closing considerations	**NB:** Ensure that throat pack has been removed. Pediatric patients should not wake up agitated. Non–cleft-side oral mouth gag and gentle oral suctioning are permissible; avoid nasal suctioning, especially from the cleft side.
EBL	100–200 mL
Postop care	PACU → ward; walking POD 1 or 2 after iliac grafts
Mortality	Rare
Morbidity	Bone graft loss: 2–10% Infection: 2–10% Refistulization: 2–10% Prolonged hip discomfort (bone graft donor site) Bleeding—oral or at bone donor site
Pain score	6

PATIENT POPULATION CHARACTERISTICS

Age range	8–12 yr
Male:Female	2:1
Incidence	Unknown
Etiology	Multifactorial, including both genetic and environmental aspects
Associated	Associated anomalies are seen in ~29% of cleft lip

conditions	cases and may include major chromosomal deletions and/or duplications, with the possibility of severe developmental delay, CHD.

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lip and Nose Surgery.

Suggested Readings

1. Trindade-Suedam IK, da Silva Filho OG, Carvolho RM, et al: Timing of alveola bone grafting determines different outcomes in patients with unilateral cleft palate. J Craniofac Surg 2012; 23(5):1283–6.
2. Also see Suggested Readings for Cleft Lip, p. 1612.

SECONDARY CLEFT LIP/NASAL SURGERY

SURGICAL CONSIDERATIONS

Description

Secondary deformities of the nose and lip develop, following the initial repair of either bilateral or unilateral cleft lip deformities. These subsequent deformities depend on the extent of the initial congenital anomaly, the quality of the surgical repair, and the resulting oral/facial function. Revision can vary from a minimal scar revision (Fig. 12.8-12) to a complete opening and reconstruction of the lip and nose, with or without ancillary procedures such as **septorhinoplasty ± cartilage grafting, forked flaps** (Fig. 12.8-13), **fascial lip augmentation, or Abbe-Estlander flap** (lip-switch flap; Fig. 12.8-14).

Occasionally, the individual born with a cleft lip and palate is severely deficient in tissue of the upper lip. This occurs most frequently in the bilateral condition. Correction involves switching tissue from the midline of the lower lip to the central portion of the upper lip, maintaining a pedicle of soft tissue between the lips, which usually contains the labial artery on one side. This pedicle normally is cut between 7 and 11 d. The redundant tissue in the midportion of the upper lip is transferred to the columellar portion of the nose at the same time, which elongates this section (Fig. 12.8-14). To avoid disruption of the flap, the older child should be cautioned to avoid wide mouth opening in the postop period.

Usual preop diagnosis

Secondary cleft deformity

ERAS: Preop family counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, and postop pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

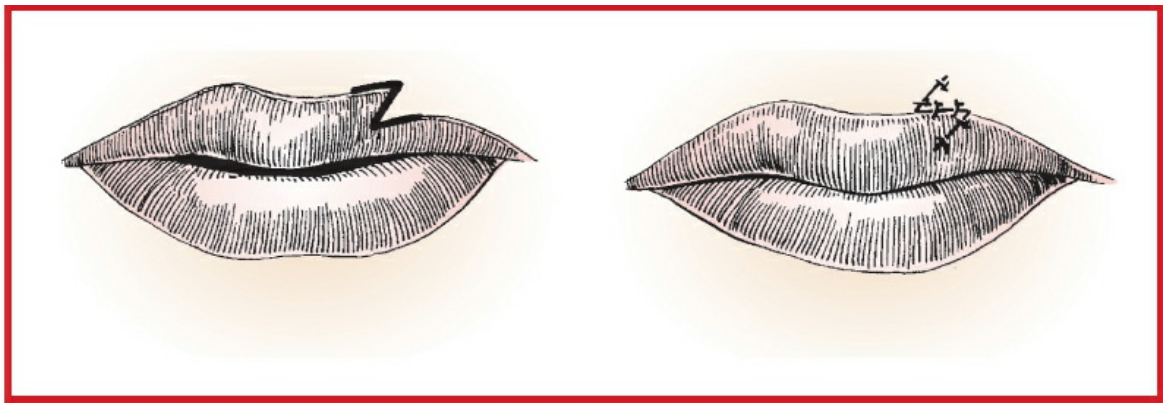

Figure 12.8-12 Z-plasty to correct notching of the vermilion border. (Reproduced with permission from Aston SJ, Beasley RW, Thorne CH, eds:Grabb and Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997. Originally from Millard DR JrCleft Craft: The Evolution of Its Surgery Little & Brown, Boston: 1976.)

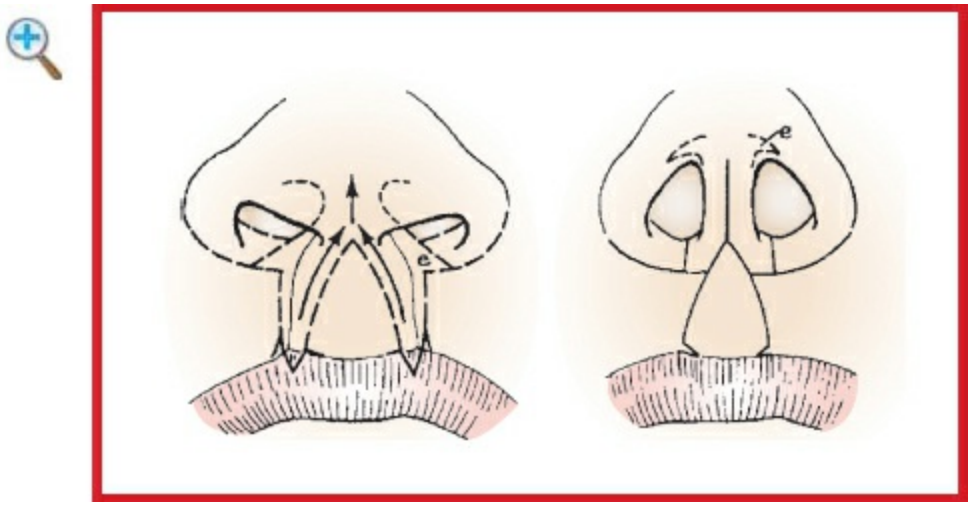

Figure 12.8-13 Short columella associated with the bilateral cleft nose, elongated by forked flaps. (Reproduced with permission from Aston SJ, Beasley RW, Thorne CH, eds:Grabb and Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

SUMMARY OF PROCEDURE

Position	Supine, table rotated 90°–180°; oral RAE; nasal RAE tube when working on lips only (especially if lips are held closed by a flap pedicle, making extubation more difficult)
	Variable, in lip or nasal areas. (See Figs. 12.8-12 to 12.8-

Incision	14.)
Special instrumentation	Throat pack; possibly rhinoplasty instruments; oral RAE tube; headlight; loupe magnification
Unique considerations	Procurement of a cartilage graft is usually from the nasal septum or ear; thus, the head may need to be turned to one side and this area also prepped. Elbow restraints for children. A switch flap leaves the lips connected at their midportion by a thin, easily damaged, soft-tissue pedicle; therefore, the patient should wake up unagitated.
Antibiotics	Cefazolin 30 mg/kg (up to l g) iv preop
Surgical time	Variable, depending on the extent of revision: 0.5–3 h
Closing considerations	**NB:** Remove throat pack.
EBL	Minimal to 75 mL
Postop care	May be obligatory mouth breathing post-rhinoplasty, or lips may be held mostly closed by the pedicle and swelling of a lip-switch flap; consider oropharyngeal airway; avoid wide mouth opening. PACU → room; elbow restraints in young children.
Mortality	Rare
Morbidity	Infection Wound breakdown Flap necrosis: <1% (with lip switch) Bleeding
Pain score	3–5 (depending on extent of procedure)

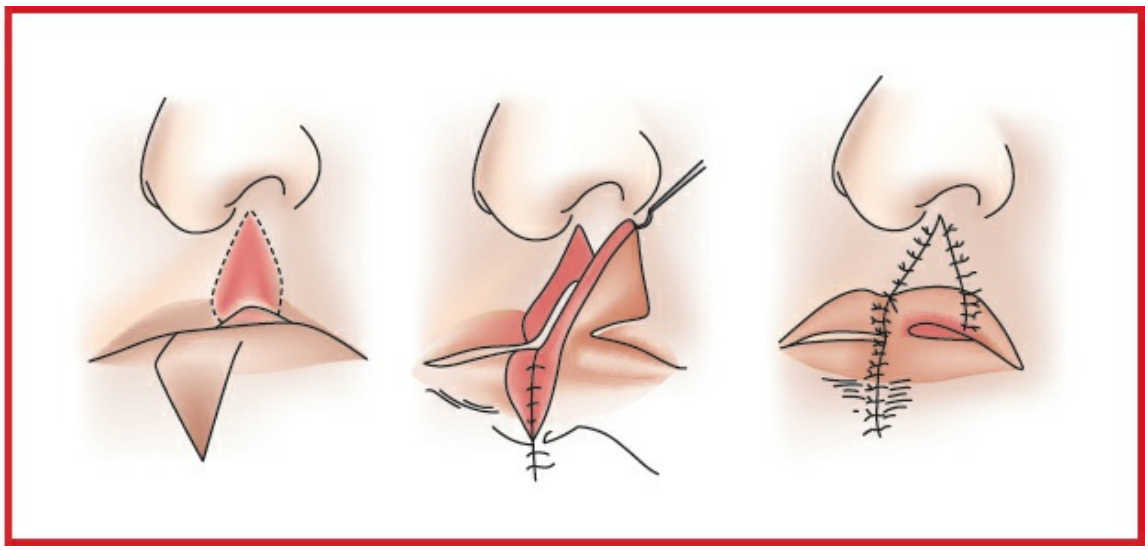

Figure 12.8-14 Abbe-Estlander flap. Note lips sutured together. (Reprinted from Converse JM, ed: Reconstructive Plastic Surgery, Vol. 3, 2nd edition. WB Saunders, Philadelphia: 1977. Copyright © 1977 Elsevier. With permission.)

PATIENT POPULATION CHARACTERISTICS	
Age range	2–50 yr
Male:Female	1:1
Incidence	20–60% of patients with primary clefts
Etiology	Unsatisfactory outcome of previous lip/nose surgery
Associated conditions	Associated anomalies are seen in ~29% of the clefts and may include major chromosomal deletions or duplications, with a possibility of severe mental retardation.

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Lip and Nose Surgery.

Suggested Reading

1. Cladis F, Grunwaldt L, Losee J: Anesthesia for plastic surgery. In: Davis PJ, Cladi FP, Motoyama EK, eds. Smith's Anesthesia for Infants and Children, 9th edition. Elsevier, Philadelphia: 2017,843–52.

ANESTHETIC CONSIDERATIONS FOR LIP AND NOSE SURGERY

(Procedures covered: cleft lip repair; palatoplasty; pharyngoplasty; alveolar cleft repair with bone graft; secondary cleft lip/nasal surgery)

PREOPERATIVE

The anesthesiologist should be aware of the parents' feelings about their child with a congenital malformation. The whole family needs to be treated with sensitivity and compassion. Cleft lip closure may be carried out as early as the first week of life in the healthy neonate; however, many surgeons and anesthesiologists find the Kilner rule of 10 helpful: the child should have an Hb > 10 g, be 10 wk old, and weigh 10 lb. The hard palate usually is closed between the ages of 1 and 5 yr; however, the soft palate should be closed prior to speech development (12–15 mo). **Palatoplasty** and **pharyngoplasty** usually are carried out from 1 to 15 yr. Patients with these midline facial defects are most likely to have other associated anomalies, including CHD, subglottic stenosis, and Pierre Robin or Treacher Collins syndrome. In patients with severe OSA, postop edema may impair ventilation. The possibility of remaining intubated postop should be discussed with the surgical team and the family.

Respiratory	Careful assessment is necessary as associated anomalies may affect airway or lungs. Chronic otitis 2° eustachian tube dysfunction is common. Treat with antibiotics before surgery. Postpone surgery (~2 wk) if Sx of acute URI is present (e.g., runny nose, fever, sore throat, cough). Chronic aspiration may be associated with cleft lip/palate. **Tests:** As indicated from H&P
Airway	Be aware of other congenital anomalies affecting the airway, such as Apert, Goldenhar, Klippel-Feil, Pierre Robin, or Treacher Collins syndrome. Review any previous anesthetic records for insights into airway management. Consider fiberoptic intubation (FOI or video laryngoscope) in patients with suspected difficult airway. Also consider elective tracheostomy under local anesthesia in patients with severe airway abnormalities. Patients with severe subglottic stenosis may require preop tracheostomy. Patients with difficult airways or severe obstructive sleep apnea undergoing palatal surgery should be

	evaluated for ICU monitoring postoperatively.
Cardiovascular	CHD is frequently associated with cleft palate. Preop evaluation of a patient with a known or suspected heart defect should include thorough H&P, EKG, Hct, baseline O_2 sat, and CXR. For children with Sx of cardiac dysfunction or those requiring cardiac medication, it is advisable to consult with a pediatric cardiologist to optimize the patient's condition prior to surgery. **Tests:** Preop ECG, echocardiogram indicated for patients with CHD; others as indicated from H&P
Nutritional	Infants with cleft lip/palate may have problems with oral feeding. Assess nutritional status from physical exam and by comparison to expected growth for age. **NB:** NPO after midnight for solids. Patients should continue to have breast milk until 4 h preop and clear liquids up until 2 h preop.
Neurologic	Delayed development of speech is common in the older child with cleft palate. Some of these children may be hearing impaired. Preop preparation and discussion is important to minimize the impact of these communication problems.
Psychological	Many patients with orofacial congenital malformations require multiple procedures; emotional support and psychological assessment of these patients are essential. Preop visits and consultation with play-therapists can be helpful, particularly if the child with a difficult airway will need a preoperative iv.
Hematologic	High incidence of iron deficiency anemia; T&C for 1 U PRBC (cleft palate) **Tests:** Hct
Laboratory	Other tests as indicated from H&P
Premedication	<9-mo-old rarely needs premedication; >9-mo-old may benefit from midazolam (0.5–0.75 mg/kg po); alternatively dexmedetomidine 1–2 μg/kg can be

	administered intranasal. Consider parent present induction for children with separation anxiety provided no difficult airway is anticipated.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Consider preop acetaminophen 15 mg/kg po (2–12 yo).

INTRAOPERATIVE

Anesthetic technique

GETA; warm room to 75°F–80°F; forced-air warmer.

Induction	Typically, an inhalational induction (sevoflurane ± N_2O/O_2) while patient is breathing spontaneously. Airway obstruction is best treated with positive pressure and jaw thrust +/- oral airway. Anticipate difficult laryngoscopy if large, prepalatal cleft is present. Intubate with oral RAE tube and secure in midline of the lower lip. In patients with difficult airways, FOI or GlideScope/videolaryngoscope may be required. IV glycopyrrolate and nebulized local anesthetics may facilitate FOI. Include amount of nebulized local anesthetic into the calculated max allowable local anesthetic to avoid toxicity. Avoid muscle relaxants for difficult intubations until ETT is placed. For children with difficult airways and a small posterior pharynx, consider preop dexamethasone 0.5 mg/kg iv to decrease palatal edema. After induction, consider morphine 0.1 mg/kg or hydromorphone 0.01 mg/kg and iv acetaminophen 10–15 mg/kg for postop analgesia.
ERAS	Verify preincision antibiotics. Assess volume status (see D-1). Maintain normovolemia. Avoid hypothermia.
Maintenance	Standard pediatric maintenance ± muscle relaxant. Airway is shared with the surgeons. The Dingman mouth gag is used for surgical exposure and may inadvertently

	compress the ETT or cause an endobronchial intubation. Monitor PIP before and after placement of Dingman. Flexion of the neck also may cause endobronchial intubation. Extension of the neck may cause complete or partial extubation. Adequacy of ventilation should be checked after every position change. Bilateral breath sounds should be equal after final positioning. In cases with the table turned 180°, a precordial stethoscope placed over the left chest can help detect endobronchial tube migration. ETT should be sutured to the alveolar ridge in complex maxillofacial procedures. In palatoplasty, the palate is infiltrated with epinephrine (in lidocaine usually) → ↓ blood loss + ↑ dysrhythmias. Confirm maximal allowable local anesthetic dose with surgeons. Moderate risk of airway fire. Reduce FiO_2 and consider throat pack if endotracheal tube leak is substantial. Approximately 18 cm H_2O or greater if patient requires increased ventilator pressure. Throat pack insertion and removal can cause inadvertent extubation. Ensure firm airway connections prior to relinquishing airway. Always have a spare stylet ETT ready in the event of inadvertent extubation.	
Emergence	Pharyngeal (throat) packs are usually placed to prevent aspiration of blood. **NB:** Packs must be removed before extubating the trachea. Consider laryngoscopy to inspect airway and remove blood and clots before extubation. A tongue stitch is useful postop following cleft palate surgery. It may be used to pull the tongue forward to relieve postop respiratory obstruction. Extubation in the lateral (tonsillar) position is useful in promoting drainage of blood and secretions.	
Blood and fluid requirements	IV: 18–22 ga × 1 BSS @: 4 mL/kg/h—0–10 kg +2 mL/kg/h—11–20 kg +1 mL/kg/h—>20 kg	Blood loss is replaced by 3:1 crystalloid or 1:1 colloid (e.g., 5% albumin or 6% hetastarch). Rarely, a blood

	(e.g., 25 kg = 65 mL/h)	transfusion may be indicated for hemorrhage.
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes	
Complications	Obstructed ETT → ↑ PIP Mucous plugging Hemorrhage Airway fire	✓ ETT to see that it is not partially or completely obstructed by mouth gag. ✓ bilateral breath sounds. Inadvertent extubation/endobronchial intubation.

POSTOPERATIVE

Complications	Retained throat pack	✓ for retained throat pack if there are Sx of airway obstruction in immediate postop period.
	Airway edema → croup Hemorrhage Obstructive sleep apnea	Rx of postintubation croup consists of cool, humidified, 100% O_2 mask or nebulization 2.25% racemic epinephrine (0.5 mL in 3 mL NS). Racemic epinephrine is given for its vasoconstrictor, rather than its bronchodilator, effect. If posterior pharyngeal edema is present, consider dexamethasone 0.5 mg/kg iv.
Multimodal pain	Acetaminophen (10–15	Avoid oversedation in

management	mg/kg po/iv or 20–30 mg/kg pr) q6h Acetaminophen 10 mg/kg iv q6h ATC Lorazepam 0.01 mg/kg iv q6h ATC Consider hydromorphone RN controlled analgesia 1 mcg/kg continuous and 2 mcg/kg q10min lockout for breakthrough pain. Alternatively: Fentanyl 1 mcg/kg iv Morphine 0.05–0.1 mg/kg iv q2–3h prn Hydromorphone 0.005–0.01 mg/kg iv q2–4h Hydrocodone/acetaminophen elixir (Hycet) 0.15 mg/kg po q6h	patients with Abbe-Estlander repair 2° airway obstruction. Aim for child to be mildly sedated (decreases bleeding) but not obstructing; intraop morphine, ketamine helpful to ensure smooth awakening. Caution for airway obstruction in PACU
Tests	Hct, if indicated	Others as indicated

OTOPLASTY

SURGICAL CONSIDERATIONS

Description

There are a number of congenital ear malformations. The two most frequently encountered in the OR are **prominent ear** and **microtia.** Both conditions can be unilateral or bilateral.

Prominent ears are usually an isolated finding. The ear is examined in thirds to determine where the prominence lies, and the surgery is tailored to correct the specific excesses. The antihelical fold is usually flattened and requires reshaping. The prominence of the ear, as measured by its projection from the mastoid process, is decreased accordingly. This usually involves an elliptical skin incision in the posterior ear area, dissection over the mastoid, and one or a combination of three techniques—mattress sutures, cartilage scoring, and/or resection.

Variant procedure or approaches

All procedures are similar, with minor differences in suturing and amount of resected tissue. In addition to the posterior incisions, an anterior incision can be used in some approaches.

Microtia is within the congenital anomaly spectrum of hemifacial microsomia, and the associated facial malformation may include a small asymmetric jaw, creating a difficult intubation. Microtia reconstruction is done by two philosophically different techniques. The first is by autogenous tissue, usually rib, and is done in multiple stages. The second technique uses an alloplastic framework and is done in one longer stage. Reconstruction with autologous rib graft is a multistaged procedure. This donor site comes with the attendant risks of pneumothorax and hemothorax (Fig. 12.8-15). Stage one is the creation of a cartilaginous framework, with placement into a cutaneous pocket symmetric with the normal ear, if present (Fig. 12.8-16). Stage one is accomplished once the rib cartilage has grown to sufficient size—usually, ~6–7 yr of age. Stage two requires transposition of the lobule 3 mo after stage one. Stage three is the elevation with skin graft of the framework from the head posteriorly. Stage four is the creation of a tragus and conchal excavation.

Variant procedure or approaches

Recently, **porous polyethylene implants** have been used to avoid donor-site morbidity, and **temporoparietal fascial flaps** provide coverage to avoid alloplastic extrusion.

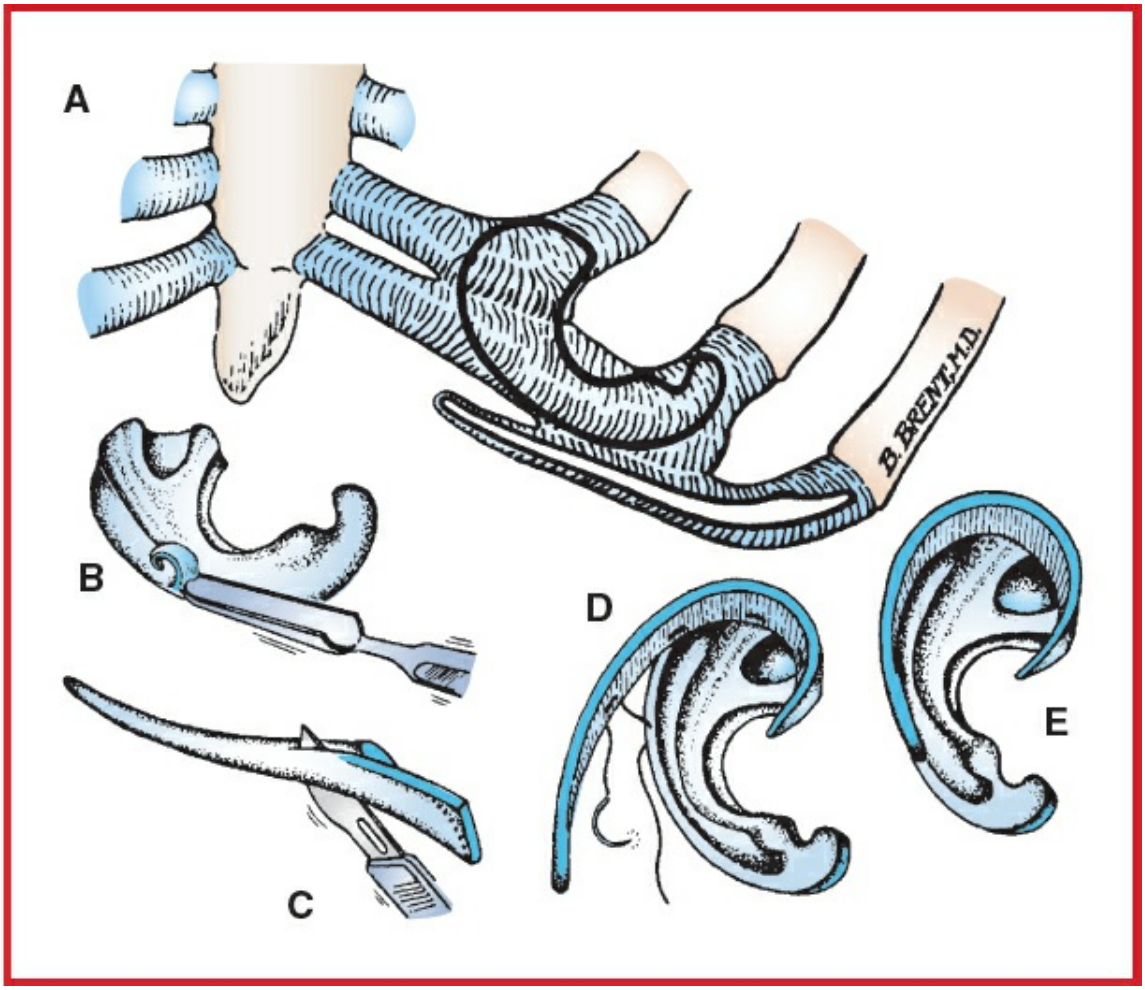

Figure 12.8-15 Fabricating an ear framework from costal cartilage. **A:** Donor site—the contralateral thorax. The helical rim is obtained from a "floating" rib cartilage, the main pattern from the synchondrosis of two cartilages. **B:** Sculpting the main block. **C:** Thinning the "floating" rib cartilage to produce a delicate helical rim. **D:** Affixing the rim to the main framework block. **E:** Completed framework. (Reproduced with permission from Aston SJ, Beasley RW, Thorne CH, eds:Grabb and Smith's Plastic Surgery, 5th edition. Lippincott-Raven, Philadelphia: 1997.)

Usual preop diagnosis

Ear malformation; prominent ears; microtia; anotia

ERAS: Preop family counseling by the surgeon/anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, and postop pain management options. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

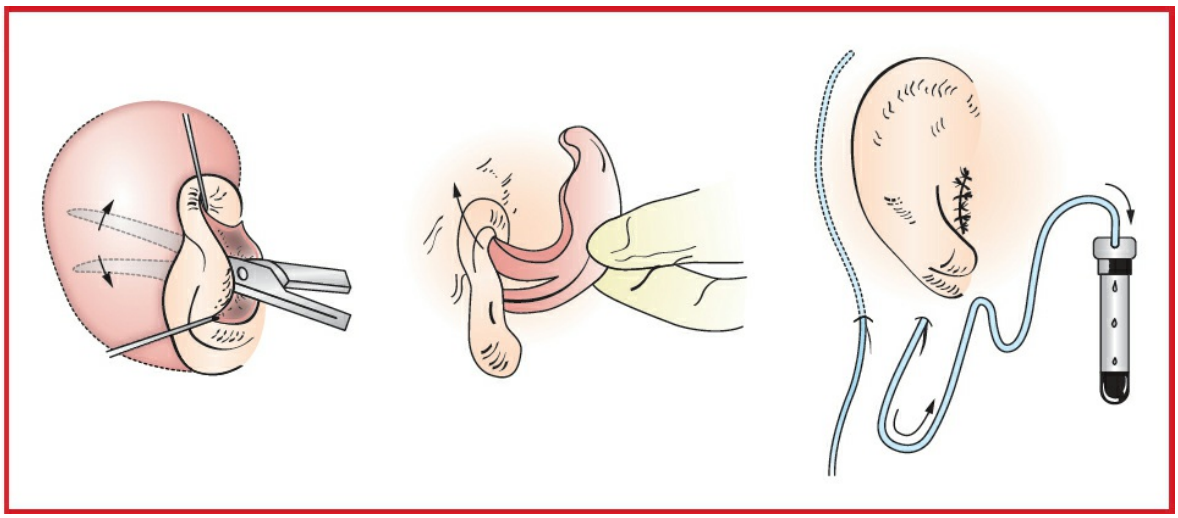

Figure 12.8-16 The cutaneous "pocket." The vestigial native cartilage is excised; then, a skin pocket is created. To provide tension-free accommodation of the framework, the dissection is carried out well beyond the proposed auricular position. Using two silicone catheters, the skin is coapted to the framework by means of vacuum tube suction. (Reprinted from Booth PW, Schendel SA, Hausamen J-E, eds: Maxillofacial Surgery, Vol. 1, 1st edition. Churchill Livingstone, Edinburgh: 1999. Copyright © 1999 Elsevier. With permission.)

SUMMARY OF PROCEDURE

Position	Supine; table rotated either 90° or 180°; oral intubation
Incision	Posterior ear; occasionally anterior ear; microtia, stage-dependent; and chest wall
Unique considerations	Head turned from side to side during operation.
Antibiotics	Cefazolin 30 mg/kg (up to 2 g) iv preop
Surgical time	2–4 h (depends on unilateral vs. bilateral); 1st stage microtia much longer
Closing considerations	Ear dressing requires 5–10 min at the end of the procedure. Delicate vacuum test-tube drainage system in the 1st stage microtia repair fixed to head dressing.
EBL	10–100 mL
Postop care	PACU → room
Mortality	Rare
Morbidity	**Protruding ears:** Hematoma formation: <1%

	Infection: <1 % Asymmetrical ear reduction: <1% Suture extrusion <1% **Microtia:** Pneumothorax or hemothorax Hematoma, infection, and skin loss: 1.6% (total) Overgrowth: 41%
Pain score	4

PATIENT POPULATION CHARACTERISTICS

Age range	6+ yr
Male:Female	2:1
Incidence	Unknown
Etiology	**Microtia:** 9.2% bilateral; 32% left vs. 58% right; 4.9% recurrence within immediate family **Protrusion:** Also seen among family members. Most are bilateral.
Associated conditions	**Protruding ears:** none known **Microtia:** Brachial arch deformities—bone/soft-tissue deficit, 36.5%; facial nerve weakness, 15.2%; cleft lip ± palate, 4.3%; macrostomia, 2.5%; urogenital defects, 4%; cardiovascular malformations, 2.5%; others, 1.6%

ANESTHETIC CONSIDERATIONS

See Anesthetic Considerations for Ear Surgery, Chapter 3.0 Otolaryngology.

Suggested Readings

1. Breugem CC, Stewart KJ, Kon M: International trends in the treatment of microtiaJ Caniofac Surg 2011; 22(4):1367–9.
2. Nour C, Ratsiu J, Singh N, et al: Analgesic effectiveness of acetaminophen fo primary cleft palate repair in young children: a randomized placebo controlled trial. Paediatr Anaesth 2014; 24(6):574–81.
3. Smith D, Abdullah SEFHJ, Moores A, et al: Post-operative respiratory distres following primary cleft palate repair. Laryngol Otol 2013; 127:65–6.

CHAPTER 12.9

Pediatric Transplantation

SURGEON
Waldo Concepcion, MD, FACS

ANESTHESIOLOGISTS
Julianne Mendoza, MD
Louise K. Furukawa, MD
Gregory B. Hammer, MD

PEDIATRIC RENAL TRANSPLANTATION

SURGICAL CONSIDERATIONS

Description

Renal transplantation is the therapy of choice for children with end-stage renal disease providing freedom from dialysis and improvement in growth. Preemptive transplantation is recommended when possible to minimize loss of growth potential and currently accounts for 25% of transplants. The source of the renal allograft may be a cadaveric (40%), living related, or living unrelated donor. More than 90% of donors are adults.

A right curvilinear incision, starting at the pubic symphysis and extending to just below the ribs, is the approach most commonly used even for children as small as 10 kg. The donor renal artery and vein are anastomosed directly to the recipient aorta and vena cava, respectively. An adult-sized kidney may occupy the majority of the right upper quadrant in a small recipient. Meticulous attention to the positioning of the kidney will prevent kinking or twisting of the donor vasculature. This may require mobilization of the right lobe of the liver or even hepatectomy in some cases and almost always a right nephrectomy in small children. The donor kidney can be temporarily taken out of ice

and placed into the recipient to determine the best site for the anastomoses. In this manner, the vessel length necessary to fashion straight yet tension-free anastomoses can be determined. It is important to avoid redundancy in the vessels and ensure a straight line from the renal hilum to the aorta and vena cava without the hooking of one vessel over another. The venous anastomosis is fashioned first. The vena cava is clamped, and an appropriate size cavotomy is made. The renal vein is sutured to the vena cava in an end-to-side fashion. A small vascular bulldog clamp is then applied to the renal vein above the anastomosis to allow for removal of the vena caval clamp and reconstitution of lower extremity venous return to the heart. Heparin is administered, and the aorta is then cross-clamped proximal and distal to the aortotomy. An end-to-side anastomosis is fashioned between the renal artery and aorta, taking care to interrupt the front wall sutures and prevent the purse-string effect of a running suture. Warm ischemia can be minimized during this time by intermittently placing iced slush around the kidney. It is critically important to achieve substantial hypervolemia prior to reperfusion of the adult-sized kidney (ASK) because reperfusion will cause an immediate drain of a large portion of a child's relatively small blood volume into the ASK. This necessitates bringing the central venous pressure to ~10–15 cm H_2O before reperfusion with a combination of crystalloid and colloid to minimize tissue edema. As prophylaxis against ischemia-reperfusion injury, a single dose of iv mannitol is administered at the time of graft revascularization, and low-dose dopamine is also initiated. Adequate renal blood flow to an ASK cannot be obtained in children without maintenance of a hypervolemic state, and infants and small children are frequently kept intubated for 24–48 h postop to maintain control of their respiratory function, while large volumes of fluid are administered.

The type of ureteral reimplantation depends on the quality of the recipient bladder. An extravesicular ureteral reimplantation can be considered in a healthy bladder of adequate size. This requires distending the bladder with GU irrigant via a three-way Foley catheter. The bladder is reflected medially to accomplish the implantation near the posterolateral portion of the bladder with the ureteral orifice located close to the trigone. The detrusor muscle is divided, and a mucosal-to-mucosal anastomosis is fashioned between the bladder and the donor ureter over a ureteral stent. The detrusor muscle is reapproximated over the ureter for an adequate length to create an antireflux valve. If the bladder is of small capacity or defunctionalized, a transvesicular approach to ureteral reimplantation is required. A bladder cystotomy is made at the dome, and the transplant ureter is brought into a shallow, mucosa-denuded, rectangular trough extending from a superiorly placed ureteral hiatus distally to the trigone. The ureter is then spatulated and directly sutured to the urinary mucosa over a ureteral stent. The ureteral stent is sutured to a cystotomy tube brought out through a separate incision in the

bladder for easy removal of the urethral catheter with its associated discomfort while ensuring adequate drainage and prevention of clot obstruction. The cystotomy is then closed and the kidney inspected for perfusion and hemostasis.

ERAS: Family preop counseling/education by the surgeon and anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, postop pain management options, DVT prophylaxis, physiotherapy plan, possibility of lines, NG tube, and urinary drain postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Lower quadrant curvilinear
Special instrumentation	Self-retaining retractor Vascular instruments Foley catheter (three-way)
Unique considerations	Recipient hypervolemia (CVP 10–15 mm H_2O) Mannitol, furosemide Dopamine Immunosuppression Potassium-free iv fluids
Antibiotics	Cefazolin 30 mg/kg (1 yr or older; max = 2 g)
Surgical time	3–5 h
EBL	Minimal
Postop care	Maintain hypervolemia (CVP > 10 mm Hg). Maintain adequate SBP > 120 mm Hg with dopamine. Maintain high UO with a combination of iv fluids + Lasix. Goal 150–200 cc/h ICU postop Transplant ultrasound postop
Mortality	<2%
Morbidity	Primary nonfunction: 2.6% Vascular thrombosis: 10.3% Renal artery stenosis: 0.7%

	Other technical: 1.3% Bleeding: 2% Wound infection: 5%
Pain score	7

ANESTHETIC CONSIDERATIONS FOR KIDNEY TRANSPLANTATION IN INFANTS AND CHILDREN

PREOPERATIVE

Patients presenting for renal transplantation tend to fall into two groups: (a) children in the infant/toddler age group who suffer from congenital syndromes (congenital nephrotic syndrome, severe polycystic kidney disease, obstructive uropathies, FSGS) or (b) the older child who may have a variety of conditions including severe autoimmune nephropathies. These children are often the recipients of a living-related transplant, and as such, the surgery proceeds as a somewhat elective procedure. Most patients have been on a well-established regimen of peritoneal or hemodialysis. Preemptive transplantation patients may have more severe electrolyte derangements preop than patients on dialysis.

Airway	Some renal conditions may have associated syndromes and dysmorphia. A thorough airway examination as well as perusal of old anesthetic records should reveal any potential airway problems.
Respiratory	Patients with autoimmune diseases (e.g., lupus) may have pulmonary involvement. Any patient presenting with signs and symptoms of URI should be allowed adequate time for resolution of heightened airway reactivity. Children born with large polycystic kidneys may have pulmonary hypoplasia. **Tests:** Pulmonary function tests, if indicated from H&P
Cardiovascular	Relatively long-standing hypertension and LVH can be seen in this patient population and may require bilateral nephrectomies prior to or during the transplantation. Adequate control of

	hypertension should be achieved during the preoperative admission period. **Tests:** EKG, echocardiogram
Gastrointestinal/hepatic	Patients with polycystic kidney disease may also have hepatic dysfunction and require future liver transplantation. Patients with congenital nephrotic syndrome tend to be hypoalbuminemic and may be on continuous albumin infusions. **Tests:** Albumin, LFTs, PT, PTT if applicable
Renal	Most patients are well maintained on hemodialysis or peritoneal dialysis. Other common electrolyte abnormalities are metabolic acidosis, hypocalcemia, and hypermagnesemia. Be aware of current weight relative to dry weight as some patients may present with dehydration in the postdialysis period. **Tests:** Serum electrolytes, BUN, and creatinine
Hematologic	Anemia and platelet dysfunction are commonly seen. **Tests:** CBC, platelet count
Premedication	Most children will require a premedication to allay separation anxiety. Oral midazolam 0.5–0.75 mg/kg or iv midazolam 0.1 mg/kg (maximum 2 mg) is usually sufficient.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of regional analgesia for postop pain management. Consider preop acetaminophen 10–15 mg/kg iv or po as an elixir.

INTRAOPERATIVE

Anesthetic technique

GETA

Induction	An inhalational induction with standard monitors will work well in patients without prior iv access. Patients in the infant/toddler age group may have significant venous access problems, and the hemodialysis catheter (if present) may be used provided that sufficient heparinized blood has been aspirated from the dead space of the catheter lumen. Use of muscle relaxation once iv access has been established is necessary for adequate surgical visualization and mobilization. If recently dialyzed, pt may be hypovolemic. Induction of immunosuppression begins in the preop period and continues intraop. Care should be taken to discuss with the surgeon and nephrologist which immunosuppressive agents should be given intraop. If thymoglobulin is used, a dedicated central line port is needed, and premedication with iv Solu-Medrol (1 mg/kg), diphenhydramine (1 mg/kg), and acetaminophen (15 mg/kg) is initiated prior to infusion. Methylprednisolone (10 mg/kg) is given just prior to unclamping of the renal artery upon reperfusion.
ERAS	Verify preincision antibiotics. Assess volume status (see p. D-1). Maintain normovolemia and normothermia. Consider preincision placement of nerve blocks.
Maintenance	Standard balanced anesthetic maintenance. Titration of a long-acting narcotic is recommended, although high doses of meperidine should be avoided due to accumulation of normeperidine. Adequate muscle relaxation is especially important in the patient under 20 kg to facilitate surgical exposure. Any coughing or straining can result in vascular injury to the renal allograft. Significant hypothermia can be seen when the iced organ is placed in the peritoneum. Tachycardia is frequently seen following reperfusion of the ASK due to the relatively large vascular volume it can accommodate and the low vascular resistance. Urine output should be closely monitored postreperfusion.

Emergence	Most children weighing <20 kg remain intubated in anticipation of large fluid shifts due to volume loading. Extubation in the OR is usually feasible for patients larger than 20 kg. All patients recover in the ICU for monitoring of hemodynamics and urine output. Discuss with surgeon local wound infiltration or nerve block (e.g., TAP or rectus sheath blocks) placement.
Management of reperfusion	**Blood and fluids:** Maintenance IV fluids without K^+ Volume loading Albumin loading Blood may be required. Warm all fluids. **Pressor support** **Promoting diuresis**	Preop fluid status is variable. Maintenance fluids should be devoid of K^+. Volume loading to a CVP of 10–15 or titrated to renal allograft turgor postreperfusion is usually requested by the surgeon for infants and small children receiving ASKs to avoid stasis and thrombosis within the allograft. Albumin boluses (10 mL/kg) or PRBC transfusion may be needed to achieve goal CVP. Dopamine (3–5 mcg/kg/min) is started to increase perfusion pressure to the allograft. In addition, vasopressin or epinephrine infusions may be needed to achieve systolic blood pressure of >120 mm Hg necessary for the ASK. For patients >20 kg, the magnitude of volume loading is decreased to a goal CVP of 8–10, which can usually be achieved with crystalloid and albumin alone. Constant communication with the surgical team regarding allograft turgor after

		reperfusion will assist in guiding fluid management. Consider use of TEE in patients with hypertensive cardiomyopathy to guide volume loading to avoid pulmonary edema. Diuresis is promoted just prior to reperfusion of the renal artery with mannitol (0.5 mg/kg) and furosemide (1 mg/kg). Goal urine output after reperfusion is 5–10 mL/kg/h.
Monitoring	Standard monitors Arterial line CVP (2–3 lumens) Hct/electrolytes Urine output (Foley catheter) PIP Temperature control	Adequate blood pressure to perfuse the ASK is crucial as is sufficient preload (CVP 10–15) prior to reperfusion. Invasive arterial blood pressure monitoring is necessary to monitor beat-to-beat variation in perfusion pressure and guide in titrating volume and vasoactive infusions. CVP monitoring is critical to management of volume status. Electrolyte derangements may occur during the case 2° large-volume replacement with albumin or blood products. ↓ Ca^{++} and ↑ K^{+} should be corrected. Hematocrit goal after reperfusion is above 25% though caution should be taken with regard to

		transfusion to avoid renal artery thrombosis. Urine output is closely monitored after ureteral reimplantation. Peak inspiratory pressures should be closely followed as risk of pulmonary edema is increased from volume loading and may be a consequence of thymoglobulin infusion. Care should be taken to avoid hypothermia that may occur following placement of iced allograft into abdominal cavity.
Complications	Ventilatory difficulties Electrolyte abnormalities Hypotension/inadequate renal perfusion Low urine output	

POSTOPERATIVE

Complications	Electrolyte abnormalities Ventilatory difficulties Inadequate pain control in the face of hypotension Hemorrhage Clot retention given small catheter size	
Multimodal pain management	Fentanyl 1 mcg/kg iv Small doses of ketamine (e.g., 1–5 mg iv) can be used for analgesia if patient is intubated.	Care must be taken in the administration of iv opioids to prevent ↓ BP, which may compromise ASK perfusion.

ERAS	PONV protocol (see p. D-1)	Encourage early enteral nutrition, Foley catheter removal, and mobilization. Consider DVT prophylaxis. Chewing gum may promote return of bowel function.

Suggested Readings

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PEDIATRIC LIVER TRANSPLANTATION

SURGICAL CONSIDERATIONS

Description

Liver transplantation was first pioneered in the 1960s as a lifesaving experimental procedure for children with end-stage liver disease (ESLD). Since then, it has developed into the accepted treatment modality for pediatric patients with ESLD or

fulminant hepatic failure. The indications for liver transplantation in children are broad and range from cholestatic cirrhosis secondary to biliary atresia to inborn errors of metabolism that, if untreated, result in devastating neurologic injury.

The current liver allocation system prioritizes pediatric recipients based on a calculated numerical value known as the Pediatric End-Stage Liver Disease (PELD) score. Th PELD score was validated as a model for predicting the 3-mo wait-list mortality. Although exemption points can be petitioned for on a case-by-case basis, a patient's severity of illness generally correlates with the PELD score. Absolute contraindications for liver transplantation include irreversible encephalopathy, uncontrollable infection, and untreatable extrahepatic malignancy. A general contraindication is poor quality of life postop.

The main constraint to pediatric liver transplantation compounding the preexisting organ shortage involves the donor-to-recipient size ratio. The minimum acceptable graft-to-body weight ratio to provide adequate postop liver function is 1%. However, the suitability of a donor is more often determined by the maximum amount of donor liver that a recipient can accommodate in the abdominal cavity. This results in the utilization of several different types of grafts in pediatric liver transplantation.

Type of Graft	Artery	Portal Vein	Venous Outflow	Biliary Reconstruction
Cadaveric full size	Celiac trunk	Main PV	Full VC	Main HD
Cadaveric reduced size	Celiac trunk	Main PV	Full VC	Main HD
Cadaveric left lobe	Common HA	Left PV	Left HV	Left HD
Cadaveric left lateral segment	Common HA	Left PV	Left HV	Left HD
Live donor left lateral segment	Left HA	Left PV	Left HV	Left HD

Although the type of graft used determines certain technical aspects of the hepatectomy and implantation, the general sequence of events consists of:

1. Recipient hepatectomy

2. Anhepatic phase (during which portal venous inflow and hepatic venous outflow are reconstituted)
3. Allograft reperfusion
4. Reconstitution of hepatic arterial inflow
5. Biliary reconstruction

A bilateral subcostal incision is used with a midline subxiphoid extension as needed. The abdomen is explored, and adhesions are lysed taking care to suture-ligate varices in patients with portal hypertension. This portion of the procedure may be tedious and bloody in patients with prior liver surgery. The falciform ligament is divided down to the suprahepatic vena cava. The left coronary ligament is divided, and the left lateral segment is mobilized from the diaphragm. The lesser omentum is divided and the lesser sac entered. The peritoneum of the hepatoduodenal ligament is divided, and a hilar dissection is performed. The connective and vascular tissue of the hepatoduodenal ligament is carefully divided taking care to suture-ligate any varices en masse until the common bile duct is identified. This portion of the procedure may result in significant blood loss in patients with severe portal hypertension and coagulopathy. The common bile duct is then suture-ligated and divided high in the hilum of the liver. The hepatic artery is similarly identified, suture-ligated, and divided. The portal vein is then completely skeletonized. The right lobe of the liver is mobilized from its retroperitoneal attachments to expose the lateral border of the vena cava. In the standard technique, the infra- and suprahepatic venae cavae are encircled taking care not to injure the right adrenal vein, right renal vein, or inferior phrenic veins. The portal inflow is occluded with a vascular clamp followed by occlusion of the infrahepatic and suprahepatic vena cava. At this point, the patient must have adequate circulatory volume to support the interruption of subdiaphragmatic venous return to the heart without developing vasopressor refractory hypotension. Although this degree of circulatory compromise is typically well tolerated by very young children and those with chronic portal hypertension, venous congestion can result in troublesome intestinal edema and hemodynamic compromise in metabolic patients or those with fulminant hepatic failure who lack alternative variceal pathways of venous return. Consideration should be given to a temporary portacaval shunt in such cases. The recipient liver and retrohepatic vena cava are excised, and donor liver implantation begins. In the piggyback technique, which is used in the living donor operation, the liver is completely mobilized from the retrohepatic vena cava by individually ligating the short hepatic veins draining directly from the liver to the cava. The liver is excised with preservation of the retrohepatic vena cava, and venous return can be restored prior to implantation by moving the vascular clamp to the junction of the vena cava with the hepatic veins.

The goal of the surgical team during the anhepatic phase is to minimize the duration of caval disruption with its ↑ associated intestinal edema and variceal congestion. The hepatic vein outflow is first reconstructed by fashioning the suprahepatic caval anastomosis. In the **piggyback technique**, there is no infrahepatic caval anastomosis, and an end-to-end portal vein anastomosis is fashioned next. The liver is flushed with Custodiol® solution (low K^+, buffered donor organ transplant solution) or albumin prior to reperfusion to minimize the risk of cardiac arrest 2° ↑ K^+ and ↓ pH. Venous outflow is then reestablished by removing the suprahepatic caval or hepatic venous clamp prior to opening the portal venous anastomosis. In a standard procedure, the infrahepatic caval clamp is also removed. Reperfusion is the portion of the procedure associated with significant hemodynamic lability, as large volume shifts may occur → pulmonary HTN and RV failure. Alternatively, the release of systemic inflammatory mediators may result in vasodilation and significant ↓ BP. The anesthesia team needs to be ready to pharmacologically intervene. Indiscriminate postreperfusion hypervolemia should be discouraged because CVP > 10 mm Hg can result in significant liver congestion and dysfunction. Hemostasis is achieved prior to arterial reconstruction. Patients who receive cut down or split livers performed ex vivo may have significant bleeding from the cut surface of the liver.

The donor hepatic artery is typically anastomosed in an end-to-end fashion to the recipient common hepatic artery. In situations of large size discrepancy or poor recipient hepatic artery quality, an anastomosis may be fashioned directly to supraceliac or infrarenal aorta. This requires aortic cross-clamping with its associated risk of ischemia-reperfusion injury and renal failure. The surgical team should notice the immediate production of bile and resolution of coagulopathy with clot formation in patients with a well-functioning graft. The biliary reconstruction can then be performed in an end-to-end fashion if possible but frequently requires a Roux-en-Y reconstruction. If a Roux-en-Y is performed, the bowel is divided distal to the ligament of Treitz, and the distal limb is brought up to the bile duct. Intestinal continuity is restored with an end-to-side enteroenterostomy, and a hepaticojejunostomy is fashioned to the Roux limb. Abdominal drains are typically left along the cut surface in split or cut down livers due to the increased incidence of bile leaks.

Compared to adult liver transplant, metabolic disorders account for a larger number of pediatric transplants and have some pre- and intraop considerations that are imperative to successful outcomes. Metabolic geneticists should be consulted in the preop period to assess the patient's immediate preop status and provide recommendations regarding fasting and intraop infusions to avoid precipitating a metabolic crisis during the procedure. Dual-organ transplantation, liver and kidney, is often necessary to prevent

disease recurrence.

Common metabolic disorders include:

1. **Methylmalonic acidemia (MMA):** severe uncontrollable lactic acidosis and metabolic decompensation during surgery. Both glucose and lactic acid levels should be monitored during surgery, and consideration should be given to preop dialysis if patient is to receive a combined liver-kidney transplant as MMA can cause direct damage to the renal allograft. Patients in acute MMA crisis should be medically stabilized prior to organ transplantation as it has been shown such patients are at increased risk for ventricular tachycardia during acute crises.
2. **Oxylosis:** patients should receive pretransplant dialysis to remove oxalate from body tissues so that, following liver transplant to correct the enzymatic defect, the kidney transplant will have an improved outcome.
3. **Atypical hemolytic uremic syndrome:** a combination of preop plasmapheresis and eculizumab (Soliris®) is used to minimize postop recurrence.

Posttransplant, the pediatric patient is taken to the intensive care unit. To ensure adequate hepatic perfusion and minimize risk of hepatic artery thrombosis in the immediate postop period, keep hematocrit <30% to decrease viscosity, and maintain perfusion pressure with goal MAP > 55 mm Hg. To further minimize hepatic artery thrombosis, consider antiplatelet therapy with aspirin and dipyridamole and antithrombotic therapy with dextran in the postop period once the coagulopathy has normalized as evidenced by normalization of INR.

ERAS: Family preop counseling/education by the surgeon and anesthesiologist should include limiting NPO duration, review of nutritional status, carb loading, postop pain management options, DVT prophylaxis, physiotherapy plan, possibility of lines, NG tube, and urinary drain postop. See Appendix K: Pediatric ERAS, p. K-6 to K-8.

SUMMARY OF PROCEDURE	
Position	Supine with arms tucked
Incision	Bilateral subcostal with midline subxiphoid extension as needed
Special instrumentation	Thompson liver retractor; vascular instruments; argon beam coagulator; arterial and central venous access (above and below the diaphragm); Foley catheter

Unique considerations	Hypothermia requiring covering extremities with gauze and plastic to minimize convective heat loss, active rewarming Hypoxemia secondary to hepatopulmonary syndrome Hyperkalemic cardiac arrest on reperfusion Air embolism during dissection and on reperfusion RV failure on reperfusion Pressor refractory hypotension with vena caval disruption DIC/fibrinolysis on reperfusion Severe acidosis Renal failure requiring intraoperative CRRT Coagulopathy and hemorrhage requiring massive transfusion Hypoglycemia
Antibiotics	Zosyn® (piperacillin + tazobactam) 80 mg of piperacillin component/kg every 6–8 h
Surgical time	4–6 h
EBL	300–1500 mL (1–5 U)
Postop care	Optimize hepatic artery flow with goal hematocrit <30 and mean arterial pressure >55 mm Hg. Dextran infusion and dipyridamole and aspirin for end-to-end arterial reconstructions ICU postop Monitor closely for signs of bleeding. Monitor closely for acidosis or worsening coagulopathy suggestive of graft dysfunction. Transplant ultrasound postop.
Mortality	2–5%
Morbidity	Primary nonfunction: <5% Portal vein thrombosis: 2–5% early, 10% late Hepatic artery thrombosis: 5–10% Bile leak: 10–20% Bleeding: 10% Wound infection: 5% Reoperation: 18%

Pain score	10

PATIENT POPULATION CHARACTERISTICS

Age range	0–18 yr
Male: Female	1:1
Incidence	500–600 transplants annually
Etiology	Biliary atresia, 35–40%; TPN related, 15%; metabolic diseases, 10%; acute hepatic necrosis, 10–15%; hepatoblastoma, 3%; autoimmune, 3%; congenital hepatic fibrosis, 2–3%

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Indications for liver transplant (LT) in children include (a) progressive subacute or chronic primary liver disease, such as biliary atresia, (b) metabolic disease of the liver, (c) acute hepatic failure, (d) hepatic tumors, and (e) retransplantation for hepatic graft failure. The most common disorder for which LT is performed in children is **biliary atresia**, accounting for more than 50% of patients. It is the most common cause of chronic cholestasis in infants and children. For the majority of these patients, a Kasai portoenterostomy is performed in early infancy. Even in those infants in whom bile flow is achieved, however, progressive liver failure commonly ensues, resulting in cirrhosis, portal HTN, and malnutrition. Complications include coagulopathy, esophageal varices, hypersplenism with splenomegaly and thrombocytopenia, ascites, and growth failure. Recurrent cholangitis following the Kasai procedure may lead to progressive hepatic injury and repeated hospitalizations for iv antibiotic therapy.

Children with metabolic liver disease represent the second largest group of patients presenting for LT. Some metabolic liver diseases including proximal urea cycle defects and organic acidemias result in hyperammonemia that causes neurologic injury despite having intact hepatic synthetic function and no portal hypertension. In these patients, LT has been shown to prevent further neurologic deterioration, resulting in a trend to transplant patients in infancy. Care should be taken with these patients to avoid catabolic states or acidosis that may exacerbate neurologic injuries. Coordination of care with the metabolic geneticists is critical to ensure that these patients receive the appropriate intravenous glucose and lipid infusions in the perioperative period. Other metabolic liver diseases that result in hepatic injury include Wilson disease, glycogen

storage diseases, and cystic fibrosis. In these patients, impaired hepatic synthetic function and portal hypertension may be present.

Patients with atypical hemolytic uremic syndrome (aHUS), primarily a disorder of complement regulation that is characterized by a triad of mechanical non–immune-mediated hemolytic anemia, renal dysfunction, and thrombocytopenia, may present for combined liver-kidney transplantation. Combined liver-kidney transplantation may be performed in patients with documented mutations of proteins that are synthesized in the liver where hepatic transplantation provides a possibility of cure. These patients are at high risk of graft thrombosis due to low complement factor H levels. Consult nephrologists and surgeons regarding specific perioperative protocol that includes preop plasma exchange transfusion via hemodialysis catheter to restore normal complement and regulatory factor levels, intraop FFP infusion (20–40 mL/kg) prior to liver reperfusion, and postop anticoagulation.

Respiratory	Previous prolonged intubation may have caused subglottic stenosis. Ascites, pleural effusions, and hepatosplenomegaly cause a reduction in lung volumes in children with liver failure. Intrapulmonary R → L shunting through abnormally dilated pulmonary arterioles and impaired hypoxic pulmonary vasoconstriction may cause severe hypoxemia. Pulmonary edema may result from hypoalbuminemia and iv fluid administration, impairing oxygenation as well as ventilation. Supplemental oxygen and, in advanced cases, mechanical ventilation may be required preop. **Tests:** CXR, ABG in hepatopulmonary syndrome
Circulatory	Chronic liver failure may be accompanied by a hyperdynamic circulatory state with ↓ SVR + ↑ CO. On the other hand, cardiomyopathy and/or pulmonary HTN may be present, and CO may actually be diminished. These changes appear to be less common in children than adults. **Test:** Echo
Neurologic	Hepatic encephalopathy is a life-threatening

	complication of ESLD. Causes include accumulation of toxins such as ammonia, GABA agonists, and other neuroactive substances. Cerebral metabolism and the blood-brain barrier may also be abnormal in advanced liver disease. The clinical manifestations of hepatic encephalopathy range from mild somnolence to coma. **Tests:** Head CT to assess for bleed and cerebral edema. Acute liver failure may be associated with severe cerebral edema and ↑ ICP, both of which are risk factors for severe posttransplant brain injury. The pathophysiology of cerebral edema in acute liver failure is not well understood though transplantation of a functioning hepatic graft has been shown to reverse the edema. Monitoring of ICP, hypertonic saline, and CVVH to treat hyperammonemia do not appear to improve outcomes in these patients.
Hematologic	In addition to the coagulation problems secondary to poor hepatic synthetic function, patients with ESLD may have anemia and thrombocytopenia. Anemia may arise from malnutrition and bleeding. Thrombocytopenia may be a result of splenic sequestration. Both conditions are worsened by dilutional effects from increased plasma volume. **Tests:** CBC, PT/INR/PTT, fibrinogen, thromboelastogram
Hepatic	Decreased concentrations of the vitamin K–dependent clotting factors II, VII, IX, and X may lead to severe bleeding. Deficiency of clotting factors may be caused by hepatic synthetic dysfunction as well as malabsorption of vitamin K 2° ↓ bile salts in the gastrointestinal tract or antibiotic therapy. Hypoalbuminemia contributes to low serum oncotic pressure, which predisposes to intravascular hypovolemia, interstitial edema, ascites, and pleural effusions. ESLD results in diminished hepatic drug clearance and reduced hepatic blood flow and hepatic extraction ratio.

	Tests: LFTs, albumin, bilirubin, PT/INR/PTT, fibrinogen, NH_3
GI	Gastrointestinal variceal hemorrhage in patients with portal hypertension is common. Aspiration of blood during an acute bleed can lead to pulmonary decompensation. Previous need for a Blakemore tube should be noted, and one should be available for intraop use. Large protuberant abdomen usually warrants rapid-sequence or modified rapid-sequence induction with rocuronium. Most patients are already on proton pump inhibitors, and some will be on an octreotide drip. Octreotide (a somatostatin mimic) is incompatible with most TPN solutions and usually requires a separate iv for infusion.
Renal	Most children with relative long-term hepatic insufficiency coming to transplant have chronically been on diuretic therapy for management of their ascites. This can result in severe alteration of electrolytes. Hepatorenal syndrome requiring hemodialysis or CVVH is not uncommon in acute hepatic failure. Preop discussion MUST occur with the nephrology team as to the feasibility of intraop CRRT. For small children with limited vascular access, the dialysis catheter may be needed for fluid resuscitation purposes. Communicate with the blood bank to request specific anticipated blood products that will be needed including considerations to minimize potassium load from transfusions of PRBCs (e.g., request freshest or washed units or nonirradiated units). Correction of metabolic acidosis while on dialysis is also preferred. **Tests:** Serum electrolytes, BUN, Cr
Metabolic	Many children with liver failure have severely impaired glycogen metabolism. Preop dextrose infusion (TPN) must be continued intraop. Either the TPN solution or a D25 mixture run at equivalent grams of dextrose per hour can be used. Preop

	consultation with the geneticist is invaluable in the management of complex metabolic disorders. **Tests:** Serum glucose
Premedication	IV midazolam is usually required to facilitate separation from parents. Ketamine 0.5–1 mg/kg iv is also effective in those children with paradoxical reactions to benzodiazepines. Avoid long-lasting sedative medications.
ERAS	Check compliance with presurgical ERAS recommendations (see above) including NPO status. Discuss with surgeon the possibility of regional analgesia for postop pain management.
Preop prep	Preparation of the room, including medications and iv fluids, may take 1 h. Underbody forced-air warmer and water-circulating blanket should be used because the patient is prepped from sternum to pubis. The following infusions are routinely prepared: dextrose-containing carrier, epinephrine, dopamine, vasopressin, and calcium chloride. Rocuronium and fentanyl infusions may be used. The following resuscitation medications must be readily available at a variety of concentrations: epinephrine, phenylephrine, ephedrine, and atropine. Drugs to treat hyperkalemia should be drawn up as unit doses, including sodium bicarbonate (1 mEq/kg), calcium chloride (10 mg/kg), dextrose (0.5 g/kg), and insulin (0.1–0.2 U/kg). A variety of cuffed ETTs should be ready. TEE, ultrasound to aid in vascular access, and rapid infusion systems should be available.

INTRAOPERATIVE

Anesthetic technique

GETA with postop ventilation.

Induction	Following the placement of standard monitors, a rapid-

	sequence induction with rocuronium (1.2 mg/kg) should be considered in patients with large abdominal girth from ascites causing decreased lung volumes.
ERAS	Verify preincision antibiotics. Assess volume status (see p. D-1). Maintain normovolemia and normothermia.
Maintenance	Standard maintenance with volatile agent, muscle relaxation, and fentanyl 10–50 mcg/kg. During periods of instability when vapor concentrations may be low, iv ketamine 1 mg/kg can be used. Nitrous oxide is avoided to prevent bowel distension. PEEP is useful to prevent atelectasis exacerbated by surgical retraction of the diaphragm. Antibiotics are dosed per surgical protocol. ABGs and thromboelastograms are drawn frequently to monitor electrolytes and acid-base status and aid in resuscitation. Establishment of vascular access can be very difficult and may take 1–2 h. Use of ultrasonic guidance can be helpful especially in the profoundly coagulopathic patient. Care should be taken to keep the patient warm during this period of vascular access. Major vascular access should be restricted to the SVC distribution because the IVC will be clamped. In cases of "piggyback" transplantation, the caval clamp time is usually reduced, and if vascular access is severely limited, IVC distribution veins may be used. This should be discussed with the surgical team.
Preanhepatic phase	This phase of surgery begins with surgical incision and concludes when the hepatic/portal vessels are clamped. Opening of the abdomen and drainage of ascites will often improve ventilation though placement of retractors may compromise ventilation. Blood loss during mobilization of the liver may be copious in the presence of portal HTN or adhesions from previous surgeries. Resuscitation with blood products should be guided by hemodynamics and clinical status as well as frequent lab values including ABG and TEG. Hypercoagulability should be avoided if venovenous bypass is planned (not

	commonly used in children <30–40 kg). Large variations in BP and cardiac filling pressures are common during this phase of surgery due to manipulation and rotation of the liver, which may cause intermittent kinking of the vena cava. The anesthesiologist must be constantly aware of the progress of surgery and communicate any protracted periods of hypotension due to surgical manipulation. Transfusion of blood/products may result in hyperkalemia, hypocalcemia, and hypothermia. All products need to be warmed. In patients weighing <10 kg, the freshest available packed red blood cells should be used to minimize potassium load from transfused blood products. A calcium chloride infusion (10 mg/kg/h) can be used to maintain the serum ionized calcium >1.0 and helps avoid BP changes associated with bolus administration of calcium. Hyperkalemia is treated with furosemide (1 mg/kg), correcting acidosis and infusing dextrose and insulin as required. Goals of this stage in preparation for the anhepatic phase include (a) serum potassium <3.5, (b) correction of metabolic acidosis, (c) ionized calcium >1.0–1.2, (d) adequate urine output (0.5–1 mL/kg/h), (e) adequate blood pressure at the lowest CVP possible, (f) hematocrit in the 30 range, and (g) euthermia. Mild hyperthermia may help mitigate the hypothermia created by the iced donor liver during the anhepatic phase. Frequent arterial blood-gas sampling is necessary. Hourly sampling is a minimum, and extreme blood loss may necessitate sampling every 15 min. Blood loss and third-space losses are considerable in this phase of surgery. Edema of internal organs and eventually the transplanted liver is undesirable. Closure of the small abdominal cavity with an edematous liver can cause pressure necrosis as well as abdominal compartment syndrome.
Anhepatic phase	The anhepatic phase begins with clamping of the hepatic vessels and ends with reperfusion of the donor liver.

	Problems during this phase include fibrinolysis, acidosis, and hypothermia. During the anhepatic phase, hydrocortisone (20 mg/kg) is given. Care should be taken at this point to avoid hypoglycemia as it can lead to osmotic diuresis and hemoconcentration. Communication must exist between surgical and anesthetic teams regarding the amount of bleeding present and which products should be used to treat it. Respiratory alkalosis may be desirable to compensate for existing or projected metabolic acidosis. Correct any metabolic acidosis with bicarbonate. Placement of the iced donor liver usually decreases the core temperature by 1.5°C. This coupled with preexisting hypothermia can increase coagulopathic bleeding. The anhepatic phase can be as short as 15 min or longer than 1 h depending on surgical difficulty. In the case of short anhepatic times, the metabolic goals should have been achieved in the preanhepatic phase. Anticipation and preparation for reperfusion should be ongoing. A split liver transplant usually entails more bleeding upon reperfusion, so the appropriate blood products must be present in the room. Anticipation and preparation for reperfusion should be ongoing. Reperfusion takes place after the portal vein and bicaval anastomoses are complete. In the piggyback liver transplant, anhepatic time is reduced because only the hepatic vein(s) and portal vein require anastomosis. Prior to tying the anastomotic suture, the liver is flushed to remove any air from the vessels. A 10-min warning to unclamp is usually given to the anesthesia team. Last-minute electrolyte corrections can be made. The patient is then placed on 100% O_2, low-dose epinephrine infusion (0.03–0.05 mcg/kg/min) and dopamine (3–5 mcg/kg/min) may be started, and inhalational agent should be decreased or turned off. IV midazolam or ketamine may be given to ensure amnesia.
Postperfusion phase	This phase begins with slow unclamping of the portal vein and vena cava with reperfusion of the donor liver.

Unclamping may be associated with hemodynamic instability and even cardiac arrest. Hypotension, tachycardia, dysrhythmias, hypothermia, severe acidosis, coagulopathy, and air embolism or thromboembolism can occur. During the unclamping, the anesthesiologist must simultaneously watch the uniform reperfusion of the liver as well as the blood pressure and ECG waveform. Increased T waves or widening of the QRS complex should be assumed to represent hyperkalemia. IV fluids in the form of RBCs or albumin should be ready in the event of anastomotic bleeding or bleeding from the cut edge of a split liver graft. A small dose of epinephrine (1–2 mcg), bolus of calcium chloride (10 mg/kg) and a bolus of sodium bicarbonate (1 mcg/kg) may help maintain hemodynamic stability during unclamping of the portal vein and vena cava. When giving iv fluids, watch the liver for swelling. The hepatic artery anastomosis is then completed, prior to which the surgeon may request that a dose of heparin (10 U/kg) be given.

Volatile agent can be restarted and the FiO_2 can be reduced. Blood-gas tensions and coagulation parameters should be checked 30–60 min after reperfusion to assess synthetic function of liver allograft. Care should be taken to maintain the hematocrit between 25 and 30, because relative polycythemia may lead to hepatic artery thrombosis.

The biliary system will be constructed either with a duct-to-duct reconstruction or, in cases of the small child or the patient with biliary atresia, with a Roux-en-Y choledochojejunostomy. Patients with previous Kasai procedures will have an existing Roux limb, and biliary reconstruction takes places quickly. Construction of a new Roux limb may take 1–2 h. During this time, it is important to keep up with third-space losses and avoid hemoconcentration while avoiding congestion of the liver. Vasopressors may be required to maintain MAP goals, which should be set after discussion with the

	surgeons.	
Emergence	The patient is taken to the ICU intubated and usually paralyzed to facilitate ventilation. Extubation is deferred to the ICU team. Discuss with surgeon local wound infiltration or nerve block (e.g., TAP or rectus sheath blocks) placement or reinforcement if initially placed >4 h previously. PONV prophylaxis may include dexamethasone (e.g., 30 mcg/kg) and ondansetron (0.1 mg/kg up to 4 mg iv).	
Blood and fluid requirements	Massive blood loss expected IV × 2 as large as tolerated based on age Arterial line in radial and femoral 2–3-lumen CVP line	IV access restricted to SVC distribution. Avoid hand veins for large-volume fluid administration because infiltration is difficult to detect. Two arterial lines are necessary because extreme vasoconstriction may dampen peripheral arterial line; femoral line is interrupted if aortic clamping occurs. Avoid iv solutions containing lactate. Normosol is preferred over NS due to lower sodium content. Administer blood based on hemodynamics and ABG and TEG because EBL is difficult to measure.
	Warm all fluids.	**Fluids to have available:** Normosol®, or NS, PRBC, FFP, cryo, and platelets; 5% albumin
	UO 0.5–1 mL/kg/h	Rapid infusion system if child is large
Monitoring	Standard monitors ETN_2 Arterial line × 2	Five-lead EKG. Bladder temp if child is large enough. Carefully insert nasopharyngeal temp probe.

	I-STAT CVP TEE	I-STAT® (bedside arterial blood-gas sampling) system is useful. Take care during insertion of TEE due to varices. May be difficult to use because continuous orogastric decompression is needed.
Coagulation management	PT PTT Plt count Fibrinogen FSP	Preexisting coagulopathy is very common. Coagulopathy may necessitate administration of products during line placement. Discuss use of cryo and platelets with surgical team prior to administration. Postreperfusion, treat clinical bleeding not lab values.
Positioning	Pad and protect lines. Pad pressure points. ✓ retraction devices	Wrap all stopcocks near patient. Use gel headrest to protect occiput. Check for pressure points due to surgical retraction devices.
Temperature	Warming blanket Control fluid warmers. Wrap patient.	Underbody forced-air warming. Hotline, Ranger, or rapid infusion system. The patient is wrapped with Webril® and Saran® wrap for warmth and to keep patient dry.
Complications	Coagulopathy Hemorrhage Air embolism Cardiac arrest Metabolic acidosis IV infiltration	

POSTOPERATIVE

Monitoring	Serial LFTs PT, PTT Lactate Glucose Bilirubin	Initial LFTs are quite high depending on level of preservation injury. Bile production and normal glucose level are good signs.
Complications	Bleeding Hepatic artery thrombosis Portal vein thrombosis Biliary leak Primary graft nonfunction Rejection Infection Intracranial bleed Electrolyte abnormalities Alkalosis Renal failure	Most care is deferred to the ICU team. Postop vascular ultrasounds are followed. Hepatic artery thrombosis is ominous, and patients are often relisted for transplant if this complication occurs. Hypertensive events in the coagulopathic patient can lead to intracranial hemorrhage.

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SECTION 13.0

NON-OPERATING ROOM PROCEDURES

CHAPTER 13.1

Non-Operating Room Procedures: Adult

PROCEDURAL SPECIALISTS

Charles DeBattista, DMH, MD (Electroconvulsive therapy)
Liong-Bing Liem, DO, FHRS, FACC (DC cardioversion, ICD, catheter ablation, lead extraction)
Michael P. Marks, MD (Interventional neuroradiology)
Daniel Y. Sze, MD, PhD (Interventional radiology)
David S. Wang, MD (Interventional radiology)
Andrew Kesselman, MD, RPVI (Interventional radiology)
Ibrahim A. Idakoji, MD, MPH (Interventional radiology)

ANESTHESIOLOGISTS

Richard A. Jaffe, MD, PhD
John G. Brock-Utne, MD, PhD (Electroconvulsive therapy)
Timothy P. Angelotti, MD, PhD (Endoscopic procedures)

ANESTHESIA FOR NON–OPERATING ROOM PROCEDURES

GENERAL COMMENTS

- Advances in the fields including radiology, cardiology, and neurology have led to a significant increase in the number of anesthesia procedures performed away from the OR. In line with these changes, the ASA has provided guidelines for the safe delivery of anesthesia at remote locations. Non–operating room anesthesia (NORA) presents significant and often unique challenges for the anesthesiologist. Compared to the general OR population, NORA patients may be less well optimized or even

medically unstable ("too sick for the OR"). The delivery of care may be urgent, while the environment in which that care must be delivered often lacks the amenities and supporting personnel available in an OR. The most common complications of NORA involve airway/respiratory events → brain damage or death, occurring approximately twice as often as in the OR. In most cases, these events were determined to be the result of substandard care and therefore preventable. NORA requires attention to detail, teamwork, and good communication to compensate for the typically resource-poor environment.

- Radiation safety is often of concern in NORA. Fluoroscopy is a significant source of radiation exposure for the anesthesiologist, and distance away from the beam source is the best protection. Six feet of air provides >99% beam attenuation, which is roughly equivalent to 0.5 mm lead (equivalent to the shielding found in heavy "lead" aprons and most shield panels). Although that degree of attenuation is impressive, given the presumed stochastic nature of radiation-induced carcinogenesis, it should not be too comforting.

Anesthetic considerations for non-OR locations (modified from ASA Guidelines) include the following:

- Complete H&P identifying any comorbidity that may require special monitoring or other precautions.
- Primary and backup O_2 sources (e.g., piped O_2 + 1 full E cylinder).
- Adequate and reliable suction.
- Adequate and reliable scavenging system (only for inhalational anesthesia).
- Self-inflating hand resuscitator bag with ability to deliver at least 90% O_2.
- Anesthetic drug supplies and administration equipment.
- Monitoring equipment to allow adherence to the "Standards of Basic Anesthetic Monitoring".
- Sufficient electrical outlets connected to an emergency power supply.
- Wet locations (e.g., cystoscopy, arthroscopy, labor, and delivery) should be equipped with either an isolated electrical source or circuits with ground-fault interrupters.
- Adequate illumination for patient observation and monitoring equipment (flashlight backup).
- Sufficient space for expeditious access to patient, machine, and support equipment.
- Emergency cart with defibrillator immediately available.
- Immediate access to skilled anesthesia support personnel.
- Provision for appropriate postanesthesia care.

Suggested Readings

1. Chang B, Urman RD: Non-operating room anesthesia: the principles of patien assessment and preparation. Anesthesiol Clin 2016; 34(1):223–40.

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ELECTROCONVULSIVE THERAPY

PROCEDURAL CONSIDERATIONS

Description

Electroconvulsive therapy (ECT) is the transcutaneous application of electrical stimuli to the brain to produce generalized seizures for the treatment of selected psychiatric disorders, such as severe depression. There are several important aspects of ECT that are of relevance to the anesthesiologist. The first is the uncontrolled motor activity associated with generalized seizures. Prior to introduction of GA, the most common injuries associated with ECT were compression fractures of the vertebral bodies and broken limbs from violent tonic-clonic motor activity. Even with complete paralysis, the masseter muscles are directly stimulated to contract during seizure induction. As a result, the most common injury currently associated with ECT is broken teeth.

A second consequence of ECT induction is that the electrical stimulus can cause contraction of scalp musculature and a brief dilation of meningeal blood vessels, resulting in postictal headaches in up to 40% of patients. Patients <50 yr and those with a Hx of migraine headaches appear most at risk for post-ECT headaches that may occasionally require aggressive pain management. Other consequences of ECT include ↓ SpO_2 especially in obese patients. The use of THRIVE has been shown to prevent desaturation in apneic obese patients undergoing ECT. Many post-ECT patients wake up agitated and require post-ECT sedation (e.g., midazolam 2 mg iv). On occasion, ECT may result in a prolonged (>2 min) seizure requiring propofol (25–100 mg) or midazolam (1–2 mg) to terminate. ECT may also be a significant hemodynamic stressor, even to the extent of causing MI with acute pulmonary edema. Initially, central parasympathetic centers are activated, resulting in ↓↓ HR in ~30% of patients. Brief sinus pauses are not uncommon. The initial parasympathetic effects are followed by sympathetically mediated increases in HR and BP up to 20–30% above baseline. Mean arterial blood pressure has been known to double in some instances. These

cardiovascular responses can persist for minutes to an hour or more after the procedure is completed.

The optimal position for ECT is supine. Occasionally, the head is kept slightly raised to help maintain an adequate airway and decrease anxiety. Patients typically come to ECT quite anxious about the procedure. ECT is generally performed in a PACU or specialized ECT suite. In many centers, outpatients make up the majority of patients seen for ECT. The electrical stimulus is applied through adhesive leads prepared with a contact gel. These leads are usually applied to the forehead in a bitemporal or right unilateral placement. Monitoring typically includes a two-lead electroencephalogram (EEG) and frequently an electromyogram (EMG) to measure motor activity. Before induction, a BP cuff is inflated to act as a tourniquet and prevent neuromuscular blockade in the distal limb. Thus, an arm or leg can be used to measure motor duration of the seizure. A special ECT device is used to generate the appropriate electrical stimulus. Seizures are typically 30–90 sec in duration, and the entire procedure—from the induction of anesthesia to patient awakening—is generally <15 min. The recovery period averages 45–90 min and allows for monitoring of vital signs, as well as the opportunity for the postictal confusion to clear. Patients can wake up mildly confused to frankly delirious and require close nursing supervision. Treatments are typically performed every other day, and the average number of treatments is 6–12 in the acute management of major depression. However, ECT treatments may be tapered rather than stopped abruptly. Thus, the frequency of treatments may go from 3/wk for acute treatment to 1/wk, 2/mo, and finally 1/mo. Maintenance ECT with a frequency ranging from every few weeks to every few months is commonly prescribed for those patients who respond to ECT but fail to benefit from pharmacotherapy.

The most common morbidities associated with ECT include headaches and myalgias. Postictal confusion is the rule, and some anterograde and retrograde memory loss occurs in most patients who have completed an acute course of ECT. Memory loss is typically confined to the period immediately before, during, and immediately after a series of ECT treatments. There tends to be a cumulative memory loss with subsequent ECT treatments within a given series. In most patients, memory deficits largely subside in the first 1–3 mo following treatments. In rare instances, autobiographical memory loss has been reported for months or years after an ECT series has been completed. Long-term memory loss appears to be more common with bilateral lead placement. ECT-related mortality is estimated at ~4/10,000. Cardiac events account for 67% of all ECT-related deaths, with malignant arrhythmias and MIs accounting for most fatalities. Pulmonary events (obstruction, pulmonary edema, or emboli) account for most additional mortality. Cerebrovascular infarctions or hemorrhages have rarely been

reported with ECT.

Variant procedure or approach: Transcranial magnetic stimulation (TMS) uses intense extracranial magnetic fields to induce intracranial electrical current flow. Although the induced currents can be sufficient to evoke motor responses, seizures are rare. Compared to ECT, TMS is painless and hemodynamically benign. Anesthesia is no required.

Usual preop diagnosis

Depression; mania; catatonia; refractory psychosis

SUMMARY OF PROCEDURE	
Position	Supine
Incision	None
Special instrumentation	Seizure generator and electrodes; EEG/EMG monitors
Unique considerations	Requires muscle relaxation to prevent injury. 50–80 mg of succinylcholine is usually sufficient. Using larger dose of succinylcholine can lead to patient waking up while paralyzed. Bite blocks are required to prevent dental injury. Apply tourniquet (e.g., BP cuff) to one arm before administration of muscle relaxant. A slow heart rate preop may require atropine. A high BP preop may require aggressive hypotensive Rx with beta-blockers, phentolamine, hydralazine, etc. If the seizure duration is not >25 sec, then another seizure may be required. Give more induction agent as needed. Because one arm is not paralyzed, asking the patient to squeeze your fingers will tell you if she/he is awake.
Antibiotics	None
Procedure time	Setup: 5–10 min Treatment: <10 min (seizure duration 25–280 sec)
Postop care	PACU → room or home
Mortality	4/10,000

Morbidity	HA/myalgias/nausea: Common Confusion/memory loss: Common. Be aware that postop hypoxia can present with confusion. Cardiac dysrhythmias: 10–40% (brief asystole common). Keep a close eye on the EKG. MI: Rare Pulmonary edema from excessive iv fluids: not uncommon. Pulmonary aspiration and/or negative pressure pulmonary edema: Rare CVA: Rare
Pain score	2–3 (HA)

PATIENT POPULATION CHARACTERISTICS

Age range	≥18 yr. ECT is rarely performed in adolescents and preadolescents; however, patients in their 90s are sometimes candidates for ECT. There is a preponderance of geriatric patients on many ECT services.
Male:Female	1:2
Incidence	The lifetime prevalence of major depression (the primary indication for ECT) is ~17%; 26% of women and 12% of men are affected. <1% of patients with major depression undergo ECT, and ~400,000 ECT procedures are performed in North America annually.
Associated conditions	Substance abuse (30% of all depressed patients meet criteria for alcohol or drug abuse); panic attacks (30% of depressed patients); psychotic symptoms (14% of patients); HTN and sinus tachycardia; dehydration; self-inflicted trauma; pregnancy

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients presenting for ECT usually have failed to respond to antidepressants; however, most will continue to take psychotherapeutic medications. Many older patients will be taking other medications for coexisting medical conditions. Drug interactions are an important consideration for the anesthesiologist (see Appendix F: Tables of Drug

Interactions and Recommendations for Preop Management). The most commonly used medications are listed in Table 13.1-1.

Anesthesia for ECT may seem to be a simple procedure; however, these cases—which seldom take >20 min—can prove very challenging, especially in the geriatric population. ECT can place significant stress on the cardiovascular system; therefore, particular care should be taken to evaluate and optimize the patient's pretreatment cardiovascular status. ECT usually takes place in remote locations, so the anesthesiologist must ensure that the location is properly equipped and complies with ASA Guidelines for Out-of-OR Procedures and Standards for Basic Anesthetic Monitoring.

Table 13.1-1 Commonly Used Medications in the Treatment of Depression

Tricyclic	MAOI	SSRI	SNRI and Other Antidepressants
Amitriptyline (Elavil, others)	Isocarboxazid (Marplan)	Fluoxetine (Prozac)	Venlafaxine (Effexor)
	Phenelzine (Nardil)	Paroxetine (Paxil)	Duloxetine (Cymbalta)
Amoxapine (Asendin)	Tranylcypromine (Parnate)	Sertraline (Zoloft)	Nefazodone (Serzone)
Desipramine (Norpramin)	Transdermal selegiline (Emsam)	Fluvoxamine (Luvox) Citalopram (Celexa)	Mirtazapine (Remeron) Bupropion (Wellbutrin)
Doxepin (Sinequan)	**Lithium** (often used as an adjunctive agent/mood stabilizer in depression)	Escitalopram (Lexapro)	Trazodone (Desyrel)
Imipramine (Tofranil)			**Atypical antipsychotics** (used adjunctively)
Maprotiline			Olanzapine

(Ludiomil)			(Zyprexa)
Nortriptyline (Pamelor)			Quetiapine (Seroquel)
Protriptyline (Vivactil)			Aripiprazole (Abilify)
Trimipramine (Surmontil)			Risperidone (Risperdal)
			Ziprasidone (Geodon)
			s-Ketamine (Spravato)

MAOI, monoamine oxidase inhibitor; SSRI, selective serotonin reuptake inhibitor; SNRI, selective norepinephrine/serotonin reuptake inhibitor.

Respiratory	These patients will require airway management and PPV. Hence, preop assessment of the airway must focus on the ease of mask ventilation and the potential need for ET intubation (e.g., airway compromise or severe GERD).
Cardiovascular	A recent MI (<3 mo) is a contraindication to ECT. Relative contraindications include aortic aneurysm, angina, CHF, and thrombophlebitis. The presence of dysrhythmias, a pacemaker, or ICD is not a contraindication for ECT. For the patient with a pacemaker, a means (e.g. a magnet) should be available to convert the pacemaker to an asynchronous mode. Patients on long-term anticoagulation therapy may require pre-ECT dose adjustment (target INR 1.5–2.5), or they should switch to heparin before each ECT session and return to their standard therapy post-ECT. **Tests:** As indicated from H&P
Gastrointestinal	Patient should be NPO. Patients with Sx of GERD should be pretreated with Na citrate (30 mL po), ± ranitidine (50 mg iv) and metoclopramide (10 mg iv). ET intubation should be considered for all patients at

	risk for aspiration.
Neurologic	ECT is relatively contraindicated in the presence of ↑ ICP, and recent CVA (<3 mo), intracranial mass lesions, or recent intracranial surgery (<3 mo).
Endocrine	Presence of a pheochromocytoma (Sx of which may be confused with a psychiatric disorder) is a contraindication to ECT. <1% of hypertensive patients will have a pheochromocytoma.
Genetic	✓ for family Hx of pseudocholinesterase deficiency. Rocuronium (0.6–1.2 mg/kg) reversed with sugammadex (8–16 mg/kg) is a suitable alternative to succinylcholine. **Tests:** Dibucaine number (normal ≥ 80) and serum cholinesterase level, if indicated from H&P
Hepatic	Hepatotoxicity has been associated with use of MAOI. **Tests:** Consider LFTs for patients on chronic MAOI therapy.
Orthopedic	In patients susceptible to bone fracture (e.g., severe osteoporosis, osteoporosis imperfecta), an increased succinylcholine dosage (1.5 mg/kg) is given to ensure profound muscle relaxation. Patients with severe rheumatoid arthritis may have unstable C-spine, and extreme care should be taken during positioning of head and neck.
Ophthalmologic	Retinal detachment is a relative contraindication to ECT. Succinylcholine should be avoided in patients with glaucoma treated with cholinesterase inhibitors (e.g., echothiophate). Mivacurium (0.15 mg/kg) is a suitable alternative.
Pregnancy	Pregnancy is not a contraindication for ECT (even in the third trimester). After the 4th mo, the need for full-stomach precautions requires rapid-sequence induction and ET intubation. Left uterine displacement should be maintained during treatment. Monitor fetal heartbeat.

Psychiatric drugs	Patients receiving tricyclic antidepressants (TCAs) may have an exaggerated pressor response to direct-acting sympathomimetic drugs, with the potential for tachycardia, dysrhythmias, and hyperthermia. The response to indirect-acting sympathomimetic drugs (e.g., ephedrine) may be attenuated in these patients. TCAs also will increase the effects of anticholinergic drugs (e.g., glycopyrrolate, atropine). Patients receiving MAOIs will exhibit exaggerated responses to indirect-acting sympathomimetic drugs (e.g., ephedrine). In addition, in these patients, succinylcholine metabolism is inhibited (↑ NMB), and meperidine is contraindicated (↑↑ BP, ↑ Sz, ↑↑ T). It is probably unnecessary to discontinue TCAs or MAOIs prior to ECT, as long as these interactions can be avoided. Lithium should be discontinued for at least 3 d prior to ECT to avoid delayed recovery and subsequent posttreatment agitation and confusion. Lithium also is associated with ↑ NMB (succinylcholine and nondepolarizing agents). SSRIs have been associated with prolonged ECT-induced seizure duration and adverse behavioral/neurologic effects following haloperidol administration (use droperidol and metoclopramide with caution). No adverse interactions have been reported between anesthetic agents and SSRIs or SNRIs.
Laboratory	Tests as indicated from H&P
Premedication	Although usually not required, some patients may benefit from an antisialagogue (glycopyrrolate 0.2 mg iv). Patients with Hx of postop N/V will benefit from a prophylactic antiemetic (e.g., ondansetron 4 mg iv). Patients with postseizure muscle pain and headache may benefit from ketorolac (30 mg iv). Some patients will require 500–1000 mg caffeine iv or po to decrease seizure threshold. The iv caffeine effect should be manifest in 5 min. However, po caffeine must be given 30–40 min in advance. Verapamil (not adenosine, which is blocked by

	caffeine) should be available to control supraventricular tachycardia (0.07–0.25 mg/kg over 2 min). Labetalol, hydralazine, esmolol, and diltiazem are alternative drugs for control of HR and BP.

INTRAOPERATIVE

Anesthetic technique

A review of previous anesthetic records is very helpful in formulating the anesthetic plan and in anticipating physiologic changes unique to each patient. Usually brief iv anesthesia (mask oxygenation and ventilation) with muscle relaxation (1–2 twitches) is required to prevent patient injury during seizures. Prior to induction, a tourniquet (BP cuff) is applied to the non-iv limb and inflated to a pressure above systolic. This prevents neuromuscular blockade distal to the cuff and permits direct monitoring of seizure activity. Preop BP control (e.g., labetalol 5–20 mg, diltiazem 10–20 mg iv, or esmolol 0.5–1 mg/kg iv in increments) is often necessary.

Induction	Preoxygenation should be attempted in all patients. In some patients who are intolerant of a mask, a less intrusive blow-by technique may be tried. Anesthesia is induced with propofol (1–2 mg/kg), sodium methohexital (0.5–1 mg/kg), or etomidate (0.1–0.2 mg/kg). An induction dose of etomidate will block stress-induced cortisol production for up to 24 h. Propofol (1–1.5 mg/kg) may be used, but may shorten seizure duration. TCAs and MAOIs can increase sleep time. After tourniquet inflation, succinylcholine (0.8–1 mg/kg) is injected to induce paralysis. Hyperventilation is carried out to enhance seizure activity. A bite block is placed, and then the patient is ready for ECT. In barbiturate-tolerant patients, remifentanil (1–3 mcg/kg) has been used as a means of reducing the barbiturate dose, thereby permitting adequate seizure duration. Patients receiving remifentanil need minimal postseizure BP control.
Maintenance	Given the brevity of this procedure, maintenance of anesthesia is rarely a concern; however, occasionally, a second or third treatment may be necessary if the

	seizures are of inadequate duration (<25 sec) and quality. In this case, a subsequent dose (10–30 mg) of succinylcholine may be needed. Assisted ventilation is necessary until spontaneous ventilation resumes. Of major concern during the seizure period is the hypertensive response. Some patients may need to be treated prior to induction of anesthesia with either labetalol (5–20 mg iv) or esmolol (10 mg q1min) to control HR/BP. SNP (5–50 mcg/bolus iv) is useful to control BP in refractory cases. Profound ↓ HR may occur in the immediate post-ECT period requiring atropine or a chest thump.	
Emergence	Patients should be awake within 5–10 min postseizure and often are disoriented. Small doses of midazolam (e.g., 0.25–0.5 mg iv) may help to control agitation, and blow-by O_2 may be less stimulating. ASA guidelines for postanesthesia care should be followed.	
Blood and fluid requirements	No blood loss IV: 20 ga × 1 BSS @ TKO	
Monitoring	Standard monitors Tourniquet EEG EMG Transcutaneous CO_2	Seizure activity is usually monitored by a psychiatrist observing the tourniqueted limb and by measuring EMG and EEG activity. (These monitors are usually an integral part of the ECT seizure generator.) Transcutaneous CO_2 monitoring may be useful in patients who are apneic for several minutes.
Positioning	Supine	
Complications	Dysrhythmias	Brief periods of asystole and profound bradycardia are not uncommon (usually related to

		parasympathetic overactivity). Treatment is rarely necessary.
	Tachydysrhythmias	Responds well to esmolol (10–15 mg iv) or lidocaine (1 mg/kg iv), although treatment is usually unnecessary.
	↑ BP	↑ BP readily responds to esmolol (10–30 mg) or labetalol (5–20 mg). In refractory cases, 10–50 mcg of SNP may be necessary.
	Dental damage Pulmonary edema Aspiration	Use of bite block is essential. Dental damage is not prevented by muscle relaxation (direct electrical stimulation of facial and jaw muscles).

POSTOPERATIVE

Complications	HA, myalgias	Rx: ketorolac 30 mg iv
	N/V	Rx: ondansetron 4 mg iv
	Disorientation	Rx: midazolam 0.25–0.5 mg iv
	Memory impairment	
	MI/ischemia	
	Dysrhythmias	
	Pulmonary edema/aspiration	
	↑ BP	Prolonged ↑ BP is unusual and may suggest the need for further workup.

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INTERVENTIONAL NEURORADIOLOGY

PROCEDURAL CONSIDERATIONS

The indications for endovascular therapy for the brain and spine have continued to grow with the technical strides made in both devices and imaging. Endovascular therapy is now considered first-line therapy in the treatment of many intracranial aneurysms. At most centers, it is the treatment of choice for arteriovenous fistulas (AVFs) and is widely used as an adjunctive therapy for arteriovenous malformations (AVMs) and vascular tumors. Recent data have made endovascular therapy the standard of care for treatment of large vessel occlusions in the setting of acute stroke, and it is also used for the treatment of cerebrovascular stenosis. Many of these procedures can be performed with the patient awake; however, GA or deep sedation often is used to minimize patient movement during procedures that require careful catheter and device control for safe operation. The endovascular procedures used in interventional neuroradiology can be divided into three broad categories: (a) embolization, (b) aneurysm therapy, and (c) cerebral revascularization.

Embolization

This therapy may be used for a variety of lesions, including AVMs, dural AVFs, vein of Galen malformations, vascular neoplasms (e.g., meningioma), hemangiomas, glomus tumors, and juvenile nasal angiofibromas, and for treatment of epistaxis.

AVM embolization is often performed as an adjunct to radiosurgery or microsurgery, although in some settings, embolization may be the definitive treatment. Brain AVMs are generally parenchymal lesions with multiple feeding pial arteries and draining veins. A common goal of embolization is to reduce the size and shunt burden presented by the AVM before either radiosurgery or microsurgical resection. Liquid embolic agents are preferred, with n-butyl cyanoacrylate (NBCA) and ethylene vinyl alcohol copolymer (EVOH) being the most widely used materials for the procedure. Embolization often is preceded by neurophysiologic testing, which may include the superselective injection of a barbiturate into the portion of the intracranial circulation being considered for embolization. This may be accompanied by the use of somatosensory and motor-evoked potential testing. Some pre-embolization testing may be performed with the patient awake to allow for more thorough clinical testing, such as language function. However, some endovascular therapists prefer to use GETA to minimize patient motion, and it is needed when motor-evoked testing is performed.

Dural arteriovenous fistulas drain directly into dural veins or sinuses and are most commonly located in the regions of the cavernous, transverse, and sigmoid sinuses. Because of their location, these malformations are supplied by dural or meningeal arteries. They are acquired lesions but often have no clear etiology or antecedent history. Patients may have a variety of symptoms depending on the location, size, and drainage pattern of the dural fistula. Those arising in the transverse or sigmoid sinus region often present with tinnitus. Cavernous sinus fistulae often present with proptosis and ophthalmoplegia. These cavernous sinus fistulae also may be posttraumatic, developing as a direct large-hole fistula between the internal carotid artery and the cavernous sinus. The embolization process for these dural-based lesions differs somewhat from the technique used for pial-based brain AVMs. Arterial embolization may be used, but venous embolization is often used to definitively occlude the fistula. Embolization of meningeal arteries may be preceded by clinical testing for cranial nerve deficits. This usually is accomplished with the superselective injection of lidocaine before embolization, and it is often preferred to have the patient awake for this procedure. If arterial embolization is utilized, a liquid embolic (NBCA or EVOH is often utilized. Venous embolization is usually done with platinum coil occlusion.

Vein of Galen malformations are congenital lesions that may present in infancy or early childhood. Presenting symptoms include congestive heart failure (CHF)

hydrocephalus, and neurodevelopmental delay. These lesions often require a staged approach to treatment and present a special challenge in the neonate or infant. In general, arterial embolization is performed as the initial endovascular approach, and a liquid embolic agent is used. In some cases, this may be augmented by a venous approach, with embolization using platinum coils.

Tumor embolization usually is performed as an adjunct to the surgical resection of highly vascular tumors (e.g., meningiomas, hemangiomas, hemangioblastomas, glomus tumors, and juvenile nasal angiofibromas). Generally, arterial embolization of meningeal supply vessels is done before surgery, using PVA or trisacryl gelatin microspheres. Physiologic testing with superselective injection of lidocaine often precedes embolization. When there is tumor encasement of a major artery, the patient may also undergo balloon test occlusion followed by permanent occlusion to reduce the risk of intraop bleeding.

Aneurysm Therapy

Endovascular therapy is the treatment of choice for many intracranial aneurysms. The earliest method for endovascular treatment consisted of direct intra-aneurysmal obliteration, filling the aneurysm pouch with detachable platinum coils. A randomized, controlled trial using this technique showed better clinical outcome for patients treated with aneurysm coiling than surgical clipping in the setting of acute subarachnoid hemorrhage.

A spate of new devices and adjunctive techniques have extended the endovascular therapist's ability to treat aneurysms of various sizes and locations that could not be treated with coils alone. Smaller, narrow-necked aneurysms may be treated with a microcatheter through which coils are introduced directly into the aneurysm. Wider-necked aneurysms are more difficult to treat using this technique because coils may prolapse into the parent artery. In this situation, coiling may be done either with balloon remodeling or with the combined use of a stent. Balloon remodeling involves placing a balloon catheter in the parent artery over the ostium of the aneurysm. The balloon is intermittently inflated as coils are inserted to prevent coil prolapse into the parent vessel. Fenestrated stents can also be introduced into the parent artery over the ostium of the aneurysm. The aneurysm is coiled by placing a microcatheter through the stent fenestrations into the aneurysm.

The use of a flow-diverting stent in the parent artery to produce thrombosis of the aneurysm has also become widely used, particularly to treat larger wide-necked aneurysms (see Fig. 13.1-1). These stents are constructed using fine mesh self-expanding metal. They are placed in the parent artery to reduce blood flow into the

aneurysm sac resulting in gradual thrombosis of the aneurysm while maintaining flow in the parent artery. This treatment is generally reserved for unruptured aneurysms as the patients require treatment with antiplatelet agents. Recently another intra-aneurysmal device (LUNA®, Medtronic) consisting of a self-expanding and self-retaining spherical braided mesh of nitinol wires has begun to be used, particularly in aneurysms arising at arterial bifurcations.

Parent artery occlusion is still used for some giant or fusiform aneurysms but has more recently been largely replaced by the use of flow-diverting stents. Parent artery occlusion is generally done in a two-step process. Test occlusion is initially performed with a balloon-tipped catheter, and the patient is evaluated using clinical testing and neurophysiologic monitoring. The testing may be done with controlled hypotension to improve the test sensitivity. If the patient tolerates test occlusion, a permanent occlusion is usually done using coils placed into the parent artery.

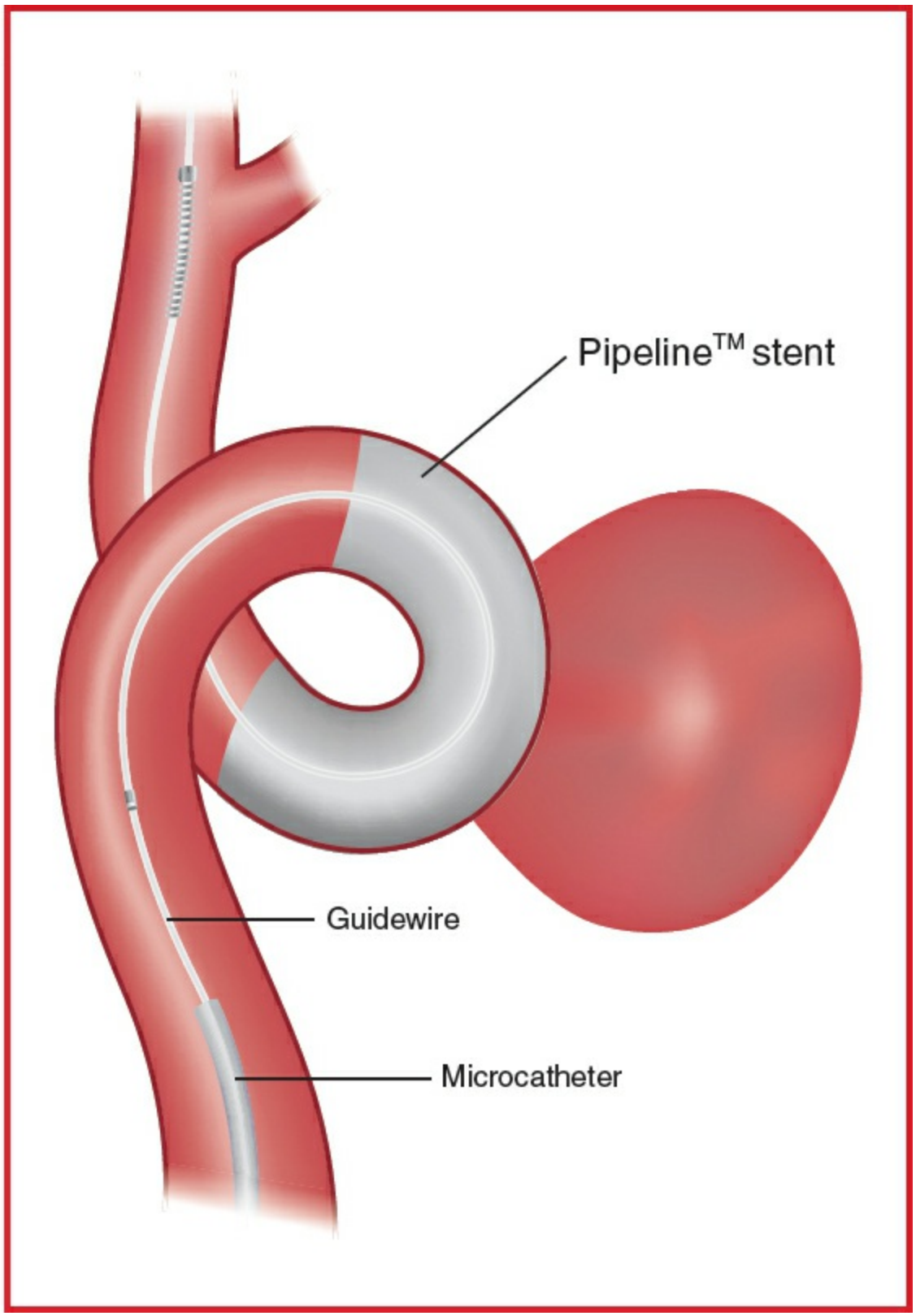

Figure 13.1-1 Example of a fine mesh, flow-diverting stent (Pipeline™) used to treat a wide-neck aneurysm.

Cerebral Revascularization

Acute stroke thrombolysis or thrombectomy is performed to recanalize larger occluded

arteries in the cerebrovascular circulation, including the internal carotid, middle cerebral, vertebral, and basilar arteries. Intravenous tissue plasminogen activator (IV-tPA) had been standard of care when the drug was administered up to 4.5 h following acute stroke onset. Randomized trials using IV-tPA beyond 4.5 h were unable to establish a benefit. In the last decade, endovascular therapeutic devices were introduced and resulted in better recanalization rates and clinical outcomes. These devices include a suction thrombectomy catheter, which can be introduced into the intracranial circulation, and retrievable stents, which are introduced into the thrombus and after entrapping the thrombus are pulled from the circulation. The devices may be used alone or in combination. Recently, five separate randomized trials have shown that endovascular therapy improves outcomes over IV-tPA alone or standard medical therapy in a 6 h (up to 24 h in selected patients) time window with endovascular therapy now being the standard of care for large artery occlusions. Physiologic imaging with either computed tomography (CT) or MR is used at many centers to select patients who will benefit from treatment in these more extended time windows. General anesthesia has become less widely used in these cases as several retrospective studies have suggested better outcomes for patients who are awake during stroke thrombectomy. Unfortunately, these studies are confounded by selection bias, and randomized control trials have not been performed.

Angioplasty and stent placement for symptomatic atherosclerotic stenosis in the cerebrovascular circulation are becoming more widely performed in lieu of medical or direct surgical therapy. Stents with distal protection devices have now been approved for the treatment of cervical carotid artery stenosis. Distal protection devices (e.g., balloon or basket devices) have been shown to reduce the thromboembolic complication rate and are now required for treatment in most cases. A recent large multicenter trial of both symptomatic and asymptomatic carotid stenosis patients found that the composite risk of stroke, myocardial infarction, or death did not differ significantly between stented patients and those undergoing endarterectomy. However, a 2017 systematic review suggests that endarterectomy is the best option for management of asymptomatic carotid stenosis. Arterial stenosis located more distally and intracranial stenotic lesions are treated with angioplasty alone or are stented following angioplasty. There are no efficacy data available for these more distal lesions, and a recent trial of stenting versus medical therapy for intracranial stenosis found that medical therapy had lower rates of stroke and death.

Transcarotid artery revascularization (TCAR): This procedure uses retrograde flow for embolic protection during carotid stent placement. Device placement requires direct access to the affected common carotid artery (CCA) through a small supraclavicular

incision. Dissection is carried down to the CCA, a loose ligature is placed around the CCA and adventitial purse string stitches are placed around the perimeter of the anticipated puncture site. The CCA is punctured and a guide wire is inserted, followed by a dilator and catheter. The CCA is clamped under direct vision, and reverse flow is initiated from the internal carotid artery through a 200 μm filter to a previously placed femoral vein cannula. Transcarotid stent placement then proceeds in the usual fashion with the reversed carotid flow flushing any procedure related embolic debris to the filter for capture.

This procedure can be accomplished with GA or local anesthesia (field block) placed by the surgeon. As usual, with the procedure MAC the anesthesiologist should be prepared to control hemodynamics (art line useful), airway and patient cooperation. ACT goal is 250–300 sec. Some patients will not tolerate the loss of antegrade flow requiring rapid conversion to GA and prompt completion of the procedure.

Vasospasm often accompanies subarachnoid hemorrhage and results in ischemic complications, which are a common cause of morbidity and mortality following aneurysmal rupture. The endovascular therapist is often asked to treat this problem with either drugs or balloon angioplasty. Direct administration of intra-arterial vasodilators, such as verapamil, nimodipine, or nicardipine, has been used particularly for treatment of more distal spasm. More proximal spasm involving the arteries of the circle of Willis is often treated using high-compliance angioplasty balloons.

SUMMARY OF PROCEDURES

	Embolization	Aneurysm Therapy	Cerebral Revascularization
Position	Supine	⇐	⇐
Incision	Femoral artery, catheterization (may utilize brachial or radial artery)	⇐	⇐
Unique considerations	BP control; AVM; anticoagulation; EP monitoring	BP control; ± EP monitoring; anticoagulation	⇐
Antibiotics	Usually none; occasionally used with closure device	⇐	⇐

Procedure time	2–5 h	2–4 h	⇐
Closing considerations	Femoral artery compression or closure device	⇐	⇐
EBL	Minimal	⇐	⇐
Postop care	Ward or ICU × 24–48 h	ICU	Ward or ICU
Mortality	1–2% (vascular lesions)	⇐	⇐
Morbidity	Overall: ~5% Thromboembolic stroke Hemorrhage (AVM, AVF)	⇐ ⇐ SAH	⇐ ⇐ Vessel rupture/dissection
Pain score	1–2	1–2	1–2

PATIENT POPULATION CHARACTERISTICS	
Age range	Neonatal–elderly
Male:Female	1:1
Etiology	Congenital; acquired (traumatic, infectious, degenerative, etc.)
Associated conditions	SAH ± vasospasm; ↑ ICP; HTN/CAD/PVD; blood dyscrasia

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients presenting for diagnostic neuroradiologic procedures may require only local anesthesia and sedation. The newer nontoxic and low osmolality contrast agents have improved patient comfort and tolerance for these procedures while minimizing adverse reactions. Patients presenting for therapeutic neuroradiologic procedures may be restless or uncooperative and, therefore, may require GA to tolerate these often lengthy procedures. The advantages of GA, however, must be balanced against the potential

need for interactive neurologic monitoring (e.g., speech, vision, and mental status assessment) that requires the patient to be awake and cooperative. In this case, close consultation among the neuroradiologist, monitoring neurologist, and anesthesiologist is required in formulating the anesthesia plan. In many cases, time is of the essence, and any delay may reduce favorable outcome.

Respiratory	Access to the airway may be limited; therefore, examination should focus on the need for elective ET intubation. Patients with chronic cough may require GA to ensure immobility. **Tests:** As indicated from H&P
Cardiovascular	Patients with recent intracranial hemorrhage may demonstrate ECG abnormalities (PVCs in 30–80%; ST-T wave changes in >50%), which need to be differentiated from new ischemic heart disease (echo, cardiac enzymes). **Tests:** ECG; other tests as indicated from H&P
Neurologic	Symptoms vary with the location, size, and type of lesion. Aneurysms seldom produce neurologic symptoms unless they leak or rupture, whereas tumors are commonly associated with symptoms of ↑ ICP (HA, N/V, altered mental status, papilledema). Patients with recent cerebral hemorrhages are likely to be medicated with calcium channel blockers (e.g., nimodipine, nicardipine) to ↓ arterial vasospasm. Patients with ↑ ICP or cranial trauma usually will need GETA and mechanical ventilation.
Premedication	Preop sedation may mask the Sx of ↑ ICP or intracranial hemorrhage. Patients at high risk for contrast-media reactions (e.g., patients with previous contrast reaction, allergy to iodine) should receive prophylactic treatment usually consisting of prednisone, 50 mg po q6h × 3, starting 18 h before the study, and diphenhydramine, 50 mg po, 1 h before the procedure.

INTRAOPERATIVE

Anesthetic technique

MAC may be adequate for patients undergoing diagnostic procedures and necessary for patients requiring neurologic assessment during more invasive procedures; otherwise, use GETA or be prepared to rapidly convert to GETA during the procedure. Although several reports suggest that patients receiving GETA for neurointerventional procedures have worse outcomes compared to those receiving sedation, these observations are not based on randomized controlled studies and are inherently biased since the patients most likely to require only sedation are also the most likely to be stable and uncomplicated at the time of the procedure.

Induction	Standard induction. Patients with ↑ ICP should be hyperventilated to an $ETCO_2$ of ~30 mm Hg. In patients with vascular lesions that may leak or rupture, BP responses to laryngoscopy and intubation should be blunted (e.g., remifentanil: 3–5 mcg/kg iv 1–2 min in advance).	
Maintenance	Standard maintenance. Muscle relaxation is usually mandatory to control ventilation and minimize the chance of movement. Maintain normocapnia, although hyperventilation may be necessary to ↓ ICP and may also enhance the quality of the angiogram. Heparin (ACT goal: 250–350 sec; $t_{1/2}$ = ~30 min) may be requested. Protamine should be immediately available.	
Emergence	Prompt awakening is important to permit neurologic evaluation. Ondansetron (4 mg iv) is useful to ↓ PONV. Extubate when airway reflexes have returned after reversal of muscle relaxant. Continuous control of BP may be necessary during emergence phase. Patients typically are transported to ICU immediately following the procedure.	
Blood and fluid requirements	IV: 18 ga × 1–2 BSS @ 3–5 mL/kg/h	Avoid glucose-containing solutions unless the patient is hypoglycemic (<70 mg/dL).
Monitoring	Standard monitors	BP can be monitored from

	Arterial line Urinary catheter	femoral line placed by radiologist. However, another arterial line often will be necessary for postop monitoring in the ICU. Place urinary catheter if procedure is lengthy (>3 h).
	± neuromonitoring	Keep isoflurane or sevoflurane <0.5 MAC and N_2O <50% to minimize interference with EP monitoring. Supplement with remifentanil infusion as necessary. TIVA may be requested in the erroneous belief that motor or sensory EPs cannot be obtained while using inhalational agents.
	Glucose	Keep serum glucose 70–140 mg/dL. Use insulin infusion to control hyperglycemia.
Control of BP	SNP (0.2–2 mcg/kg/min) Maintain normovolemia. Esmolol (50–200 mcg/kg/min)	BP control may be necessary during intracranial catheter manipulation, embolization, and postembolization. Optimal BP management remains unclear. Close communication with the radiologist is important. In general, in patients with acute ischemic stroke, keep SBP 140–180 mm Hg. In acute hemorrhagic stroke, lowering SBP to 140 mm Hg is recommended. SNP/esmolol may be necessary and can be infused through a second peripheral

		iv. Clevidipine (1–21 mg/h; $T_{1/2}$ = 5–15 min) can be used in place of SNP ($t_{1/2}$ = <2 min), although it is significantly more costly (2019).
Positioning	✓ and pad pressure points ✓ eyes	X-ray table may not be well padded → nerve damage.
Complications, contrast related	Common reactions: N/V Itching Urticaria Sensation of warmth Pain Anxiety Rash	These reactions occur in >5% of patients and may require no treatment apart from reassurance or a mild anxiolytic. Mild allergic reactions may be treated with diphenhydramine 25–50 mg iv. Monitor patients for progression of Sx → need for more aggressive therapy.
	Neurotoxic Sx: Hemiplegia Blindness Aphasia ↓ consciousness	These reactions may be related to the hyperosmolarity of the agent. If persistent, procedure should be terminated. Rx may require steroids, and vasopressors to improve perfusion. In the anesthetized patient, these Sx will be masked.
	Major allergic reactions: Bronchospasm ↓ BP Cardiac arrest Pulmonary edema Laryngeal edema Dysrhythmias	Epinephrine (0.25–0.5 mg iv) should be given immediately for severe reactions. **Rx of anaphylaxis** includes the following: eliminate antigens (e.g., contrast agent, latex); secure airway; administer 100% O_2, iv fluids,

		epinephrine, and diphenhydramine + ranitidine. Supplemental Rx may include steroids (e.g., hydrocortisone 5 mg/kg), atropine, $NaHCO_3$, vasopressin, and epinephrine infusion.
Complications, other	Hemorrhage	Reverse heparin (e.g., 1 mg protamine/100 mg heparin after 30–60 min). Intracranial bleeding may require immediate transport to OR for surgical repair.
	Vasospasm	Rx: vasodilators (e.g., NTG or papaverine) delivered by catheter, or balloon angioplasty.
	Occlusion of vessel	Deliberate hypertension may be beneficial. Rx: angioplasty. (Recanalization and stenting may be used for thrombotic occlusions.)

POSTOPERATIVE

Complications	Neurologic deficits	CT scan for evaluation, as prompt neurosurgical intervention may be required.
	Vasospasm	May require Ca^{++} channel blocker (e.g., nimodipine). Consult with neurosurgeon.

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DIRECT CURRENT CARDIOVERSION

Bing Liem

PROCEDURAL CONSIDERATIONS

Description

Direct-current (DC) cardioversion is a treatment for various cardiac arrhythmias (e.g., atrial fibrillation [AF], atrial flutter [AFL], other supraventricular tachyarrhythmias [SVT], or, rarely, slow ventricular tachycardia [VT]) that uses a brief, dosed discharge

of electricity across the heart. Depending on the seriousness of the arrhythmia (with respect to its effect on hemodynamic stability), cardioversion to restore normal rhythm may be performed emergently or electively (Fig. 13.1-2).

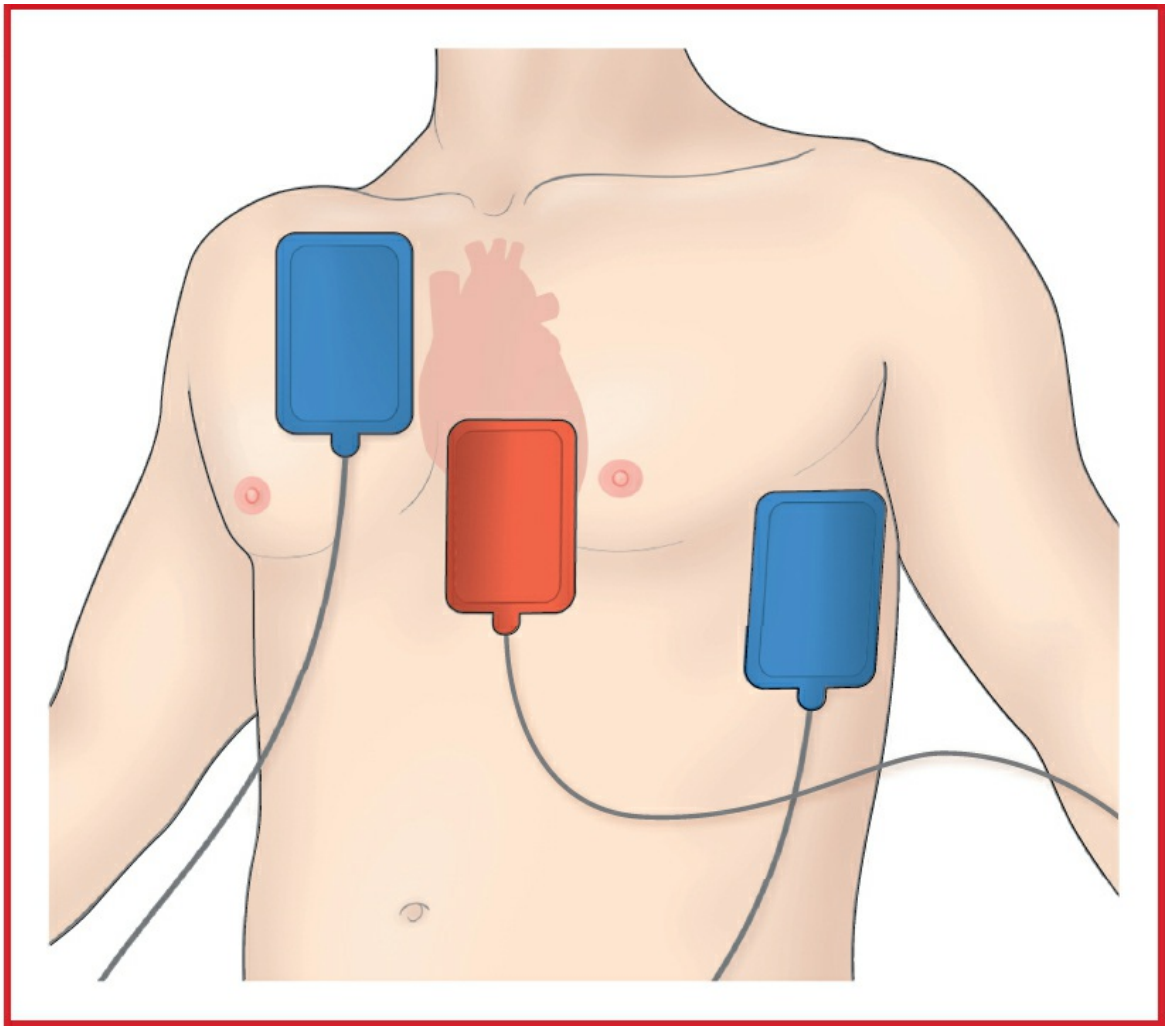

Figure 13.1-2 Positions of defibrillation pads are shown; the AP positions in red and anterolateral in blue. (Modified from Lynn P. Taylor's Clinical Nursing Skills, 5th edition. Wolters Kluwer, Philadelphia: 2019, 970.)

Unlike emergent shock, which is typically performed for ventricular fibrillation (VF), elective cardioversion should always be performed with the patient under deep sedation or brief GA to avoid discomfort. The shock energy is delivered across the heart either from an external source (a defibrillator unit) or internally (from a previously implanted ICD/CRT-D). External cardioversion requires placement of a pair of pads that should be positioned to ensure current flow through the heart. The most common positions are anteroposterior (AP) and basilar-apical/anterolateral (right shoulder and left lateral chest). In one randomized study, the AP position was shown to be more effective than the anterolateral position. Biphasic waveform shock energy is typically 25–200 J (25–

100 J for AFL and SVT and 150–200 J for AF). Most external defibrillators deliver a maximum of 200 J. Special units can deliver up to 360 J, for circumstances requiring higher energy (e.g., very large patients or patients with severe hypertrophic cardiomyopathy). Monophasic waveform is no longer used. When internal cardioversion is performed, the implanted unit is typically set to deliver its full energy (30–40 J biphasic waveform). In either case, the shock is delivered synchronous with the QRS complex as to avoid the vulnerable electrical period (during the T-wave, which may risk induction of VF). In patients with implanted devices (pacemaker [PM] or ICD/CRT-D), the pads should be placed at least 6 inches away from the implanted generator to avoid potential damage to the implanted system. The implanted device should be interrogated before and after the procedure. If unsuccessful, cardioversion may need to be repeated using higher energy, using an alternate pad positions or after infusion of ibutilide (class III agent) to lower defibrillation threshold. If the arrhythmia immediately recurs, cardioversion is repeated after infusion of an antiarrhythmic drug to promote maintenance of normal rhythm.

Usual preop diagnoses: AF, AFL, SVT, and slow VT along with underlying cardiovascular diseases such as hypertension, cardiomyopathy (ischemic or nonischemic), valvular disease(s) (most commonly mitral valve regurgitation), and congenital heart disease(s).

SUMMARY OF PROCEDURE	
Position	Supine with defibrillator pads positioned AP or anterolateral
Unique considerations	In patients with AF, adequate anticoagulation: INR = 2–3 for those on warfarin and uninterrupted use for those on target-specific oral anticoagulants (NOAC) for at least 3 wk prior; otherwise, TEE should be considered to rule out left atrial thrombus.
Antibiotics	None
Procedure time	≤30 min
Postop care	Monitoring of cardiac rhythm in treatment room
Mortality	0.1%
Morbidity	Skin burns: <15% (1st degree); <2% (2nd degree); lesser incidence with biphasic waveform Embolic event: 2% (↑ risk with mitral valve disease)

	Acute pulmonary edema: 1% More serious arrhythmia: 1% Myocardial damage: Incidence unknown, but estimated to be very low—proportional to delivered energy
Pain score	2–3

PATIENT POPULATION CHARACTERISTICS

Age range	All ages
Male:Female	3:1 male predominant but no recent statistics available
Incidence	100,000/yr in the United States
Etiology	Reentry arrhythmia substrates (e.g., AF, AFL, SVT, VT) from hypertensive heart disease, cardiomyopathy (ischemic or nonischemic); idiopathic.
Associated conditions	Systolic or diastolic heart failure, CAD, cardiomyopathy, HTN, valvular heart disease, COPD, obesity, CVA, diabetes, obstructive sleep apnea, obesity

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients presenting for cardioversion fall into one of two categories: elective or emergent. The presence or absence of hemodynamic instability will define the category. In the emergency patient, full-stomach precautions may be necessary. Elective cardioversions usually are carried out on patients who have failed drug therapy. In patients with recent onset AF, optimal timing for cardioversion is reported to be 24–48 h after onset.

Respiratory	Preop evaluation of the airway should focus on the need for elective ET intubation (patients with GERD, difficult mask fit, or airway compromise).
Cardiovascular	Relative contraindications to elective cardioversion include ↓ K^+, inadequate anticoagulation, presence of β-blockade, AV block, and rare digitalis toxicity (toxic = >3 ng/mL). The presence of significant CHF, CAD,

	or valvular disease may predispose this patient population to ↓↓ BP in response to anesthetic agents. Consider use of etomidate (0.1–0.2 mg/kg). Patients at ↑ risk for an embolic event include those with Hx of embolization within 2 yr, mitral stenosis, intra-arterial thrombus, CHF, or hyperthyroidism. In these patients, ensure adequate anticoagulation (PT 1.5–2 × baseline, INR 2.0–3.0). It has been suggested that NTG patches near the electrodes be removed prior to cardioversion to avoid risk of explosion. **Tests:** ECG; TEE (✓ for thrombus and size of atrium); digitalis level (toxic = >3 ng/mL → refractory VF following cardioversion); electrolytes; INR
Endocrine	Hyperthyroidism → AF
Gastrointestinal	Full-stomach precautions may be necessary in the emergency patient.
Neurologic	✓ Hx for TIAs or CVAs → ↑ risk of embolic event. Pre- and postprocedure neurologic exams should be done.
Hematologic	✓ need for anticoagulation (see above).
Laboratory	Other tests as indicated from H&P
Premedication	Usually not needed. For the emergency patient, take full-stomach precautions.

INTRAOPERATIVE

Anesthetic technique

Brief GA with mask oxygenation and ventilation

Induction	Preoxygenate patient. For many patients, etomidate (0.1–0.2 mg/kg iv) is the agent of choice (**NB**: etomidate-induced clonus → ECG artifact). Propofol (1.0–1.5 mg/kg iv slowly) until loss of lid reflex can be used in hemodynamically stable patients but may be associated with slower recovery. Supplemental analgesia

	may be provided by fentanyl (e.g., 0.5–1 mcg/kg preinduction) or remifentanil (1–2 mcg/kg), thereby reducing anesthetic requirements.	
Maintenance	Occasionally necessary to repeat cardioversion. Additional small doses of propofol, etomidate, or remifentanil may be required.	
Emergence	Patients should awaken rapidly with full recovery of airway reflexes. Outpatients are usually discharged to home within 1–2 h.	
Blood and fluid requirements	No blood loss IV: 20 ga × 1 NS/BSS @ TKO	
Monitoring	Standard monitors	Avoid placement of ECG electrodes in precordial area.
Positioning	Hospital bed, supine	Procedure takes place at patient's bedside.
Complications	Loss of airway	Use airway manipulation ± artificial airways; always be prepared to intubate.
	VF	Use ACLS protocols.
	↑↑ BP/myocardial ischemia	Cardioversion → catecholamine surge → acute MI in susceptible patient population.
	Severe bradycardia	Rx: atropine (e.g., 0.4 mg iv)
	Thermal injury	Ensure good electrode/skin contact.
	↓ CO	2° anesthetic drugs or myocardial stunning from cardioversion. Rx: inotropic support (e.g., ephedrine)

POSTOPERATIVE

Complications	Recall	Especially in hemodynamically fragile patients. Discuss possibility with patient in advance.
	Systemic embolization	Neurologic exam should be repeated postcardioversion.
	↓ BP/↓ CO/CHF new dysrhythmia	Atrial contraction may not be effective following cardioversion → ↓ CO/↓ BP.
	Renal dysfunction	Incidence: 17%. ✓ renal function labs.
Pain management	Minimal	Myalgias not uncommon; consider iv ketorolac.
Tests	ECG	Verify NSR.

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IMPLANTATION OF CARDIOVERTER-DEFIBRILLATOR (ICD) OR CARDIAC RESYNCHRONIZATION THERAPY DEFIBRILLATOR

(CRT-D)

PROCEDURAL CONSIDERATIONS

Description

The implantable cardioverter-defibrillator (ICD) is an effective device for the prevention of premature death from VT or VF. The results of randomized clinical trials involving survivors of cardiac arrest and those considered at risk for sudden death showed the superiority of ICD therapy over conventional medical therapy in lowering the incidence of sudden death and overall mortality. Hence, ICD therapy has become the gold standard for patients considered at risk for sudden death (primary prevention) or those with a history of spontaneous or inducible sustained VT/VF (secondary prevention). Since its inception in 1983, there have been significant advances in ICD technology. The more efficient biphasic shock waveform allows for a much lower defibrillation threshold and, hence, a lower required energy delivery, which, in turn, allowed for dramatic reduction in the generator's size and the need for epicardial electrodes. Furthermore, the firmware now provides significantly broader spectrum in functionality. Newer devices can incorporate the full capabilities of a permanent pacemaker along with resynchronization therapy (see below), the ability to differentiate VT from SVT, and deliver antitachycardia pacing for VT or shock for VF. Therapy for atrial tachyarrhythmias (atrial tachycardia and flutter) with atrial overdrive pacing is also available in select devices. The need for GA in ICD implantation has been diminishing and deep sedation is required mainly during defibrillation threshold testing (DFT). DFT (Fig. 13.1-3) may be unnecessary since clinical trials have shown that ICDs rarely fail in defibrillating VF and, furthermore, that unnecessary ICD shocks are associated with negative cardiovascular outcomes, including increased overall mortality. Thus, deep sedation or GA is necessary only for patients with other cardiovascular and pulmonary comorbidities.

A new ICD system using entirely subcutaneous approach for the lead and generator placement is now available (Fig. 13.1-4). The lead is implanted subcutaneously along the sternum and the generator placed in the lateral chest. The need for DFT with this system is higher than for the standard ICD; hence, deep sedation or GA is required.

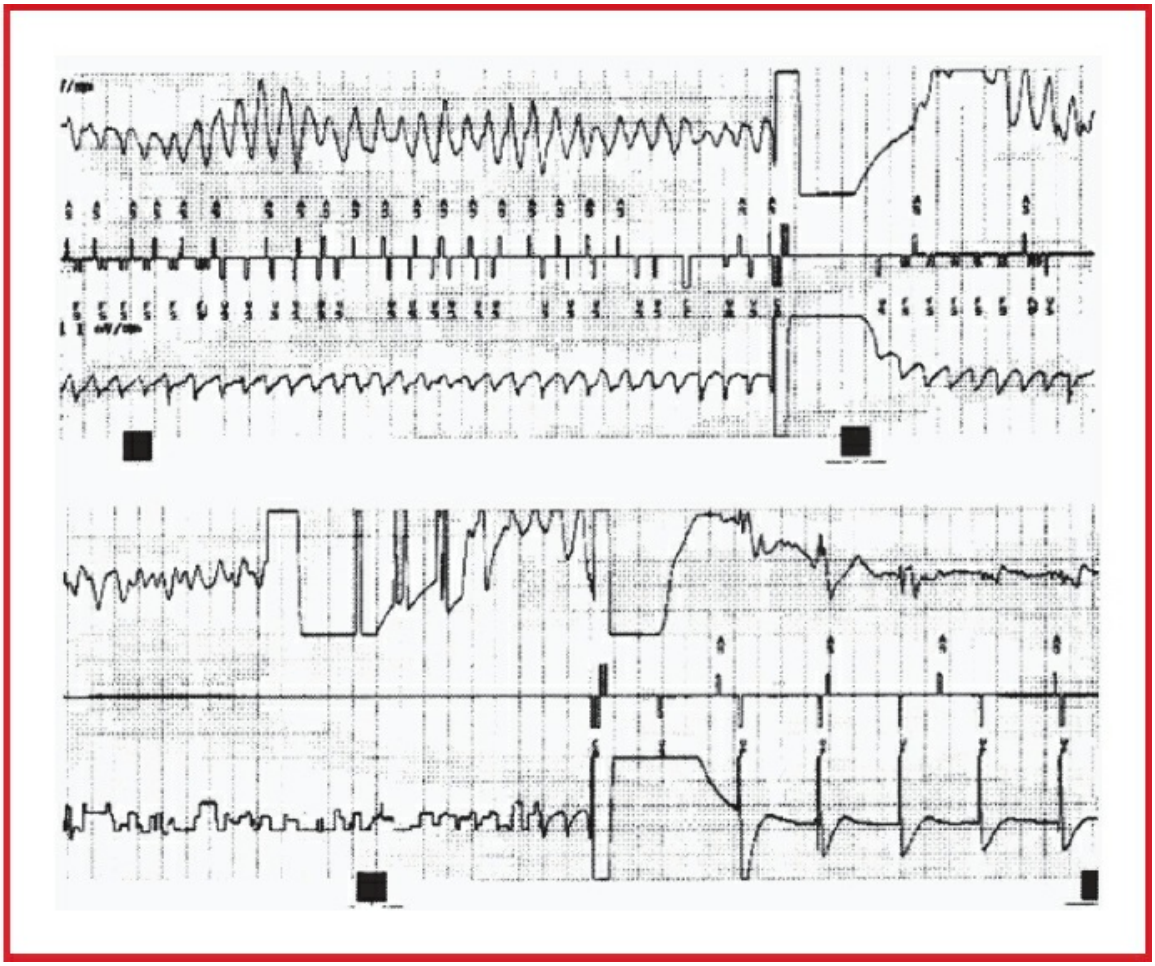

Figure 13.1-3 Induced VF (with underlying AF) is shown on top panel, whereby the first (24-J) shock failed to terminate VF but terminated AF (as indicated by the ICD annotation). The second shock (34-J) terminated VF, resulting in V-paced rhythm with underlying sinus and AV block. Total downtime during VF was 16 sec. Downtime is dependent on the detection time and charge time, which, in turn, depend on the energy programmed.

Cardiac resynchronization therapy (CRT) was developed for symptomatic systolic heart failure (HF) patients with electrical and/or mechanical dyssynchrony, typically an intraventricular conduction delay (e.g., LBBB) causing a mechanical dyssynchrony → systolic inefficiency. Resynchronization of right and left ventricular (LV) depolarization requires implantation of a LV lead into one of the tributaries of the coronary sinus in addition to the other standard pacing leads. The LV lead placement can increase the procedure time significantly, and combined with the more compromised underlying systolic function, monitored deep sedation or GA may be the more appropriate approach for this procedure.

Usual preop diagnosis

Documented, induced, or high-risk VF; moderate-severe heart failure

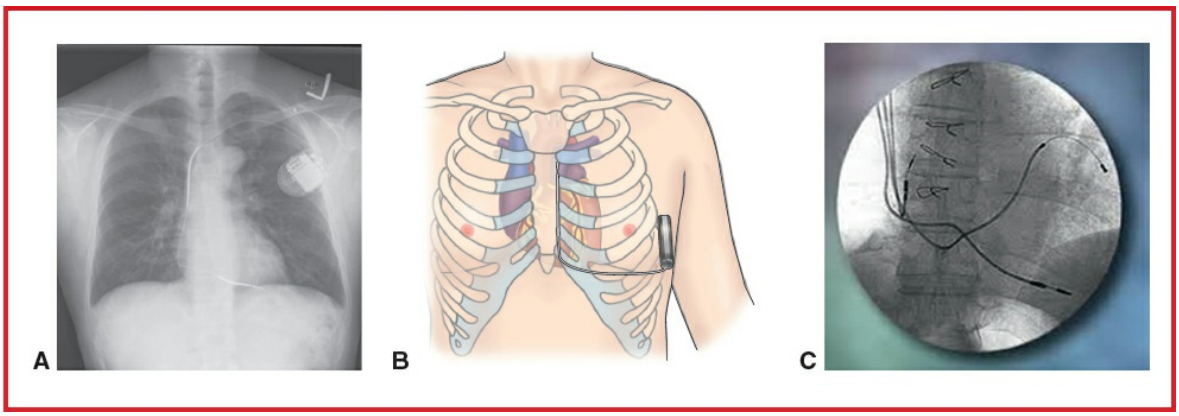

Figure 13.1-4 Shown here is **(A)** the radiograph of a single-lead ICD with dual-coil system, **(B)** subcutaneous ICD system (Modified from Hinkle JL, Cheever KHBrunner & Suddarth's Textbook of Surgical Nursing 14th edition. Wolters Kluwer, Philadelphia: 2018, 697.), and **(C)** the leads in a CRT system.

SUMMARY OF PROCEDURE

Position	Supine with defibrillator pads positioned AP or basilar-apical
Incision	Left pectoral
Special instrumentation	ICD pulse generator, lead(s), and testing system (manufacturer specific)
Unique considerations	VT/VF induction with associated ↓ CO, ↓ BP
Antibiotics	Cefazolin 2 g iv
Surgical time	1–2 h (more for ICD with cardiac resynchronization [CRT-D])
Closing considerations	Routine subcutaneous/submuscular pocket closure
EBL	5–20 mL
Postop care	Monitoring of arrhythmia, pocket bleeding/hematoma, pneumothorax
Mortality	0.1% (transvenous); ≤5% (thoracotomy)
Morbidity	New-onset arrhythmias: ≤5% Pneumothorax: ≤5% (transvenous) Pericardial effusion/tamponade: ≤1% (transvenous)

Pain score	3 (6–9, thoracotomy)

PATIENT POPULATION CHARACTERISTICS	
Age range	Any
Male:Female	Male preponderance
Incidence	>50,000/yr in the United States
Etiology	Reentry substrates from remote myocardial fibrosis, channelopathies (e.g., Long QT and Brugada syndromes)
Associated conditions	LV dysfunction; CAD; cardiomyopathy; HTN; valvular disease

Suggested Readings

1. Al-Khatib SM, Stevenson WG, Ackerman MJ, et al: 2017 AHA/ACC/HRS Guideli for management of patients with ventricular arrhythmia and the prevention of sudden cardiac death. Heart Rhythm 2018;138(13):e210–71.
2. Boersma L, Barr C, Knops R, et al: Implant and midterm outcomes of th subcutaneous implantable cardioverter-defibrillator registry. The EFFORTLES study. J Am Coll Cardiol 2017; 70:830–41.
3. Healey JS, Hohnloser SH, Glikson M, et al: Cardioverter defibrillator implantatio without induction of ventricular fibrillation: a single-blind, non-inferiority, randomized controlled trial (SIMPLE). Lancet 2015; 385:785–91.

EXTRACTION OF PACEMAKER AND IMPLANTABLE CARDIOVERTER-DEFIBRILLATOR (ICD) LEADS

PROCEDURAL CONSIDERATIONS

Almost all PM and ICD systems are implanted utilizing endovascular lead(s). Thes leads have excellent longevity, typically beyond 25 yr, and hence in the case of a PM implantation for sick sinus syndrome (SSS), most patients will not need a lead "replacement" procedure. However, in younger patients (e.g., PM implantation in the pediatric population and ICD implantation in the young athlete), "replacement" may become necessary. Unfortunately, some leads may undergo premature degradation due to a manufacturing deficiency. In the majority of lead "replacement" (now more

commonly called "revision") procedures, the simple addition of a new lead will suffice, but in some cases where multiple leads are already present, a "debulking" procedure is necessary to avoid vascular congestion or unwanted lead-to-lead interaction. Hence, removal of some, or all, of those leads would be necessary. In some cases (e.g., refractory sepsis or bacteremia), lead removal is considered mandatory. There are other rare scenarios where lead removal is at least strongly recommended. Examples include progressive tricuspid valve regurgitation that is suspected to be caused by the presence of multiple RV leads and where the presence of multiple leads has caused SVC syndrome.

Leads that have been implanted for longer than 1 yr are likely to have adhered to the adjacent vascular wall or endocardial surface. Adhesion sites are typically located in the subclavian vein, the junction of the innominate vein and SVC, along the SVC, the tricuspid valve, and the RV tissue (Fig. 13.1-5). Therefore, removal of chronic leads typically requires fibrotic tissue cutting tools in the form of telescoping sheaths. The forward advancement of the sheaths is done either by manual force or with the aid of thermal tissue ablation (using LASER or radiofrequency [RF] heating). The areas at the junction of the innominate vein and the superior vena cava and along the superior vena cava are of concern in terms of risks for vascular tear because the sheath may not conform to the lead angulation. In utilizing any of these methods, vascular injury is inevitable and may result in transmural tear with rapid exsanguination. Thus, lead extraction procedures should be performed with complete preparation for immediate **emergency sternotomy** with a surgical team on active standby. For these reasons, GETA is a necessity. In addition, the patient should be prepped and draped for possible sternotomy and surgical instruments, and a CPB machine should be in the room with the perfusionist team nearby. Blood products should also be immediately available. Vascular access should be large bore and a central line is advisable. Continuous blood pressure monitoring via an arterial line is mandatory and continuous TEE or standby TTE should be used. The surgical approach of the procedure is similar to a standard implantation or pulse generator change. The patient will have continuous ECG monitoring and external defibrillator/PM pads applied. The pulse generator is removed from the pocket as usual and the leads are released from encapsulation. For the patient who is PM dependent, a temporary PM is mandatory. The temporary PM lead should be placed through a venous entry other than the one being used for the extraction. If temporary pacing support is expected to be necessary for several days or weeks (e.g., in the case of an infected system when reimplantation is delayed), it has become customary to utilize a permanent PM lead with an active fixation, as this will provide more reliable backup pacing. The lead is connected to a permanent PM generator securely taped against the skin, thus improving patient ambulation. The right IJ venous entry is the

best route for placement of this "temporary-permanent" pacing system. In the event of incomplete lead removal, retrieval of the remnant is best done using a femoral approach. Several retrieving tools, such as snares and baskets (Fig. 13.1-6), are available in the market.

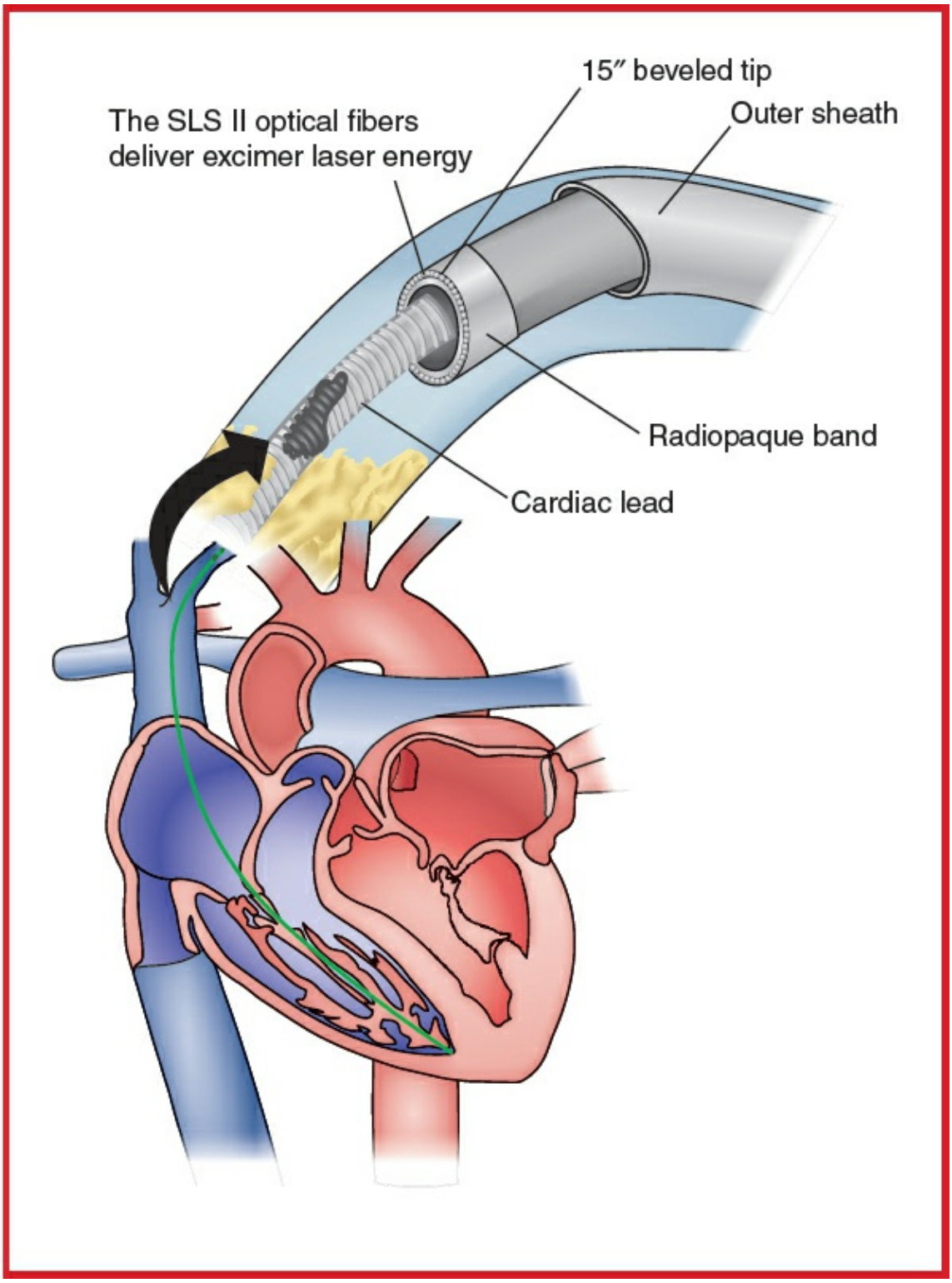

Figure 13.1-5 The laser sheath is placed over the lead to be extracted and advanced into the heart. The laser is then used to ablate scar tissue surrounding the lead to facilitate extraction.

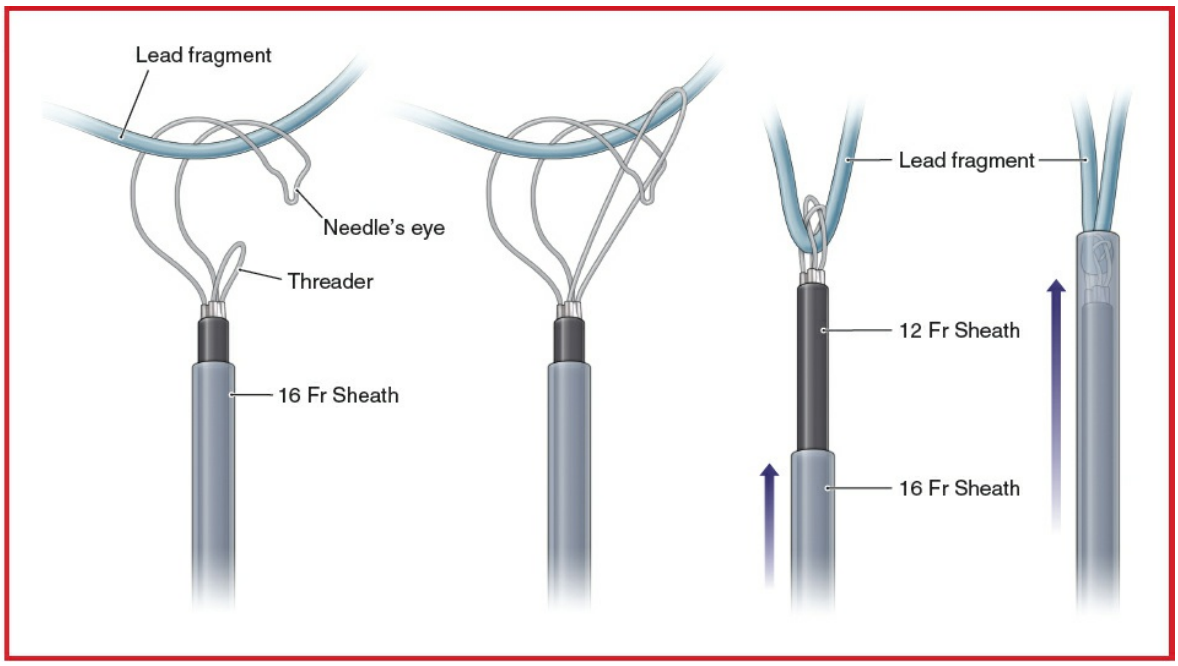

Figure 13.1-6 An example of a lead retrieval tool in use to capture and remove a lead fragment.

Suggested Readings

1. Bongiorni MG, Segreti L, Di Cori A, et al: Overcoming the current issue surrounding device leads: reducing the complications during extraction. Expert Rev Med Devices 2017; 14(6):469–80.
2. Kratz JM, Toole JM: Pacemaker and internal cardioverter defibrillator lead extraction: a safe and effective surgical approach. Ann Thorac Surg 2010; 90(5):1411–7.
3. Kusumoto FM, Schoenfeld MH, Wilkoff BL et al: 2017 HRS expert consensus statement on cardiovascular implantable electronic device lead management and extraction. Heart Rhythm 2017; 14:e503–51.
4. Sonny A, Wakefield BJ, Sale S, et al: Transvenous lead extraction: a clinical commentary for anesthesiologists. J Cardiothorac Vasc Anesth 2018; 32(3):1101–11.
5. Wilkoff BL, Byrd CL, Love CJ, et al: Pacemaker lead extraction with the laser sheath: results of the Pacing Lead Extraction with Excimer Sheath (PLEXES) Trial. J Am Coll Cardiol 1999; 33:1671–6.
6. Wilkoff BL, Love CJ, Byrd CL, et al: Transvenous lead extraction: Heart Rhythm Society expert consensus on facilities, training, indications, and patient management. Heart Rhythm 2009; 6:1085–104.

CATHETER ABLATION OF ATRIAL FIBRILLATION

PROCEDURAL CONSIDERATIONS

Description

Catheter ablation involves placement of catheters onto the desired cardiac chambers via venous and/or arterial access (most commonly the femoral blood vessels) and more recently via pericardial space. Through the electrodes at the tip of the catheters, intracardiac (or epicardial in the case of pericardial approach) signals can be recorded, arrhythmias can be monitored and/or induced using specific pacing protocols, and small areas of cardiac tissue can be ablated using various modalities. The most common modality is radiofrequency (RF) energy. Other emerging ablation techniques include cooling with cryoenergy and heating using ultrasonic, LASER, and microwave modalities. For atrial fibrillation (AF), the ablation is aimed at the triggers and substrates. The triggers can be found at various sites, most commonly at the entries of the pulmonary veins, superior vena cava, and coronary sinus into the left and right atria. The substrates for AF are believed to be in various areas on the left atrial wall, usually the posterior wall (Fig. 13.1-7).

Unlike catheter ablation procedures for other arrhythmias with a more focused area of interest, AF ablation requires energy delivery at a significantly greater number of sites. In most cases, the mapping and ablation are guided by a three-dimensional tracking system. The procedure also requires access to the left atrium, typically via a transseptal catheterization, which is usually guided by intracardiac echocardiogram. In the typical scenarios, two transseptal sheaths are placed in the left atrium to facilitate recording, pacing, and application of ablation. Typically, pulmonary vein isolation (PVI) is the basic approach. Left appendage isolation is also being performed in some centers. If elimination of left AFL substrate is a target, a significant amount of additional ablations are necessary. Typically, a "roof" line is created as well as a line connecting the left lower pulmonary vein to the mitral valve annulus. More recently, single-shot ablation devices to isolate pulmonary veins (e.g., cryoballoon) have become available (Fig. 13.1-8). These devices allow a single application of energy to produce a circumferential isolating lesion.

The standard procedure typically requires several (2–4) hours to complete. Cryoballoon procedures can be significantly shorter. The patient is continuously anticoagulated with iv heparin. Many centers are now performing the procedure with the patient already fully anticoagulated prior to the start of the procedure. One or more cardioversions may also be necessary, especially in patients with persistent AF. Furthermore, many centers are now using high-dose isoproterenol and adenosine after the ablation to assess likelihood of recurrence.

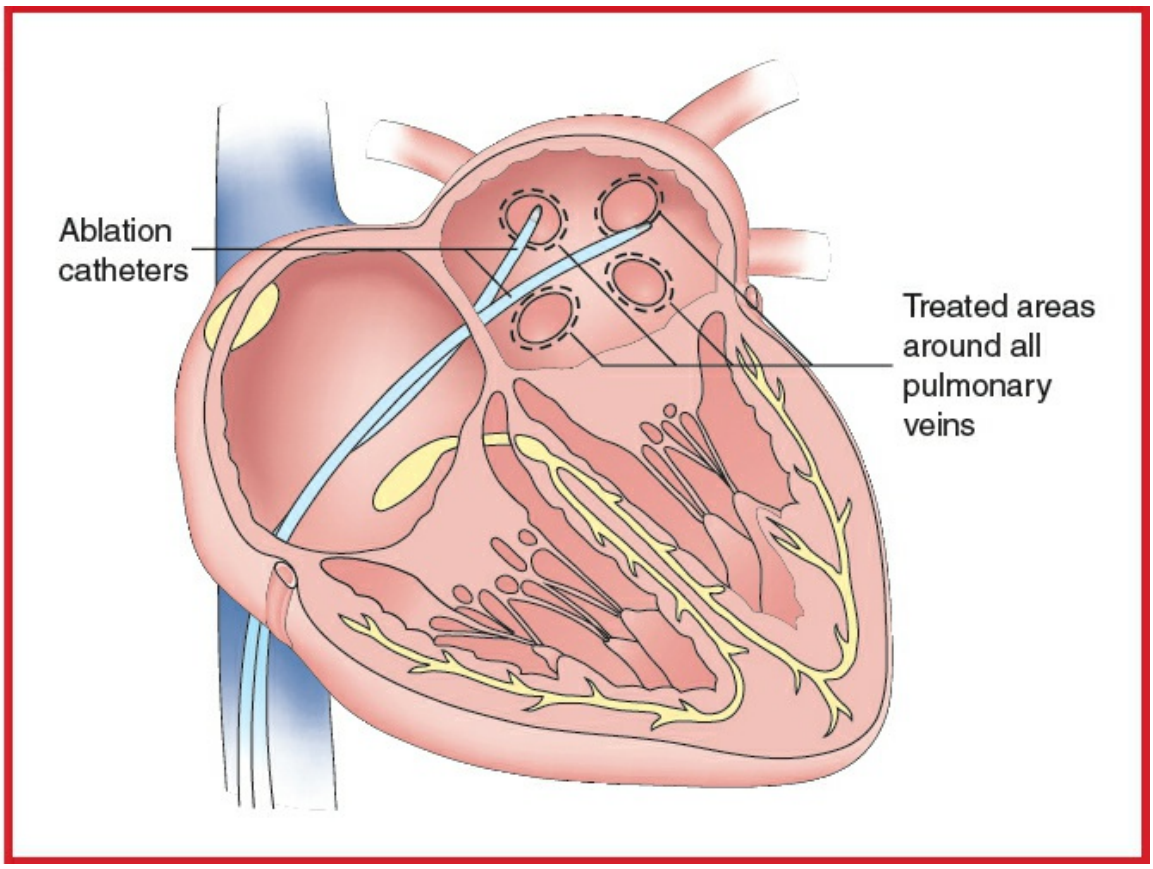

Figure 13.1-7 A transvenous transceptor catheter electrode is used to ablate target areas around the pulmonary vein entry sites to treat atrial fibrillation. Other common target sites include atrial walls as well as SVC and coronary sinus inlets.

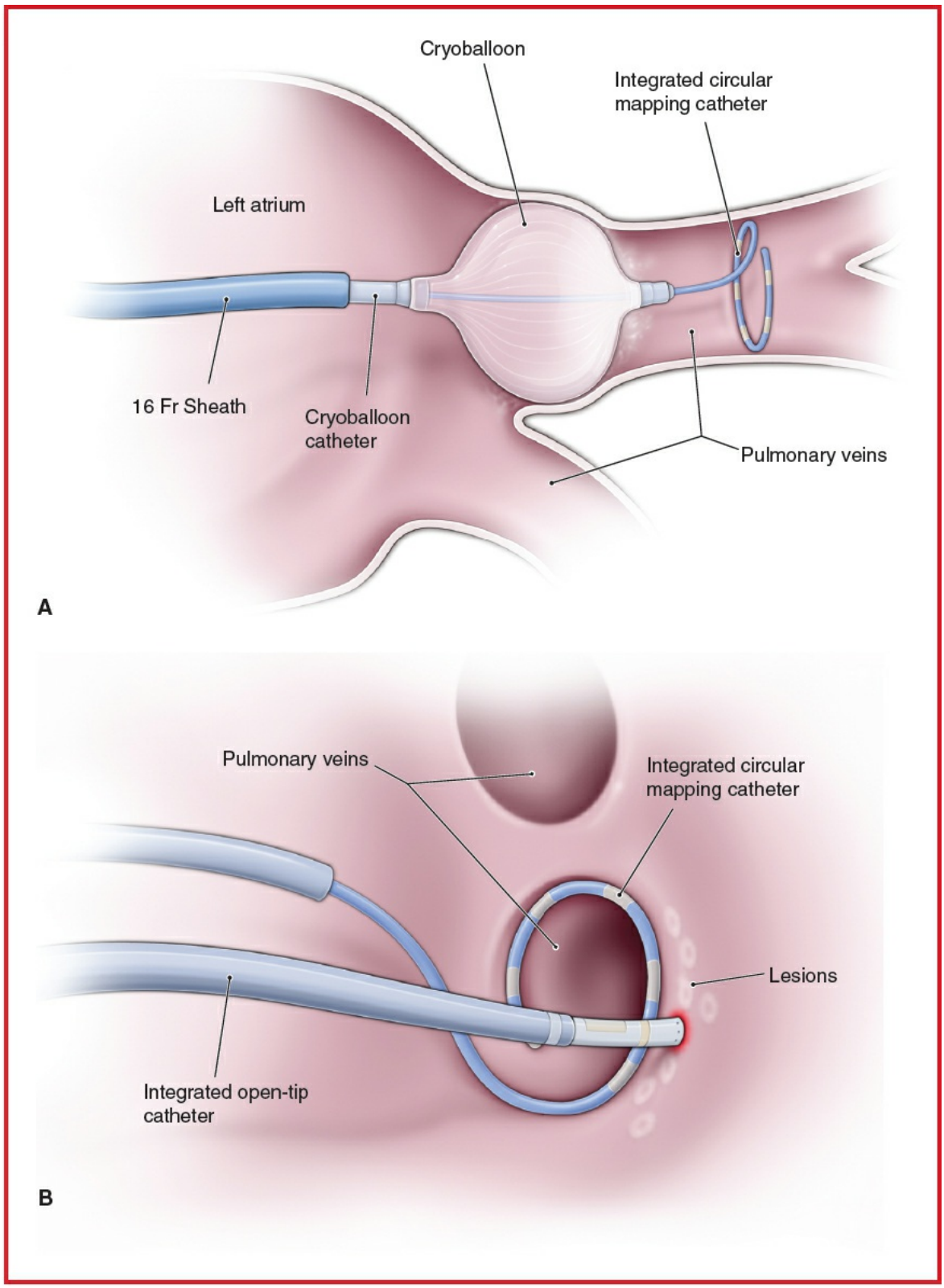

Figure 13.1-8 **A:** Cryoballoon ablation. **B:** Catheter tip RF ablation. Shown on panel **(A)** is localization mapping of an RVOT VT by mapping a single PVC with the same morphology of the VT and on panel **(B)** the cluster of ablation points.

GETA has been the standard modality for providing comfort and safety for patients. In

addition to the length of the procedure, there is a higher risk for cardiac and vascular perforation compared to a simple ablation procedure. The significant ablation volume is associated with an increased chance of left atrial perforation. A misdirected transseptal catheterization in itself can cause perforation of the aorta, posterior wall of the left atrium, and other structures. An emergency thoracotomy may be necessary. In addition to safety, GETA provides a stationary patient, which is critical in the acquisition and maintenance of three-dimensional map accuracy. Transesophageal temperature monitoring has become a standard of care and would be poorly tolerated in unanesthetized patients.

When feasible, AF ablation procedures should be performed in a hybrid procedure room such that, if needed, emergency thoracotomy can be performed with minimal delay. Under expert operators, the need for emergency thoracotomy is low (under 1–2%), and hence, surgical "standby" is not usually necessary, but this precautionary step is advisable for centers with low patient volumes.

Suggested Readings

1. Briceno DF, Madan N, Villablanca PA, et al: Periprocedural anticoagulation for catheter ablation of atrial fibrillation: practical implications for perioperative management. J Cardiothorac Vasc Anesth 2017; 31(4):1519–26.
2. Chen S, Schmidt B, Bordignon S, et al: Atrial fibrillation ablation using cryoballoon technology: recent advances and practical techniques. J Cardiovasc Electrophysiol 2018; 29(6):932–43.
3. Kuck KH, Brugada J, Fürnkranz A, et al: Cryoballoon or radiofrequency ablation for paroxysmal atrial fibrillation. N Engl J Med 2016; 374:2235–45.

CATHETER ABLATION OF VENTRICULAR TACHYCARDIA

PROCEDURAL CONSIDERATIONS

Description

The pathophysiology of VT is diverse. Catheter ablation of VT encompasses a wide spectrum of procedural complexity, and planning must incorporate the patient's underlying cardiovascular status. The most "benign" forms of VT have a focal origin, most commonly in the right ventricular outflow tract (RVOT). The mechanism is usually automatic or triggered activity and hence tends to be self-terminating. Other sites with a similar mechanism are in the LV (e.g., LVOT) and the left fascicles. These patients

typically have preserved LV systolic function. The most "malignant" forms of VT are associated with underlying structural myocardial damage (e.g., prior MI) and nonischemic ("idiopathic") cardiomyopathy. A less common form of cardiomyopathy is arrhythmogenic right ventricular dysplasia/cardiomyopathy (ARVD/C). VT mechanism is reentry, and therefore, it tends to be sustained and results in hemodynamic instability. Other (less common) VTs are those from sarcoidosis and Chagas disease. In patients with congenital disorders, VT can be found in many scenarios, such as noncompaction cardiomyopathy and postop tetralogy of Fallot (ToF).

Unlike the approach to ablation for AF (which is largely anatomical), ablation for VT is similar to that of catheter ablation for SVT. Induction of "clinical" VT is necessary to confirm the site that is critical to the initiation and/or maintenance of the tachycardia. The incorporation of 3D mapping has been a very useful advancement in this quest, but nonetheless, VT typically needs to be induced multiple times during the procedure. This is usually of minimal hemodynamic consequence in the case of the more benign VTs, but in patients with compromised systolic function, induction of sustained VT causes significant hemodynamic sequelae; hence, inotropic support is frequently necessary, such as iv phenylephrine or occasionally a transvenous LVAD device. Repeated cardioversions are frequently involved when overdrive pacing fails, which may cause more systolic dysfunction. While these patients typically already have an implanted ICD, external cardioversion is preferred for better timing. VT induction is again repeated after the ablation has been completed.

Once mapping of the critical focus has been completed, ablation is carried out. The majority of ablation is done via an endocardial approach with/without transseptal access. Some VTs (Chagas and 40% of nonischemic cardiomyopathy) have a critical site on the epicardial surface and therefore require pericardial entry (typically using a subxiphoid approach). For VTs with localized origin (RVOT, LVOT, FT), a small clusters of ablations will usually suffice (Fig. 13.1-9), keeping in mind that some outflow tract origins are located at one of the aortic valve cusps. For these procedures, MAC anesthesia would suffice and also is frequently preferred to allow for "lightening up the sedation," which is frequently necessary to promote induction of these types of VT. For re-entry VT caused by ischemic and nonischemic cardiomyopathy, the critical area is usually an "isthmus" of surviving myocardium in between scars (Fig. 13.1-10). In many cases, a very broad area of "diseased" myocardium (marked by a large area of low voltage) is the cause of VT, especially polymorphic VT; thus, a broad area of ventricular myocardium will be ablated (known as homogenization technique, Fig. 13.1-11). Procedural duration varies significantly, and it is not unusual to encounter long procedure times. Clearly, GETA would be required. Postop care for these patients can

also be challenging as prolonged hemodynamic compromise as well as residual VT episodes can require delayed extubation.

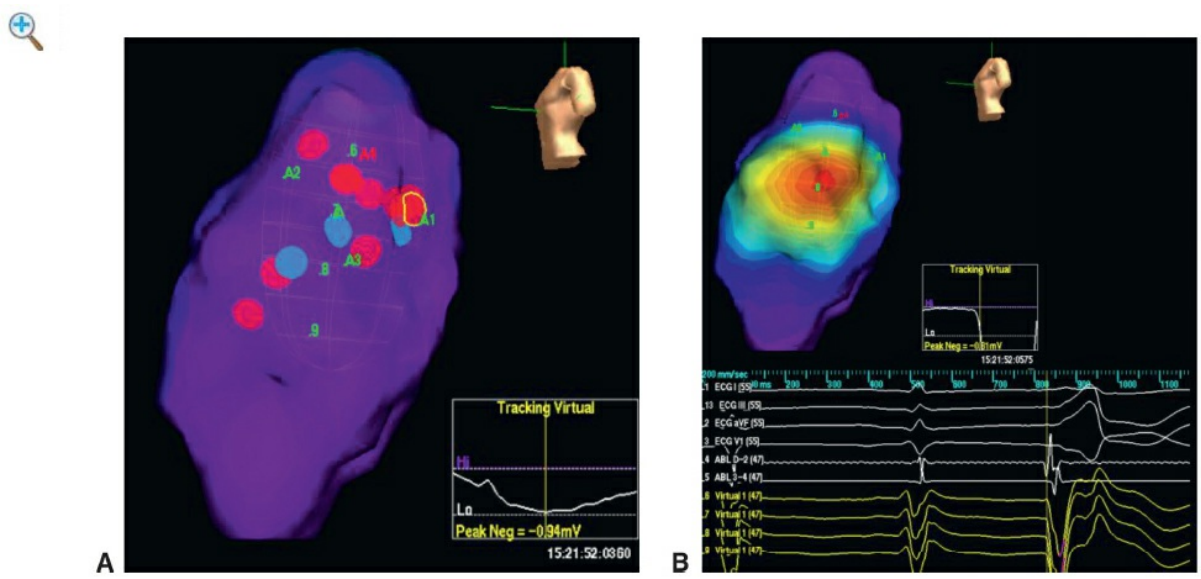

Figure 13.1-9 Shown on panel **(A)** is localization mapping of an RVOT VT by mapping a single PVC with the same morphology of the VT and on panel **(B)** the cluster of ablation points.

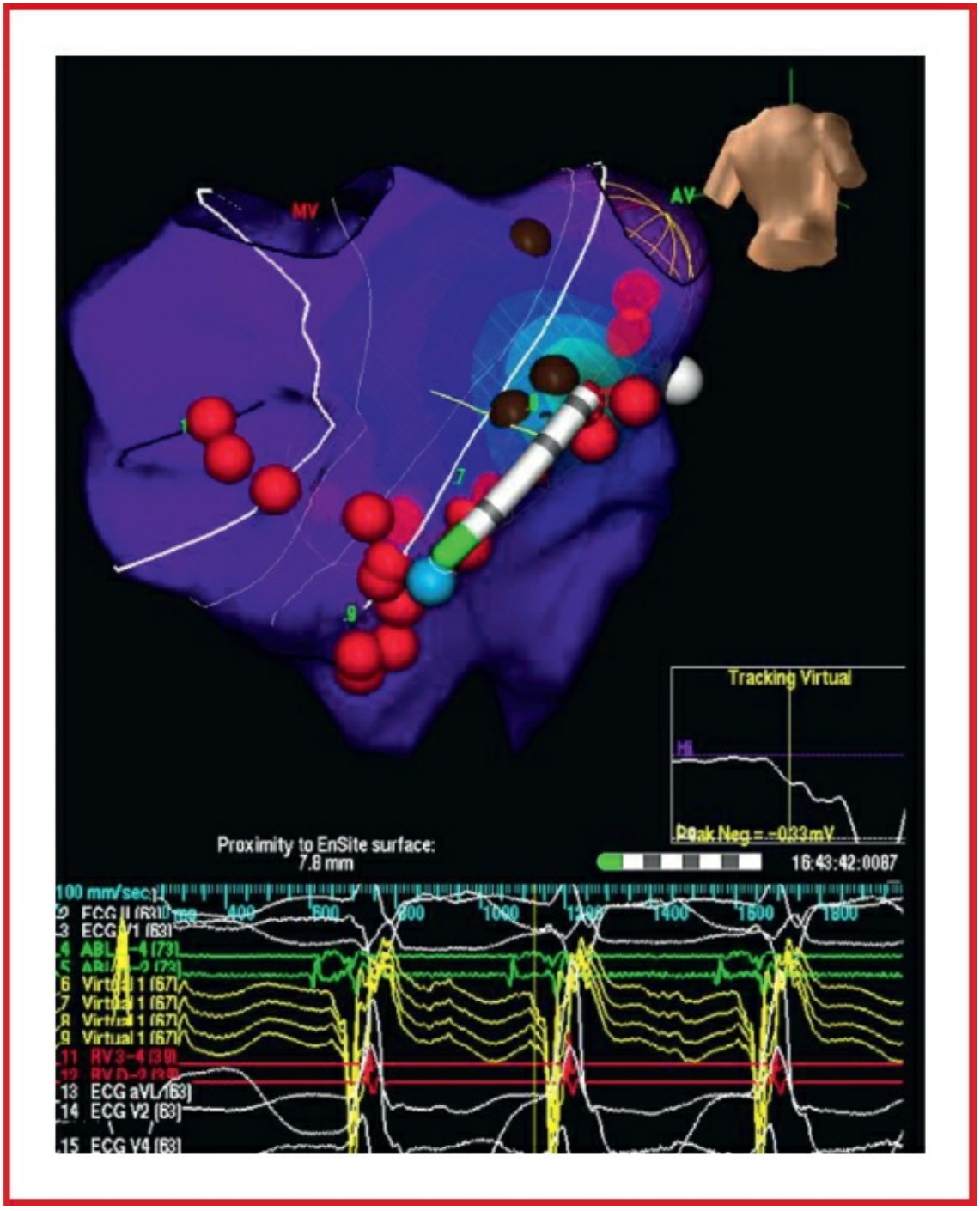

Figure 13.1-10 In the top panel, an "isthmus" ablation was performed based on sites of early activation. In the electrogram (EGM) series (lower panel), the ablation catheter recorded (ingreen) an early sharp depolarization preceding the onset of virtual unipolar signals collected by the multipolar noncontact recording catheter (in yellow).

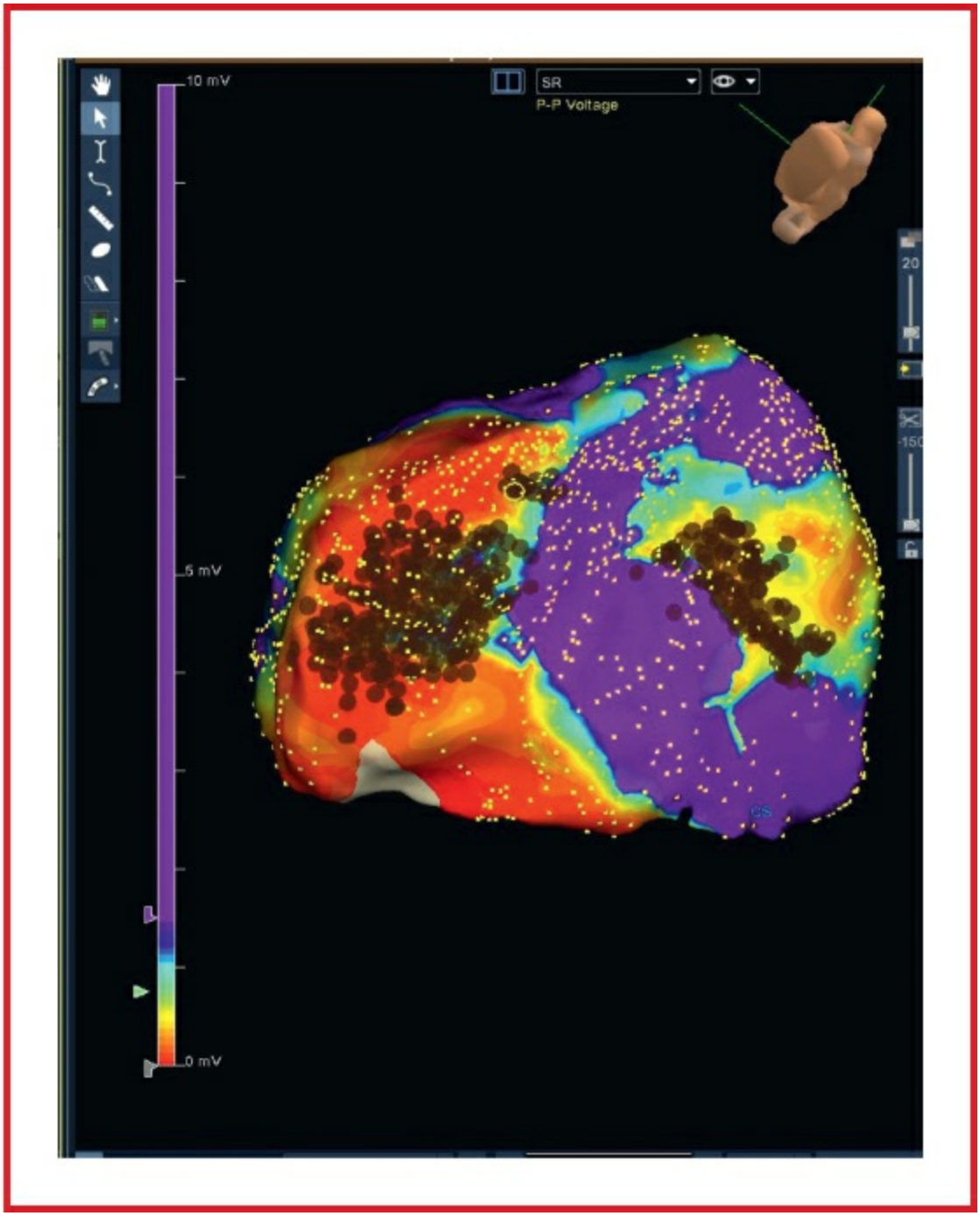

Figure 13.1-11 Shown here is a broad epicardial ablation (brown dots) of areas with low voltage (denoted by colors that are below the set threshold as marked by the arrow on the voltage scale); an example of "homogenization" ablation. The yellow points marked voltage recording points.

Suggested Readings

1. Al-Khatib SM, Stevenson WG, Ackerman MJ, et al: 2017 AHA/ACC/HRS Guideli for management of patients with ventricular arrhythmia and the prevention of sudden cardiac death. Heart Rhythm 2018; 15(10):e73–189.
2. Della Bella P, Brugada J, Zeppenfeld K, et al: Epicardial ablation for ventricula tachycardia. A European multicenter study. Circ Arrhythm Electrophysiol 2011;

4:653–9.
3. Josephson ME, Anter E: Substrate mapping for ventricular tachycardia. Assumptions and misconceptions. J Am Coll Cardiol Clin Electrophysiol 2015; 1:341–52.

ANESTHETIC CONSIDERATIONS FOR ICD, CRT-D, AND PACEMAKER PLACEMENT; LEAD EXTRACTION; CATHETER ABLATION

PREOPERATIVE

Patients presenting for **ICD/CRT-D placement** may be divided into three populations, based on symptomatology, associated pathology, and probable outcome: (a) **Supraventricular dysrhythmias** (e.g., Wolff-Parkinson-White [WPW] syndrome) usually young and otherwise healthy patients. May be associated with Ebstein anomaly (tricuspid valve defect → RV failure), mitral valve disease, or CAD. Low perioperative mortality (1%). (b) **Ventricular dysrhythmias:** usually older patients with significant ventricular dysfunction (EF = 10–35%) and other pathologies, such as CAD or cardiac failure. These patients have either survived an episode of VT/VF or are otherwise at risk for sudden death. (c) **Congestive heart failure (CHF)** without significant dysrhythmias, usually 2° dilated cardiomyopathy. These patients have very low EFs (10–25%), LBBB, and Hx of failed conventional CHF treatment. The CRT-D device is implanted in these patients to provide paced "resynchronization" of the contractions of the LV and RV. This requires a third pacer lead placed into the coronary sinus to pace the LV independent of the RV (see Fig. 13.1-12B). In this case, the device is not placed primarily for its defibrillator function, but for its ability to pace both ventricles synchronously (biventricular pacing). Patients presenting for **permanent pacemaker insertion** may have a variety of dysrhythmias, including SSS, heart blocks (2nd and 3rd degree), and tachycardias refractory to medication. CRT patients may be quite frail with significant comorbidities.

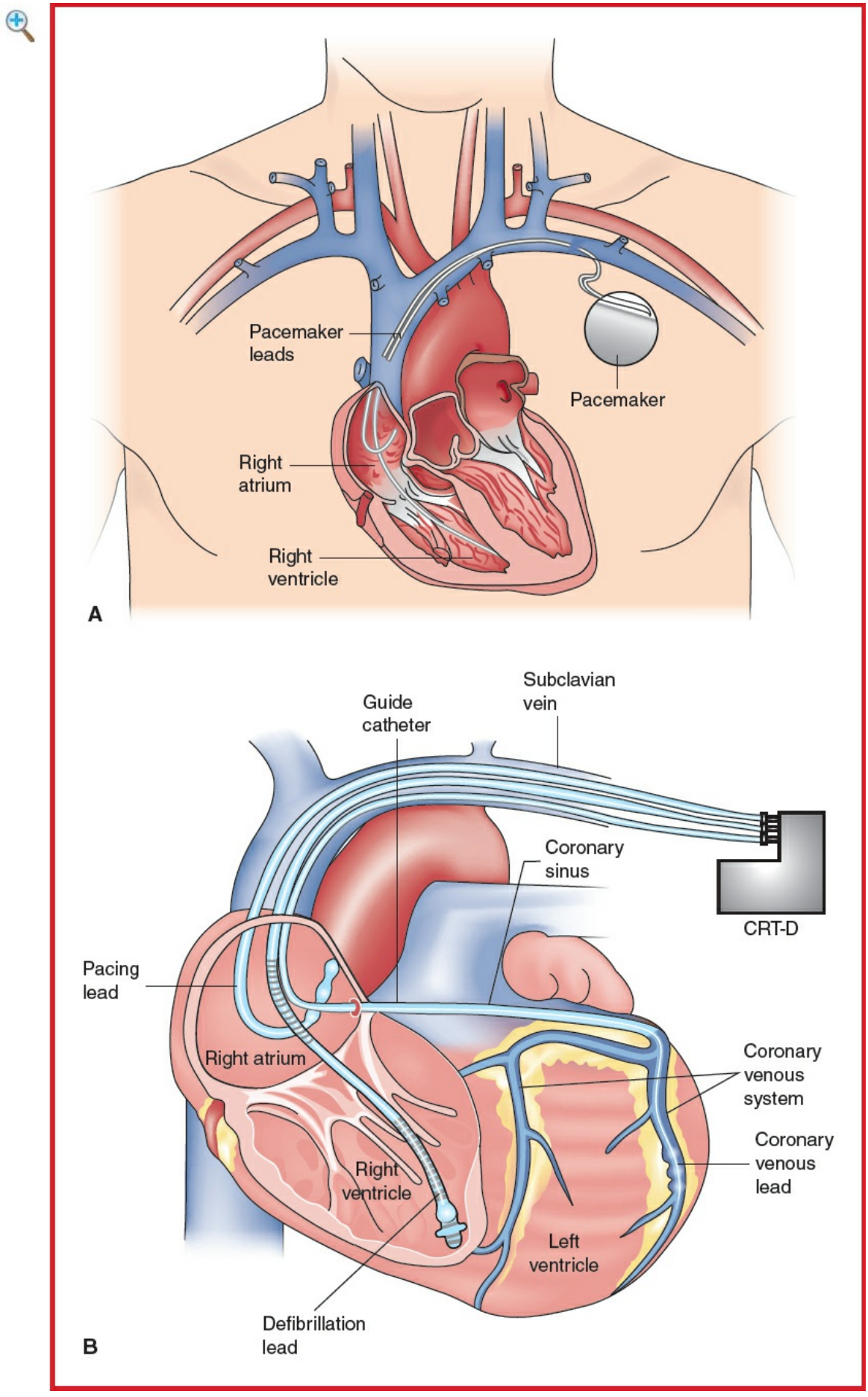
Pacemaker leads
Pacemaker
Right atrium
Right ventricle
A
Subclavian vein
Guide catheter
Coronary sinus
CRT-D
Pacing lead
Right atrium
Coronary venous system
Coronary venous lead
Right ventricle
Left ventricle
Defibrillation lead
B

Figure 13.1-12 Placement of cardiac leads.

Patients presenting for **lead extraction** typically have infected leads (often methicillin-resistant Staphylococcus) or, less commonly, malfunctioning leads.

Patients presenting for **catheter ablation** usually have paroxysmal or chronic refractory AF or episodic polymorphic VT or VF related to structural heart disease. They may be at significant risk for death (VT/VF) or thromboembolic events including stroke (AF) AF patients may be receiving a variety of medications, including beta-blockers (e.g., carvedilol), calcium channel blockers (e.g., diltiazem) (less often digitalis or amiodarone), aspirin, clopidogrel, warfarin, direct thrombin inhibitors (e.g., dabigatran), or direct Factor Xa inhibitors (e.g., rivaroxaban, apixaban). VT/VF patients will often have a repeatedly activated ICD in place and be receiving amiodarone or sotalol.

Respiratory	May have associated pulmonary disease 2° smoking **Tests:** CXR; consider PFT, as indicated from H&P
Cardiovascular	**ICD:** ICD patients are left on full medication because it usually is impossible to wean them from antidysrhythmic medications before surgery. In most studies, patients have a mean LV EF of 35% and a New York Heart Association functional class of II or III. **Supraventricular dysrhythmias:** Look for precipitating factors in the dysrhythmia and any methods that have been used to terminate the dysrhythmia. Usually, drug therapy is terminated before surgery to make a dysrhythmia inducible. Note type of drugs used to terminate a dysrhythmia. **Ventricular dysrhythmias:** Ask about any methods that have been used to terminate dysrhythmia. Look for associated conditions, including CAD, CHF, cardiomyopathy, LV aneurysm, HTN, mitral insufficiency, and diabetes. Generally, these patients have poor LV function with ↑ sensitivity to myocardial depressants. It is important to note that they may be on combinations of antidysrhythmics. Many of these drugs have

significant negative inotropic effects. Of special note is amiodarone, which has been associated with intractable bradydysrhythmias, refractory vasodilation, and difficulty in weaning from CPB.

Pacemaker: The anesthesiologist should be aware that there is an NASPE code (North American Society of Pacing and Electrophysiology) that describes pacemaker function with a three- to five-letter code (see table below).

Position I Pacing Chamber(s)	Position II Sensing Chamber(s)	Position III Response(s) to Sensing	Position IV Programmability	Position V Multisite Pacing
O = None	O = None	O = None	O = None	O = None
A = Atrium	A = Atrium	I = Inhibited	R = Rate Modulation	A = Atrium
V = Ventricle	V = Ventricle	T = Triggered		V = Ventricle
D = Dual (A + V)	D = Dual (A + V)	D = Dual (T + I)		D = Dual (A + V)

For example, a VVI notation indicates that the ventricle is paced and sensed and there is inhibition by native beats.

Catheter ablation: Most commonly, presenting patients have medically refractory or paroxysmal atrial fibrillation or VT/VF and are at increased risk for thromboembolic events or sudden death. Preop antidysrhythmic and anticoagulant medications should be managed in consultation with the prescribing physician and the interventional cardiologist.

Infected leads: Patients with infected leads may have endocarditis, tricuspid valve dysfunction, and sepsis.

Tests: ECG: ✓ dysrhythmia, ischemia, electrophysiologic report. Echo: ✓ ventricular function, wall motion abnormalities, valvular problems. Cardiac angiography: ✓ ventricular function, CAD, valvular disease, LV aneurysm. ICD: identify and interrogate device.

Renal	Patients with poor ventricular function may have associated renal compromise. Electrolyte abnormalities (K^+, Mg^{++}) may be associated with ↑ cardiac irritability and should be corrected preop. **Tests:** BUN; Cr; electrolytes
Hematologic	Hb/Hct; coag tests (PT, PTT, Plt)
Laboratory	Other tests as indicated from H&P
Premedication	For adults: midazolam 0.5–2.0 mg iv, with careful observation and supplemental O_2.

INTRAOPERATIVE

Anesthetic technique

Local anesthesia with sedation, GA with LMA, or GETA, as indicated. Cathete ablation and placement of most ICDs, CRT-Ds, and PMs are done in the cardiac catheterization suite. ICDs are very small and are implanted in the same position as a PM. If patients are orthopneic due to their CHF, or if the procedure is projected to be long, GA is often preferable. Also, elderly patients may become disoriented with sedation and, thus, may require urgent GA. Lead extraction is often done under GETA.

Induction	Exact type of induction depends on the patient's medical condition. Sedation can be provided with small doses of midazolam (1–2 mg) ± fentanyl (25–50 mcg) titrated to effect. An alternative technique is to use a propofol infusion (e.g., 25–75 mcg/kg/min). Because local anesthesia is provided by the surgeon, the procedure usually is not painful and does not require postop pain control. It is important to avoid oversedating these patients because they will tend to become disoriented and uncooperative. Even if local anesthesia with sedation is provided for the placement of leads and the device, a brief period of GA is usually required for device testing. This can be provided easily with mask ventilation and induction with propofol (e.g., 1 mg/kg iv) or etomidate (e.g., 0.1 mg/kg iv), similar to anesthesia for cardioversion procedures. For those patients requiring GA for the entire procedure, induction with propofol (1–2 mg/kg) or etomidate (0.1–0.3 mg/kg) is often used.

	Muscle relaxants are not required unless intubation is planned. Narcotics usually are not required because local anesthesia is used.	
Maintenance	As previously discussed, verification of correct lead placement usually involves the induction of VF or VT and the testing of the device's capability to restore NSR. External defibrillation should be available at all times, as should antidysrhythmics (e.g., lidocaine and amiodarone). While the device is tested, the patient should be breathing 100% O_2. Multiple testing cycles can result in depressed LV function, and inotropes may be needed.	
Emergence	These patients are extubated (if GETA used). Recovery is in a PACU. If, however, multiple test shocks are needed or the heart displays evidence of injury (need for inotropes, ST-segment abnormalities), then extubation may need to be deferred to ICU.	
Blood and fluid requirements	IV: 16–18 ga × 1 BSS @ 2–3 mL/kg/h	Care should be taken to minimize iv fluids in CHF patients.
Monitoring	Standard monitors ± Arterial line ± CVP/TEE	A CVP catheter or TEE may be used depending on LV function. ICD patients generally require only an arterial line.
	External defibrillation	Because antidysrhythmics may affect the testing procedure, they should be avoided when possible. Defibrillation or cardioversion is treatment of choice.
	Temperature	Normothermia should be maintained.
Positioning	Supine	

	✓ and pad pressure points ✓ eyes	
Complications	Pneumohemothorax Pericardial effusion/tamponade HTN/CHF Coronary sinus rupture/central vein laceration	Rarely, cardiac rupture or central vein laceration may occur during lead extraction. Significant blood loss may occur. Coronary sinus rupture has been reported during biventricular lead placement and may require open repair.

POSTOPERATIVE

Complications	Recurrent dysrhythmias Hemorrhage Myocardial ischemia	Pacemaker lead thrombosis → PE has been reported.
Pain management	Usually managed with oral analgesics	
Tests	CXR	✓ line/lead placement, r/o pneumohemothorax.
	ECG	✓ for ischemia, dysrhythmias.
	Electrophysiologic testing	
	Electrolytes	

Suggested Readings

1. Dukkipati SR, et al: Catheter ablation of ventricular tachycardia: indications strategies, and outcomes—Part I and II. J Am Coll Cardiol 2017; 70(23):2909–41.
2. Lee G, Sanders P, Kalman JM: Catheter ablation of atrial arrhythmias: state of the art. Lancet 2012; 380(9852):1509–19.
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4. Sonny A, Wakefield BJ, Sale S, et al: Transvenous lead extraction: a clinical commentary for anesthesiologists. J Cardiothorac Vasc Anesth 2018; 32(3):1101–11.
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TRANSJUGULAR INTRAHEPATIC PORTOSYSTEMIC SHUNT (TIPS)

PROCEDURAL CONSIDERATIONS

Description

Hepatic cirrhosis is a progressive disease that eventually results in portal HTN and the development of varices at a variety of sites. Bleeding from esophageal varices is a serious complication of portal HTN, occurring in 25% of patients within 1 yr of diagnosis (~50% mortality). Prior to 1989, surgically placed shunts were used to direct high-pressure portal blood into the systemic venous circulation in patients with recurrent bleeding after endoscopic sclerotherapy or banding. The **transjugular intrahepatic portosystemic shunt (TIPS)** procedure has almost completely replaced surgical shunts.

TIPS is a percutaneous shunt between the portal and systemic circulations. The shunt is created between the hepatic vein and portal vein within the liver parenchyma, maintained by placement of a stent graft. This creates a low-resistance conduit to decompress the portal circulation, thereby decreasing variceal blood flow and ascites formation. Although it can be performed with conscious sedation, balloon dilation of the tract is extremely painful, typically requiring GA.

TIPS was developed initially by Rosch in dog studies in 1969. Palmaz and Richter performed the first successful TIPS in humans in 1989, using metallic stents to maintain the patency of the tract. Since then, TIPS has become the procedure of choice for patients who fail sclerotherapy and banding. In addition, it addresses another common problem associated with cirrhosis: refractory ascites.

Through the right IJ, a 10-Fr sheath is placed in the upper IVC. A catheter/guide wire combination is used to select the right hepatic vein. A wedged hepatic venogram using CO_2 is performed. Injection of iodinated contrast can result in rupture of the liver

capsule and exsanguination. The wedged venogram refluxes contrast through the sinusoids and into the portal vein, thereby providing a map. The catheter is exchanged over a stiff wire for a metallic introducer/needle. A variety of needle kits are available. All include a long introducer sheath and coaxially inserted curved-tip needle or metal cannula, with directional indicator, to help steer the needle toward the right portal vein.

Portal venous pressures are measured, and the pressure gradient between the portal vein and right atrium is determined. Following a portal venogram, the catheter is exchanged for an angioplasty balloon and the tract dilated (Fig. 13.1-13C). The use of covered stents for TIPS creation led to significantly improved patency rates, and for this reason, the Viatorr® (Gore, Flagstaff, AZ) self-expanding covered stent has largely replaced the bare metal stents. The Viatorr is positioned across the tract, and the uncovered portion is first deployed within the portal venous system (Fig. 13.1-13D). The covered portion is then pulled into the tract and deployed in a separate step. The stent may be dilated to a diameter of 8–10 mm using an angioplasty balloon, depending on the stent diameter and desired portosystemic gradient. If necessary, a second stent is deployed to cover any remaining unstented portions of the hepatic tract. Following TIPS placement, portal venogram and pressure gradients are remeasured. Ideally, the pressure gradient following shunting should be between 6 and 12 mm Hg. If the gradient is too high, there is a risk of rebleeding; if too low, there is overshunting of blood, thus bypassing the entire portal venous system and increasing the risk of encephalopathy and liver failure. After successful creation of the shunt, all devices, including the right jugular sheath, are removed, and hemostasis is achieved. Patients are closely monitored in an ICU or step-down unit for 24–48 h.

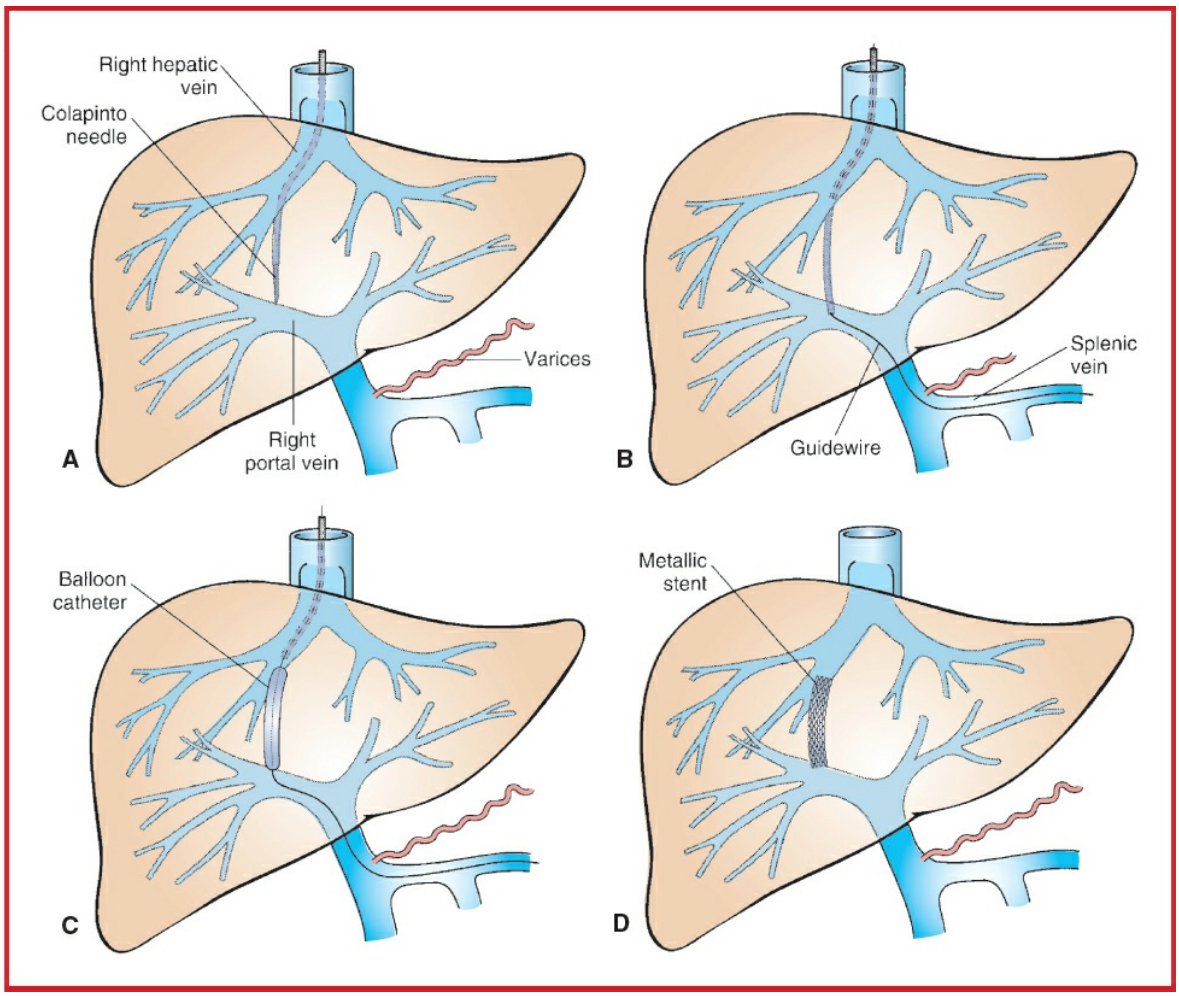

Figure 13.1-13 TIPS placement.**A:** Sheathed Colapinto needle is advanced out of hepatic vein into portal vein branch. Varices are present. **B:** Guide wire is advanced through the needle sheath into splenic vein. **C:** Parenchymal liver tract is dilated using a balloon angioplasty catheter. **D:** The metallic stent is deployed within the shunt tract. (Redrawn from Haskal ZJ, Ring FCurrent Techniques in Interventional Radiology. Current Science, Philadelphia: 1994. Reprinted with permission from Ziv J Haskal, MD.)

Direct IVC-to-portal shunt (DIPS) is a newer alternative to TIPS. Simultaneous venou access is required from both the internal jugular vein and common femoral vein. For DIPS, an intravascular ultrasound (US) probe is used to guide needle puncture from the IVC, through the caudate lobe, and into the main portal vein. Because the tract traverses extrahepatic regions, placement of a covered stent is mandatory. A theoretically fewer number of passes is needed to access the portal vein because the puncture is US guided; however, there is likely a greater risk of intraperitoneal hemorrhage with each puncture attempt.

If TIPS/DIPS is performed for the treatment of bleeding varices, it may be necessary t embolize and sclerose the varices if they persistently fill following shunt creation. This may be accomplished using sclerosing agents (e.g., ethanolamine) with an occlusion

balloon and embolic agents (e.g., metallic coils, Gelfoam™), depending on operator preference.

Usual preop diagnosis

Bleeding esophageal varices (as a result of portal HTN); ascites; Budd-Chiari and hepatorenal syndromes

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Right IJ access
Special instrumentation	Rosch-Uchida, Colapinto, or Hawkins needle set; angioplasty balloons; endovascular stent grafts, marker pigtail, CO_2 injection apparatus, intravascular ultrasound (IVUS) for DIPS, embolic agents (e.g., coils, Gelfoam, ethanolamine) for variceal embolization/sclerosis if necessary
Unique considerations	May need FFP
Antibiotics	Cefazolin 2 g iv
Procedure time	2–6 h
EBL	0–3000 mL
Postop care	ICU or step-down unit; careful fluid management
Mortality	Emergency: 50–100% Postprocedure: See Tables 13.1-2–13.1-5
Morbidity	Encephalopathy: 18–30% Late liver failure: 10–25% Shunt occlusion: 10%/yr Liver capsule puncture → intraperitoneal hemorrhage (continue procedure to decompress portal venous system → ↓ bleeding) Hepatic artery puncture: may require embolization Allergic reactions MI (related to ↑ CVP) Renal failure (usually transient)

Pain score	7–8 (first few hours only)

Table 13.1-2 MELD Score Calculation

The Model for End-Stage Liver Disease (MELD) score is calculated using three objective indicators—serum bilirubin, serum creatinine level (Cr), and international normalized ratio (INR)—according to the United Network for Organ Sharing modification of the original formula:

$$MELD = 9.6 \times \log e\,(cr) + 3.8 \times \log e\,(Bilirubin) + 11.2 \times \log e(INR) + 6.4$$

The MELD score can easily be calculated by accessing the following website: http://www.mayoclinic.org/meld/mayomodel7.html

Table 13.1-3 Overall Mortality Based on MELD Score

MELD Score	No. of Patients	Mortality Rate (%)		
		30 d	3 mo	6 mo
≤10%	28	0 (0, 0)	0 (0, 0)	0 (0, 0)
11–17	83	7.3 (1.7, 12.9)	16.0 (8.0, 24.0)	24.9 (15.1, 34.7)
18–24	40	17.9 (5.9, 29.9)	34.8 (19.4, 50.2)	38.6 (22.4, 54.9)
≥25	15	42.6 (16.7, 68.4)	65.5 (39.9, 91.2)	74.2 (50.0, 98.3)

Patients undergoing elective TIPS creation with a MELD score of 18 or more had a significantly lower 3-mo survival rate than those with a MELD score of 17 or less. Numbers in parentheses are 95% confidence intervals.

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Table 13.1-4 Mortality Based on MELD Score and Cause of Cirrhosis

MELD Score	Group	No. of Patients	Mortality Rate (%)		
			30 d	3 mo	6 mo
≤17	A	39	5.1 (0, 12.1)	7.7 (0, 16.1)	13.9 (2.5, 25.2)
	B	72	5.6 (0.3, 11.0)	14.4 (6.1, 22.7)	21.4 (11.3, 31.4)
≥18	A	14	42.9 (16.9, 68.8)	57.1 (31.2, 83.1)	57.1 (31.2, 83.1)
	B	41	17.9 (5.9, 29.9)	37.9 (22.0, 53.7)	45.9 (28.1, 63.2)

A, alcohol-induced disease; B, non–alcohol-induced disease.

Patients undergoing elective TIPS creation with a MELD score of 18 or more had a significantly lower 3-mo survival rate than those with a MELD score of 17 or less. Numbers in parentheses are 95% confidence intervals.

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Table 13.1-5 Mortality Based on MELD Score and Ascites

MELD Score	Ascites	No. of Patients	Mortality Rate (%)		
			30 d	3 mo	6 mo
≤17	No	48	4.2 (0, 9.8)	4.2 (0, 9.8)	4.2 (0, 9.8)
	Yes	63	6.4 (0.3, 12.5)	18.4 (8.6, 28.3)	31.3 (18.6, 43.9)
≥18	No	18	22.2 (3.0, 41.4)	39.8 (16.8, 62.8)	46.5 (22.6, 70.4)
	Yes	37	25.4 (11.0, 39.8)	44.4 (27.4, 61.4)	48.7 (31.1, 66.3)

Patients undergoing elective TIPS creation with a MELD score of 18 or more had a significantly lower 3-mo survival rate than those with a MELD score of 17 or less. Numbers in parentheses are 95% confidence intervals.
Reprinted with permission from Ferral H, Gamboa P, Postoak DW, et al: Survival after elective transjugular intrahepatic portosystemic shunt creation: prediction with Model for End-Stage Liver Disease Score. *Radiology* 2004;231(1):231 -6. Copyright © 2004 Radiological Society of North America.

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients presenting for TIPS procedures have portal HTN usually 2° end-stage live disease (ESLD), which will affect the function of a variety of organ systems, as described below.

Respiratory	Abdominal distension → atelectasis → ↑ pulmonary shunting → hypoxemia (hepatopulmonary syndrome in ESLD) Encephalopathy → hyperventilation → ↓ $PaCO_2$ (respiratory alkalosis with chronic acidosis as compensation). Pulmonary effusion may be present in 5–10% of patients. **Tests:** ✓ CXR (for Sx of atelectasis); ABG and PFT, if indicated
Cardiovascular	Cardiomyopathy (ETOH) and CAD (tobacco) occur at higher incidence in this patient population. Diuretic therapy → hypovolemia + ↓ K^+ (furosemide) or ↑ K^+ (spironolactone). Hyperdynamic circulation 2° to ↓ peripheral resistance and ↓ cardiac reserve are common findings and correlate with poor postop outcome. **Tests:** ECG; electrolytes; cardiac echo, if indicated from H&P

Neurologic	Symptoms of hepatic encephalopathy range from mild confusion to coma. These patients may be very sensitive to narcotics and sedatives. A characteristic finding in liver failure is asterixis (liver flap). Hyponatremia and hypoglycemia may mimic hepatic encephalopathy. **Tests:** As indicated from H&P
Hepatic	Drug metabolism may be markedly reduced; anticipate prolonged effect with sedative and narcotic drugs. Drugs with particularly prolonged action include midazolam, meperidine, ranitidine, and lidocaine. Apparent resistance to all muscle relaxants is most likely due to an increased volume of distribution. Succinylcholine effects may be prolonged in patients with severe ESLD (2° ↓ plasma cholinesterase). **Tests:** Bilirubin; PT; albumin; LFTs
Gastrointestinal	Ascites → ↑ intra-abdominal pressure → ↑ risk of aspiration. Full-stomach precautions and rapid-sequence induction are recommended. Portal HTN → variceal bleeding. If possible, avoid esophageal instrumentation (e.g., TEE, esophageal stethoscope). Gastritis and peptic ulceration may be present.
Renal	Oliguric renal failure may complicate ESLD (hepatorenal syndrome). This may be reversible if liver failure improves. Differential Dx includes prerenal azotemia and acute tubular necrosis. **NB:** Bilirubin metabolites interfere with creatinine measurement and may mask ↑ creatinine levels. **Tests:** BUN; Cr; electrolytes
Endocrine	Hypoglycemia may be present in cases of severe cirrhosis. ESLD patients may have ↓ response to catecholamines. **Tests:** Glucose
Hematologic	Patients may be anemic 2° GI bleeding. The majority of patients will exhibit coagulopathy 2° ↓ hepatic

	synthetic function (all factors except VIII and fibrinogen) and ↓ Plt. Patients may require vitamin K (if coagulopathy is present and time permits), FFP (if PT > 2 sec above baseline), or Plt transfusion (if Plt < 100 K) before procedure; these products should be readily available.
Premedication	**Tests:** CBC; Plt; PT; others as indicated from H&P Patients with significant ascites will require full-stomach precautions. **NB:** Benzodiazepines should be used with caution in liver failure patients.

INTRAOPERATIVE

Anesthetic technique

In some patients (and at some centers), sedation with local anesthesia may be satisfactory; however, balloon dilation of the intrahepatic tract can be exceedingly painful. Remember, these patients may be very sensitive to narcotics → respiratory arrest. GETA is often necessary to provide adequate analgesia and airway protection. The patient will be positioned so that the interventional radiologists can approach both the internal jugular and femoral veins, thus limiting the anesthesiologist's access to the head and airway.

General anesthesia

Induction	Rapid-sequence induction is necessary in patients with encephalopathy, abdominal distention, and recent variceal bleeds (blood in the stomach).	
Maintenance	Standard maintenance. If muscle relaxation is to be maintained, low-dose vecuronium (1–1.5 mcg/kg/min), cisatracurium (3 mcg/kg/min infusion), or rocuronium (5–15 mcg/kg/min) may be used to maintain muscle relaxation.	
Emergence	Extubate when the patient is awake and protective laryngeal reflexes are present. Patient should be transferred to PACU accompanied by anesthesiologist.	
Blood and fluid requirements	Potential for large blood loss	Glucose-containing solutions may be required for patients

	IV: 14–16 ga × 1–2 FFP available Plt available 2–4 U PRBC available NS/BSS (as appropriate)	with hepatic failure ± CHF. ✓ blood glucose levels frequently. Vasopressor response may be impaired.
Monitoring	Standard monitors	Ventricular arrhythmias can be provoked by hepatic vein catheterization.
Positioning	✓ and pad pressure points ✓ eyes	Radiology tables usually are not well padded → nerve damage.
Complications	Portal vein rupture Liver capsule perforation	Intra-abdominal hemorrhage may be massive and require emergency surgery.
	Complete heart block	Patients with preexisting LBBB may require a pacemaker pre-TIPS (2° risk of RBBB during procedure).
	CHF	Shunt → ↑↑ venous return → CHF

POSTOPERATIVE

Complications	Portal vein thrombus	May mimic symptoms of PE or MI
	↑ encephalopathy	2° ↓ hepatic portal blood flow
	Sepsis	
	Bleeding	May require hemodynamic support (e.g., dopamine)
	Fluid/electrolyte disturbance	Stent insertion → ↑ venous return → ↑ diuresis → electrolyte/fluid imbalance
Pain management	IV opiates	

Suggested Readings

1. Amin AA, Alabsawy EI, Jalan R, et al: Epidemiology, pathophysiology, and management of hepatorenal syndrome. Semin Nephrol 2019; 39(1):17–30.
2. Fidelman N, Kwan SW, LaBerge JM, et al: The transjugular intrahepatic portosystemic shunt: an update. Am J Roentgenol 2012; 199(4):746–55.
3. Landrigan-Ossar M: Common procedures and strategies for anaesthesia in interventional radiology. Curr Opin Anaesthesiol 2015; 28(4):458–63.
4. Riggio O, Nardelli S, Moscucci F, et al: Hepatic encephalopathy after transjugular intrahepatic portosystemic shunt. Clin Liver Dis 2012; 16(1):133–46.
5. Shah RP, Sze DY: Complications during transjugular intrahepatic portosystemic shunt creation. Tech Vasc Interv Radiol 2016; 19(1):61–73.

ENDOSCOPIC RETROGRADE CHOLANGIOPANCREATOGRAPHY

PROCEDURAL CONSIDERATIONS

Description

Endoscopic retrograde cholangiopancreatography (ERCP) was originally used as a diagnostic procedure; however, it is now almost exclusively used for therapeutic purposes. As with many invasive procedures, success (including the absence of complications) is well correlated with operator experience. Basically, ERCP consists of passing an endoscope through the mouth, esophagus, and stomach into the duodenum, where the papilla of Vater is located. A catheter (sometimes preceded by a wire) is inserted through the sphincter of Oddi into the common bile duct or pancreatic duct (see Fig. 13.1-14). At that point, contrast can be injected, tissue sampled, stones extracted, stents placed, or a sphincterotomy accomplished. The endoscopist may request administration of glucagon (0.25–2 mg iv; side effects, n/v, ↓ BP) to decrease duodenal motility and/or secretin (0.2 mcg/kg iv over 1 min; side effects, flushing, n/v) to help locate the minor papilla.

The overall complication rate is 5–10%, being <5% for simple stone extraction to 20% or more for sphincterotomy. Post-ERCP pancreatitis is the most common complication (up to 40%), being more common in young patients with sphincter of Oddi dysfunction and normal bilirubin levels. Placement of a pancreatic stent may reduce the risk of post-ERCP pancreatitis and is commonly used in high-risk patients. Unfortunately, stent placement itself may cause complications, including ductal and parenchymal injury and

ductal stenosis. Balloon dilation as an alternative sphincterotomy has been associated with a higher risk of pancreatitis.

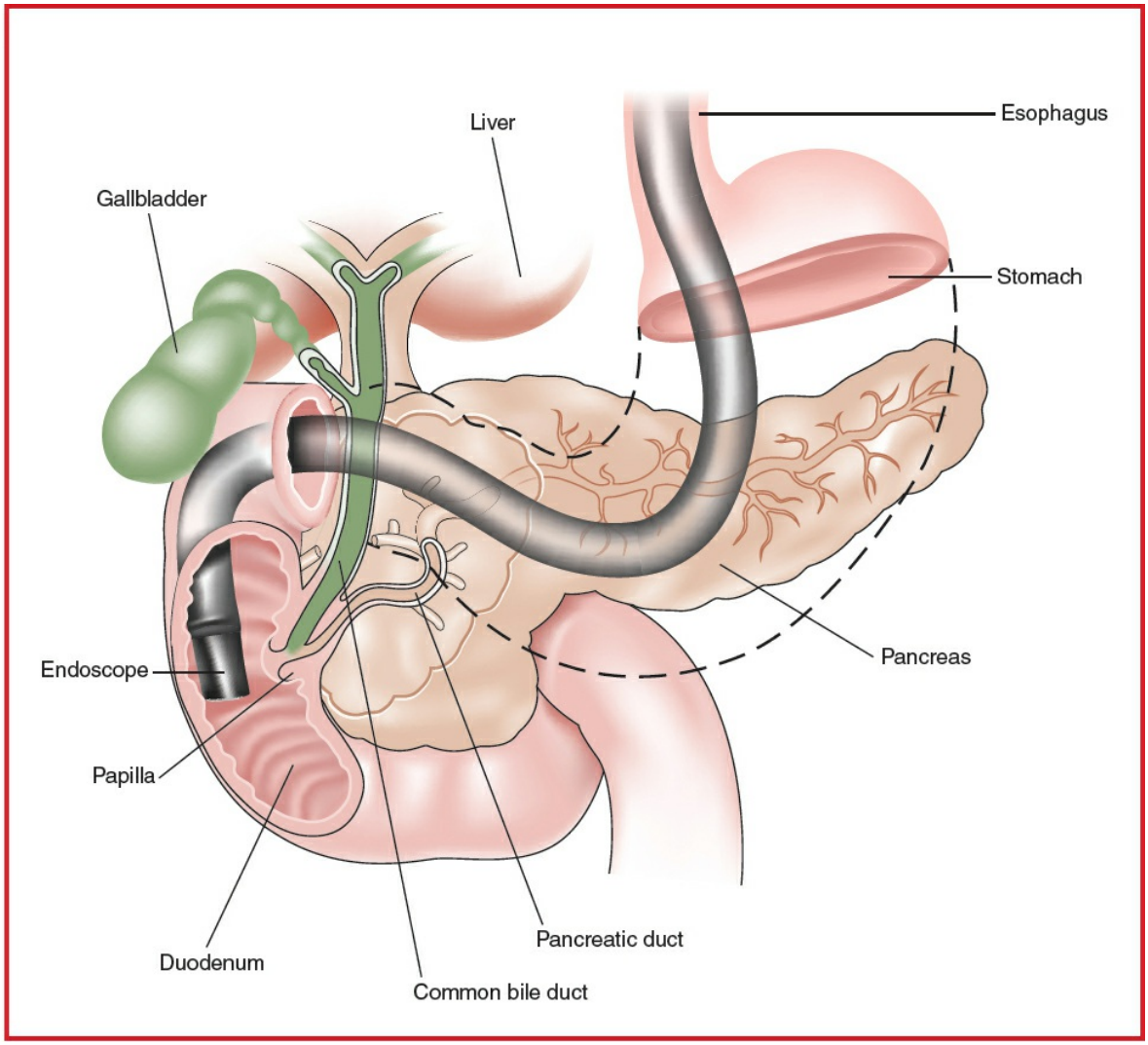

Figure 13.1-14 Anatomy for ERCP.

Usual preop diagnosis

Patients typically present with persistent pain or jaundice as a result of gallstones or other disease processes (e.g., infection, tumor, pancreatitis) that obstruct the bile duct and/or pancreatic duct.

SUMMARY OF PROCEDURE	
Position	Initially left lateral decubitus, rotating to prone
Incision	None
Special	Endoscope (duodenoscope) and supporting equipment;

instrumentation	mouth guard; fluoroscopy
Unique considerations	X-ray protection will be required; glucagon may be requested (0.25–2 mg iv 10 min before procedure; contraindications, pheochromocytoma, insulinoma)
Antibiotics	Ciprofloxacin 500 mg po 30–60 min before procedure is common.
Procedure time	45–90 min
EBL	Usually minimal
Postop care	PACU → home (occasional overnight stay for stone removal or stent placement)
Mortality	Rare
Morbidity	Pancreatitis: typically 5% (1–40% reported) Bowel or duct perforation: <1% Hemorrhage: 0.1–2% Cholangitis/cholecystitis Aspiration Cardiopulmonary (e.g., myocardial ischemia, respiratory arrest)
Pain score	2–4

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Patients presenting for ERCP most commonly have obstruction of hepatic and/or pancreatic ducts. They may be jaundiced with elevation of both conjugated and unconjugated bilirubin or exhibit Sx of pancreatic disease with associated peritoneal and pleural effusions. As a result of underlying disease processes (typically ASA 3–4), they may be quite frail with limited physiologic reserve. Discuss intraprocedure management with the endoscopist.

Respiratory	Airway evaluation should focus on the need for GETA. Access to the airway may be limited during the procedure. Ascites and pleural fluid accumulation → impaired ventilation, ↑ aspiration risk. Gas insufflated during the procedure may further

	compromise ventilation and ↑ aspiration risk. Rales/percussive dullness suggests pulmonary edema/effusion. **Tests:** As indicated from H&P
Cardiovascular	ECG changes are not uncommon during this procedure, and a preop ECG may be helpful. Hypotension is not uncommon. **Tests:** As indicated from H&P
Neurologic	Altered mental status may result from impaired hepatic function.
Hepatic	Hepatic dysfunction → coagulopathy, altered drug metabolism, and other metabolic disturbances. Jaundice is common. **Tests:** As indicated from H&P
Renal	↑ BUN/Cr suggests volume depletion or acute renal failure. In acute pancreatitis, fluid deficit may be severe; volume resuscitate before proceeding. **Tests:** As indicated from H&P
Endocrine	↑ glucose (>180 mg% should be treated preop) **Tests:** As indicated from H&P
Premedication	Morphine may ↑ sphincter of Oddi tone → ↑ductal pressure + ↑ pain. Midazolam 1–2 mg iv may be appropriate in the anxious patient. Consider aspiration prophylaxis (e.g., Bicitra™ 30 cc po; avoid metoclopramide).

INTRAOPERATIVE

Anesthetic technique

Deep sedation using propofol (avoiding respiratory depression or loss of protective airway reflexes) supplemented with topical anesthesia of the oropharynx is sufficient for many ERCP procedures. GETA is associated with a higher procedure success rate and should be considered for complex ERCP procedures, patients at high risk for aspiration, or uncooperative patients.

General anesthesia

Induction	Rapid-sequence induction is necessary in patients with gastroparesis or abdominal distention. Otherwise, standard induction. Consider etomidate (0.1–0.3 mg/kg) for hemodynamically unstable patients.	
Maintenance	Standard maintenance. An immobile patient will be appreciated by the endoscopist. Manipulation of the endoscope may cause ETT movement → mainstem intubation or extubation.	
Emergence	The duodenum and stomach should be decompressed by the endoscopist before extubation. Standard emergence.	
Blood and fluid requirements	IV: 18 ga × 1 BSS @ 3–5 mL/kg/h	Patients with acute pancreatitis may be hypovolemic.
Monitoring	Standard monitors ± Arterial line	✓ glucose in patients receiving glucagon.
Positioning	Left lateral decubitus → prone ✓ and pad pressure points ✓ eyes	
Complications	Pancreatitis Myocardial ischemia Aspiration	Δ ECG may occur in 25% of patients >65 yr.

POSTOPERATIVE

Complications	Myocardial ischemia Hypoxemia Hemorrhage	
Pain Management	Usually managed with oral analgesics	Avoid morphine (↑ sphincter of Oddi tone).

Suggested Readings

1. ASGE Standards of Practice Committee, Anderson MA, Fisher L, et a Complications of ERCP. Gastrointest Endosc. 2012; 75(3):467–73.

2. Correia LM, Bonilha DQ, Gomes GF, et al: Sedation during upper GI endoscopy i cirrhotic outpatients: a randomized, controlled trial comparing propofol and fentanyl with midazolam and fentanyl. Gastrointest Endosc 2011; 73(1):45–51.
3. Freeman ML: Complications of endoscopic retrograde cholangiopancreatography: avoidance and management. Gastrointest Endosc Clin N Am 2012; 22(3):567–86.
4. Garewal D, Vele L, Waikar P: Anaesthetic considerations for endoscopic retrograde cholangio-pancreatography procedures. Curr Opin Anaesthesiol 2013; 26(4):475–80.
5. Sharp CD, Tayler E, Ginsberg GG: Anesthesia for routine and advanced upper gastrointestinal endoscopic procedures. Anesthesiol Clin 2017; 35(4):669–77.

Suggested Viewing

Links are available online to the following videos:

Wire Guided Cannulation Techniques, S. Edmundowicz, MD: https://www.youtube.com/watch?v=L3wqfPCeCIc

Dilation Assisted Stone Extraction (DASE), Dr. Abhitabh Patil, MD:https://www.youtube.com/watch?v=Y1yVsnbosBg

Animation of Dilation Assisted Stone Extraction (DASE):http://endosuite.com/videos/dilation-assisted-stone-extraction-dase-procedural-animation

IMAGING AND IMAGE-GUIDED PROCEDURES

PROCEDURAL CONSIDERATIONS

Description

Projectional imaging includes x-ray fluoroscopy, and cross-sectional imaging includes computed tomography (CT), ultrasound (US), and magnetic resonance imaging (MRI) These techniques have become indispensable in modern diagnosis. In addition, a growing number of invasive procedures are being performed using imaging for guidance, not only for diagnostic purposes but also for therapeutic purposes. Indications include Dx of primary or metastatic tumors; tumor staging; Dx of benign processes, including infections; percutaneous drainage of fluid collections; local-regional treatment of tumors and vascular malformations; endovascular treatment of hemorrhage, vascular malformations, aneurysms, and dissections; percutaneous ablation; catheter-directed thrombolysis and thrombectomy; IVC filter implantation or retrieval; placement of portosystemic shunts; recanalization and angioplasty/stenting of chronically occluded veins; endovascular treatment of varicose veins; dialysis-related interventions; percutaneous placement of feeding tubes; percutaneous treatment of urinary and biliary obstructions; and placement of venous access devices.

Selection of imaging modality depends on ease of identification of the target lesion and resolution of surrounding and intervening structures. Patient compliance is crucial to success because image resolution and spatial accuracy require the patient to be immobile during image acquisition and the procedure itself. In compliant adults, most of these procedures may be done using moderate sedation. For procedures in the pediatric population, as well as for more invasive procedures in adults, GA is frequently necessary.

Diagnostic imaging

Pediatric: In general, moderate sedation is sufficient to ensure pediatric patient compliance for diagnostic CT, US, or MRI, but occasionally, GA is necessary (see Section 13.2).

Adults: Almost all CT, US, and MRI studies are performed without anesthesia. Approximately 5% of adult patients are too claustrophobic to complete an MRI study. Some of these patients may benefit from sedation, but use of GA is rare. Most patients with implanted PM and ICDs can safely undergo MRI if appropriate precautions are observed (see Fig. 13.1-15).

Image-guided procedures

Pediatric: Procedures performed on the pediatric patient routinely require GA (see Section 13.2).

Adults: X-ray fluoroscopy and CT- and US-guided procedures, including biopsies, fluid drainage, and tissue ablation, are routinely performed under moderate sedation. More invasive and painful procedures, such as stent graft repair of aneurysms and dissections, and thermal ablation of unresectable tumors, frequently require GA, spinal, or epidural anesthesia. The required site of access and the positioning of the operators should be considered before the procedure. Position of the ETT and central lines can be immediately confirmed using fluoroscopy. Occasionally, iv injection of iodinated contrast medium is necessary, and adverse reactions—such as urticaria, airway edema, hormone release (e.g., from pheochromocytoma), or anaphylaxis—may occur.

Section I - This section is to be filled out by the PATIENT:

The MRI room contains a very strong magnet. Before you go into the room, we must know if you have any metal in your body. Please complete the following:

Pacemaker/Wires* **If yes, radiology/cardiology staff must complete section III.*	☐ Yes	☐ No	Recent Stent Placement	☐ Yes	☐ No
Aneurysm Clips	☐ Yes	☐ No	Shunt	☐ Yes	☐ No
Surgical Clips	☐ Yes	☐ No	Ear Implant	☐ Yes	☐ No
Eye Implant	☐ Yes	☐ No	IUD	☐ Yes	☐ No
Implantable Defibrillator	☐ Yes	☐ No	Blood Vessel Coil	☐ Yes	☐ No
Bullets, Pellets, etc	☐ Yes	☐ No	Heart Valve	☐ Yes	☐ No
Stimulator/Wires	☐ Yes	☐ No	Artificial Limb	☐ Yes	☐ No
Infusion Pump	☐ Yes	☐ No	Cochlear Device	☐ Yes	☐ No
Penile Prosthesis	☐ Yes	☐ No	Tracheostomy	☐ Yes	☐ No

Do you have kidney disease?	☐ Yes	☐ No
Have you ever been a machinist or metal worker?†	☐ Yes	☐ No
Have you ever had a facial injury from metal?	☐ Yes	☐ No
Have you ever had metal removed from your eyes?	☐ Yes	☐ No
Are you pregnant? Last menstrual period	☐ Yes	☐ No
Do you have any allergies? If yes, please specify	☐ Yes	☐ No

Current medications:

Weight:

Section II - This section is to be filled out by the RADIOLOGY STAFF for all patients:

†Orbit Films	☐ Yes	☐ No
Anyone attending the patient in the MRI room has been cleared for MRI safety requirements.	☐ Yes	☐ No

Section III - This section is to be filled out by the RADIOLOGY/CARDIOLOGY STAFF for patients with implantable cardiac devices:

Was the pacemaker or ICD generator implanted after 1998 or 2000, respectively?	☐ Yes	☐ No • *If not, cancel MRI*
Were the leads implanted ≥ 6 weeks before today?	☐ Yes	☐ No • *If not, cancel MRI*
Are non-transvenous epicardial or abandoned leads present? (Chest x-ray may be necessary if device implantation records are unavailable)	☐ Yes	☐ No • *If yes, cancel MRI*

☐ Pacemaker ☐ ICD

Dependent upon pacing?

☐ Yes
- *If yes, and the device is an ICD, cancel MRI*
- *If yes, and the device is a pacemaker, program pacing to VOO/DOO*

☐ No
- *If not, program pacing to VVI/DDI and deactivate tachycardia detection and therapies*

- *Deactivate magnet, rate, PVC, noise, ventricular sense, and conducted atrial fibrillation response*
- *Monitor blood pressure, ECG, oxygen saturation, and symptoms during MRI*

• *Device Manufacturer & model number:*	Prior to MRI RA	Prior to MRI RV	Prior to MRI LV	After MRI RA	After MRI RV	After MRI LV
Sensing **Capture Threshold** **Impedance**						
Battery Voltage						

- *Keep on ECG monitor after MRI until initial device programming has been restored*
- *Advise follow-up in device clinic in 3-6 months after MRI*

Figure 13.1-15 MRI safety checklist. (Reproduced with permission from Nazarian S, Beinart R, Halperin HR: Magnetic resonance imaging and implantable devices.Circ Arrhythm Electrophysiol 2013; 6(2):419–28. Copyright © 2013 American Heart Association, Inc.)

The field of MRI-guided procedures—sometimes referred to as interventional MR (iMRI) or magnetic resonance-guided therapy (MRT)—reflects the emergence of new magnet geometries, allowing physician access to the patient during imaging. These geometries may be C-arm configurations, parallel discs above and below the patient, or dual rings where the patient is placed either through the apertures of the rings or perpendicularly between the rings. Faster image acquisition pulse sequences are allowing near–real-time feedback. In addition to guiding biopsies and drainage, this technology enables more aggressive procedures, such as craniotomies or percutaneous tumor ablations, to be performed with immediate feedback showing the progress of excision or ablation. Many of these procedures require GA and, accordingly, require MRI-compatible monitoring and anesthetic equipment. For safety, the anesthesiologist and proceduralist also are subject to the same restrictions that apply to patients, so having a pacemaker, ICD, ferromagnetic aneurysm clips, or a metallic foreign body in the orbit precludes that person's suitability to perform these cases. Hybrid systems also are being marketed, combining MRI and x-ray fluoroscopy, CT and x-ray fluoroscopy, or CT and positron emission tomography (PET). These may involve overlapping precautions and risks.

Usual preop diagnosis

Tumor, primary or metastatic; lymphadenopathy; abscess, effusion, empyema, pseudocyst, or other fluid collection; cholecystitis; arterial occlusive disease; aneurysm or pseudoaneurysm; trauma; deep venous thrombosis; chronic venous occlusion; thromboembolic disease; pulmonary embolism; venous insufficiency; implanted IVC filter; biliary obstruction; obstructive uropathy; hydronephrosis; portal hypertension; cirrhosis; renal failure

SUMMARY OF PROCEDURES

	CT/X-Ray Fluoroscopy	US	MRI/MRT
Position	Supine, prone, lithotomy, or lateral decubitus	⇐	⇐
Unique considerations	Metallic objects should be kept out of the CT imaging field. Exit the procedure room during scanning to avoid	No ionizing radiation. Room lights are	All equipment, including monitors, valves, anesthesia machine, O_2 tanks, laryngoscopes, etc., must be

	radiation exposure, or use protective lead garment. Contrast reaction possible.	frequently dimmed for better viewing of the screen.	nonferromagnetic. Other metals should be removed from the imaging field to avoid artifact.
Antibiotics	Indicated for open procedures or when draining infected fluid collections, including abscesses, empyemas, and obstructed biliary or urinary systems.	⇐	⇐
Procedure time	0.5−4+ h, depending on complexity of the procedure	⇐	⇐
EBL	Procedure dependent; may be internal hemorrhage, may be preexisting hemorrhage	⇐	⇐
Postop care	PACU → room Level of care dependent on complexity of procedure and patient's overall status	⇐	⇐
Mortality	Rare	⇐	⇐
Morbidity	Contrast reaction Hemorrhage Infection/sepsis Organ injury/perforation Pneumothorax	⇐	⇐

	Pulmonary embolus Arrhythmia Hemodynamic collapse		
Pain score	Procedure dependent	⇐	⇐

PATIENT POPULATION CHARACTERISTICS

Age range	All
Male:Female	1:1
Incidence	Common
Associated conditions	**Fluid collections:** Patients may present with fever, sepsis, pain, or ileus. Mass effect, such as with empyema or pericardial effusion, may also affect respiratory or cardiovascular function. Instrumentation or relief of mass effect may induce a vasovagal response or acute bacteremia and sepsis. Some infections (Echinococcus, Entamoeba, methicillin-resistant Staphylococcus aureus [MRSA], vancomycin-resistant Enterococci [VRE]) may require special precautions, such as respiratory isolation, gown/glove standards, and pre- and postprocedure equipment sterilization. **Solid tumors:** Mass effect may result in obstruction of airways, blood vessels, GI/biliary tract, or urinary tract or neural impingement. HTN may be seen with significant renal compression and, occasionally, with neuroendocrine tumors. Hematopoietic, hepatic, or renal compromise may result in coagulopathy or Plt dysfunction. **Vascular pathologies:** Aggressive anticoagulation and/or antiplatelet therapy may be used intraop. Restoration of arterial flow to kidneys may → rapid ↓ of renin production and BP. Interventional procedures for venous thrombosis can → PE. Placement of central vascular access catheters can cause air embolism or cardiac dysrhythmias from right atrial

	irritation. Sclerosis of vascular malformations may result in pulmonary embolism, acute pulmonary vasospasm, and HTN.

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

The adult patient population requiring anesthesia for imaging is medically quite diverse; however, many have in common the inability or unwillingness to lie still during the procedure. Some of these patients are very ill, requiring the services of an anesthesiologist to maintain cardiopulmonary stability. Adult patients should be NPO (solid food and nonclear liquids) for 6 h preprocedure (elective). In general, US and CT scans present fewer problems for the anesthesiologist than MRI. Regardless of the method of anesthesia chosen, these patients must lie perfectly still, the airway must be protected, and IPPV may be required. Thus, children, the cognitively challenged claustrophobic, uncooperative, or critically ill patients usually require GA.

Respiratory	As a result of limited access to the patient's airway, the preop examination should focus on the need for elective ET intubation to protect the airway. ET intubation and mechanical ventilation also may be required in trauma patients, the critically ill, or patients with GERD or sleep apnea. An LMA/iGel may be suitable for patients not at risk of aspiration.
Cardiovascular	Presence of a cardiac pacemaker or ICD is not a contraindication to MRI (see Safety Checklist, Fig. 13.1-15). The presence of PA catheter thermistors or retained pacing wires and lead fragments is a relative contraindication.
Neurologic	Patients with ↑ ICP or cranial trauma usually need GA with mechanical ventilation and intubation. The presence of ferromagnetic aneurysm clips and/or coils may be a contraindication to MRI (✓ with surgeon or radiologist). Some aneurysm clips are nonferromagnetic and are, therefore, MRI compatible.

Musculoskeletal	The presence of spinal instrumentation, metal plates, pins, screws, joint replacements, or other prostheses is usually not a contraindication to MRI.
Premedication	Midazolam 1–5 mg iv (titrated to effect) may be appropriate in the very anxious adult patient; alternatively, lorazepam 1–2 mg po/sl 1 h before procedure.

Considerations for MRI/MRT

The MRI/MRT suite poses many challenges to the anesthesiologist. Because of the intense magnetic fields involved in MRI, any equipment containing ferromagnetic components—such as ECG monitors and anesthesia machines—cannot go near the magnet. Thus, MRI-compatible equipment is mandatory in the area of the MRI scanner. The magnetic field will destroy information on credit card/access card magnetic strips and may damage pagers as well as mechanical devices, including wrist watches and infusion pump motors. A microdrip infusion set can be a suitable replacement for an infusion pump.

Noise	May be very distressing for some patients and may be as high as 110 dB in a 1.5-T scanner and >130 dB in a 3-T scanner. Exposure to noise levels of this magnitude should not exceed 2 h/d. Hearing protection is strongly recommended.
Thermal injury	Thermal injury is caused by induced currents in metal implants or in looped conductors in contact with the skin.
Projectile effect	The magnet has a strong attraction for ferromagnetic objects that can then become lethal missiles; therefore, all objects, including pens, scissors, iv poles, O_2 cylinders, keys, stethoscopes, and eyeglasses or jewelry containing ferrous materials must be removed before entering the scanning room.
Implanted/foreign material	There are several reports describing problems that may occur with cardiac pacemakers (see Safety Checklist; Fig. 13.1-15; failure to pace), aneurysm clips (hemorrhage), and intravascular wires (induced currents). Metal workers may be at special risk for

	ocular damage 2° imbedded particles (see Safety Checklist; Fig. 13.1-15).
Contrast agent	Currently, gadolinium chelates are the primary agents in use and have a higher safety margin than iodinated contrast agents. Adverse reactions, however, occur in ~2% of patients and include HA, nausea, dizziness, hemodynamic instability, dysrhythmias, and nephrogenic systemic fibrosis.

INTRAOPERATIVE

Anesthetic technique

Typically, iv/po sedation, often without the services of an anesthesiologist. Patients unwilling or unable to cooperate will require GA.

IV sedation	In patients with a normal airway and no Hx of GERD, sedation can be carried out most easily using dexmedetomidine (1 mcg/kg loading dose over 10 min + 0.2–0.7 mcg/kg/h infusion) or propofol infusion (25–100 mcg/kg/min), ± midazolam (0.025–0.10 mg/kg) titrated to effect. **NB**: Only MRI-compatible infusion pumps should be used. (A microdrip infusion is a useful alternative.)

General anesthesia

Induction	Standard induction on an MRI gantry (typically in the magnet anteroom). The anesthetized patient is then transported into the magnet.
Maintenance	Standard maintenance. Most commonly, a propofol or dexmedetomidine infusion provides satisfactory sedation for the procedure (see pump considerations, above). Because continuous muscle relaxation is usually not required, spontaneous ventilation may be safest.
Emergence	Emergence (and extubation) is often accomplished after the patient has been moved back to the anteroom, where additional airway and other support equipment

	should be readily available. The patient should be recovered in the PACU, which may be some distance from the MRI suite. Appropriate monitoring and personnel should accompany the patient during transport.	
Blood and fluid requirements	Usually no blood loss IV: 20 ga × 1 BSS @ TKO	
Monitoring	Standard monitors	Monitoring in the MRI/MRT suite presents special problems, discussed below.
Monitoring, MRI	ECG	ECG may be distorted by magnetic fields. Use MRI-compatible electrodes. Twist leads together to avoid creating loops (↓ artifacts, ↓ burns). V5 and V6 are least likely to develop artifacts.
	Pulse oximetry	MRI-compatible oximeters are available. Locate probe outside bore of the magnet (e.g., toe). Avoid burn injury 2° induced current in looped leads.
	BP (NIBP)	Replace all ferrous connections on cuff and tubing with nylon connectors. Use tubing extensions to keep apparatus away from the field.
	± Arterial line	If an arterial line is medically indicated, keep the transducer close to the patient to avoid recording artifacts. Use MRI-compatible transducers and connectors.

		Recording equipment should have radiofrequency filters.
	Precordial/esophageal stethoscope	Often unsatisfactory because of magnet noise. An MRI-compatible, infrared, wireless stethoscope is available.
	Temperature	MRI-compatible T monitors are available, although usually not necessary for short procedures in adults.
	Capnography	MRI-compatible capnographs are available. Long sample lines will distort waveforms, and $ETCO_2$ concentration may not be accurate; however, this is still useful for measuring RR and relative changes in $ETCO_2$.
	PA catheter	PA catheters with thermistors or retained pacing wires are MRI contraindications.
	Urinary catheter	Catheters with T probes may be MRI compatible up to 3 Tesla, but the thermistor must be disconnected to avoid electrical or burn hazards.
	Verbal/visual	The patient and the monitors may be viewed directly (in procedure room) or through a screened window. Contact should be maintained throughout the procedure.
Positioning	✓ and pad pressure points ✓ eyes	CT and MRI gantries may be poorly padded → potential nerve injury.
Complications	Contrast related	Gadolinium → local and

		systemic reactions
	Loss of airway	Patient must be promptly extracted from the magnet bore and moved beyond the range of the magnet to permit use of emergency intubation and resuscitation equipment.
	Psychological	Panic attacks and claustrophobia occur in 5–10% of patients. Use of an eye mask may be helpful in selected patients. Heavy sedation or even GA may be necessary.
	Hearing loss	Temporary hearing loss and tinnitus may be expected in 40% of patients. Prevent by using ear plugs or other forms of hearing protection. GA: ↑ risk of hearing damage 2° stapedius muscle relaxation
	Thermal injury	Results from induced current heating of oximeter probe and looping cables

POSTOPERATIVE

Complications	Hearing loss	See discussion above.
	Thermal injury	See discussion above.

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TRACHEOBRONCHIAL STENTING

SURGICAL CONSIDERATIONS

Description

Tracheobronchial stenting may be performed for benign or malignant strictures of upper and lower airways that are unsuitable either for surgical reconstruction or as a temporizing measure. Patients may not be considered surgical candidates due to poor medical condition (e.g., comorbidity, recent thoracic surgery, limited life expectancy) or certain characteristics of the stricture (e.g., active disease, airway inflammation, extensive length, or multifocality). The most common cause of tracheobronchial narrowing is bronchogenic carcinoma, with the leading benign cause being stricture secondary to prolonged intubation. Less common causes include radiation-induced stenosis, polychondritis, tracheomalacia, and, in children, extrinsic strictures 2° vascular malformations.

Since the first lung transplant in 1963, posttransplant bronchial stenosis has joined the list of indications for tracheobronchial stenting. Bronchial stenosis is a relatively common complication of lung transplantation, occurring in single-lung, double-lung, and heart/lung transplant recipients with an overall incidence of 7–40%. It is believed that this complication is 2° the lack of bronchial arterial supply, with resulting airway ischemia. These ischemic stenoses occur at the bronchial suture line and in the more distal airways.

Stent types

There are two primary types of airway stents: silicone based and metallic, with both bare and covered metallic prostheses available. The development of biodegradable airway stents is an active area of research.

Silicone stents

Silicone-based stents (Silastic) are available both as straight, short tubes and as bifurcated Y-shaped devices. Selection of the appropriate size and length is critical. The stent must be long enough to extend across the stricture and of satisfactory diameter to maintain the caliber of the airway. The main **advantage** of silicone stents is that they are easily removed, either when the patient's ventilatory status has recovered sufficiently or when reconstructive surgery is possible. In addition, the stent can be easily repositioned to obtain optimal placement. Bifurcated silicone stents are also available to accommodate the Y-shaped configuration of the carina with extension into the distal trachea and both mainstream bronchi.

Silicone-based stents do have **disadvantages**. Stenotic airways need to be predilated before silicone stent insertion, whereas metallic stents can be placed within a narrow airway lumen and subsequently dilated. Silicone stents frequently become occluded with mucus plugs and granulation tissue or tumor overgrowth; therefore, regular bronchoscopic examination and treatment are necessary to keep the stented airway clear. Silicone stents and covered metallic stents are more likely to migrate than bare stents due to lack of incorporation into the bronchial wall. In general, silicone stents must be placed under GA because of the need for rigid bronchoscopy.

Metallic stents

The main **advantages** of metallic stents are the ease of insertion, a thin wall that rapidly becomes embedded in the airway, and the large gaps in the stent wall that allow normal ciliary function and reduced mucus impaction. The procedure can be performed using flexible bronchoscopy in the interventional room, with sedation. The main **disadvantage** of metallic stents is the difficulty in removing or repositioning these

devices once deployed. Metallic stents become firmly embedded in the wall of the airway and incorporated into the epithelium in <6 wk. Removal can be accomplished by using forceps to grip the wall of the stent and applying a twisting motion to pull the stent away from the wall. Potential complications from this maneuver may be catastrophic, and once these devices are placed, they should be considered permanent. However, if removal becomes necessary, the patient will require TIVA, muscle relaxants, and IPPV. Complications could include tracheal/bronchial disruption, pulmonary artery injury, and pneumothorax and airway obstruction. Another problem associated with metallic stents is the development of granulation tissue either at the ends of the stents or through the interstices. This requires careful follow-up by repeat bronchoscopy and may require subsequent procedures, such as bronchoplasty, restenting, and laser tissue ablation. Because of these potential complications, the FDA issued a warning in 2005 to limit the use of metallic stents in benign airway strictures only after all other treatment options have been explored.

Because of the flexibility and low profile of the deployment systems used for metallic stents, it is feasible to place them under conscious sedation; however, our practice is to utilize GA for tracheal stent placement to reduce patient movement due to the coughing that occurs with tracheal irritation.

Insertion techniques

Silicone stents have low inherent radial force; therefore, strictures need to be dilated before stenting. Rigid bronchoscopy is necessary to allow dilation and subsequent stent placement. Dilation can be performed with the Holinger bronchoscope, which is abutted to the stricture and advanced with a corkscrew motion. Gum-tipped Jackson dilators and various angioplasty balloons also can be used. In patients with tracheal stomas, a T-tube stent can be inserted via either the stoma or the mouth. This extends up to the vocal cords and down as far as the carina. In patients without tracheal stomas, either Y-tubes or straight stents are inserted in a similar fashion. The stent is mounted on the rigid scope, which is advanced across the stricture and then withdrawn, leaving the stent in place. Biopsy forceps are used to advance a limb of the Y-tube into the other bronchus. Placement of stents above the carina in this fashion is relatively straightforward, and the stents can be removed and repositioned until a satisfactory result is achieved. With more distal bronchial stents, the operator's vision is somewhat obscured, and deployment is more difficult.

For insertion of **metallic stents,** cross-sectional and fluoroscopic imaging is used to determine the optimal length and diameter of the stent. During the procedure, selective tracheobronchography may be performed by injecting water-soluble nonionic contrast

through a catheter at the level of stricture. Flexible bronchoscopy helps guide the stent placement with a soft-tipped guide wire being advanced through either the scope or the ETT into the distal airway. In the rare case where the stricture is too narrow and tight to allow passage of a small, flexible bronchoscope, a guide wire is passed, and the stent is positioned before deployment based on fluoroscopy, reconstructed CT images, or bronchography. Using fluoroscopy, the stent is deployed and visually confirmed with bronchoscopy.

Usual preop diagnosis

Bronchial compression 2° carcinoma; posttransplantation anastomotic stricture; radiation-induced stricture; relapsing polychondritis; sarcoidosis

SUMMARY OF PROCEDURE	
Position	Supine
Incision	None
Special instrumentation	Bronchoscope (flexible or rigid); silicone stent; self-expanding metallic stent (covered or uncovered)
Unique considerations	May have to pull the end of the tracheal tube back to the level of the vocal cords to adequately treat the entire trachea. Alternatively, can stent through LMA
Antibiotics	Not usually administered
Procedure time	1–2 h
EBL	0
Postop care	ICU or step-down unit
Mortality	1–5%
Morbidity	Tracheobronchial irritation (usually temporary). Stent malposition → bronchial occlusion or vocal cord paralysis
Pain score	2–4 (first few hours only)

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Respiratory compromise due to airway obstruction may pose a significant management challenge. It is therefore somewhat controversial and institution dependent, whether

these procedures should be performed outside of the OR. A thorough preop workup is necessary before anesthesia. The majority of patients present for palliation of an obstructing pulmonary malignancy or treatment of granulation tissue obstruction of a lung transplant anastomosis. Some may present emergently with impending airway obstruction that precludes a complete preop workup. The choice of anesthesia is primarily a function of the type of stent, surgeon preference, and the comorbid conditions of the patient. In general, silicone stent placement, which requires airway dilation with rigid bronchoscopy, will necessitate GA. Metallic stents can be placed without the need for preceding airway dilation; therefore, either topical anesthesia, with or without conscious sedation, or GA can be used. Immediate improvements in FEV_1, FVC, and PEF can be expected after stenting an obstructed tracheobronchial segment.

Respiratory	Patients with upper or lower airway stricture may present with cough, stridor, dyspnea, and fatigue. Airway obstruction can be classified as dynamic or fixed, depending on whether the obstruction varies with the respiratory cycle. Stridor that worsens during inspiration suggests an extrathoracic dynamic obstruction, whereas expiratory stridor is associated with intrathoracic dynamic obstruction. Other physical findings may include bronchospasm (in COPD patients), clubbing, or cyanosis. Preop fiberoptic bronchoscopic examination and/or high-resolution, thin-section CT scans will help to define the location, size, and extent of the obstruction. In patients suspected of having tracheomalacia, scans are performed at maximal inspiration and maximal expiration to unmask subtle areas of narrowing exacerbated by ↑ intrathoracic pressure on inspiration. Using this information, the appropriate size for an ETT can be estimated and potential problems with tracheal intubation can be anticipated. **Tests:** CXR; PFTs with flow/volume loops (see Fig. 5-14 in Anesthetic Considerations for Mediastinoscopy); CT scans preferably with thin slices and multiplanar reconstructions
Cardiovascular	Directed at any underlying disease process. Restoration of intravascular volume before induction

	of GA is important in patients with hypovolemia 2° chronic malnutrition from malignancy. **Tests:** As indicated from H&P
Musculoskeletal	Patients with lung cancer may have myasthenic syndrome (Eaton-Lambert) with ↑ resistance to depolarizing muscle relaxants and ↑ sensitivity to NDMRs. Post–lung transplant patients on certain immunosuppressive therapies (e.g., cyclosporine) may have prolonged muscle blockade from NDMRs.
Hematologic	Blood cross-match not necessary unless high risk of hemorrhage from injury (e.g., rigid bronchoscopy used in patients with friable tumors). Maintaining adequate O_2-carrying capacity is important in patients with poor pulmonary reserve. **Tests:** CBC; others as indicated from H&P
Laboratory	Other tests as indicated from H&P
Premedication	Patients in respiratory distress are extremely anxious; however, anxiolysis has to be balanced against the risk of impending respiratory arrest in some patients. Careful titration of anxiolytic medications is necessary to avoid oversedation. An antisialagogue (e.g., glycopyrrolate 0.2 mg iv) will help minimize secretions and improve visualization through the bronchoscope. Post–lung transplant patients may be steroid dependent and stress-dose steroid supplement may be required.

INTRAOPERATIVE

Anesthetic technique

Be prepared for an airway emergency. Preparations should be made for emergency rigid bronchoscopy and/or tracheostomy below the lesion. A variety of laryngoscope blades and ETTs of all sizes, including small, uncuffed (5–6 mm) tubes, should be readily available. Endoscopic evaluation of the airway must be performed in a spontaneously breathing patient if the airway lesion has not been defined. Muscle relaxation must be avoided until a detailed examination is completed and the operator is certain an airway can be maintained subsequently. Vocal cord paralysis, which can mimic tracheal

stenosis, can be obscured by muscle relaxation.

Topical anesthesia	Anesthetize palate, pharynx, larynx, vocal cords, and trachea with lidocaine (2–4%), using atomizer (e.g., MADgic™ Atomizer) or having the patient gargle viscous lidocaine (4%). Avoid local anesthetic overdose.
Conscious sedation	Midazolam will increase the seizure threshold in the setting of relative local anesthetic overdose. Other options include dexmedetomidine (0.2–0.7 mcg/kg/h after loading dose) and propofol (10–100 mcg/kg/min), with or without a short-acting opioid (e.g., fentanyl 25–50 mcg; remifentanil 0.05–0.1 mcg/kg/min). Caution should be exercised when mixing opioids and sedatives to avoid respiratory depression.
Induction	Patients should be well preoxygenated. Patients may be unable to lie flat 2° respiratory distress. Low-density helium-oxygen mixtures (Heliox) reduce airflow resistance past the obstruction, which may be beneficial in ventilating the patient. Ideally, spontaneous ventilation should be maintained until the airway is secured. Inhaled sevoflurane, intravenous ketamine, judicious propofol (without opioid), or awake FOB with topical anesthesia is appropriate. Optimally, the ETT is positioned ~1 cm above the lesion. Flexible bronchoscopy of the distal airways is then performed through the stricture, and the distal extent of the stricture relative to the carina is identified. In patients with a stricture near the vocal cords, the use of an LMA is a viable option, as it avoids passing an airway through the lesion and offers the ability to bronchoscopically examine the entire lesion. Avoid muscle relaxation if possible; if necessary, consider small dose of succinylcholine (or rocuronium → sugammadex). Distal or mild airway stenoses may be appropriately managed with an RSI.
Maintenance	Inhalational anesthesia is unreliable in most cases due to the limited ventilation with a bronchoscope in situ (resistance and leak). TIVA is preferable: use propofol

	(50–100 mcg/kg/min) and remifentanil (0.05–0.2 mcg/kg/min) infusions. Once the airway is secured, muscle relaxation can be given to avoid movement or coughing during the procedure. Succinylcholine drip (0.25–1 g/250 mL NS, titrated to twitch suppression; avoid phase II block by keeping dose <5–6 mg/kg) or intermediate-acting (cisatracurium 0.1 mg iv, vecuronium 0.1 mg/kg iv, rocuronium 0.15–0.3 mg/kg iv) muscle relaxant may be used. Manual IPPV through sidearm of rigid bronchoscope or via the swivel connector if fiber-optic bronchoscope is used. High-flow (up to 20 L/min) O_2 or O_2 flush (barotrauma risk) may be required to compensate for leak if rigid bronchoscope is used. Hyperventilate patient in preparation for periods of apnea. Low-frequency jet ventilation (50 psi at 10/min with I:E 1:2–4) via a Sander injector is an alternative. Barotrauma and dynamic lung hyperinflation are potential problems with this approach.	
Emergence	Patient must be fully awake before extubation with no residual neuromuscular blockade. Emergence can be "stormy." Patient may cough violently to clear secretions and blood. Wake-up on low-dose (e.g., 0.5 mcg/kg/min) remifentanil infusion tends to be smoother; consider airway suctioning and lidocaine (1 mg/kg iv) to decrease airway reactivity. Postop O_2 supplementation (preferably humidified).	
Blood and fluid requirements	IV: 18 ga × 1 BSS @ 1–2 mL/kg/h	Transfusion unnecessary except to optimize O_2-carrying capacity or to treat hemorrhage.
Monitoring	Standard monitors ± Arterial line	$ETCO_2$ not accurate during rigid bronchoscopy Art line depending on patient's comorbidities.
Positioning	Supine ✓ and pad pressure points ✓ eyes	

Complications	Hypoxemia	Suction secretions/blood; airway instrumentation may have to be interrupted and bronchoscope removed to improve oxygenation and ventilation.
	Hypercarbia	Commonly 2° inadequate ventilation. May cause increased sympathetic drive with 2° hypertension/tachycardia/dysrhythmias. Simply ↑ TV and RR.
	Hypertension	Ensure adequate ventilation and sedative/anesthesia.
	Bronchospasm	Rx: bronchodilator (e.g., albuterol puff)
	Stent dislodgement	From coughing or movement. Ensure adequate anesthesia and muscle relaxation.
	Bleeding	More likely with rigid bronchoscope
	Tracheobronchial injury Aspiration of debris	Requires frequent suctioning. Major hemorrhage may require thoracotomy using DLT or BB to isolate and/or tamponade bleeding site. Transfusion.
		Patient may need to be kept intubated after the procedure.

POSTOPERATIVE

Complications	Airway edema	Rx with corticosteroids (dexamethasone 10 mg iv) and/or racemic epinephrine nebulizer. Impending airway obstruction will require reintubation.
	Airway obstruction	May be catastrophic. Secretion retention or stent dislodgement. Rigorous suction. Reintubation or restenting

	Stent fracture/migration	May be catastrophic. May require emergent reintubation or restenting
	Pneumothorax	Obtain CXR. May require chest tube placement if >20% or enlarging
	Secretion retention	Humidified O_2
Pain management	None	

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THERMAL ABLATION OF TUMORS AND OTHER TARGETS

SURGICAL CONSIDERATIONS

Description

Percutaneous thermal ablation is a minimally invasive procedure often used for treatment of liver, kidney, lung, and bone tumors. It is a treatment option for nonsurgical candidates either in conjunction with or as a standalone therapy to radiation and/or chemotherapy.

The most commonly used thermal ablation platforms are radiofrequency ablation (RFA), microwave ablation (MWA), high-intensity–focused ultrasound (HIFU), and

cryoablation. Irreversible electroporation (IRE) is a nonthermal ablation modality which is reviewed separately. With the exception of HIFU, these thermal ablation systems consist of a generator and applicators that are placed into the target tumor percutaneously through small incisions using imaging guidance (US, CT, or MRI) to deliver cytotoxic thermal energy directly into the target lesion. In contrast, HIFU employs MR guidance to deliver focused US energy from an external source to the target lesion without an incision. MWA, RFA, and HIFU utilize tissue heating to >60° C to achieve lethal coagulation, while cryoablation utilizes tissue freezing to less than −40°C to cause cell death.

Mechanism of tissue destruction

In general, temperatures less than −40° C or more than 60° C cause complete necrosis in most tissues, although cell type and local environment can affect these temperature thresholds. RFA is based on the interaction of high-frequency alternating electric currents (460–500 kHz) within living tissue to generate frictional heat. MWA uses dielectric hysteresis with a rapidly oscillating electromagnetic field, typically in the range of 900–2450 MHz, to force polar molecules, primarily water, to continuously realign in order to generate heat, rendering it more useful in tissues with poor electrical conductance. HIFU uses an acoustic lens to concentrate multiple intersecting beams of US onto a focal target, achieving high acoustic intensities to generate heat.

Heat-based ablation aims to cause acute coagulative necrosis within the target tissues. Initial thermal injury involves the expression of heat shock response with increased thermal resistance in tissues that survive the primary insult. As temperatures increase within the target tissue, irreversible damage occurs with microvascular thrombosis, ischemia, and hypoxia. When temperatures reach more than 60°C, proteins denature and plasma membranes melt, leading to nearly instantaneous cell death.

To achieve rapid cooling, cryoablation devices employ the Joule-Thomson effect, whereby gas, typically argon, cools when rapidly expanded at room temperature after being forced through a narrow opening in the distal end of a cryoprobe. Freezing-based ablations destroy cells at temperatures less than −40°C through ice crystal formation and osmotic shock. Initially, as tissues are cooled, cellular metabolism slows down and ice begins to form outside of the cell, leading to a hyperosmotic extracellular space and cell dehydration. Subsequent thawing can cause fluid influx into the cell with swelling and membrane rupture. When there is rapid cooling, ice crystals can form within the cell, expanding the cell to cause irreversible cell membrane damage.

Techniques of percutaneous thermal ablation

For applicator-based systems, probe number and positioning are often determined based

on preprocedural and periprocedural imaging and manufacturer recommendations. Most commonly, US and/or CT are used to guide probe placement into the target lesion. Some centers use MRI for imaging guidance. The generator or device is activated and output is gradually increased to a predetermined maximum. The treatment time is also programmed into the unit and monitored throughout the procedure. The operator can adjust the ablation time and power during the procedure based on the size of the ablation zone. For cryoablation, two alternating freeze-thaw cycles are typically used to achieve successful tumor necrosis. RFA and MWA ablation zones can be monitored using CT and/or US with varying degrees of success. In contrast, cryoablation allows for direct visualization of a low-density ablation "ice ball" by noncontrast CT.

RFA requires the use of grounding pads typically placed on the patient's thighs. If a single RFA probe is used, at least two and, preferably, four pads (96 cm^2 surface area each) or the equivalent (minimum total surface area ~200 cm^2) must be used. If a three-probe cluster is used, at least four grounding pads or their equivalent (~400 cm^2 surface area) must be used. The grounding pads and the treatment probes are connected to the RF generator. MWA does not require grounding pads. Furthermore, newer-generation MWA devices may be more effective for treatment of larger (>3 cm) tumors compared to RFA.

Treatment volume varies according to the size and number of ablation probes, the modality, duration of treatment, and local blood flow. For heat-based ablations, tumor cells adjacent to large blood vessels may not be treated thoroughly due to the heat-sink effect of flowing blood, which carries away the thermal energy once deposited. It is important to note that MWA is less susceptible to heat-sink effects. Cryoablation is thought to be sparing of sensitive adjacent structures, such as nerves, and would be useful in areas such as the chest or abdominal wall as compared to heat-based therapies. Additionally, temperature-sensitive structures (e.g., bowel) near the planned ablation zone can be displaced using hydrodissection, pneumodissection, and/or percutaneous balloon catheter placement.

Liver ablation

The most well-known and best-studied application of RF is in the treatment of primary and metastatic liver tumors. RF has been used widely to treat hepatocellular carcinomas (HCC) as well as liver metastases. Prospective and retrospective studies have demonstrated that complete necrosis can be achieved in 90% of tumors measuring <3 cm in fewer than two sessions. However, the success rate drops markedly in tumors measuring >3.5 cm, with complete necrosis achieved in <50% at two sessions. MWA is increasingly being favored over RFA in this application given shorter ablation times,

higher efficacy in the treatment of larger lesions (>3 cm), and decreased susceptibility to heat-sink effects. Cryoablation is avoided in the liver given its association with increased bleeding risk and a DIC-like reaction termed “cryoshock.”

Renal ablation

Renal tumors smaller than 3 cm in diameter can be ablated successfully with both RFA and cryoablation. Emerging data on MWA for renal tumors are promising. For central renal tumors, cryoablation is favored because of decreased risk for injury to the collecting system and ureter. Overall, the efficacy for percutaneous ablation for small renal tumors is reported to be >90% with a complication rate of ~7%.

Lung ablation

Percutaneous RFA, MWA, and cryoablation in patients with primary lung cancer or lung metastases demonstrate low rates of serious complications. Pneumothorax is seen in ~30% of cases (similar to rates reported for lung biopsies). Efficacy of RFA of lung tumors has been limited due to the inherent poor conduction of electric current and heat in aerated lung. MWA is not susceptible to these limitations and is thus able to create predictable and larger ablation zones in lung. Cryoablation can effectively ablate tumors in the lung and has the advantage of being relatively resistant to the cold-sink effects of ventilation compared with heat-based ablations. Another advantage of cryoablation is seen with tumors in close proximity to the mediastinum or chest wall as it is less likely to cause thermal damage to these structures.

Bone ablation

Percutaneous thermal ablation has been applied to both benign and malignant painful bone tumors. The first use was for thermocoagulation of small, painful osteoid osteomas. The pain caused by osteoid osteoma is related to prostaglandin production by the cells of the small, central vascularized tumor nidus. Pain relief is obtained only after complete removal of the nidus, surgically or percutaneously. RFA has emerged as the method of choice for treating osteoid osteoma. Patients typically have 1–2 d of postprocedure pain that differs from the pain caused by osteoid osteoma. Relief of the osteoid osteoma pain almost always occurs within the first 24–48 h. Cure with one treatment session can be as high as 90%, and retreatment can be performed if the first treatment is not immediately successful or if the patient’s pain recurs. MWA may have a role in the future as antennae with shorter ablation zones become available.

Metastatic disease to the bone can be associated with intractable pain. Preliminary studies of percutaneous thermal ablation of painful metastatic bone lesions for pain relief show promise. The results of these trials suggest that although both heat-based

ablation and cryoablation can be effective, cryoablation is associated with more rapid and durable pain relief.

Prostate ablation

Transrectal ablation of localized prostate cancer using HIFU has shown promise as a non-invasive treatment modality. Although still a subject of clinical trials, it is FDA and Medicare approved. The procedure uses MR and US image guidance for targeting accuracy. Procedural discomfort often requires GA.

Parkinson disease and essential tremor treatment

Transcranial HIFU has been used to mitigate the signs and symptoms of tremor-dominant Parkinson disease and essential tremor. This is accomplished by ablating specific targets in the thalamus, globus pallidus or adjacent areas. Studies suggest that this technique can be as effective as invasive procedures including deep brain stimulation. Most patients will not require the services of an anesthesiologist.

Usual preop diagnosis

Primary or metastatic hepatic, pulmonary and renal malignancies; osteoid osteoma; prostate cancer; Parkinson disease.

SUMMARY OF PROCEDURE	
Position	Supine, prone, or lateral decubitus
Incision	Over the site to be accessed
Special instrumentation	RFA probes and generator microwave generators and probes; ultrasound probes
Unique considerations	Mild ↑ or ↓ T during procedure; RFA and MWA can be painful, while cryoablation is not.
Antibiotics	Cefazolin 2 g; occasionally ciprofloxacin 500 mg iv
Procedure time	2–4 h
EBL	None
Postop care	Step-down unit
Mortality	<5%
Morbidity	Postprocedure pain at site Hepatic hemorrhage: Rare Pneumothorax (during hepatic dome lesion ablation,

	pulmonary ablation) Hepatic abscess (↑ incidence in patients with previous biliary manipulation)
Pain score	5–8 (first few hours only)

PATIENT POPULATION CHARACTERISTICS

Age range	Adults
Male:Female	M > F
Incidence	Uncommon
Etiology	Pain; metastatic cancer; primary malignancies; neurodegenerative disorder
Associated conditions	metastatic cancer; chronic pain

ANESTHETIC CONSIDERATIONS

Patients presenting for percutaneous thermal ablation range from those with end-stage lung cancer to otherwise healthy chronic pain patients. In addition, analgesic/anesthetic requirements are highly variable, depending on the size and location of the target lesions. Close communication between the various care providers is essential to achieving a positive outcome.

Respiratory	Access to the airway may be limited in the typical interventional radiology suite; thus, a patient with a potentially difficult airway may require elective intubation. Appropriate airway adjuncts (LMA/iGels, light wand, fiberoptic cart, etc.) should be readily available. Intraop risks include the possibility of pneumothorax, so needle decompression supplies also should be available. Lung cancer patients presenting for tumor ablation may have compromised pulmonary function and require objective assessment of pathophysiology with PFTs and/or ABG analysis. **Tests:** PFTs, ABG, as indicated from H&P

Cardiovascular	HTN and CHF are seen frequently in elderly patients presenting for these procedures. These patients may have a severe disease process, which may be complicated by other significant comorbidities. The potential for cardiac ischemia should be evaluated carefully. **Tests:** ECG, echo, noninvasive stress testing as indicated from H&P
Neurologic	A thorough neurologic exam is important to document neurologic deficits that are present before the procedure.
Hepatic	Patients may have coagulation defects and mental status changes 2° systemic liver disease. The potential for severe hemorrhage from vascular injury, the risk of aspiration, and the lack of cooperation (encephalopathy) should all be taken into account when planning the anesthesia. Patients with severe liver disease also may exhibit hepatopulmonary or hepatorenal syndrome manifested as hypoxemia or renal failure. Consider the need for preop correction of coagulation and fluid status. **Tests:** LFTs; ammonia; INR
Endocrine	The possibility of endocrine and metabolic derangements should be assessed. Lung cancer patients may have electrolyte problems 2° SIADH, whereas patients with liver disease are prone to developing hypoglycemia. **Tests:** As indicated from H&P
Hematologic	Consider the possibility of chronic anemia or hypercoagulability 2° neoplastic disease. Chemotherapy or systemic disease may have depressed bone marrow function and altered the activity of WBCs and Plts. **Tests:** Hct, Plt count, or CBC, as indicated by H&P
Premedication	Sedation must be adjusted according to patient requirements. Small doses of midazolam, titrated to minimal sedation, are most reasonable (0.5–1 mg

	increments). Patients with end-stage disease often require very little premedication.

INTRAOPERATIVE

Anesthetic technique

Sedation or GA, depending on the size and location of lesions, patient comorbidities, patient positioning, and ablation modality. Most ablations are well tolerated with MAC; however, large lesions may require GA. MWA procedures also tend to require GA secondary to pain during ablation.

MAC

MAC cases are performed with fentanyl (25–150 mcg) and midazolam (0.5–2 mg) boluses, combined with a propofol infusion (25–100 mcg/kg/min). The substitution of remifentanil (0.02–0.1 mcg/kg/min) for fentanyl allows rapid titration of analgesia for the brief periods of intense stimulation.

Induction	Standard induction, preceding placement of an ETT or LMA	
Maintenance	Standard maintenance. Because procedures are of an unpredictable duration, short-acting muscle relaxants (e.g., rocuronium 0.6 mg/kg) are advised. Propofol (25–100 mcg/kg/min) and remifentanil (0.02–0.1 mcg/kg/min) are an appropriate combination that easily can be titrated to effect. Persistent intraop HTN may be treated with labetalol (5–25 mg) or hydralazine (5–20 mg).	
Emergence	Standard emergence. Short-acting analgesics (e.g., fentanyl 25–150 mcg) should be used in outpatients. Prophylactic treatment with antiemetics (ondansetron 4 mg iv) is beneficial because there is a high incidence of PONV.	
Blood and fluid requirements	IV: 20–14 ga × 1–2 BSS: 2–4 mL/kg/h	Larger access needed for hepatic lesions
Monitoring	Standard monitors ± Arterial line	

	± Urinary catheter	Foley for longer procedures (> 2 h)
Positioning	✓ and pad pressure points ✓ eyes	Radiology tables often poorly padded. Underbody Bair Hugger™ may be useful for avoiding hypothermia.
Complications	Hemorrhage	Blood or colloid should be readily available, if the need is anticipated. Large retroperitoneal hemorrhage can develop, yet not be appreciated until blood loss is extensive.
	Pneumothorax Hemothorax	Needle decompression and/or thoracostomy tube placement may be necessary during thoracic or high hepatic procedures.
	Electrical shock Thermal injury	RFA can produce serious injury if not properly grounded.
	Hyperthermia	Patients may develop rapid T increases 2° direct heating of large lesions.

POSTOPERATIVE

Complications	PONV Hemorrhage	Common Occult blood loss may continue for several h after the procedure is terminated.
Pain management	Multimodal pain management	Postprocedure pain is usually well tolerated.
Tests	Postprocedure HCT, as indicated	

Suggested Readings

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8. Wah TM: Image-guided ablation of renal cell carcinoma. Clin Radiol 2017; 72(8):636–44.
9. Woodrum DA, Gorny KR, Mynderse LA: MR-Guided Prostate InterventionsTop Magn Reson Imaging 2018; 27(3):141–151.

IRREVERSIBLE ELECTROPORATION (IRE ABLATION)

SURGICAL CONSIDERATIONS

Description

Electroporation is a method of exposing cells to ultrashort high-voltage electrical pulses to create small pores in the cell membrane. In reversible electroporation, the induced cell membrane porosity is temporary and cells are able to recover. This transient increase in cell permeability has been used in research for delivery of DNA, RNA, and macromolecules, such as antibodies, drugs, and tracers into cells. With the application of higher electrical voltages, permanent pores are created, resulting in disruption of cell homeostasis and apoptotic cell death. This process is known as **irreversible**

electroporation (IRE) and has emerged as a minimally invasive tissue ablation method. IRE presents several advantages compared to the traditional temperature-based ablation methods (i.e., RF or MWA and cryoablation). Because IRE uses nonthermal energy, it avoids undesirable thermal damage to surrounding tissues. IRE is able to induce cell death in a selective, well-defined manner and has been shown to preserve extracellular structures and connective tissue scaffolds, including large blood vessels and bile ducts. It is also not susceptible to perfusion-mediated heat-sink or cold-sink effects that can lead to suboptimal treatments when using temperature-based ablation methods. As such, IRE may be better suited for ablation of tumors located in close proximity to major portal or hepatic veins and arteries, bile ducts, or bowel.

Mechanism of tissue destruction

IRE utilizes high-voltage pulses ranging from 1000 to 3000 V/cm to create an electric field across the tissue between electrodes placed by the operator. Therefore, the shape and size of the IRE ablation field can be manipulated to include the entire area to be ablated. The intensity of the electric field within a given tissue is dictated by the distance between the electrodes and the voltage difference across the electrodes. The creation of permanent nanopores in the cell membrane irreversibly impairs the cell's ability to maintain homeostasis, resulting in cell death via apoptosis. Apoptosis is a natural, tightly regulated process in which cells are phagocytized by immune cells and then replaced by innate cellular regeneration. This process results in minimal damage to surrounding tissues with minimal fibrosis and scarring. Although the major mechanism of tissue ablation in IRE is electroporation, thermal tissue damage is possible if excessive electric fields are applied. Every electrical field produces thermal energy, which is referred to as the Joule effect. If the parameters of IRE are not chosen correctly, the electrical field generated can cause thermal damage, negating the nonthermal advantages of this therapy.

Techniques of irreversible electroporation

Careful planning is necessary before beginning IRE treatment to determine the proper placement and number of electrodes that will achieve the desired outcome. The commercially available NanoKnife™ IRE system (AngioDynamics; Latham, NY) has treatment planning software program that helps determine the number and placement of electrodes needed for the desired ablation zone. The voltage setting is determined by the distance between each pair of electrodes with the purpose of generating at least 1000 V/cm between them. The number of electrodes used depends on the site and volume of the target area and ease of electrode access. Current flow is determined by tissue resistance and degree of IRE achieved.

With the patient under GA, electrodes are placed in a predetermined pattern in the target area using US and/or CT guidance. To minimize the risk of cardiac dysrhythmias, the patient's electrocardiogram is synchronized to the IRE device such that pulses are delivered during the refractory period of the cardiac cycle. Typically, 70 brief pulses of high-voltage (1500–3000 V) direct current between 20 and 50 A are delivered in groups of 10, at intervals of 70 ms (bipolar) or 100 ms (unipolar). At 2-cm probe spacing and 3000 V delivered, the maximum effective treatment area is 2 cm diameter from each probe (maximum of 4 cm total ablation diameter).

Pancreas IRE: IRE has been shown to be successful in managing surgically unresectable pancreatic tumors encasing the celiac and superior mesenteric vessels.

Liver IRE: Clinical IRE was first attempted in patients diagnosed with HCC with promising clinical results. Liver function tests were normal at 24 h and at 1, 3, and 6 mo postop. There was, however, an expected increase in alanine aminotransferase, a marker for acute hepatocyte damage. Most patients with increased levels will return to baseline levels after 1 mo.

Prostate IRE: IRE has been shown to be a safe and technically feasible primary treatment for localized prostate cancer in carefully selected men.

Usual preop diagnosis

Most centers perform IRE on primary or metastatic malignancies in the liver, kidney, lung, prostate, and pancreas.

SUMMARY OF PROCEDURE	
Position	Supine or prone
Incision	Over the site to be accessed determined by preop CT, MRI, or US
Special instrumentation	AngioDynamics IRE electrodes and NanoKnife IRE generator
Unique considerations	Stimulation of skeletal muscles and diaphragm (minimized by the use of muscle relaxants) ↑ cardiac dysrhythmias ↓ T during lengthy procedures in CT room
Antibiotics	Cefazolin 2 g iv; >120 kg = 3 g iv, redose in 4 h
Procedure time	1–2 h

EBL	Usually minimal (although large-volume blood loss may occur during ablation of liver tumors)
Postop care	PACU then step-down posttreatment unit
Mortality	<5%
Morbidity	Post-procedure pain at site Brachial plexus injury (during positioning for liver ablation) Pneumothorax (related to lung ablation, segment VIII, or dome liver ablation) Subcapsular hematoma (related to multiple needle punctures) Intraperitoneal hematoma (related to pancreas ablation)
Pain score	3–8 (first few hours only)

PATIENT POPULATION CHARACTERISTICS

Age range	Adults
Male:Female	50:50
Incidence	Uncommon
Etiology	Primary and metastatic tumors
Associated conditions	Liver, lung, kidney, pancreas, prostate cancer

ANESTHETIC CONSIDERATIONS

GA is mandatory for IRE procedures. Because the high-voltage electrical pulses can cause intense whole body muscle contractions, complete neuromuscular blockade is required. To minimize the risk of inducing cardiac dysrhythmias, treatment is performed with cardiac synchronization. Defibrillator pads are placed prior to initiation of treatment. The electrocardiogram should be closely monitored.

Respiratory	Lung cancer patients presenting for tumor ablation may have compromised pulmonary function and require objective assessment with PFTs and/or ABG analysis before the procedure. Access to the airway may be limited in the CT/MRI scanning suite. Intraop

	risks include the possibility of pneumothorax. Tests: PFTs, ABG, as indicated from H&P
Cardiovascular	Patients with underlying cardiac disease are especially susceptible to IRE-induced cardiac dysrhythmias. History of cardiac arrhythmias is a contraindication for IRE. A defibrillator should be available in the procedure room. The potential for myocardial ischemia should be evaluated carefully. Defibrillator pads are preferably placed on the patient prior to initiation of treatment. A cardiac anesthesiologist is not usually required. **Tests:** ECG, echo, noninvasive stress testing as indicated from H&P
Neurologic	A thorough neurologic exam is important to document preexisting neurologic deficits.
Hepatic	Patients may have coagulation defects and mental status changes related to liver disease. Patients with severe liver disease may exhibit a hepatopulmonary or hepatorenal syndrome manifested as hypoxia or renal failure. Consider the need for preop correction of coagulation and fluid status. **Tests:** LFTs; ammonia; INR
Endocrine	The possibility of endocrine and metabolic derangements should be assessed. Lung cancer patients may have electrolyte problems 2° SIADH, while patients with liver disease are prone to developing hypoglycemia. **Tests:** As indicated by H&P
Hematologic	Consider the possibility of chronic anemia or hypercoagulability 2° neoplastic disease. Chemotherapy or systemic disease may have depressed bone marrow function and altered the activity of WBCs and platelets.
Premedication	Consider midazolam 0.5–2 mg iv. Patients with end-stage disease often require very little premedication.

INTRAOPERATIVE

Anesthetic technique

GETA with muscle relaxation is usually required to minimize any involuntary movement caused by IRE ablation. Some small-volume ablations may be tolerated with MAC, and anesthetic requirements should be discussed with the radiologist.

Induction	Standard induction	
Maintenance	Standard maintenance. Procedure duration may be unpredictable. It is important that adequate neuromuscular blockade is maintained due to intense direct muscle stimulation that may be caused by IRE treatment.	
Emergence	Standard emergence. Short-acting analgesics (e.g., fentanyl 25–150 mcg) should be used in outpatients. Prophylactic treatment with antiemetics may be beneficial because there is a high incidence of PONV.	
Blood and fluid requirements	IV: 20–14 ga × 1–2 BSS: 3–5 mL/kg/h	Larger iv access may be needed for procedures with a high risk for, e.g., hepatic lesions.
Monitoring	Standard monitors ± Arterial line ± Foley catheter	↑ BP (20–30 mm Hg) is common following treatment cycles but may be extreme during treatment of upper pole renal tumors (inadvertent adrenal stimulation). Arterial line may be useful for ablation procedures near the heart, for large-volume ablations, and in patients with renal impairment.
Positioning	✓ and pad pressure points ✓ eyes	Extension of the arms above the head may be required for optimal imaging; if prolonged, this may result in

		a brachial plexus injury, particularly when the patient is in a supine position.
Complications	Hemorrhage	Blood should be readily available for high hemorrhage risk procedures. Large retroperitoneal hemorrhage may develop.
	Pneumothorax	Needle decompression and/or thoracostomy tube placement may be necessary during thoracic or high hepatic procedures.
	Muscle stimulation	Intense stimulation of skeletal muscles and the diaphragm may be produced. Movement should be minimalized by use of muscle relaxants. Neuromuscular monitoring is useful to maintain a constant level of neuromuscular blockade.
	Dysrhythmias	Application of large currents may cause dysrhythmias. Occasionally, the treatment pulses may capture the ventricles resulting in a short run of ventricular tachycardia, which should resolve at the end of each 10 pulse treatment cycle. Although rarely required, a defibrillator/external pacer should be available.
	Acid-base and electrolyte disturbances	Patients may develop ↑ K during ablation of very large tumors or in the presence of

	Hypothermia	preexisting renal impairment. Monitor arterial blood electrolytes during the procedure in those patients. Patients may experience ↓ body temperature during lengthy procedures in the scanning room. Underbody hot-air blankets may be used.

POSTOPERATIVE

Complications	Complications PONV Hemorrhage	Common Occult blood loss may continue for several hours after the procedure has terminated.
Pain management	Standard pain management	Postprocedural pain is usually mild and well tolerated.
Tests	HCT, as indicated	

Suggested Readings

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2. Distelmaier M, Barabasch A, Heil P, et al: Midterm safety and efficacy of irreversible electroporation of malignant liver tumors located close to major portal or hepatic veins. Radiology 2017; 285(3):1023–31.
3. Lee EW, Chen C, Prieto VE, et al: Advanced hepatic ablation technique for creating complete cell death: irreversible electroporation. Radiology 2010; 255(2):426–33.
4. Martin RC, Schwartz E, Adams J, et al: Intraoperative anesthesia management in patients undergoing surgical irreversible electroporation of the pancreas, liver, kidney, and retroperitoneal tumors. Anesth Pain Med 2015; 5(3):e22786.
5. Wagstaff PG, Buijs M, van den Bos W, et al: Irreversible electroporation: state of the art. Onco Targets Ther 2016; 9:2437–46.

Suggested Viewing

Links are available online to the following videos:

TIPSS, Transjugular Intrahepatic Porto-Systemic Shunt: https://www.youtube.com/watch?v=O2u4_hF3234

ONYX embolization of AVM (skip to minute 5 for the animation): https://www.youtube.com/watch?v=gYTVA3PoeY8

AVM Embolization Using Onyx-18: https://www.youtube.com/watch?v=057r1Zo1pj4

Endovascular Coiling of Unruptured Ophthalmic Artery Aneurysm: https://www.youtube.com/watch?v=waEtv93XnTU

ICD Implantable Cardioverter Defibrillator: https://www.youtube.com/watch?v=F_E06rkY4T8

NEJM Procedure: Thrombus Aspiration: https://www.youtube.com/watch?v=_bUMm8E0w6s

AERO Fully Covered Tracheobronchial Stent Video: https://www.youtube.com/watch?v=0IzNZ4_0rNg

CHAPTER 13.2

Non–Operating Room Procedures—Pediatric

PROCEDURAL SPECIALISTS

Claudia Mueller, MD, PhD
William E. Berquist, MD (Gastroenterology)
Sarah S. Donaldson, MD, FACR, FASTRO (Radiation oncology)
Anne M. Dubin, MD (Pediatric cardiac catheterization)
Gary E. Hartman, MD, MBA (ECMO)
Susan M. Hiniker, MD (Radiation oncology)
Katsuhide Maeda, MD, PhD (Pediatric cardiac electrophysiology)
Lynn Peng, MD (Pediatric cardiac electrophysiology)
Ann Ming Yeh, MD (Gastroenterology)

ANESTHESIOLOGISTS

Claudia Benkwitz, MD, PhD (ECMO, Pediatric cardiac electrophysiology)
Erin Bushell, MD (Epidermolysis bullosa)
Rebecca E. Claure, MD (Radiation therapy, oncology, endoscopy, imaging)
Louise K. Furukawa, MD (Epidermolysis bullosa)
Brenda Golianu, MD (Radiation therapy, oncology, endoscopy, imaging)
Kristin Sun, MD (Oncology)
Lisa Wise-Faberowski, MD, MS, FAAP (ECMO, Pediatric cardiac electrophysiology)
Komal Kamra, MBBS, MMI

PEDIATRIC RADIATION THERAPY

PROCEDURAL CONSIDERATIONS

Susan Hiniker and Sarah S. Donaldson

Description

Modern pediatric radiation therapy (XRT) requires that the patient be in a stable and reproducible position for daily treatment. Sharply defined beams with secondary collimation are used to irradiate the tumor volume and to spare normal tissue. Patient movement may undermine techniques for sparing normal tissue, and although movement cannot be completely prevented, it must be minimized. In very young children, it is often impossible to prevent movement and achieve adequate cooperation for radiation treatment. In such cases, daily anesthesia is required. Close cooperation of the radiation oncology and anesthesia teams allows for safe and reproducible daily treatment. In general, children older than 3 or 4 yr can be persuaded to lie still for radiation therapy. Children from 2.5 to 4 yr may cooperate during the treatment (which is usually <15 min), but not for the treatment planning and simulation, in which an immobilization-stabilization device is made (often requiring 1–1.5 h). In most infants and young children (<4 yr), anesthesia is essential.

The optimal position for XRT must also be optimal for the anesthesiologist. Ideally, the area to be treated is determined using 3-dimensional conformal techniques to optimize treatment and to minimize normal tissue exposure. This requires a cross-sectional imaging study (e.g., CT scan), with the patient in the identical position as will be used during the radiation treatment. A series of radiographs are taken at the treatment-planning (simulation) appointment, which typically lasts 1–1.5 h and requires GA. It is essential that there be no patient movement between exposures; if the patient moves, the entire procedure must be repeated. Typically, the patient is transported to the CT suite for a 3-dimensional treatment-planning CT scan. Anesthesia preparation may be initiated in the treatment-planning suite or in a nearby preparation room. After scans are obtained, individual beam-shaping devices are made, and a multistep process of contouring begins for treatment planning.

Seven to 10 d following the initial planning session, the patient often has a verification procedure, which is usually of shorter duration—generally requiring only 30 min of anesthesia time. The verification procedure consists of a series of radiographs using the beam-shaping devices, which simulate the treatment to be given. When this procedure is successfully completed, the anesthetized patient is moved to the treatment room. The child is put in the identical position achieved during the planning/verification procedures, and treatment is administered.

The first day or two, and weekly thereafter, a verification x-ray (called a “port film”) is taken to confirm the accuracy of the treatment field. The treatment itself is only a few

minutes in duration for each field; ideally, the entire procedure is completed within 15–30 min. A form of radiotherapy treatment planning and delivery known as intensity-modulated radiation therapy (IMRT) may require slightly longer treatment times due to the larger number and increased complexity of fields treated, while volumetric modulated arc therapy (VMAT) may be of shorter treatment time. A course of treatment may be only a few days or may last for 5–6 wk, generally with treatment given 5 × per week. Occasionally, multiple (2–3) treatments per day are given at 4–8 h (usually 6 h) intervals. At the initial appointment, the patient's optimal position is determined, an immobilization device is constructed, and measurements are taken. The immobilization device is usually a body cradle or cast, and often a head/face mask is made for head and neck or brain treatment. Initially, temporary marks or Band-Aids® are used; however, when the final positioning has been determined, a more permanent mark, such as a tattoo, may be applied. Often, a head holder with a mask is applied to ensure the position for XRT.

In managing certain brain tumors (e.g., medulloblastoma, high-grade intratentorial ependymoma, germ cell tumors, and CNS leukemia), **cranial spinal irradiation** (CSI) may be used. Conventionally, this procedure requires that the patient be placed in the prone position with the head flexed as much as possible to minimize a cervical lordosis. This positioning, however, creates special difficulties for the anesthesiologist. If the child is intubated for the setup, the radiation stabilization device must allow space for the ETT. If the child is not intubated, there must be adequate access to the airway. Current techniques allow patients to be treated with CSI in the supine position facilitating easier airway access for the anesthesiologist, more secure patient immobilization, and faster treatment times.

Fractionation

Pediatric protocols have been testing the efficacy of giving multiple fractions (treatments) of radiation 2–3 × per day, usually at 6-h intervals, to allow higher total radiation doses to be administered with possible less normal tissue morbidity. These schemes have been or are being evaluated for children with central nervous system tumors and total body irradiation (TBI) in preparation for bone marrow transplantation. Until proven to be of increased efficacy, such schemes should remain part of large protocol studies. The timing of radiotherapy may be at 4-, 6-, or 8-h intervals 2–3 × per day, depending on the protocol. These studies provide several challenges for anesthesiologists, radiotherapists, and parents. Radiotherapy under anesthesia, however, has been successfully administered to infants undergoing multiple fractions per day. Attention must be given to potential malnutrition and/or dehydration from prolonged periods of NPO status.

Total body irradiation

Although most TBI techniques are administered with the patient standing, infants and small children must lie prone and supine for the treatment. This positioning requires sedation and/or anesthesia. Gastrointestinal upset, sometimes provoked by the radiation, presents an additional challenge for proper radiotherapy technique, as well as for anesthetic management.

Cranial or body radiation/radiosurgery/IGRT

The technique of using precision, stereotactically localized radiation with a highly collimated radiotherapy photon beam, as generated from a linear accelerator, is currently being employed for select patients with small cranial, base-of-skull, or body tumors. There is increasing enthusiasm for this technique for infants and children with recurrent posterior fossa and cerebral tumors, craniopharyngiomas, optic nerve and chiasmal gliomas, and small AVMs. Radiosurgery has historically required a frame-based technique that requires 6–10 h of continuous anesthesia while a patient undergoes application of a metal frame, CT localization, and multiport radiotherapy treatment. However, newer technology, using image guidance, called image-guided radiation therapy (IGRT) now allows frameless radiation delivery to the cranium or body. This technique requires a 1–1.5-h treatment planning and simulation session followed by a single fraction or limited number of treatment sessions each lasting 1.5–2 h. These approaches require close coordination between the anesthesiologist, neurosurgeon, oncologic surgeon, and radiotherapist.

IMRT/protons/VMAT

Recent developments in external beam radiotherapy techniques have allowed for increasingly conformal treatment using IMRT or proton therapy. However, these complex techniques generally involve image-guided therapy and a greater number of beam directions, thereby resulting in longer overall treatment times. The development of VMAT, in which dose is delivered using a single gantry arc rotation, has allowed for treatment of very conformal volumes with increased speed as well as delivery of fewer monitor units. VMAT is increasingly used in the treatment of pediatric patients, particularly in those who require anesthesia during treatment.

Usual preop diagnosis

Leukemia; brain tumors (benign or malignant); retinoblastoma; solid tumors of childhood

SUMMARY OF PROCEDURES

	Standard XRT/IMRT	TBI	Frameless Radiosurgery
Position	Supine or prone	Supine or prone	Supine or prone
Unique considerations	If prone: head flexed for maximal straightening of the C-spine	May be repeated 2–3 ×/day at 4–6 h intervals	Head extended for stabilization of airway
Anesthesia time	Planning: 30–120 min Treatment: <15 min (IMRT: 15–30 min)	45–60 min <20 min	30–90 min 90–120 min
Postop care	PACU → home	PACU → room	PACU → home

PATIENT POPULATION CHARACTERISTICS

Age range	Usually ≤4 yr
Male:Female	1:1
Incidence	NA
Associated conditions	**Brain tumors:** ↑ ICP is of concern in these patients. Postradiation edema following the first few treatments may further ↑ ICP, with potential for brainstem herniation. Some children with brainstem tumors are particularly difficult to anesthetize, perhaps because of disruption of nerve pathways in those areas of the brainstem that are affected by anesthetics. **Neuroblastoma:** Neuroblastomas are capable of secreting catecholamines and related substances; hence, there is a potential for paroxysmal HTN during anesthesia induction. In these children, the principles of anesthetic management are similar to those for pheochromocytoma. **Retinoblastoma:** It is imperative that the patient be properly immobilized with no movement, as even a mm of change, as occurs with a sigh, may cause unnecessary radiation to the radiosensitive lens and

	anterior chamber. Optimal anesthesia prevents nystagmus and motion of the head. Even minimal lateral or rotary nystagmus may increase the risk of cataract induction.

ANESTHETIC CONSIDERATIONS

Rebecca E. Claure and Brenda Golianu

PREOPERATIVE

Orientation to the XRT suite, positive reinforcement, and play therapy can reduce the number of children requiring anesthesia for XRT; however, the majority of children ≤4 yr will require anesthesia. A detailed preanesthesia visit is essential and is also an opportunity to gain the confidence of both child and parents. The majority of these patients will have received chemotherapy and should be evaluated for side effects. The importance of NPO status needs to be stressed repeatedly, discussing the potential danger of emesis during treatment. Written instructions regarding preop protocols are extremely helpful in this context. For children with cancer, prolonged preop fasting for XRT once or twice daily could severely compromise an already marginal nutritional intake. Infants, children, and adolescents should be encouraged to drink clear liquids until 2 h before treatment. Milk and solid foods should be held for an appropriate time interval (6–8 h depending on age; see Appendix D: Standard Pediatric Anesthetic Management). Reassessment before each anesthetic is recommended because the patient's medical status may change during the course of radiation therapy. Some children will have Sx of ↑ ICP, which must be taken into account when designing an anesthetic plan to avoid ↑ $PaCO_2$ and other factors that may further ↑ ICP.

The most common diagnoses are primary CNS tumor (28–33%), retinoblastoma (9-26%), acute leukemia (9–26%), neuroblastoma (2–18%), lymphoma (8%), rhabdomyosarcoma (5–7%), Wilms tumor (5%), and Ewing sarcoma (5%). The total number of treatments can range from 1 to 65 (median 20–24). Many patients require a mold of the head and neck. Children can range in age from infants to adolescents, with a median age of 2.4–3.8 yr.

Respiratory	Careful evaluation for respiratory compromise due to chemotherapy. Patients with Sx of URI (rhinorrhea, cough, fever) are commonly seen during XRT treatment. If Sxs are significant, XRT should be

	delayed, and the patient should be evaluated by primary service. Fortunately, most children can be managed without the use of an ETT, which itself can increase the risk of oxygen desaturation, laryngospasm, and bronchospasm. The benefit of XRT vs. delaying treatment must be balanced against the risks of anesthesia. **Tests:** As indicated from H&P
Cardiac	Careful evaluation for cardiac compromise due to chemotherapy **Tests:** As indicated from H&P
Neurologic	Patients with intracranial tumors may have ↑ ICP. Postradiation edema following the first few treatments may further ↑ ICP. Sx includes irritability, HA, N/V, and papilledema. Suspicion of ↑ ICP mandates ETT intubation and controlled ventilation to induce hypocarbia.
Laboratory	Tests as indicated from H&P
Premedication	Usually unnecessary in this patient group. Parents usually present for induction, and majority of patients have some form of central venous access or heplock in situ. If inhalational induction is necessary, midazolam 0.5–0.75 mg/kg po may be helpful.

INTRAPROCEDURE

Anesthetic technique

Provision of anesthesia to children at sites remote from the OR is challenging. During XRT, patients must remain immobile so that the tumor can be reliably irradiated while minimizing damage to uninvolved tissue. Anesthetic goals should include patient immobility, rapid onset, brief duration of action, and prompt recovery. The anesthetic should allow maintenance of a patent airway and spontaneous ventilation in a variety of body positions. Propofol bolus and infusion have been shown to be safe and effective for XRT. Higher doses may be needed due to tolerance with repeated treatments. Ketamine is rarely used, but may be effective if there is a history of reaction to propofol. Ketamine is a potent sialagogue and can cause nystagmus, which may interfere with precision radiation of retinoblastomas. It may cause prolonged or unpleasant

emergence and should be avoided in patients with ↑ ICP. Choice of anesthetic technique may be limited by equipment or logistical issues. Anesthesia machines may not be available in all XRT suites.

Induction	**IV:** Propofol (2–4 mg/kg), titrated slowly to effect. Additional propofol boluses may be needed as patients may develop tolerance. Intubation is usually not needed. **Inhalation:** Mask induction with sevoflurane is appropriate in children without iv access and may be preferred by some children. The airway can almost always be maintained by careful positioning and extension of the neck. It is essential that this same degree of extension/flexion be maintained for each treatment. A molded immobilization device may be placed over the patient's head and neck, limiting airway access and potentially causing airway obstruction.	
Maintenance	**IV:** Propofol (100–250 mcg/kg/min) by continuous infusion. Supplemental O_2 should be administered via nasal prongs. **Inhalation:** Sevoflurane in O_2	
Emergence	Patients awaken rapidly following cessation of propofol infusion or sevoflurane. XRT may cause nausea/vomiting, so antiemetics should be given (ondansetron 0.1–0.15 mg/kg). Avoid dexamethasone (may conflict with chemotherapy protocols and in rare cases may cause tumor lysis syndrome).	
Blood and fluid requirements	IV: Central access BSS: Routine maintenance	Majority of children receiving radiotherapy have some form of central venous access.
Monitoring	Standard monitors	A critical problem is the lack of access to the patient and monitors during XRT. A video camera with a zoom lens can focus on the monitors, and a second camera is trained on the patient. In XRT suites with a viewing window, a

		small marker may be placed on the chest so that the rise and fall of chest motion are seen easily.
Positioning	✓and pad pressure points ✓eyes	Careful positioning 2° possible chemotherapy-induced peripheral neuropathy
Complications	Airway obstruction	Respiratory obstruction may occur; it usually responds to nasal or oral airways and careful repositioning.
	Patient movement	Deepen anesthesia

POSTPROCEDURE

Complications	PONV	Many patients have chemotherapy-induced nausea, which may be exacerbated by anesthesia, XRT, and stress.
	Central line sepsis	Patients may be immunocompromised following chemotherapy. Attention to sterility during access of the central venous line is critical because repeated use by multiple health care providers → ↑ risk of catheter contamination. Aseptic preparation of anesthetic iv medications, especially propofol, is important.
	Cerebral edema	In patients with ↑ ICP, XRT can provoke an acute ↑ ICP,

		with consequent ↑ HA, ↑ N/V, ↓ consciousness, and cardiac arrest. These patients should be monitored × 24-h post-XRT.
Pain management	Standard approaches	Radiation treatments are not associated with pain, but narcotics may be useful in relieving pain associated with neoplastic disease.

Suggested Readings

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PEDIATRIC CARDIAC CATHETERIZATION AND ELECTROPHYSIOLOGY

PROCEDURAL CONSIDERATIONS

Lynn F. Peng, Anne M. Dubin, Stanton B. Perry, Jeffrey A. Feinstein, and Katsuhide Maeda

Cardiac catheterization and electrophysiology testing have evolved over the recent decades from purely diagnostic tools to combined diagnostic and therapeutic

procedures. Although the use of GA varies from institution to institution, higher levels of sedation are required at a minimum for critically ill patients, those requiring complex interventional strategies, small children who must remain totally still, and when TEE is used for image-guided therapy. A thorough review of diagnostic and interventional cardiac catheterization and electrophysiology is not possible in this chapter, and the interested reader is referred to the multiple textbooks available on the subject.

The placement of anesthesia equipment for these procedures must allow for (a) proper positioning of the patient, (b) easy access to the head and neck and/or groin for the physician performing the procedure, and (c) rotation and angulation of the imaging equipment. The goal of sedation in all of these procedures is to provide a nontraumatic, safe environment for the patient. Many patients can be cared for adequately and safely using conscious sedation; however, there is a subset of pediatric patients who may require GA. This group may include patients with complex congenital heart disease, ventricular dysfunction, or airway abnormalities.

It is important to understand that certain anesthetic agents may alter cardiac conduction, making arrhythmia inducibility more difficult. Catecholamine-dependent arrhythmias, such as an automatic atrial tachycardia, may be impossible to induce with the patient under GA. Furthermore, the arrhythmia itself may complicate anesthetic care, by causing sudden decreases in BP due to excessively rapid rates. In patients undergoing radiofrequency ablation (RFA) in areas close to other critical structures of the heart, GA may be necessary to keep the patient motionless during application of energy. During anesthesia, the use of muscle relaxants may mask diaphragmatic/phrenic nerve stimulation during mapping and poses the risk of ablation of structures other than the abnormal pathway. In patients returning for a previous failed ablation, controlled ventilation using low tidal volumes to minimize electrophysiologic catheter movement may be helpful.

VASCULAR ACCESS

The modified **Seldinger technique** of cannulating blood vessels percutaneously is used to establish vascular access for cardiac catheterization. (The femoral and IJ veins are most commonly used for venous access.) Transhepatic access to the IVC has been used safely and successfully in patients without femoral venous access. The femoral artery is most commonly used, although the carotid and axillary arteries may be used for specific procedures or when there is bilateral femoral artery occlusion. In newborns, the umbilical artery and vein may be used. Access may be especially difficult in patients who have undergone multiple previous procedures. In the most severe cases,

reconstructive transcatheter techniques, including **balloon angioplasty** and **stent implantation** to rehabilitate the vessels, have been used to allow future catheter-based diagnostic and therapeutic interventions.

Infiltration of the skin and the subcutaneous tissues with a local anesthetic agent to reduce pain is used when the procedure is being performed under conscious sedation. With GA, infiltration of a local anesthetic agent may be helpful as placement of lines can be stimulating. The use of local anesthetic is helpful in minimizing the amount of GA used to produce a similar depth of anesthesia in patients with depressed myocardial function. Local anesthetic may also be deferred to the end of the procedure to alleviate pain and discomfort at vascular access sites during recovery.

HEMODYNAMIC DATA

O_2 sat measurements are made routinely in the various cardiac chambers, venae cavae, and great vessels. These measurements are used to calculate the systemic flow (CO, Q_s), pulmonary flow (Q_p), the ratio of the pulmonary to systemic flow (Q_p:Q_s), and PVR and SVR.

It is ideal to obtain the data with the patient awake and breathing spontaneously in room air. This is rarely possible in pediatric patients. The use of light anesthesia and sedation during the diagnostic part of the study facilitates acquisition of data in as near-normal state as possible. It is important to recognize and limit effects on intracardiac and intrapulmonary pressures and systemic and pulmonary resistances when the procedure is done under GA with IPPV. Though one could argue that the work of breathing and airway apparatus resistance are less with an LMA compared to an ETT, improper seating of the LMA can influence the pressure waveforms. Thus, for patients with obstructive airway disease, a mask supplemented with an oral airway may be more helpful. At a minimum, and when tolerated, baseline hemodynamic measurements should be performed with an FiO_2 as close to 0.21 as possible. In some cases, additional diagnostic information may be collected to study the effects of O_2, NO, vasodilators or inotropes, exercise and balloon occlusion of intracardiac or extracardiac shunts on the CO, pulmonary flow, and PVR and SVR.

From O_2 sat, dissolved O_2 (PO_2), and Hb measurements, the O_2 content (mL/dL) of the mixed venous blood and systemic arterial blood is used to calculate systemic AV O_2 content difference. Pulmonary AV O_2 content difference is similarly estimated by calculating the O_2 content of pulmonary venous and arterial blood. Systemic (Q_s) and

pulmonary flow (Q_p) can then be derived using the **Fick principle:**

$$\text{Flow (Q) (L/min)} = \frac{O_2 \text{ consumption (mL/min)}}{\text{AV } O_2 \text{ difference (mL of } O_2\text{/L of blood)}}$$

$$\text{Pulmonary Flow } (Q_p) = \frac{O_2 \text{ consumption}}{\text{Pulmonary vein } SaO_2 - \text{Pulmonary artery } SaO_2}$$

$$\text{Systemic Flow } (Q_S) = \frac{O_2 \text{ consumption}}{\text{Systemic artery } SaO_2 - \text{Mixed venous } SaO_2}$$

Based on Ohm law, which states V = IR, where V = voltage (or pressure drop) across a circuit, I = the current (or flow) through the circuit, and R = the resistance in the circuit. SVR and PVR can be calculated as follows:

$$PVR = (PA_p - LA_p)/Q_p$$

$$SVR = (Ao_p - RA_p)/Q_S$$

where PA_p = pulmonary artery pressure; LA_p = left atrial pressure; Ao_p = aortic pressure; RA_p = right atrial pressure; PVR = pulmonary vascular resistance; and SVR = systemic vascular resistance.

When the partial pressure of dissolved O_2 is <100, the PO_2 portion of the equation can be ignored, and the flow can be calculated using the O_2 consumption and O_2 sat measurements alone.

$$\text{Systemic Flow } (Q_S) = O_2 \text{ consumption/(systemic arterial } O_2 \text{ content} - \text{systemic venous } O_2 \text{ content)}$$

$$\text{Pulmonary Blood Flow } (Q_p) = O_2 \text{ consumption/(pulmonary venous } O_2 \text{ content} - \text{pulmonary arterial } O_2 \text{ content)}$$

$$\text{Systemic Flow } (Q_S) = O_2 \text{ consumption/13.6} \times \text{Hgb} \times (\text{systemic artery saturation} - \text{mixed venous saturation})$$

$$\text{Pulmonary Blood Flow } (Q_p) = O_2 \text{ consumption/13.6} \times \text{Hgb} \times (\text{pulmonary vein saturation} - \text{pulmonary artery saturation})$$

ANGIOGRAPHY

Biplane cineangiography is performed to delineate intracardiac or vascular anatomy and to evaluate ventricular function. Images are obtained by injection of radiographic contrast agents through angiographic catheters positioned in appropriate locations. The

angiograms may be performed in posteroanterior and lateral projections or by angling the cameras to obtain cranial, caudal, left anterior, or right anterior oblique projections. Based on the site of injection and the information required, the injection may be performed with a power injector, delivering large amounts of contrast quickly, or by hand.

INTERVENTIONAL PROCEDURES

Valvuloplasty

Aortic valvuloplasty

A retrograde approach from the femoral artery generally is used, although an antegrade and transseptal approach from the femoral vein is preferred by some. In either approach, following hemodynamic evaluation and angiographic estimate of the aortic valve annulus, a wire is positioned across the valve, and a balloon catheter is advanced over the wire and positioned across the aortic valve. The balloon is then inflated and deflated quickly. The inflation of the balloon leads to a transient loss of CO, ↓ SBP, and occasionally may be accompanied by ↓ HR. These hemodynamic changes recover quickly on balloon deflation. Although complications of aortic valvuloplasty are rare, the anesthesiologist must be "prepared for the worst," which includes annular rupture and the creation of significant aortic regurgitation. Supplementation with oxygen and airway intervention, including intubation, should be considered for complicated interventional procedures.

Pulmonic valvuloplasty

After femoral venous or IJ access is obtained, the technique for balloon dilation of the pulmonary valve is nearly identical to that outlined above for the aortic valve. Loss of CO and ↓ HR are seen during the time of balloon inflation with this intervention as well. Although annular rupture is also a potential complication of this procedure, the creation of pulmonary insufficiency is of less concern and better tolerated than aortic insufficiency. Consider supplementing with 100% oxygen during interventional procedures, prior to the period of diminished cardiac output. If complications occur, airway intervention, including intubation, should be considered. Age-appropriate airway equipment and suction should be readily available.

Angioplasty

A number of transcatheter treatment options are available for management of **pulmonary artery stenoses**, including **balloon angioplasty** and **endovascular stent implantation.** Angioplasty has been shown to be highly effective in anatomically appropriate cases with a low complication rate. Hemodynamic and angiographic assessment of the lesion

is obtained, followed by selection of an optimal balloon catheter, based on both the size of the stenosis and surrounding "normal" tissue. Using the same "over-the-wire technique," a balloon is advanced and centered over the stenosis. Hemodynamic and angiographic data are assessed following each intervention. A high index of suspicion for complications—including dissection or pulmonary artery tear, obstructive intimal flaps, thrombi, and reperfusion pulmonary edema—is justified, as management may require ventilatory manipulations and/or emergent cardiovascular resuscitation. Consider endotracheal intubation prior to intervention since airway management in the presence of pulmonary edema and/or blood in the airway can be difficult to manage.

Balloon angioplasty of coarctation of the aorta may be performed for treatment of native or recurrent coarctation. Angiography of the aorta is performed to delineate the coarctation and estimate the dimension of the coarctated segment and the adjacent aorta. As with other angioplasty techniques, the balloon size is based on the dimensions of the stenotic area and surrounding vessel. Transient loss of lower body perfusion and ↓ HR are to be expected, as with balloon valvuloplasty, on inflation of the balloon. Pressure and angiographic data are obtained to determine adequacy of results and absence of complications. There is a 4–5% incidence of intimal tear and dissection that, in most cases, are nonprogressive. Rarely, aortic disruption may require emergent surgical repair.

Endovascular stent placement

Stent implantation in the pulmonary arteries or for aortic coarctation is used to maintain vessel diameter and decreased gradients in patients unresponsive to balloon dilation. Stents are mounted on balloon catheters, and the balloon/stent combination is advanced over a previously placed wire. A long sheath (originating in the groin or neck) is placed across the area of narrowing to prevent the stent from slipping off the balloon catheter as it makes its way through the heart or vessels. After the stent has been properly positioned, the long sheath is withdrawn to expose the balloon/stent combination. The balloon is inflated to expand the stent and appose it to the vessel wall. Placement of long sheaths, particularly through the right ventricular outflow tract (RVOT), can be difficult and may result in transient bradyarrhythmias and loss of CO.

Closure of congenital defects

Atrial septal defects (ASDs)

As many as 80–85% of secundum ASDs may be amenable to device closure in the cath lab. Most devices currently used include a left atrial disc with an occlusive membrane, a central spool or connecting pin, and a right atrial disc with an occlusive membrane. The membrane occludes flow through the defect, and within months, the device becomes

incorporated into the septum due to endothelialization. Concomitant use of TEE or TTE is indicated and serves three purposes: (a) to ensure an adequate rim for device placement, (b) to confirm appropriate placement of the device so as to avoid valvar structures, and (c) to confirm that once deployed, the device remains seated in the appropriate position. Thus, the use of GETA is preferred. Upon echocardiographic examination and confirmation of an adequate rim for device placement, a prophylactic antibiotic (usually a cephalosporin) is administered by the anesthesiologist. A sizing balloon inflated across the defect permits estimation of the stretched diameter. A long sheath is then placed across the defect over a wire. The device attached to the delivery cable is loaded in the long sheath and advanced to the left atrium. The left atrial disc is opened; the device is withdrawn until the left atrial disc is in contact with the atrial septum; then, the right atrial disc is opened, effectively "sandwiching" the atrial septum between the two discs.

Ventricular septal defect (VSD)

Closure with a device can be performed in the cath lab for isolated or multiple muscular VSDs, as well as perimembranous defects. The technique requires establishment of a continuous AV guide wire loop across the defect. Most often, the wire course is from the femoral vein, through the right atrium, into the RV, across the VSD, out the aortic valve, around the aorta, and out the femoral artery. The device is then deployed via a long sheath placed across the VSD through the RV aspect. Hemodynamic compromise may be seen with tension on the wire if aortic or tricuspid insufficiency is induced. Transient arrhythmias are routine while crossing the VSD and deploying the device. Great care must be taken to avoid entrapment in the mitral, aortic, and tricuspid valves during device deployment. In addition to fluoroscopy, TEE or TTE is used to guide placement of the device. Recent improvements in the devices have significantly reduced the morbidity of this procedure.

Coil occlusion

Aortopulmonary collaterals, AVMs, Blalock-Taussig (B-T) shunts, venous collaterals, coronary artery fistulae, and patent ductus arteriosus (PDA) have all been successfully occluded using the technique of coil embolization. The embolization coils consist of a metal wire, either stainless steel or platinum, and may additionally have Dacron strands, which are available in multiple sizes, lengths and shapes. As with other device procedures, antibiotic prophylaxis is indicated. Although PDA or coronary artery fistula embolization may obviate the need for surgery, most embolizations serve to either reduce the cardiac workload by decreasing the amount of shunting or simplify a planned surgical procedure.

The technique for coil closure of collaterals or other communications is straightforward. A catheter is placed in the vessel to be occluded, and a selective angiogram is done to delineate the anatomy and diameter of the vessel to be closed. Coils that are slightly larger than the diameter of the vessel are used because the vessel will distend when the coil is deployed. Using a long "pusher" wire, the coil is advanced through the catheter and deployed in the vessel. Repeat angiography is performed to confirm complete closure. If residual flow remains, additional coils are placed. Coil dislodgement and embolization to a distal blood vessel are the most common complications. In general, the errant coil can be retrieved in the cath lab without much difficulty and a new coil of a larger size placed to occlude the vessel.

OTHER PROCEDURES

Endomyocardial biopsy is commonly performed for rejection surveillance in patients following cardiac transplantation. It also may be performed in patients presenting with acute onset of cardiomyopathy for histopathologic Dx of myocarditis. The preferred site for obtaining cardiac biopsy is the RV aspect of the intraventricular septum. The specimen is obtained with a biopsy forceps advanced to the RV through a long sheath. It is usual to obtain four to five specimens to improve the diagnostic gain, as the histopathologic changes can be patchy. Complications of endomyocardial biopsy include cardiac perforation and tricuspid valve damage. GA is required in patients with compromised airway and/or cardiopulmonary status from lymphoproliferative disease or obesity 2° to steroid therapy. With right heart catheterization and biopsies, the arms are usually at the patient's side. However, with annual studies, as with all studies requiring left heart catheterization, the arms are pulled upward toward the head. Though this permits observation of the IV site, utmost attention to detail in padding pressure points is needed, specifically to avoid brachial plexus injury.

A variety of other transcatheter therapeutic procedures may be performed in the cardiac cath suite. **Rashkind balloon atrial septostomy, static balloon septoplasty, Brockenbrough transseptal needle puncture,** and **radiofrequency-assisted perforation** of the pulmonary valve or the atrial septum are all less commonly used than the procedures described above, but routinely are undertaken in high-volume cath labs.

ELECTROPHYSIOLOGY STUDY (EPS)

Patients with atrial or ventricular arrhythmias may require either diagnostic or therapeutic interventions in the cath lab. EP studies are catheterization procedures in which intracardiac electrical signals are recorded via specialized catheters that can

both record electrical activity and stimulate the heart. These studies often are used to make a Dx of the mechanism of arrhythmia, assess the hemodynamic impact of the arrhythmia, assess efficacy of pharmacologic therapy, and map the location of abnormal conduction pathways or automatic foci. Although routine studies usually take 2–3 h, some may be quite lengthy. For all procedures, access is obtained via the RIJ or femoral vein; thus, the head may be turned to the side. Though providing easier access for the cardiologist, it makes airway management more tenuous. Pressure on/near the trachea can promote coughing.

Radiofrequency ablation (RFA) is a procedure in which abnormal electrical conducting pathways or automatic electrical foci (identified by EPS) are destroyed using the application of RF energy delivered through a deflectable electrode catheter. This procedure was first described in pediatric surgery in 1991, but has rapidly become a preferred therapeutic option for supraventricular tachycardia in this population. On some occasions, RF lesions must be placed close to other critical structures in the heart (e.g., AV node).

With advances in technology and an increased understanding of high-risk pediatric patient populations, **transvenous pacemaker** and **implantable cardioverter defibrillator (ICD)** placements are becoming more common in the pediatric population. Pacemaker placement has become more common as data have accumulated regarding the risk of sudden death in patients with congenital complete heart block, as well as increased survival with postop heart block. New indications for ICD placement in patients with long-QT syndrome, congenital heart disease, and hypertrophic cardiomyopathy have increased the number of ICD implantations in the last 5 yr. These procedures are commonly performed in the cath lab under GA. However, for the placement of loop recorders and subcutaneous ICDs, light sedation can be considered.

Transcatheter valve placement

Pulmonary valve

The most common site for interventional valve replacement is the pulmonary valve. These cases are performed via the femoral or jugular veins. A stiff wire is placed in secure position from the access site to a distal PA branch. A long sheath is then placed across the RV outflow tract and is used for angiography and intervention. There are multiple steps in this procedure involving first pulmonary valvuloplasty of the conduit, bioprosthetic valve, or native pulmonary valve (see pulmonary valvuloplasty above). Contained conduit tear occurs in about 5% and does not have any hemodynamic consequence. The next step involves bare metal stent placement across the site of intended valve deployment in order to open up stenotic and calcified conduits or to

provide a landing zone in a native outflow tract. A covered stent can be used to cover more sizeable tears. The same hemodynamic instability can occur during stent placement as during valvuloplasty with the added risk of stent malposition or embolization. After proper stent placement, the transcatheter valve is then prepared and delivered. The manipulation of the delivery system to properly position the valve can cause short-lived dysrhythmias. Repeat hemodynamic measurements and angiography are performed after valve deployment.

Tricuspid valve

The procedure is similar to PV in that a stiff wire is positioned across the tricuspid valve. Balloon valvuloplasty is performed to open up the stenotic leaflets and to size the bioprosthetic tricuspid valve. The transcatheter valve is then deployed within the tricuspid valve. Again, with balloon angioplasty and valve deployment, there can be a temporary ↓ CO and ↓ O_2 saturations that return once the balloon is deflated.

Aortic valve

This is a much more common procedure in adults; however, AV replacements occasionally do occur in pediatric patients. The approach is usually from the femoral artery although a hybrid procedure can be done with surgeons and an LV apical approach. From the femoral artery, the AV is crossed retrograde and a stiff wire is positioned in the LV. Valvuloplasty may first be performed (see Aortic Valvuloplasty). For valve deployment, rapid ventricular pacing (of the RV) is performed, and TEE is used to confirm proper placement. Potential complications include aortic regurgitation or paravalvular leak, aorta injury secondary to the wire or delivery system, and other vascular injury.

ANESTHETIC CONSIDERATIONS

Claudia Benkwitz and Lisa Wise-Faberowski

PREPROCEDURE

Cardiac catheterization and interventional procedures in children, ranging from those requiring simple diagnostic procedures to those requiring complex interventional procedures, such as balloon angioplasty/valvuloplasty, stent placements, or closure of shunts have facilitated care of younger, smaller, and sicker patients. These patients are often challenging for the anesthesiologist due to their abnormal cardiac anatomy and physiology. Many of them have undergone repeated catheterizations and have had multiple anesthetics. All patients require a thorough preanesthetic evaluation with

emphasis on cardiorespiratory function and associated comorbidities (almost 30% of patients show associated anomalies or syndromes with Down syndrome being the most common). Most children will follow the same NPO protocol as they would for surgery. Particular attention should be paid to patients with single-ventricle physiology (Fontan circulation), who are dependent on their venous return for hemodynamic stability and oxygenation as well as being prone to shunt thrombosis, specifically when dehydrated. In such patients, early establishment of IV access to prevent dehydration is advisable. Clear liquids can be given up to 2 h before surgery. Similarly, Williams syndrome patients with pulmonary, aortic outflow tract, and/or coronary obstruction are at risk of sudden death upon anesthetic induction if they have an inadequate preload.

Previous anesthesia	✓Surgical, interventional, and radiologic procedures; h/o difficult access; endotracheal tube size and anesthetic techniques; problems with previous anesthetics
Family history	✓Family history for anesthetic-related problems; h/o malignant hyperthermia
Prematurity	✓Gestational age. Need for postop admission and apnea monitoring if <55 wk postconceptual age; any associated clinical problems
Neurologic	✓Head ultrasound in neonates to rule out ischemia and hemorrhage; note preoperative neurologic status due to risk of embolism during procedure; h/o seizures or developmental delay. Heparinization during cardiac catheterization may increase the risk of bleeding.
Craniofacial and airway	✓H/o difficult airway; any surgery to the airway; h/o tracheal stenosis due to multiple intubations in the past; stridor due to laryngo- or bronchomalacia; h/o loose teeth. DiGeorge (22qll deletion) and William syndrome patients may present with abnormal airway anatomy. Trisomy 21 patients and post–heart transplant patients on steroids may present with obstructive airway disease. **Tests:** Recent bronchoscopy, imaging of the airway
Respiratory	✓Current problem(s): ✓Respiratory reserve (i.e.,

	playing activities, respiratory rate, nasal flaring, intercostal/subcostal retractions, diaphoresis). ✓H/o cyanosis, chronic cough, steroid use for RAD and other chronic respiratory problems → ensure that they are under optimal control. ✓H/o recent URI → risk of adverse perioperative events. Note: frequent "URIs" along with FTT may be signs of pulmonary overcirculation in the setting of large L → R shunts as opposed to being of infectious etiology ✓Patients with pulmonary hypertension may have obstructive sleep apnea. ✓Cardiac transplant patients can develop lymphoproliferative disease, which results in redundant lymphoid tissue in the pharynx and epiglottis → possible airway obstruction. ✓Requirement for supplemental O_2, CPAP, BiPAP, nitric oxide. Medications for pulmonary HTN should be continued. **Tests:** SpO_2, CXR to r/o infiltrates, CHF and cardiomegaly, PFTs. Compare with baseline. Assess perfusion scan for distribution of PBF if necessary.
Cardiovascular	✓Current problem(s): ✓Past surgical history, pacemaker, ICD, etc. If the patient has a pacemaker → check settings, indication(s), underlying rhythm, pacer dependency, and last interrogation. ✓Existing shunts → may affect anesthetic plan and FiO_2. ✓Assess cardiopulmonary reserve (e.g., exercise tolerance, diaphoresis, SOB, feeding difficulties, poor weight gain). ✓H/o syncope, hypoxic spells, and chest pain. Transplant patients may develop CAD. ✓Arrhythmias, palpitations, murmurs, pulses in all extremities. **Tests:** SpO_2, ECG; BP (upper/lower extremity) ✓Recent echo, cardiac catheterization +/− CT/MRI/MRA reports
Gastrointestinal	✓Feeding difficulties, reflux due to chronic use of steroids. May have G-tube/Nissen. ✓Some single-ventricle patients may have hepatic dysfunction and protein-losing enteropathy (↑ risk

	ascites, pleural/pericardial effusion, infection). Alagille patients may also present with hepatic dysfunction and hyperbilirubinemia. SaO_2 saturation measured using pulse oximetry or NIRS may pose difficulties as high bilirubin levels can affect light absorbance.
Renal	✓Patients with CHF are frequently on diuretics and/or ACE inhibitors/digoxin → expect hypovolemia and potential electrolyte disturbances (i.e., ↑ ↓ K^+). ✓Transplant recipients may develop renal dysfunction due to antirejection medication or HTN. ✓Patients may have had renal insult during previous surgery. **Tests:** ✓BUN and Cr as these patients are also at risk for renal injury due to contrast and also to guide hydration therapy.
Endocrine/steroid	✓Transplant patients are on steroids. ✓for other endocrine concerns.
Hematology/ immunology	✓History of previous transfusions and reactions. Immunologic deficiency that may affect the type of blood transfusion (e.g., neonates require CMV-negative blood and products). **Tests:** Recent hematocrit
Syndromes	✓For coexisting syndromes and associated anomalies
Ob/Gyn	✓Last menstrual period
Vascular	✓H/o thromboembolism. H/o difficult access and vascular occlusion
Current medications	✓Stop warfarin before cardiac catheterization. Anticoagulate with heparin if needed; d/w cardiology. ✓Coagulation studies prior to procedure. ✓Antiarrhythmic drugs are usually stopped prior to EP studies unless the arrhythmia is frequent and poorly tolerated. Hold diuretics and ACE inhibitor starting the night before due to ↑ risk for hypotension

	following induction; continue other cardiac meds.
Laboratory	✓CBC: Use Hgb/HCT baseline to determine need for transfusion; ↑ Hgb/HCT suggests chronic hypoxia; transfusion threshold will vary depending on patient age and comorbidities. Severe anemia should be corrected prior to cath. ✓Have T&C blood available in the catheterization lab for procedures with risk of increased bleeding. ✓WBC: if the child has a h/o fever and recent URI. ✓Electrolytes/Bun and creatinine, especially if the patient is on diuretics and/or digitalis. ✓Coagulation studies. ✓Drug levels (e.g., digitalis, antiseizure medications) to ensure therapeutic range. Pregnancy test must be done the morning of surgery if patient has attained menarche.
Premedication	✓Midazolam 0.5–1.0 mg/kg po or via G-tube. Ketamine 5–8 mg/kg po or via GT may be added in either extremely uncooperative patients or those with significant hemodynamic instability (i.e., severe AS, PAH, ventricular dysfunction), in whom an inhalational induction would not be safe. In patients unwilling to take PO premed, nasal dexmedetomidine 1–3 mcg/kg may be used, however may take 30–45 min to reach full effect. Be cautious in patients with OSA as they are more sensitive to respiratory depression. Cyanotic patients should have SaO_2 saturation monitored before and continuously after premedication. Antibiotics are given to patients as required for SBE prophylaxis per most current (2007) AHA guidelines and for those undergoing interventional procedures. In patients scheduled for EP studies in whom anxiety is a known precipitant of the arrhythmia, preop anxiolysis is a relative contraindication as it may result in a false-negative study.
NPO	ASA fasting guidelines should be followed (see p. D-1, NPO guidelines). Prolonged NPO in single-ventricle physiology and other shunt-dependent lesions should

	be avoided, as shunt flow might decrease with dehydration → ↑ viscosity → ↑ shunt thrombosis. Special consideration for patients with hypertrophic cardiomyopathy (HCM) and Williams syndrome patients.
Equipment	Transport patient to and from the catheterization lab with a pulse oximeter and other monitors as appropriate. Equipment to manage difficult airway and hemodynamically unstable patients should be readily available (e.g., difficult airway cart, I-stat, arterial line, blood pump, pumps to infuse vasopressors, pacemaker, defibrillator, NIRS).

INTRAPROCEDURE

Anesthetic technique

Cardiac catheterization can be done under sedation, monitored anesthesia care, and general anesthesia. Intravenous access is usually in an upper extremity as the lower extremities may be needed for unilateral or bilateral femoral access by the cardiologist. Intravenous contrast administered in an IV in the left upper extremity may be requested to confirm vascular patency for transvenous pacemaker wire placement. A spontaneously breathing patient is preferable so as to mimic normal baseline cardiac and respiratory physiologic state and to perform subsequent hemodynamic calculations. General anesthesia with an ETT may be a safer option to provide a secure airway for neonates and younger children as the surgical field often covers the entire patient. However, there is wide variety of practice among different institutions with regard to airway management. Patients with moderate to severe pulmonary hypertension present extra challenges, and care for these patients differs as well among institutions. Because physiologic changes associated with intubation, and more likely extubation, might result in a pulmonary hypertensive crisis in these patients, sedation is favored by some anesthesiologists. However, others prefer muscle relaxation and ETT placement, as hypoxia-hypercarbia related to an unsecured airway can also lead to life-threatening increases in PAP. Older children or patients undergoing procedures of shorter duration with no other significant comorbidities may tolerate incremental IV sedation with local anesthesia.

A large variety of drug regimens can be used to provide anesthesia/sedation for children undergoing cardiac catheterization procedures. These include propofol, ketamine, remifentanil, dexmedetomidine, midazolam, fentanyl, and morphine infusions either

alone or in combination. While all have been used successfully, bradycardia/sinus arrest, heart block, hypotension, transient increase in systemic and pulmonary pressures (SVR > PVR) after rapid bolus injection, as well as insufficient anesthesia/analgesia and prolonged recovery have been reported.

Several approaches have proven safe and effective. Currently, there is no consensus on what constitutes optimal anesthetic management. Propofol and ketamine, propofol and dexmedetomidine, dexmedetomidine and ketamine, as well as volatile anesthetics, in combination with spontaneous ventilation or GETA, have all been safely employed. Often, there is institutional preference for one or the other, based on previous clinical experience.

A few sample regimes are reviewed here:

- Propofol 10 mg/ketamine 1 mg or "ketofol" at a dose of 50–200 mcg/kg/min
- Propofol (50–200 mcg/kg/min) and dexmedetomidine (0.5 mg to 2 mcg/kg/h). This regimen eliminates concerns about ketamine-related secretions with the attendant need for glycopyrrolate, but may delay discharge from PACU due to prolonged sedation.
- Dexmedetomidine (2 mcg/kg/h) and ketamine (20 mcg/kg/min) supplemented by additional ketamine +/− midazolam as needed

Independent of what technique is ultimately used, normoxia and normocarbia are key for these procedures, since hypoxemia, hyperoxemia, acidosis/alkalosis, and PPV all exert significant disturbances in pulmonary vascular resistance. PPV decreases systemic venous return, particularly in the setting of depleted intravascular volume. This is of particular relevance in those patients with restrictive RV or single-ventricle physiology, where pulmonary blood flow is mostly passive and depends on adequate preload. When possible, patients with Glenn and Fontan physiology should be allowed to breathe spontaneously. This improves systemic venous return, pulmonary blood flow and hence systemic blood flow, and cardiac output. Both circulations are dependent on passive pulmonary blood flow as opposed to a shunt physiology (BT or central), which provides active pulmonary blood flow. Pulmonary blood flow and adequate cardiac output depend on PVR.

ECMO backup should be considered in patients with poor ejection fraction and critically ill neonates, as well as for some patients with severe PAH or Williams Syndrome, who have a significantly higher mortality regardless of the anesthetic technique. Rarely, for certain interventional procedures, surgical backup and OR availability may have to be prioritized. Significant preparation and coordination are necessary to transport a newborn from the delivery room to the catheterization lab for

emergent procedures such as an atrial septostomy.

Induction	Standard inhalation or iv induction (see p. D-1). As in all patients with CV morbidities having anesthesia, the choice of anesthetic drugs must include careful consideration of their effects on myocardial contractility, preload and afterload, pulmonary and systemic vascular resistance, and respiration. FiO_2 should also be carefully controlled in ductal or shunt-dependent lesions where a balance of Q_p:Q_s is desired.
Maintenance	General anesthesia with volatile agents (e.g., sevoflurane) or TIVA techniques as previously described may be used. O_2 supplementation via mask/nasal cannula might be appropriate in many cases; however, an ETT/LMA to protect airway should be strongly considered in high-risk patients and/or interventions. For EP procedures, the Supreme LMA with the orogastric port allows for ease in placement of a transesophageal pacing probe if needed. EP procedures are long; thus, an LMA provides for not only a protected airway during IJ access, but allows for controlled ventilation when minimal catheter movement is desired. Most catheterizations require the patient to be maintained on room air for accurate SaO_2 sat and pressure measurements. With higher FiO_2 (>0.3), firstly, it will be necessary to consider the dissolved oxygen fraction when calculating Q_p with the Fick equation. Secondly, high inspired FiO_2 will likely result in a reduction of PVR, thereby increasing the Q_p/Q_s ratio. More importantly, any FiO_2 changes should be communicated with the interventionist so that Q_p:Q_s calculations can be corrected. Similarly, routine use of antisialagogues should be avoided so that the heart rate remains at baseline. The same holds true for other vasoactive drugs, such as ephedrine and phenylephrine. If deemed necessary, and after other measures have failed, (e.g., adjustment of anesthetic depth, volume resuscitation, etc.), their intended use should be

	communicated prior to administration. EP studies are best managed with iv propofol 75–200 mcg/kg/min, because this agent has the least ability to induce dysrhythmias or to interfere with the induction of tachyarrhythmias for diagnostic purposes. Sevoflurane or isoflurane (<1 MAC) as well as a combination of propofol and ketamine (7.5–20 mcg/kg/min) is also acceptable. In contrast, remifentanil and dexmedetomidine have both been shown to significantly depress sinoatrial and atrioventricular nodal function and are therefore not desirable in patients undergoing EPS for ablation of SVT or in patients with prolonged QTc. In patients with a history of prolonged QT interval, TIVA (propofol/remifentanil) has been recommended since both drugs have been shown to have none to minimal effects on the QTc interval. Caution should be exercised with reversal agents and various antiemetics, including 5-HT_3 receptor antagonists, since they can also prolong the QT interval. Since the electrophysiologist is often aware of the likely underlying mechanism of the arrhythmia, this allows for adaptation of the anesthesia technique that is the least likely to interfere with the patient's electrophysiology. Heparin 50–100 U/kg is given for patients with arterial sheaths. The activated clotting time (ACT) should be in the range of >200–300 sec during the procedure and <175 sec when the catheters are removed. Once the sheath is removed, a considerable amount of time is needed to attain hemostasis. NO +/− inhaled prostacyclins may be required for the Rx of pulmonary HTN. In the latter case, check with RT to ensure the appropriate setup for administration via either ventilator or nasal cannula is available. A special injector is needed when administering NO via nasal cannula.
Emergence	If the patient's clinical status allows for deep extubation, it can be done to prevent coughing. Interventional procedures and EP/ablation likely require hospital admission for observation. For neonates with SV physiology or other patients with complex underlying

	disease, comorbidities or significant hemodynamic instability, a prearranged ICU bed might be advisable.	
Blood and fluid requirements	IV: 20–22 ga × 1 BSS PRBCs Fluid warmer	A second volume iv may be desirable for interventional cases. The cardiologist will also have a venous access line that can be used if necessary. Interventional procedures may cause tearing of vessels and/or myocardium and can cause abrupt hemorrhage; therefore, blood must be available in the room. Neonates can lose significant blood during access and sampling and may also require transfusion. Follow serial Hcts. In patients who are TPN dependent or receiving G-tube feeds, hypoglycemia may occur. Glucose monitoring is helpful and the administration of glucose containing fluids may be indicated.
Monitoring	Standard monitors, including ± arterial line ± Foley catheter ± NIRS	Respiratory monitoring can be performed via oxygen masks or nasal cannulae adapted to measure CO_2 flow in a spontaneously breathing patient. Discuss with the cardiologist if A-line access is required. Frequently, the femoral artery is cannulated for the catheterization and may be available for use. However, access may be limited at critical times (e.g., stenting or coiling) and not available during a critical induction; therefore, a peripheral

		arterial line may be desirable. ST-segment analysis (requiring proper lead placement) is useful in patients with a tenuous hemodynamic state, ductal-dependent lesions, or Williams syndrome. CAD is the leading cause of death in posttransplant patients. For cases of long duration, consider Foley catheter placement. Monitor temperature. In ductal-dependent lesions, monitoring of both pre- and postductal saturations may be helpful. Cerebral oximeter monitoring is recommended in single-ventricle and in other cyanotic lesions as pulse oximetry is a poor predictor of changes in cerebral saturation. Arterial line also plays an important role in patients with poor cardiac function and/or placement of melody valve.
Positioning	✓pad pressure points	Supine, arms may be flexed above the head to allow fluoroscopy of the chest. Adolescent patients are at risk of brachial plexus injury. Keep extension <90°.
	✓cover eyes	All ECG leads and monitoring wires must be cleared from axilla and chest to allow fluoroscopy. Corneal abrasions are not uncommon as often the patient's face is covered by surgical drapes and cardiologists may rest their arms, hands, and instruments on

		the patient's face.
Complications	Airway obstruction	Rx: Airway support, oral/nasal airway, LMA. Intubate if necessary.
	Aspiration	Rx: Suction, and secure airway if needed. Bronchodilators, H_1- and H_2-blockers if needed. CXR. O_2 monitoring. Admit if postop oxygen requirement persists.
	Arrhythmias	Determine etiology, whether hemodynamically stable or not. Cardiovert/defibrillate/emergency drugs as necessary. Check electrolytes and ABG. Consult EP.
	Hemorrhage (access site, rupture of vessels, tamponade)	Rx: Fluid resuscitation with crystalloid, 5% albumin and/or blood; vasopressors as needed. Secure airway, 100% FiO_2. Check Hct.
	Valvular incompetence (severe regurgitation/annular rupture)	Rx: Secure airway, volume resuscitation, vasopressor support, consult surgeon and proceed with emergent surgical repair if needed.
	Hypoxemia	Try to determine the cause. Check Hct in single-ventricle patients. Rx: Airway support; increase FiO_2. Intubate and ventilate as needed.
	Pulmonary hypertensive crisis	Avoid hypoxia, hypercarbia, acidosis, and pain/agitation. Rx: FiO_2 100%, deepen anesthetic if tolerated. Consider NO and systemic vasopressors.
	Contrast reaction/anaphylaxis	Rx: Support airway, 100% FiO_2, intubate if needed: phenylephrine, volume

		resuscitation, steroid, antihistamine, H_2-blocker.
	Hypothermia	Especially neonates. Rx: Forced-air warming device, heat lamp. Increase environmental temperature.
	Air embolism	Rx: 100% FiO_2; identify and occlude source; Trendelenburg; fluid resuscitation; vasopressor support. Aspirate air from central access if possible.
	Positioning injury	Especially brachial plexus injury. Careful documentation, consult neurologist. Prevention = diligent positioning is key.
	Vascular thrombosis/stroke	Support airway, 100% FiO_2, intubate if needed; obtain emergent brain CT; consult neuro/stroke team.

POSTPROCEDURE

Complications	Hematoma at access site Ischemic limb Emergence delirium Pericardial tamponade Corneal abrasion Recurrent arrhythmia
Pain management	Postop analgesia is usually managed with acetaminophen, or fentanyl; rarely are long-acting opioids (morphine, hydromorphone) needed; care should be taken to avoid hypoxia or hypercarbia. The access sites are commonly infiltrated with local anesthetic by cardiologist. Use of ketorolac should be discussed with the cardiologist.
Tests	CXR, if indicated

TTE, if clinical picture is suggestive of tamponade

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PEDIATRIC ONCOLOGIC PROCEDURES

Kristin Sun, Neyssa Marina, Rebecca Claure, and Brenda Golianu

Pediatric oncology patients represent a unique population of patients who come for frequent procedures requiring anesthesia over the course of several years. These patients require anesthesia for a variety of procedures: diagnostic imaging, surgical resection, radiation therapy, central line placement, and multiple minor procedures for staging and intrathecal chemotherapy. The pediatric anesthesiologist is in the position of caring for these patients for long periods from initial diagnosis, through years of induction and maintenance therapy, and finishing with end of therapy procedures. More than in other patient populations, the anesthesiologist plays a critical role in a child's experience over several years in the hospital environment.

Pediatric oncology patients now often have a 5-yr survival rate of over 80%. It is important to keep in mind the possible effects of anesthesia and sedation on the developing brain. Current recommendations are primarily based on extrapolating animal studies to humans. The main concerns are in patients under 3 yr of age who are undergoing procedures over 3 hours or are having multiple anesthetics. Oncology patients face a unique combination of stressors from illness, hospitalization, and multiple painful procedures that may affect psychoemotional development. Anesthesiologists and oncologists need to be mindful of these issues and be prepared to discuss the risks versus benefits of anesthesia. Conscious sedation may be an alternative to GA; however, most children under 12 yr of age will be better served by a brief GA for each procedure.

When patients first present for evaluation of possible malignancy, either solid organ tumors or hematologic cancers, they may undergo multiple imaging studies such as computed tomography scans of the chest, abdomen, and pelvis, bone scintigraphy, and magnetic resonance imaging scans. These studies are not painful, but require patients to be immobile for anywhere from a few minutes to over an hour. Sedation or general anesthesia is usually required, especially in patients under 5 yr of age.

For solid organ tumors of the brain, chest, abdomen, pelvis, and bone, pediatric patients may undergo daily doses of radiation therapy over the course of several weeks before or after resection. Although radiation therapy may only be a few minutes long, the specific anatomic dosing requires the patient to be immobile, again requiring multiple brief anesthetics. Solid organ tumors involve major surgical resection, or diagnostic tissue biopsy, either before or after concomitant radiation therapy or chemotherapy.

In the initial evaluation of hematologic diseases, patients must undergo evaluation of bone marrow with bone marrow aspirates and/or biopsies. Involvement of the cerebrospinal fluid is evaluated with a diagnostic lumbar puncture (LP). These patients then go on to require repeat bone marrow procedure and serial LPs for staging and for

intrathecal chemotherapy dosing when indicated. Approximately 50% of leukemia patients will develop CNS disease without intrathecal prophylaxis.

In addition to the above diagnostic and treatment procedures, the majority of pediatric oncology patients undergo placement of indwelling central venous catheters, including percutaneous intravenous central catheters (PICC), Hickman or Broviac catheters, or portacaths. With the exception of PICC placements, most of these catheters are inserted under anesthesia and in a sterile operating room environment. When full therapy is completed, central venous line removal again requires sedation or general anesthesia.

PREPROCEDURE

Pediatric oncology patients are followed very closely during their treatment, undergoing at least monthly physical exams to evaluate for side effects of therapy to determine whether proceeding with the prescribed therapy is indicated. When these patients require invasive procedures, it is essential to work with the primary oncology team to evaluate whether the requested procedure is elective or urgent. All patients undergo routine periodic blood counts to determine the safety of continuing chemotherapy dosing. Occasionally, a procedure, such as LP for intrathecal chemotherapy, may be postponed if blood counts have dropped too low. Checking with the primary team is important to determine if the procedure is to proceed as planned. It is important to remember that the toxicity of chemotherapeutic drugs may affect every organ in the body beyond the target cancer tissue.

A thorough preanesthetic history and physical exam should be performed for all major and minor cases and the standard NPO protocol applied.

Respiratory and airway	Major surgical procedures for patients with symptoms of upper respiratory infection (e.g., cough, fever) are postponed unless there are circumstances (CNS disease, bone marrow relapse) that require the treatment to proceed. In those circumstances, LPs and BMAs can be performed either with sedation or with the use of local anesthesia. A number of chemotherapeutic agents have been associated with pulmonary toxicity: bleomycin (2–5%), BNCU (20–50%), busulfan (2.5–11.5%), cyclophosphamide (rare), and methotrexate (rare). The use of these agents requires follow-up evaluation to make certain

the patient is able to proceed with his/her procedure. Patients who present with an anterior mediastinal mass may present with signs and symptoms of superior vena cava compression or with superior mediastinal syndrome with tracheal compression. It is critical to recognize and evaluate patients with a mediastinal mass prior to inducing general anesthesia. The adolescent patient presenting with a new diagnosis of Hodgkin or non-Hodgkin lymphoma or acute lymphoblastic leukemia should be carefully assessed for the possibility of a mediastinal mass. Younger patients may also present with symptoms of anterior mediastinal compression. Careful preop evaluation should be made for respiratory symptoms or compromise, as well as obtaining a chest x-ray, and possibly even chest CT scan. Careful consideration should be given to performing diagnostic procedures under minimal sedation, since general anesthesia in these patients can result in significant cardiorespiratory complications and fatality. Preop treatment with irradiation or corticosteroids may reduce tumor size; however, this may also change tissue pathology. Key features in GA management, if absolutely required, are the maintenance of spontaneous ventilation, no paralysis, having a rigid and flexible bronchoscope immediately available, and preparing for postop ICU monitoring.

Routine airway assessment is essential. Chemotherapy may result in severe, painful oral mucositis or stomatitis. Patients are also more susceptible to infectious viral oral lesions, such as herpetic lesions, and may require isolation. Frequent URI may occur due to immune compromise. Fever, loose cough, wheezing, or coarse BS requires evaluation and likely postponement of any procedures.

Tests: All pediatric oncology patients undergo

	weekly complete blood counts to evaluate for toxicity from therapy. In addition, patients who have received any of the agents associated with pulmonary toxicity undergo pulmonary function tests at regular intervals. Although some chemotherapy agents are associated with pulmonary toxicity, the cumulative doses of those agents are such that most patients are asymptomatic. CXR may be indicated to evaluate upper respiratory symptoms.
Cardiovascular	Anticancer treatment can produce a wide range of cardiac toxicity. Anthracycline-induced cardiomyopathy, while rare, can lead to significant cardiovascular compromise. This complication is associated with the use of cumulative doses >300 mg/m. Cardiomyopathy is insidious in origin and most commonly presents many years following treatment with doxorubicin, daunorubicin, or amacrine. The use of high doses of radiotherapy is also associated with cardiac complications, including constrictive pericarditis, atherosclerosis, and early myocardial infarction. Signs of CV toxicity may include SOB, ECG changes, rhythm disturbances, pericarditis, or CHF. Preop hemodynamic status needs to be evaluated. Patients on steroid therapy may develop steroid-induced hypertension. It is important to obtain a careful history of any antihypertensive medication, especially a record of medications taken on the day of the procedure or surgery. Conversely, patients who are dehydrated or anemic may become significantly hypotensive after induction of general anesthesia. These patients may require preop hydration, and vasoactive medication should be available for intraop use. Patients actively receiving chemotherapy may also have 3rd spacing and may need aggressive hydration and/or pressor support. **Tests:** Patients receiving any agents associated with cardiac toxicity are monitored at yearly interval with

	echocardiograms and electrocardiograms. These tests do not need to be performed routinely prior to a procedure requiring GA unless history and physical exam suggest a change in the patient's clinical condition.
Hematologic	Bone marrow suppression occurs with all cytotoxic drugs. The anesthesiologist and oncologist need to work together to evaluate anemia and thrombocytopenia. Due to myelosuppression, anemia is common in oncology patients. In assessing the degree of anemia in a given patient, it is important to assess his or her overall clinical appearance and hemodynamic compensation. A very low hemoglobin level <6–7 increases the patient's risk of significant BP instability during GA. For the procedure planned, can the patient tolerate the stress from anesthesia, and is there further blood loss expected during the procedures? Patient assessment with expectations for the surgical/diagnostic procedure will determine whether red blood cell or platelet transfusion is required preop. If no transfusion is planned and the patient is anemic, prepare fluid replacement, colloid (e.g., albumin), and/or vasoactive support. **Tests:** Complete blood counts are performed once to twice a week in all pediatric oncology patients. These tests help determine whether continuing with the prescribed therapy is indicated. Baseline platelet and hemoglobin counts need to be measured before proceeding with lumbar punctures and bone marrow aspirates.
Neurologic	Peripheral neuropathies due to vincristine, vinblastine, cisplatin, and procarbazine may be present. Patient should be carefully positioned and padded. These patients may require additional attention to preop pain management and anxiolysis, with supplemental intraop and postop pain control.
GI/Hepatic	Many chemotherapy agents cause significant nausea

	and vomiting. Patients may present with these symptoms preop or may be dehydrated due to vomiting and poor fluid intake. Hepatotoxicity may also occur from chemotherapy or radiation therapy. Asparaginase can induce severe pancreatitis. ✓LFT, amylase, lipase.
Endocrine	Most cancer patients are treated with corticosteroids at some point in their therapy. Steroids can lead to weight gain, suppression of the stress response, and rarer complications such as psychosis. In addition, steroid-induced hyperglycemia may require pre- and postop glucose monitoring and insulin therapy.
Premedication	For major procedures, individualized premedication is recommended. Since oncology patients often have an indwelling intravenous catheter, or are familiar with having venipunctures and iv placed, iv induction is frequently used. Intravenous midazolam may be easily administered when required for anxiolysis. Some patients may require premedication with oral midazolam or lorazepam, if they do not have iv access. However, many radiology and minor oncology procedures may be performed in a less restrictive environment, such as a procedure room, where the parents may stay with their child through induction. For the very anxious patient, or a child who has undergone significant emotional trauma in the hospital environment, preop counseling with a child life specialist or psychologist can be very important and helpful in alleviating fears and helping the child adjust to the stress of frequent hospital/procedure visits.

INTRAPROCEDURE

Anesthetic technique

For major surgical procedures, GETA management is indicated. Below are recommendations for pediatric oncology patients undergoing minor procedures.

Procedures such as LPs and bone marrow aspirates are usually short, 10–20 min. Adolescent patients may be evaluated by their provider or the anesthesiologist for possible conscious sedation. Younger patients usually require brief general anesthesia —inhalation or intravenous.

Induction	For lumbar punctures in the patient without iv access, a brief inhalation anesthetic may be adequate. However, since most patients will have iv access, intravenous anesthesia with propofol provides adequate anesthesia, causes less nausea, and allows a rapid recovery. Standard protocol should include meticulous sterile technique in using the central venous line and confirmation of blood aspiration and catheter flow, both prior to beginning induction and after repositioning the patient in a lateral decubitus position. On positioning a patient for lumbar puncture in the left lateral position, it is possible to dislodge the portacath needle, with resulting extravasation of fluid or propofol into the subcutaneous tissue.
Maintenance	Intermittent boluses of propofol 0.5–1 mg/kg may be used or an infusion of 200 mcg/kg/min. N_2O or low-dose sevoflurane may be added. For BMA, add fentanyl 1 mcg/kg or hydromorphone 1–2 mcg/kg for postop pain management. The provider performing the procedures infiltrates the area with lidocaine. For Broviac catheter removals, heparin must be removed from the catheter and discarded before use for induction. A sufficient bolus of propofol (e.g., 0.5–1 mg/kg) must be given just prior to pulling the catheter. Additional iv usually is not warranted because the procedure is normally ≤10 min, but may be desirable if postop pain medication is anticipated. Occasionally, the catheter may break during attempted removal, and the surgeon will have to make a skin incision to allow for removal of the internal fragment. In such cases, a peripheral iv may be inserted quickly to facilitate administration of additional propofol, or mask anesthesia may be given. If the SpO_2 decreases,

	blow-by O_2 with gentle head and neck positioning are generally sufficient. For more significant obstruction, deepening of anesthetic with additional propofol and positive pressure ventilation may be needed.	
Emergence	Allow child to awaken in procedure room. Ondansetron 0.15 mg/kg for patients receiving intrathecal chemotherapy during their lumbar puncture. Avoid dexamethasone, as steroids may be part of the patient's chemotherapy protocol or may precipitate tumor lysis syndrome.	
Blood and fluid requirements	Patients may require blood or factor supplementation prior to or during procedure based on preop laboratory values.	It is important to be aware of patients where fluid restriction may be required, such as in a recent bone marrow transplant patient, or patient with graft vs. host disease, who may have complications of fluid overload. Sodium bicarbonate infusion is common during chemotherapy and should be continued during anesthesia when possible.
Monitoring	Standard monitors	
Positioning	Lateral decubitus (lumbar puncture) Supine, seated, or prone (bone marrow aspiration, biopsy) Supine (Broviac)	
Complications	Airway obstruction	Head and neck repositioning, jaw thrust
	Retained central venous catheter	May require open surgical procedure
Postprocedure pain management	Lumbar punctures are not generally painful, whereas bone marrow aspirations and biopsies can be. Preop care includes the application of EMLA cream to the LP or bone marrow site, as well as having the oncologist infiltrate	

with lidocaine after induction. For pain management, low-dose fentanyl 1 mcg/kg or hydromorphone 2 mcg/kg may be used and repeated in the PACU if needed. Check with the oncologist before administering acetaminophen. Acetaminophen is not routinely given for pain prophylaxis due to the possibility of masking a fever. Acetaminophen is not given unless needed and should never be given as a rectal suppository to the immunocompromised patient. Some patients may have chronic or acute pain syndromes due to tumor bone pain or as a side effect from chemotherapy. These patients need to be evaluated on an individual basis for their pain management. After lumbar punctures, the patient should remain in a horizontal position for at least 30 min to prevent post–dural puncture headache.

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UPPER/LOWER GI ENDOSCOPY

Ann Ming Yeh, William Berquist, Rebecca E. Claure, and Brenda Golianu

Upper and lower endoscopy allows for accurate diagnosis and treatment of gastrointestinal diseases. Diagnostic indications for upper endoscopy include dysphagia; odynophagia; persistent vomiting; abdominal pain with weight loss/anorexia; acid peptic disease, dyspepsia, and heartburn despite medical therapy; diarrhea, hematemesis, or melena; obtaining samples or biopsies; and diagnosis of infection or disease (graft vs. host disease, inflammatory disorders, malignancy) especially in an immunocompromised patient. Indications for colonoscopy include evaluation of gross or occult bleeding, symptom evaluation of new-onset constipation or unexplained diarrhea or abdominal pain, screening or surveillance for inflammatory bowel disease, and screening for colorectal neoplasia. Therapeutic indications for gastrointestinal endoscopy include esophageal dilation, foreign body removal, sclerotherapy or banding of esophageal varices, hemostasis with directed thermal or injection therapy, percutaneous endoscopic gastrostomy tube placement, decompression of sigmoid volvulus or megacolon, polypectomy, PEG placement, and removal or change of gastrostomy or GJ tubes. Children presenting for endoscopy may have congenital and acquired abnormalities of the GI tract. Examples include repaired tracheoesophageal fistula (TEF) with esophageal dysmotility or strictures, ingestion of a caustic material, and presence of a foreign body.

Many endoscopy procedures are done with sedation only. Requests for anesthesia are dependent on the gastroenterologist's preference, as well as the severity of the patient's underlying illnesses. All patients must receive a complete preanesthesia H&P and follow the same NPO protocol used for surgery (see Appendix D: Standard Pediatric

Anesthetic Management). Patients undergoing colonoscopy require bowel preparation to have the colon free of solid stool for adequate visualization. Common bowel preparation regimens include a combination of magnesium citrate, bisacodyl, and polyethylene glycol.

Absolute contraindications of upper and lower endoscopy include suspected perforation and peritonitis in a toxic patient. Relative contraindications include coagulopathy, neutropenia, fulminant colitis, bowel obstruction and toxic dilation with increased risk of perforation, torrential colonic bleeding, poor bowel preparation, and cardiopulmonary instability.

Overall complication rates of upper GI endoscopy are generally rare, with complications estimated at 0.3% risk of bleeding following an EGD with biopsy and risk of perforation in <0.3% of cases. Hypoxia secondary to sedation, hematoma, missed lesions, and infections are also potential infrequent complications. Complications of colonoscopy occur in <2% of patients, with bleeding and perforation reported in <0.3% and 0.3%, respectively.

ANESTHETIC CONSIDERATIONS

Gastrointestinal	Carefully evaluate for esophageal dysfunction and Sx of GERD. The stomach and bowel will be insufflated with air during the procedure, possibly increasing the likelihood of reflux.
Laboratory	As indicated from H&P. Hct, plt, INR, T+S, if GI bleeding
Premedication	If inhalation induction is planned, administration of midazolam 0.5–0.75 mg/kg po may be helpful for anxiolysis. Consider midazolam for younger children requiring an iv induction (1–2 mg).

INTRAPROCEDURE

Anesthetic technique

Upper GI endoscopy for esophageal dilation, foreign body removal, severe GERD gastrointestinal bleeding, and banding/sclerotherapy of esophageal varices requires GETA. For children ≥2, with no contraindications, supplemental O_2 via nasal cannula, spontaneous respiration, and propofol infusion can be considered. Children ≤2 have a

higher incidence of complications when not intubated due to the relatively large endoscope. Complications include partial airway obstruction, tracheal compression, laryngospasm, bronchospasm, and desaturation. Placement of the endoscope in the mouth precludes the ability to use a mask or LMA. For lower GI endoscopy (e.g. colonoscopy), supplemental O_2 via nasal cannula or mask, spontaneous respiration, and propofol infusion may be preferable.

Induction	If rapid-sequence indication is indicated, iv catheter should be placed prior to induction. Proceed with preoxygenation, cricoid pressure, propofol (2–3 mg/kg), and succinylcholine (1–2 mg/kg) or rocuronium (1 mg/kg). ETT should be well secured to the side of the mouth. If risk of aspiration is relatively low, a standard pediatric iv or mask induction is appropriate (see Appendix D: Standard Pediatric Anesthetic Management).
Maintenance	GETA with inhalational agents or iv infusion of propofol (100–250 mcg/kg/min), ± remifentanil (0.05–0.10 mcg/kg/min). Alternatively, GA/sedation may be continued with supplemental O_2 via nasal cannula, spontaneous respiration, and infusion of propofol (100–250 mcg/kg/min), ± remifentanil (0.05–0.10 mcg/kg/min). If intubated, careful observation and/or holding the ETT prevents inadvertent extubation during removal of the endoscope. If spontaneously breathing, careful attention is needed to observe for breath holding, laryngospasm, and/or desaturation.
Emergence	If intubated, extubate awake. Emergence in procedure room. Patients usually transported to and recovered in PACU.
Blood and fluid requirements	No blood loss. IV: 22 or 24 ga × 1 BSS at maintenance
Monitoring	Standard monitors (see Appendix D: Standard Pediatric Anesthetic Management)
Positioning	✓and pad pressure Lateral decubitus for upper

	points ✓ eyes	and lower endoscopy
Complications	Airway obstruction Hypoxemia 2° gastric insufflation Inadvertent extubation Pulmonary aspiration GI perforation	Due to endoscopist working in the mouth and pharynx

POSTPROCEDURE

Pain management	Acetaminophen (35–40 mg/kg pr or 10–15 mg/kg po 10 mg/kg iv), hydromorphone (0.01–0.015 mg/kg iv), or morphine (0.05–0.1 mg/kg iv)

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ANESTHESIA FOR THE PATIENT WITH EPIDERMOLYSIS BULLOSA (EB)

Erin Bushell and Louise Furukawa

Introduction: Care of the patient with epidermolysis bullosa (EB) is always challenging, requiring familiarity with the disease and its sequelae and how it affects the ability to perform the procedure and anesthetic. This section will focus on recessive

dystrophic EB (RDEB), as it is the most common form in patients presenting for esophageal dilation. Esophageal stricture is present in 50% of patients by age 10 with a cumulative risk of stricture of 95% by age 45. Generally speaking, procedures performed out of the OR take the patient and provider away from resources and help, adding additional risk and complexity. Out-of-OR procedures have been identified as higher risk for adverse events, particularly in shared airway cases such as endoscopy. Furthermore, a primary tenet of Crisis Resource Management is "know your environment," which can be difficult if the procedure takes place in an infrequently utilized location. EB patients often require multiple procedures at specialty institutions. The cost of travel and caregiver loss of wages can be prohibitive; therefore, coordinating multiple procedures under the same anesthetic may be desirable. The care of the EB patient in a multidisciplinary clinic is optimal.

PREPROCEDURE CONSIDERATIONS

Education of team members	• EB clearly known beforehand and indicated on schedule • Staff (including anesthesia techs) familiar with care of EB patient • Special equipment or supplies available
Past anesthetic history	• Vascular access history • Past anesthetic records with previous intubation techniques (disease is progressive so old records may not predict current airway status) • History of PONV, postop pain/sore throat
Craniofacial/airway	• Review of past records • In-person visit or video interview important. Document detailed oral exam. Important to include pictures in preop note • H/o stridor concerning for extensive pharyngeal scarring • H/o corneal abrasions/scarring. Note eye care regimen. Careful dental exam—poor dentition common. Esophageal stricture may compromise the ability to swallow oral secretions.

Respiratory	• Severe kyphoscoliosis or extensive cicatricial scarring may impair pulmonary mechanics and cause restrictive disease.
Cardiac	• Cardiomyopathy may be present with mean age of onset 9–12 yr.[5] • Signs and symptoms similar to patients without EB. Active patients will have DOE. Most will display orthopnea and edema.
Gastrointestinal	• Stricture, poor nutrition, hypoalbuminemia, and iron deficiency anemia are common.
Renal	• Some patients have renal failure—increases risk for cardiomyopathy (cause unknown)[5,6]
Hematology	• Multifactorial anemia common • Many receive Fe infusion vs. transfusion[5]
Oncologic	• Squamous cell carcinoma (SCCA) can arise as early as the second decade of life. • Metastatic SCCA is the principal cause of death in patients with RDEB.
Chronic pain	• Chronic pain is experienced by every patient due to extensive wounds and arduous dressing changes. Some use narcotics frequently.
Psychological	• Chronic pain, anxiety, PTSD, and regression are common. • Most patients have a very close attachment to caregivers. • Caregivers may have difficulty relinquishing control and should be allowed to participate in the preoperative process.
Current medications	

	• Patients should continue essential preoperative medications.
Lab tests	• CBC; hematologist may ask for additional tests such as iron studies. • If vascular access is difficult, labs are often drawn after anesthetic induction. • Chemistries if renal failure is present
Premedication	• Some patients allow IV access preop. • Many (even older) patients may have significant psychological trauma and request mask induction. • ELA-max (lidocaine) cream is useful. • Ultrasound-guided access is helpful and US gel is safe. Oral or GT versed OK to use. • IM premedication may also be indicated.
NPO	• Standard NPO guidelines apply. • Many patients have gastrostomy tubes and should be hydrated with clear liquids until NPO cutoff time.
Check-in process	• Staff involved with checking in the patient should be aware of disease and have modified equipment for monitoring vital signs. • Sheepskin should be placed on the gurney and follow patient throughout procedure. • Caregiver should be able to stay with patient and assist preoperative preparation.

INTRAOPERATIVE ANESTHETIC CONSIDERATIONS

Induction: IV **IV induction—TIVA**	**Adults and pediatric patients with IV access**: A standard IV induction followed by a TIVA is appropriate. Preoxygenation can be accomplished by careful application of the face mask (as below) or using a heated, humidified high flow nasal cannula such as the Optiflow™. Most awake patients tolerate flows of 30

No IV—inhalational	lpm, which then can be increased to 70 lpm after induction to maintain oxygenation during intubation. IV access is often difficult. Asking the patient and caregivers about which veins have been successfully used in the past and use of ultrasound is advised. Elastic tourniquets should generally be avoided. However, if a hand tourniquet is not sufficient, an elastic tourniquet may be carefully placed over Webril™. The area may be gently cleaned with baby shampoo on a moist gauze or an alcohol swab, taking care to avoid any shear stress. The IV must be secured with care. Mepilex® transfer foam can be used to pad under the IV hub, Mepitel® may be placed over the catheter, and a self-adherent wrap such as Coban™ is used to secure the IV by wrapping it circumferentially around extremity. It is suggested that an extension such as a T-piece be used so the IV may be disconnected during patient positioning and transfers without risk of displacement. Once patient is induced and an IV has been placed and secured, a TIVA allows for maintenance of anesthesia while securing the airway. **Pediatric patients without IVs**: An inhalational induction with sevoflurane and N_2O (see p. D-1) is appropriate for these patients. Great care must be taken to avoid trauma from the face mask and jaw thrust. Petroleum jelly or other petroleum-based lubricants applied to a well-inflated mask and petroleum jelly gauze beneath the mask can reduce the risk of mask-related facial trauma. Mepilex® transfer foam can be used to pad the area over the angle of the mandible to reduce trauma related to jaw thrust. Again, avoidance of shear stresses is of primary importance. (Note: These patients may have psychosocial issues due to their illness and psychological trauma related to past procedural experiences, and this may necessitate inhalational induction in patients older than one traditionally would consider this approach.) Intubation: Patients with EB often have ankyloglossia,

	limited mouth opening, and intraoral and pharyngeal mucosal scarring and adhesions. They tend to have patent natural airways, so ventilation is not difficult, but intubation can be both difficult and potentially traumatic to friable tissues. Therefore, fiberoptic intubation with a smaller tube than would normally be used is recommended. Microlaryngeal tubes (MLT)—pediatric diameter tubes that are adult size in length, and have a standard adult cuff—can be used for both oral and nasal intubations. Once placed, the ETT is tied with umbilical tape placed over petroleum jelly gauze to avoid trauma to the face and lips. There is no way to truly secure the ETT in these patients, and it is, therefore, recommended that the anesthesiologist manually hold the tube during times when the risk of accidental extubation is high such as when the dilating catheters and endoscopes are being placed or removed. Nasal intubation may decrease the risk of accidental extubation and thus should be considered for complex cases. It is strongly suggested that during the time out, the team review the importance of having the proceduralist notify the anesthesiologist prior to inserting or removing anything from the mouth so the anesthesiologist may take appropriate steps to prevent unintentional extubation.
Maintenance	TIVA with short-acting agents such as propofol (100–250 mcg/kg/min) and remifentanil (0.1–3 mcg/kg/min). Muscle relaxation is not necessary.
Emergence	Patients awaken rapidly after discontinuation of TIVA. A narcotic should be employed to address postop pain and an antiemetic such as ondansetron (0.1–0.15 mg/kg for children, 4 mg for adults) should be given. Dexamethasone (0.1 mg/kg for children, 4 mg for teens, or 4–8 mg for adults) will reduce nausea and the edema that occurs following these procedures. Deep extubation should be considered as it reduces coughing on tube in these patients already prone to sore throat and trauma.
Blood and fluid	No blood loss. Routine maintenance fluids

requirements	IV: 22 or 24 ga × 1 BSS at maintenance	are required unless a major complication such as esophageal perforation occurs.
Monitoring	Standard ASA monitors (see p. D-1). Applied without adhesives to avoid shear injury	Standard monitors must be applied in a nonstandard fashion to avoid injury to the patient.[5] EKG leads may be either applied to gel pads such as Defib-Pads (3M™) covered with moistened 2 × 2 gauze to prevent the gel from drying out and sticking to the patient's skin and secured with Coban™ if on an extremity or merely placed on patient's chest. Adhesive pulse oximetry probes should be rendered nonadhesive by placing transparent film dressing such as a Tegaderm™ adhesive side to adhesive side and trimming away the excess. The probe may then be secured to a digit (or stump if pseudosyndactyly is present) with Coban™. The blood pressure cuff may be placed over the patient's existing dressings or over Webril™ to avoid skin trauma due to cuff inflation.
Positioning	✓and pad pressure points ✓eyes Sheepskin under patient	A sheepskin pad underneath the patient can provide protection as well as a means to move the patient in a way

that avoids shear stress. Instead of utilizing a roller to move the patient between bed and gurney, which can create a significant amount of shear stress, the patient is lifted directly up using the sheepskin, moved through the air, and placed carefully down upon the bed. The majority of EB patients, including adults, are of low weigh and small physical size and can be easily moved in this manner by the operative team.

A moisturizing cream or ointment such as Albolene[R] or Eucerin[R] applied to the cheeks and lips can reduce the risk of a facial trauma due to airway management. Careful attention must be paid to the eyes as the majority of these patients have corneal blistering and other ocular complications associated with EB and are at extremely high risk for perioperative eye injury. An ophthalmic ointment or methylcellulose eye drops should be applied to both eyes, which should then be closed to the extent possible and covered with Mepitel™ and moistened 2 × 2 gauze.[6] Prior to draping the patient, it

	is advisable to carefully examine the patient by head-to-toe checking to ensure that all pressure points are padded and that no iv lines or monitoring cables are against the patient's skin. NB: Drapes should not touch the skin directly, as they may stick to the skin and create new lesions when removed.
Complications	Esophageal perforation and bleeding are the most common procedure-related complications, and the patients should be intubated to provide airway protection should this occur. If perforation does occur, it is considered a surgical emergency and the patient should proceed to the OR. The majority of complications are related to the patient's disease and injury from positioning. Careful attention to protect the patient from these injuries is paramount. • Esophageal perforation/rupture/mediastinitis. • Contrast esophagram may be performed during the procedure to rule out esophageal injury. • Formation of new lip, intraoral, pharyngeal, or esophageal blisters from manipulation during anesthesia or pharyngeal/esophageal trauma during the dilation procedure.
Pain	• Sore throat due to intubation may be caused by traumatic intubation but also by excessive endotracheal tube cuff pressures. It is therefore important to use MLT tubes instead of non-MLT small tubes with excessively inflated cuffs. • Sore throat and odynophagia caused by the dilation procedure are also common in the postoperative period. • May use narcotics as well as nonnarcotic adjuvants. • Oral budesonide mixed with honey or sucralose may help ease postoperative discomfort.

PONV	• Postoperative nausea and vomiting are common. • Dexamethasone, ondansetron, and adequate hydration are helpful.
Restenosis	• A recent study suggests that regular treatment with budesonide slurry may slow the development of restenosis.

POSTPROCEDURE

Pain management	Acetaminophen (35–40 mg/kg pr or 10–15 mg/kg po 10 mg/kg iv), hydromorphone (0.01–0.015 mg/kg iv), or morphine (0.05–0.1 mg/kg iv)

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CROSS-SECTIONAL IMAGING (CT, MRI)

Rebecca E. Claure and Brenda Golianu

PREPROCEDURE

A complete preanesthetic H&P should be performed in all cases and the usual NPC protocol followed (see Appendix D: Standard Pediatric Anesthetic Management). Fo MRI, thorough questioning regarding potentially ferromagnetic implants (neurostimulators, cochlear implants, pacemakers, surgical clips, infusion pumps, etc.) is critical. Direct questions regarding suitability of implants for scanning to radiologist.

Respiratory	Procedures for patients with Sx of URI (nasal congestion, cough, fever) are usually postponed for 3–4 wk unless the study is urgent. If Sx are minor, the study may proceed.
Cardiovascular	Pacemakers are usually contraindicated. Prosthetic heart valves may be contraindicated (identify the type of valve present and consult with radiologist). Fresh surgical clips (e.g., recent PDA ligation) may also represent a contraindication for MRI. For cardiovascular patients, hold ACE inhibitors the morning of the procedure.
Neurologic	Head CT or MRI may be performed in patients with seizure disorders or brain tumors. Review seizure meds and ✓serum levels if appropriate. Recent drug levels may not be necessary in children with well-controlled or stable seizure disorders. If ↑ ICP or ↓ intracranial compliance are present (e.g., 2° tumors or hydrocephalus), the anesthesia plan should include tracheal intubation with controlled

	ventilation. Metal surgical clips or coils are usually contraindications for MRI. Children with head trauma may have concurrent C-spine injuries.
Laboratory	As indicated from H&P. Usually none required
Premedication	If inhalation induction is planned, administration of midazolam 0.5–0.75 mg/kg po may be helpful for anxiolysis. If iv induction is planned, apply topical anesthesia (see Appendix D: Standard Pediatric Anesthetic Management).

INTRAPROCEDURE

Unique considerations for MRI

See Adult Out-of-OR Procedures, p. 1686.

Anesthetic technique

CT scans: With current scanners, many studies can be completed in <10 min. Each set of data takes 2–3 min to collect, allowing many children to complete scans without any sedation. In some institutions, children undergo noninvasive CT scans with sedation by radiology personnel. For more complex cases, sedation/GA is provided by an anesthesiologist. Most commonly, noninvasive CT scans are performed with inhalation anesthesia via mask or with a continuous infusion of propofol (100–250 mcg/kg/min). For patients undergoing invasive CT-guided procedures (needle biopsy, placement of drainage tubes, such as thoracostomy tube, etc.), GETA is usually performed. Techniques include inhalational anesthesia and/or continuous infusion of propofol (100–200 mcg/kg/min) and remifentanil (0.05–0.10 mcg/kg/min).

MRI: MRI requires GA more often than noninvasive CT because prolonged immobility is required for up to 1–2 h. Options include inhalational anesthesia with an MRI-compatible anesthesia machine or continuous propofol infusion with an MRI-compatible infusion pump. Hypothermia frequently occurs in small children. The cooling fan for the magnet can sometimes be turned off to decrease heat loss (discuss with MRI technician). One blanket over patient is usually permissible. The iv, airway circuit, and monitors require extensions. Ferromagnetic objects in the MRI environment are a hazard. Objects can be propelled toward the magnet with sufficient speed and force to result in serious or fatal injury to the patient and/or health care provider.

Induction	Standard pediatric mask or iv induction (see Appendix D:

	Standard Pediatric Anesthetic Management) can be accomplished in the CT scanner room or in a special induction area outside the MRI scanner. After induction and stabilization of the airway, the patient and all personnel entering the MRI scanner should undergo a second check for removal of metal objects and equipment. Once check completed, transport patient into scanner and resume monitoring.	
Maintenance	GA continued with supplemental O_2 via nasal cannula, spontaneous respiration, and infusion of propofol (100–250 mcg/kg/min). In children with an LMA or ETT, maintenance with inhalational agent or propofol infusion. Typically, these patients do not require muscle relaxants, and spontaneous breathing is appropriate unless controlled ventilation is required to treat ↑ ICP or for protocols involving breath holding for prolonged periods of time (e.g., several minutes for abdominal scans). Most infusion pumps need to remain a specific distance from the MRI scanner. The appropriate distance is dependent on the degree of shielding of each particular magnet. Adequate ear protection should be routinely used during MRI.	
Emergence	Transport MRI patient back to induction area for emergence so that airway equipment is readily available. Patients are transported to and recovered in PACU.	
Blood and fluid requirements	No blood loss. IV, if required: 22 or 24 ga × 1 BSS @ maintenance	
Monitoring	Standard MRI-compatible monitors	For infants, use a child-size NIBP cuff on the leg.
Positioning	Ear protection necessary ✓and pad pressure points ✓eyes	
Complications	Airway obstruction	Repositioning, nasal or oral airway
	Hypothermia	Minimize duration of scan in

		younger patients. Have available warming devices—blankets, Bair Hugger, warming pads, etc.
	Burn injury	From inappropriate placement of pulse oximeter probe or EKG. Avoid coiling of wires and use only MRI-compatible monitors.
	IV contrast reaction	
	Hearing loss (MRI)	

POSTPROCEDURE

Pain management	Noninvasive procedures are painless. Acetaminophen (35–40 mg/kg pr, 10–15 mg/kg po, or 10 mg/kg iv), hydromorphone (0.01–0.015 mg/kg iv), or morphine (0.05–0.1 mg/kg iv) as appropriate for invasive procedures

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SURGICAL CONSIDERATIONS FOR ECMO

PROCEDURAL CONSIDERATIONS

Gary Hartman and Claudia Mueller

Extracorporeal membrane oxygenation (ECMO) for prolonged periods (3–21 d) allows cardiopulmonary support for newborns and children with reversible respiratory failure. The most common indications are meconium aspiration and pulmonary HTN associated with congenital diaphragmatic hernia. The procedure is performed in the NICU with OR techniques. Patients are given anticoagulants prior to cannulation. Subsequently, repair of the diaphragmatic hernia also may be performed in the NICU on ECMO support before decannulation. (Fig. 13.2-1 shows ECMO schematic.)

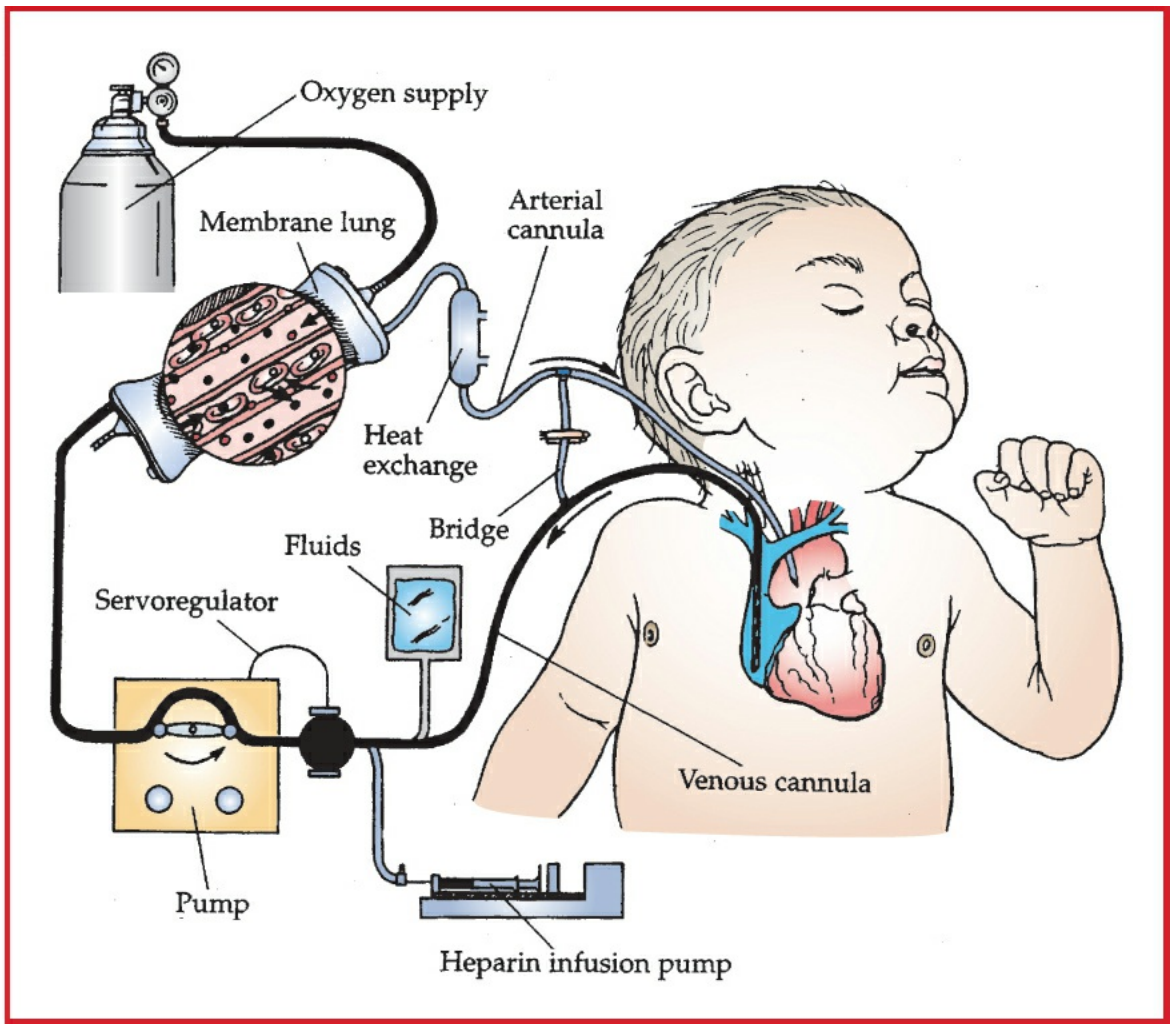

Figure 13.2-1 ECMO circuit illustrating venoarterial (VA) cannulation. Venous blood is withdrawn by gravity through a servoregulator to prevent pump from actively siphoning venous return. A pump delivers blood back to the arterial cannula after it passes through the membrane oxygenator and heat exchanger. Venous return is from the right atrium, whereas arterial infusion is into the aortic arch in double-cannula (VA) or right atrium (venovenous) techniques. (Reproduced with permission from Baker RJ, Fischer JE: Mastery of Surgery, Vol. I, 4th edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

The potential detrimental effects of the diaphragmatic repair on respiratory function can be managed with increased circuit flow. ECMO also has been helpful in some newborns with cardiopulmonary failure following correction of congenital cardiac defects. Vascular access is accomplished with one (venovenous) or two (venoarterial) cannulae. The IJ vein is cannulated in both methods with the tip of the cannula in the right atrium. In venoarterial ECMO, the common carotid artery is used with the tip o the cannula at the aortic arch. The wound is closed around the cannulae, which are secured to the infant's scalp.

Usual preop diagnosis

Meconium aspiration; diaphragmatic hernia

SUMMARY OF PROCEDURE	
Position	Supine
Incision	Right neck incision; subcostal for hernia repair
Special instrumentation	ECMO circuit (Fig. 13.2-1)
Unique considerations	Anticoagulation
Antibiotics	Broad spectrum based on underlying condition
Surgical time	1–2 h
Closing considerations	Assess for changes in ventilation (e.g., PIP, pre- and postductal ABG); assess hemostasis.
EBL	>5–10 mL/kg
Postop care	Paralysis maintained; fentanyl infusion at 2–4 mcg/kg/h
Mortality	Based on underlying conditions
Morbidity	Respiratory failure Sepsis
Pain score	6–7

PATIENT POPULATION CHARACTERISTICS	
Age range	Primarily neonatal with increasing use in older children

Male:Female	1–2:1
Incidence	1:4000 live births
Etiology	Unknown
Associated conditions	For diaphragmatic hernia: congenital heart disease (15%); renal anomalies; intestinal atresia; CNS abnormalities

ANESTHETIC MANAGEMENT FOR SURGICAL PROCEDURES UNDER ECMO

Claudia Benkwitz and Lisa Wise-Faberowski

ECMO has become a standard therapy for refractory neonatal and pediatric cardiorespiratory failure. Over the past 2 decades, the indications for ECMO have changed. The use of ECMO for neonatal respiratory failure peaked in the early 1990s but its use has now decreased with the development of alternative strategies such as surfactant, high-frequency oscillation, and inhaled nitric oxide. In contrast, cardiac indications for ECMO have continued to increase especially for cardiopulmonary arrest (ECPR) refractory to standard CPR management. Improved patient outcomes with ECMO have been achieved by combining new technologies with refined management strategies and improved training of personnel.

Anesthesiologists may find themselves encountering an increasing number of neonatal and pediatric patients on ECMO support for various surgical procedures and imaging studies. Successful management of these patients includes meticulous planning, comprehensive teamwork, communication, and attention to detail. Intrahospital transport of these patients often requires multiple personnel from various medical specialties, and therefore, it is important to elect a team leader prior to transport and to allocate specific tasks (e.g., protection of ECMO cannulae) in order to avoid any confusion or conflict.

The delivery of anesthetic agents can be via a TIVA technique or a combination of intravenous and inhalation agents. However, the oxygenator membrane of the bypass circuit can sequester varying amounts of lipid-soluble intravenous agents, such as fentanyl, altering the plasma levels and resulting in unpredictable hemodynamic changes. Volatile anesthetics are not routinely available on ECMO circuits due to difficulties with scavenging. Anesthetic agents cause preload and afterload changes, and therefore additional volume (blood products and colloids) and vasoactive agents should

be readily available in order to maintain adequate filling and blood pressure.

It is important to keep in mind that altering the surgical table height and thus the patient's height will have an impact on the venous return to the ECMO circuit (passive gravity-assisted drainage); hence, the perfusionist must be informed before undertaking this maneuver.

Diaphragmatic hernia repair is the most common noncardiac procedure undertaken on ECMO support. ECMO therapy protects the pulmonary alveoli from ventilator associated barotrauma and oxygen toxicity while maintaining tissue oxygenation. Prior to surgery, a trial period off bypass is used to assess the adequacy of conventional ventilation independent of ECMO. If the neonate is unable to be weaned, then the surgery occurs on full ECMO support. ACT is maintained at ~200 sec by the addition of heparin to the ECMO circuit. The potential detrimental effects of diaphragmatic repair on respiratory function can be managed with increased circuit flow.

Monitoring includes heart rate, arterial blood pressure, temperature, and pump flow rate with frequent ABGs and VBGs.

The majority of practitioners employ VA cannulations for ECMO support (see Fig. 13.2-1) although some centers prefer VV ECMO support if hypoxemia is the primary indication.

Suggested Readings

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SECTION **14.0**

OFFICE-BASED ANESTHESIA

PROCEDURAL SPECIALISTS

David A. Berman, MD (Facial Rejuvenation)
Vernon J. Adams Jr., DMD (Dental Rehabilitation)
Azeem K. Lakha, DMD (Dental Implants)

ANESTHESIOLOGISTS

Richard A. Jaffe, MD, PhD
Terri D. Homer, MD

INTRODUCTION—ANESTHESIOLOGIST'S PERSPECTIVE

Richard A. Jaffe, MD, PhD and Terri D. Homer, MD

DEFINITION OF OFFICE-BASED ANESTHESIA

Office-based anesthesia (OBA) is distinct from outpatient anesthesia in a freestanding surgery facility. OBA is used in many medical specialties, including most dental subspecialties, dermatology, plastic surgery, ophthalmology, otolaryngology, and gynecology. The procedures described in this chapter are representative of the ways in which anesthesia is used in medical/dental offices. Although anesthesia practiced in an office carries the same risks, burdens of responsibility, and skill requirements as in a fully equipped surgical center, in the office setting, the anesthesiologist may be expected to arrange for the oxygen supply, suction, monitoring, and emergency equipment. They may even bring a portable anesthesia machine with them from site to site. This unique challenge for the anesthesia provider includes working with personnel unfamiliar with anesthesia concerns, converting the office into a facility appropriate for anesthesia, selecting appropriate patients, providing safe and effective anesthesia/analgesia, and properly preparing and recovering the patients.

STATE REGULATIONS REGARDING OFFICE-BASED ANESTHESIA

Many states have laws listing strict requirements for medical facilities where anesthesia is provided for surgical procedures. Some states have regulations based on the type of surgical procedure performed. Others regulate and credential the facility based on the type of anesthesia used (i.e., GA, iv, local). Still others base regulations on the type of facility itself. In California, for example, dental offices are regulated differently than medical offices. For many years, the California Dental Board has regulated anesthesia in the dental or oral surgery office by credentialing the anesthesia provider and/or the office facility itself. An oral surgeon, dentist, or physician issued a GA permit by the Dental Board goes through a credentialing process by one or two examiners that includes direct observation of an anesthesia case, demonstration of emergency drills, and examination of required monitoring and resuscitation equipment on site. The permit allows the holder to provide GA in any dental office. The Dental Board also issues "Conscious Sedation" permits to those dental practitioners who qualify and want to use this technique. Physicians in California wishing to have iv sedation or general anesthesia available in their office must first be accredited as a surgery center by one of

several agencies providing this service such as AAAHC.org.

EQUIPMENT NEEDED FOR OFFICE-BASED ANESTHESIA

In the office setting, the anesthesia provider may or may not have the use of an anesthesia machine or other sophisticated equipment that is readily available in a surgical center. In some respects, however, this setting is analogous to other non-OR locations. The ASA Guidelines for Nonoperating Room Anesthetizing Locations covers all types of out-of-OR facilities, and these recommendations should be followed. Appropriate monitoring—including pulse oximetry, ECG, and BP—is required. Many portable monitors have $ETCO_2$ monitoring capability, which may be useful for the spontaneously ventilating, sedated patient. A precordial stethoscope is quite useful for monitoring respirations, especially in the dental patient, in whom airway obstruction is a frequent occurrence during the procedure. Also in accordance with the ASA guidelines, full resuscitation equipment, an adequate source of O_2 (and backup O_2), a functioning suction, adequate lighting and electrical outlets (with backup battery source), and a telephone with immediate access to a hospital ER also must be available. In the credentialed medical (nondental) facility, these items are required to be on site. In the dental facility, they may or may not be present. It is the responsibility of the anesthesia provider to make sure these items are available in the medical or dental facility before administering an anesthetic.

ANESTHETIC TECHNIQUES IN THE OFFICE SETTING

Typically, the anesthetic techniques in the office setting can range from conscious sedation to GETA. The type of procedure, the patient's clinical status, and the surgeon or dentist's preference all contribute to the decision of which technique is best for that particular situation. In the pediatric patient having dental restoration work, "conscious sedation" is not adequate because most often the dental restoration required is very extensive and will likely take several hours to accomplish. In this situation, GETA with nasal intubation (or oral intubation if nasal intubation is not possible) is usually the best choice of anesthetic technique. In the patient having dental implant placement, minimal or moderate sedation may be all that is required. The oral surgeon may require the patient's cooperation at times during the procedure. The patient undergoing full-face laser resurfacing will most likely require deep sedation or GA because this procedure can be quite painful. However, because sedation is a continuum, the anesthesia provider must be prepared to rescue any patient receiving any sedation in the office (see Continuum of Depth of Sedation, ASA Guidelines).

PATIENT SELECTION

As in all medical facilities, the patient's safety is of paramount importance. In the office setting, the ability to achieve a successful outcome is dependent first of all on appropriate patient selection. The patients presenting for OBA will fall into several categories, depending on the procedure and the patient's age and medical condition. An "appropriate patient" can be an ASA 1 or 2 patient. They may even be an ASA 3 if (a) their medical problems are stable and well controlled with medication and (b) the office procedure itself will not pose an undue risk to them.

PREOPERATIVE PREPARATION

An important role of the anesthesiologist is to educate the patient (or patient's parents, as appropriate) about the office anesthesia experience. A preop phone call discussing the patient's medical history, past anesthesia experience (in a hospital, surgery center, or dental office), the NPO requirements, the anesthesia technique(s) to be used, postanesthesia expectations, and the anesthesia fees is essential. A written packet describing some of this information can be given to the patient in advance.

Safe and accepted NPO requirements on the day of the procedure are as follows:

- A light meal at least 6 h before the appointment.
- Clear liquids (including Gatorade, Jell-O, fruit popsicles) up to 2 h before the appointment.
- The patient's usual medications should be continued on the day of the procedure.

RECOVERY AND DISCHARGE

In a medical or dental office, often there is no separate recovery area designated as such. It is common practice for the patient to be recovered by the anesthesiologist in the treatment room until they can open their eyes and maintain an adequate airway without assistance. At that point, any iv or monitors that may have been used can be removed. If it is a pediatric patient, the parents may be brought into the room, although recovery remains under the supervision of the anesthesiologist. Office anesthesia patients can be discharged when they are well oriented, their pain and nausea are controlled, and they have a responsible adult to accompany them. They may still feel drowsy, but this should not prevent them from being able to walk with assistance.

Discharge instructions regarding appropriate postop activities should be given to the responsible adult with the patient. Generally, patients are asked to adhere to the following instructions upon discharge:

- NPO except clear liquids in the first 2 h after arriving at home. (Unless the ride is >1

h, we ask the patient not to drink anything in the car on the way home from the procedure facility.)
- A light meal after the first 2 h, if the patient wishes.
- Adults should take it easy the rest of the day and have a responsible adult companion for at least 4 h after the procedure.
- No driving for 24 h.
- Children should stay home for the rest of the day postprocedure, under the direct supervision of a responsible adult.

The anesthesiologist also should give the responsible party (parent, friend, other relative) his/her pager or cell phone number in the event they need to contact the anesthesiologist after patient discharge.

Suggested Readings

1. American Society of Anesthesiologists: Office Based Anesthesia and Denta Anesthesia guidelines 2019: https://www.asahq.org/advocacy-and-asapac/advocacy-topics/office-based-anesthesia-and-dental-anesthesia
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FACIAL REJUVENATION: LASERS AND RF TISSUE TIGHTENING

SURGICAL CONSIDERATIONS

David A. Berman, MD

Description

A variety of medical devices have been approved for use to improve skin concerns, such as wrinkles, precancerous skin lesions (actinic keratoses), discoloration, acne scars, traumatic scars, and sagging skin. In the mid-1990s, laser resurfacing using the fully ablative CO_2 laser was very popular. This procedure yielded wonderful results, but extensive heat from this procedure caused some undesirable side effects such as

scarring or pigmentation problems, prompting the industry to develop the cooler and more conservative resurfacing tool using the erbium laser. Less than a decade later, a novel fractionated laser resurfacing device was developed that removed only a fraction of the skin in a pattern reminiscent of pixels in newspaper print. Certainly, the risks and side effects were reduced compared to the older technology, though this more conservative approach rendered a more modest improvement of skin concerns. Further research led to the development of nonablative technologies such as radiofrequency/ultrasound/nonlaser light-based devices, most of which resulted in better side effect profiles and positive outcomes. Although the holy grail of devices would render a no downtime, painless procedure void of negative effects, the search for such continues to elude us. Meanwhile, physicians who perform these procedures should encourage patients to opt for office-based anesthesia and thus make the experience a more pleasant one for all involved.

Because some devices deliver a tremendous amount of heat to the skin surface, ablating both the epidermis and a portion of the dermis, nerve blocks and local anesthetic infiltration are often inadequate, thus requiring either iv sedation or GA. Facial nerve blocks may be performed to supplement iv sedation. After a Betadine® prep, anesthetic eye drops are used, followed by the insertion of protective corneal shields. The treatment then begins with one or more passes performed at various energy levels.

Usual preop diagnosis

Wrinkles; precancerous skin lesions (actinic keratoses); acne scars; traumatic scars

SUMMARY OF PROCEDURE	
Position	Supine, with shoulder roll. Surgeon at head of table
Antibiotics	None during procedure. Some patients will require antivirals and/or antibiotics started 1 d before procedure.
Surgical time	30–60 min
Postop care	Supine position, occasional ice packs, antiviral medications/antibiotics. Some require facial dressings.
Mortality	None reported
Morbidity	Bacterial infection Herpes simplex virus reactivation Delayed reepithelialization

	Fat atrophy Hypertrophic or keloid scar formation Corneal abrasion Delayed healing with redness Hyperpigmentation and hypopigmentation
Pain Score	3–6 depending on the type of medical device used

PATIENT POPULATION CHARACTERISTICS	
Age range	18–85 yr
Male:Female	1:4
Incidence	*Facial rejuvenation procedures: ~340,000/yr in US
Etiology	Solar radiation, acne, or trauma resulting in scars

*2018, American Society for Aesthetic Plastic Surgery.

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Some facial rejuvenation procedures are quite painful and can be very stressful to the patient; thus, local anesthesia is often inadequate. For these procedures, it is important to make sure that the patient with chronic HTN and/or other cardiovascular or respiratory disease is being adequately treated for these problems before undergoing either laser resurfacing or RF tissue tightening. A preop ECG (taken within the last year) is recommended for those patients >60 yr old or those being treated for HTN.

Premedication	In the adult patient, an oral premed can be given, if necessary, before the patient arrives in the office for the procedure. Lorazepam 0.5–1.0 mg po 1 h before the appointment will help relax the severely anxious patient.

INTRAOPERATIVE

Anesthetic technique

MAC and/or GA

MAC/GA	During full-face laser resurfacing procedures, the patient will need to be under deep iv sedation, unless the surgeon is willing to use a large amount of local anesthetic (often RF tissue tightening will require less sedation, depending on the device used). Usually, a combination of intermittent doses of midazolam (1–2 mg iv), meperidine (25 mg iv), ketamine (25–30 mg iv q1h prn), and propofol (25–50 mcg/kg/min iv) will provide an adequate anesthetic state. If a nasal airway is inserted, nasal O_2 can be used (limit FiO_2 to ≤0.30). Otherwise, O_2 should be administered between facial passes if a laser is used. Again, the patient is not electively intubated, but an LMA may be needed if it is difficult to maintain a patent airway. Usually, patients having this procedure will require at least 75–150 mg meperidine (or its equivalent) to relieve the painful burning caused by multiple passes of these devices. Patients will shiver and sustain HTN and tachycardia unless an adequate level of analgesia is achieved. Because of the narcotic requirement, they should have prophylactic antiemetics during the procedure. Dexamethasone (8 mg iv) and metoclopramide (15 mg iv) or ondansetron (4 mg) are a good combination.	
Blood and fluid requirements	IV: 20 ga × 1 BSS @ 2–4 mL/kg/h	
Monitoring	Standard monitors	
Positioning	✓ and pad pressure points ✓ eyes (eye shields in place)	
Complications	Laser fire	Use intermittent, low-flow O_2. Consider wrapping foil around cannula. Limit FiO_2 to ≤0.30.

POSTOPERATIVE

Complications	PONV
Pain management	Oral analgesics
Recovery and discharge	The patient recovering from a full-face procedure usually has received a lot of anesthetic medication in a short period of time. They often require at least 45–60 min to recover in the office. Vital signs should be stable (↑ BP and HR must be treated). Pain and nausea also should be under control. These patients must be accompanied by a responsible adult who can stay with them at home for a few hours after the procedure. A follow-up phone call to the patient by the anesthesiologist that evening is very helpful and appreciated.

OFFICE DENTAL REHABILITATION UNDER DEEP IV SEDATION

SURGICAL CONSIDERATIONS

Vernon J. Adams Jr, DMD

Description

Dental rehabilitation includes the restoration of good dental health by removal of caries and decayed teeth, replacement of crowns or bridges, root canals, and periodontal treatment. A throat pack with external tie is placed and a mouth prop inserted. Dental rehabilitation is usually done in phases, one quadrant at a time. A rubber dam is placed to isolate the teeth that will be treated. All dental caries are removed, the restorations are placed, and all debris is irrigated and suctioned away from the rubber dam, which is then removed. This sequence is repeated in other quadrants as needed. After the operative phase of treatment is completed, the next treatment phases proceed (e.g., taking impressions for various appliances or dental prosthetics, dental extractions, or a dental prophylaxis). After the treatment is completed, the dentist examines the mouth and removes any loose gauze, debris, or other material left over from the treatment before the anesthesiologist begins the process of emergence from anesthesia.

Usual preop diagnosis

In-office dental rehabilitation usually focuses on treatment of the patient who is unable

to be treated in a conventional setting for primarily behavioral/emotional reasons. These include dentophobia; pediatric patients who are excessively apprehensive and/or combative or who have a significant amount of dental caries; "special needs" pediatric patients—autistic, mentally retarded, developmentally delayed—and patients with mild-to-moderate forms of cerebral palsy.

SUMMARY OF PROCEDURE	
Position	Supine, on a dental chair or bench. A pillow under the knees will improve comfort and prevent sliding.
Incision	± Gingival or intraoral mucosa
Special instrumentation	Dental setup
Unique considerations	Intubation recommended; throat pack placed; airway protection of paramount importance
Antibiotics	None used routinely
Surgical time	90–180 min
EBL	Minimal
Postop care	Recover in lateral position
Mortality	Rare
Morbidity	Biting of lips or tongue 2° local anesthesia: 1% Bleeding: 1% Infection: <1% Delayed bleeding: rare
Pain Score	1–3; higher for certain procedures (e.g., extraction of impacted tooth or when all quadrants of the mouth are restored)

PATIENT POPULATION CHARACTERISTICS	
Age range	13 mo+
Male:Female	1:1
Incidence	>20,000/yr in the United States
Etiology	Poor oral hygiene and/or dietary habits; lack of

	continuing periodic dental care

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

In the pediatric dental office, the patients presenting for GA are those who cannot cooperate due to age (too young), too anxious, or to a preexisting mental or physical disease. Examples include a 20-mo-old child with early childhood caries, an 8-yr-old autistic child, or a child of any age with cerebral palsy, obesity, Down syndrome, or other congenital syndrome. Obviously, the anesthetic treatment plan must be tailored to the patient's individual needs. These patients must be screened in advance for clinical conditions that would put them at risk for problems intraop or postop. Specifically, a patient with any cardiac, respiratory, endocrine, or neurologic problem must be evaluated. If the clinical condition is mild, stable, and under good control, the patient may be considered for GA in the office. Examples of such conditions include mild non–steroid-dependent asthma, corrected congenital heart disease, or a stable Sz disorder. The child with Down syndrome, obesity, snoring, or OSA may pose a very difficult problem in this setting because airway obstruction can occur easily under deep sedation. Also, these patients frequently have concurrent congenital heart disease. The child with a current or recent URI always poses a dilemma. Although there is controversy on this issue, these children generally should have their procedures postponed because their chances of sustaining periop respiratory problems are higher than normal.

Premedication	There are several options available for preprocedure sedation. In the older child (>8 yr) who is psychologically mature, an iv can be placed without premedication. In a dental office that is equipped with N_2O, the patient can breathe a high-flow N_2O/O_2 mix through a nasal mask for 10 min before iv placement. If the patient accepts the mask, this technique can help lessen the patient's fear of and reaction to the iv. The use of a 30-ga needle for infiltration of buffered 2% lidocaine and, sometimes, the use of EMLA cream (placed 30 min in advance) can be very helpful. Oral premedication is used commonly in children 4–8 yr old. Midazolam (0.5–0.7 mg/kg; maximum = 20

mg) mixed in an appropriate dose of liquid acetaminophen, given in the office 20 min before the procedure, can provide adequate sedation. In some, the addition of oral ketamine 2–3 mg/kg to the midazolam solution may result in a better sedating effect, especially in older pediatric patients.

Although an oral premed is popular and usually effective in the hospital setting, it may not be appropriate in the setting of the dental office for a variety of reasons. First, many of these children are not cooperative with oral hygiene or with taking oral medications at home and will not cooperate with taking them in the office. The special-needs children or adults will often be totally unable to take an oral premed. Second, many of the patients are anxious that the oral premed may not be effective. Third and may be most important, having any volume in the stomach adds to the risk of aspiration management, which is extremely problematic in the dental office.

One safer and certainly more effective and predictable premedication for the young healthy child (6 yr or younger) or for the special-needs child is an intramuscular injection consisting of ketamine 2 mg/kg, midazolam 0.2 mg/kg, and glycopyrrolate 0.1 mg/kg. The anesthesiologist can administer this injection while the patient is in his or her parents' arms in the waiting area. Within 5 min after the injection, the patient will be sedated adequately to allow a smooth separation from the parent and sufficient amnesia for induction. Most parents will accept this premed option when the anesthesiologist explains the rationale for it in advance, usually during the preop phone call.

In the child over age 6, an inhalation induction without premed may work very well, especially when explained properly to the child and the parent.

After the premed, the induction of GA in the adult, pediatric, or special-needs patient in the dental office

	is similar to anesthetic induction in the OR. Monitors are placed, and in the pediatric patient, this is followed by an inhalation induction, and then the placement of the iv. Intubation (preferably a nasal ETT) follows. After confirmation of proper ETT placement, throat packs are placed with dental floss tied to them and left outside the mouth as a reminder of their presence in the throat. If x-rays are needed, the dentist and/or the dental assistants will get these done after the patient is intubated and then, finally, dental treatment can begin. There are no special considerations for maintenance of GA, and an inhalation agent, TIVA or a combination, can be used. Some intraop narcotic should be used in the pediatric patient for postop analgesia as well as to minimize emergence delirium. Local anesthetic is often avoided in the pediatric patient undergoing a dental procedure under GA to avoid the possibility of the child biting a numb lip, cheek, or tongue as they recover. In the healthy adult patient undergoing dental work or oral surgery with GA, local anesthesia is usually administered by the dentist or oral surgeon intraop. The routine use of prophylactic intraop antiemetics is highly recommended and may include a combination of dexamethasone, metoclopramide, and ondansetron.

INTRAOPERATIVE

Anesthetic technique

If necessary, a flexible LMA can be used for airway management. Following sedation, the patient is placed in the dental chair, with the head positioned to maintain an open airway. A shoulder roll may be needed to help with head extension. Monitoring—including pulse oximeter, ECG, BP cuff, and precordial stethoscope—is attached. O_2 is supplied, and $ETCO_2$ can be measured through a nasal cannula. An iv is started if not previously placed. A nasal airway is positioned with care (to avoid epistaxis) after the dental x-rays are taken. The anesthesiologist must be constantly vigilant in maintaining

an open airway in these patients in the face of an oral procedure. Placing a flexible LMA may make airway management easier without interfering with the dental procedure. A propofol infusion can be started at a rate of 100–150 mcg/kg/min. Administration of a small amount of meperidine (e.g., 5–15 mg iv) may be useful in alleviating emergence delirium, especially if there is not adequate local anesthesia.

Emergence	No special considerations, except that throat packs must be removed.
Blood and fluid requirements	IV: 20–22 ga × 1 BSS @ 2–4 mL/kg/h
Monitoring	Standard monitors
Positioning	✓ and pad pressure points ✓ eyes

POSTOPERATIVE

Complications	PONV	These patients may swallow blood, with consequent PONV.
Pain management	Oral analgesics	Acetaminophen can be started ~4 h after discharge.
Recovery and discharge	In the dental office, there may not be a separate, designated recovery area. Usually, the pediatric patient is recovered by the anesthesiologist in the treatment room for at least 30–45 min, or until the patient is opening his/her eyes and maintaining a normal airway without assistance. At this point, the iv and monitors can be removed and the patient can continue recovering with his/her parents or family in the office until the patient can keep his/her eyes open, follow commands, seem calm, and is free of nausea. Postop instructions given to the parents include no outside or unsupervised activities for the rest of the day, no drinking or eating in the car on the way home, clear liquids for the first h, and	

	gradually advancing the diet to soft foods. The anesthesiologist should give the parents his/her pager or cell phone number so they can call with any questions that arise after they are at home. Regardless, a follow-up phone call from the anesthesiologist is always a good policy.

DENTAL IMPLANTS AND BONE GRAFTING

SURGICAL CONSIDERATIONS

Azeem K. Lakha, DMD

Description

A dental implant consists of a tooth root–shaped titanium post that is used to support a crown, bridge, or denture. Dental implants are inserted surgically into the mandibular or maxillary alveolar bone where teeth are missing. Single implants may be done with local anesthesia, but multiple or complex procedures are best accomplished with iv sedation. After the local anesthetic is administered, a mucoperiosteal flap is raised over the edentulous alveolus, and the bone is exposed. Precise drill holes are made in the bone, and the implants are screwed or tapped into place. Bone grafting may be necessary around the implants to fill in defects and is carried out using autologous, allogeneic, xenogeneic, or synthetic materials. In most cases, the gum tissue is closed over or around the implant. The bone is allowed to heal around the implant, and 2–6 mo later, the implant can be used to attach crowns, bridges, or dentures. In cases where there is insufficient bone, a bone graft is necessary **before** implants can be placed. Typically, bone grafts are allowed to heal for 6 mo before implant insertion. Most minor grafting procedures are accomplished in the dental office under iv sedation and local anesthesia. Major grafts requiring extraoral donor sites may have to be done under GA via nasal ETT intubation.

Usual preop diagnosis

Acquired or congenital absence of dentition

SUMMARY OF PROCEDURE

Position	Supine, with head tilted back, using an articulating headrest in the dental chair

Incision	Intraoral mucoperiosteal flaps
Special instrumentation	Precordial stethoscope
Unique considerations	Throat packs are used to prevent aspiration of teeth, crowns, blood, and irrigation fluids. Ensure that they are removed at the end of the case.
Antibiotics	Prophylactic antibiotics, given orally before surgery
Surgical time	1–3 h
EBL	25–100 mL
Mortality	Rare
Morbidity	Infection: 1% Bleeding: Rare Delayed bleeding: Rare Aspiration: Rare
Pain score	1–4, depending on procedure

PATIENT POPULATION CHARACTERISTICS	
Age range	17+ yr
Male:Female	1:1
Incidence	Becoming more common as technology improves
Etiology	Tooth loss

ANESTHETIC CONSIDERATIONS

PREOPERATIVE

Many patients having dental implant procedures are older and/or have multiple medical problems. The anesthesiologist should be consulted in advance about these patients so that questions about their medical conditions can be answered and a current list of medications can be obtained. Sometimes, the patient's primary care physician needs to be contacted to discuss details of medical Hx. If chronic medical conditions are stable, patients often can receive "conscious sedation" and monitoring by the anesthesiologist for this procedure in the office.

Premedication: Usually not necessary

INTRAOPERATIVE

Anesthetic technique

MAC: These patients are not intubated electively. In the adult patient having dental implants, the maintenance of a lightly sedated state can be achieved using a combination of iv midazolam, fentanyl (or meperidine), ± low-dose ketamine (20–30 mg/dose). A pulse oximeter, ECG, BP cuff, precordial stethoscope or $ETCO_2$ monitor, and nasal O_2 should be in place. Glycopyrrolate (0.1–0.2 mg) should be given to decrease secretions. Dexamethasone 4–8 mg and metoclopramide 15 mg are useful as an antiemetic combination. Usually, the oral surgeon needs the patient's cooperation at some point during the procedure; therefore, propofol is not an ideal drug to use. It can be given, however, in small doses to the patient who requires more than the other drugs for sedation. Occasionally, the adult patient in this setting will require a nasal airway.

Emergence	No special considerations, except that throat packs must be removed at end of procedure.
Blood and fluid requirements	IV: 20–22 ga × 1 BSS @ 1–3 mL/kg/h
Monitoring	Standard monitors
Positioning	✓ and pad pressure points ✓ eyes

POSTOPERATIVE

Complications	PONV	These patients may swallow blood, with consequent PONV.
Pain management	Oral analgesics	
Recovery and discharge	In the dental office, there may not be a separate, designated recovery area. Usually, the patient is recovered by the anesthesiologist in the treatment room until the patient is responding appropriately. At this point, the iv and monitors can be removed and the patient can continue recovering with	

	family/accompanying adult as necessary in the office until the patient is comfortable, free of nausea, and able to drink water or fruit juice.

SECTION 15.0

EMERGENCY PROCEDURES FOR THE ANESTHESIOLOGIST

ANESTHESIOLOGIST
Frederick G. Mihm, MD

EMERGENCY CRICOTHYROTOMY

Clinical situation

Typically, this procedure is performed in a hypoxic patient with an obstructed airway who cannot be ventilated with a mask or LMA and cannot be intubated.

Emergency "Stab" Cricothyrotomy

Equipment	• Scalpel, preferably with no. 11 blade • ETT no. 6 • Syringe for inflating cuff • Prep solution such as alcohol, chlorhexidine, or povidone-iodine

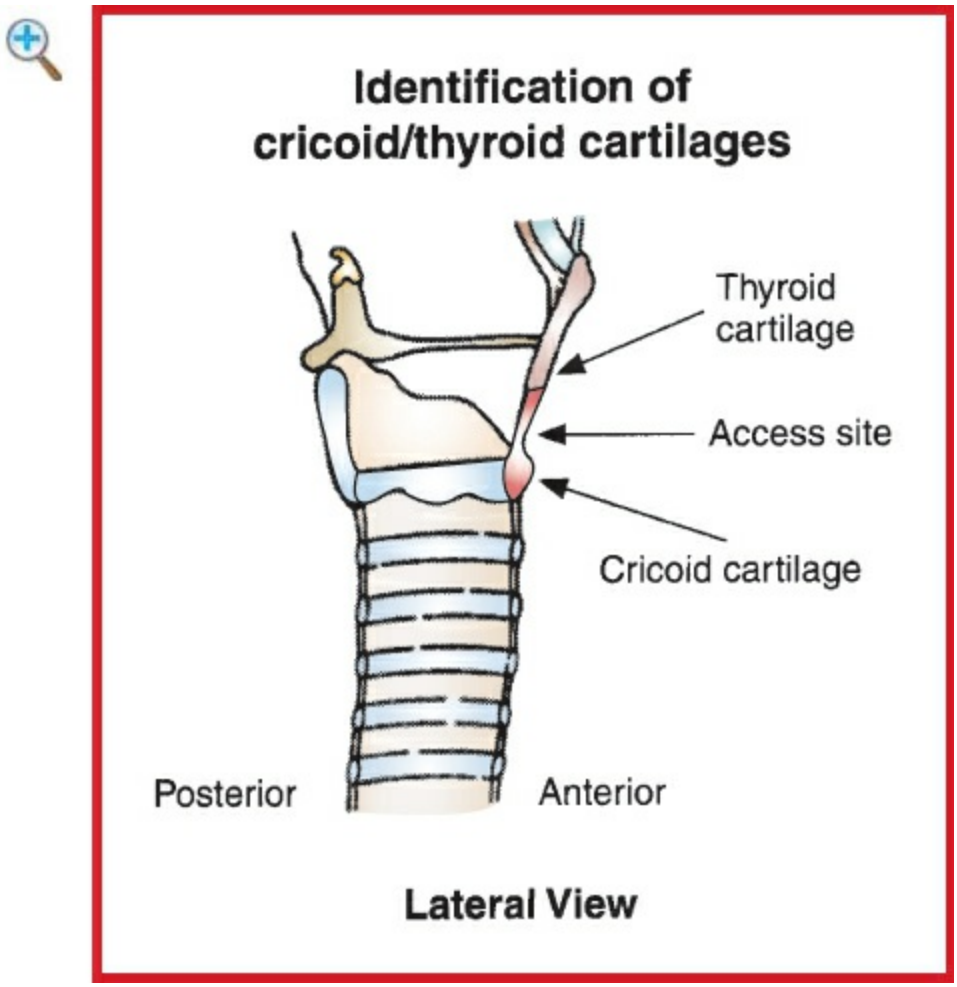

Figure 15.1 Identify cricoid membrane.

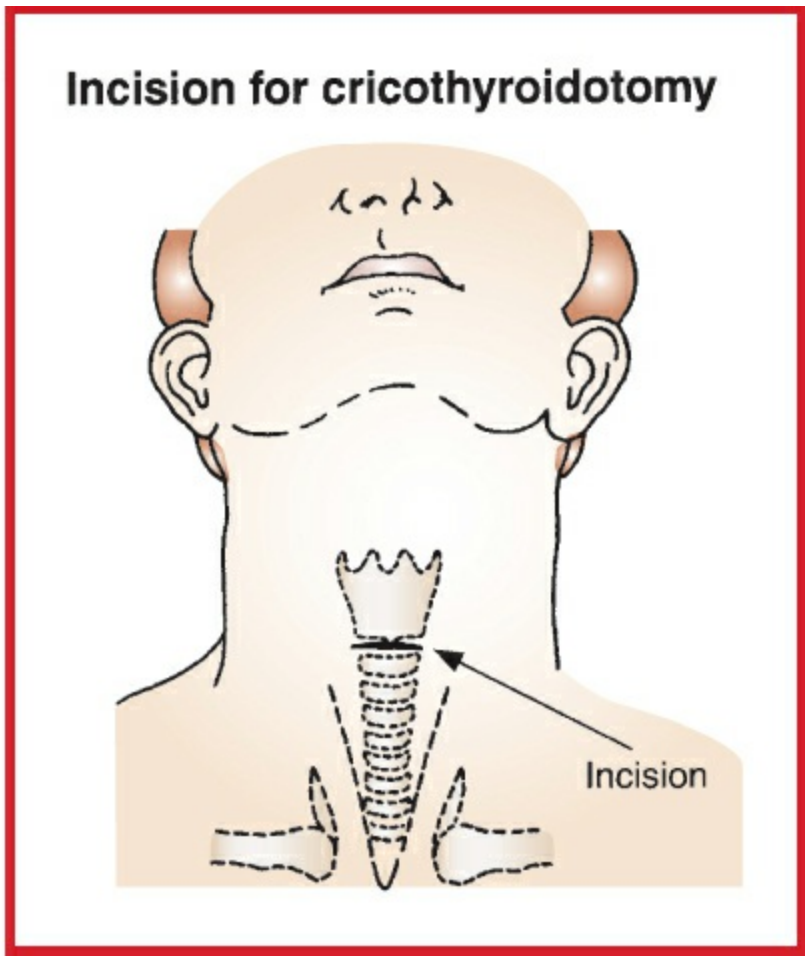

Figure 15.2 If possible, extend head and place bolster between scapula. Palpate thyroid and cricoid cartilages and then identify cricothyroid membrane (CTM). Skin incision may be vertical if unsure of CTM location, as a finger inserted through a vertical incision may have more ability to palpate the CTM by blunt pressure in a vertical or horizontal search.

Procedure	1. Prep skin if time permits. 2. Identify cricothyroid membrane between cricoid and thyroid cartilages (Fig. 15.1). 3. Make 2- to 3-cm transverse or vertical incision through skin. 4. Make 2.5-cm incision through cricothyroid membrane with single stab (Fig. 15.2). 5. Reverse scalpel, place handle into wound, and turn 90° to expand incision. 6. Pass tracheostomy tube (or standard ETT) into trachea. 7. Inflate cuff on tracheostomy/ETT. 8. Ventilate patient with capnography if possible. 9. Secure tube.

Emergency "Four-Step" Cricothyrotomy

Equipment	• Scalpel with no. 11 blade • Tracheal hook (may be improvised by bending a 16-ga needle into a hook with a hemostat) • ETT no. 6 • Syringe for inflating cuff • Prep solution such as alcohol, chlorhexidine, or povidone-iodine
Procedure	1. Right hand dominant operator stands on patient's left side. Position with head and neck extended. 2. Prep skin if time permits. 3. Nondominant hand identifies cricothyroid membrane while stabilizing thyroid cartilage. Dominant hand makes 2.5-cm transverse incision through skin and cricothyroid membrane with single stab, keeping blade in place. 4. Nondominant hand places tracheal hook into incision, lifting cricoid cartilage ventrally, and then scalpel is removed. 5. Dominant hand inserts ETT and then removes tracheal hook. 6. Inflate cuff. 7. Ventilate patient with capnography if possible. 8. Secure tube.

Emergency "Bougie-Guided" Cricothyrotomy

Equipment	• Scalpel and hemostat (central line kit) • ETT no. 6 • Syringe for inflating cuff • Bougie (pediatric 10 Fr for ETT 4.0–5.5 or adult 15 Fr for ETT 6.0) • Prep solution such as alcohol, chlorhexidine, or povidone-iodine
Procedure	1. Operator may stand at head or either side of the patient. Position with head and neck extended. 2. Prep skin if time permits.

3. Nondominant hand identifies cricothyroid membrane while stabilizing thyroid cartilage.
4. Dominant hand makes a 3-cm incision (vertical or transverse) through skin.
5. Nondominant hand index finger placed into incision, palpates cricothyroid membrane with a side-to-side motion, and then finger is removed from incision.
6. Dominant hand makes a 2.5-cm horizontal incision in the cricothyroid membrane.
7. Dominant hand inserts coude tip end of bougie via incision seeking tracheal clicks and hang-up sign.
8. Pass ETT over bougie into trachea. If difficult, use hemostat to dilate cricothyroid membrane with bougie in place and then pass ETT (Fig. 15.3).
9. Remove bougie.
10. Inflate cuff.
11. Ventilate patient and monitor capnogram if possible.
12. Secure tube (Fig. 15.4).

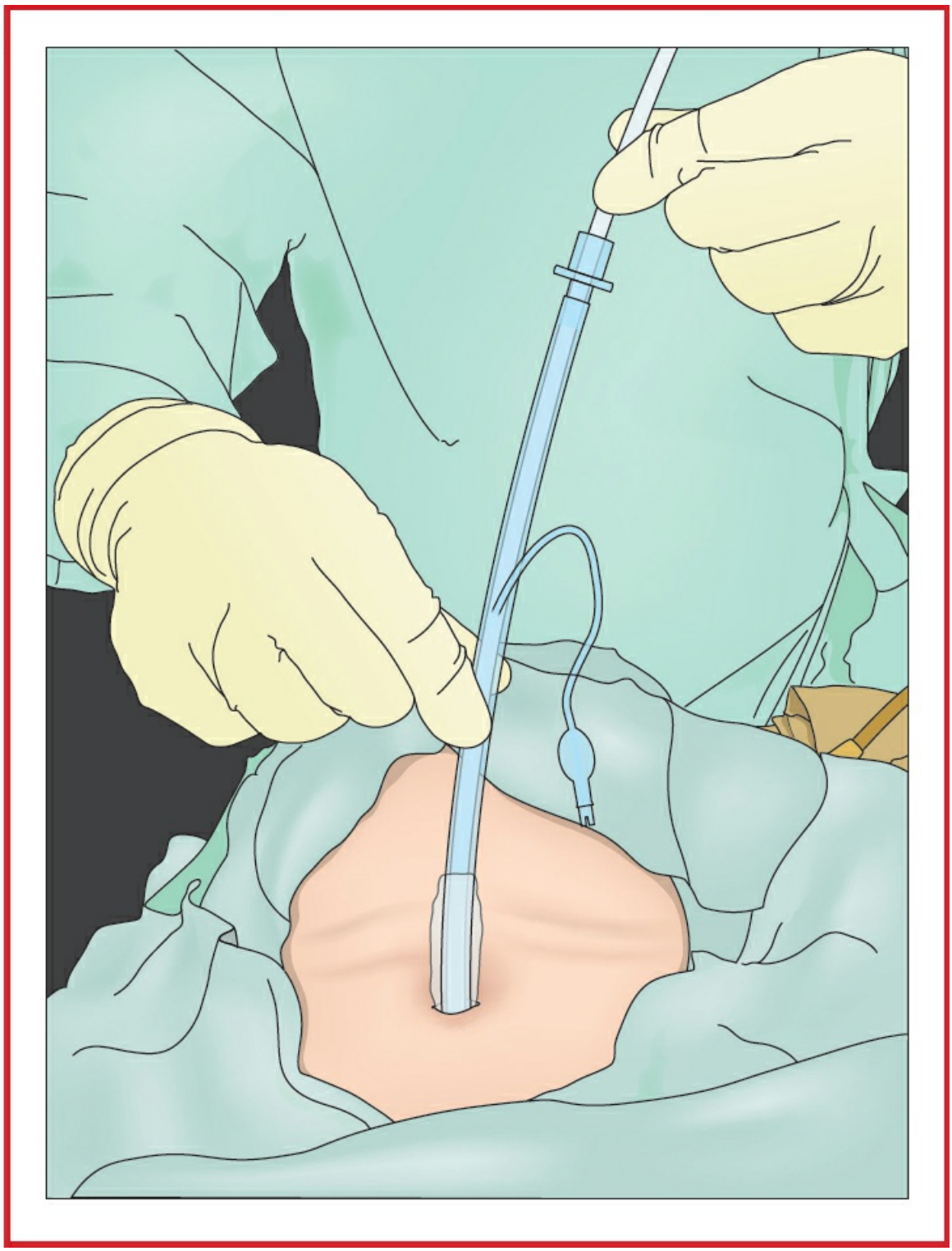

Figure 15.3 Adult bougie 15 Fr passed via incision with coude tip directed caudally attempting to feel for tracheal clicks and/or carinal hang-up sign. Average depth from skin to carina is 12–15 cm. A 6.0 or greater ETT will pass over an Adult 15 Fr bougie.

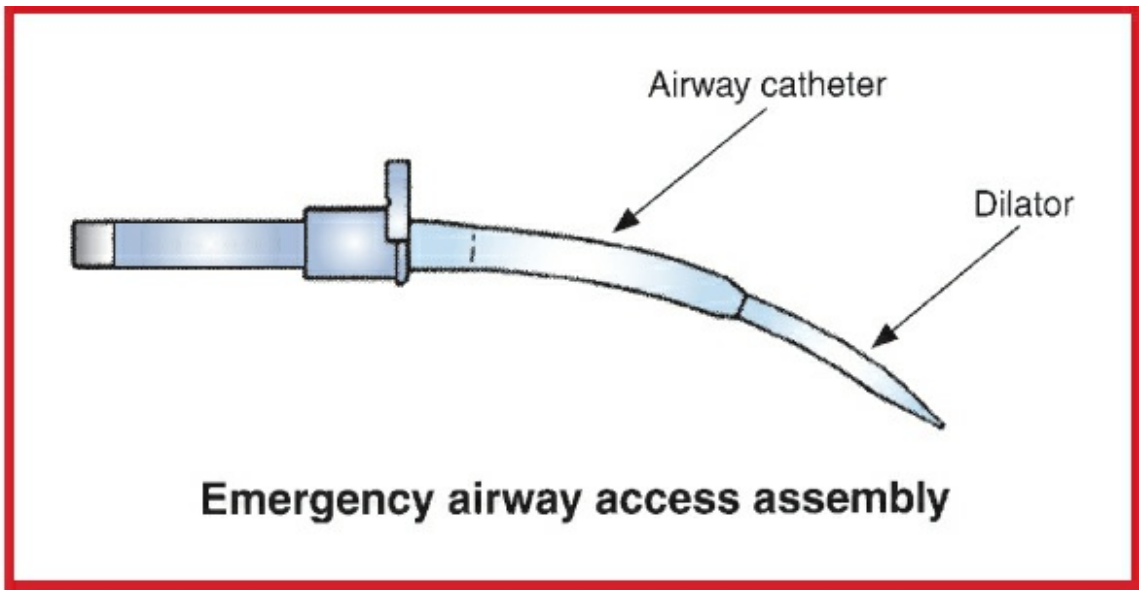

Figure 15.4 Melker cricothyroidotomy kit with dilator passed firmly into airway catheter prior to accessing the CTM.

EMERGENCY PERICARDIOCENTESIS

Clinical situation

The patient typically has severe ↓BP unexplained by any other causes (e.g., anesthetic drugs, autoPEEP, tension pneumothorax) and consistent with acute cardiac tamponade (dyspnea, tachypnea, ↓BP, ↑HR, electrical alternans, ↓voltage EKG, ↓pulse pressure or pulsus paradoxus, ↑CVP/JVD, distant heart sounds) ± equalization of pressures (RAP ~ RVEDP ~ PAD ~ PAOP) ± confirmation by TEE/TTE. Because of the high intrapericardial pressures, all "filling pressures" of both right and left heart appear high when preload is actually very low. In severe cases, patients will experience cardiac arrest with pulseless electrical activity (PEA).

Equipment	• 10-mL syringe • 18-ga spinal needle
Procedure	1. Identify xiphoid process and point 1 inch below and 1 inch left of midline (Fig. 15.5). 2. Prep skin below xiphoid. 3. An 18-ga spinal needle is directed toward the left shoulder and inserted at a ≤45° angle to the skin. 4. Attach needle to syringe, and direct needle at ≤45° to the skin under rib toward left shoulder (Fig. 15.5).

5. If pericardial fluid is withdrawn, BP will ↑ immediately.

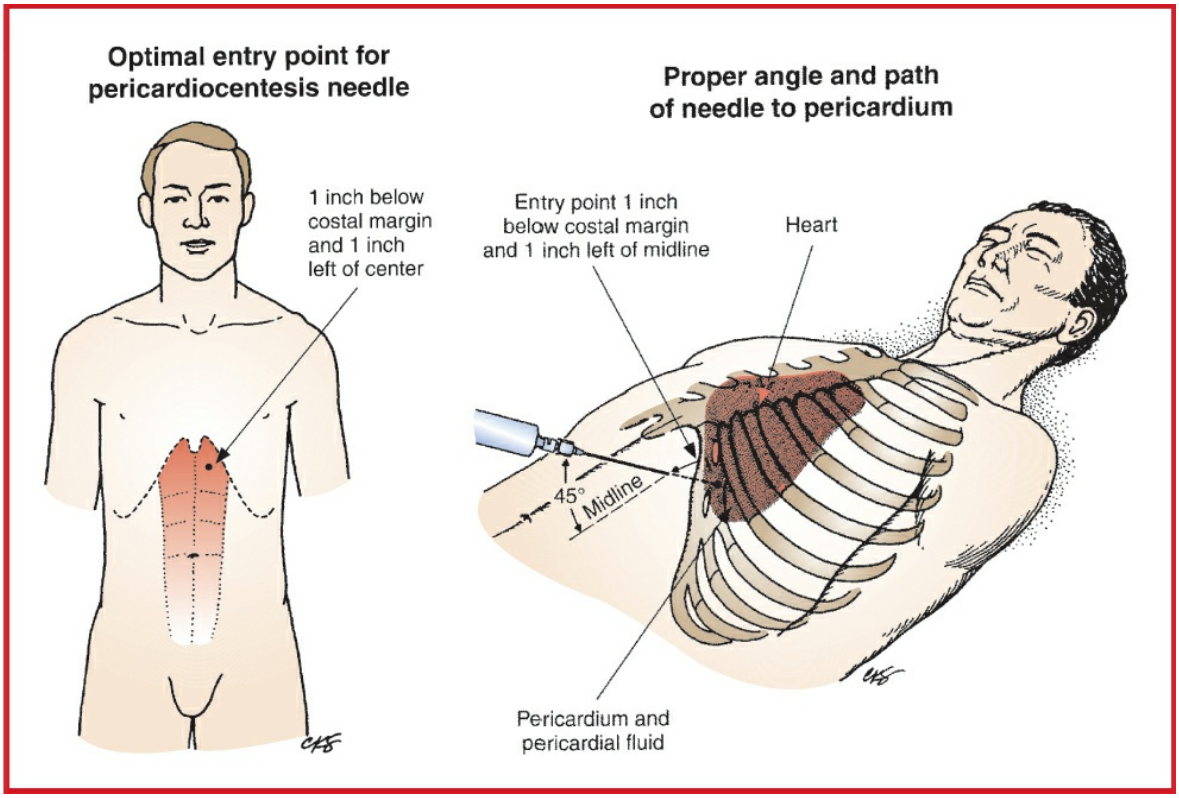

Figure 15.5 Emergency blind pericardiocentesis. Once diagnosis of cardiac tamponade is made, elevate head of bed to 30–45° to allow gravity to assist in fluid access. If hemodynamics do not allow this, place the patient into a supine position. The access site is 2.5 cm below the xiphoid process and 2.5 cm to the patient's left. An 18-ga spinal needle is directed toward the left shoulder and inserted at a ≤45° angle to the skin. The stylet is removed, a syringe with stopcock attached, and the apparatus advanced with aspiration. If time allows, anesthetize the route with lidocaine 1–2% 5–10 mL.

EMERGENCY ULTRASOUND-GUIDED PERICARDIOCENTESIS[1,5]

In the above-described setting of respiratory and hemodynamic stability, ultrasonography may be used to aid in diagnosis and treatment of cardiac tamponade. If you are unfamiliar with basic cardiac ultrasonography, a stat consult with a skilled ultrasonographer is necessary for performance of an ultrasound-guided pericardiocentesis. Precepted hands-on training must be sought prior to using ultrasound for diagnosis or treatment of cardiac tamponade.

Cardiac tamponade is a clinical diagnosis. Ultrasound findings include pericardial fluid with a "swinging heart" (ultrasound visualization of electrical alternans); increasing

pericardial pressure causes right atrial systolic collapse, right ventricle diastolic collapse, septal shift toward left ventricle in systole; respiratory variation across tricuspid and mitral valves; in addition, IVC plethora with no respiratory variation may be seen. Patients with normal, stable hemodynamics and pericardial effusion do not require emergent pericardiocentesis.

Equipment	Minimum • Skilled ultrasonographer • Ultrasound machine with phase array, curvilinear, or vascular access probe • Ultrasound gel or lubricant • Syringe • 18-ga 5-inch spinal needle or 18-ga Tuohy needle or longest 18-ga angiocatheter/needle available
	Preferred • Alcohol, chlorhexidine, or povidone-iodine skin prep • Sterile gloves • Skilled ultrasonographer • Ultrasound machine with phase array, curvilinear, or vascular access probe • Sterile ultrasound probe sheath with gel • 10-, 20-, or 60-mL syringe • 18-ga spinal needle • 3-way stopcock • Lidocaine 1–2% 5–10 mL with 5-mL syringe and 3-inch 25-ga needle
Subxiphoid Approach	1. Identify xiphoid process and point 1 inch below and 1 inch left of midline (Fig. 15.5). 2. Prep skin, then attach needle to 3-way stopcock on a syringe. 3. Use ultrasound probe with sterile sheath to find largest accessible collection of pericardial fluid in the subxiphoid space. A subxiphoid four-chamber view or short-axis midpapillary view should be attempted. Note that you may need to pass the needle through the liver to get to the pericardial space. If no chest compressions are being performed, consider positioning the patient in slight head-up or left lateral decubitus position to

optimize fluid accessibility. If the patient is conscious, consider local anesthetic injection along anticipated needle path under ultrasound visualization.

4. Place needle next to probe in same alignment to the skin and pericardial fluid (Fig. 15.6).
5. Advance needle tip under direct ultrasound visualization (Fig. 15.6).
6. When needle tip enters fluid collection, withdraw fluid. If flowing freely, continue to withdraw fluid until syringe is full, or you may turn the 3-way stopcock open to atmosphere to allow pericardial pressure to decompress. (If unsure of needle tip position, abort attempt or consider injection of 1- to 3-mL agitated saline via needle to identify location of tip relative to pericardial fluid.)
7. Remove needle once hemodynamics have improved with fluid removal.
8. Monitor patient for reaccumulation of pericardial fluid and consult for formal evaluation and possible pericardial drain placement.

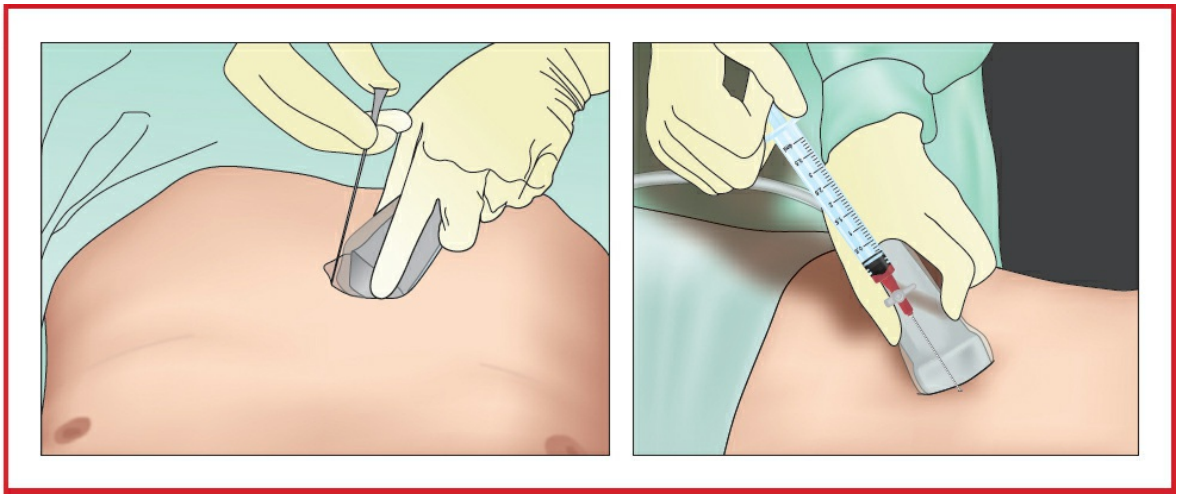

Figure 15.6 Emergency ultrasound-guided pericardiocentesis. Subxiphoid approach. Once ultrasonographic diagnosis of cardiac tamponade is made, elevate head of bed to 30–45° to allow gravity to assist in fluid access. If hemodynamics do not allow this, place the patient into a supine position. The subxiphoid access site is 2.5 cm below the xiphoid process and 2.5 cm to the patient's left. With the ultrasound probe in place, visualizing the effusion and the heart, an 18-ga spinal needle is directed toward the left shoulder and inserted at a ≤45° angle to the skin. The stylet is removed, a syringe with stopcock attached, and the apparatus advanced with aspiration under direct visualization. If unsure of needle tip location, stop advancement and wait for expert help or consider injection of 1–3 mL of agitated saline to visualize tip location. If time allows, anesthetize the route with lidocaine 1–2% 5–10 mL. Both in-plane

and out-of-plane techniques are acceptable.

Parasternal Approach (Fig. 15.7)	Prep skin, then attach needle to 3-way stopcock onto syringe. Use ultrasound probe with sterile sheath to find largest accessible collection of pericardial fluid in the parasternal area; 4th or 5th rib interspace along left sternal border. Note that you should not pass the needle through the pleural space/lung/vessels to enter the pericardial space. If patient is conscious, consider local anesthetic injection along anticipated needle path under ultrasound visualization. Place needle next to probe in same alignment to the skin and pericardial fluid. You may use color flow Doppler to visualize vessels in intended needle path. Advance needle tip under direct ultrasound visualization. When needle tip enters fluid collection, withdraw fluid. If flowing freely, continue to withdraw fluid until syringe is full, or you may turn the 3-way stopcock open to atmosphere to allow pericardial pressure/fluid to decompress. (If unsure of needle tip position, abort attempt or consider injection of 1- to 3-mL agitated saline via needle to identify location of tip relative to pericardial fluid.) Remove needle once hemodynamics have improved with fluid removal. Monitor patient for reaccumulation of pericardial fluid and consult for formal evaluation and possible pericardial drain placement.

Suggested Reading

1. Fitch MT, et al: Videos in clinical medicine. Emergency pericardiocentesis. N Engl J Med 2012; 366(12):e17.

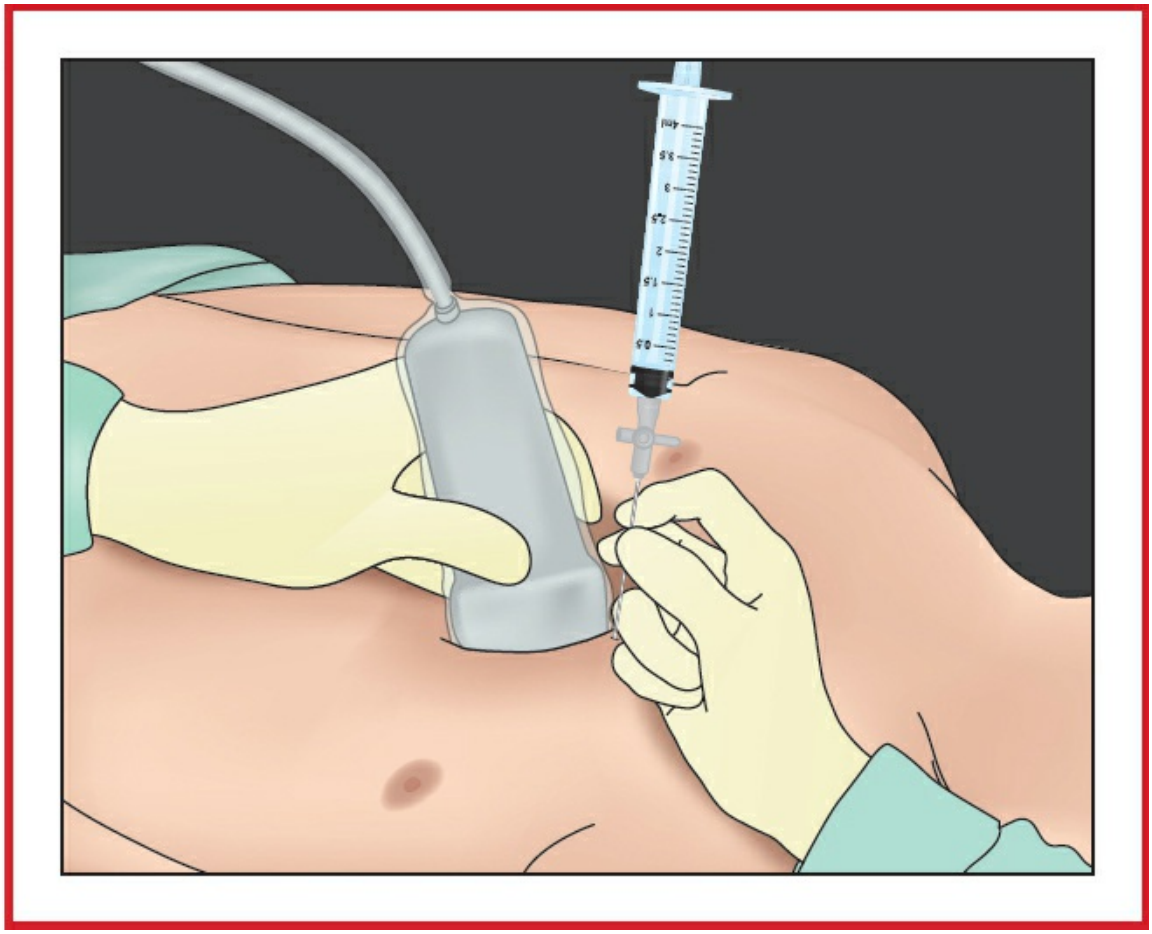

Figure 15.7 Emergency ultrasound-guided pericardiocentesis. Parasternal approach. Place the patient supine or in Trendelenburg to maximize fluid collection size in intended needle path. Identify the heart and fluid collection in the 4th or 5th intercostal space between the sternum and the midclavicular line. Be sure that the lung is not entering into ultrasonographic view. An 18-ga spinal needle is directed toward the patient's back and inserted at a 90° angle to the skin. The stylet is removed, a syringe with stopcock attached, and the apparatus advanced with aspiration under direct visualization. If unsure of needle tip location, stop advancement and wait for expert help or consider injection of 1–3 mL of agitated saline to visualize tip location. If time allows, anesthetize the route with lidocaine 1–2% 5–10 mL.

Suggested Viewing

Links are available online to the following videos:

Chest tube insertion: https://www.youtube.com/watch?v=hQlt57AyQmg

Emergency surgical airway: https://www.youtube.com/watch?v=BwWIvJNecSg

Cricothyrotomy: https://www.youtube.com/watch?v=_VFJGkJy1G8

Ultrasound-guided pericardiocentesis procedure—SonoSite ultrasound: https://www.youtube.com/watch?v=T6Z9DvPPmXg

Needle thoracostomy—www.proceduresconsult.com: https://www.youtube.com/watch?v=4cuotNQPRNc (subscription required to view complete video)

Needle decompression (thoracostomy): https://www.youtube.com/watch?v=TZpq8EPJ13Q&list=PLAB3A880AAEFB4992&index=2

Needle decompression hazards: https://www.youtube.com/watch?v=fQqPktj_gFc

Venous cutdown.mp4: https://www.youtube.com/watch?v=AHuJZHvTNGE

EMERGENT NEEDLE/CATHETER THORACOSTOMY

Clinical situation

A patient is experiencing severe hypotension and hypoxemia unexplained by any other cause (e.g., autoPEEP, cardiac tamponade) and consistent with acute tension pneumothorax (dyspnea, tachypnea, tachycardia, syncope, ↑P_{aw}, ↓movement of involved chest, ↓breath sounds, ↑resonance to percussion, and ↑rib interspace distance compared to uninvolved side) and cardiovascular Sx related to ↑thoracic pressures and ↓preload (↓BP, ↑HR, ↑pulse pressure, ↑CVP). The CVP is artificially elevated, reflecting the hig intrathoracic pressures. Actual (transmural) CVP is very low. In severe cases, patients may experience cardiac arrest with pulseless electrical activity (PEA) because high intrathoracic pressures effectively stop venous return to the heart.

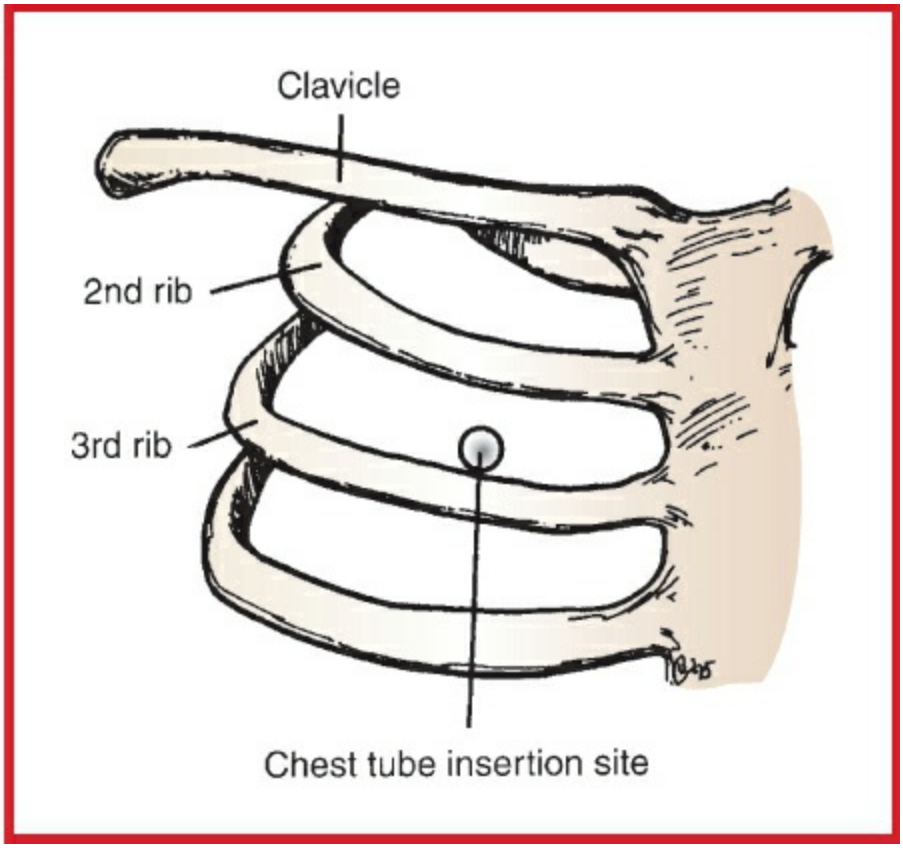

Figure 15.8 Midclavicular 2nd intercostal space. Lateral needle decompression in the 4th or 5th midaxillary line. To avoid injury to neurovascular bundle, insert needle along upper border of the inferior rib at the selected space.

Note: AutoPEEP MUST be ruled out first, particularly when the diagnosis is bilatera

tension PTX. AutoPEEP is effectively ruled out (except with a ball valve airway lesion) by disconnecting the ETT from ventilator/Ambu® bag and allowing patient to exhale. If the patient's condition immediately improves, you have made the diagnosis of autoPEEP.

Note: With a pneumothorax, release of the pressure that has built up in the chest is a lifesaving maneuver. A large-bore chest tube does not need to be placed emergently. The much simpler needle/catheter thoracostomy is effective and less demanding for the nonsurgeon.

Equipment	One of the following: • 16-ga needle or iv catheter/needle (preferred) with a length of 5 cm • 16-ga single-lumen CVP kit • Alcohol, chlorhexidine, or povidone-iodine skin prep
Procedure	1. Identify the space. Identify the 2nd intercostal space by palpating the angle of Louis (union of manubrium and sternum); then move laterally to find the insertion of the 2nd rib. The interspace directly below this rib is the 2nd intercostal space (Fig. 15.8). Access should occur in the midclavicular line in this space. Alternatively, the anterior or midaxillary line in the 4th–5th intercostal space may be used. Identify the anterior axillary line by drawing an imaginary line caudally from the anterior axillary fold to rib space at or above the nipple line. 2. Prep skin. 3. Enter the selected intercostal space anteriorly over the upper border of the inferior rib to avoid neurovascular bundle running along the underside of the superior rib. 4. With entry into the pleural space, there may be an audible rush of air and with immediate hemodynamic improvement. 5. Remove needle. 6. The angiocatheter may be held in place until a chest tube is inserted. 7. Note: A more permanent chest tube will still need to be placed (i.e., the patient no longer has a tension

	pneumothorax, but still has a pneumothorax). This can be done in a more controlled situation by someone skilled in that procedure.

EMERGENT ULTRASOUND-GUIDED NEEDLE/CATHETER THORACOSTOMY

Tension pneumothorax diagnosis and management have been described earlier. If progressive pneumothorax with worsening cardiopulmonary function is suspected, a skilled ultrasonographer is needed to rule out pneumothorax prior to tension pneumothorax development. Lung ultrasound has >90% sensitivity and >90% specificity for pneumothorax.[6] A vascular access, curvilinear, or phase array probe with a depth field of 6 cm using 2D imaging may be utilized to detect pneumothorax. 2D and M mode may be used to identify signs to rule in or out a pneumothorax. Precepted hands-on training must be sought prior to using ultrasound to diagnose or treat pneumothorax.

Equipment	• Skilled ultrasonographer • Ultrasound machine with phase array, curvilinear, or vascular access probe • Ultrasound gel or lubricant • 16-ga needle or angiocatheter/needle
Procedure	1. Identify pneumothorax with ultrasound.[7] 2. Scan least dependent area of chest with ultrasound probe (in supine patients—3rd–5th rib interspace midclavicular line) at 6 cm in 2D with indicator toward the patient's head and held perpendicular to chest wall (Fig. 15.9). 3. Identify the pleural line and seek lung sliding. Lung sliding confirms that the lung is touching the chest wall. Presence of lung sliding rules out large tension pneumothorax. 4. Seek B lines in 2D. Presence of B line rules out large tension pneumothorax in the scanned space. 5. Check for seashore sign in M mode at site of lung sliding (Fig. 15.10). Presence of seashore sign rules out large tension pneumothorax in the scanned space.

6. Alternatively, absence of seashore sign and presence of bar code (Fig. 15.11) sign indicate pneumothorax. The lung point sign is a moving dark point seen at the interface of normal lung sliding to the air of the pneumothorax. If lung point sign is present, this indicates pneumothorax.
7. If all the above signs are absent and A lines are present, this does not rule out or in pneumothorax. Other modalities such as CXR or CT for diagnosis or continuing with diagnostic/therapeutic needle thoracostomy will be required.
8. Prep skin. Place angiocath/needle to side of probe.
9. Enter the selected intercostal space anteriorly over the upper border of the inferior rib to avoid neurovascular bundle; attempt to visualize needle tip.
10. With entry into the pleural space, there may be an audible rush of air, and there should be immediate hemodynamic improvement.
11. Remove needle once hemodynamics or ventilation improves to avoid lung laceration. The angiocatheter may be held in place until a chest tube is inserted.

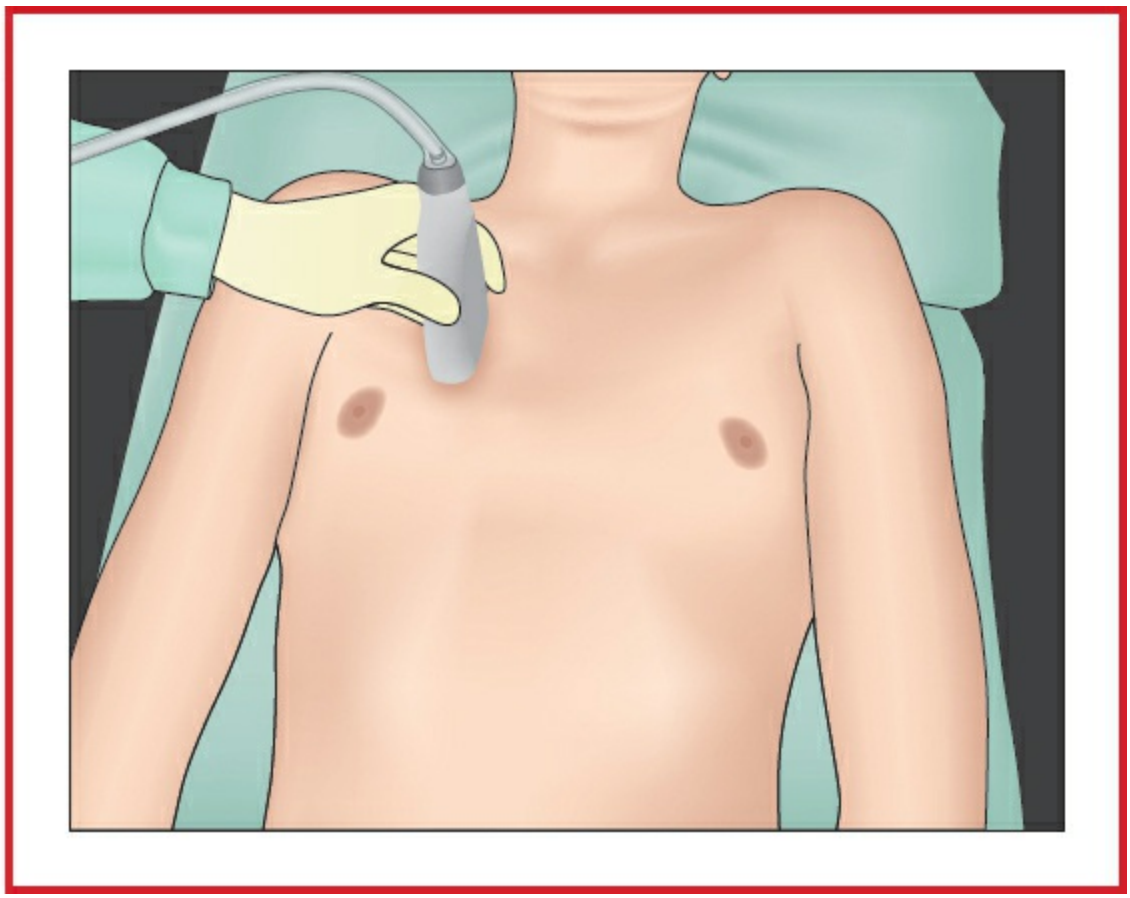

Figure 15.9 Place probe with indicator toward patient's head, perpendicular to chest wall, at the 3rd–5th intercostal space midclavicular line. In a supine patient, gas typically rises to this least dependent area of the chest cavity. You may move the probe caudally to scan multiple rib spaces in the midclavicular and axillary lines. (Ueda K, Ahmen W, Ross AF: Intraoperative pneumothorax identified with transthoracic ultrasound. Anesthesiology 2011; 115(3):653–5.[8])

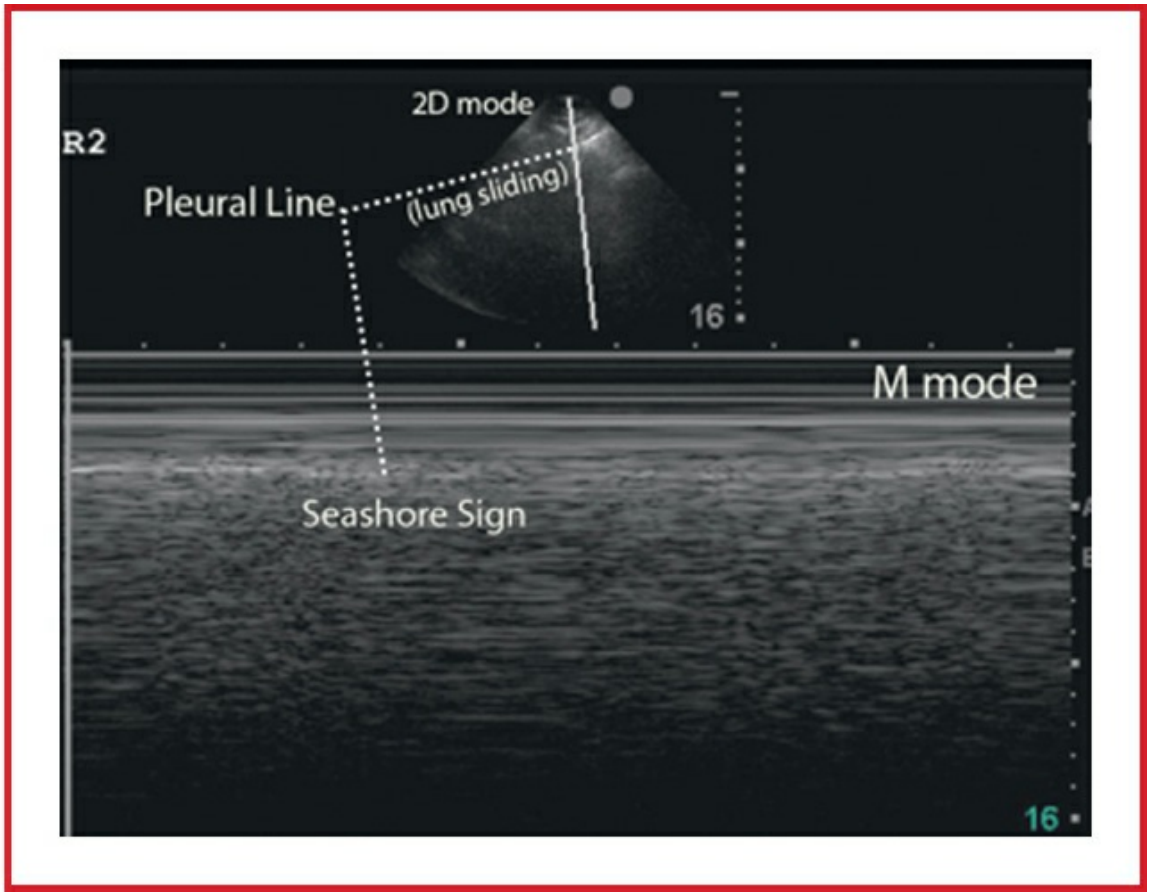

Figure 15.10 Seashore sign. M mode between the rib interspace with normal lung motion. The less mobile subcutaneous tissues and pleural tissues are seen as horizontal lines implying "waves" landing on a "sandy beach," the moving lung tissue represented by granular pattern below the pleural line.

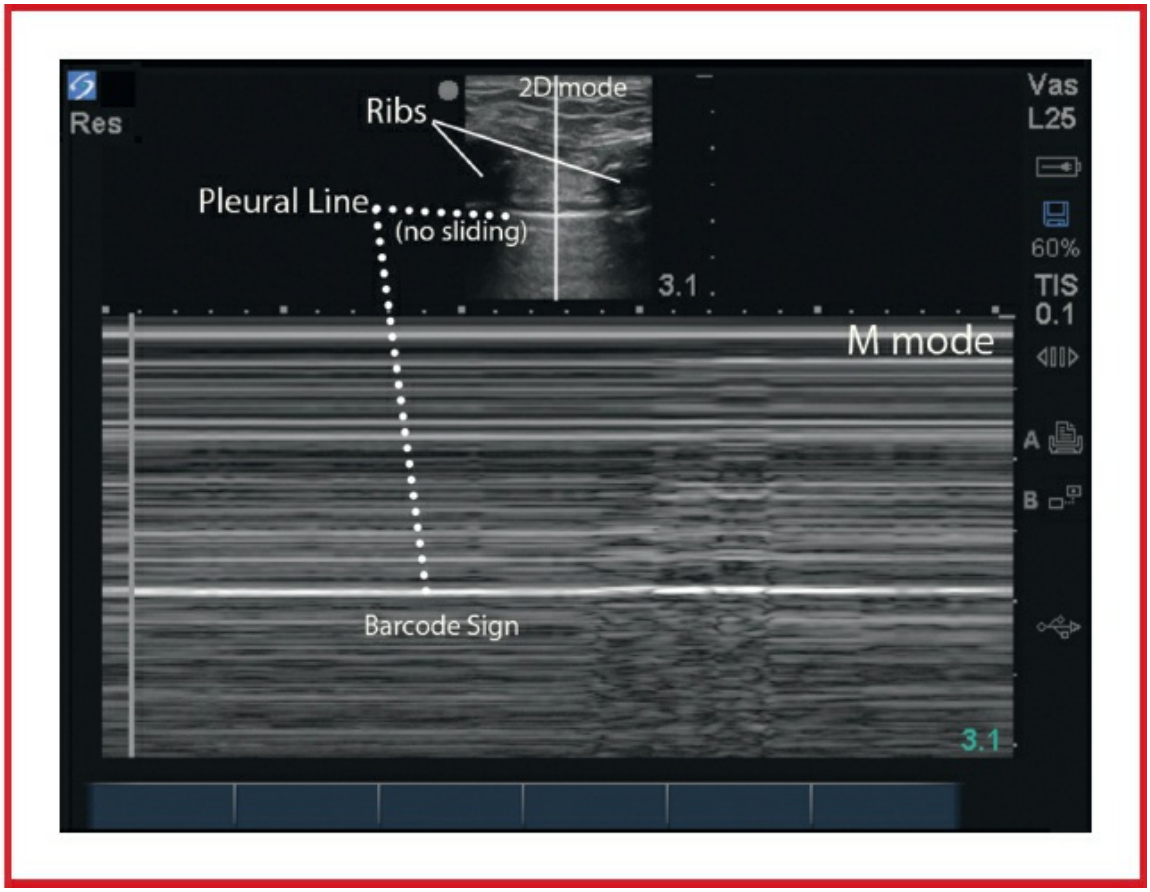

Figure 15.11 Bar code sign. During respiratory cycle, the "sand" (normal granular pattern) under the pleural line is replaced by "bar code" horizontal lines, indicating no lung sliding. (You-Ten KE, Siddiqui N, Teoh WH, et al: Point-of-care ultrasound (POCUS) of the upper airway.Can J Anaesth 2018; 65(4):473–84.[9])

EMERGENCY INTRAOSSEOUS ACCESS

Emergency intraosseous (IO) access is indicated when immediate vascular access is needed, and peripheral/central access is not possible, and endotracheal medication administration will not suffice. We discuss the use of the EZ-IO system of IO access Contraindications include burn, infection, or fracture of bone selected for access, joint replacement at selected site, or inability to identify landmarks.

Procedure	1. Prior to attaching the EZ-Connect®: ensure clamp is open. Prime set and purge air. Identify and clean insertion site (Fig. 15.12). 2. Snap EZ-IO needle set with plastic hub onto EZ-IO power driver (Fig. 15.13); (Red 15 ga, 15 mm for <40 kg. Blue 15 ga, 25 mm for >40 kg. Yellow hub 15 ga,

45 mm, >40 kg and excessive tissue or humerus site).

3. Remove needle safety cap.
4. Gently press needle set through skin until tip touches bone.
5. At least 5 mm of the catheter must be visible (Fig. 15.14).
6. Squeeze driver trigger and apply gentle, steady pressure. Release trigger when sudden "give" or "pop" is felt, indicating entry into medullary space. If driver stalls or will not penetrate the bone, you may be applying too much downward force. Humerus site: to improve stability, needle should be advanced 2 cm after contact with bone. In adults, advance needle until catheter hub is against the skin. Change sites for access rather than have repeated attempts at the same site.
7. Remove power driver and stylet; confirm catheter stability with at least three of the following four methods:
   - Stability of catheter
   - Ability to aspirate
   - Physiologic or pharmacologic changes with medication administration
   - Adequate flow rate
9. Secure with EZ-stabilizer or have an assistant manually stabilize hub until secured, roll 2 sets of 4 × 4s into tight cylinders, apply cylinders in a parallel orientation around catheter, "sandwiching" the hub, then secure with tape or transparent adhesive film with hole cut out for hub access.
9. Attach EZ-Connect® extension set. DO NOT ATTACH A SYRINGE DIRECTLY TO THE EZ-IO CATHETER HUB EXCEPT WHEN DRAWING BLOOD FOR LABORATORY ANALYSIS (STABILIZE NEEDLE SET).
10. Flush the EZ-IO catheter with normal saline (10 mL for adults; use appropriate weight-based dose for smaller patients). For patients responsive to pain, consider lidocaine up to 0.2–1 mg/kg io slowly prior to saline

	flush.
EZ-IO Removal	Attach Luer-lock syringe. Rotate syringe and catheter clockwise while using traction to withdraw catheter—DO NOT ROCK OR BEND THE CATHETER DURING REMOVAL (Fig. 15.15).

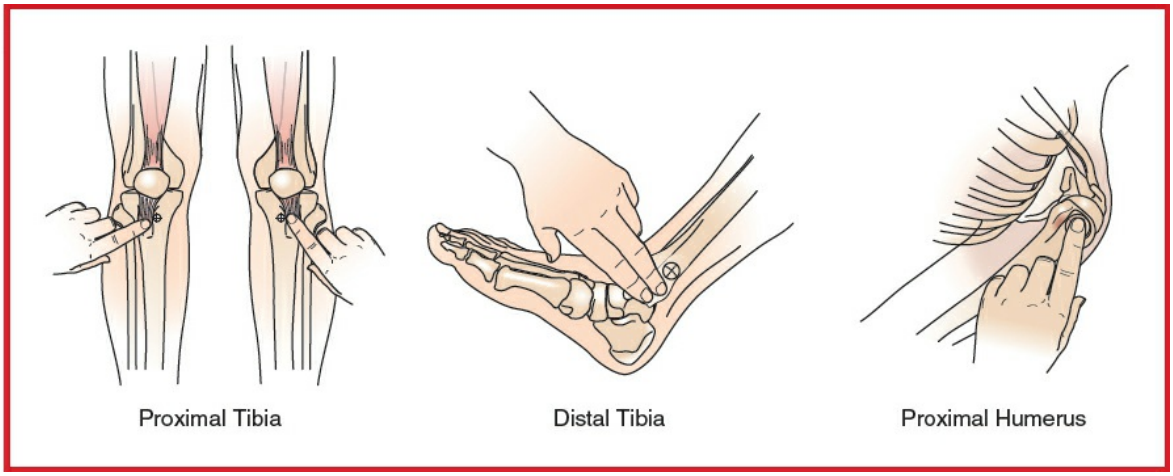

Figure 15.12 Identify and clean insertion site (proximal or distal tibia or humeral head).

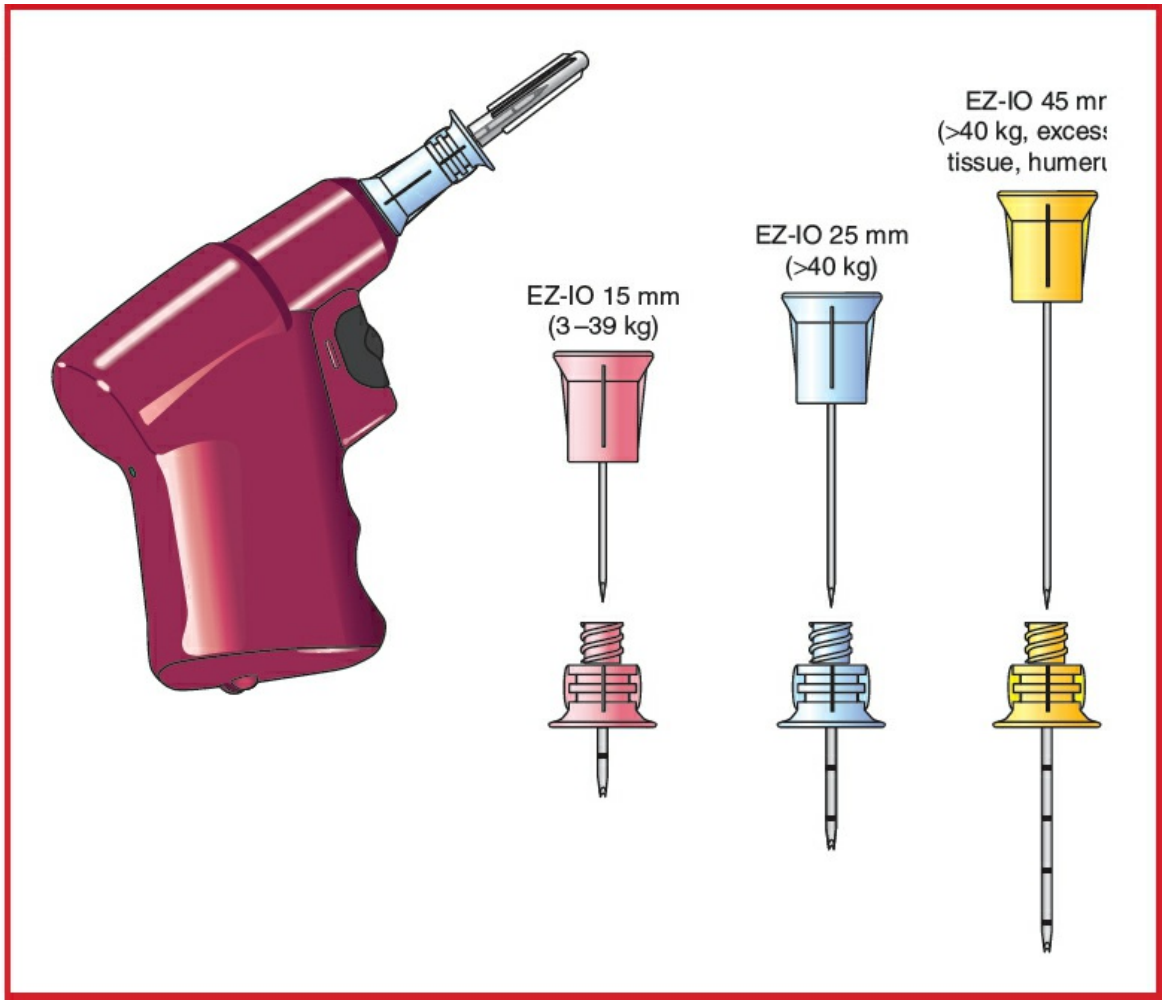

Figure 15.13 EZ-IO power driver and needle set sizes.

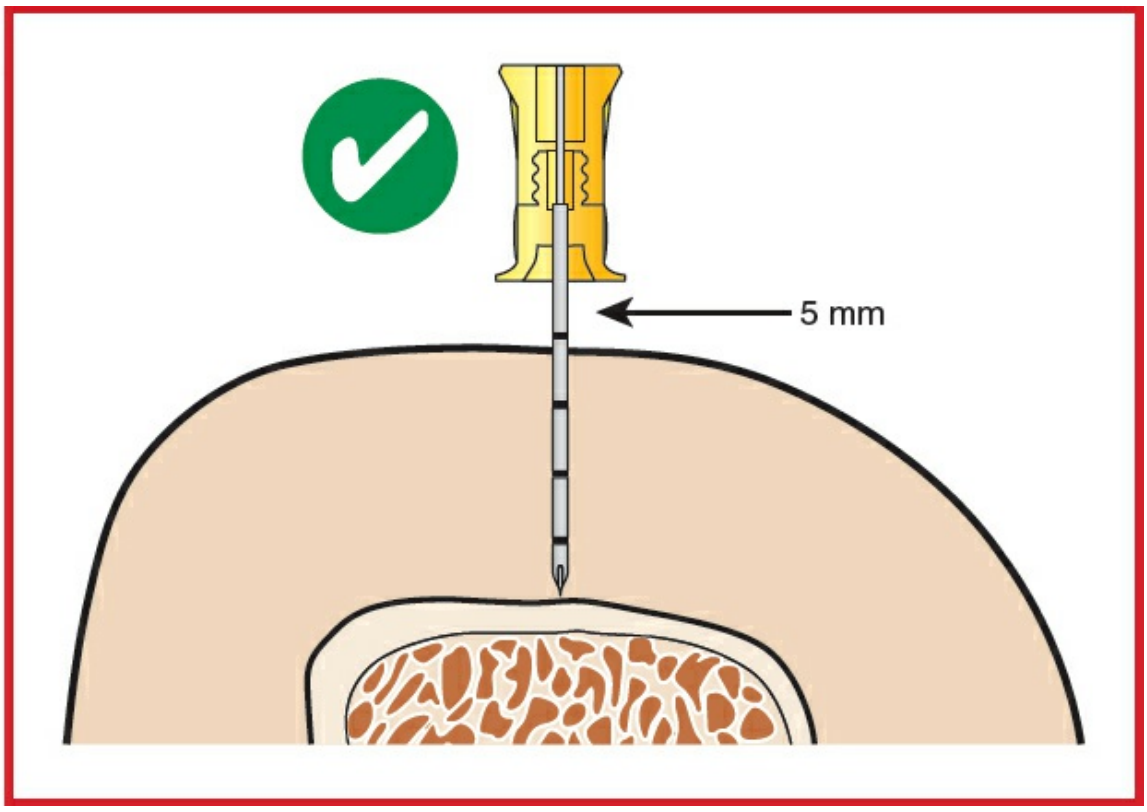

Figure 15.14 At least 5 mm of the catheter must be visible after pressing needle through skin to contact bone and prior to squeezing trigger.

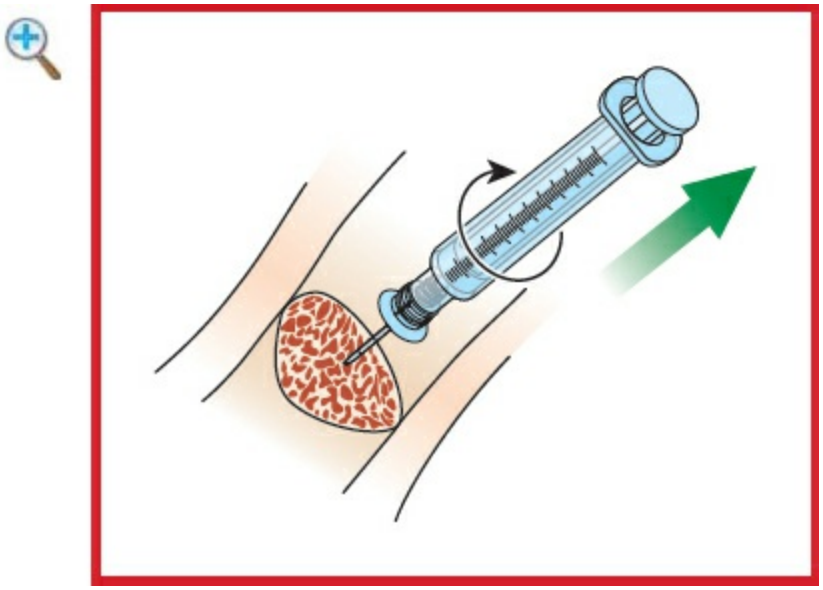

Figure 15.15 To remove EZ-IO catheter, attach Luer-lock syringe. Rotate syringe and catheter clockwise while using traction to withdraw catheter.

References

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SECTION 16.0

REGIONAL BLOCKS—A BRIEF OVERVIEW

ANESTHESIOLOGISTS
Jean-Louis Horn, MD
Mastoora Nasiri, MD

UPPER EXTREMITY BLOCKS

INTERSCALENE

Indications	Shoulder surgery

Anatomy

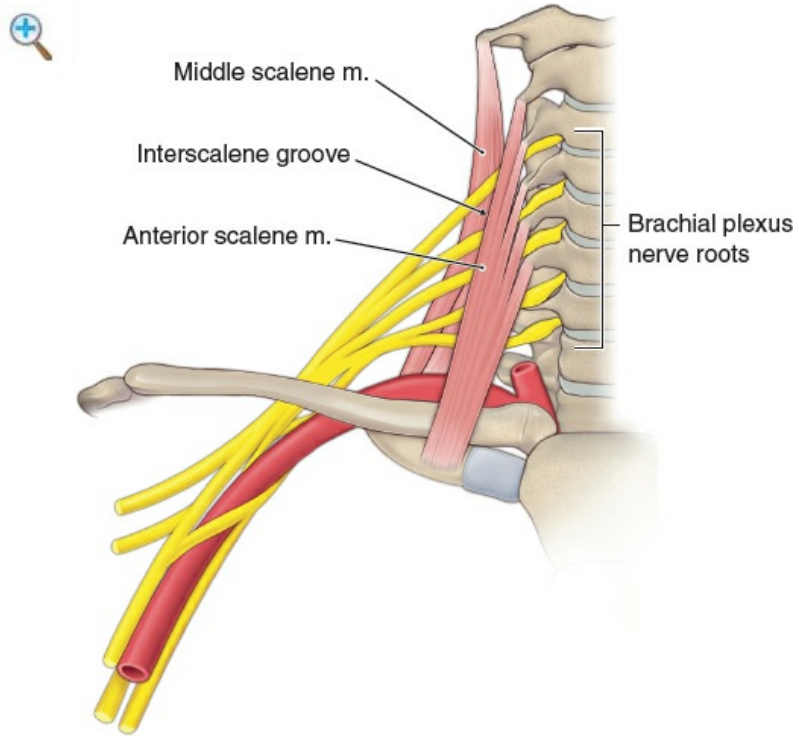

Figure 16.1 Interscalene anatomy. Superior trunk of the brachial plexus (C5-C6).

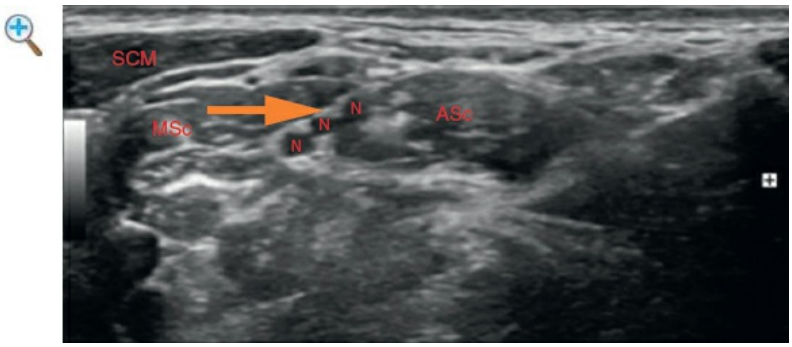

Figure 16.2 Interscalene ultrasound. SCM, sternocleidomastoid; MSc, middle scalene; ASc, anterior scalene; N, nerve.

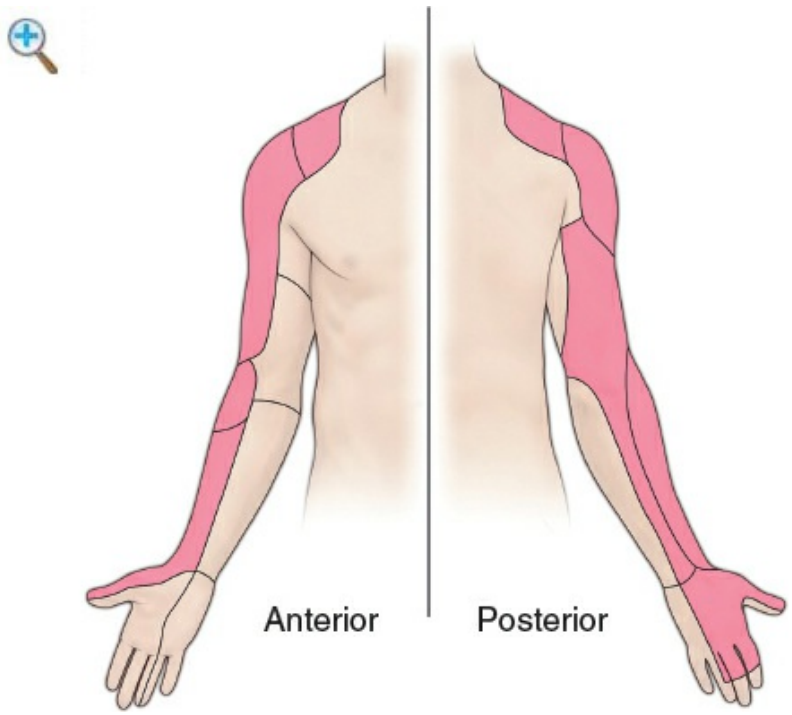

Figure 16.3 Interscalene anatomy.

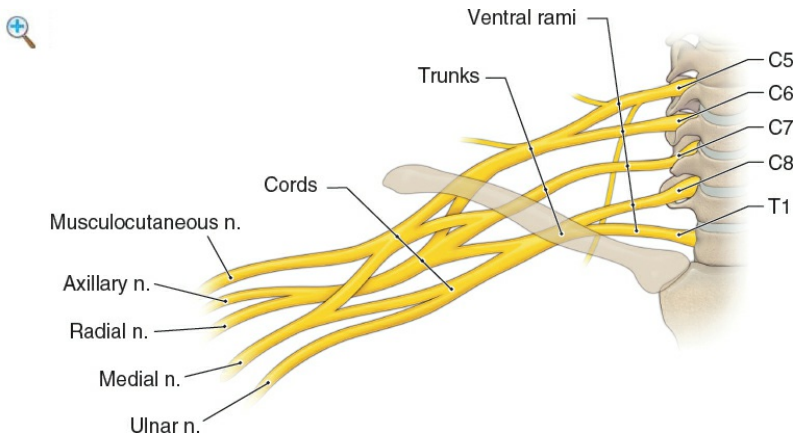

Figure 16.4 Interscalene anatomy.

Dosage	10–20 mL (0.25–0.5% ropivacaine/bupivacaine or 1–1.5% mepivacaine)
Nerve stimulation	Deltoid, distal extensor or lateral flexor
Side effects	Phrenic nerve block (nearly 100% with higher volume local anesthetic) Horner syndrome (rare, risk increases with high volume, fast injection) Recurrent laryngeal nerve block (rare, risk increases with high volume, fast injection) Superficial cervical plexus block extending to the ear

Complications	Permanent phrenic nerve palsy → hemidiaphragm paralysis: very rare Pneumothorax: low risk compared to more distal brachial plexus blocks Dorsal scapular nerve injury → winged scapula Long thoracic nerve injury → both DSN and LTN injury resulted in winged scapula can/or pain
Pearls	• Patient can be placed in the supine or lateral decubitus position • Ultrasound probe placed transversely with a 15–30° caudal angle, 3–4 cm above clavicle (level of cricoid cartilage) over external jugular vein with an in-plane or out-of-plane approach • Avoid injecting between C5 and C6 as this can increase risk of intraneural injection and side effects • Supplement with an intercostobrachial nerve block to cover the medial upper arm when needed (infrequent) • Special contraindications: contralateral phrenic nerve paresis; severe pulmonary disease
Alternative	Combined distal suprascapular and axillary nerve blocks Supraclavicular block Proximal suprascapular nerve block
Further reading	Mian A, et al: Brachial plexus anesthesia: a review of the relevant anatomy, complications, and anatomical variations. Clin Anat 2014; 27(2):210–21.

SUPRACLAVICULAR

Indications	Shoulder, arm, elbow, forearm, and hand surgery
Anatomy	

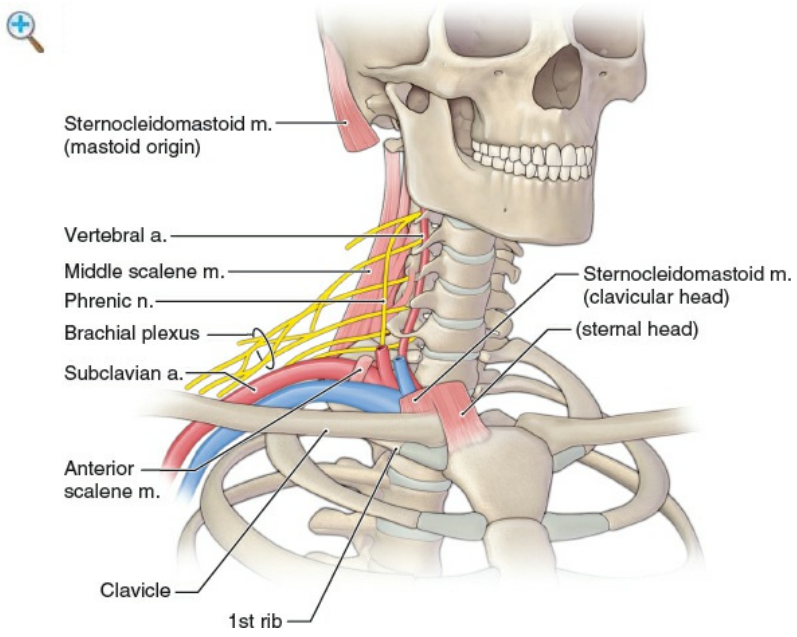

Figure 16.5 Supraclavicular anatomy. Often branches of the thyrocervical trunk cross the divisions creating a fascia preventing spread of local anesthetic. Divisions of the brachial plexus (anterior and posterior) lie mostly posterior to the artery.

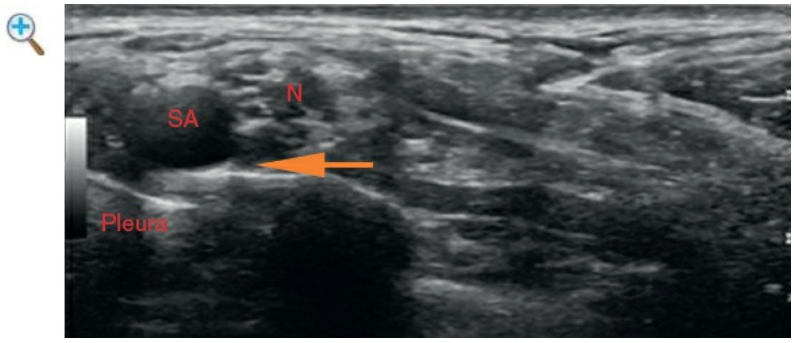

Figure 16.6 Supraclavicular ultrasound. SA, subclavian arter; N, nerve.

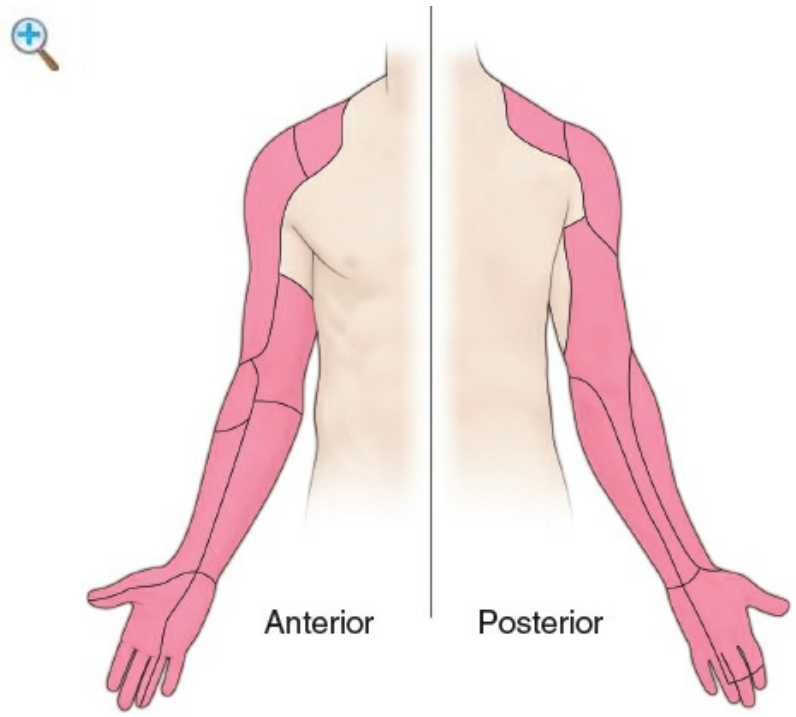

Figure 16.7 Supraclavicular anatomy.

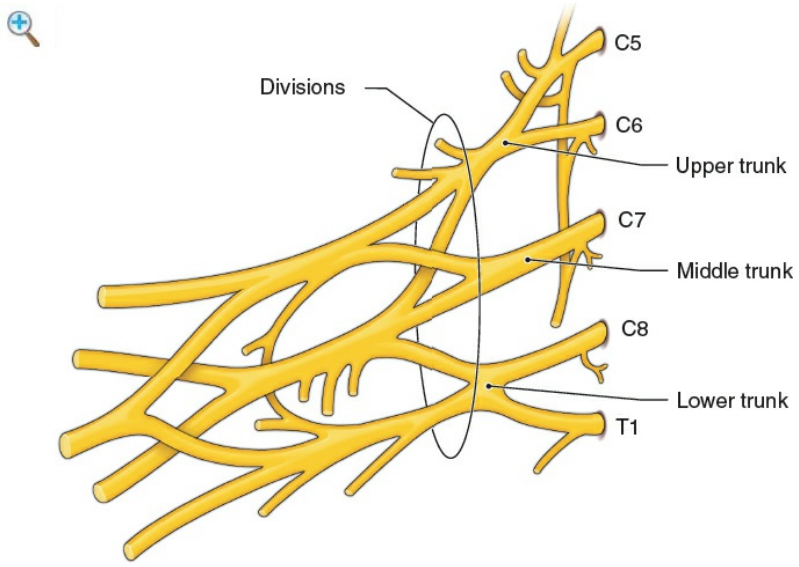

Figure 16.8 Supraclavicular anatomy.

Dosage	15–30 mL (0.5% ropivacaine/bupivacaine or mepivacaine 1–1.5%)
Nerve stimulation	Elbow, forearm, distal arm, hand
Side effects	Phrenic nerve block (40%) → hemidiaphragm paralysis Horner syndrome (very rare)

Complications	Pneumothorax: rare with ultrasound guidance Puncture of overlying vasculature: suprascapular, superficial cervical, transverse cervical, and dorsal scapular arteries (<1%) Suprascapular nerve injury → ↓ abduction and external rotation (supraspinatus + infraspinatus muscles)
Pearls	• Slightly prop the spine up to give space for injection. • Place ultrasound probe immediately parallel to the clavicle in the supraclavicular fossa and adjust the beam to place the target above the first rib to shield the lung. • Use a short needle to minimize chance of pneumothorax. • Success is associated with LA spread under the divisions next to the subclavian artery described as the corner pocket; however, fasciae often present barriers necessitating multiple site injections. • This is not the best site for catheter placement. • Supplement with an intercostobrachial nerve block to cover the medial upper arm when needed (infrequent). • Special contraindications: contralateral phrenic nerve paresis; severe pulmonary disease
Alternative	Axillary or infraclavicular block (especially with significant pulmonary disease to avoid phrenic nerve block)
Further reading	Vermeylen K, et al: Supraclavicular brachial plexus blocks: review and current practice. Acta Anaesthesiol Belg 2012; 63(1):15–21.

INFRACLAVICULAR

Indications	Arm, elbow, forearm, and hand surgery
Anatomy	

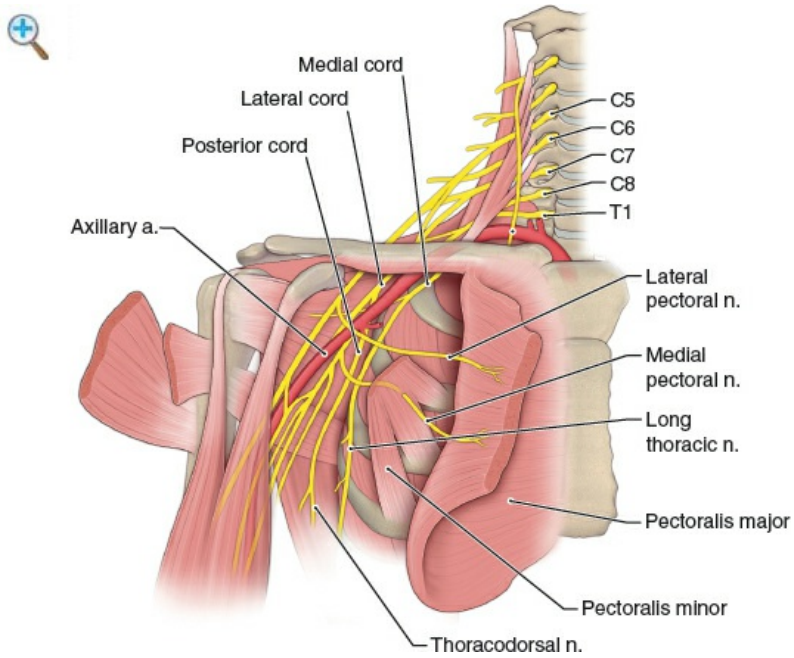

Figure 16.9 Infraclavicular anatomy.

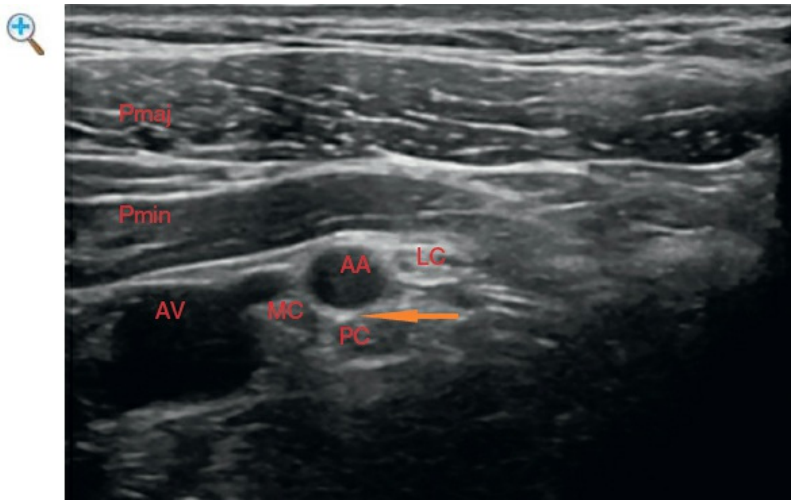

Figure 16.10 Infraclavicular ultrasound. Pmaj, pectoralis major; Pmin, pectoralis minor; AV, axillary vein; AA, axillary artery; LC, lateral cord; PC, posterior cord; MC, medial cord.

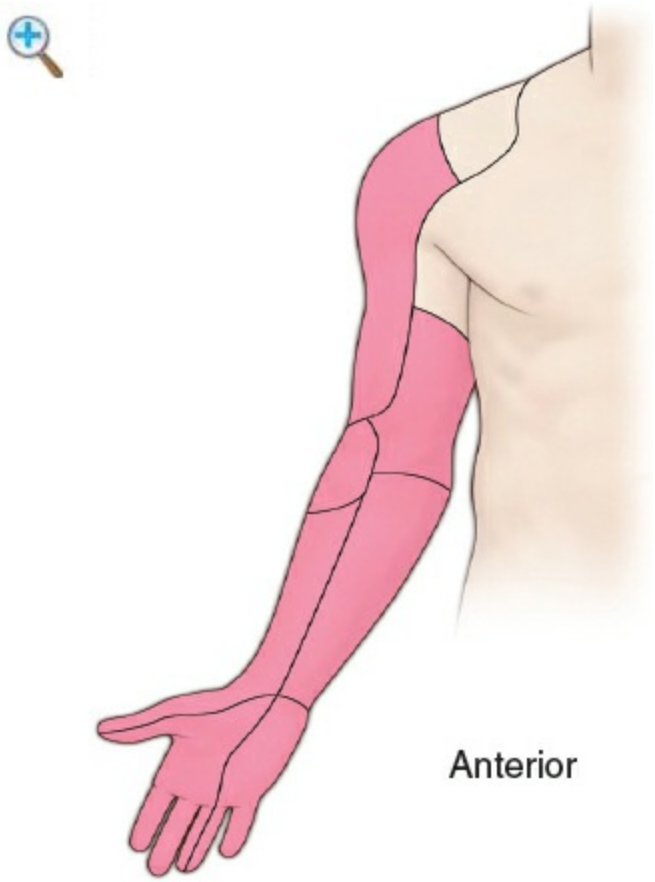

Figure 16.11 Infraclavicular anatomy.

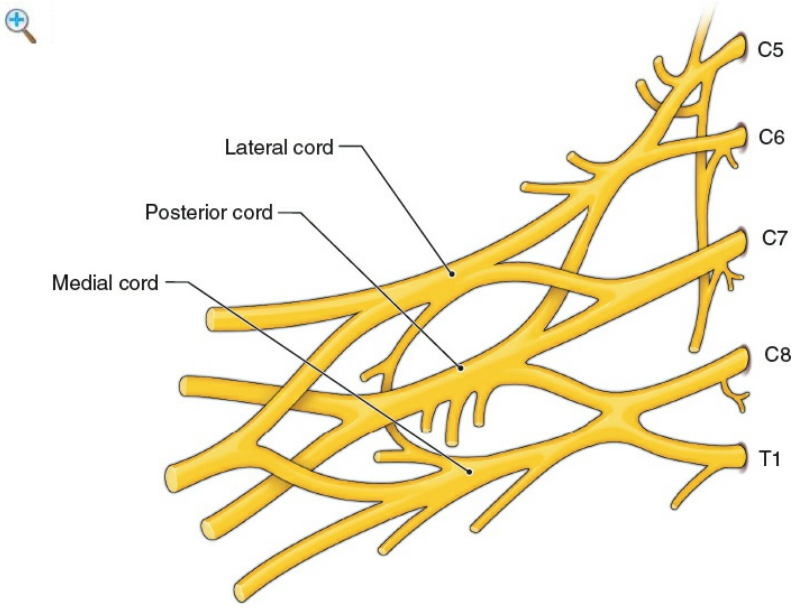

Figure 16.12 Infraclavicular anatomy.

Dosage	20–40 mL (0.5% ropivacaine/bupivacaine or mepivacaine 1–1.5%)
Nerve stimulation	Distal stimulation at the hand

Side effects	Minimal
Complications	Pneumothorax: rare with ultrasound guidance Vascular injury: <1% Lateral pectoralis nerve injury → ↓ pectoralis major muscle strength
Pearls	• Abduct the arm at the shoulder 90° to elevate the clavicle and open access to the cords. Place the probe in a sagittal plane. • For painful shoulder or arm, keep the arm adducted, rotate and translate the probe against the clavicle for a costoclavicular approach. Then tilt the probe slightly under the clavicle. • Success is associated with LA spread under the artery often described as the double bubble or eight ball for the sagittal approach. For the costoclavicular approach, the target is the corner pocket similar to the supraclavicular approach. • Supplement with an intercostobrachial nerve block to cover the medial upper arm when needed (infrequent).
Alternative	Supraclavicular block Axillary block
Further reading	Chin KJ, et al: Infraclavicular brachial plexus block for regional anaesthesia of the lower arm. Anesth Analg 2010; 111(4):1072.

AXILLARY BLOCK

Indications	Forearm and hand surgery
Anatomy	

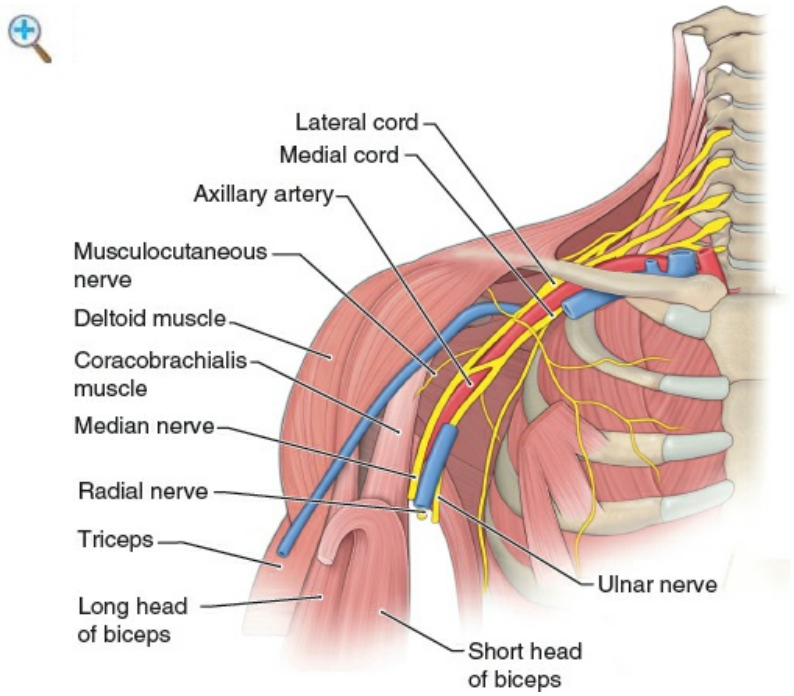

Figure 16.13 Axillary block anatomy. Terminal branches of the brachial plexus (median, ulnar, radial) surround the axillary artery. Musculocutaneous nerve is lateral to the artery and runs through the coracobrachialis muscle and then between the biceps brachialis and coracobrachialis muscles.

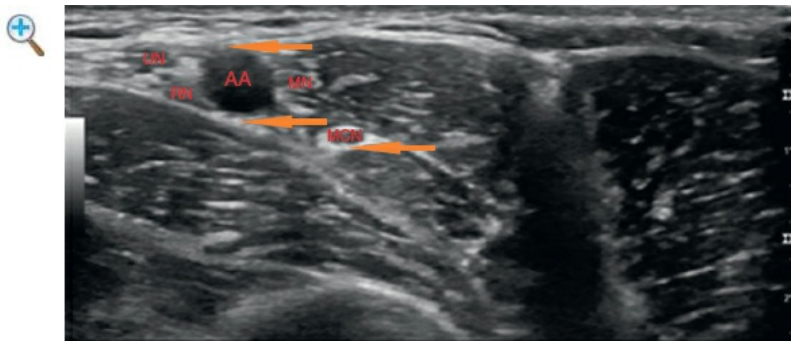

Figure 16.14 Axillary block ultrasound. AA, axillary artery; MCN, musculocutaneous nerve; MN, median nerve; RN, radial nerve; UN, ulnar nerve.

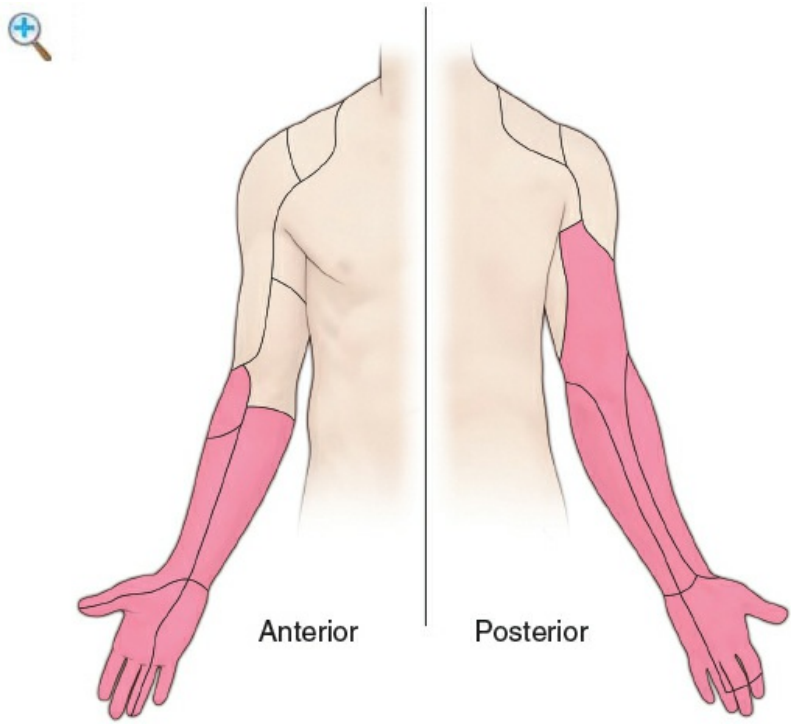

Figure 16.15 Axillary block anatomy.

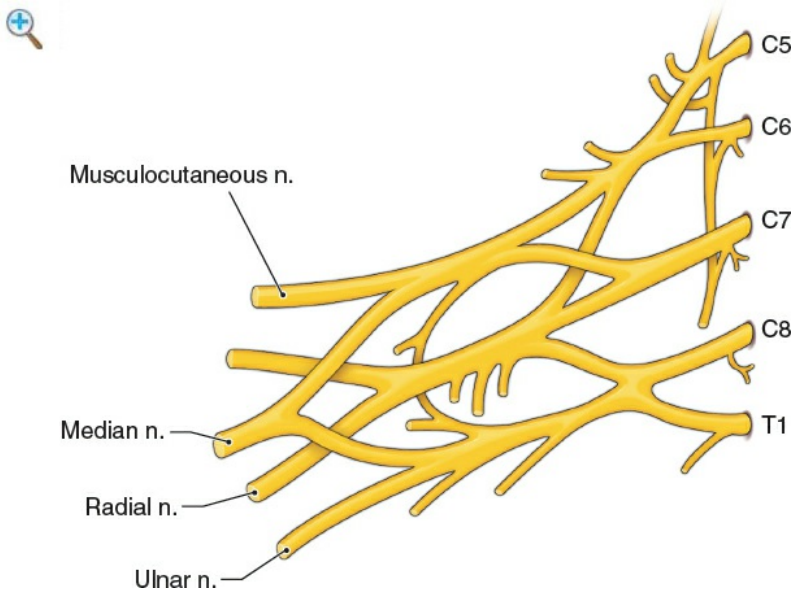

Figure 16.16 Axillary block anatomy.

	Musculocutaneous nerve is lateral to the artery and running through the coracobrachialis muscle and then between the biceps brachialis and coracobrachialis muscles
Dosage	20–40 mL (0.5% ropivacaine/bupivacaine or mepivacaine 1–1.5%)

Nerve stimulation	Distal stimulation at the hand, biceps brachialis stimulation for the musculocutaneous nerve
Side effects	Minimal
Complications	Intravascular injection/injury (<1% with ultrasound guidance)
Pearls	• Supplement with an intercostobrachial nerve block to cover the medial upper arm and improve tourniquet tolerance. • Separate injections for each nerve hasten the onset and increase success. • Catheter will only cover the adjacent nerve and usually provides only partial brachial plexus block. • Special contraindications: infected axillary lymph nodes.
Alternative	Supraclavicular block Infraclavicular block
Further reading	Nowakowski P, Bieryło A: Ultrasound guided axillary brachial plexus block. Part 1 and Part 2. Anaesthesiol Intensive Ther 2015; 47(4):409–24.

LOWER EXTREMITY BLOCKS

FEMORAL NERVE

Indications	Anterior thigh, knee, and medial ankle surgery

Anatomy

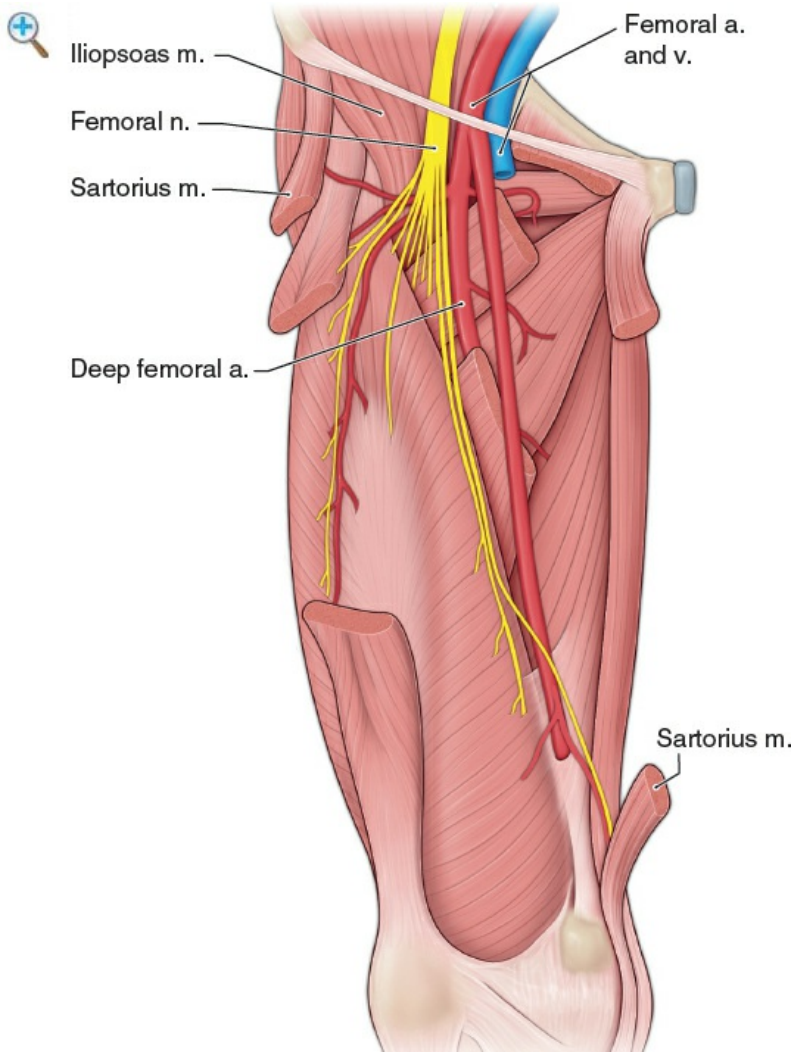

Figure 16.17 Femoral nerve anatomy. Originates from L2 to L4 nerve roots.

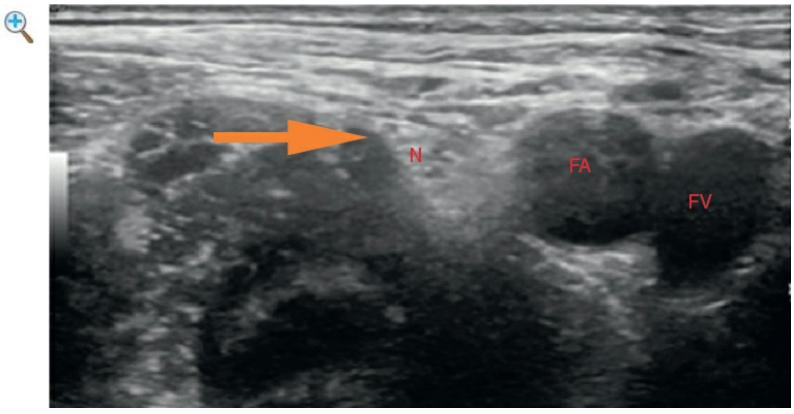

Figure 16.18 Femoral nerve ultrasound. FA, femoral artery; FV, femoral vein; N, nerve.

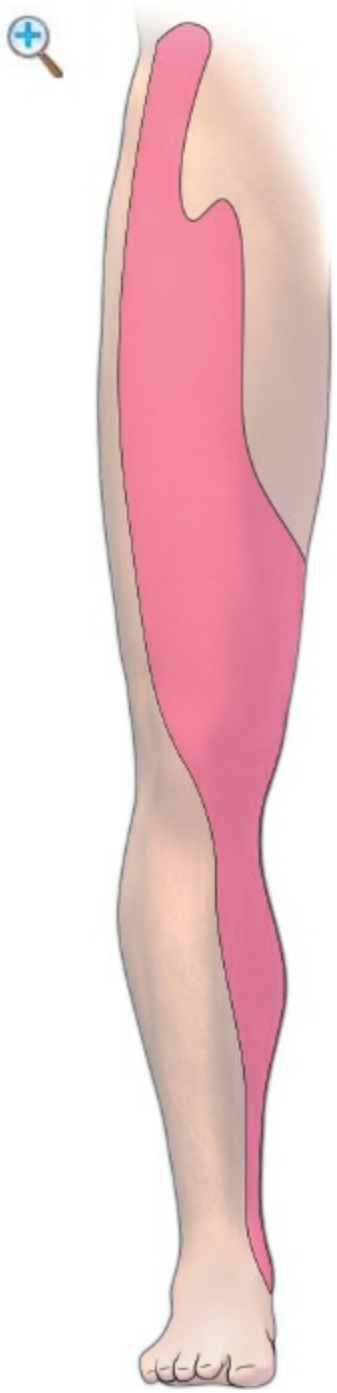

Figure 16.19 Femoral nerve anatomy.

Dosage	15–30 mL (0.25–0.5% ropivacaine/bupivacaine or mepivacaine 1–1.5%)
Nerve stimulation	Quadriceps femoris with patellar twitch
Side effects	Quadriceps weakness with ambulation difficulties
Complications	Vascular injury: <1% using ultrasound guidance
Pearls	• Supine with the leg extended, probe placed transverse for

	an in-plane or out-of-plane approach • The nerve lies deep to the fascia iliaca while the artery is superficial; the fascia iliaca has an S shape placing the nerve in a deeper anatomical plane than the artery.
Alternative	A posterior approach of the lumbar plexus will reliably cover the femoral, obturator, and lateral femoral cutaneous nerves for surgical anesthesia. A fascia iliaca block will reliably cover the femoral, obturator, and lateral femoral cutaneous nerves for analgesia. An adductor canal block or subsartorial distal saphenous block will cover the medial ankle for surgical anesthesia and, partially, the knee for analgesia.
Further reading	Szucs S, et al: Femoral nerve blockade. Med Ultrason 2010; 12(2):139–44.

LUMBAR PLEXUS

Indications	Hip, anterior, medial and lateral thigh, and knee surgery
Anatomy	

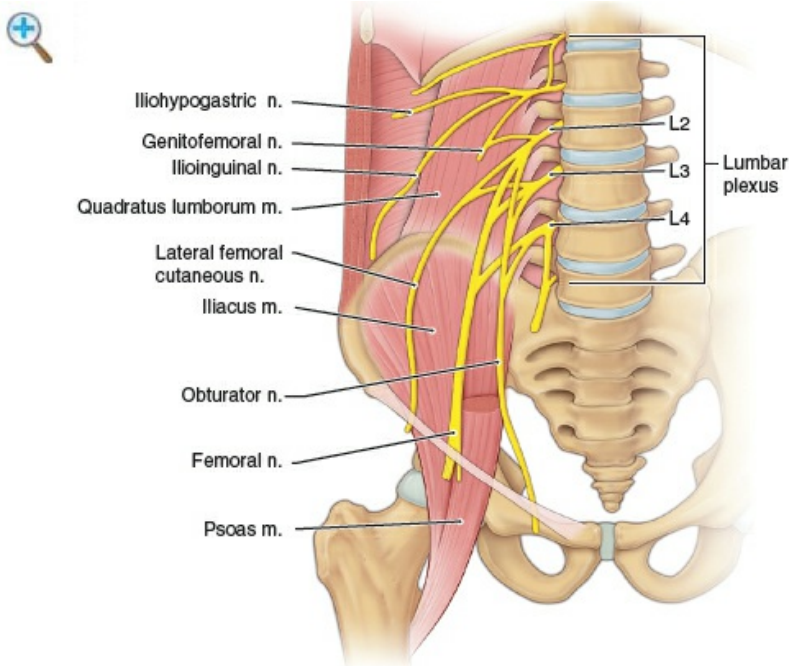

Figure 16.20 Lumbar plexus anatomy. The portion of the

lumbar plexus covering the lower extremity originates from L2 to L4 nerve roots: femoral, lateral femoral cutaneous, and obturator nerves.

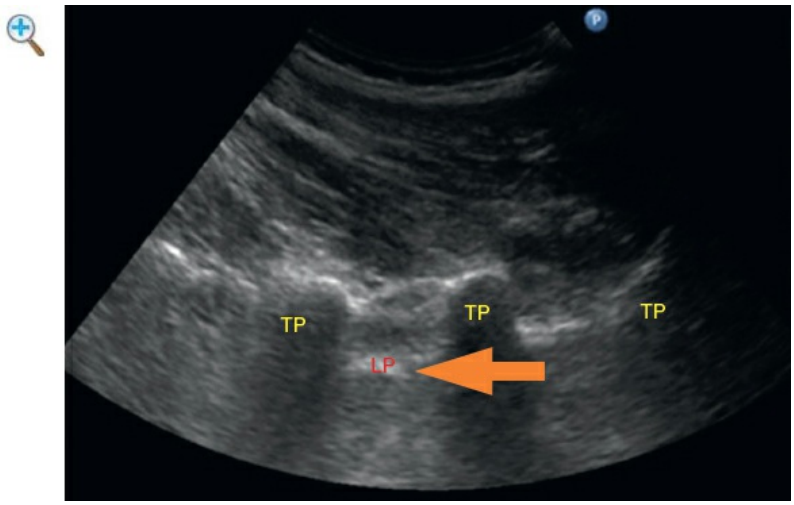

Figure 16.21 Lumbar plexus ultrasound. TP, transverse process; LP, lumbar plexus.

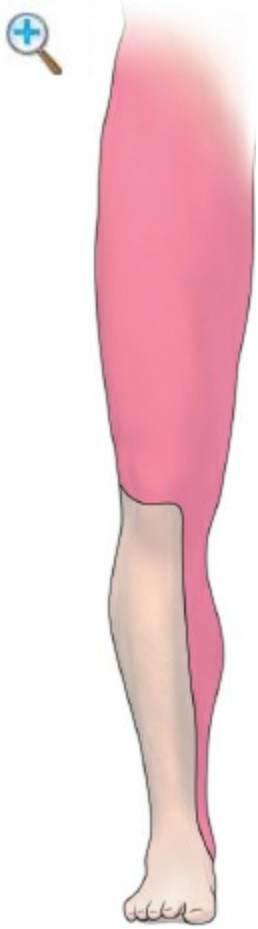

Figure 16.22 Lumbar plexus anatomy.

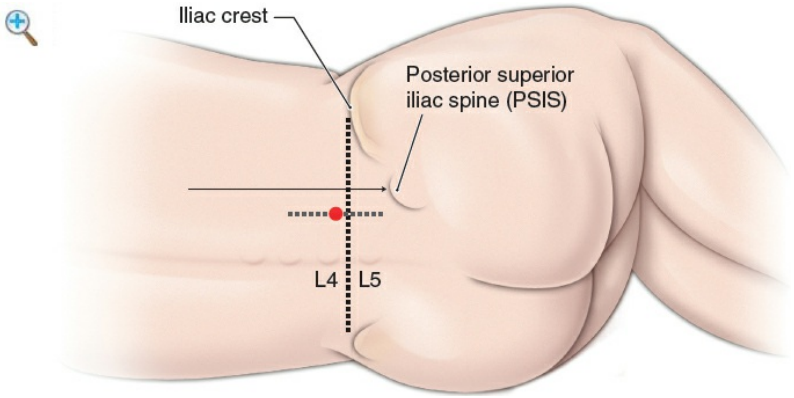

Figure 16.23 Lumbar plexus anatomy.

Dosage	10–20 mL (0.25–0.5% ropivacaine/bupivacaine)
Nerve stimulation	Quadriceps femoris with patellar twitch
Side effects	Quadriceps weakness with ambulation difficulties Epidural spread with partial sympathectomy
Complications	Epidural/bilateral spread (up to 10%) Epidural/intrathecal placement Vascular puncture: <1% Local anesthetic systemic toxicity (LAST): rare Renal puncture/retroperitoneal hematoma: rare
Pearls	• Lateral decubitus with fetal position, i.e., epidural positioning • Prescan with ultrasound to map the area with best angle of approach, angles to avoid, and to estimate depth. • Probe placed transverse and sagittal to create a 3D representation of the target • Direct ultrasound guidance is best in small and lean patients with transverse probe placement in the flank aiming toward the spine. • If hamstring twitch on nerve stimulation, move one level cephalad • Always give a test dose to diagnose intrathecal placement. • Keep volume low to prevent epidural spread.
Alternative	Fascia iliaca block Femoral block
Further reading	Chin KJ, Perlas A. Ultrasonography of the lumbar

spine for neuraxial and lumbar plexus blocks. Curr Opin Anaesthesiol 2011; 24(5):567–72.

FASCIA ILIACA AND LATERAL FEMORAL CUTANEOUS NERVE

Indications	Hip, anterior, medial and lateral thigh, and knee

Anatomy

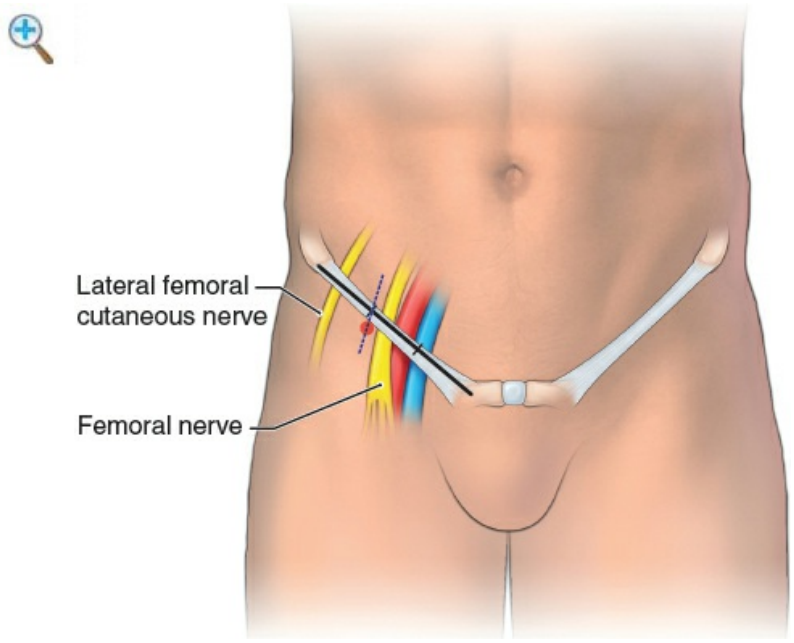

Figure 16.24 Fascia iliaca anatomy. Originates from L2 to L4 nerve roots.

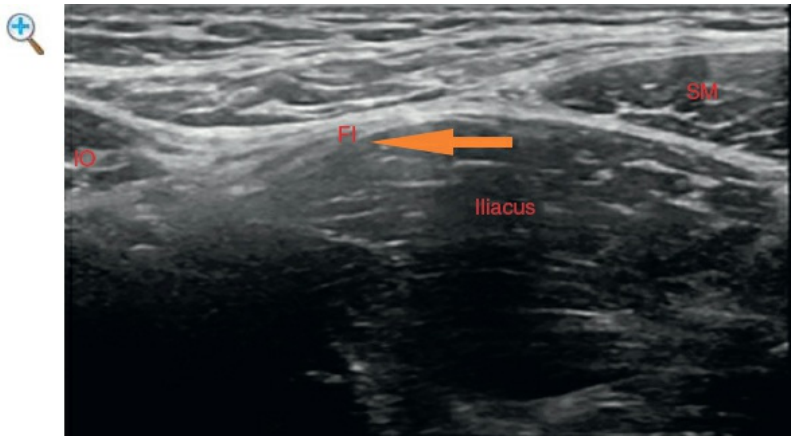

Figure 16.25 Fascia iliaca ultrasound. SM, sartorius muscle; FI, fascia iliaca; IO, internal oblique.

Figure 16.26 Fascia iliaca anatomy.

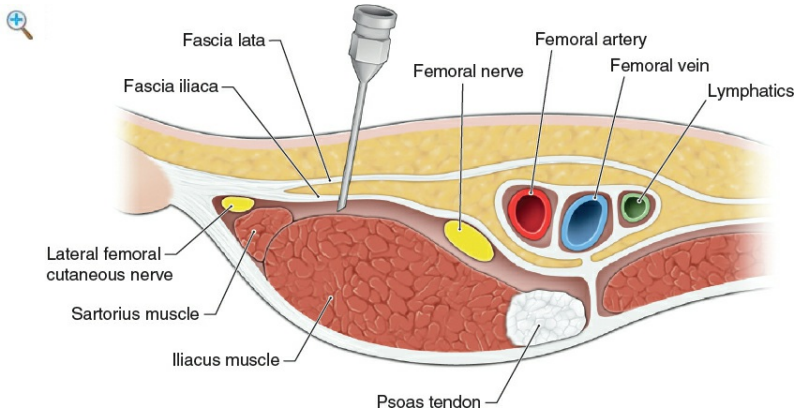

Figure 16.27 Fascia iliaca anatomy.

Dosage	20–60 mL (0.25% ropivacaine/bupivacaine)
Nerve stimulation	None
Side effects	Quadriceps weakness with ambulation difficulties
Complications	Vascular puncture: <1%

	Local anesthetic systemic toxicity (LAST): <0.1% Bowel puncture (rare)
Pearls	• Supine positioning • Position ultrasound transducer transversely near the femoral cease, superficial to the iliopsoas muscle, lateral to femoral vessels and then rotate the probe 90° to drive the needle cephalad under the inguinal ligament. • Use color to avoid the inferior epigastric vessels. • Large-volume dilute local anesthetic allows spread to block both femoral and lateral femoral cutaneous nerves, and sometimes the obturator nerve. • Nonultrasound technique describes the "double pop" as needle traverses the fascia lata and fascia iliaca, but only reliably covers the femoral nerve.
Alternative	Lumbar plexus block Femoral block
Further reading	Steenberg J, et al: Systematic review of the effects of fascia iliaca compartment block on hip fracture patients before operation. Br J Anaesth 2018; 120(6):1368–80.

ADDUCTOR CANAL (SAPHENOUS NERVE)

Indications	Knee and medial ankle surgery
Anatomy	

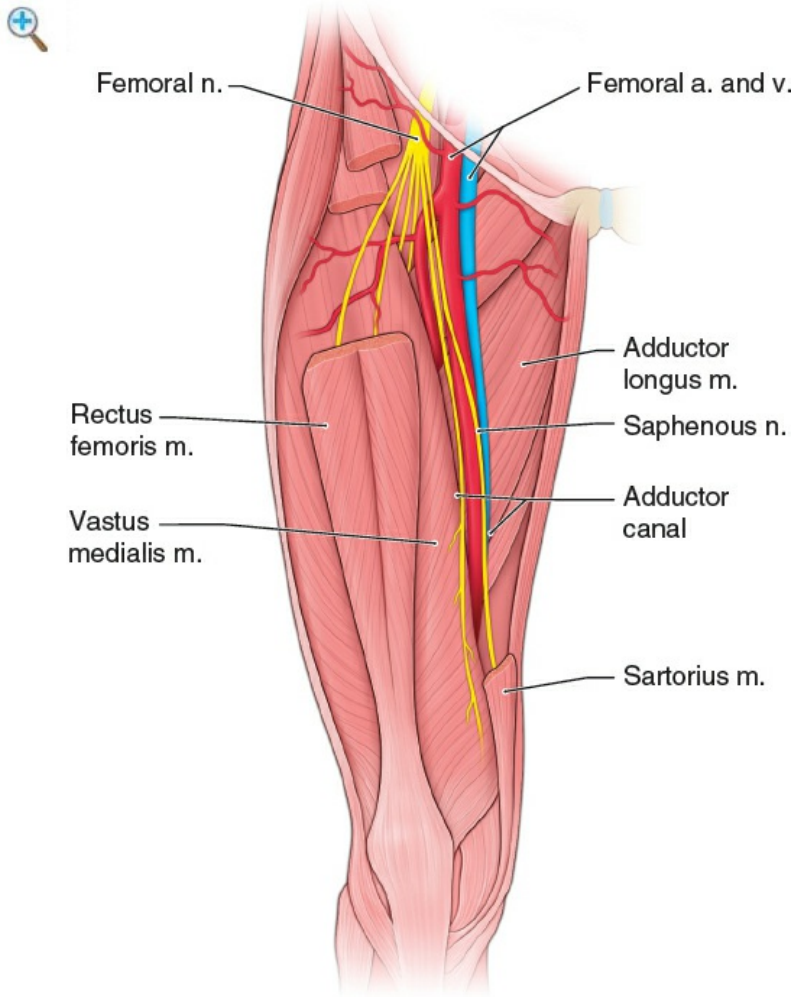

Figure 16.28 Adductor canal anatomy. At the level of the distal femoral triangle, the saphenous nerve runs with the nerve to the vastus medialis. Distal to the adductor hiatus, the nerve runs under the sartorius muscle, with the descending genicular artery.

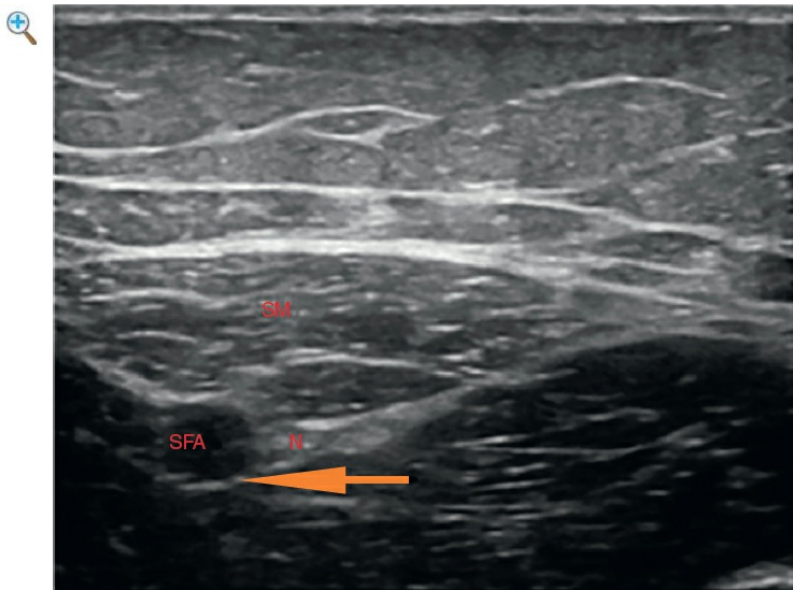

Figure 16.29 Adductor canal ultrasound. SFA, superficial femoral artery; SM, sartorius muscle; N, nerve.

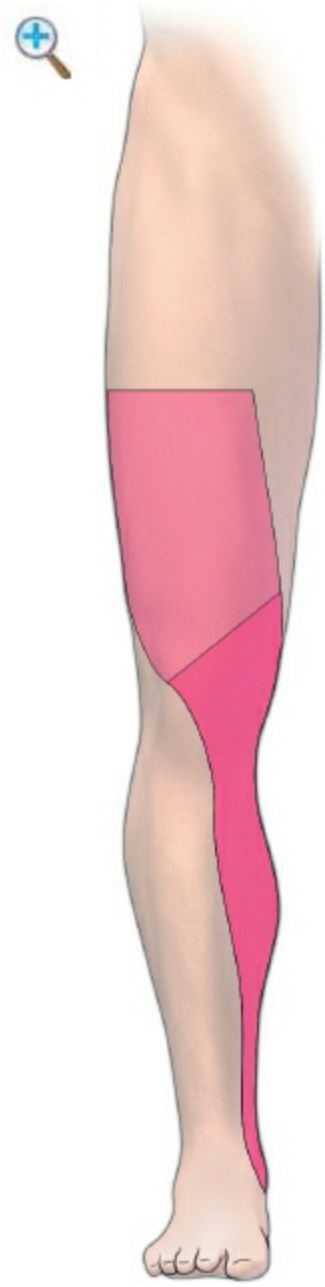

Figure 16.30 Adductor canal anatomy.

Dosage	10–30 mL (0.25–0.5% ropivacaine/bupivacaine or mepivacaine 1–1.5%)
Nerve stimulation	Sensory stimulation at ankle
Side effects	Quadriceps weakness with ambulation difficulties (rare) Infrequent spread to tibial nerve

Complications	Femoral artery injury
Pearls	• Supine with the leg externally rotated, probe placed transverse for an in-plane or out-of-plane approach • The saphenous nerve lies adjacent to the femoral vessels. • A proximal block will provide blockade of both the saphenous nerve and nerve to the vastus medialis. • A block distal to the adductor hiatus will avoid risk of injury to the femoral artery but will only provide appropriate blockade for the ankle/foot. • Despite traditional assumption, the saphenous nerve innervates deep structures of the medial ankle, talocrural joint, and sometimes the first metatarsal.
Alternatives	A posterior approach of the lumbar plexus, a fascia iliaca, or a femoral nerve block will reliably cover all branches of the femoral nerve. For foot surgery, a subcutaneous injection of the saphenous nerve at or above the ankle
Further readings	Eglitis N, et al: The importance of the saphenous nerve in ankle surgery. Anesth Analg 2016; 122(5):1704–6. Horn J-L, et al: Anatomical basis to the ultrasound-guided approach for saphenous nerve blockade. Reg Anesth Pain Med 2009; 34(5):486–9. Vora MU, et al: Adductor canal block for knee surgical procedures: review article. J Clin Anesth 2016; 35:295–303.

POPLITEAL SCIATIC NERVE

Indications	Posterior capsule of the knee and leg, ankle, and foot with the addition of a saphenous nerve block for the medial leg/ankle/forefoot

Anatomy

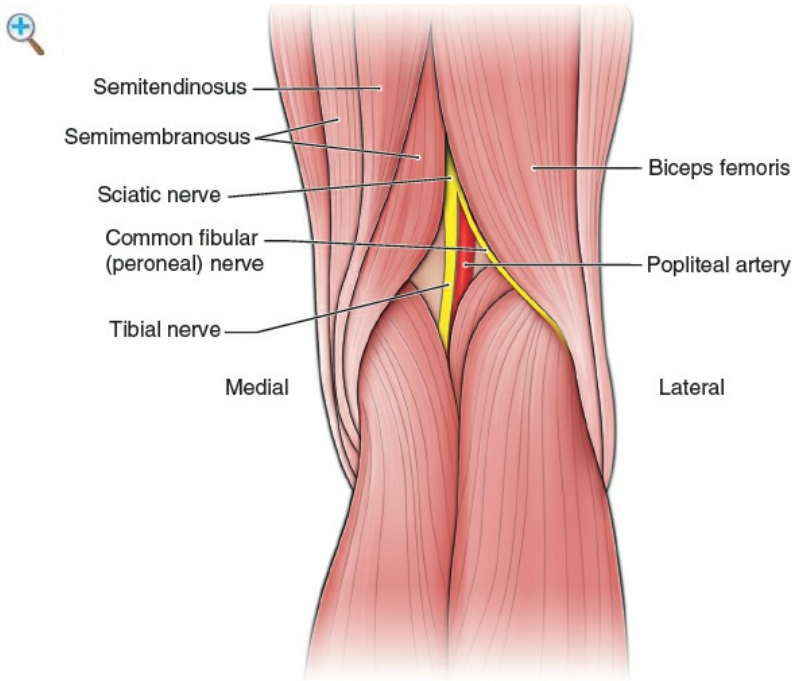

Figure 16.31 Popliteal sciatic anatomy. The sciatic nerve arises from L4 to S3 nerve roots. The level of the split into tibial and common peroneal nerves varies from knee capsule to about 10 cm more proximal.

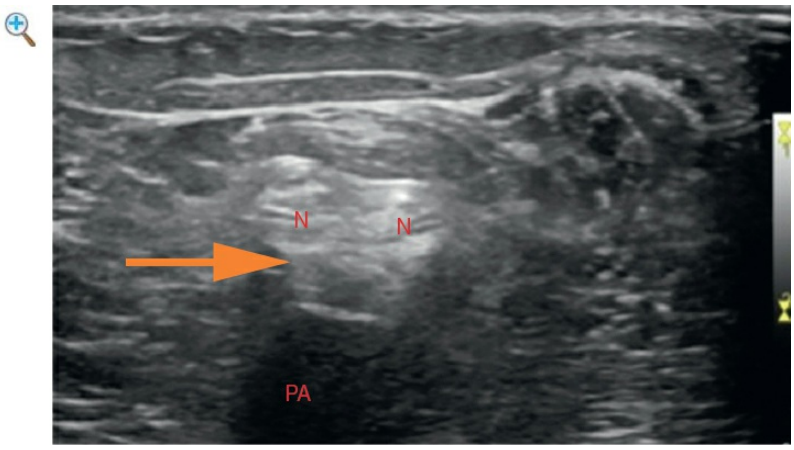

Figure 16.32 Popliteal sciatic ultrasound. PA, popliteal artery; N, nerve.

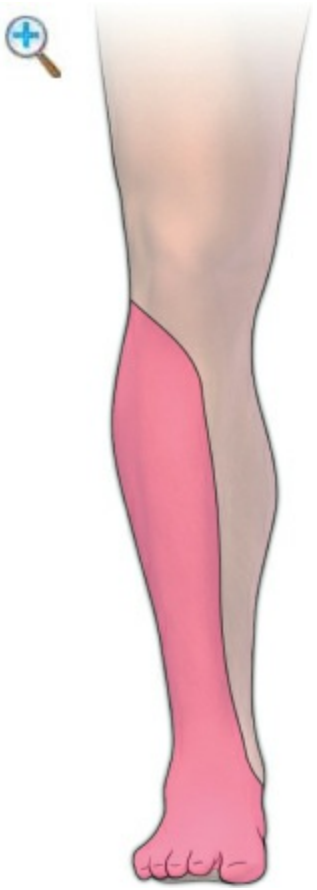

Figure 16.33 Popliteal sciatic anatomy.

	The level of the nerve split into the tibial and common peroneal nerves varies usually from the knee crease to about 10 cm more proximally
Dosage	20–30 mL (0.5% ropivacaine/bupivacaine or mepivacaine 1–1.5%)
Nerve stimulation	Dorsiflexion for common peroneal stimulation, extension for tibial stimulation
Side effects	Complete block of all muscles below the knee with ambulation difficulties
Complications	Vascular injury: <1% Nerve injury: <5%
Pearls	• Prone, lateral decubitus with probe placed transverse for an in-plane or out-of-plane approach. Supine position with elevated leg makes the needle placement more difficult but is more comfortable for the patient. • Adding a saphenous nerve block is essential when the

	medial leg, ankle, and forefoot are involved. • Single shot placed at or just distal to the nerve split speeds the onset. • Catheter placement above the split ensures more reliable results.
Alternative	Higher sciatic approach Ankle block for forefoot and toe surgery
Further reading	Dufour E, et al: Combined ultrasound and neurostimulation guidance for popliteal sciatic nerve block: a prospective, randomized comparison with neurostimulation alone. Anesth Analg 2008; 106:1553–8.

SCIATIC NERVE

Indications	Posterior thigh/knee and ankle/foot with the addition of a saphenous nerve block for the medial ankle/forefoot
Anatomy	

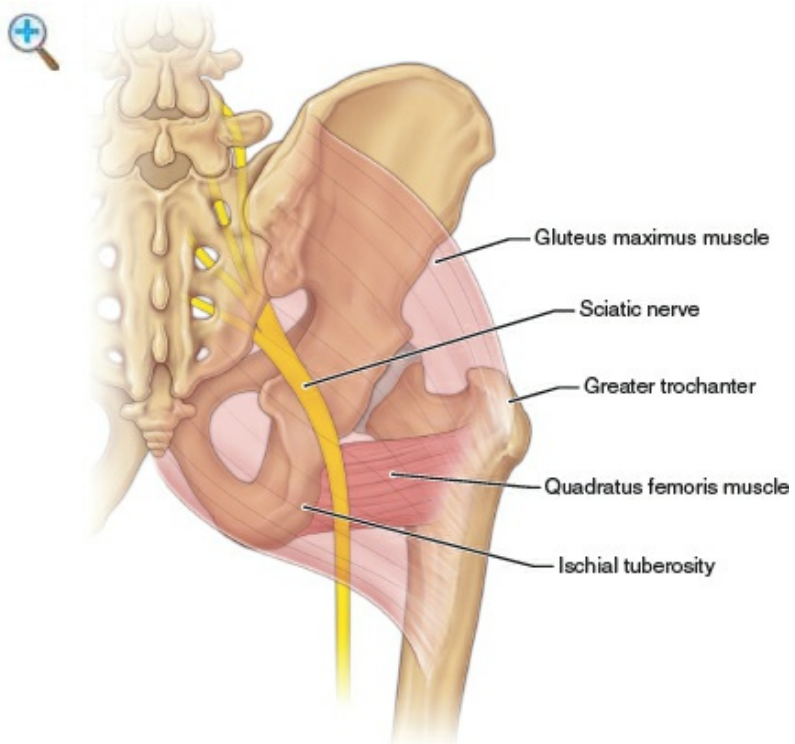

Figure 16.34 Sciatic anatomy—The sciatic nerve arises from L4 to S3 nerve roots.

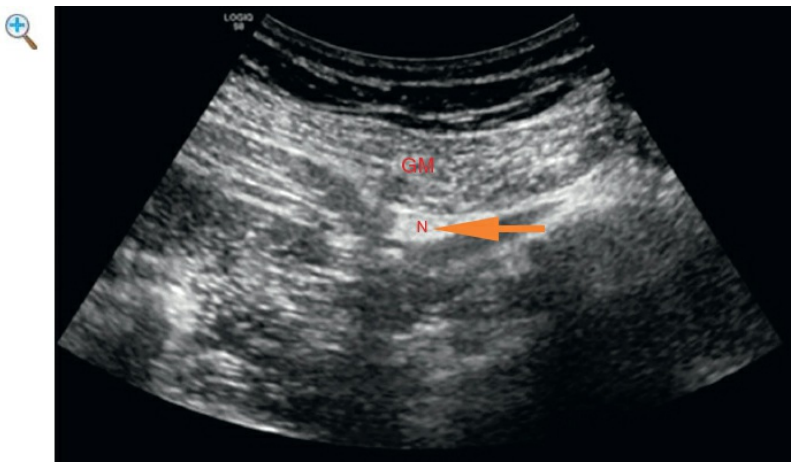

Figure 16.35 Sciatic ultrasound. GM, gluteus muscle; N, nerve.

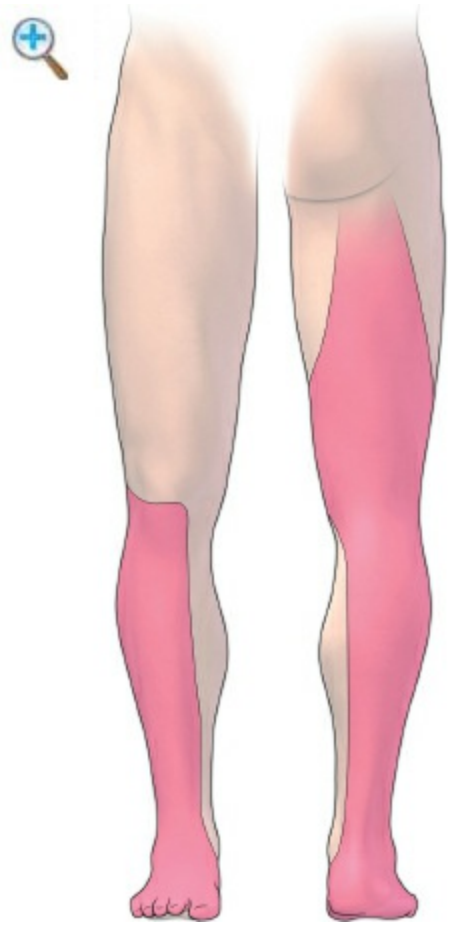

Figure 16.36 Sciatic anatomy.

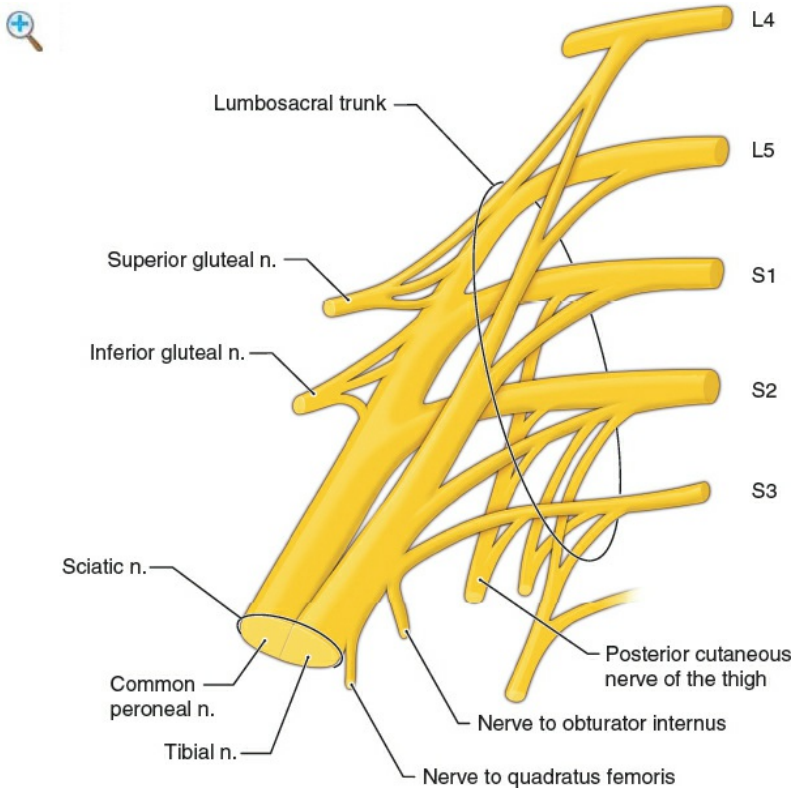

Figure 16.37 Sciatic anatomy.

Dosage	15–30 mL (0.5% ropivacaine/bupivacaine or mepivacaine 1–1.5%)
Nerve stimulation	Dorsiflexion for common peroneal stimulation, extension for tibial stimulation
Side effects	Complete block of all muscles below the knee +/− hamstring muscles with ambulation difficulties
Complications	Vascular injury: <1% Nerve injury: <5%
Pearls	• Lateral decubitus with leg flexed, probe placed transverse for an in-plane or out-of-plane approach • The parasacral approach is the most challenging due to the depth and angle of the nerve entering the sacrum. • A proximal block, parasacral, or subgluteal above the long head of the biceps is necessary to cover the posterior thigh or knee to catch the posterior femoral cutaneous nerve before it branches posterior to the biceps femoris.
Alternative	Anterior approach when the patient cannot be moved

	(but can be challenging due to the depth of the nerve). Popliteal sciatic nerve block is more superficial and works well for structures below the knee, and it may also cover the posterior capsule of the knee joint. Ankle block for forefoot and toe surgery
Further reading	Rodziewicz TL, et al: Sciatic Nerve Block. 2017 Nov 26. StatPearls [Internet]. StatPearls Publishing, Treasure Island: 2018. Available from: http://www.ncbi.nlm.nih.gov/books/NBK470391/

OBTURATOR NERVE

Indications	Medial distal thigh, medial knee, preventing thigh adduction in transurethral bladder surgery, rescue after knee surgery when femoral block is insufficient

Anatomy

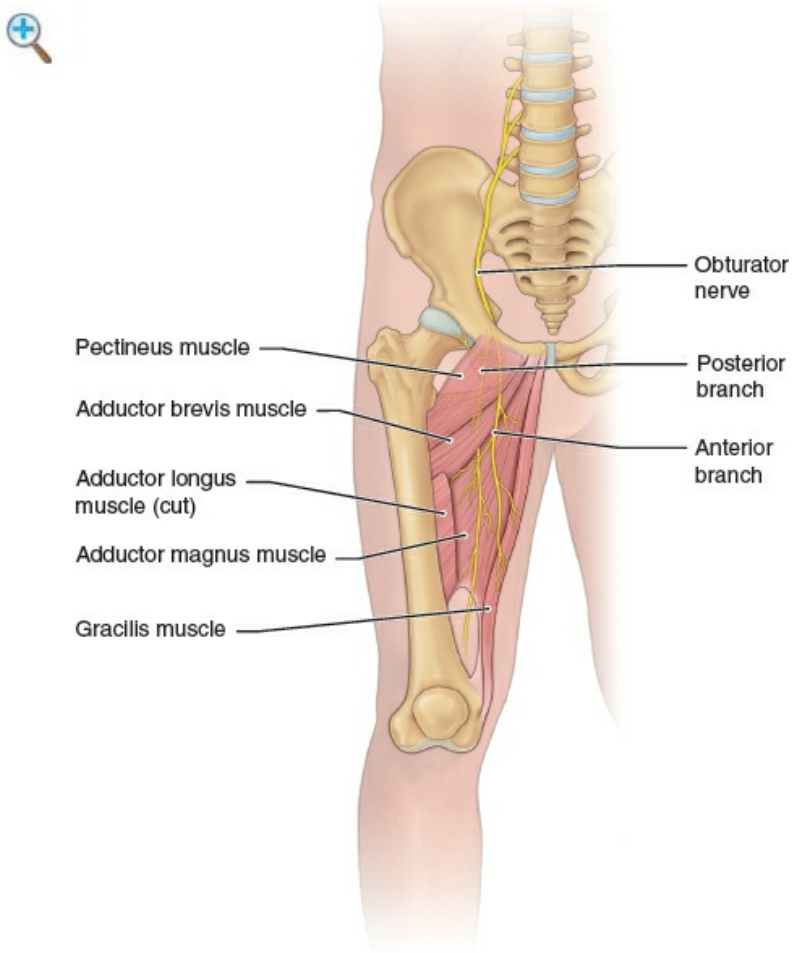

Figure 16.38 Obturator nerve anatomy. Originates from the

lumbar plexus (anterior rami of L2-L4).

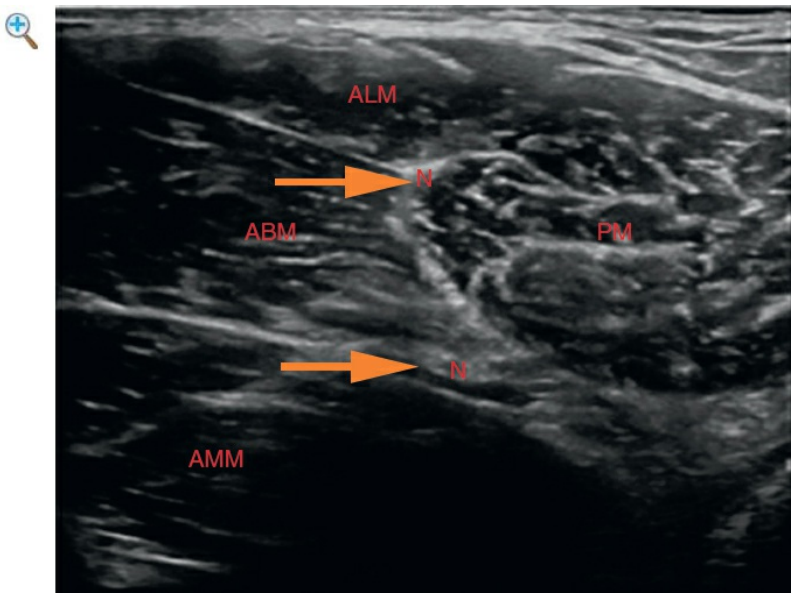

Figure 16.39 Obturator nerve ultrasound. PM, pectineus; ALM, adductor longus muscle; ABM, adductor brevis muscle; AMM, addcutor magnus muscle.

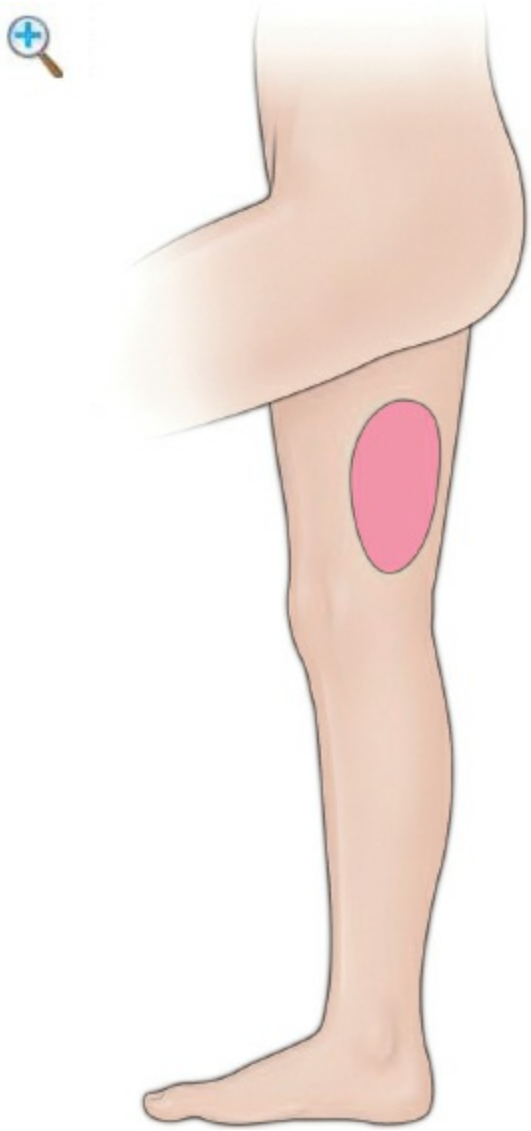

Figure 16.40 Obturator nerve anatomy.

	An interfascial plane block. The anterior branch is between the pectineus, adductor longus, and adductor brevis muscles. The posterior branch is between the adductor brevis and adductor magnus.
Dosage	10 mL (0.25–0.5% ropivacaine/bupivacaine)
Nerve stimulation	Adductor twitch (rarely used)
Side effects	Inability to adduct leg (rarely impairs mobility)
Complications	Vascular injury: rare
Pearls	• Supine with the leg extended, probe placed transversely over the femoral vessels and then slide medially over the pectineus and adductor muscles for an in-plane or out-of-

	plane approach. • The anterior branch is mostly cutaneous, and posterior branch is mostly motor.
Alternative	Lumbar plexus block Fascia iliaca block
Further reading	Yoshida T, et al: Ultrasound-guided obturator nerve block: a focused review on anatomy and updated techniques. Biomed Res Int 2017; 2017:7023750.

ANKLE

Indications	Forefoot or toe surgery

Anatomy

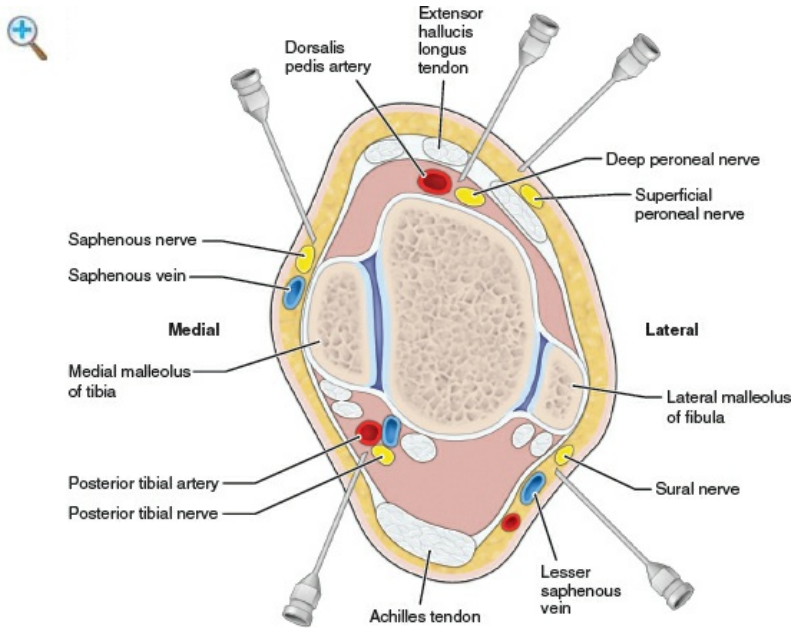

Figure 16.41 Ankle anatomy. The deep peroneal nerve is located lateral to the extensor hallucis longus tendon and dorsalis pedis artery. The posterior tibial nerve is posterior to the distal medial malleolus and posterior tibial artery.

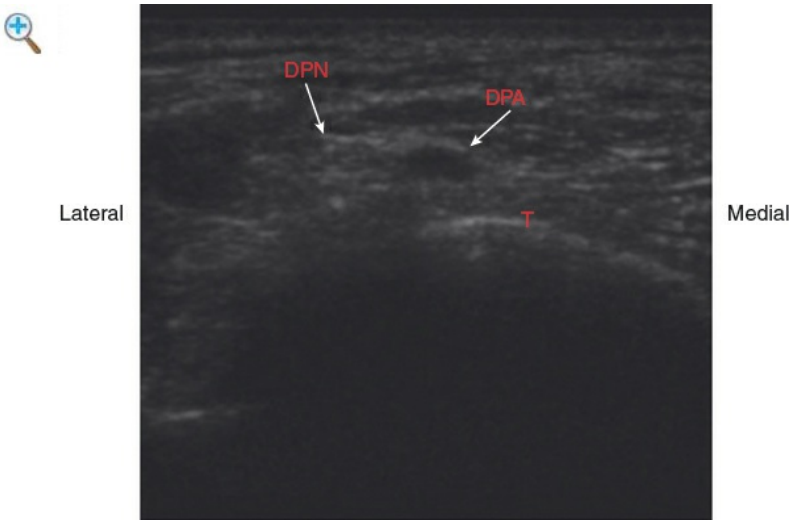

Figure 16.42 Ankle ultrasound. DPN, deep peroneal nerve; DPA, dorsalis pedis artery; T, Tibia.

Figure 16.43 Ankle anatomy.

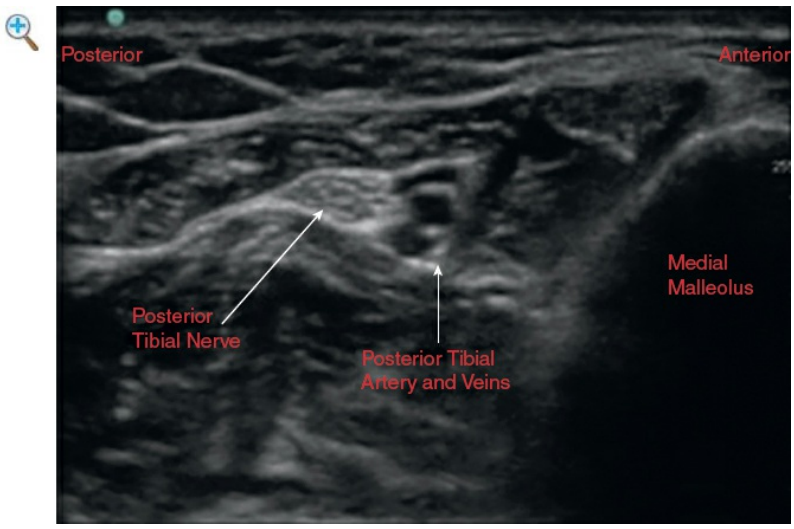

Figure 16.44 Ankle ultrasound.

	Posterior tibial and deep peroneal nerves are targeted individually, and superficial nerves (superficial peroneal, sural, and saphenous) are blocked with a subcutaneous field block. The deep peroneal nerve is located directly lateral to the extensor hallucis longus tendon and the anterior tibial artery. The posterior tibial nerve is located immediately posterior to the distal medial malleolus and the posterior tibial artery. The superficial nerves are targeted with a subcutaneous ring block at the narrowest part of the ankle proximal to the malleoli excluding the tissue overlying the Achilles tendon.
Dosage	5 mL (0.5% ropivacaine or 1.5% mepivacaine) for each nerve
Nerve stimulation	Nerve stimulation is only useful for posterior tibial nerve localization.
Side effects	Discomfort during placement Failure in acidic milieu
Complications	Vascular injury: <1%
Pearls	• Adding sodium bicarbonate (10%) to local anesthetic may correct local acidosis. • Start with the superficial nerves (S), less risk of paresthesia. • Place a circular subcutaneous wheel for the S at the

	narrowest point of the ankle. • Then block the deep peroneal nerve at the distal tibia adjacent to the anterior tibial artery or dorsalis pedis artery more distally. • Lastly, block the posterior tibial nerve behind the medial malleolus next to the posterior tibial artery, as it is the most uncomfortable injection.
Alternative	Combined popliteal and saphenous nerve blocks
Further reading	Coe A, Ram S: Ultrasound-guided ankle block for forefoot surgery: is sural nerve block necessary? Reg Anesth Pain Med 2013; 38(3):251.

THORACOABDOMINAL BLOCKS

TRANSVERSUS ABDOMINIS PLANE (TAP)

Indications	Abdominal surgery

Anatomy

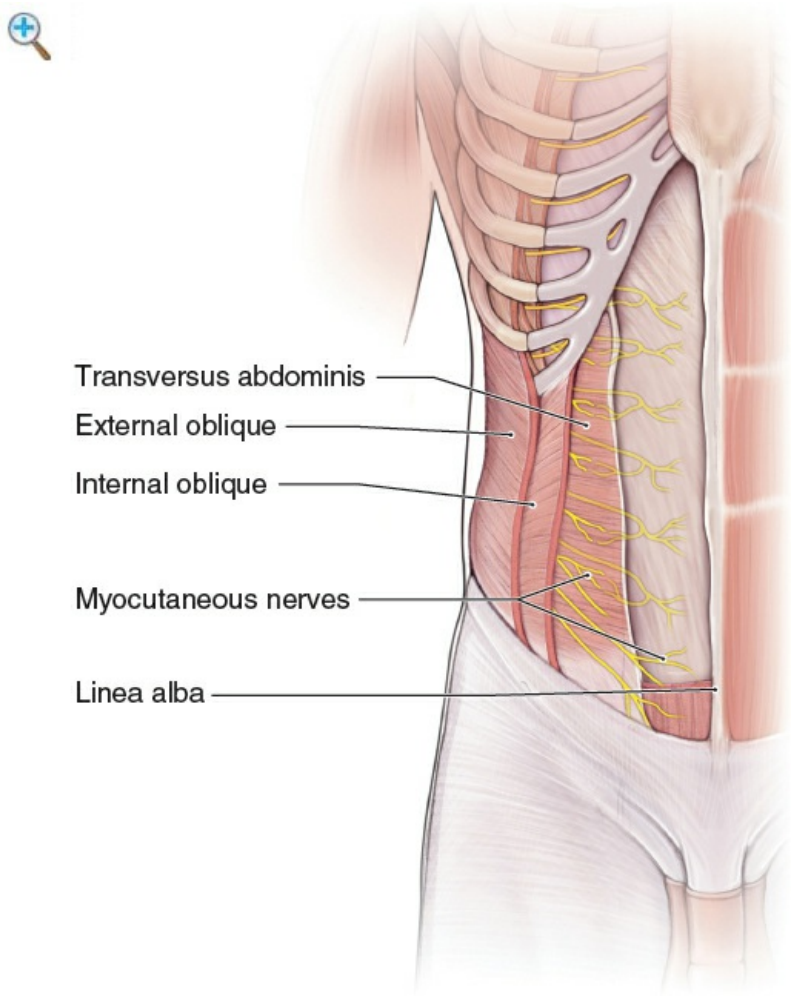

Figure 16.45 Transversus abdominis anatomy. The thoracoabdominal nerves, T6-T12, and the ilioinguinal/iliohypogastric nerves, T12-L1, run in the fascial plane deep to the internal oblique and superficial to the transversus abdominis. The subcostal approach targets higher-level dermatomes (T6-T9), while the lateral approach (mid axillary line) targets lower dermatomes (T10-L1).

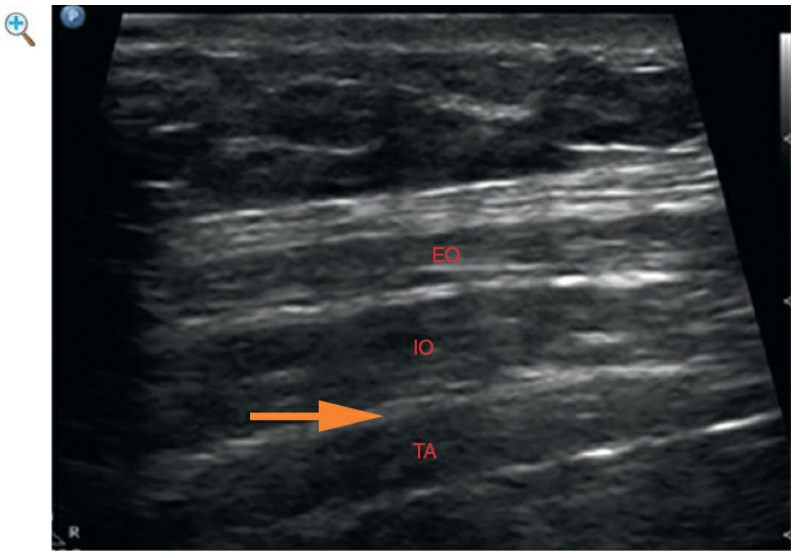

Figure 16.46 Transversus abdominis ultrasound. EO, external oblique; IO, internal oblique; TA, transversus abdominis.

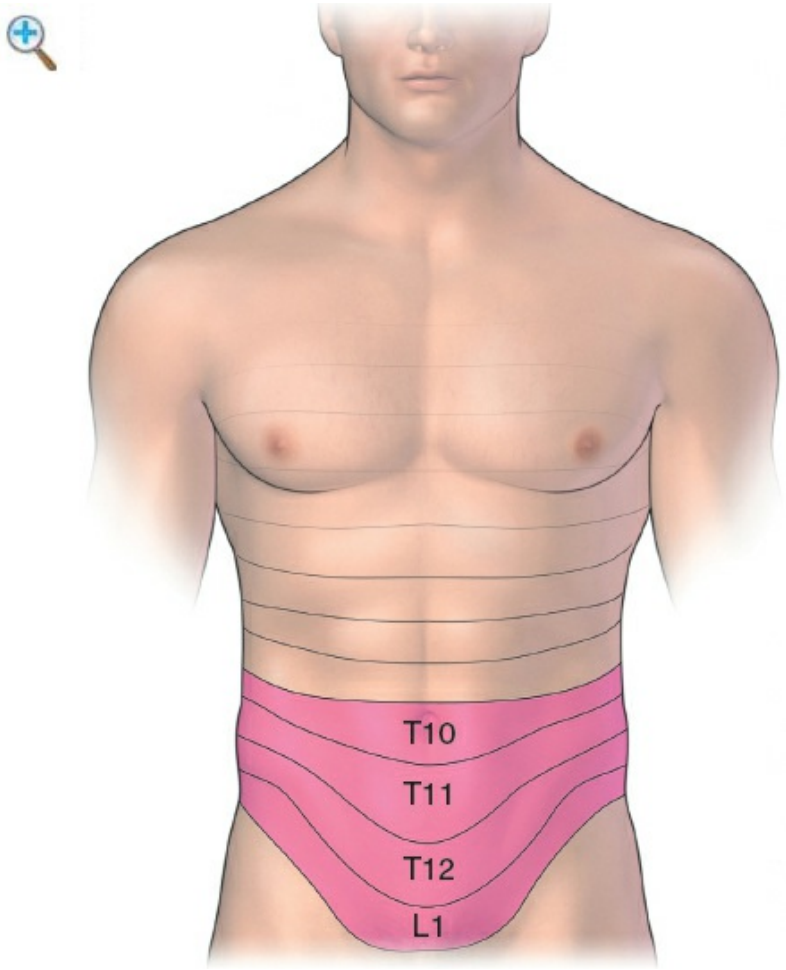

Figure 16.47 Transversus abdominis anatomy.

	The thoracoabdominal nerves, T6-T12, and the ilioinguinal/iliohypogastric nerves, T12-L1, run in the fascial plane deep to the internal oblique and superficial to the transversus abdominis. The subcostal approach targets higher-level dermatomes (T6-T9), while the lateral approach (mid axillary line) targets lower dermatomes (T10-L1).
Dosage	15–30 mL (0.25% ropivacaine)
Nerve stimulation	None
Side effects	Minimal

Complications	Visceral puncture: <0.1% Local anesthetic systemic toxicity (LAST): <0.1% Hematoma: <1%
Pearls	• The posterior approach may extend axially like the blind angle of petit approach. • Large bolus may provide better spread/effect. • Landmarks may be altered by surgery.
Alternative	Local infiltration by the surgeon Epidural Paravertebral block Quadratus lumborum block Rectus sheath block Erector spinae plane block
Further reading	Chin KJ, et al: Essentials of our current understanding: abdominal wall blocks. Reg Anesth Pain Med 2017; 42(2):133–83.

ERECTOR SPINAE PLANE

Indications	Chest wall, abdominal wall, shoulder, and possibly hip
Anatomy	

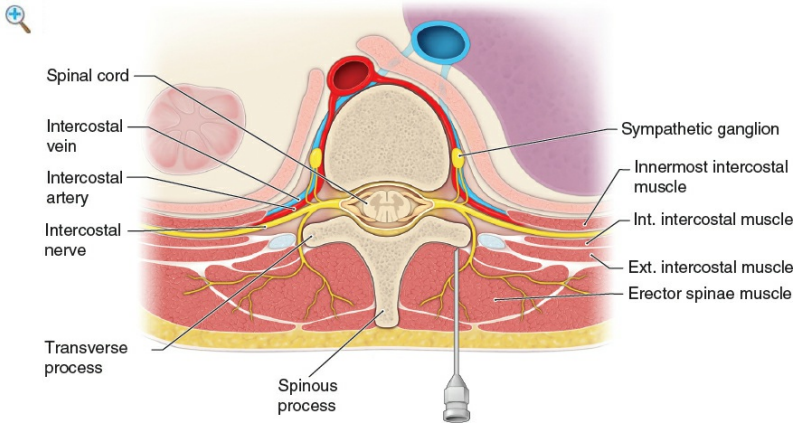

Figure 16.48 Erector spinae anatomy. Potential blockade of dorsal and ventral rami of the thoracic spinal nerves.

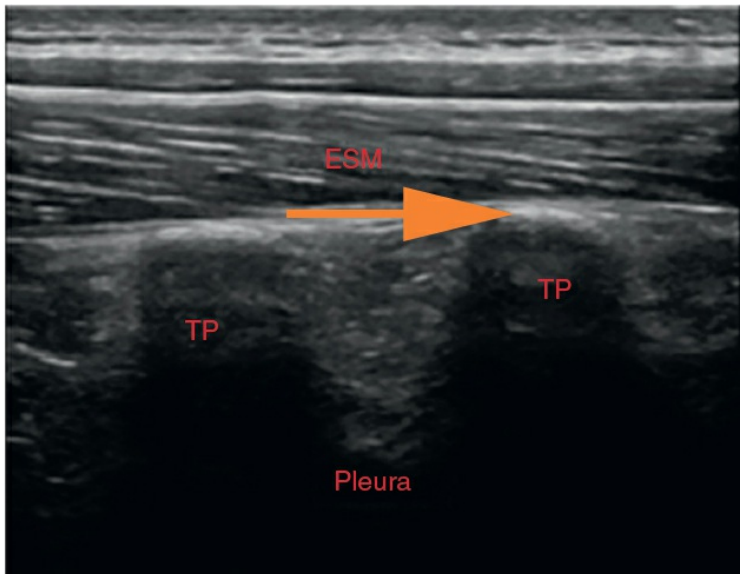

Figure 16.49 Erector spinae ultrasound. ESM, erector spinae muscle; TP, transverse process.

	Fascial plane block. Deposition of local anesthetic deep to the erector spinae muscle along the tip of the transverse processes, potentially blocking dorsal and ventral rami of the thoracic spinal nerves
Dosage	10–20 mL (0.5% ropivacaine or 1.5% mepivacaine)
Nerve stimulation	Not used
Side effects	Minimal
Complications	Paravertebral spread LAST (rare)
Pearls	• Positioning: prone, sitting, or lateral • Ultrasound guided: parasagittal or transverse probe placement with an in- or out-of-plane approach
Alternative	Epidural Intercostal block Paravertebral block
Further reading	Forero M, et al: Erector spinae plane block in the management of post thoracotomy pain syndrome: a case series. Scand J Pain 2017; 17:325–9.

PARAVERTEBRAL

Indications	Thoracic, breast, axillary, abdominal surgeries

Anatomy

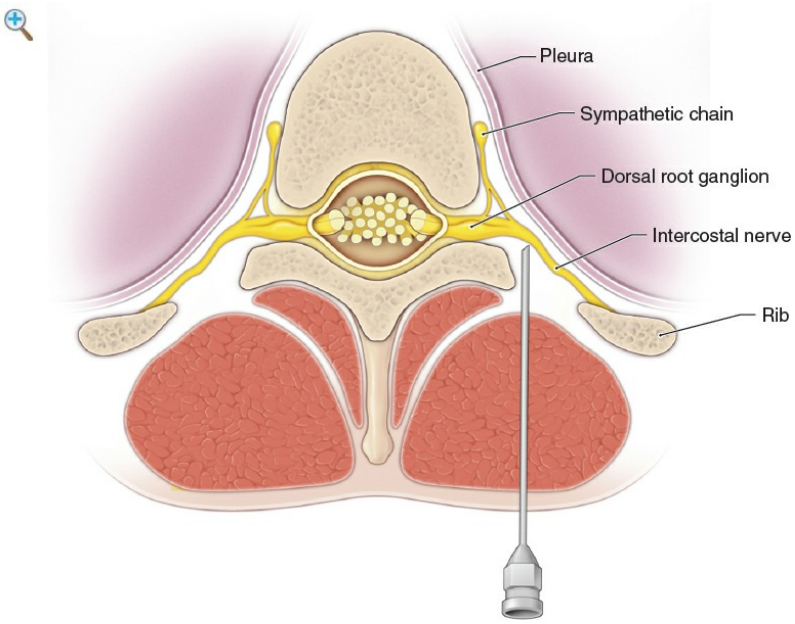

Figure 16.50 Paravertebral anatomy. Triangular spaces lateral to the vertebral column. Bordered anteriorly by the parietal pleura, posteriorly by the superior costotransverse ligament, and medially by the transverse process and foramen. Space contains fat, vessels, intercostal nerves, sympathetic chain, and dorsal rami of the spinal nerves.

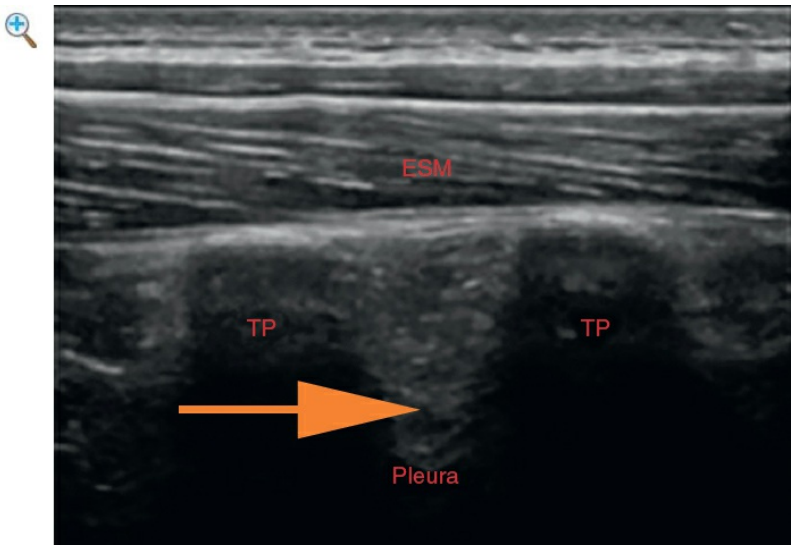

Figure 16.51 Paravertebral ultrasound. ESP, erector spinae muscle; TP, transverse process.

	Target the triangular space lateral to the vertebral column, bordered anterior by the parietal pleura, posteriorly by the superior costotransverse ligament

	and transverse process, and medially by the vertebral body and foramen. The space contains fat, vessels, intercostal nerves, sympathetic chain, and dorsal rami of the spinal nerves.
Dosage	3–5 mL 0.25–0.5% ropivacaine/bupivacaine or 1.5% mepivacaine per level for multiple levels; 15–20 mL 0.25–0.5% ropivacaine/bupivacaine or 1.5% mepivacaine for single level injection
Nerve stimulation	Helpful to confirm level
Side effects	Hypotension Epidural spread
Complications	Epidural or intrathecal injection (~1%) Pneumothorax (~0.5–5%) Hematoma (2.4%)
Pearls	• Positioning: prone, sitting, or lateral • Ultrasound guided: parasagittal probe placement with in- or out-of-plane approach • For parasagittal approach, tilting the probe medial to lateral to obtain a good beam reflection on the pleura • Obtain a "loss of resistance" when passing the posterior border, with depression of the pleura with fluid spread.
Alternative	Epidural Intercostal block Erector spinae plane block
Further reading	Wardhan R: Update on paravertebral blocks. Curr Opin Anaesthesiol 2015; 28(5):588–92.

PECTORALIS PLANE (PECS 1, 2 AND SERRATUS ANTERIOR)

Indications	Breast, anterior chest surgery

Anatomy

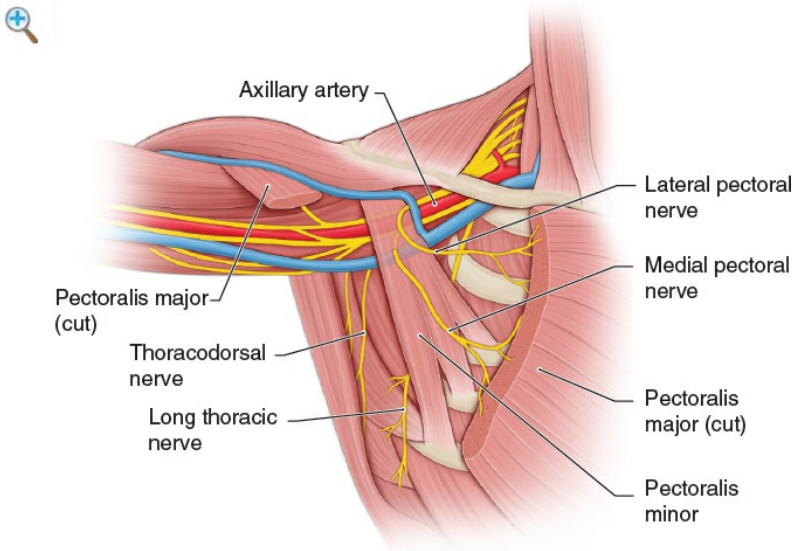

Figure 16.52 Pectoralis plane anatomy.

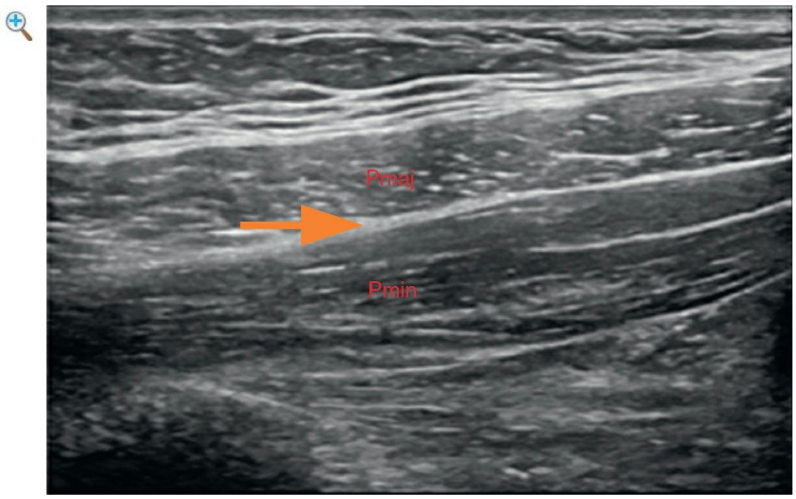

Figure 16.53 Pectoralis plane ultrasound. Pmaj, pectoralis major; Pmin, pectoralis minor.

	PECS I between the pectoralis major and minor muscles targeting the lateral and medial pectoral nerves PECS II under the pectoralis minor muscles and the ribs covering the lateral cutaneous branches of the upper intercostal nerves (T2-T4) PECS III or serratus anterior block covering the lateral cutaneous branches of the mid intercostal nerves (T5-T7). LA is injected either superficial or deep to the serratus anterior muscle
Dosage	10–20 mL (0.25–0.5% ropivacaine or bupivacaine)

Nerve stimulation	Not used
Side effects	Long thoracic nerve block → loss of serratus anterior muscle function
Complications	Local anesthetic systemic toxicity (LAST): <0.1% Vascular puncture: thoracoacromial trunk for PECS I (6.8%) Pneumothorax (0.5%)
Pearls	• Supine positioning with arm abducted or at side • PECS I: ultrasound probe parasagittal, midclavicular line below clavicle, identify the thoracoacromial trunk adjacent to the lateral pectoralis nerve • PECS II: move the probe laterally at an angle along breast contour directing the probe to the anterior axillary line • PECS III: continue to slide the probe caudate over the serratus anterior muscle
Alternative	Epidural Intercostal block Paravertebral block Erector spinae plane block
Further reading	O'Scanaill P, et al: Single-shot pectoral plane (PECs I and PECs II) blocks versus continuous local anaesthetic infusion analgesia or both after non-ambulatory breast-cancer surgery: a prospective, randomized, double-blind trial. Br J Anaesth 2018; 120(4):846–53.

RECTUS SHEATH

Indications	Abdominal midline/umbilical surgery
Anatomy	

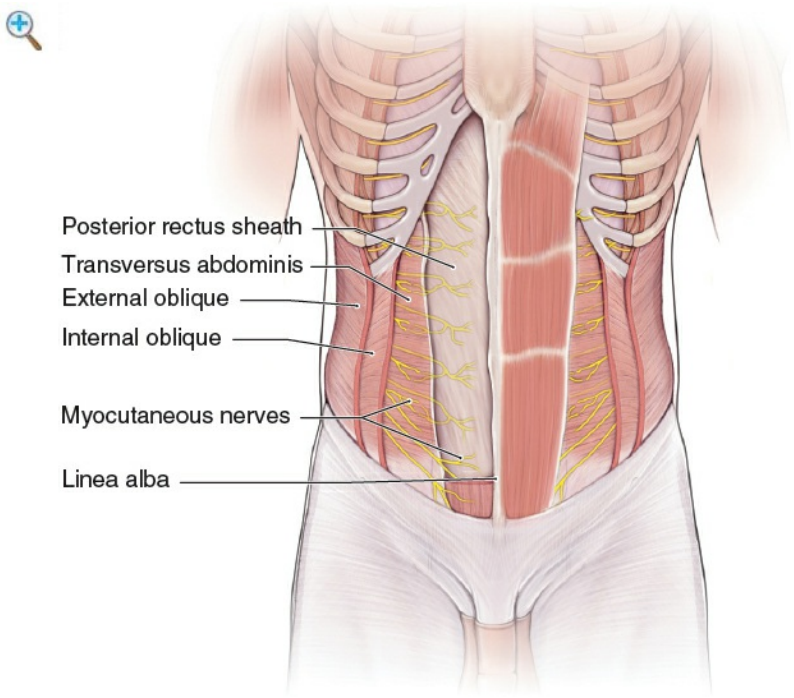

Figure 16.54 Rectus sheath anatomy. Local spread between the oval-shaped rectus muscle and its posterior fascia with blockade of T6-T11.

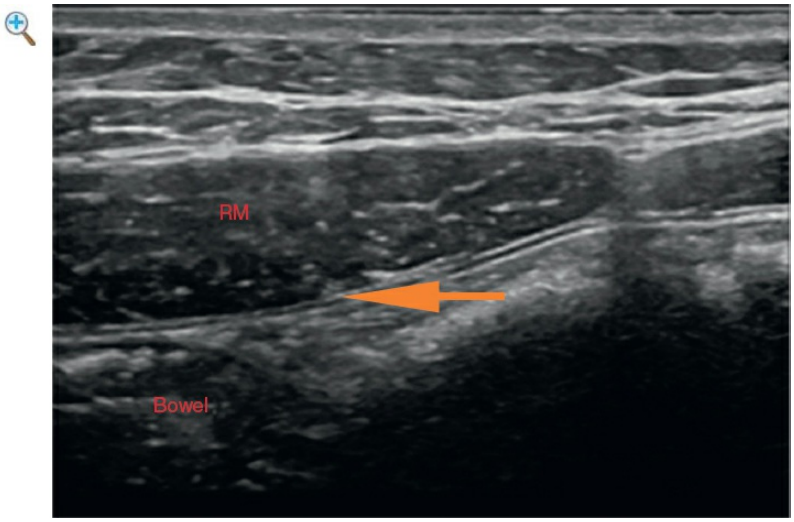

Figure 16.55 Rectus sheath ultrasound. RM, rectus muscle.

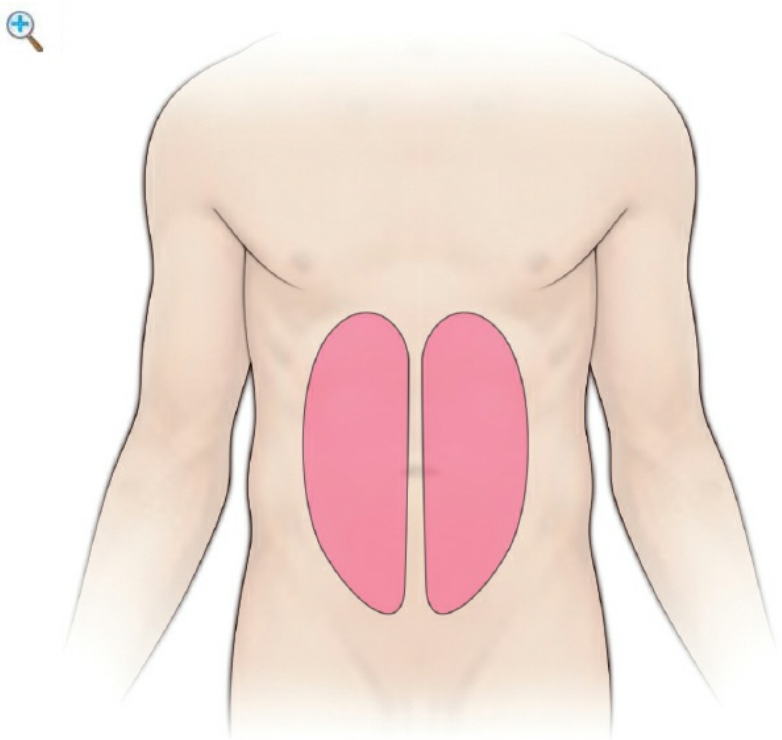

Figure 16.56 Rectus sheath anatomy.

Dosage	10–30 mL (0.25–0.5% ropivacaine or bupivacaine)
Nerve stimulation	Not used
Side effects	Minimal
Complications	Local anesthetic systemic toxicity (LAST): <0.1% Vascular puncture: epigastric artery: <1% Visceral puncture: <1%
Pearls	• Supine positioning • Ultrasound probe placed in the transverse position at the level of the desired injection site • Look for the superior epigastric at medial part of the rectus muscle, stay lateral to the artery • Injection posterior to the muscle fascicles but anterior to the posterior rectus sheath
Alternative	Epidural Transversus abdominis plane block Paravertebral block
Further reading	Chin KJ, et al: Essentials of our current understanding: abdominal wall blocks. Reg Anesth

Pain Med 2017; 42(2):133–83.

QUADRATUS LUMBORUM (QL)

Indications	Abdominal surgery, possibly useful for hip surgery

Anatomy

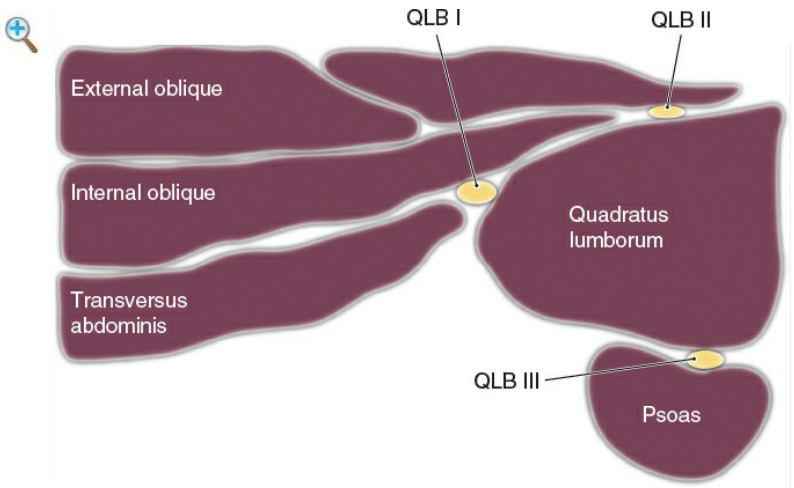

Figure 16.57 Quadratus lumborum anatomy. The quadratus lumborum lies deep and posterior to the aponeurosis of the abdominal wall musculature and is covered by the thoracoabdominal fascia.

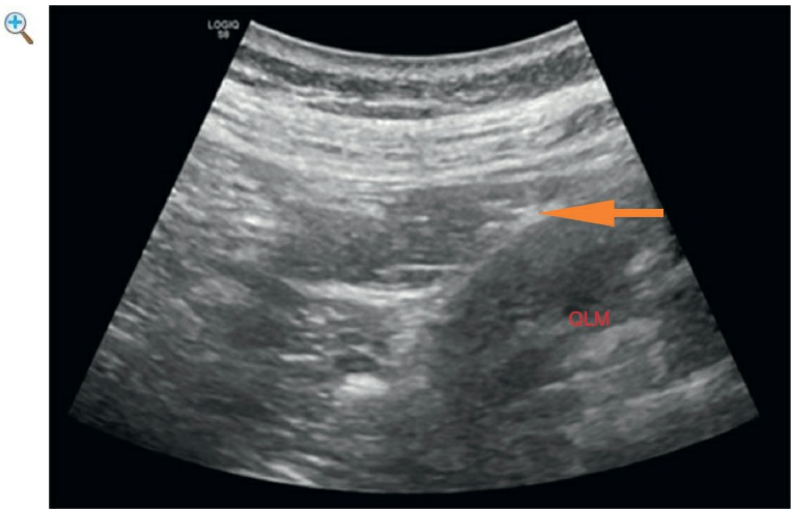

Figure 16.58 Quadratus lumborum ultrasound. QLM, quadratus lumborum muscle.

The quadratus lumborum lies deep and posterior to the aponeurosis of the abdominal wall musculature and is covered by the thoracoabdominal fascia. LA is injected either lateral, posterior, or anterior to the

	QL muscle defined as QL 1, 2, or 3 (transmuscular), respectively. All injection sites have spread of LA into the space under the transversus abdominis muscle aponeurosis with spread along the thoracoabdominal fascia with possible paravertebral space spread.
Dosage	20–30 mL (0.25% ropivacaine or bupivacaine)
Nerve stimulation	Not used
Side effects	Minimal
Complications	Local anesthetic systemic toxicity (LAST): <0.1% Vascular puncture: epigastric artery: <1% Visceral puncture: <1%
Pearls	• QL1, lateral, is close to a posterior TAP and the key landmark is a thick fascia: the lumbar interfascial triangle (LIFT). • QL2, posterior, is between the latissimus dorsi and the QL. • QL3, transmuscular, injection adjacent to the psoas muscle • Large bolus may be better.
Alternative	TAP block Epidural Erector spinae plane block Paravertebral block
Further reading	Chin KJ, et al: Essentials of our current understanding: abdominal wall blocks. Reg Anesth Pain Med 2017; 42(2):133–83.

Suggested Readings

1. Farag E, et al: Atlas of Regional Anesthesia. Elsevier, Philadelphia: 2017.
2. Grant S, Auyong D: Ultrasound Guided Regional Anesthesia. Oxford University Press, Oxford, England, UK: 2017.
3. Hadzic A: Hadzic's Textbook of Regional Anesthesia and Acute Pain Management. McGraw-Hill Education, New York: 2017.

APPENDICES

AUTHORS

Erin Bushell, MD
Alex J. Butwick, MD, MS, FRCA
Brendan Carvalho, MBBCh, FRCA
Rebecca E. Claure, MD
Genevieve D'Souza, MD
Andrew J. Giustini, MD, PhD
Brenda Golianu, MD
Julie Good, MD
Anita Honkanen, MD
Richard A. Jaffe, MD, PhD
Sharon Jung, PharmD
Jamie Kuo, PharmD, BCCCP
Birgit Maass, MD
Carolyn Nguyen, PharmD
Einar Ottestad, MD
C. Philip Larson Jr., MDCM
Roya Saffary, MD
Clifford A. Schmiesing, MD
Jeannie Seybold, MD
Steven L. Shafer, MD

APPENDIX A: PREOPERATIVE CONSIDERATIONS

PREOPERATIVE LABORATORY TESTING AND DIAGNOSTIC STUDIES

Clifford A. Schmiesing, MD

The value and utility of preop diagnostic studies have become central issues in evaluating cost-effective health care in the surgical patient. Approximately $3 billion is spent in the United States annually on preop laboratory and diagnostic studies. Unnecessary testing is inefficient and expensive, and it requires additional technical resources. Inappropriate studies may lead to evaluation of "borderline" or false-positive laboratory abnormalities. This may result in unnecessary OR delays, cancelations, and potential patient risk through additional testing and follow-up.

Surgical patients require preop lab and diagnostic studies that are consistent with their medical conditions, the proposed operative procedures, and the potential for blood loss. Preop lab and diagnostic testing should be ordered for specific clinical indications rather than just because the patient is about to undergo a particular surgical procedure.

The following preop diagnostic guidelines provide basic recommendations. They are not absolute or standard requirements. Practice guidelines should be modified based on clinical needs and individual practice to ensure the highest quality of anesthesia and surgical patient care.

SUMMARY OF PREOP STUDIES

Chest x-ray (CXR)	**Overview**: A preop CXR should be used to assess the presence of acute, progressive, or chronic changes in cardiac/pulmonary disease. The decision to obtain a preop CXR should be individualized and based on clinical indications (see Table A-1). CXRs should not be part of a routine preop screening protocol. **Clinical indications**: Pneumonia; pulmonary edema; atelectasis; aortic aneurysm; mediastinal or pulmonary masses; tracheal deviation; pulmonary HTN; cardiomegaly; advanced COPD and blebs;

	dextrocardia; pulmonary embolism
Electrocardiogram (ECG)	**Overview**: ECGs evaluate cardiac rhythm/conduction disturbances, ischemia, myocardial infarction, hypertrophy, and metabolic and electrolyte disorders. **Clinical indications**: Patients with suspected or known Hx of CAD; patient age >60; HTN; Hx of dysrhythmias, chest pain; CHF; diabetes; OSA, cerebrovascular disease, and PVD; syncope or presyncope; dizziness; SOB; DOE; PND; palpitations; leg/ankle edema; abnormal valvular murmurs
Liver function test (LFT)	**Overview**: LFTs establish the absence or presence of hepatic injury and the degree of hepatic reserve in disease states. LFTs consist of AST (SGOT), ALT (SGPT), GGTP, alkaline phosphatase, serum albumin, and bilirubin. **Clinical indications**: Patients with suspected or known Hx of hepatitis (viral, alcohol, drugs, high BMI); infiltration (tumor, immunologic); cirrhosis; portal HTN; gallbladder or biliary tract disease; jaundice; intravascular hemolysis
Renal function testing	**Overview**: Renal function testing measures glomerular filtration and the magnitude of renal tubular dysfunction. These tests include serum creatinine and BUN. **Clinical indications**: Renal function testing is indicated for patients with HTN; increased fluid overload (CHF/peripheral edema/ascites) associated with cardiac or hepatic disease or dehydration; diabetes; nausea, emesis, or anorexia; polyuria; nocturia; oliguria; anuria; high-risk surgery in patients with low-CO syndrome; hematuria; costovertebral angle pain: renal transplant Hx; acute and chronic kidney disease; and dialysis.
Hemoglobin (Hgb),	**Overview**: The decision to obtain a preop Hgb, Hct,

hematocrit (Hct), CBC	or CBC should be individualized and based on clinical indications, medical Hx, and the proposed surgical procedure. Hgb/Hct or CBC should not be part of a routine preop screening protocol. **Clinical indications**: Hematologic disorder; bleeding/coagulopathy Hx; malignancy; chemotherapy; radiation therapy (CBC); renal disease; anticoagulant and steroid therapy; surgical procedures with high blood loss (>1500 mL); highly invasive or trauma surgery; malabsorption/poor nutrition status; CNS disease
Pregnancy testing	**Overview**: The decision to obtain a preop pregnancy test may be based on clinical Hx and examination or OR policy. Several assays are available (serum hCG, urine hCG); β-hCG is detectable in maternal urine and blood 8–9 d postconception. **Clinical indications**: Sexually active; time of last menstrual period; presence or absence of birth control method; patient intuition. OR policy may require pregnancy testing based on specific criteria including age and ability to become pregnant (i.e., no Hx of hysterectomy).
Coagulation testing	**Overview**: Coagulation testing, or clotting function studies, should be considered in patients with known or suspected coagulopathies as indicated from H&P and drug therapies. Tests include PT, PTT, INR, and platelet count. **Clinical indications**: Bleeding disorder Hx; anticoagulants or other drugs affecting coagulation; critical-risk surgeries with significant blood loss expected; hepatic disease: malabsorption/poor nutrition
Urinalysis	**Overview**: Assessment of renal function, infection, intravascular volume status, and metabolic disorders **Clinical indications**: There are no routine anesthesia preop requirements for a urinalysis.

We gratefully acknowledge the past contributions of Stephen P. Fischer, MD.

Table A-1. Diagnosis-Based Preop Testing

Tests →	ECG	CXR	Hct/Hb	CBC	Lytes	Renal	Glucose	Coag	LFTs	Drug Levels	Ca^+
Preop Diagnosis ↓											
Cardiac Disease											
Chronic atrial fib	X									X*	
CHF	X	±				±					
HTN	X	±				X†	X				
MI history	X				±						
PVD	X										
Stable angina	X				±						
Valvular heart disease	X	±									
CNS Disorders											
Seizures	X			X	X		X			X	
Stroke	X			X	X		X			X	
Tumor	X			X	X						
Vascular/aneurysms	X	X									
Coagulopathies				X				X			
Endocrine Disease											
Addison disease				X	X		X				
Cushing disease				X	X		X				
Diabetes				±	X		X				X
Hyperthyroidism	X	X	X								X
Hypoparathyroidism	X		X								X
Hypothyroidism	X	X	X								X
Hematologic disorders				X							X

Hepatic Disease										
Alcohol/drug-induced									X	X
Infectious hepatitis									X	X
Tumor infiltration									X	X
Malabsorption/poor nutrition	X		X	X	X	±				
Malignancy										
Morbid obesity	X	±					X			
Pulmonary Disease										
Asthma	(PFT only if symptomatic; otherwise, no tests are required)									
Chronic bronchitis	X	±	X							
Emphysema	X	±								X‡
Kidney Disease										
Acute kidney disease					X	X	X			
Chronic kidney disease					X	X	X			
Select Drug Therapies										
Anticoagulants					X				X	
Aspirin/NSAID									X	
Chemotherapy				X						
Digoxin (digitalis)	X					±			X	
Dilantin									X	
Diuretics							X	X		
Phenobarbital									X	
Steroids					X			X		
Theophylline									X	

X = OBTAIN; ± = CONSIDER.
*Patients on diuretics.
†Patients on digoxin.
‡Patients on theophylline.

Suggested Readings

1. Bapoje SR, Whitaker JF, Schulz T, et al: Preoperative evaluation of the patient with pulmonary disease. Chest 2007; 132(5):1637–45.
2. Cohn SL, Auerbach AD: Preoperative cardiac risk stratification 2007: evolving evidence, evolving strategies. J Hosp Med 2007; 2(3):174–80.
3. Feely MA, Collins CS, Daniels PR, et al: Preoperative testing before noncardiac surgery: guidelines and recommendations. Am Fam Physician 2013; 87(6):414–8.
4. Johansson T, Fritsch G, Flamm M, et al: Effectiveness of non-cardiac preoperative testing in non-cardiac elective surgery: a systematic review. Br J Anesth 2013; 110(6):926–39.
5. Mooney JF, Ranasinghe I, Chow CK, et al: Preoperative estimates of glomerular filtration rate as predictors of outcome after surgery: a systematic review and meta-analysis. Anesthesiology 2013; 118(4):809–24.

PREOPERATIVE EVALUATION OF PATIENTS WITH A CARDIAC RHYTHM MANAGEMENT DEVICE

Preoperative evaluation should include at least the following:

Device-Specific Considerations	• Date of most recent device interrogation (preferably <6 mo) • Type of device, manufacturer, model number, implant date (information typically on "pacemaker card" carried by patient) • Indication (including underlying dysrhythmia) for pacemaker or ICD. Include whether patient is "pacemaker dependent." • Determine underlying rate and rhythm. • Confirm adequate battery life. • Presence of freshly implanted leads (<3 mo old) → ↑ risk of dislodgement • Programming information including pacing mode, lower rate, pacer/ICD thresholds, and the response to magnet placement (asynchronous mode, ICD inactivation) • If any questions or concerns arise during evaluation, contact patient's cardiologist. Pacemaker companies can be contacted through 24-h service centers.
Patient-Specific Considerations	• Determine if patient has developed new symptoms possibly related to pacemaker dysfunction since last interrogation, including dizziness, syncope, fatigue, dyspnea, chest pain, or palpitations. • Review status of any associated cardiac disease (CAD, cardiomyopathy, valvular lesions). • Obtain 12-lead electrocardiogram; consider rhythm strip as needed. • If patient is pacemaker-dependent, consider placing magnet for procedures above T10. • If ICD/CRT, consider placing magnet for procedures above T10.

	• Advise surgeon to use short electrocautery applications (<5 sec). • External defibrillation equipment should be immediately available. • Consider placement of external pacer pads. • Use caution when placing upper body central lines with a guidewire. • A magnet should be immediately available.
Procedure-Specific Considerations	• Anatomical location of the surgery and patient position during surgery • Is monopolar cautery necessary? • Will there be other sources of electromagnetic interference (e.g., IORT, ECT, SSEP, MEP, RF ablation, or resection). • Will cardioversion or defibrillation be used during the procedure?

A complete discussion of this topic can be found in the following consensus statement

Grossley GH, Poole JE, Rozner MA, et al: The Heart Rhythm Society (HRS)/Americ Society of Anesthesiologists (ASA) Expert consensus statement on the perioperative management of patients with implantable defibrillators, pacemakers, and arrhythmia monitors: facilities and patient management: this document was developed as a joint project with the ASA, and in collaboration with the American Heart Association (AHA), and the Society of Thoracic Surgeons (STS)Heart Rhythm 2011; 8(7):1114–54.

ASA PHYSICAL STATUS CLASSIFICATION SYSTEM

ASA Physical Status	Preop Health Status	Examples Include
1	A healthy patient	No Hx acute illness or chronic medical conditions, no meds, no significant substance abuse, negative ROS
2	A patient with mild	No functional limitations: mild obesity,

	systemic disease	pregnancy, smoking, well-controlled hypertension or diabetes
3	A patient with significant systemic disease	Functionally limited: morbid obesity with comorbidities, CHF, COPD, poorly controlled HTN or diabetes, stable angina or old MI, renal failure on dialysis, stable cerebrovascular disease, unruptured aneurysm
4	A patient with severe systemic disease that is a constant threat to life	Severe functional limitations: unstable angina, unstable cerebrovascular disease, symptomatic CHF or COPD, ruptured aneurysm
5	A moribund patient who is not expected to survive without the operation	Not expected to survive >24 h without surgery; severe sepsis, multiorgan failure, severe coagulopathy, or intracranial hemorrhage
6	A declared brain-dead patient whose organs are being removed for donor purposes	

PERIOPERATIVE BETA-BLOCKER THERAPY

Clifford A. Schmiesing, MD

In the absence of new data showing benefit and safety of perioperative beta-blockers (PBB), published guidelines have tempered their support for starting therapy before surgery. Although PBB decreases the risk of cardiac complications, it increases the risk of stroke. The current ACC/AHA updated report continues to give a class recommendation (should be performed) to continue beta-blockers in patients undergoing surgery who are already receiving the drugs for management of other conditions including but not limited to HTN, afib, heart failure, and coronary artery disease. The report recommends against starting beta-blockers on the day of surgery due to the risk of bradycardia, hypotension, and stroke. Specific recommendations are listed in Table A-2 below.

When starting PBB therapy before surgery, consider the following general

recommendations. “Start low and go slow.” Initiate therapy days to weeks in advance of surgery and titrate to a heart rate of 60–80 beats per minute (assuming not hypotensive), maintain a systolic blood pressure of >100 mm Hg, and monitor vigilantly. Choose medications that are beta-1 selective (e.g., atenolol, metoprolol, and bisoprolol). Consider contraindications before initiating PBB therapy and how it will interact with other medications, medical conditions, and other surgical and anesthetic factors (Table A-3).

Table A-2. Guidelines for Perioperative Beta-Blocker (PBB) Therapy (Adapted from current ACC/AHA Guideline)

Recommendation	Recommendation Class	Level of Evidence
Continue BBs for patients taking them chronically.	Should be performed (1)	Limited (B)
Guide management of BB after surgery by clinical circumstances, independent of when the agent was started.	Reasonable to perform (2a)	Limited (B)
It may be reasonable to begin PBB Rx in patients with intermediate- or high-risk myocardial ischemia noted in preop risk stratification tests.	Reasonable to perform (2a)	Very limited (C)
It may be reasonable to begin PBB Rx in patients ≥3 RCRI risk factors (high-risk surgery, diabetes mellitus, heart failure, CAD, CKD, or stroke).	Reasonable to perform (2a)	Limited (B)
Uncertain benefit to begin PBB Rx in patients with a compelling long-term indication for beta-blocker therapy but no other RCRI risk factors	Reasonable to perform (2a)	Limited (B)
If beginning PBB Rx, it may be reasonable to start long enough in advance to assess effect and safety, preferably >1 d before surgery.	Reasonable to perform (2a)	Limited (B)

PBB Rx should not be started on the day of surgery.	Harmful (3)	Limited (B)

Table A-3. Recommendations for Perioperative Beta-Blocker Therapy (Adapted from the Focused AHA/ACC Recommendations for Perioperative Beta-Blocker Therapy Based on Published Randomized Clinical Trials)

Surgery Type	≤1 Risk Factor	>1 Risk Factor	CHD or Finding of Ischemia on Preop Testing	Taking β-Blocker
Vascular	Usefulness β-blocker uncertain*,†	Reasonable to give β-blocker‡,§	Probably give β-blocker	Continue β-blocker‖
Intermediate risk	Usefulness β-blocker uncertain	Reasonable to give β-blocker	Reasonable to give β-blocker	Continue β-blocker
Low risk	Usefulness β-blocker uncertain	Usefulness β-blocker uncertain	Usefulness β-blocker uncertain	Continue β-blocker

*In patients who are not currently taking β-blockers.
†β-blockers should not be given to patients undergoing surgery who have absolute contraindications to β-blockade.
‡Titrated to heart rate and blood pressure.
§Routine administration of high-dose β-blockers in the absence of dose titration is not useful and may be harmful to patients not currently taking β-blockers who are undergoing noncardiac surgery.
‖β-blockers should be continued in patients undergoing surgery who are receiving β-blockers for treatment of conditions with ACA/AHA class I guideline indications for the drugs.

Suggested Readings

1. Bangalore S, Wetterslev J, Pranesh S, et al: Perioperative beta blockers in patients having non-cardiac surgery: a meta-analysis. Lancet 2008; 372:1962–76.
2. Devereaux PJ, Yang H, Yusuf S, et al: Effects of extended-release metoprolol succinate in patients undergoing non-cardiac surgery (POISE trial): a randomized controlled trial. Lancet 2008; 371:1839–47.
3. Fleisher LA, Fleischmann KE, Auerbach AD, et al: 2014 ACC/AHA guideline on perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines Circulation 2014; 130:2215–45.
4. Lee TH, Marcantonio ER, Mangione CM, et al: Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. Circulation 1999; 100:1043–9.

PREOPERATIVE MEDICATION MANAGEMENT

Preop medication management is a crucial step in patient preparation for surgery. It is made challenging by several factors. Input from the surgeon and other consultants may

be needed. Patients often take a large number of medications, and many require active and deliberate management before surgery, including stopping and starting, dose adjustment, and conversion to other medications, and these adjustments often require different timing. Patients frequently find it challenging to follow these medication instructions. Many EHR systems do not provide robust support for this complex workflow. Medication management before surgery must be individualized, thorough, thoughtful, and transparent—a tall order. The following is intended as general recommendations and considerations. Specific management of preop medications must be based on a detailed assessment of the patient's medical history including a current and accurate medication list, planned surgery, and anesthetic plan.

Preoperative Medication Management Considerations			
Medication	**Day Before Surgery**	**Day of Surgery (DOS)**	**Other Management Considerations**
Antihypertensives	Take*	Take*	*Hold ACE, ARBs ≥ 24 h. Hold diuretics DOS unless indicated for management of CHF. Note: hemodialysis (HD) may completely filter off ACE/ARB and lead to rebound HTN. Consider timing of HD and ACE/ARB cessation after HD.
Oral antidiabetics	Take	Hold	Include many antidiabetic medication classes including sulfonylureas, meglitinides, and metformin. Consider holding metformin ≥24 h inpatient with CKD and those who will receive IV contrast.
Insulin, long-acting	No change	Consider 50–100% a.m.	Consider ↓ p.m. dose day before surgery if patient is

(peakless)		dose.	prone to nighttime or morning hypoglycemia.
Insulin, intermediate-acting	No change daytime dosing 50–75% of p.m. dose	50–75% a.m. dose	Consider ↓ p.m. dose day before surgery if patient is prone to nighttime or morning hypoglycemia.
Insulin, short-acting	No change	Hold	
Antiplatelet agents (APA)	Risk dependent →	→	Consider risk of thrombosis vs. risk of hemorrhage. Need to individualize based on indication and duration for therapy and surgical urgency and risk of bleeding. Consider carefully before stopping or adjusting antiplatelet therapy, especially dual therapies (DAPT). It is often helpful to consult with the clinician who manages antiplatelet therapy and surgeon to ensure optimal periop management. Guidelines exist for a variety of antiplatelet agent regimens (see Suggested Reading). Consider other hemostatic defects when formulating optimal plan.
NSAIDs	**Risk dependent** →	→	Consider holding NSAID 3 d before surgery unless the anticipated benefit of pain relief outweighs the

		risk of bleeding. Ibuprofen's effect on platelet function is shorter, and it can often be held for as little as 24 h. Selective COX-2 inhibitors have limited antiplatelet effect and are often continued and even initiated preoperatively. Consider other hemostatic defects (CKD, liver disease, thrombocytopenia) when formulating optimal plan.
Anticoagulants	Risk dependent →	Consider risk of thrombosis vs. risk of hemorrhage. Need to individualize based on the indication for anticoagulation, surgical urgency, and risk of bleeding. Thoughtful and timely planning is crucial. It is often helpful to consult with clinician who manages anticoagulant therapy and surgeon to ensure optimal periop management that may include cessation up to a week in advance or bridging strategies. Guidelines exist for periop anticoagulant Rx. (See Suggested Reading.) Consider other hemostatic defects (CKD, liver

			disease, thrombocytopenia, etc.) when formulating optimal plan.
Pure opiate agonists	Take	Take	Consider both fixed dose and PRN use. Helpful to calculate an MME score to determine overall opiate use and the potential effect on periop dosing. Anticipate tolerance when MME is significant.
Partial and complete opiate antagonists	Individualized →	→	Partial opiate agonists, especially buprenorphine, are increasingly used to manage opiate use disorder and chronic pain conditions. Preop management needs to be individualized and may include continuation with or without weaning to lower dose. See suggested readings. Full antagonists, especially naltrexone, are being increasingly used for indications including alcohol use disorder. It should usually be held 3–4 d before surgery that is painful, especially postop pain. Depot naltrexone use is on the rise and lasts up to 40 d. Recognition and management well in advance of surgery are necessary.

Antirejection medications	Take	Take	
Psychiatric medications	Take	Take if helpful	Consider drug-drug interactions, especially for MAOI inhibitors.
Acid-lowering	Take	Take	
Statins	Take	Take	
Corticosteroids	Take	Take or ± stress dose	
Dietary supplements	Consider holding supplements 7 d before, especially if constituents are hard to identify. Vitamins generally can be continued up to the day before surgery.		
Preemptive analgesia	Consider a multimodal approach that may include acetaminophen, gabapentin or pregabalin, and COX-2 inhibitors.		

Suggested Readings

1. Anderson TA, Quaye ANA, Ward EN, et al: To stop or not, that is the question: acute pain management for the patient on chronic buprenorphine. Anesthesiology 2017; 126(6):1180–6.
2. Dowell D, Haegerich TM, Chou R: CDC guideline for prescribing opioids fc chronic pain—United States, 2016. JAMA 2016; 315(15):1624–45.
3. Heit JA: Perioperative management of the chronically anticoagulated patient.J Thromb Thrombolysis 2001; 12(1):81–7.
4. Jørgensen ME, Torp-Pedersen C, Gislason GH, et al: Time elapsed after ischemi stroke and risk of adverse cardiovascular events and mortality following elective noncardiac surgery. JAMA 2014; 312(3):269–77.
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6. Lembke A, Ottestad E, Schmiesing C: Patients maintained on buprenorphine fo opioid use disorder should continue buprenorphine through the perioperative period. Pain Med 2019; 20(3):425–8. [cited 2018 17]; Available from: https://academic-oup-com.laneproxy.stanford.edu/painmedicine/advance-article/doi/10.1093/pm/pny019/4858540
7. Levine GN, Bates ER, Bittl JA, et al: 2016 ACC/AHA guideline focused update c duration of dual antiplatelet therapy in patients with coronary artery disease: a report of the American College of Cardiology/American Heart Association Task Force or

Clinical Practice Guidelines. J Am Coll Cardiol 2016; 68(10):1082–115.

APPENDIX B: STANDARD ADULT ANESTHETIC PROTOCOLS

Richard A. Jaffe, MD, PhD, Clifford A. Schmiesing, MD, and Steven L. Shafer, MD

STANDARD MONITORS (NONINVASIVE)	
Blood pressure (BP)	Usually noninvasive (oscillometric) technique. Match cuff width to arm size to avoid inaccurate BP.
Capnometry/capnography	Measurement of $ETCO_2$/display of waveform
Gas analyzer (e.g., IR, mass spectrometry)	Measurement of respired gases including end-tidal CO_2 and inhaled anesthetics
Electrocardiogram (ECG)	5-Lead preferred. Usual display: lead II and $V_{4\text{ or }5}$. EASI lead system can be used to derive a 12-lead ECG that may improve detection of intraop ischemia.
Esophageal or precordial stethoscope	Breath and heart sounds are monitored; dysrhythmias and pulmonary system changes may be quickly detected. Seldom used today.
Nerve stimulator	Monitor status of neuromuscular blockade usually by stimulating the ulnar nerve. Automated systems to measure TOF ratio are more accurate than visual assessment but still may fail to detect residual blockade.
Oxygen analyzer	Measurement of FiO_2
Pulse oximetry	Measurement of O_2 saturation of arterial hemoglobin; also gives a pulse sound that indicates heart rate, rhythm, and change in saturation
Temperature	Nasal, esophageal, bladder, rectal, tympanic, or skin (deep esophageal best approximates core

	temperature)
Visual observation of patient	Skin color, pupils, edema, sweating, movement
Ventilator function monitors	PIP, TV, disconnect alarm, pressure-volume/flow-volume loops, etc.

STANDARD ANESTHETIC MANAGEMENT (ADULT ASA 1 AND 2)

NB: The following sections are guidelines only (for an otherwise healthy 70-kg adult). Specific drugs and drug dosages should be individualized, based on the physiologic and pharmacologic status of the patient, including factors such as age, weight, concurrent medication, and comorbidities.

PREMEDICATION FOR ANXIOLYSIS ± ANALGESIA

Light	Midazolam 1–2 mg iv- or- Lorazepam 1–2 mg - or- Hydroxyzine 25–100 mg	Before induction or transport to OR po 1 h preop po 1 h preop
Moderate	Midazolam 2–3 mg iv ± Fentanyl 25–100 mcg iv	Prior to transport to OR Monitor for respiratory depression or apnea.
Heavy	Lorazepam 1–2 mg Midazolam titrated to effect	PO the night before surgery Before transport to OR. May require >10 mg iv. **NB:** severe respiratory depression when combined with opiates. Flumazenil should be available.

PREINDUCTION CHECKLIST

Anesthesia machine	Complete ASA preanesthesia checkout procedures. Sample procedures for specific

	machines/workstations are on the ASA Web site: http://www.asahq.org/For-Members/Clinical-Information/2008-ASA-Recommendations-for-PreAnesthesia-Checkout/Sample-Procedures.aspx.
Airway management	Appropriate-sized face masks Working laryngoscope and blade Working backup laryngoscope and blade Working suction ETT with nonleaking cuff + backup ETTs in other sizes ETT stylet and bougie available Oral and nasal airways available McGill forceps available Ambu® bag or equivalent self-inflating resuscitator available Unexpected difficult airway plan and equipment available
Monitoring	Standard monitors (see section above) Invasive monitoring if necessary, before induction
Patient	Working IV access Verify status of regional blocks (if in use). Positioning plans discussed with surgeon Fire risk assessment (especially if open O_2 delivery is planned)
Medication	Emergency drugs available Infusions prepared and pump function verified Anesthetic plan and drugs reviewed

INDUCTION TECHNIQUES

Preinduction	1. Administer 100% O_2 by mask × 3 min (ideally ETO_2 should be >90%). 2. Administer supplemental sedation/analgesia (as appropriate). e.g., fentanyl 1–3 mcg/kg iv			
Induction agents	Propofol	1.5–2.5 mg/kg iv (in increments) **NB:** pain on injection may be lessened by prior administration of lidocaine 1% 5–10 mL in conjunction with temporary venous occlusion.		
	Thiopental	3–5 mg/kg iv (still unavailable in the United States)		
	Etomidate	0.2–0.4 mg/kg iv **NB:** pain on injection; myoclonus		
Muscle relaxants for intubation	**Drugs**	**Doses**	**Onset**	**Duration**
	Vecuronium	0.1 mg/kg	2–3 min	24–30 min
		0.2 mg/kg (rapid onset)	<2 min	45–90 min
	Rocuronium	0.6 mg/kg	90–120 sec	30–45 min
		1.2 mg/kg	60–90 sec	60–120 min
	Pancuronium	0.1 mg/kg	3–4 min	40–65 min
	Gantacurium*	0.2–0.5 mg/kg	1–2 min	5–10 min
	Cisatracurium	0.2 mg/kg	2 min	40–80 min
	Succinylcholine	1.0 mg/kg	30–60 sec	4–8 min
	If given after defasciculating dose of NMR	1.5 mg/kg	30–60 sec	4–8 min
	Infusion	1 g/250–500 NS: 50–100 mcg/kg/min (titrated to effect)	+60 sec	While infusing +5–8 min (phase II block possible)
	*Gantacurium is not yet (2019) available in the United States.			

MAINTENANCE TECHNIQUES

Inhalational anesthesia	30–100% O_2 (NB: absorption atelectasis rapid above 80% O_2) + 0–70% N_2O + Sevoflurane (MAC = 2.0%) or isoflurane (MAC in 100% O_2 = 1.2%) or titrated to effect. Desflurane (MAC = 6.6%) may be useful for rapid recovery in morbidly obese patients.
Balanced anesthesia	30–100% O_2 (NB: absorption atelectasis rapid above 80% O_2) + 0–70% N_2O + Hydromorphone 3–10 mcg/kg/3–4 h (intermittent bolus) or fentanyl 1–10 mcg/kg prn response to surgical stimulation or remifentanil 0.05–2 mcg/kg/min prn response to surgical stimulation (no residual analgesia)

	+ Isoflurane or sevoflurane titrated to effect or propofol 50–200 mcg/kg/min (titrated to effect)		
Total intravenous anesthesia (TIVA)*	Oxygen usually mixed with air to a final concentration of 30–50%		
	Remifentanil†	Induction infusion	@ 0.5–1 mcg/kg/min × 1–2 min
		Maintenance infusion	@ 0.1–0.35 mcg/kg/min
		10 min before end of surgery, reduce infusion rate	@ 0.05–0.1 mcg/kg/min
		5 min before end of surgery	Infusion off
	Propofol	Induction bolus Maintenance infusion 10 min before end of surgery, reduce infusion rate 3 min before end of surgery	1–1.5 mg/kg @ 60–90 mcg/kg/min @ 20–40 mcg/kg/min Infusion off
	*Steven Shafer, MD. †No residual analgesia: Postop pain management depends on the type of surgery, and analgesic requirements may be substantial. Recommend having fentanyl or meperidine for quick pain relief followed by hydromorphone as a component of multimodal analgesia for prolonged pain relief.		

If **continued muscle relaxation** is required during the above maintenance techniques, several options are available. Always use a nerve stimulator to assess block before bolus redosing.

Short-acting	Gantacurium*	0.2 mg/kg/10–20 min
	Rocuronium	Rocuronium can be rapidly reversed shortly (3 min) after administration (1.2 mg/kg bolus) by using

		sugammadex (16 mg/kg iv).
Intermediate	Vecuronium	0.025 mg/kg/30 min; 1–2 mcg/kg/min infusion
	Rocuronium	0.6 mg/kg/30 min; 5–12 mcg/kg/min infusion
	Cisatracurium	0.2 mg/kg/40 min; 1–2 mcg/kg/min infusion
Long-acting	Pancuronium	0.02 mg/kg/60–90 min

*Not yet (2019) available in the United States.

EMERGENCE

1. Reversal of muscle relaxant	As surgical conditions permit, reverse residual muscle relaxant (when at least one twitch is present in train-of-four) with one of the following: Sugammadex 2 mg/kg actual body weight if twitch 2 in TOF has reappeared, otherwise 4 mg/kg Neostigmine 0.05–0.07 (maximum dose) mg/kg iv + glycopyrrolate 0.01 mg/kg iv Edrophonium 0.5–1.0 (maximum dose) mg/kg iv + atropine 0.015 mg/kg iv
2. Analgesia	If remifentanil was used during surgery, supplemental analgesics will be necessary and should be given promptly after emergence.
3. Nausea prophylaxis	Ondansetron (4 mg iv before emergence) or granisetron (1 mg iv for a longer duration effect). Also, consider adding dexamethasone 4 mg at induction, metoclopramide (20 mg iv before emergence), or aprepitant (40 mg po 1–3 h before induction). The use of droperidol (0.625 mg iv) is unfortunately controversial because of QT prolongation at higher doses. Consider OG tube suction to empty stomach. See Prevention of PONV (below).
4. O_2	d/c N_2O/volatile agents and administer 100% O_2.

5. Suction	Suction oropharynx thoroughly.
6. Extubation	Extubate after protective airway reflexes have returned and the patient is breathing spontaneously and ideally (with adequate analgesia) can follow commands.

LUNG PROTECTIVE VENTILATION

The traditional use of high tidal volume (10–15 mL/kg) mechanical ventilation has been associated with alveolar overdistension → ventilator-associated lung injury → release of inflammatory mediators → pneumonia and multiorgan dysfunction in ICU patients. Recent studies have suggested that a strategy of lung-protective ventilation using a pressure-controlled, volume-directed ventilator mode may improve postop outcomes in a variety of surgical patient populations. The types of surgery most commonly associated with postop pulmonary dysfunction include thoracic abdominal aortic aneurysm, neurosurgery, upper abdominal surgery, and emergency surgery.

Recommendations for lung-protective ventilation in hemodynamically stable patients (without ARDS) at risk for adverse postop pulmonary complications include:

- FiO_2 titrated to keep $SpO_2 > 92\%$ (optimal PaO_2 is patient dependent)
- Tidal volume = 6–8 mL/kg predicted body weight (see Table B-1)
- PEEP = 4–8 cm H_2O (less if venous return is impaired)
- Recruitment maneuvers (CPAP of 30 cm H_2O × 30 sec, prn atelectasis)

In the IMPROVE trial, recruitment maneuvers started immediately after intubation and were standardized as follows:

1. Pressure support ventilation mode
2. PEEP set to 30 cm of water
3. Inspiratory gas flow set to the highest value
4. Duration of the maneuver = 30 sec

Table B-1. Duration of the maneuver = 30 sec

Height (inches)	Female Predicted Body Weight (kg)	Female Tidal Volume (mL) (@6–8 mL/kg)	Male Predicted Body Weight (kg)	Male Tidal Volume (mL) (@6–8 mL/kg)
5′ 0″	45.5	273–364	50	300–400
5′ 1″	47.8	287–382	52.3	314–418
5′ 2″	50.1	301–401	54.6	328–437
5′ 3″	52.4	314–419	56.9	341–455
5′ 4″	54.7	328–438	59.2	355–474
5′ 5″	57	342–456	61.5	369–492
5′ 6″	59.3	356–474	63.8	383–510
5′ 7″	61.6	370–493	66.1	397–529
5′ 8″	63.9	383–511	68.4	410–547
5′ 9″	66.2	397–530	70.7	424–566
5′ 10″	68.5	411–548	73	438–584
5′ 11″	70.8	425–566	75.3	452–602
6′ 0″	73.1	439–585	77.6	466–621

Formula: males, PBW (kg) = 50 + 2.3 (height [inches] – 60); females, PBW (kg) = 45.5 + 2.3 (height [inches] – 60)

Suggested Readings

1. Futier E, Constantin JM, Paugam-Burtz C, et al; IMPROVE Study Group: A trial intraoperative low-tidal-volume ventilation in abdominal surgery. N Engl J Mec 2013; 369(5):428–37.
2. Mills GH: Respiratory complications of anaesthesia.Anaesthesia 2018; 73(Suppl 1):25–33.

MONITORED ANESTHESIA CARE (MAC)

1. Standard monitoring with regular verbal contact.
2. Nasal O_2 (qualitative measurement of respiratory rate, and $ETCO_2$ can be obtained by attaching a sampling catheter to the nasal cannula). The open administration of O_2 should be limited to a maximum concentration of 30% O_2 for procedures above T4 to minimize fire risk.
3. Light-to-moderate levels of sedation (±analgesia) can be maintained using a propofol (25–100 mcg/kg/min) or dexmedetomidine (see below) infusions, with PRN intermittent bolus injections of midazolam (1 mg) or propofol (20–30 mg), or with a remifentanil infusion (0.025–0.07 mcg/kg/min), titrated to effect. Monitor closely for respiratory depression.

4. Alternatively, dexmedetomidine (a α-2 agonist) can produce excellent sedation and analgesia without respiratory depression. The loading dose is typically 1 mcg/kg iv over ~10 min (↓ BP may occur) followed by an infusion of 0.2–0.7 mcg/kg/h.
5. If the initial local anesthetic injection is painful (e.g., retrobulbar block), then a brief period of analgesia, sedation, and amnesia can be induced with

	Advantages	**Disadvantages**
A. Midazolam (0.5–2 mg) ± ketamine (10–20 mg) ± alfentanil 3–7 mcg/kg or remifentanil 0.5 mcg/kg all injected 2–3 min before acute pain	Profound amnesia and analgesia. Usually no apnea, and airway reflexes are maintained. The patient is usually able to cooperate.	Patient not "asleep" Possible ↑ BP and HR
B. Propofol (0.5–1 mg/kg) ± fentanyl (25–50 mcg/kg)	Patient "asleep"	Possible apnea with loss of airway. ↓ BP may occur; patient may become unresponsive.

RAPID-SEQUENCE INDUCTION OF ANESTHESIA (FULL-STOMACH PRECAUTIONS)[1]

1. ↓ Gastric volume/acidity	Ranitidine 50 mg iv at least 30–60 min before induction if possible Metoclopramide 10 mg iv 30–60 min before induction if possible 0.3 M sodium citrate 30 mL po within 15 min of induction
2. Induction	Preoxygenation × 3 min (or until ETO_2 > 90%). Suction must be readily available. Stylet ETT. ± Defasciculate, e.g., rocuronium 3–4 mg iv 1.5–3 min before using succinylcholine. Cricoid pressure (Sellick maneuver) by an assistant (8–10 lb; beware of force transfer to C6 vertebra). Effective cricoid pressure makes laryngoscopy, mask ventilation, and LMA insertion difficult and will not

	eliminate the risk of aspiration. Choice of induction agent depends on patient condition including hemodynamic stability. Options include Etomidate 0.1–0.4 mg/kg (minimal hemodynamic effects) or Ketamine 1 mg/kg (usually ↑BP and HR) For patients better able to tolerate ↓ BP: Propofol 1–2.5 mg/kg + succinylcholine 1.5 mg/kg or rocuronium 1.2 mg/kg (slightly slower but <2 min) for intubation (sugammadex 16 mg/kg can be used for rapid reversal) Lungs may be ventilated while waiting for NMB—avoid airway pressure >20 cm H_2O (to reduce stomach insufflation).
3. Intubation	Intubate only when the patient is fully relaxed. After intubation, watch chest movement and auscultate for equal BBS. ✓ expired CO_2 on monitor. Listen over the stomach. Secure ETT and release cricoid pressure. Pass NG/OG tube and suction stomach contents.
4. Failed intubation protocol	[See Anesthetic Considerations for Cesarean Section, Obstetric Surgery, p. 297]
5. Maintenance	As indicated by patient's condition and type of surgery
6. Extubation	Repeating NG/OG suction is often useful before emergence and extubation. Extubate when patient is awake and has active laryngeal protective reflexes. Postop ICU care may be necessary until safe extubation can be assured.

[1]SPECIAL PEDIATRIC CONSIDERATIONS

1. The same principles apply in children requiring surgery and in those who may have

full stomachs. Consider emptying the stomach with an OG tube before induction ir patients with pyloric stenosis or with high-grade intestinal obstruction following po barium. If iv is placed, continue as indicated previously. If iv access is difficult, O_2/sevoflurane induction with cricoid pressure, and succinylcholine (2–4 mg/kg im) will permit intubation and minimize risks of gastric aspiration.

2. Awake intubation in neonates and sick infants may be the safest method.

PREVENTION OF PONV (ADAPTED FROM GAN ET AL., 2014)

Clifford A. Schmiesing, MD

PONV Risk Factors	Patient-related Anesthetic-related Surgical-related	Female gender Nonsmoking status Hx PONV or motion sickness Volatile anesthetics Nitrous oxide Intra-/postop opiates High-dose neostigmine Duration of surgery Type of surgery	Simple risk score for PONV in adults: assign 1 point for each of the following risk factors—female gender, nonsmoker, hx of PONV, and postop opioids. Risk of PONV: point sum 0 = 10%; 1 = 20%; 2 = 40%; 3 = 60%, and 4 = 80%.
Antiemetics	**Pharmacologic Agents** Serotonin blockers Dexamethasone 4–8 mg iv Droperidol 0.625–1.25 mg iv or Haloperidol 1 mg iv Metoclopramide 10–25 mg iv	**Timing of Administration** End of surgery Postinduction 30 min before end of surgery 30 min before end of surgery 30 min before end of surgery 2–4 h before surgery	Ondansetron 4–8 mg iv or po, granisetron 0.35–1.5 mg iv, dolasetron 12.5 mg iv, palonosetron 0.075 mg iv (long-acting) Adverse effects not seen with single-bolus dose.

	Promethazine 6.25–25 mg iv Scopolamine transdermal patch Neurokinin-1 receptor antagonists	Before surgery	May cause perianal pruritus when given iv to awake patient Minimal risk of QT prolongation, cardiac dysrhythmias, or extrapyramidal reactions at these low doses Can cause anxiety, confusion, or visual changes. 20–25 mg more effective than lower doses Sedating and may cause local tissue damage if iv catheter infiltration occurs May cause sedation, dry mouth, dilated pupils, visual changes, and confusion, especially in the elderly Aprepitant 40–80 mg po. Long-acting
Nonpharmacologic PONV prevention	Acupuncture, acupressure	Before or after surgery	
PONV prevention strategies	↓ Anesthesia-related RFs	Consider regional anesthesia where	

		appropriate. Propofol for induction and maintenance where appropriate ↓ N_2O and volatile agents ↓ Intraop and postop opioids ↓ Neostigmine	
PONV risk stratification and management	Low risk Intermediate risk High risk Very high risk	No prophylaxis → treat PONV when it occurs Choose 1–2 interventions Choose 2 interventions Consider 3–4 interventions	Consider including both short- and long-lasting antiemetics that will be effective post PACU discharge.

Adapted from Gan TJ, Diemunsch P, Habib AS, et al. Consensus guidelines for the management of postoperative nausea and vomiting. Anesth Analg 2014; 118(1):85–113. Copyright © 2017 Elsevier. With permission.

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2. Apfel CC, Philip BK, Cakmakkaya OS, et al: Who is at risk for postdischarge nausea and vomiting after ambulatory surgery? Anesthesiology 2012; 117(3):475–86.
3. Apfelbaum JL, Silverstein JH, Chung FF, et al: Practice guidelines for postanesthetic care: an updated report by the American Society of Anesthesiologists Task Force on Postanesthetic Care. Anesthesiology 2013; 118(2):291–307.
4. Cao X, White PF, Ma H: An update on the management of postoperative nausea and vomiting. J Anesth 2017; 31(4):617–26.
5. Gan TJ, Diemunsch P, Habib AS, et al; Society for Ambulatory Anesthesia Consensus guidelines for the management of postoperative nausea and vomiting. Anesth Analg 2014; 118(1):85–113.
6. Horn CC, Wallisch WJ, Homanics GE, et al: Pathophysiological and neurochemical mechanisms of postoperative nausea and vomiting. Eur J Pharmacol 2014; 722(Suppl

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7. Jokinen J, Smith AF, Roewer N, et al: Management of postoperative nausea and vomiting: how to deal with refractory PONV. Anesthesiol Clin 2012; 30(3):481–93.
8. Lee A, Fan LT: Stimulation of the wrist acupuncture point P6 for preventing postoperative nausea and vomiting. Cochrane Database Syst Rev 2009; (2):CD00328

VENOUS THROMBOEMBOLISM (VTE) PROPHYLAXIS

Clifford A. Schmiesing, MD

Common patient risk factors for VTE	• Increasing age • Previous VTE or family h/o VTE • Pregnancy and the postpartum period • Obesity • Inherited or acquired thrombophilia • Immobility, lower extremity paresis
Common disease-related risk factors for VTE	• Estrogen-containing oral contraceptives or hormone replacement therapy • Major surgery trauma (major trauma or lower extremity injury) • Cancer (known or occult) • Inflammatory bowel disease • Nephrotic syndrome • Myeloproliferative disorders • Paroxysmal nocturnal hemoglobinuria

VTE Risk Factor Assessment: Caprini Score Worksheet

Venous Thromboembolism Risk Factor Assessment Please Choose All That Apply				
Each Risk Factor Represents 1 Point	**Each Risk Factor Represents 2 Points**	**Each Risk Factor Represents 3 Points**	**Each Risk Factor Represents 5 Points**	**Women Only: Each Risk Factor Represents 1 Point**
☐ Ages 41–60 y ☐ Minor surgery planned (<45 min) ☐ History of prior major surgery (>1 mo) ☐ Varicose veins ☐ History of inflammatory bowel disease ☐ Swollen legs (current) ☐ Obesity (BMI > 25) ☐ Acute myocardial infarction (<1 mo) ☐ Congestive heart failure (<1 mo) ☐ Sepsis (<1 mo) ☐ Serious lung disease including pneumonia (<1 mo) ☐ Abnormal pulmonary function (COPD) ☐ Medical patient currently at bed rest ☐ Other risk factors: _____	☐ Ages 61–74 y ☐ Major surgery (>45 min) ☐ Arthroscopic surgery (>45 min) ☐ Laparoscopic surgery (>45 min) ☐ Previous or present malignancy ☐ Central venous access ☐ Immobilizing leg plaster cast (<1 mo) ☐ Patient confined to bed (>72 h)	☐ Age 75 y or more ☐ History of DVT/PE ☐ Family history of DVT/PE ☐ Positive factor V Leiden ☐ Positive prothrombin 20210A ☐ Elevated serum homocysteine ☐ Positive lupus anticoagulant ☐ Elevated anticardiolipin antibodies ☐ Heparin-induced thrombocytopenia (HIT) ☐ Other congenital or acquired thrombophilia ☐ If yes: Type_____	☐ Elective major lower extremity arthroplasty ☐ Hip, pelvis, or leg fracture (<1 mo) ☐ Stroke (<1 mo) ☐ Multiple trauma (<1 mo) ☐ Acute spinal cord injury (paralysis) (<1 mo)	☐ Oral contraceptives or hormone replacement therapy ☐ Pregnancy or postpartum (<1 mo) ☐ History of unexplained stillborn infant, recurrent spontaneous abortion (≥3), premature birth with toxemia, or growth-restricted infant
Total risk factor score =				

Venous Thromboembolism Prophylaxis Recommendations for Caprin Risk Score

Caprini Score	Risk Level	Prophylaxis Recommendation
0	Very low	Early ambulation
1–2	Low	Mechanical prophylaxis (sequential compression)
3–4	Moderate	Chemoprophylaxis (mechanical prophylaxis optional): heparin, 5000 units sc tid; low-

		molecular-weight heparin, 30 units sc bid; low-molecular-weight heparin, 40 units sc QD
≥5	High	Chemoprophylaxis and mechanical prophylaxis: heparin, 5000 units sc tid; low-molecular-weight heparin, 30 units sc bid; low-molecular-weight heparin, 40 units sc QD

Adapted from Jacobs B, Henke PK. Evidence-Based Therapies for Pharmacologic Prevention and Treatment of Acute Deep Vein Thrombosis and Pulmonary Embolism. Surg Clin North Am 2018; 98(2):239–53. Copyright © 2017 Elsevier. With permission.

Suggested Readings

1. Gould MK, Garcia DA, Wren SM, et al: Prevention of VTE in nonorthopedi surgical patients: Antithrombotic Therapy and Prevention of Thrombosis, 9th ed: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines Chest 2012; 141:w227S–77S.
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POSTOPERATIVE DELIRIUM: PRACTICAL GUIDELINES

Postoperative delirium (POD) can occur in any patient. DSM-5 criteria define delirium as "a disturbance in attention (i.e., reduced ability to direct, focus, sustain, and shift attention) and awareness (reduced orientation to the environment)" that develops over a short period of time and includes impaired cognition not explained by preexisting conditions. POD may be characterized as hyperactive or hypoactive, the latter being more difficult to diagnose. POD has been associated with long-term morbidity including POCD (postoperative cognitive dysfunction) and PTSD (posttraumatic stress disorder). POD usually starts in the recovery room and may persist for several days postop. The complex and often unpredictable interactions of both predisposing and precipitating factors make an accurate preop risk assessment for POD difficult.

RISK FACTORS ASSOCIATED WITH POD INCLUDE:

Preop	• Cognitive impairment • Patient self-assessment of health if fair, poor, or very poor (compared to good or very good) • Functional age greater than 65 years

	• Functional impairments • Dehydration/malnutrition • Significant comorbidities (e.g., CVD, CAD, PVD, DM, PD, anemia, depression/anxiety disorders) • Vision or hearing impairments • Polypharmacy or h/o substance abuse • Emergency surgery
Intraop	• Surgery of long duration • General anesthesia or deep sedation • Hypo or hyperglycemia • Hypotension (SBP < 90 mm Hg)
Postop	• Surgical complications • Hypothermia on arrival in recovery • Poorly controlled pain

Prevention should include when possible the use of fast-track (ERAS) protocols, preop Midazolam for significant anxiety, intraop dexmedetomidine, perioperative multimodal analgesia, and avoidance of deep anesthesia/sedation.

Treatment should include the return of any hearing or vision aids, minimal restraint, frequent reassurance and reorientation, supplemented (if necessary) with low-dose dexmedetomidine (e.g., 0.2 mcg/kg over 2 minutes followed by 0.2 mcg/kg/h infusion) or haloperidol (e.g., 0.25 mg titrated up to 2 mg iv at 30-minute intervals).

In recovery, patients should be screened for POD and if confirmed, treated before discharge. The Nursing Delirium Screening Scale (Nu-DESC) is often used for POD diagnosis (see Fig. B-1 below), but like similar screening tests, its reported sensitivity (32–95%) is quite variable. As usual, other potentially treatable explanations for POD-like Sx (e.g., electrolytes, ventilation, temperature, Sz, stroke, central cholinergic syndrome) should be ruled out.

Features and descriptions	Symptoms Rating (0-2)		
Symptom / Time Period	Midnight - 8 AM	8 AM - 4 PM	4 PM - Midnight
I. Disorientation Verbal or behavioural manifestation of not being oriented to time or place or misperceiving persons in the environment			
II. Inappropriate behaviour Behaviour inappropriate to place and/or for the person; e.g., pulling at tubes or dressings, attempting to get out of bed when that is contraindicated, and the like.			
III. Inappropriate communication Communication inappropriate to place and/or for the person; e.g., incoherence, noncommunicativeness, nonsensical or unintelligible speech.			
IV. Illusions/Hallucinations Seeing or hearing things that are not there; distortions of visual objects.			
V. Psychomotor retardation Delayed responsiveness, few or no spontaneous actions/words; e.g., when the patient is prodded, reaction is deferred and/or the patient is unarousable.			
Total score			

Fig. B-1. The Nursing Delirium Screening Scale (Nu-DESC). Symptoms are rated from 0 to 2 based on the presence and intensity of each symptom, and individual ratings are added to obtain a total score per shift. A score of 2 or more is strongly correlated with the presence of postop delirium.

Suggested Readings

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APPENDIX C: MULTIMODAL PERIOPERATIVE PAIN MANAGEMENT

Roya Saffary, MD and Einar Ottestad, MD

INTRODUCTION

Periop pain management continues to be a challenging aspect of anesthesiology with significant effects on patient satisfaction and clinical outcomes. According to the Centers for Disease Control and Prevention (CDC), about 48 million surgical and nonsurgical procedures were performed in the United States in 2010. A large survey of periop pain management revealed that ~80% of patients experienced acute pain postop, with 86% of those patients characterizing their pain as ranging from moderately to extremely painful. Furthermore, postop pain management was the most common concern of the patients surveyed. Expertise in neuraxial and regional anesthesia, as well as analgesic pharmacology, makes the anesthesiologist the ideal advocate for improving periop pain management.

The Joint Commission has recognized the importance of pain management in reducing periop pain while facilitating improvements in functionality. Poor pain control leads to adverse clinical outcomes, including decreased ability to ambulate with increased risk for thromboembolic events and fatal pulmonary embolism. Inadequate pain control following abdominal and thoracic surgeries may → splinting, atelectasis, and pneumonia.

The neuroendocrine stress response to surgery involves the release of stress hormones and catecholamines, which lead to many deleterious clinical effects and outcomes. These include weight loss, fatigue, immunosuppression, thromboembolism, hypercoagulability, dysrhythmias, urinary retention, and impaired pulmonary function. Furthermore, ongoing, uncontrolled pain in the postop period is a risk factor for chronic postsurgical pain. The continuous nociceptive barrage to the spinal cord and brain can lead to central sensitization, or "windup," which is thought to result in persistent pain beyond the acute recovery period. As we learn more about periop pain management, we can minimize pain while reducing morbidity and mortality in our surgical patients.

Opioids remain the primary treatment for postop pain. However, the recent opioid epidemic and the clinical application of enhanced recovery after surgery (ERAS) protocols have emphasized the potential risks and weaknesses of opioid-dominated

treatment. In addition to respiratory depression, opioids can lead to dependence, opioid-induced hyperalgesia, decreased testosterone levels, depressed immune function, lack of functionality, slowed recovery, and morphologic brain changes, particularly in patients with a preexisting chronic pain condition and/or opioid tolerance. In contrast to traditional pain management, ERAS protocols utilize an opioid-sparing approach by incorporating other medication families. Initially introduced to standardize key aspects of periop management including pain management for colorectal surgery, ERAS has since been applied to other surgical subspecialties, including gynecologic and orthopedic surgeries. Studies have shown that this approach significantly improves patient comfort and overall recovery and may even decrease hospital stay.

MULTIMODAL ANALGESIA

The concept of multimodal analgesia is based on the understanding that no single analgesic medication targeted to one receptor system allows for sufficient postop pain control. Therefore, rather than relying solely on opioids, ERAS protocols utilize agents that act on several receptor systems in the nociceptive pathway often combined with neuraxial or regional techniques to provide more effective postop analgesia. A number of medication classes have been effectively used for this purpose throughout the periop period. Please refer to Table C-1 for an outline of medication classes and examples.

Table C-1. Pain Medication Classes

Class	Examples
Mu opioid receptor agonists	IV or po morphine; sublingual sufentanil
Mixed COX inhibitors	IV or po ketorolac
COX-2 inhibitors	PO celecoxib
Central COX inhibitors	IV or po acetaminophen
Sodium channel blockers	IV lidocaine; po mexiletine
Multisite effects including Ca^{++} channel modulation	PO gabapentin or pregabalin
SNRIs	PO duloxetine or venlafaxine
TCAs	PO desipramine or nortriptyline

Alpha-2 agonists	Patch clonidine or IV dexmedetomidine
NMDA antagonists	IV ketamine; magnesium
Inhaled low-dose anesthetic	Methoxyflurane (experimental)

Postop pain management and patient recovery are most successful when an integrated, multispecialty, rehabilitation-orientated approach is utilized. Input from surgeons, anesthesiologists, rehabilitation specialists, nursing, pharmacy, and other key health care providers is necessary for this to occur. Best outcomes require that the patient be given appropriate preop education, excellent periop nociceptive blockade, attenuation of the neuroendocrine stress response, postop exercise, and early enteral nutrition.

PREEMPTIVE ANALGESIA

Preemptive analgesia refers to the administration of antinociceptive agents especially during the pre- and intraop periods to prevent the formation of central sensitization caused by incisional and inflammatory injuries. The benefit of preventing sensitization is a reduction in the patient's risk of developing chronic pain after surgery. It has been demonstrated clinically that preincisional analgesics help improve postop pain control. A number of agents have been studied in this context with promising results, including lidocaine, ketamine, neuraxial anesthesia, peripheral nerve blockade, topical anesthetics, peripheral opioid, gabapentin, and central opioid agonists. ERAS protocols often recommend oral administration of nonopioid analgesics in the preop area, including NSAIDs, gabapentin, and acetaminophen.

THE NEW ANALGESIA PARADIGM

This new paradigm, with ERAS at the forefront, emphasizes the preemptive and multimodal administration of a variety of analgesic classes through various routes of administration, including iv, po, neuraxial, peripheral nerve exposure, and topical agents. The traditional approach using mainly short-duration opiates has been shown to be suboptimal and inferior to providing the patient with a more comprehensive periop pain management regimen. In addition to improved pain control, this approach leads to less reliance on opioids and their associated side effects, as well as reduced risk of sensitization and development of chronic postop pain. When used in conjunction with a structured postop rehabilitation program, these techniques can lead to decreased patient morbidity and mortality, increased patient satisfaction, decreased recovery time, and shorter hospitalization (Table C-2).

Table C-2. An Example of Multimodal Analgesia for a 70-kg Patient Without Specific Drug Contraindications, Undergoing Major Surgery		
Preinduction	Systemic	Ibuprofen 800 mg or celecoxib 200 mg (decreased bleeding risk) po 30–60 min before induction and/or acetaminophen 1000 mg po 30–60 min before induction and/or gabapentin* 600–1200 mg or pregabalin* 150–300 mg po 60 min before induction
	Regional	Neuraxial analgesia (e.g., epidural or spinal opiates) or regional/peripheral nerve blocks
Preincision	Systemic	Fentanyl 100–250 mcg iv and/or ketamine 0.5 mg/kg iv bolus + 0.25 mg/kg/h infusion during surgery (especially useful in opioid-dependent patients)
	Local	Incision-site local anesthetic infiltration
Intraop	Systemic	IV opiates (e.g., fentanyl, hydromorphone)
		Lidocaine infusion 1–3 mg/kg/h
		Acetaminophen 1000 mg IV if not given preop
		Magnesium sulfate infusion 1 g/h
		Continuous regional anesthetic
Postop	Systemic	IV opiates (e.g., fentanyl, hydromorphone) bolus and PCA
		Ketorolac 15 mg iv q6h or ibuprofen 200–800 mg po q8h or celecoxib 100 mg bid
		Acetaminophen 650–1000 mg q6–8h

*Recent meta-analyses suggest that gabapentinoids may be associated with an increased incidence of adverse events (e.g. sedation, respiratory depression) while providing minimal opioid-sparing effects.

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STANDARD ADULT POSTOP PCA ORDER

Typical orders	1. Call anesthesiologist with any questions about PCA. 2. Check respiratory rate q1h while PCA is in use. 3. Call anesthesiologist if respiratory rate <10/min. If rate <6/min, treat with naloxone 0.4–0.8 mg iv push (may repeat q2–3min to 2 mg), and assist ventilation while waiting for anesthesiologist. 4. Encourage patient to ambulate 4–6 h after surgery (unless contraindicated).

	5. After PCA d/c'd, start po pain medications (per surgeon). 6. If patient required a large loading dose, the PCA lockout dose may need to be increased. Expect patient to need about 1/3 loading dose q h. Change PCA dose or lockout time to permit this dosing.	
Analgesics	Morphine	1–2 mg q10–15min
	Hydromorphone	0.2–0.4 mg q10–12min
	Fentanyl	10–25 μg q8–10min*
*Very short-acting might need small basal infusion dose.		

Epidural Analgesia*

Lumbar Epidural		Thoracic Epidural	
Morphine Bolus	**Hydromorphone Bolus**	**Morphine Bolus**	**Hydromorphone Bolus**
2–4 mg	0.4–0.8 mg	1–2 mg	0.1–0.4 mg
Morphine infusion	**Hydromorphone infusion**	**Morphine infusion**	**Hydromorphone infusion**
0.5–1 mg/h	0.05–0.2 mg/h	0.25–0.5 mg/h	0.1–0.2 mg/h
*Age <65 consider half dosing.			

Special considerations

1. Concentrations of opioids used for epidural infusions (in preservative-free solution):
   - Morphine, 0.15 mg/mL
   - Hydromorphone, 0.05 mg/mL

Epidural Anesthesia/Postop Analgesia*

Surgical Site	Epidural Catheter Location	Initial Bolus of 0.5% Bupivacaine	Infusion Rate of 0.125% Bupivacaine
Thoracic or upper abdomen	T6-T8	4–6 mL	4–8 mL/h

Lower abdomen	T10	10 mL	6–10 mL/h
Hip or knee	L2-L3	8 mL	6–10 mL/h
*Divided doses.			

Special considerations

1. iGve initial bolus dose before incision. Then, if patient is hemodynamically stable, give 1/2 bolus dose 30 min before end of surgery.
2. In recovery room, ✓ sensory level. If no sensory block, ✓ whether catheter is functioning with 5–10 mL 2% lidocaine bolus. (✓ vital signs.) If thoracic epidural starts with 2–3 mL, redose with 2 mL q5–10min, up to 10 mL.
3. Start infusions: If catheter is functional, as evidenced by loss of sensation, start local anesthetic + opioid infusions (see table, above).
4. Best results: Local anesthetics and opioids are mixed in line using two separate infusion pumps. Thus, if either causes side effects, one can be stopped without affecting the other.

PATIENT-CONTROLLED EPIDURAL ANALGESIA (PCEA)

Bupivacaine	0.125–0.25% with 3–5 mL bolus q12–20min
Fentanyl	2–4 mcg/mL

Special considerations

1. For thoracic epidural, decrease all doses by one-third; if high thoracic, decrease by one-half.

TYPICAL ORDERS FOR POSTOP EPIDURAL/SPINAL ANALGESIA

I. EPIDURAL MEDICATIONS

_____ **1. Epidural Infusion—Opiate**

- ❑ Hydromorphone (Dilaudid) 0.05 mg/mL concentration @_____mg/h =_____mL/h
- ❑ Morphine sulfate 0.15 mg/mL concentration @_____mg/h =_____mL/h
- ❑ Fentanyl (Sublimaze) 10 mcg/mL concentration @_____mcg/h =_____mL/h
- ❑ Range: May vary infusion between_____/h and_____/h prn pain.

_____ **2. Epidural Infusion—Anesthetic**

- ❑ Bupivacaine 0.125% concentration @_____mL/h
- ❑ Bupivacaine 0.25% concentration @_____mL/h
- ❑ Turn off bupivacaine on POD # 1 @ 5 a.m.

_____ **3 Epidural Bolus—Opiate**

- ❑ Hydromorphone (Dilaudid)_____mg q_____h in 10 mL preservative-free NS (PFNS)
- ❑ Morphine sulfate_____mg q_____h in 10 mL PFNS

_____ **4. Breakthrough Pain**

- ❑ Fentanyl PCEA 10–20 mcg q10min or Bupi 0.125% with fentanyl 4 mcg/mL 3 mL bolus q10min
- ❑ Call MD if > 2 doses in [2] h.
- ❑ Ketorolac (Toradol) [15] mg iv q6h × [3] d (for a maximum of 12 doses)

II. NURSING CARE

_____ **1. Vital Signs**

- ❑ For opiates: T, P, BP q4h; RR q2h; then q8h, if stable.
  Continuous O_2 sats × 24 h; then d/c if O_2 sats >90% on room air.
- ❑ For anesthetics: BP & P q2h; then q4h, if stable.
  Orthostatic BP before ambulation × 24 h.

_____ **2.** Label tubing, pump, infusion as "epidural." Place sign over bed; cover "Y" ports on tubing.

_____ **3.** Place naloxone (Narcan) and syringe at bedside.

_____ **4.** Administration of any additional opiates, sedatives, or antiemetics must be approved by anesthesiologist.

_____ **5.** Assess patient's pain (0–10 scale: 0 = no pain; 10 = worst pain imaginable) and level of sedation (awake, drowsy, asleep, unresponsive), along with VS.

_____ **6.** d/c Epidural Protocol when epidural d/c'd.

III. SIDE EFFECTS MANAGEMENT

_____ **1. Respiratory depression:** For RR < 6 or O_2 sat <86% (on two separate occasions <5 min apart):
Administer naloxone (Narcan) 0.1–0.2 mg iv STAT; may repeat, to total of 0.6 mg.
Administer O_2 10 L/min via nonrebreathing mask. TURN OFF INFUSION. CALL ON-CALL MD STAT.

_____ **2. Excessive somnolence/sedation:**
Administer naloxone (Narcan) 0.1–0.2 mg iv STAT; may repeat, to total of 0.6 mg.
Administer O_2 10 L/min via nonrebreathing mask. TURN OFF INFUSION. CALL ON-CALL MD STAT.

_____ **3. Nausea/Vomiting:**

- ❑ Metoclopramide (Reglan) [*10 mg*] iv q4–6h prn
- ❑ Ondansetron [*4 mg*] q6h prn
- ❑ Nalbuphine (Nubain) [*2.5–5.0 mg*] iv q4h prn

_____ **4. Pruritus:**

- ❑ Nalbuphine (Nubain) [*2.5–5.0 mg*] iv q2–4h prn
- ❑ Diphenhydramine (Benadryl) [*10–25 mg*] iv q4h prn

Suggested dosage shown in brackets [–]

APPENDIX D: STANDARD PEDIATRIC ANESTHETIC MANAGEMENT

Birgit Maass, MD, and Brenda Golianu, MD

Standard Pediatric Monitors (Noninvasive)	
Blood pressure (BP)	
Capnometry/capnography	Measurement of $ETCO_2$ display of waveform
Gas analyzer (e.g., Raman, IR, or mass spectroscopy)	Measurement of respired gases and anesthetics
Electrocardiogram (ECG)	5-lead preferred
Esophageal or precordial stethoscope	Breath and heart sounds monitored; dysrhythmias detected
Nerve stimulator	Monitor status of neuromuscular blockade.
Oxygen analyzer	Measurement of FiO_2
Pulse oximetry	Measurement of O_2 saturation; two pulse oximeters in neonates—one preductal; one postductal
Temperature	Nasal, esophageal, rectal, skin, or Foley
Visual observation of patient	Skin color, pupils, temperature, edema, sweating, movement
Ventilator function monitors	PIP, TV, disconnect alarm, etc.

Standard Preop Fasting (NPO) Guidelines
• All solid foods should be withheld after midnight or 6–8 h before procedure. Fatty (fried) solids, 8 h • Nonclear liquids (e.g., milk, infant formula, orange juice) should be withheld 6 h prior to surgery. • Breast milk has a relatively short transit time through the stomach and may be given up to 4 h prior to surgery.

• All clear liquids should be discontinued 2 h prior to scheduled surgery.

⋆NB: the following sections are guidelines only. Specific drugs and drug dosages should be individualized, based on the physiologic and pharmacologic status of the patient, including factors such as age, weight, medication, and concurrent diseases.

ASSESSMENT OF FLUID STATUS

Preop fluid management is essential and includes assessment of preexisting dehydration before fasting, minimization of NPO status, and estimation of any ongoing fluid or blood losses before surgery.

In addition to an historical assessment of recent oral intake, enteral nutrition, iv or other source of fluid administration, and recent urine output, a physical examination will include evaluation of vital signs, level of alertness, skin turgor, and the fontanelle status in infants. Laboratory analysis (e.g. electrolytes, Hb) may be useful.

Dehydration can be classified as mild (50 ml/kg, 5% body weight loss), moderate (100 ml/kg, 10% body weight loss) and severe (150 ml/kg, 15% body weight loss). For severe dehydration, it may be difficult to obtain iv access, and intraosseous access may be needed. In emergency surgery, optimizing fluid status will need to occur concurrently with surgery. For neonates and some infants, concurrent administration of dextrose may be needed.

Intraop volume management is guided by several parameters: preop fluid status, maintenance requirements during surgery, "third-space" fluid loss, urine output, and blood loss. Alterations in body temperature, patient positioning, and the use of vasopressors, vasodilators or other agents will affect assessment of volume status.

Positioning of the patient.

Surgical requirements (e.g. volume loading before reperfusion of transplanted organ) must also be considered

Postop volume management requires assessment of any ongoing bleeding, extracellular fluid shifts, and urine output. Volume assessment can be affected by administration of opioids, regional anesthesia, and patient comfort.

PREMEDICATION

- In general, patients <8 mo of age do not need sedative premedication. Infants <1 mo

and premature infants may require atropine 10–20 mcg/kg iv or 20 mcg/kg im or glycopyrrolate 5–10 mcg/kg iv before intubation. Older children (8 mo to 10 yr) can be premedicated successfully by using po midazolam (0.5–0.75 mg/kg with maximum of 20 mg) in syrup, grape Kool-Aid, or cherry-flavored acetaminophen elixir (10–15 mg/kg po) 20–30 min before surgery.

- Another option for premedication is intranasal dexmedetomidine 1–2 mg/kg or intranasal midazolam 0.2–0.4 mg/kg via atomizer.
- For patients >35 kg, po lorazepam (0.03–0.05 mg/kg) or diazepam (0.1–0.15 mg/kg) may be given 60 min before surgery with a sip of water if needed. Distraction with computer games, movies, and interaction with child life personnel has been used successfully.

Parental presence may not decrease the need for premedication but has been shown to increase parental satisfaction.

INDUCTION TECHNIQUES

Preinduction	1. ✓ anesthesia machine, suction, airway equipment, drugs 2. Attach monitors and verify function. 3. Premedication: <6 mo—consider atropine 0.01–0.02 mg/kg iv or glycopyrrolate 5–10 mcg/kg iv before laryngoscopy to prevent vagally mediated bradycardia.
IV induction	Indicated in cases with a difficult airway, in full-stomach considerations, in complex medical conditions, and in older children (>10). If iv induction is planned, topical anesthesia, such as Synera® (lidocaine/tetracaine) patch (30 min), EMLA® (lidocaine/prilocaine, 1 h), and ELA-Max® (liposomal lidocaine, 20 min), may be applied prior to iv placement.
Induction	**Routes of administration:** 1. IM: ketamine hydrochloride 3–5 mg/kg (with atropine 0.02 mg/kg or glycopyrrolate 0.01/mg/kg and 0.05–0.1 mg/kg midazolam) 2. IV: propofol 2–3 mg/kg 3. Inhalational: sevoflurane (MAC = 3.3% for neonates and younger infants, 2.5% for older infants and children) in N_2O (up to 70%)/O_2. Increase inspired concentration of

	sevoflurane incrementally every three breaths (up to 8%). Monitor BP and HR closely.
Muscle relaxation	1. Rocuronium: 0.6–1 mg/kg iv; 1 mg/kg recommended for rapid-sequence induction. If airway concerns exist, consider awake intubation and use of succinylcholine. 2. Succinylcholine: 1–2 mg/kg iv. May be useful for rapid-sequence intubations, especially if airway concerns exist. Succinylcholine 2–4 mg/kg im should always be available for urgent administration if needed for treatment of laryngospasm during induction that has not responded to CPAP and deepening of inhalational anesthesia. It may cause bradycardia; consider concomitant atropine (20 mcg/kg). 3. Vecuronium: 0.1 mg/kg iv 4. Deep sevoflurane anesthesia
Laryngoscope	**Blade** — **Age** Miller 0 — Neonate Miller 1 — 6–9 mo Wis-Hipple 1.5 — 9 mo–3 yr Macintosh 2 — 1–5 yr Macintosh 3 or Miller 2 — >5 yr
	*Succinylcholine may trigger MH or hyperkalemia with cardiac arrest in susceptible patients; therefore, many pediatric anesthesiologists avoid the use of succinylcholine especially in male patients under 6 yr unless airway concerns exist. Sugammadex is able to reverse paralysis with rocuronium at any time; rocuronium is becoming more popular as an agent for a rapid-sequence induction in pediatric patients.

TYPICAL ETT SIZE AT DIFFERENT AGES

Age	Wt	Uncuffed ETT Size	Cuffed ETT Size	LMA Size
Premature Newborn	1–3 kg 3–4 kg	2.5 or 3.0 3.5	n/a 3.0	1 (<5 kg)
≤6–8 mo	6–8 kg	3.5 or 4.0	3.0 or 3.5	1.5 (5–10 kg)
≤8–16 mo	10–12 kg	4.0 or 4.5	3.5 or 4.0	2 (10–20 kg)
2–3 yr	13–15 kg	4.5	4.0 or 4.5	2 (10–20 kg)
6 yr	20	Formula (uncuffed tubes): 4+ (age/4) = ETT size (to allow for a slight leak when positive pressure is applied). For cuffed tubes, use 0.5 size smaller and inflate as necessary to attain leak of 20–30 cm H_2O.		2.5 (20–30 kg)
9 yr	30 kg			3 (30–50 kg)
12 yr	40 kg			3 (30–50 kg)

NB: these ETT sizes are guidance only. ✓ ET placement of tube by auscultation of breath sounds bilaterally. ✓ depth of carina by auscultation over left axilla as ETT is slowly advanced. Withdraw and secure ETT 2 cm from carina. Positive pressure leak between 20 and 30 cm H_2O is desirable to prevent airway tissue necrosis due to inadequate perfusion. Leaks <20 cm may result in volume loss and difficulty in providing appropriate ventilation during critical phases intraop or postop. Conversely, leaks >30 cm H_2O may carry a higher risk of subglottic edema and/or stenosis. Consider length of case, difficulty of placing ETT, and adequacy of ventilation. A throat pack may assist in decreasing the leak if tube exchange is not desired.

In the past few years, mostly cuffed ETT are used in the OR in order to minimize need for tube exchange and optimize ventilation. This has not been associated with an increased risk of stridor; however, care should be exercised if N_2O is utilized in long cases, as it will cause an increase in cuff inflation pressure.

MAINTENANCE TECHNIQUES

Inhalational anesthesia only	30–100% O_2 + 0–70% N_2O. In preemies and for cases where N_2O is contraindicated, air should be used to lower FiO_2. + Sevoflurane or isoflurane, titrated to effect Consider warming and humidifying all gases for long cases. Warm room to 75–80°F for infants, 70–75°F

	for children.	
Balanced anesthesia	30–100% O_2 + 0–70% N_2O + ~0.5% isoflurane or propofol (50–250 mcg/kg/min) **TIVA**—propofol 100–250 mcg/kg/min, + remifentanil 0.05–0.2 mcg/kg/min. Consider including amnestic agents: midazolam and low-dose inhalational agents (e.g., sevoflurane, isoflurane). Dexmedetomidine 0.5–2 mcg/kg/h + remifentanil 0.05–0.1 mcg/kg/min Ketamine 0.2–1.5 mg/kg/h + Morphine (0.05 mg/kg/h) or fentanyl (1–3 mcg/kg/h) + hydromorphone 2 mcg/kg/h + Consider acetaminophen PR 30–40 mg/kg or iv 10–15 mg/kg for pain control. Temperature monitoring; forced-air warming; fluid warming if volume/blood/resuscitation is expected Fluid requirements LR/NS at maintenance: 0–10 kg = 4 mL/kg/h +11–20 kg = 2 mL/kg/h +>20 kg = 1 mL/kg/h (e.g., 25 kg = 65 mL/h) If continued muscle relaxation is required during the above maintenance techniques, several options are available. Always use a nerve stimulator to assess block before redosing. Neonates may demonstrate delayed return of neuromuscular function.	
Intermediate	Rocuronium (most commonly used)	0.6 mg/kg → 30 min 1 mg/kg for rapid-sequence induction → onset in 1 min, lasts 45–60 min
Vecuronium	0.1 mg/kg → 25–30 min	

EMERGENCE

1. Reverse muscle relaxant	As surgical conditions permit, reverse residual muscle relaxant (when at least one twitch is present in train-of-four) with one of the following: • Neostigmine 0.05–0.07 (maximum dose) mg/kg iv + glycopyrrolate 0.01 mg/kg iv or sugammadex: for rocuronium and vecuronium • A dose of 4 mg/kg is recommended if spontaneous recovery of the twitch response has reached 1–2 posttetanic counts (PTC) and there are no twitch responses to train-of-four (TOF) stimulation. • A dose of 2 mg/kg is recommended if spontaneous recovery has reached the reappearance of the second twitch (T2) in response to TOF stimulation for rocuronium only. • A dose of 16 mg/kg is recommended if there is a clinical need to reverse neuromuscular blockade soon (~3 min) after administration of a single dose of 1.2 mg/kg of rocuronium. • The efficacy of the 16-mg/kg dose following administration of vecuronium has not been studied. • NB: Sugammadex may decrease the effectiveness of hormonal contraceptives for up to 7 d.
2. Nausea prophylaxis	Ondansetron 0.1 mg/kg iv and/or metoclopramide 0.1 mg/kg iv (~1 h before emergence). Dexamethasone 0.1 mg/kg can be considered (avoid in oncology patients due to special protocols). TIVA. A scopolamine patch (e.g., one patch if >15 kg) may be useful in selected patients with h/o severe PONV although no safe/effective dose has been established by the manufacturer.
3. O_2	d/c N_2O/volatile agents and administer 100% O_2.
4. Suction	Suction oropharynx thoroughly.
5. Extubation	Laryngeal spasm is common in children; therefore, it is common practice to extubate them when they are awake, moving all limbs, and breathing adequately. Infants and children with full stomachs or difficult airways must be extubated when they are fully

awake. Deep extubation on 1.5–2 MAC sevoflurane or on propofol infusion is also common, except in patients <1 yr, moderate to severe sleep apnea, full stomach, or difficult airway. The pharynx and stomach should be suctioned thoroughly prior to extubation. If laryngeal spasm occurs, Rx with 100% O_2 and CPAP or PPV. If spasm fails to resolve and hypoxemia occurs, give succinylcholine 0.1–0.5 mg/kg and administer PPV. Consider reintubation if hypoxemia fails to resolve quickly. Consider atropine 0.01–0.02 mg/kg before succinylcholine, to preempt bradycardia.

PEDIATRIC EPIDURAL ANESTHESIA

Epidural anesthesia may be combined with GA for infants and children undergoing surgery involving the lower extremities, abdomen, chest, or spine. Single-dose ("single-shot") techniques may be used, or epidural catheters may be placed for longer procedures and to facilitate postop epidural analgesia (see below). Ropivacaine 0.1–0.2% ± 1:200K epinephrine or bupivacaine 0.25% ± 1:200K epinephrine is most commonly used intraop. For patients admitted following surgery, opioids (e.g., hydromorphone) are generally added, together with ropivacaine or bupivacaine 0.1% (see Appendix E). Use saline-filled syringe for loss of resistance to minimize chances of VAE.

TECHNIQUES AND DOSAGES

1. Caudal

- Single shot: 22-ga iv catheter is inserted via sacrococcygeal membrane. Usually only performed for age <6 yr.
- A test dose with 0.1 mL/kg (max 3 mL) lidocaine or bupivacaine + epinephrine 1:100K or 1:200K is given. (If epidural catheter is used, add 0.8 mL to test dose volume due to dead space volume of catheter.)
- Initial dose: 0.5 mL/kg for lower extremity/perineal/genital procedures, 1.0 mL/kg for abdominal procedures (max 15 mL).
- Catheter technique: 18-ga iv catheter is used; in patients <10 kg, first dilate the epidural space with 5–10 mL NS; then, a 20-ga epidural catheter may be inserted through 18-ga iv catheter and advanced so that the tip is located near the level of incision (e.g., ~17 cm from the skin to T4 in infant). If resistance is met, it may be necessary to pull the catheter back slightly, together with the needle (to avoid

shearing catheter), or repeat procedure. The tip of the catheter should be visualized with ultrasound or via x-ray with 0.5–1 mL of contrast. (If epidural catheter is used, add 0.8 mL to test dose volume due to dead space of catheter.)

2. LUMBAR

- 18-ga epidural needle is inserted via L3-L4 or L4-L5 interspace for single-sho injection or placement of 20-ga epidural catheter.
- Use loss-of-resistance technique with fluid-filled syringe (air may cause VAE).
- Good estimate of depth to epidural space is 1 mm/kg, up to ~30 kg.
- Catheter should be threaded 3–4 cm beyond the tip of needle.
- A test dose with 0.1 mL/kg lidocaine or bupivacaine + epinephrine 1:200K is given, max 3 mL. (If epidural catheter is used, add 0.8 mL to test dose volume due to dead space of catheter.)
- Initial dose: 0.5 mL/kg for lower abdominal procedures, 1.0 mL/kg for upper abdominal and thoracic procedures

3. THORACIC

- The technique described for lumbar epidural catheter placement may be used between T6 and T12 in children.
- A test dose with 0.1 mL/kg lidocaine or bupivacaine + epinephrine 1:100K or 1:200K is given, max 3 mL. (If epidural catheter is used, add 0.8 mL to test dose volume due to dead space of catheter.)
- Initial dose: 0.5 mL/kg
- Local anesthetic–dosing guidelines same as above (note that volume will be ~1/3 less than with caudal approach).
- Erector spinae plane block:

Most recently, erector spinae catheters have emerged at a safe alternative to central neuraxial blockade for major pediatric surgeries. Though still described primarily via case studies, these catheters hold promise as a simpler and safer alternative to thoracic epidural or paravertebral blocks, as the site can be easily visualized with sonography and is distant from the neuraxis, pleura, and major vascular structures. Catheter placement may be bilateral if warranted by the surgical incision. Dosing is accomplished by alternating hourly boluses via R and L catheters.

For indwelling catheter techniques, hourly maintenance doses of half the initial dose may be given. For continuous infusion, maximum rate for ropivacaine and bupivacaine is 0.5 mg/kg/h (0.3 mg/kg/h for neonates).

PEDIATRIC SPINAL ANESTHESIA AND ANALGESIA

Spinal anesthesia is used primarily for procedures such as inguinal herniorrhaphy in former preterm infants at risk for postop apnea following GA. By avoiding GA, the incidence of postop apnea is reduced, but not eliminated.

After standard monitors are applied, the infant is placed in a supine or lateral decubitus position. Care is taken to avoid neck flexion, which may cause airway obstruction. The skin is infiltrated with 1% lidocaine using a 27- or 30-ga needle. Lumbar puncture is performed with a 22-ga 1.5-inch spinal needle to an average depth of 1.5 cm from the skin. The most commonly used local anesthetic for spinal anesthesia in infants is tetracaine 1.0%, mixed with an equal volume of 10% dextrose in a dose of 0.8–1.0 mg/kg. Epinephrine 1:1000 0.01 mL/kg is added. This dose usually provides adequate anesthesia for 90–120 min for inguinal herniorrhaphy. Little change in BP or HR occurs in infants <6 mo of age.

Complications include high spinal anesthesia requiring tracheal intubation. PDPH is very uncommon in children <12 yr of age and probably rare in infants.

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APPENDIX E: MULTIMODAL PEDIATRIC POSTOPERATIVE PAIN MANAGEMENT

Genevieve D'Souza, MD, Julie Good, MD, and Brenda Golianu, MD

INTRODUCTION

Traditionally, children have been undermedicated for their pain because of difficulty with assessment, concerns for safety, and lack of understanding of the physiologic consequences of untreated pain. There is now strong evidence that it is not only safe but also beneficial to treat children's procedural pain. For example, infants have adverse behavioral cardiorespiratory and neuroendocrine responses to pain, which improve when appropriate analgesia is administered.

Pain assessment	Unlike most adults, infants and children <7 yr have difficulty understanding and using a Visual Analog Scale (VAS). A frequently used tool for assessing pain in children 3–7 yr old is the Wong-Baker Faces Scale (Fig. E.1). For infants and nonverbal children, observational scales that rely on behavioral and/or physiologic parameters are often used (e.g., the FLACC Pain Scale, Table E.1, PIPP, NIPS, CHEOPS, CRIES, as well as appropriate translations). The "gold standard" of pain measurement is to solicit a direct subjective report from the child whenever possible.
Oral medications	For simple outpatient procedures, such as hernia repair, circumcision, or closed reduction of a fracture, a weak oral opioid, in combination with acetaminophen, is appropriate. Care must be exercised in the use of opioids for management of pain in outpatients following tonsillectomy due to risk of hypoventilation and airway obstruction, especially in patients with severe sleep apnea.
Intravenous medications	**Patient-controlled analgesia (PCA)** can be considered in patients >5 yr who are expected to

	remain hospitalized overnight, especially in those who are unlikely to tolerate oral intake during the initial hours after surgery. For younger children, a **nurse-controlled analgesia (NCA)** can be employed. When the patient begins oral medications, d/c the basal rate but continue to provide the lockout dose for several more hours to be sure that the child is tolerating the oral medication. For opioid-related side effects such as nausea and vomiting, ondansetron can be added (0.1 mg/kg q6h to maximum of 4 mg q6h), and for pruritus, diphenhydramine (0.5 mg/kg q6h max 50 mg), or nalbuphine (0.05 mg/kg q6h max 20 mg), especially effective for epidural opioid-related pruritus. For respiratory depression, naloxone can be carefully titrated beginning at 0.001 mg/kg q1–2min as needed to restore adequate respiratory effort and wakefulness. Care must be taken, as naloxone will have a short half-life (10–15 min), and respiratory depression may recur. Reversal of analgesia may also occur if naloxone is administered for treatment of pruritus or respiratory depression.
Adjuvant medications	In addition to opioids, several adjuvant medications are useful in the periop period. **Lorazepam** (Ativan) 0.001 mg/kg iv q6h is useful in preventing spasms and lessening fear in an unfamiliar environment. It is important to remember that lorazepam has a half-life of up to 16 h, and doses can be additive. Another useful adjuvant is **ketorolac** 0.5 mg/kg, up to a maximum of 30 mg loading dose, followed by 0.5 mg/kg (up to 15 mg) q6h, up to 72 h. Ketorolac is not recommended in patients with poor renal function or following surgeries where there is a large bleeding surface or complex bone repair. Ketorolac has been shown to cause delay in bony fusion in animal models, but conflicting information has been presented in humans. It also has been reported to cause acute renal failure with prolonged use and is not recommended for use in bariatric patients due to

	its potential adverse impact on renal function. Given these concerns, it is helpful to observe hydration status, plt count, and Cr, and discuss the use of this medication with the surgical team. Other adjuvants to consider include **acetaminophen** iv or po (10–15 mg/kg/dose q6h, maximum 650 mg). Medications to manage side effects, such as pruritus, N/V, constipation, and respiratory depression, are presented in detail on the PCA order form. **Gabapentin** (15 mg/kg po, maximum 300 mg po tid) or pregabalin (2 mg/kg po) preop, followed by gabapentin 5 mg/kg po postop 3×/day for 5 days or **pregabalin** 1 mg/kg po, maximum 150 mg po bid postop for 5 days has been shown to decrease opioid requirement postop and should be considered for major surgeries. **Celecoxib** (2 mg/kg/dose, maximum 100 mg po bid twice a day for 5 days) can also be considered instead of ketorolac if the surgeon allows. Ketamine (0.1–0.3 mg/kg/h iv) may also be used as an adjuvant, though studies have not found a postop opioid-sparing effect.

Figure E.1 Wong-Baker Faces Scale used in pain assessment in children (and other patients developmentally from 3 to 7 years old). The higher the score, the greater the child's pain. (Courtesy of the Wong-Baker FACES Foundation (2019). Wong-Baker FACES® Pain Rating Scale. Retrieved Aug 7, 2019 with permission from http://www.WongBakerFACES.org. Originally published in Whaley & Wong's Nursing Care of Infants and Children. © Elsevier Inc.)

Epidural pain management	In children, it is generally considered safer to place epidurals after induction of GA to avoid movement

during placement. For children 0–12 mo, a **caudal technique** can be used. The patient is placed in the lateral decubitus position, the caudal anatomy is identified, and an 18-ga iv catheter is used to enter the caudal space. The catheter is advanced and aspirated. The space is then dilated with 5–8 mL of preservative-free NS. A 20-ga epidural catheter is then advanced to the desired location or until obstruction is felt (~10–15 cm). The catheter tip may be visualized using ultrasound or nerve stimulation, if available. The catheter is taped securely with a moisture-resistant dressing, as it can easily become dislodged with regular activity. A test dose is given (lidocaine 1.5% with 1:200,000 epinephrine 0.1 mL/kg + 0.8 mL for the dead space of the catheter). **Lumbar** and **thoracic epidurals** can be placed in children >10–12 mo or earlier in experienced hands. **Contraindications** for epidural catheters include infection at the local site, coagulopathy, low plt, sepsis, progressive neurologic deficit, and refusal of patient or parent.

Epidural placement should be checked by syringe aspiration before starting the infusion. Return of any bloody fluid or >0.5 mL clear aspirant necessitates further evaluation before use of the catheter for pain control. Patients with indwelling epidural catheters may receive postop analgesia with either continuous infusion or automatic programmed intermittent epidural bolus (PIEB), which delivers the full hourly rate at once each hour on schedule.

Continuous infusion can be used alone or with intermittent bolus dosing (**patient-controlled epidural analgesia** [PCEA]). Similar to PCA, PCEA can be used in ages = 5–7 yr. Typical starting infusions are described in the table below.

Medication dosage will depend on patient's age, location of surgical pain, catheter insertion level, and catheter tip location. If the patient has an extra-wide

	incision or other areas of discomfort, or if tolerant to opioids, the anesthesiologist may choose to run the epidural infusion at a fixed rate with local anesthetic alone (ropivacaine 0.1% or bupivacaine 0.1%) and provide the patient with an IV PCA with bolus (lockout) dose only (i.e., no continuous or basal rate). A bolus dose equivalent to the hourly volume of infusion may be given when a patient is uncomfortable. Increase the infusion by 10% to maintain the new level of analgesia. Infusion should not exceed 0.3 mg/kg/h in infants under 6 mo or 0.5 mg/kg/h in older patients. If inadequate analgesia persists after two dosing increases, it may be appropriate to abandon this form of treatment in favor of systemic analgesia. Do not leave a patient in pain for an extended period of time trying to "fix" an epidural catheter. If in doubt, check catheter placement, then bolus catheter with 2% lidocaine w/ 1:200,000 epi 0.1 mL/kg to determine if a level is able to be obtained.
Erector spinae catheters	When epidural infusions are not desired, or if there are concerns related to increased risk of bleeding, such as thrombocytopenia, coagulopathy, or need for intraop anticoagulation, erector spinae catheters may be an effective alternative to epidural catheter insertion. Catheters may be placed unilaterally or bilaterally, depending on surgical intervention. If unilateral, an hourly bolus dose can be administered. If bilateral, a bolus dose can be administered alternately to each side every 2 h, taking care not to exceed the maximum hourly dose of local anesthetic noted above.
Peripheral nerve catheters	Increasingly, peripheral nerve catheters are being employed for periop pain control. Local anesthetic infusions (ropivacaine 0.1% or bupivacaine 0.1%) are continued for 3–5 d postop.

Table E-1. FLACC Pain Scale for Pain Assessment in Nonverbal Patients			
	FLACC Pain Scale (For Nonverbal Patients)		
	Scoring		
Categories	**0**	**1**	**2**
Face	No particular expression or smile	Occasional grimace or frown, withdrawn, disinterested	Frequent-to-constant quivering chin, clenched jaw
Legs	Normal position or relaxed	Uneasy, restless, tense	Kicking, or legs drawn up
Activity	Lying quietly, normal position, moves easily	Squirming, shifting back and forth, tense	Arched, rigid, or jerking
Cry	No cry (awake or asleep)	Moans and whimpers; occasional complaint	Crying steadily, screams or sobs, frequent complaints
Consolability	Content, relaxed	Reassured by occasional touching, hugging, or being talked to; distractible	Difficult to console or comfort

Each of the five categories (F) Face, (L) Legs, (A) Activity, (C) Cry, and Consolability is scored from 0 to 2, which results in a total score between 0 and 10.

From Merkel SI, Voepel-Lewis T, Shayevitz JR, Malviya S. The FLACC: a behavioral scale for scoring postoperative pain in young children. Pediatr Nurs. 1997 May–Jun;23(3):293–7. The FLACC scale was developed by Sandra Merkel, MS, RN; Terri Voepel-Lewis, MS, RN; and Shobha Malviya, MD at C.S. Mott Children's Hospital, University of Michigan Health System, Ann Arbor, MI.

Suggested Readings

1. Brooks MR, Golianu B: Perioperative management in children with chronic pain Pediatr Anesth 2016; 26(8):794–806.
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5. Kaplan I, Jiao Y, AuBuchon JD, et al: Continuous erector spinae plane catheter for analgesia after infant thoracotomy: a case report. A A Pract 2018; 11(9):250–2.
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10. Niesters M, Overdyk F, Smith T, et al: Opioid induced respiratory depression in pediatrics: a review of case reports. Br J Anesth 2013; 110(2):175–82.
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STANDARD PEDIATRIC INTRAOP EPIDURAL/CAUDAL DOSING

	Ropivacaine 0.2% ± epi	**Bupivacaine 0.25% ± epi**	**Lidocaine**
Caudal	0.25 mL/kg	0.25 mL/kg	0.25 mL/kg
Lumbar	0.5 mL/kg	0.5 mL/kg	0.5 mL/kg
Thoracic	0.3 mL/kg	0.3 mL/kg	0.3 mL/kg

Maximum LA dosage: bupivacaine/ropivacaine/lidocaine 3 mg/kg.

Common additives for single dose administration

1. Preservative-free morphine: 30–50 mcg/kg
2. Hydromorphone 3–5 mcg/kg (commonly 3 mcg/kg in younger children, 5 mcg/kg in older children and teenagers)
3. Fentanyl 0.25–0.5 mcg/kg

l. Clonidine 0.5–2 mcg/kg (commonly 1 mcg/kg)

Lumbar epidural space depth (mm): ≈18 + 1.5 × age (yr)

STANDARD PEDIATRIC POSTOP ANALGESICS AND ANTIEMETICS

Analgesics	Acetaminophen	10 mg/kg po iv q6h 20 mg/kg po pr q6h	Max: 30–45 mg/kg/24 h (neo); 60 mg/kg/24 h (infants); max 80 mg/kg/24h pr (children>1)
	Hydrocodone/Acetaminophen Liquid or Tablet	0.15 mg/kg po iv q6h	Dose based on maximum acetaminophen allowed for weight (up to 10 mg/kg/dose) q4–6h, but not to exceed 60 mg/kg/d
	Oxycodone/Acetaminophen	0.1 mg/kg po q6h Oxycodone may also be prescribed without acetaminophen, and doses may be increased as needed, commonly 0.15 mg/kg po q6h	Dose should also be based on maximum acetaminophen allowed for weight (up to 10 mg/kg/dose) q4–6h, but not to exceed 60 mg/kg/d)
	*__NB__: Codeine is not recommended in pediatrics. Patients with CXP2D6 polymorphism may be ultrarapid metabolizers of		

	codeine, leading to oversedation and in some cases to fatalities in patients with OSA following tonsillectomy. In addition, 16% of people cannot metabolize codeine and thus may have suboptimal analgesia.		
Antiemetics	Metoclopramide* Ondansetron	0.1 mg/kg, may repeat × 1 iv 0.1 mg/kg iv	May increase risk of extrapyramidal reactions

Notes: To prevent irreversible liver damage, it is important to d/c or supervise all other use of acetaminophen when prescribing the above medications, so as not to exceed the maximum dose of 60 mg/kg/d (40 mg/kg/d in neonates) of acetaminophen.

Hydro, hydrocodone; APAP, acetaminophen; Cod, codeine.

PATIENT-CONTROLLED IV ANALGESIA (PCA)

In a setting with trained nursing supervision, PCA can be used safely by children <5 yr old (about the age they are able to play video games). The lockout time usually is set at 10 min but can be as short as 5 min for fentanyl. Common PCA medications and recommended starting doses in opiate-naive patients are listed below, followed by typical order for iv PCA.

Common PCA Medications

Medication	Loading Dose	Basal Rate	Patient-Controlled Bolus
Morphine (1 or 5 mg/mL)	0.03 mg/kg	0.01 mg/kg/h	0.02–0.03 mg/kg
Hydromorphone (100 mcg/mL)	3–5 mcg/kg	1 mcg/kg/h	2 mcg/kg
Fentanyl (50 mcg/mL)	0.3 mcg/kg	0.1 mcg/kg/h	0.2–0.3 mcg/kg

Continuous iv infusion

When PCA is not practical (e.g., in children unable to understand PCA), continuous iv infusion of opiates may be used. Morphine infusion of 10–30 mcg/kg/h results in serum concentrations of 10–22 ng/mL and provides adequate analgesia. A common technique is to initiate iv morphine infusion with 1 mg/kg of morphine in 100 mL of D5W at 1 mL/h (the effective infusion rate is 10 mcg/kg/h). The infusion rate is slowly increased

to provide adequate pain relief.

TYPICAL ORDERS FOR PATIENT-CONTROLLED IV ANALGESIA (PCA)

Patient's Name:_____ Medical Record No.:_____

Weight (kg):_____ Allergies:_____

Drug	Recommended Concentration	Loading Dose	Mode (*select one*)			PCA Dose	Lockout Interval	Basal Rate
			PCA Only	Continuous	PCA + Continuous			
Morphine	1 mg/mL	30 mcg/kg*				20–30 mcg/kg*	8–10 min	10 mg/kg/h*
Hydromorphoine	100 mcg/mL	5 mcg/kg*				2 mcg/kg*	8–10 min	1 mcg/kg/h*
Fentanyl	50 mcg/mL	0.3 mcg/kg*				0.2–0.3 mcg/kg*	8–10 min	0.1 mcg/kg/h*

Physician: Check all orders that apply: **Recommended starting dose for opiate-naive patients.*

Nursing Care:

- ❑ 1. For renewed or changed PCA orders only, continue PCA nursing are as previously ordered.
- ❑ 2. Do not administer any other opioids, benzodiazepines, sedatives, or antiemetics unless approved by:
  Service Pager No.:
- ❑ 3. Continuous O_2 sat monitor. For $SaO_2 < 94\%$, place order for and administer O_2 per nasal cannula to maintain $SaO_2 \geq 94\%$ and re-evaluate PCA doses.
- ❑ 4. Assess and record at least q2h: RR, O_2 sat, and level of pain, using appropriate tool.
  (*0–10 Scale, Wong-Baker Faces Scale, FLACC Scale, or PIPP Scale*)
- ❑ 5. Assess and record at least q4h: HR, BP, and T. Spot-check SaO_2 with vitals.
- ❑ 6. Bag and mask at bedside.
- ❑ 7. Assess for bladder retention. If no void for_____ h (since surgery or last void), may straight cath prn × 2.

Medications:

- ❑ 1. For renewed or changed PCA orders only, continue prn medications for PCA as previously ordered.
- ❑ 2. Metoclopramide (Reglan)_____mg iv q6h prn N/V (0.1 mg/kg/dose; max 15 mg).
- ❑ 3. Ondansetron (Zofran)_____mg iv q8h prn N/V (0.1 mg/kg/dose; max 4 mg).
- ❑ 4. Diphenhydramine (Benadryl)_____mg iv q6h prn pruritus (0.5 mg/kg/dose; max 50 mg).
- ❑ 5. Nalbuphine (Nubain)_____mg iv q4 prn pruritus (0.05 mg/kg/dose; max 20 mg).
- ❑ 6. Polyethylene glycol (Miralax) T packet po bid.
- ❑ 7. If no stool by_____(POD 3), administer:
  - ❑ 1 pediatric glycerin suppository pr 1 or 2 × daily prn (ages 2–6 yr).
  - ❑ Bisacodyl 5 mg (½ suppository) pr daily prn (ages 6–11 yr).
  - ❑ Bisacodyl 10 mg (1 suppository) pr daily prn (ages >11 yr).
  - ❑ Senna (Senokot) 8.6 mg tablet po bid prn.
  - ❑ If no stool within 24 h of beginning treatment, notify physician listed above.
- ❑ 8. If unable to arouse or SaO_2 < 90%, turn off PCA pump, administer O_2 and/or ambu-bag, stimulate patient, administer naloxone_____mg (0.001 mg/kg) q1–2min (obtain naloxone from floor stock) as needed to restore consciousness, and STAT page physician.
- ❑ 9. Other medications:_____

Date: Time:	Physician's Signature: Pager:	Noted by: Date/Time:
Orders signed		RN: Date/Time:

POSTOPERATIVE EPIDURAL ANALGESIA

Patients with indwelling epidural catheters may receive postop analgesia with either continuous infusion alone or continuous infusion with intermittent bolus dosing (PCEA or PIEB). The infusate may be either local anesthetic with an opioid, local anesthetic alone, or opioid alone. At Stanford, the most commonly used epidural infusate for continuous infusion or PIEB is ropivacaine 0.1% with hydromorphone 3 mcg/mL. In patients receiving PCEA, ropivacaine 0.1% with hydromorphone 25 mcg/mL is often used.

At Stanford, patients receiving epidural analgesia are managed by the Pediatric Pain Service.

Hydromorphone (Dilaudid): May bolus dose 5–10 mcg/kg or just add to continuous infusion. Reduced dose for thoracic catheters.

When opioid epidural analgesia is indicated, hydromorphone is most commonly used because

a. It causes less itching and nausea, compared with morphine.
b. It is more water soluble than fentanyl (decreased systemic absorption, spread over

more dermatomes).

2. It is less water soluble than morphine (thereby minimizing late respiratory depression).

STARTING DOSES FOR EPIDURAL INFUSION

Age	Starting Dose
0–6 mo	Hydromorphone 3 mcg/mL + 0.1% ropivacaine @ 0.1–0.15 mL/kg/h (max ropi 0.3 mg/kg/h); for neonates, consider 0.1% ropivacaine infusion only
6 mo to 3 yr	Hydromorphone 3 mcg/mL + 0.1% ropivacaine @ 0.1–0.15 mL/kg/h (max ropi 0.5 mg/kg/h)
3–7 yr	Hydromorphone 3–5 mcg/mL + 0.1% ropivacaine @ 0.1–0.15 mL/kg/h (max ropi 0.5 mg/kg/h)
>7 yr	Hydromorphone 5–10 mcg/mL + 0.1% ropivacaine @ 0.1–0.15 mL/kg/h + 0.05 mL/kg/h PCEA dose q30min lockout (max ropi 0.5 mg/kg/h)

Notes: In general, use a lower concentration of opiate infusion for neonates. When spread is needed (for surgeries with incisions that cross multiple dermatomes or when catheter placement is below the level of anticipated pain), a lower concentration and higher volume infusion may be desired.

Suggested Reading

1. Ivani G, Mosetti V: Regional anesthesia for post-operative pain control in children: focus on continuous central and perineural infusions. Paediatr Drugs 2008; 10(2):107–14.

TYPICAL ORDERS FOR CONTINUOUS EPIDURAL ANALGESIA
(may also be utilized for Peripheral Nerve Blockade)

Patient's Name:_____ Medical Record No.:_____

Weight (kg):_____ Allergies:_____

Drug and Concentration (*Check one*)	**Basal Rate** (0.15 mL/kg/h) (maximum 0.3 mL/kg/h for 0–6 mo)
❑ Hydromorphone 3 mcg/mL with bupivacaine 0.1% →	Epidural infusion rate_____ mL/h
❑ Hydromorphone 3 mcg/mL with bupivacaine 0.1% → **and** Clonidine 0.2 mcg/mL	Epidural infusion rate_____ mL/h
❑ Hydromorphone 3 mcg/mL with levobupivacaine 0.1% →	Epidural infusion rate_____ mL/h

Physician: Check all orders that apply:

Nursing Care:

❑ 1. Do not administer any other opioids, benzodiazepines, sedatives, or antiemetics unless first approved by Pain Management Service.

❑ 2. Maintain iv access until epidural catheter d/c'd.

❑ 3. Check epidural site qd and notify Pain Management Service if site is soiled, red, or tender.

❑ 4. Check lower extremities q8h while awake, and notify Pain Management if numbness or weakness exist.

❑ 5. Continuous O_2 sat monitor. For $SaO_2 < 94\%$, administer O_2 per nasal cannula to maintain $SaO_2 \geq 94\%$.

❑ 6. Assess and record at least q4h: RR, O_2 sat, and level of pain, using appropriate tool. (0–10/*Numeric Scale, Wong-Baker Faces Scale, FLACC Scale, or PIPP Scale*)

❑ 7. Assess and record at least q4h: HR, BP. Confirm absence of postural hypotension before ambulating for the first time.

❑ 8. Assess for bladder retention. If no void for 8 h (since surgery or last void), may straight cath prn × 2.

❑ 9. Bag and mask at bedside.

❑ 10. Check catheter entry site q8h and notify Pain Management Service if soiled, red, or tender

Medications:

- ❑ 1. Metoclopramide (Reglan)_____mg iv q6h prn N/V (0.1 mg/kg/dose; max 15 mg).
- ❑ 2. Ondansetron (Zofran)_____mg iv q6h prn N/V (0.1 mg/kg/dose; max 4 mg).
- ❑ 3. Diphenhydramine (Benadryl)_____mg iv q6h prn pruritus (0.5 mg/kg/dose; max 50 mg).
- ❑ 4. Nalbuphine (Nubain)_____mg iv q4 prn pruritus (0.05 mg/kg/dose; max 20 mg).
- ❑ 5. Polyethylene glycol (Miralax) 1 packet po bid
- ❑ 6. If no stool by_____(POD 3), administer:
  - ❑ 1 pediatric glycerin suppository pr 1–2 × daily prn (2–6 yr).
  - ❑ Bisacodyl 5 mg (½ suppository) pr daily prn (6–11 yr).
  - ❑ Bisacodyl 10 mg (1 suppository) pr daily prn (> 11 yr).
  - ❑ Senna (Senokot) 8.6 mg tablet T po bid prn
  - ❑ If no stool within 24 h of beginning treatment, notify physician listed above.
- ❑ 6. If unable to arouse or SaO_2 is <85%, turn off PCA pump, administer O_2 and/or ambu-bag, stimulate patient, administer naloxone (Narcan)_____ mg (0.001 mg/kg) q1–2min (obtain naloxone from floor stock) as needed to restore LOC, and STAT page pain Management Service.
- ❑ 7. Other medications:_____

Date: Time:	Physician's Signature: Pager:	RN Signature: Date/Time:
Orders signed		

Electronic Order Sets for Epidural and Regional Block Infusions in Pediatrics

Pump type : _____ CADD—On-Q—Nimbus—Other

Local anesthetic Infusion:

Bupivacaine _____% 0.05%; 0.0625%; 0.08%; 0.1%; 0.125% 0.2% 0.25% **(Usually 0.1%)**

Lidocaine _____% 0.25%; 0.5%; 1%

Ropivacaine _____% 0.05%; 0.08%; 0.1%; 0.2%; 0.25%(Usually 0.1% or 0.2%)

Adjuvants

Clonidine _____ mcg/mL 0.1 mcg/mL; 0.2 mcg/mL; 0.5 mcg/mL; 1 mcg/mL (**Usually 0.2 mcg/mL)—decrease for sedation—higher doses may be used if not using opioid)**

Fentanyl _____ mcg/mL 0.5 mcg/mL; 1 mcg/mL; 2 mcg/mL; 5 mcg/mL

Hydromorphone _____ mcg/mL 3 mcg/mL; 5 mcg/mL; 10 mcg/mL; 20 mcg/mL **(Usually 3 mcg/mL)**

Morphine (Preservative free) _____ mcg/mL

Example of frequently utilized infusions:

Immediately postoperatively: Ropivacaine 0.2% (or bupivacaine 0.1%) with clonidine 0.1 or 0.2 mcg/mL (depending on possible concerns of postoperative hypotension), hydromorphone 3 mcg/mL

Run infusion at 0.2–0.3mL/kg; check anesthetic level.

For thoracic infusions, reduce dose to 0.15–0.2 mL/kg. Check anesthetic level and assess for hypotension.

It can be particularly effective to administer the hourly dose of anesthetic as an hourly bolus—e.g., 8 cc delivered in one bolus, and the subsequent bolus is delivered in 1 h. This can be accomplished with the CADD and Nimbus devices but not with On-Q.

Maximum local anesthetic dose infusion: neonates–9 months 0.3 mg/kg/h; > 9 mo 0.5 mg/kg/h

When ambulation is being considered, reduce ropivacaine concentration to 0.1%. Verify orthostatic vital signs, lower extremity strength. Patient should always ambulate with assistance.

PCEA (patients >12 yr old): Local anesthetic and adjuvant mixture as above.

Begin Basal infusions at 0.1 – 0.15 mL/kg/h, and epidural bolus at 0.05 mL/kg/h q30min. Thus to total volume in the epidural will not exceed 0.25 mL/kg/h. This can be adjusted as needed for patient comfort to not exceed the above noted 0.3 mL/kg inepidural volume, or 0.5 mg/kg/h of local anesthetic.

Vital sign parameters for regional block infusions in pediatrics:

Age Group	1–9 mo	9 mo–3 yr	3–6 yr	6–15 yr	>15 yr
Heart Rate Minimum (pulse/min)	100	85	75	65	60
Heart Rate Maximum (pulse/min)	170	155	150	130	115
Resp Rate Minimum (breaths/min)	10	10	10	10	10
Resp Rate Maximum (breaths/min)	55	50	50	50	50
Systolic BP minimum (mm Hg)	60	75	75	90	90
Systolic BP maximum (mm Hg)	120	130	130	135	140
Diastolic BP minimum (mm Hg)	40	40	45	50	50
Diastolic BP maximum (mm Hg)	70	80	80	80	90
Temp Minimum (°C)	36.5	36.5	36.5	36.5	36.5
Temp Maximum (°C)	38	38	38	38	38

APPENDIX F: TABLES OF DRUG INTERACTIONS AND RECOMMENDATIONS FOR PREOP MANAGEMENT

Carolyn Nguyen, PharmD

These tables are intended only as an advisory overview of potential interactions between various drug classes or herbals that patients may be taking preop and the drugs used in anesthetic practice. They are not intended to be comprehensive lists. Drug interactions are dynamic and depend on a variety of circumstances including dosage, duration of administration, as well as the patient's genetics and current physiologic state. An excellent source for the predictive values of drug interactions due to altered metabolism can also be found in references for inhibitors, inducers, and substrates of the cytochrome P450 enzymes. In view of the constant flow of new drug information, the reader is strongly encouraged to check the primary literature of each drug or online resources, such as DRUG-REAX, Lexi-Interact, and Facts and Comparisons for dru interactions, and then tailor drug usage to the patient-specific clinical situation.

TABLE F-2 HERBAL AGENTS

It may be difficult to accurately predict the potential for drug interactions, because the majority of people neglect to inform health care providers of their consumption of herbal agents, natural remedies, alternative or complementary medicines, nutritional supplements, and illicit substances. The significance of the potential interaction is also difficult to assess due to variations of botanical species, the different parts of plants that are used, assay of active ingredient(s), and product formulation. Herbs that alter hemostasis should be discontinued 14 d before surgical, dental, or invasive procedures.

TABLE F-1 DRUG-DRUG INTERACTIONS

Preop Drug or Drug Class	Anesthetic Drug or Drug Class	Interaction	Clini Man
Acetylcholinesterase inhibitors (neostigmine, pyridostigmine, donepezil, rivastigmine)	Nondepolarizing neuromuscular blockers (NMBs)	↓ blockade	Titra thera

	(atracurium, rocuronium, vecuronium)		
Acetylcholinesterase inhibitors	Succinylcholine	↑ blockade	Mon supp funct
Adrenergics/sympathomimetics (ephedrine, epinephrine, norepinephrine, isoproterenol)	Anesthetic gases (desflurane, enflurane, isoflurane, sevoflurane)	↑ risk of dysrhythmias	Limit epin local
Alfentanil	Propofol, fospropofol	Opisthotonos, seizure	Mon seda hypo
Aliskiren	Any cardiovascular depressant or vasodilator	↓↓ BP	d/c 5 surg refra with
Aminoglycosides (gentamicin, tobramycin, amikacin)	Anesthetic gases	↑ potential for nephrotoxicity secondary to fluoride	Mon funct
Aminoglycosides	Botulinum toxins	↑ neuromuscular blocking	Mon bloc
Aminoglycosides	NMB	↑ respiratory depression	Mon supp funct
Amiodarone	Anesthetic gases	↑ myocardial depression and conduction defects	Mon rhyth
Amiodarone	Phenylpiperidone derivative opiate agonists (alfentanil, fentanyl,	↓ HR and ↓ BP, sinus arrest	Mon hem funct

	sufentanil)		
Amphetamines	Cocaine (topical)	↑↑ BP, ↑ HR	Mon BP.
Amphetamines	Opioids	↑ analgesic effects	Mon supp resp
Anthracyclines (daunorubicin, doxorubicin, idarubicin)	Isoflurane	Prolonged QT interval	Mon rhyth
Aprepitant, fosaprepitant	Opiate agonists (alfentanil, fentanyl, sufentanil) Meperidine	↑ respiratory or CNS depression ↑ opioid effects	Mon supp resp
Aprepitant, fosaprepitant	Midazolam	↑ midazolam levels	Mon supp resp
Aripiprazole	Midazolam	Genotype-dependent ↑ aripiprazole concentrations	Mon Cons dose aripi
Armodafinil	Midazolam	↓ midazolam effect	Titra effec
Arsenic trioxide	Halothane	Prolonged QT interval	Mon rhyth
Atorvastatin	Midazolam	↑ midazolam effect	Titra effec
Atracurium	Ketamine	↑ neuromuscular blocking	Adju moni prolo resp depr
Atracurium	Propofol, fospropofol	Bronchospasm	Anap reac

Azole antifungals (fluconazole, isavuconazonium, itraconazole, ketoconazole, posaconazole, voriconazole)	Alfentanil	↑ opioid effect	Cons alfer Mon supp resp
Azole antifungals	Midazolam	↑ midazolam effect	Dose neec mida Mon supp resp
Barbiturates	Midazolam	Potentiation of CNS depression	Mon supp resp
Benzodiazepines	Nonpolarizing NMBs	May prolong or antagonize blockade	Mon supp resp
Beta-blockers	Alfentanil, fentanyl, remifentanil, sufentanil	↑ risk of hypotension and bradycardia	Mon BP.
Beta-blockers	Alpha/beta-agonists (ephedrine, epinephrine, norepinephrine, phenylephrine)	Enhanced vasopressor effect	Use Reac depe ager
Boceprevir	Midazolam	↑ midazolam effect	Cont
Botulinum toxins	NMBs	↑ blockade	Toxi from caus weal
Calcium channel blockers—nondihydropyridines (diltiazem,	Alfentanil, fentanyl,	↑ risk of hypotension and bradycardia	Mon BP.

verapamil)	remifentanil, sufentanil		
Calcium channel blockers—nondihydropyridines	Midazolam	Prolonged sedation	Avoi mida dose
Calcium channel blockers—nondihydropyridines	Nondepolarizing NMBs	↑ prolonged blockade	Mon supp resp
Carbamazepine	Nondepolarizing NMBs	↓ blockade	Titra thera
Carbamazepine	Midazolam	Possible ↓ midazolam effect	Titra effec
Catecholamines, sympathomimetics	Halothane	↑ risk of catecholamine-induced dysrhythmias	Use inhal
Clindamycin	Nondepolarizing NMBs	↑ intensity or prolongation of blockade	Mon supp resp Antic or ca bene
Clindamycin	Succinylcholine	Prolonged blockade	Mon supp resp
Clonidine	Naloxone	Possible hypertension	Mon
Conivaptan	Alfentanil, fentanyl, sufentanil	↑ analgesic effect	Avoi
Conivaptan	Midazolam	↑ midazolam effect	Avoi
Corticosteroids	Nondepolarizing NMBs	Muscle weakness possibly progressing to polyneuropathies and myopathies	Titra thera
Crizotinib	Alfentanil	↑ analgesic effect	Avoi

Cyclophosphamide	Succinylcholine	↑ blockade	Cons alter rece cyclo in th dose succ Mon supp resp
Cyclosporine	Midazolam	Decreases clearance of midazolam. Prolonged sedation	Mon supp resp
Cyclosporine	Nondepolarizing NMBs	↑ blockade	Mon supp resp
Dasatinib	Alfentanil, fentanyl, sufentanil	↑ analgesic effect	Mon supp resp
Digoxin	Succinylcholine	Precipitate new dysrhythmias or potential existing dysrhythmias.	Mon
Disulfiram	Anesthetic gases	Reduction in gas metabolism	Mon of in
Dobutamine	Anesthetic gases	Ventricular dysrhythmias	Mon rhyth
Dofetilide	Sevoflurane	Prolonged QT interval	Mon rhyth
Dopamine	Anesthetic gases	↑ risk of dysrhythmia	Avoi
Echothiophate iodide (ophthalmic)	Succinylcholine	Prolonged blockade	Cons redu alter

Enzalutamide	Alfentanil	↓ analgesic effect	Avoi
Gabapentin	Anesthetic gases	Case report of myotonia and dystonia	Mon pote reac
Imatinib	Fentanyl	Increases fentanyl concentration and duration	Use dose for p effec
Isoniazid (INH)	Enflurane	Fast acetylators of INH facilitate defluorination of enflurane—high-output renal failure	Mon funct
Isoniazid (INH)	Halothane	↑ risk of hepatotoxicity	Avoi rifam after anes
Ivacaftor	Alfentanil, fentanyl, sufentanil	↑ opioid effect	Mon supp resp
Ivacaftor	Midazolam	↑ midazolam effect	Mon supp resp
Ketamine	Halothane	↓ BP, CO	Mon
Ketamine	Nondepolarizing NMBs	↑ blockade	Mon supp resp
Ketorolac	Nondepolarizing NMBs	Case reports of apnea	Mon resp
Labetalol	Anesthetic gases	↓ BP	Mon
Linezolid	Alpha/beta-agonists	Enhanced vasopressor effect	Use

Linezolid	Metoclopramide	Serotonin syndrome and NMS	Mon symp synd comb poss
Lithium	Nondepolarizing NMBs	Possible ↑ blockade	Mon supp resp
Local anesthetic (large doses)	Nondepolarizing NMBs	↑ blockade	Mon supp resp
Loop diuretics (bumetanide, ethacrynic acid, furosemide, torsemide)	Nondepolarizing NMBs	Low dose—enhance blockade; high dose—diminish blockade	Titra
Loop diuretics	Succinylcholine	Dose-dependent prolongation (low doses) or antagonism (high doses) of blockade	Titra
Macrolides (clarithromycin, erythromycin, telithromycin)	Alfentanil	↑ analgesic activity	Mon supp resp alfer Sufe to us
Macrolides	Midazolam	Prolonged sedation	Mon supp resp
Magnesium	NMBs	Enhanced blockade	Mon supp resp
MAO inhibitors (nonselective = phenelzine, tranylcypromine) (type B = rasagiline, selegiline)	Alfentanil, fentanyl, remifentanil, sufentanil	Serotonin syndrome, orthostatic hypotension	Mon and

MAO inhibitors	Alpha/beta-agonists	Enhanced vasopressor effect	Use reac upon dosa
MAO inhibitors	Metoclopramide	Serotonin syndrome	Mon symp avoi if po
MAO inhibitors	Succinylcholine	↑ blockade	Mon supp resp
Mercaptopurine	Nondepolarizing NMBs	May decrease or reverse blockade	Titra thera
Methadone	Alfentanil, fentanyl, remifentanil, sufentanil	↑ CNS depression	Avoi
Methotrexate	Nitrous oxide	Potentiation of cytotoxic effects	Avoi durir meth treat
Methylphenidate	Anesthetic gases	Enhanced hypertensive effect	Hold day avoi
Midazolam	Propofol, fospropofol	↓ clearance of midazolam	Mon supp resp
Mifepristone	Alfentanil, fentanyl, sufentanil	↑ analgesic effect	Mon supp resp
Mirtazapine	Alfentanil, fentanyl, remifentanil, sufentanil	↑ CNS depression	Avoi

Nitrates	Pancuronium	↑ blockade	Mon supp resp
NMBs	Anesthetic gases	↑ blockade	Titra ager
NNRTIs (note, these drugs are also in combination medications)	Midazolam	↑ midazolam effect	Cont
Octreotide	Opioids	↑ analgesic effects	Mon supp resp
Olanzapine	Midazolam	Possible excessive sedation and cardiorespiratory depression	Avoi olan pare benz
Opioids	Anesthetic gases	↑ potential for opiate toxicity	Mon supp resp
Opioids	Propofol, fospropofol	↓ BP	Titra each
Opioids	Succinylcholine	↓ HR	Mon brad hear
Phenothiazines (chlorpromazine, fluphenazine, prochlorperazine, thioridazine)	Metoclopramide	Extrapyramidal symptoms	Mon symp
Phenothiazines	Ondansetron, granisetron, dolasetron	Prolonged QTc interval	Mon rhyth
Phenothiazines	Opioids	↑ respiratory depression	Mon supp resp

Phenytoin, fosphenytoin	Nondepolarizing NMBs	Acute (<14 d—↑ blockade). Long term (>14 d—↓ blockade)	Mon supp resp
Pimozide	Propofol, fospropofol	QTc prolongation	Avoi
Piperacillin/tazobactam	Nondepolarizing NMBs	↑ blockade	Mon supp resp
Polypeptide antibiotics (bacitracin, colistimethate, polymyxin B)	Nondepolarizing NMBs	↑ blockade. Colistimethate and polymyxin B may have independent NMB activity.	Supp resp Cons gluc reve bloc colis
Polypeptide antibiotics	Succinylcholine	↑ blockade. Colistimethate and polymyxin B may have independent NMB activity.	Supp resp Cons gluc reve bloc colis
Procaine, procainamide	Nondepolarizing NMBs	↑ blockade	Mon supp resp
Procaine, procainamide	Propofol, fospropofol	↑ blockade secondary to competition for pseudocholinesterases	Mon supp resp
Protease inhibitors (note, these drugs are also in combination medications)	Fentanyl	CYP3A4 interaction	Cons litera spec cont
Protease inhibitors	Midazolam	↑ midazolam effect	Cont with mida

			mida contr with and mida be u cauti
Quinidine	NMBs	↑ blockade	Mon supp resp
Quinine	NMBs	↑ blockade	Avoi use.
Quinolones (ciprofloxacin, levofloxacin, moxifloxacin, norfloxacin)	Ondansetron, granisetron, dolasetron	Prolong QTc interval	Mon rhyth
Rifamycin derivatives (rifampin, rifabutin, rifapentine)	Alfentanil	↓ analgesic effect	Incre titrat appr relief
Rifamycin derivatives	Halothane	↑ risk of hepatotoxicity	Avoi rifam after anes
Ropivacaine	Propofol, fospropofol	↑ ropivacaine toxicity	Cons redu ropiv
Sotalol	Sevoflurane	Prolonged QTc interval	Mon rhyth
Spironolactone	Nondepolarizing NMBs	↑ blockade	Mon supp funct
SSRIs (citalopram, escitalopram, fluoxetine, paroxetine, sertraline)	Metoclopramide	NMS	Mon signs Cons dant

			NMS
SSRIs	Ondansetron, granisetron, dolasetron	Prolonged QTc interval	Mon rhyth
SSRIs	Opioids	Serotonin syndrome	Mon and
Succinylcholine	Nondepolarizing NMBs	↑ blockade	Mon supp resp
Succinylcholine	Propofol, fospropofol	↓ HR	Cons prem prop succ
TCAs (amitriptyline, imipramine, nortriptyline)	Metoclopramide	Extrapyramidal symptoms and NMS	Mon sign
Telaprevir	Midazolam	Increases midazolam concentrations	Oral cont mida be u cauti redu
Tetracyclines	NMBs	↑ blockade	Mon supp resp
Theophylline	Halothane	↑ risk of catecholamine-induced dysrhythmias	Use inhal
Theophylline	Midazolam	↓ midazolam effects	Titra
Thiazide diuretics	Nondepolarizing NMBs	↑ blockade may be secondary to hypokalemia	Corr hypo
Thiazide diuretics	Opioids	Orthostatic hypotension	Mon BP.

Thiotepa	Nondepolarizing NMBs	↑ blockade	Mon supp resp
Tranexamic acid	Estrogens, HRT	↑ VTE risk	Mon
Vancomycin	NMBs	↑ blockade	Mon supp resp
Vecuronium	Propofol, fospropofol	↑ blockade	Mon supp resp
Vemurafenib	Midazolam	↓ midazolam concentration	Titra to ef

TABLE F-2 HERBAL AGENTS

Plant	Precautions for Anesthesia and Surgery
Aloe vera	May impair hemostasis
Bilberry (Vaccinium myrtillus)	May impair hemostasis
Black cohosh (Cimicifuga racemosa)	Potential for hypotension and bradycardia
Bladderwrack (Fucus vesiculosus)	May impair hemostasis
Cat's claw (Uncaria tomentosa)	May impair hemostasis (inhibit platelet aggregation)
Cayenne (Capsicum annuum)	May impair hemostasis (inhibit platelet aggregation). Has biologic effect of increased catecholamine secretion. Overdose may cause hypothermia.
Chamomile. German (Matricaria chamomilla)	May enhance CNS depression
Coleus (Coleus forskohlii)	May impair hemostasis. Has antithrombotic effects and potential for hypotension
Devil's claw (Harpagophytum	May have chronotropic and inotropic effects.

procumbens)	May impair hemostasis
Dong quai (Angelica sinensis)	Has anticoagulant effects. May impair hemostasis. May cause vasodilation
Echinacea	May increase the sedative effect of midazolam
Ephedra (ma huang) (Ephedra sinica)	Potent sympathomimetic may cause cardiac arrhythmias, heart failure, and stroke.
Evening primrose (Oenothera biennis)	May impair hemostasis (inhibit platelet aggregation)
Fenugreek (Trigonella foenum-graecum L.)	May impair hemostasis. Contains coumarin
Feverfew (Tanacetum parthenium)	May impair hemostasis (inhibit platelet aggregation). Increase risk of serotonin syndrome
Fish oils	May impair hemostasis (inhibit platelet aggregation). Potential prolonging bleeding during and after surgery
Garlic (Allium sativum L.)	May impair hemostasis. May inhibit platelet aggregation; potential for enhanced ↓ BP. May ↓ blood glucose
Ginger (Zingiber officinale)	May → prolonged bleeding time (irreversible platelet inhibition); possible ↓ catecholamine secretion; cardioactive in large and prolonged doses
Ginkgo (Ginkgo biloba)	Selective antagonist of platelet aggregation; may cause vasodilation. Antithrombotic effect
Ginseng, American (Panax quinquefolius)	May impair hemostasis (possibly irreversible platelet inhibitor)
Ginseng, Panax (Panax ginseng) root	Dose-dependent effects on BP. May cause tachycardia. May impair hemostasis
Ginseng, Siberian (Eleutherococcus senticosus)	May impair hemostasis. Use barbiturates with caution. May affect BP.

Goldenseal (Hydrastis canadensis)	May impair hemostasis. Potential for hypotension and bradycardia. May alter liver enzymes
Grapefruit	Cytochrome P450 (CYP3A4) inhibition. Onset of midazolam may be delayed and action increased.
Grape seed (Vitis vinifera)	May impair hemostasis
Green tea (Camellia sinensis)	May impair hemostasis
Guggul (Commiphora mukul)	May impair hemostasis
Hawthorn (Crataegus oxyacantha)	High doses may cause hypotension + CNS depression. May ↑ digoxin and ACE inhibition.
Horse chestnut (Aesculus hippocastanum)	May impair hemostasis (contains coumarin). Has cholinergic properties
Kava kava (Piper methysticum)	Synergy with midazolam and anesthetic drugs. Chronic use may ↑ anesthetic requirements. Antagonizes dopamine
Licorice (Glycyrrhiza glabra)	May impair hemostasis. Mineralocorticoid effect ↓ K^+
Melatonin	May enhance CNS depressants
Passion flower (Passiflora spp.)	Synergy with CNS depressants. Avoid combination with MAOI.
Red clover (Trifolium pratense)	May impair hemostasis. Contains coumarins
Reishi (Ganoderma lucidum)	May impair hemostasis
Saw palmetto (Serenoa repens)	May cause ↑ BP. Antiestrogen effect
Schisandra (Schisandra chinensis)	Inducer of cytochrome P450 enzyme system
St. John's wort (Hypericum perforatum)	May have some MAOI activity. May reduce midazolam levels due to enzyme induction. Delayed emergence from anesthesia. Avoid meperidine.

Turmeric (Curcuma longa)	May impair hemostasis
Valerian (Valeriana officinalis)	Potentially synergistic with opiates and CNS depressants, including anesthetics
White willow (Salix alba)	Salicylate, may impair hemostasis
Yohimbe (Corynanthe yohimbe) (Pausinystalia yohimbe)	May cause CNS stimulation. May have cardiovascular effects

TABLE F-3 PREOPERATIVE MANAGEMENT OF PATIE MEDICATIONS

Drug/Drug Class	Continue to Time of Surgery?	Otherwise d/c Before Surgery
Aliskiren (renin inhibitor)	Do not continue unless essential for BP control (consult prescribing MD).	At least 2 d and preferably 7–10 d before lengthy or high blood loss surgery in patients taking other renin/angiotensin system drugs.
Alpha- and alpha-beta-blockers	Continue except for tamsulosin in cataract surgery.	Stop tamsulosin several days prior to cataract surgery to prevent floppy iris syndrome. Consider use of labetalol for intraop blood pressure control.
Amiodarone	Continue (long elimination half-life).	
Angiotensin-converting enzyme (ACE) inhibitors		May intensify hypotension in anesthesia—ensure adequate intravascular volume d/c 24 h prior to surgery.
Angiotensin receptor blockers (ARB)		May intensify hypotension in anesthesia. Hypotension may be less responsive to vasopressors—ensure

		adequate intravascular volume d/c 24 h prior to surgery.
Anticytokines in general	Consider consult.	
Anticytokines, adalimumab		d/c 1–2 wk prior to surgery. Restart 1–2 wk after surgery.
Anticytokines, anakinra		d/c 1–2 wk prior to surgery. Restart 1–2 wk after surgery.
Anticytokines, etanercept		d/c 1–2 wk prior to surgery. Restart 1–2 wk after surgery.
Anticytokines, infliximab	May continue if indication is inflammatory bowel disease	
Anticytokines, rituximab		d/c 1–2 wk prior to surgery. Restart 1–2 wk after surgery.
Antigout medications in general	Continue.	Monitor for fluid and electrolyte shift leading to changes in uric acid levels. Treat flares with NSAIDs or corticosteroids.
Antiparkinsonian medications	Continue prior to surgery as prescribed to prevent relapse.	
Antiparkinsonian medications, levodopa/carbidopa	Give dose evening before surgery.	
Antiparkinsonian medications, entacapone		Hold 24 h before surgery.

Antiparkinsonian medications, tolcapone		Hold 24 h before surgery. Resume when the patient is taking po and stable.
Antiparkinsonian medications, bromocriptine		Hold 24 h before surgery. Resume when the patient is taking po and stable.
Antiparkinsonian medications, pergolide		Hold 24 h before surgery. Resume when patient is taking po and stable.
Antiparkinsonian medications, ropinirole	Administer morning of surgery to avoid precipitating neuroleptic malignant syndrome.	Resume when the patient is taking po.
Antiparkinsonian medications, pramipexole	Administer morning of surgery to avoid precipitating neuroleptic malignant syndrome (NMS).	Resume when the patient is taking po.
Antiparkinsonian medications, selegiline		d/c 3 d before surgery because it is a MAOI type B.
Antiparkinsonian medications, anticholinergic agents		Parenteral diphenhydramine and benztropine can be used to control symptoms in patients who cannot take po medications.
Antipsychotic medications	Continue.	Haloperidol, olanzapine, and ziprasidone are available parenterally.
Antiseizure medications (AEDs)	Continue. Anesthesia, metabolic changes, ethanol withdrawal, and neurosurgical procedures may increase risk of seizures.	Check drug levels. Substitute iv alternatives.

Antithyroid medications	Continue antithyroid medications and beta-blockers.	
Apixaban		d/c 24 h before minor surgery and 48 h before any surgery with a moderate or higher bleeding risk.
Aspirin	Continue in vascular surgery or stents. Secondary prophylaxis in patients at high risk	d/c 5–7 d (up to 10 d) before surgery if risk or consequences of bleed are high or if taken only for primary prophylaxis.
Benzodiazepines	Continue to prevent development of withdrawal symptoms.	Support with iv preparations if necessary.
Beta-adrenergic blockers	Continue because abrupt discontinuation is associated with rebound ischemia, hypertension, and tachycardia.	If d/c prior to surgery, consider use of esmolol intraop for pressure and rate control.
Buspirone	Continue to prevent development of withdrawal symptoms.	
Calcium channel blockers	Continue in patients with normal or slightly impaired heart function. Continue with caution in patients with LV dysfunction.	
Cholestyramine, colestipol		d/c day before surgery.
Cilostazol		d/c 3–5 d before surgery.
Clonidine	Continue to prevent withdrawal symptoms	Consider use of transdermal system 3–4 d

	such as rebound hypertension, tachycardia, tremors, and anxiety.	before surgery with overlap oral dose for 2–3 d if the patient is NPO perioperatively. Observe for hypotension and bradycardia. Resume oral dose 8 h after transdermal patch removal.
Clopidogrel	In patients with: Drug-eluting stents <12 mo Bare metal stents <1 mo if asymptomatic Bare metal stents <12 mo if symptomatic + any others	d/c 5–10 d before surgery. d/c at least 24 h before urgent on-pump CABG if possible, and urgent off-pump CABG may be considered within 24 h of clopidogrel administration.
Clozapine	Continue to prevent withdrawal symptoms and disease relapse. May need psychiatric consult	
Corticosteroids	Continue. May need to supplement due to surgical stress.	
Dabigatran		d/c 1–2 d prior to surgery in patients with good renal function and 3–5 d prior to surgery in patients with CrCl < 50 mL/min. Consider d/c earlier for patients undergoing major surgery or neuraxial anesthesia. Check aPTT morning of surgery. Reversible with idarucizumab
Digoxin	Continue (long half-life).	

Dipyridamole		d/c 2–3 d before surgery
Diuretics (thiazides, loop)	Continue but monitor for volume depletion and ↓ K.	
DMARDs (disease-modifying antirheumatic drugs)	Consider consult.	May increase immunosuppression and increase the risk of wound infection
DMARDs, methotrexate	Continue in patients with normal renal function.	
DMARDs, leflunomide		d/c 2 wk prior to surgery (long half-life)
DMARDs, sulfasalazine	Continue.	
DMARDs, azathioprine	Continue.	
DMARDs, hydroxychloroquine	Continue.	
Ezetimibe		d/c day before surgery.
Fibric acid derivatives (gemfibrozil, fenofibrate)		d/c day before surgery.
Fondaparinux		d/c 24 h prior to surgery. Start no sooner than 6 h postop. Not reversible with protamine
H2-blockers	Continue.	Consider iv formulations.
Heparin		d/c 4–6 h before surgery. Reversible with protamine. Restart postop 12–24 h after procedures with low risk of postop bleeding. Restart postop 48–72 h after procedures with high risk of postop bleeding.

		Monitor for HIT (heparin-induced thrombocytopenia).
Herbals		d/c at least 14 d prior to elective surgery due to potential CV effects and/or bleeding.
HIV therapy	Be cognizant of drug interactions between HIV medications and anesthetic agents.	
HMG Co-A reductase inhibitors (“statins”)	Continue—may be cardioprotective and anti-inflammatory	
HRT (e.g., estrogen)	Balance risk of VTE with risks of stopping HRT.	Consider VTE prophylaxis.
Inhaled pulmonary medications including beta-agonists, ipratropium, and steroids	Continue.	
Insulin		Reduce evening dose of insulin (give about 2/3 dose). Adjust or omit morning dose of insulin. Use a sliding scale replacement.
Insulin pump		Decrease dose on evening of surgery. Switch to insulin infusion except for short, simple cases.
Leukotriene inhibitors (montelukast, zafirlukast)	Continue.	
Lipid-controlling		d/c day before surgery

agents (cholestyramine, colestipol, gemfibrozil, niacin)		
Lithium	Continue with caution. May prolong blockade of NMBs	Monitor sodium and fluid status.
LMWH		d/c 12–24 h prior to surgery; 24 h if planning neuraxial anesthesia. Partially reversible with protamine. Restart 4 h after epidural catheter is removed.
MAOIs		d/c 10–14 d prior to surgery. Use MAOI-safe anesthetic agents.
Meds for myasthenia gravis	Risk for respiratory insufficiency. Use pyridostigmine evening before surgery.	Postop management with pyridostigmine im 1/10th dose and iv 1/30th dose continuous infusion at 2 mg/h.
Niacin		d/c day before surgery
Nitrates	Continue.	May use nitroglycerin 2% ointment to substitute for po nitrates
NSAIDs		Usually d/c 1–3 d before surgery depending on the medication
Opioids, chronic use	Continue to avoid withdrawal and pain exacerbation.	Review equianalgesic substitutions. Patient may need multimodal approach to temporarily control the surgical pain.
Oral antidiabetic		Hold sulfonylureas and

agents (in general)		nonsulfonylurea secretagogues evening before surgery. Short procedures—delay morning doses until po intake. Monitor for hypoglycemia especially in the longer-acting sulfonylureas.
Oral antidiabetic agents: metformin		Risk of lactic acidosis (rare). Recommendations vary from holding 48 h prior to surgery to continuing (in patients with normal renal function).
Oral contraceptives	Balance risk of VTE with risks of d/c.	Consider VTE prophylaxis.
Pentoxifylline		d/c at least 8 h prior to surgery
PPIs	Continue.	Consider iv formulation.
Prasugrel		d/c 7 d before surgery
Rivaroxaban		d/c at least 24 h prior to surgery or longer (3 d in patients with CrCl < 50 mL/min) if bleeding risk is of primary importance. Nonreversible with protamine. Check aPTT morning of surgery.
Selective estrogen receptor modulators (SERM)	Balance risk of VTE with risks of d/c.	Consider VTE prophylaxis.
SSRIs	Continue.	If it is decided to d/c, taper for 3 wk prior to surgery.

TCAs	Long half-life	If it is decided to d/c, taper for 3 wk prior to surgery. Norepinephrine is pressor of choice.
Theophylline		Hold morning of surgery. Toxic levels are associated with arrhythmias.
Thyroid medication	Medication has long half-life, so omitting a dose is unlikely to have clinical effect.	
Ticagrelor		d/c 5 d before surgery
Ticlopidine		d/c 10–14 d before surgery
Valproic acid	Continue.	Consider iv formulation.
Warfarin	Assess bleeding risk of procedure compared with risk of thromboembolism. Consider bridging therapy.	Hold warfarin 3–5 d prior to surgery and consider bridging therapy. Check INR morning of surgery. Consider low dose of vitamin K on day of surgery if INR remains above surgeon's target INR. If INR is significantly elevated and surgery is immediately necessary, consider a warfarin reversal protocol, which includes vitamin K, FFP, PCC, and factors.

APPENDIX G: SPECIAL CONSIDERATIONS FOR LATEX ALLERGY

Andrew J. Giustini, MD, PhD, Rebecca E. Claure, MD, Anita Honkanen, MD and Brenda Golianu, MD

Latex is the second most common cause of anaphylactic reactions under anesthesia (20%) after neuromuscular blocking agents. The incidence of intraop latex reactions has declined significantly as latex-containing materials have been removed from the OR. Latex gloves were the major source of latex proteins and were implicated in most cases of latex-mediated reactions. Latex exposure may occur through skin contact, mucous membrane exposure, inhalation of glove powder, ingestion, or parenteral injection. Reactions to latex are divided into three types: irritant contact dermatitis, type IV hypersensitivity (skin reaction similar to poison ivy), and type I, IgE-mediated hypersensitivity, which can lead to life-threatening anaphylaxis.

Populations at risk

- Patients with history of multiple surgical procedures, including those with myelomeningocele, spina bifida, and congenital genito-urinary tract anomalies.
- Patients with a history of myelomeningocele and spina bifida should be treated with a "latex precaution" regimen from birth, regardless of prior history of exposure or latex reactivity.
- Health care personnel with occupational exposure.
- Other individuals with occupational exposure such as rubber industry workers and hairdressers.
- Patients with history of atopy, hay fever, asthma, or eczema.
- Patients with history of food allergy to tropical fruits (such as avocado, kiwi, banana, mango) and chestnuts, which contain cross-reacting proteins with latex.
- Patients with history of rash or swelling following contact with balloons, rubber bands, erasers, gloves or other products which may contain latex.

It is currently estimated that as many as 17% of health care workers have been sensitized to latex. Occupational exposure can be minimized by avoiding powdered latex gloves and limiting the use of latex-containing gloves. Applying lotion to hands before using latex gloves facilitates the transfer of latex proteins to hands, and should be avoided.

In high-risk patients, latex-avoidance protocols are recommended as this may decrease

the incidence of subsequent intraop allergic reactions. Hospitals and ORs have decreased the use of products that contain latex to the extent that many are essentially latex free. Anesthesia carts can be assembled with latex-free products, reducing the risk of latex sensitization for all patients and negating the need for a special "latex-free cart." The latex content of commonly used materials can be identified from external labeling, from package inserts, or directly from the manufacturers. Even minimal latex exposure (e.g., an injection through a latex port of iv tubing or opening a package of powdered latex gloves) has resulted in anaphylaxis.

Diagnosis of latex allergy is based on a focused history and physical examination with positive in vivo or in vitro test. In vitro serum tests for latex-specific IgE such as RAST are highly specific but have a high false-negative rate, up to 30%. Skin testing identifies patients with a high titer of IgE to latex but must be performed with appropriate safeguards because it may induce systemic anaphylaxis.

Pharmacologic prophylaxis in the acute setting is controversial for patients with documented latex allergy. Prophylaxis medications, such as diphenhydramine, ranitidine, and hydrocortisone, are not universally successful in preventing latex anaphylaxis. Some authors have argued that pretreatment may mask the early immune responses, leaving anaphylaxis as the first evidence of an allergic reaction.

To prepare a latex-safe environment

- Notify OR nurses, anesthesia technicians, and surgical staff of the need for a latex-free room.
- Place a sign on the door stating: "LATEX-FREE ROOM."
- Schedule the latex-allergic patient as the first case of the day to minimize the presence of airborne latex particles.
- Set up the room with latex-free materials (e.g., bag, bellows, ECG electrodes, pulse oximeter clip, iv tubing without latex ports, vinyl gloves, vinyl BP cuffs, clear micropore tape).
- Avoid bouffant surgical hair caps and shoe covers that contain latex bands.
- Wrap Webril™ around latex tubing on stethoscope, BP cuff, or tourniquet with Webril™ or cotton gauze if they contain latex derivatives.
- Removal of rubber stoppers from drug vials (instead of withdrawing through the stopper) is controversial.

Diagnosis of anaphylaxis or latex allergy

- **Early Manifestation** Skin: hives or urticaria at site of contact with latex product, red eyes, angioedema of eyelids, nasal congestion, GI cramping, headache, anxiety.
- **Late Manifestation** Respiratory: bronchospasm, wheezing, ↑ PIP, ↓ O_2 sat,

upsloping of $ETCO_2$ tracing.

- Intraop cardiac: ↓ BP, ↑ HR, cardiac arrest. Generally, type I hypersensitivity may not occur immediately at the beginning of a surgical procedure but after exposure of peritoneum or mucous membranes to latex.

Treatment of anaphylaxis

- Remove latex.
- Notify surgical team.
- Call for help.
- 100% O_2; secure airway; manually ventilate if needed.
- Discontinue all anesthetic agents, ± Trendelenburg's.
- Epinephrine 0.1–1 mcg/kg iv initially, increasing to 10 mcg/kg; repeated boluses may be needed to support BP; may require an epinephrine infusion (0.05–0.1 mcg/kg/min) and may be increased up to 1 mcg/kg/min in severe cases. IM dose of epinephrine is 0.01 mg/kg (maximum dose of 0.5 mg). If hypotension is refractory to epinephrine, consider the use of a vasopressin bolus of 0.01-0.05 units/kg iv; repeated boluses may be necessary. The use of an infusion can be considered after blood pressure is stabilized: 0.3 milliunits/kg/min to 2 milliunits/kg/min iv with a maximum of 40 milliunits/min (0.04 units/min).
- Administer iv fluid to ↑ preload and support BP.
- Review field to ensure all possible latex-containing equipment has been removed. (Instruct surgical staff to change to nonlatex gloves and scrutinize all equipment.)
- Administer steroids (hydrocortisone 100 mg iv or methylprednisolone 0.5 mg/kg iv (max 125 mg)), antihistamine (diphenhydramine 50 mg or 0.5 mg/kg iv; max = 50 mg), and H-2 blockers (ranitidine 1 mg/kg; max = 50 mg).
- Administer bronchodilators (albuterol) via nebulizer for bronchospasm.
- Continue steroids and diphenhydramine for 24–48 h or until symptoms resolve.
- Collect blood for mast cell tryptase (peaks at 30–60 min, $t_{1/2}$ is 2 h) and histamine (peaks at <30 min).
- Inform pharmacy of latex sensitivity to ensure all products are prepared latex free.
- Refer patient to allergist for follow-up. Skin prick test or RAST can be performed (4–6 wk after the acute reaction resolves) to specifically test for latex allergy.
- Patients with a history of latex anaphylaxis should be advised to wear a Medic Alert bracelet.

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APPENDIX H: PERIOPERATIVE ACUPUNCTURE

Brenda Golianu, MD, and Jeannie Seybold, MD

We gratefully acknowledge the past contributions of Emily F. Ratner, MD

INTRODUCTION

Acupuncture is a treatment modality that has been practiced in China for over 3 millennia. Initially transmitted as an oral tradition, it was first described in written form in the Huangdi Neijing or the Yellow Emperor's Inner Canon, the seminal text of ancient Chinese medicine dating back to the 3rd century BC. Acupuncture involves placing very thin needles in the skin to stimulate the flow of qi (pronounced "chee") in a complex network of meridians in the body. There are 12 principal and 8 curious acupuncture meridians that correspond to physiologic and anatomical organ functions. Qi is a dynamic form of physical and spiritual energy that flows within the universe and in all organisms. One of the basic tenets of Chinese medicine is that illness and pain are caused by the stagnation or blockage of qi flow and/or the invasion of pathologic influences—traditionally known as wind, heat, cold, dampness, dryness, or fire—that result in imbalances of yin and yang. When a point is needled, a heavy sensation known as "deqi," or a mild paresthesia, may be experienced by the patient. The practitioner may sense a gentle contraction of the connective tissue surrounding the needle or may observe a flare developing around the needle. Needling, electrical and laser stimulation, acupressure, or even herbal therapies (moxibustion or capsicum plaster) over specific points have all been documented to alleviate pain and pathologic states. In addition to body acupuncture, which developed in China, Japan, and Korea, many different traditions have been developed that focus on needling specific body parts, that is, the ear, scalp, or hand, as microsystems representing the entire body. Acupuncture has been used to provide analgesia during surgery since the 1950s in China. However, it was little more than a curiosity in the United States before 1971, when reporter James Reston went to China to report on the diplomatic efforts of Henry Kissinger and President Richard Nixon. While in Beijing, Reston required an emergency appendectomy and received acupuncture for postoperative ileus and pain control. The popularity of acupuncture in the United States exploded after he published his experiences in the New York Times. In 1997, the NIH released a consensus statement supporting the use of acupuncture for adult postoperative and chemotherapy-induced nausea and vomiting and postoperative dental pain. It also stated that acupuncture may

be a useful adjunctive treatment in addiction, stroke rehabilitation, headache, menstrual cramps, tennis elbow, fibromyalgia, myofascial pain, osteoarthritis, low back pain, carpal tunnel syndrome, and asthma. During the last 10 years, acupuncture has been increasingly studied and used to treat acute postoperative pain as well as in chronic pain clinics throughout the United States.

MECHANISMS

Several mechanisms for acupuncture analgesia have been proposed. The gate control theory by Melzack and Wall in 1965 postulated that stimulation of a-beta fibers inhibits a-delta and c-fiber transmission of pain signals. This may be a local mechanism of action. Other studies have shown that electroacupuncture at low (2–4 Hz) and high frequencies (100 Hz and greater) selectively induces endorphin and enkephalin release, respectively. Conflicting evidence exists regarding the ability of naloxone to antagonize the analgesic effects of acupuncture. Some studies show that naloxone reverses acupuncture-induced analgesia, while others dispute this. This suggests the analgesic mechanisms of acupuncture are more complex than the release of endorphins. Additional evidence suggests that the frequency and intensity of stimulation determine the degree of naloxone reversibility. A review of functional MRI and positron emission tomography studies has shown that electroacupuncture exerts effects over the hypothalamus, somatosensory motor cortex, and rostral anterior cingulate cortex, with nonspecific modulation of the limbic system and hypothalamus. Other mechanisms of action may include the local generation of plasma and nitric oxide and release of adenosine. Acupuncture may also have anti-inflammatory properties.

PERIOPERATIVE USE

Acupuncture is effective for reducing PONV. P6 (Neiguan), the most thoroughly studied acupoint, is located three fingerbreadths proximal to the wrist crease, between the flexor carpi radialis and palmaris longus tendons and directly over the median nerve. A Cochrane review of 26 randomized trials noted significant reduction in nausea and the need for rescue antiemetics with the use of P6 acupoint stimulation (Fig. H-1). Direct electrical stimulation of this point was shown to be as efficacious as a standard dose of ondansetron for PONV in adults and resulted in a 37% reduction in nausea in children after tonsillectomy. There is evidence that transcutaneous electrical acupoint stimulation is also effective in reducing PONV. Stimulation of P6 by twitch monitoring using a standard nerve stimulator (at 1 Hz, 0.2 ms, 50 mA) during general anesthesia for laparoscopic surgery significantly reduced PONV for 24 h with an efficacy similar to that of commonly used antiemetic drugs. A trained medical acupuncture practitioner

would likely integrate P6 with a combination of body and ear acupuncture points to minimize PONV. Acupuncture has not been shown to eliminate the need for anesthetic medications during surgery, but it may be a useful adjuvant for perioperative analgesia and anxiolysis. In a randomized controlled trial of perioperative acupuncture for abdominal surgery, Kotani et al. showed 50% reduction in postoperative morphine use, 20–30% reduction in postop nausea, and 30–50% reduction in plasma cortisol and epinephrine levels. A reduction in postoperative pain and analgesic requirements was also seen in studies of acupuncture in patients having gynecologic, abdominal, thoracic, and orthopedic surgeries. Acupuncture is known to produce deep relaxation and sedation and may be useful for preoperative anxiolysis or for postoperative weaning of opioid medications in opioid-tolerant patients. Two recent studies demonstrated cardioprotective effects of electrical acupuncture in adult and pediatric cardiac surgical patients, as indicated by decreased postoperative serum cTn1 (cardiac troponin 1), decreased duration of postoperative mechanical ventilation, and shorter ICU stay. The risks of acupuncture are rare. The most common are minor bruising, limited capillary bleeding, pain, or local infection at the needling site. Anesthesiologists can be trained to provide acupuncture treatment for PONV and anxiolysis. More comprehensive perioperative treatment should be performed by or under the supervision of a trained medical acupuncturist.

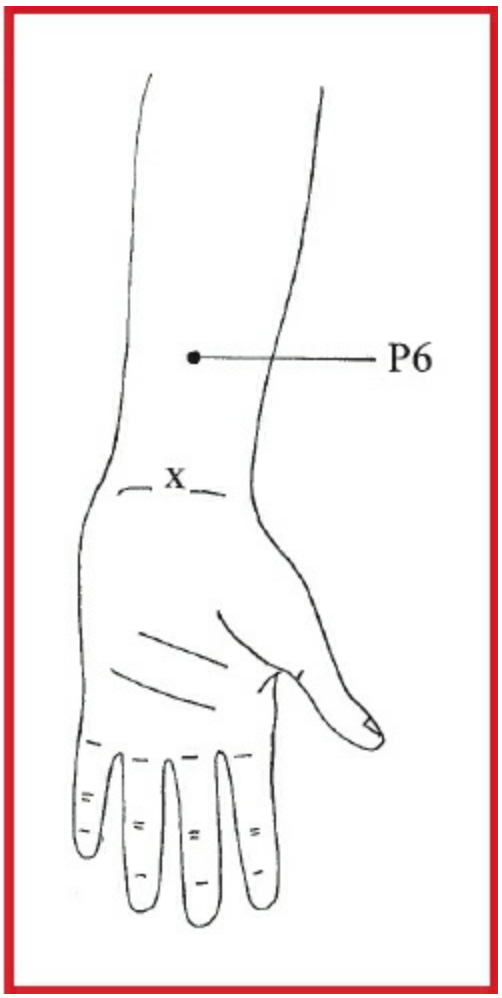

Figure H-1 P6 acupoint. P6 is located three fingerbreadths proximal to the wrist crease directly over the median nerve and between the tendons of palmaris longus and flexor carpi radialis. For PONV prophylaxis, the two nerve stimulator electrodes can be placed over the median nerve (1) at a point proximal to the wrist crease (marked with an x) 2 cm proximal to P6 and (2) on P6 or 1 cm distal to the P6 point. Stimulus parameters: 1 Hz, 0.2 ms, 50 mA during anesthesia.

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APPENDIX I: MANAGEMENT OF THE DIFFICULT AIRWAY

C. Philip Larson Jr., MD, CM

Management of the airway, particularly the difficult airway, effectively and safely is a skill that every anesthesia provider must have to be qualified to provide clinical anesthesia. Competency in airway management is mandatory before undertaking independent clinical practice of anesthesia.

DIFFICULT AIRWAY VERSUS DIFFICULT VENTILATION

Difficult airway	5–10% of patients depending on type of practice Tip-offs include prior history of difficult airway/intubation, small mouth opening, large tongue, prominent teeth, large neck, limited range of motion of head, short thyromental distance (<3 cm), Mallampati grade >2, upper-lip bite test below vermilion. Management: multiple options (see below)
Difficult ventilation	Rare, <1% of patients Causes obvious: large beard, thick redundant jowls, oropharyngeal mass, fractured larynx, mediastinal mass compressing trachea, lingual tonsillar hyperplasia (easily ventilated with LMA) Management: Consider LMA and Plan C (see below) or awake fiberoptic intubation (FOI).

MANAGEMENT OF DIFFICULT AIRWAY

Caution

Always determine that ventilation is possible with bag-mask or LMA before inducing full general anesthesia and paralysis. If it is not possible and ET tube is needed, consider awake intubation.

Patient positioning	Have head at top edge of table; bed height at umbilical level of operator. Do not bend over. Can

	reposition patient for surgical needs after airway established.
Direct laryngoscopy (plan A)[1]	Stand sideways facing right wall; keep left arm at side with ET tube in the left axilla (the only place where operator does not have to look away once the glottis identified). Put patient's head in sniff position by directing laryngoscope along the plane of handle (do not lift or pull handle toward oneself). With proper positioning, intubation should be a leg activity with the arm only acting as a fulcrum. Do not do more than two direct laryngoscopies. Multiple laryngoscopies result in inability to ventilate as well as intubate.
Endotracheal tube selection	Always use the smallest appropriate tube (7.0 men, 6.5–7.0 women). Small tubes are easier to insert than large tubes. If larger tube needed later, can always change tube using airway exchange catheter (AEC). Choice of tubes: standard, wire-reinforced (for prone surgery), EMG no. 6 (for nerve monitoring), laser, MLT tube (for microlaryngeal surgery)
Choice of LMAs	Many choices available, each with specific benefits/problems. Either classic or disposable suitable for routine care. Use classic when using as a conduit for FOI or Aintree catheter. Use LMA no. 4 for men and no. 3 or no. 4 for women. Avoid no. 5 when doing FOI as it blocks the glottic opening by invaginating the epiglottis. Intubation LMA; success rate 90–95%; less when intubation difficult. Make certain balloon on reusable silicone tube does not leak. Loosen 15-mm connector before inserting tube. Determine that tube is in trachea. Do not drop 15-mm connector while inserting tube holder and removing LMA. Fix connector firmly before utilizing ET tube.
Video laryngoscopes (plan B)[3]	GlideScope™ or C-MAC™ gives the best picture. Use the largest blade for most adults. Use either special rigid stylet provided or shape another stylet to same

	curvature as blade. Watch the tube enter the mouth before looking at the screen to avoid soft tissue trauma. Extract stylet slightly once tube at glottis opening if tube does not advance easily.
Intubating catheters (plan B)[1]	Cook (Frova) catheters: two types, styleted and unstyleted. 70-cm long and styleted has two adaptors (15 mm for O_2 insufflation, one for attaching syringe or gas sampling line). Tip rounded so it will not perforate soft tissue. Needs some shaping before use. Must see the epiglottis to use effectively; cannot be advanced beyond the carina. Use ET tube that closely approximates catheter size (6.5–7.5). Can use intubating catheter together with video laryngoscope if catheter bent to conform to the shape of the laryngoscope blade. Eschmann: 60 cm long, easily wound in circle for transport. Loses shape and stiffness after a few washings Aintree: 60-cm-long, hollow tube blunt at both ends; has snap-on 15-mm adaptor for O_2 insufflation. Use classic LMA or Tudor-Williams airway as conduit for insertion; may not advance through disposable LMAs. Must be experienced at FOI as all control and direction done with handle. Use. 7.0–7.5 tube for insertions (6.5 will not advance).

FIBEROPTIC INTUBATION PROTOCOL; AWAKE AND ASLEEP[2–4]

Awake	Preferred technique when ventilation by bag-mask or LMA not possible
Premedication	If not contraindicated, patients should receive mild-to-moderate sedation with dexmedetomidine 1 mcg/kg over 10 min or fentanyl 0.3–0.5 mcg/kg and/or midazolam 2–4 mg iv.
Topical anesthesia	When premedication has been established, for awake FOI, the oropharynx is sprayed vigorously ~6

	times over a span of 10 min with lidocaine 4% solution using a disposable EZ spray unit powered with oxygen. Initially, the spray is directed at the front of the tongue; gradually, it is directed further back in the throat, until the entire oropharynx is numb. Having the patient inhale deeply while spraying enhances anesthetic spread into the airway. In reality, the lateral recesses of the oropharynx need not be anesthetized topically because both fiberoptic laryngoscope (FOL) and ETT are confined to the midline of the mouth.
Tracheal anesthesia	With patient breathing oxygen from anesthesia circuit or transport mask, transtracheal injection of cocaine or lidocaine 4% (4 mL) is made through the cricothyroid membrane, using a 5-mL syringe and a 23-ga, 3/4-inch needle. So that this injection can be made as rapidly as possible, it is important to use a small syringe, making certain that the connection between syringe and needle is tight. It is important that operator's hand be fixed firmly against the patient's upper chest to assure that needle movement is minimized should the patient start to cough and that the full injection is made into the trachea. When the injection is complete, the patient is urged to cough vigorously.
Laryngoscopy	After the mouth and trachea are anesthetized with local anesthetic, an oral airway with a central orifice (e.g., Tudor-Williams, Patel, Ovassapian airway) is placed in the midline of the mouth. A 7-mm orotracheal tube, without connector attached, is placed over an FOL. With the operator at the patient's side near the waist, the FOL is introduced through the hole in the airway and advanced to the end of the airway. At this point, the epiglottis should be visible. The tip of the fiberoptic scope is flexed toward the operator about 15–20°, which should bring arytenoid cartilages and laryngeal opening into view. The scope is advanced into the larynx so that

	tracheal rings can be visualized. Often, the carina also can be visualized. The laryngoscopist also can place the scope in the airway by darkening the room and using the scope as a light wand, directing the light externally to the sternal notch and advancing it down the trachea. If a wire-reinforced tube is desired, use a Patel or Ovassapian airway instead of the Tudor-Williams airway for guidance, because these airways can be removed with the tube connector in place.
Intubation	The scope is placed on the patient's chest and, holding it so that it not advanced further, the orotracheal tube is advanced gently into the trachea. To facilitate passage of the orotracheal tube past the arytenoid cartilages and into the larynx, it is necessary to rotate the tube counterclockwise 90°—or even as much as 180°—several times as it is being advanced. Using rotational movement, the operator should never need to push hard on the tube to position it in the larynx. After the tube is in place, the FOL and oral airway are removed, and the 15-mm connector is reattached to the tube. $ETCO_2$ confirms proper placement. The orotracheal tube is then firmly taped in place at one side of the mouth. If manual ventilation of the lungs is possible, it is often beneficial for both patient and anesthesiologist to perform FOI with the patient anesthetized. This is particularly true for patients with cervical spine injuries where manipulation of the head during direct laryngoscopy or coughing during topicalization of the airway or insertion of the tube during awake FOI may aggravate the spinal cord injury. Asleep FOI involves inducing GA, inserting an LMA, and placing the patient on controlled ventilation. Then, proceed with plan C (see Ref 6). In brief, a 6.0 uncuffed tube is mounted on the FOI, the FOI is inserted into the trachea using the LMA as a guide, and the 6.0 tube is

	lubricated and inserted into the laryngeal opening. The FOI is removed and the lungs are ventilated via the 6.0 tube. A medium-sized airway exchange catheter (AEC) is lubricated on one end and inserted into the trachea via the 6.0 tube. The AEC usually meets resistance at the distal end of the 6.0 tube. If this occurs, rotate the 6.0 tube while pushing on the AEC. Once the AEC is a few centimeters beyond the tip of the 6.0 tube, the tube and LMA are removed en bloc leaving the AEC in the airway. With the AEC in the far right corner of the mouth, thread the final endotracheal tube on the AEC and gently advance it through the mouth into the larynx, rotating it counterclockwise to avoid obstruction from the right arytenoid cartilage. Then, remove the AEC and connect the ETT to the anesthetic circuit.
Asleep (plan C)[1]	Preferred technique when ventilation possible by bag-mask or LMA. Easy to determine by administering very low-dose propofol and initiating assisted/controlled ventilation with sevoflurane. Major induction agent is sevoflurane. Establish excellent anesthesia and paralysis. Insert classic LMA. Disposable LMAs have internal ridge that makes advancement of scope and/or tube impossible. In emergency, ridge can be cut out before insertion in the mouth. Mount 6.0 uncuffed ET tube with very tight 15-mm connector onto the scope. Focus FOL, maximize light source, minimize room light, and insert FOL via center struts of LMA into the glottis and trachea. Lubricate no. 6 tube and advance into the trachea; remove FOL; attach tube to circuit and ventilate lungs. Need high gas flow because of leak between the tube and LMA. Lubricate medium airway exchange catheter (AEC) and insert via no. 6 tube about 35–37 cm (5–7 cm beyond tube tip); remove ET tube and LMA together; insert final tube (6.5 or 7.0) rotating gently counterclockwise; remove AEC

	and palpate balloon on tube for final positioning above the sternal notch. Technique can be practiced safely in normal patient so, when needed, operator is comfortable and confident performing it.
Failed plans A–C (plan D)[1]	Plans A–C very rarely fail, but if they should, plan D would present two choices: Proceed with a surgical airway (cricothyrotomy, tracheostomy) or awaken patient and bring back another day for awake FOI.

NASAL FIBEROPTIC

Awake	Requires adequate sedation and excellent topical anesthesia of the nose preferably with cocaine 4% pledgets or cotton applicators and oral spray with lidocaine 4% via EZ spray. Dilate nasal cavity with progressively larger nasal airways. Mount the smallest acceptable nasal RAE on the scope, insert the scope in the nose keeping it in the midline and asking an assistant to pull up on the jaw to open the oropharynx. Do not advance nasal RAE until the scope is well into the trachea.
Asleep	Preferred to awake as it is much more pleasant for both patient and anesthesia provider. Despite general anesthesia and paralysis, topical anesthesia of the nose with cocaine 4% and gradual nasal dilation are essential to avoid nasal bleeding. Have assistant do jaw thrust to open oropharynx.

CERVICAL SPINE INJURY: INTUBATION OPTIONS

Awake FOL	Preferred technique by many despite serious drawbacks: namely, coughing and bucking during oropharyngeal topicalization; during transtracheal injection (if used); and during insertion of fiberoptic scope and/or tube into the trachea. Should rarely be used now, and only in circumstance where bag-mask

	ventilation is not possible.
In-line traction	Commonly used in emergency rooms in combination with direct laryngoscopy with patient either sedated or anesthetized. Multiple problems with this technique: (1) There is no established standard for how in-line traction should be applied, and no documentation of its effectiveness or safety. (2) In-line traction requires the use of excessive leverage on the laryngoscope to visualize the laryngeal opening. (3) In-line traction greatly compromises operator's ability to visualize glottis opening, even in patients who are not classified as difficult airways on preop assessment.[5,6]
Plan C (asleep)	Strongly preferred technique since there is no movement of the head during the procedure and there is no coughing/bucking since the patient is anesthetized and paralyzed. The only prerequisite for use is that bag-mask or LMA ventilation is possible. This is easily determined by administering a sedative dose of propofol in conjunction with low-dose inhaled sevoflurane and seeing if assisted ventilation is possible. If as the depth of anesthesia is increased with sevoflurane the patient becomes more difficult to ventilate, administration of a neuromuscular blocking drug and insertion of an LMA will usually resolve the problem. This technique can be used with a patient in a cervical collar or halo traction.
Difficult pediatric airway	Airway difficulties in infants and small children are generally due to congenital abnormalities of the face, mouth, chin, or upper airway. These can usually be handled effectively and safely by a combination of sedation or GA and insertion of a fiberoptic scope directly into the mouth or via a conduit such as an LMA.
Intubation	The scope is placed on the patient's chest, and, holding it so that it is not advanced further, the orotracheal tube is advanced gently into the trachea.

	To facilitate passage of the orotracheal tube past the arytenoid cartilages and into the larynx, it is necessary to rotate the tube counterclockwise 90°—or even as much as 180°—several times as it is being advanced.

EXTUBATION STRATEGY

Delayed extubation	Always have an extubation strategy. Delaying extubation and mechanically ventilating the lungs for a time postop is frequently a good option.
Postoperative extubation	Establish full recovery from GA and paralysis, with sustained, spontaneous ventilation. Consider deflating the balloon on the tube, occluding the ET tube and determining if ventilation is possible around the tube. This finding is reassuring but no guarantee of sustained airway patency when the tube is removed. Consider inserting an LTA spray down the tube to prolong tolerance to the tube. If there is any question regarding airway patency, insert an AEC 5–7 cm beyond the tube before removing it. As long as it does not touch the carina and is not moved, it will not cause coughing and will not affect voice. Remove AEC when sustained ventilation is evident. If reintubation is necessary, use a tube that closely approximates the AEC in diameter.

MANAGEMENT OF LARYNGOSPASM

Standard technique	Positive pressure ventilation with oxygen along with jaw thrust. Technique may not work until patient is sufficiently hypoxic that vocal cords relax. May need to administer succinylcholine 20–50 mg iv or im. If this fails and ET intubation is not possible, consider immediate cricothyrotomy.
Best technique	Learn to do the laryngospasm maneuver[2] and apply

	it immediately after every removal of ETT or LMA. Should be standard of care because if done correctly, it always relieves laryngospasm within 15–20 sec. Find "laryngospasm notch," which is behind the pinna of the ears. It is bounded by the coronoid process of the mandible anteriorly, the mastoid process posteriorly, and the base of the skull superiorly. To be effective, operator must feel the base of the skull. With patient lying supine, very firm pressure is directed inward bilaterally and at the same time pulling upward (skyward) on the coronoid process. Place transport mask with oxygen flowing on patient's face prior to starting laryngospasm maneuver. Continue maneuver until patient moves arms up toward head (Larson reflex). Once the patient can do this, laryngospasm will not recur. The maneuver corrects airway obstruction from the tongue because the forward displacement of the mandible pulls the tongue forward. Why it corrects laryngospasm is not known. It is not due to pain because pain elsewhere does not resolve laryngospasm.

CRICOTHYROTOMY

Indications	Every anesthesia provider should be trained to perform a cricothyrotomy and be prepared to do it when needed. The risks associated with doing it are minimal and the benefit is lifesaving. Indications: partial or complete airway obstruction and inability to ventilate lungs or perform tracheal intubation; massive oral/tracheal bleeding making mask ventilation or tracheal intubation impossible, combined with rapidly decreasing SaO_2
Technique	Identify cricothyroid membrane between the thyroid cartilage superiorly and cricoid cartilage (round, signet ring shape) inferiorly. With scalpel, penknife,

	or scissors, make 1–1.5 inches horizontal or vertical incision at the level of the cricoid. Cut down quickly to the cricoid cartilage, cut through it, and insert a small tube (no. 4–6F) or an AEC followed by a small tube in the opening. One generally has little time before the patient goes into cardiac arrest from hypoxia, so the maneuver must be done quickly. There are no structures in the midline of the neck that will be harmed by the incision, and bleeding from the incision is generally minimal. Reluctance to perform the maneuver when indicated generally results in patient death. Needle cricothyrotomies are not recommended. They are harder and more time consuming to perform and far less effective in establishing an airway.

Selected References with Condensed Abstracts/Suggested Readings

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APPENDIX J: ANTICOAGULATION GUIDELINES FOR NEURAXIAL PROCEDURES

Einar Ottestad, MD, Alex J. Butwick, MD, MS, FRCA, Brendan Carvalho, MBBCh, FRCA, MDCH, Jamie Kuo, PharmD, BCCCP, and Sharon Jung, PharmD

ANTICOAGULATION GUIDELINES FOR NEURAXIAL PROCEDURES

GUIDELINES TO MINIMIZE RISK FOR SPINAL HEMATOMA W NEURAXIAL PROCEDURES**			
	PRIOR TO NEURAXIAL/NERVE PROCEDURE Minimum time between last dose of antithrombotic agent AND neuraxial injection or neuraxial/nerve catheter placement	**WHILE NEURAXIAL/NERVE CATHETER IN PLACE** Restrictions on use of antithrombotic agents while neuraxial/nerve catheters are in place and prior to their removal	**AFTER NEURAXIA PROCEDU** Minimum ti between n injection or neuraxial/n catheter re AND next antithromb
ANTICOAGULANTS, INJECTABLE			
Heparin 5000 units SQ q8h or q12h	4–6 hours	May be given; preferred over alternatives	1 hour
Heparin 7500 units SQ q8h or q12h	12 hours verify normal aPTT	May be given; preferred over alternatives	1 hour
Heparin IV infusion	4–6 hours verify normal aPTT	May be given; preferred over alternatives	1 hour
Dalteparin (Fragmin)	≥12 hours	No data - use not recommended	4 hours

Enoxaparin (Lovenox) 40 mg SQ daily	≥12 hours	CONTRAINDICATED Risk of spinal/epidural hematomas	4 hours
Enoxaparin (Lovenox) 30 mg SQ q12h	≥12 hours		4 hours
Enoxaparin (Lovenox) 1.5 mg/kg SQ daily or 1 mg/kg SQ q12h	≥24 hours		4 hours
Fondaparinux (Arixtra)	36–42 hours	CONTRAINDICATED	6 hours
ANTICOAGULANTS, ORAL			
Apixaban (Eliquis) 2.5 mg BID–5 mg BID	3 days	No data - use not recommended	6 hours
Rivaroxaban (Xarelto) 15–20 mg daily	3 days	No data - use not recommended	6 hours
Betrixaban (Bevyxxa) 80 mg daily	3 days	No data - use not recommended	5 hours
Edoxaban (Savaysa) 30–60 mg daily	3 days	No data - use not recommended	6 hours
Dabigatran (Pradaxa) 75–150 mg BID	CrCl < 30 mL/min: avoid NA CrCl 30–49 mL/min: 5 days CrCl 50–79 mL/min: 4 days CrCl ≥ 80 mL/min: 3 days Renal fxn unknown: 5 days	No data - use not recommended	6 hours
Warfarin	4–5 days	check INR daily;	remove wh

(Coumadin)	verify normal INR	assess risk vs benefit when INR 1.5-3	1.5 and/or hours of fir
DIRECT THROMBIN INHIBITORS, INJECTABLE			
Argatroban IV infusion	Avoid neuraxial techniques		
Bivalirudin (Angiomax) IV infusion	Avoid neuraxial techniques		
ANTIPLATELET AGENTS			
Aspirin	May continue dosage	Avoid neuraxial techniques if early postoperative use of other anti-hemostatic drugs is anticipated	May contin dosage
NSAIDs	May continue dosage		May contin dosage
Aspirin/dipyridamole (Aggrenox)	24 hours	No data - use not recommended	6 hours
Cangrelor (Kengreal) IV infusion	3 hours	No data - use not recommended	8 hours
Clopidogrel (Plavix)	5–7 days	No data - use not recommended	Without LD immediate hours
Prasugrel (Effient)	7–10 days	No data - use not recommended	Without LD immediate hours
Ticagrelor (Brilinta)	5–7 days	No data - use not recommended	Without LD immediate hours
Abciximab (Reopro) IV infusion	24–48 hours	No data - use not recommended	Contraindic weeks afte monitor ne status if giv neuraxial te
Tirofiban (Aggrastat) IV infusion	4–8 hours	No data - use not recommended	

Eptifibatide (Integrelin) IV infusion	4–8 hours	No data - use not recommended	
THROMBOLYTIC AGENTS			
Alteplase (TPA) Full dose for stroke, MI, etc	48 hours and normalization of clotting studies (e.g. fibrinogen)	No data - use not recommended	Normalizat fibrinogen

**Guidelines do not address risks with multiple therapies or comorbidities that interfere with coagulation. Consult appropriate expert(s) as needed.

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APPENDIX K: ENHANCED RECOVERY AFTER SURGERY

Richard A. Jaffe, MD, PhD, Andrew J. Giustini, MD, PhD, and Brenda Golianu, MD

GENERAL CONSIDERATIONS

Enhanced recovery after surgery (ERAS) was conceived as an enhanced fast-track approach to the management of patients undergoing colorectal surgery that incorporated the additional goals of improving postop functional status and decreasing morbidity. ERAS principles have since been expanded both in scope and in application to many other types of surgery. Studies have demonstrated significant benefits of ERAS protocols including decreased length of stay, improved patient satisfaction, decreased morbidity, and cost reduction. ERAS works best as a multispecialty team approach to perioperative patient care. Even in the absence of a formal team, the application of individual elements of ERAS (e.g., limiting NPO duration, multimodal pain management, etc.) is likely to be beneficial for most patients undergoing anesthesia and elective surgery. Importantly, the unique combination of elements most beneficial for any specific surgical procedure and patient cannot be arbitrarily defined.

In the following table, many of the individual elements of enhanced recovery protocols are briefly presented (further details can be found in the Suggested Reading list below). ERAS protocols continue to evolve as the relative importance of the individual elements of enhanced recovery are studied. When considering individual elements, it is essential to appreciate their interdependence. For example, reducing the NPO interval and achieving adequate preop hydration will facilitate intraop fluid management. Obviously, the implementation of any ERAS element must take into consideration patient condition, co-morbidities, and surgical requirements that could affect applicability.

Element	Recommendations
Preop counseling/education	Patients should be routinely counseled regarding what to expect from their surgical and anesthetic experience and be given ample opportunity to have their questions answered in appropriate detail. Discussion should include lines, drains and urinary catheters, along with plans for postop pain

	management emphasizing the use of regional analgesia along with peripheral nerve blocks where possible. Postop wound care, activity limitations, and physiotherapy plans should also be discussed. A procedure-specific enhanced recovery handout with preop checklist should be given to patients.
Prehabilitation program	A program of preop exercise activities designed to increase aerobic capacity may improve recovery in selected patients. For obese patients with time permitting, the benefits of weight loss to a BMI < 30 may be beneficial. For elective major surgery, consider preop physical therapy for patients with significant deconditioning. More generally, prehabilitation refers to any preop intervention that can improve postop recovery including the optimization of any comorbid conditions, and implementation of the interventions listed below.
Preop smoking and alcohol cessation	Abstinence from both alcohol and smoking should be recommended in preparation for surgery. Chronic alcoholics may require withdrawal precautions.
Preop nutritional status	The patient's nutritional status should be assessed in advance of the surgery and optimized if possible. Immunonutrients (most trials have used some combination of arginine, glutamine, omega-3 fatty acids, and ribonucleic acid as a dietary supplement) may have anti-inflammatory effects, boost immune function, and improve outcome in surgical patients. Further study will be necessary to identify effective formulations and specific patient populations most likely to benefit. Impact Advanced Recovery® immunonutrition drink (Nestlé Health Science) is an example of a commercially available preop supplement that has been shown to improve some surgery outcome measures.

Preop fasting and carbohydrate loading	For most procedures, preop fasting should be limited to 2 h for clear (see-through) liquids and 6 h for solid foods or opaque liquids. Preop carbohydrate loading should be encouraged and can be accomplished using oral rehydration sports drinks (e.g., regular Gatorade™ or equivalent) 2 h before surgery.
Antithrombotic prophylaxis	Assess VTE risk. The use of sequential pneumatic compression sleeves is recommended to prevent venous thromboembolism. The addition of anticoagulants (e.g. heparin 5000u sc 30–60 min preop) should be discussed with the surgeon and should take into account patient risk factors for VTE.
Antimicrobial prophylaxis, bowel prep, and skin cleansing	Patients will often be provided with an antimicrobial skin cleanser to use before surgery. Minimize surgical site shaving. Bowel prep is now rarely indicated. Prophylaxis with iv cefazolin 30–60 min before skin incision is recommended.
Regional anesthesia and nerve blocks	When possible, the use of bolus or continuous regional anesthesia and/or specific nerve blocks should be encouraged as a component of anesthetic and analgesic management, particularly for major open surgical procedures.
Surgical approach	Although not always an option, minimally invasive and endoscopic approaches are associated with less postop pain, improved recovery, and patient satisfaction.
Anesthetic protocol	There is insufficient evidence of improved recovery to support the use of TIVA vs. inhalational anesthesia or to support the choice of specific anesthetic agents for most surgical procedures. When appropriate, the use of N_2O will reduce the need for other anesthetics and facilitate rapid recovery from anesthesia. PONV concerns can be eliminated with prophylactic antiemetics, and

	effects on intraop bowel distention appear to be minimal. Optimal ventilation can usually be achieved using volume controlled, pressure mode with TV = 8 ml/kg IBW, PEEP at least 5 cmH_2O, and $ETCO_2$ = 40mmHg (mild permissive hypercapnia).
Fluid management	Fluid balance can be assessed by PPV (if art line in place), TEE (if available), or PVI especially when used in combination with small-volume (100–250 mL) bolus tests. Noninvasive cardiac output monitoring may also be useful. For most minor surgeries, a restrictive (**zero balance**) strategy is appropriate (see section below). A **goal-directed** fluid management strategy is useful for many major surgeries (see section below). Vasopressors should be used in preference to volume in euvolemic patients to maintain MAP unless otherwise contraindicated.
Multimodal pain management emphasizing nonopioid analgesia **(see p. K-5)**	PO or IV acetaminophen (e.g., 1 g) is a useful component of multimodal analgesia. PO celecoxib (COX-2 inhibitor; 200–400 mg po qd) or ketorolac (COX-1 inhibitor; 15–30 mg iv q6h) can provide other modes of analgesia (although some surgeons may be concerned about impaired hemostasis). A ketamine bolus (0.5 mg/kg) and subsequent infusion (5–10 mcg/kg/min) after induction may be a useful intraop analgesic supplement in select patient populations. Gabapentin (300–600 mg po preop) and tramadol (50 mg po postop) have side effects (e.g., prolonged sedation, N/V, pruritus, respiratory depression) that may be unfavorable in some patients or following some surgical procedures. Regional analgesia should be used when possible.
PONV	Routine use of 5-HT3 antagonists (e.g., ondansetron 4 mg iv) and dexamethasone (4–8 mg) is recommended. The addition of preop

	aprepitant (40 mg po qd) is often reserved for procedures or patients with a high risk of PONV. Scopolamine and promethazine have side effects (e.g., sedation, dysrhythmias) that may make them undesirable as primary agents especially in older patients.
Avoiding hypothermia	In general, active heating (e.g., forced-air blanket, circulating water blanket, airway humidifier) should be used to maintain core normothermia.
Oxygenation	Liberal oxygen administration (resulting in SpO_2 > 95%) may be detrimental (e.g., ↑mortality, absorption atelectasis, acute lung injury, etc.) and should be avoided throughout the postop period if possible.
Urinary drainage	Bladder catheters should be removed as early as possible (usually POD 0–1).
Chest tube and other surgical drainage	Active management is required to avoid retention of fluids. Drainage tubes should be removed as soon as it can be safely accomplished.
Postop delirium management	Postop delirium is thought to be underdiagnosed and may result in delayed recovery, extended hospital stay, and cognitive impairment. Medical, metabolic, and medication etiologies should be excluded or treated. Effective pain management, along with nonpharmacologic interventions (return of hearing aids/eyeglasses, reassurance/reorientation, minimizing physical restraints, presence of family/friends, etc.) should be emphasized. Avoiding ketamine and high-dose benzodiazepines in older adults may be helpful. If nonpharmacologic treatment has failed, consider treating hyperactive delirium with low-dose haloperidol (0.5–1 mg iv) if not otherwise contraindicated (onset of beneficial effects may require >15 min). A dexmedetomidine infusion (e.g., 0.1 mcg/kg/h) should be considered in patients for whom haloperidol has failed or is

	contraindicated (see section on Postoperative Delirium in Appendix B for more details).
Postop nutrition	Postop enteral nutrition should be initiated as soon as possible. Chewing gum (30 min tid) may speed up the return of postop bowel function.
Early mobilization	Extubate as soon as criteria are met. Encourage early mobilization, at least sitting up in chair starting POD1 if possible.
Physiotherapy	Immediate pulmonary physiotherapy is often beneficial after long GETA. A physical therapist may be needed to assist with early mobilization following major surgery.

Suggested Readings

1. Chu DK, Kim LH, Young PJ, et al: Mortality and morbidity in acutely ill adult treated with liberal versus conservative oxygen therapy (IOTA): a systematic review and meta-analysis. Lancet 2018; 391(10131):1693–705.
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ENHANCED RECOVERY AFTER SURGERY: FLUID MANAGEMENT

Intraoperative fluid management strategies for enhanced recovery

Intraop fluid management can be significantly affected by the patient's adherence to liberal NPO instructions including preop hydration. In the past, "NPO after midnight" ensured that patients would be dehydrated, uncomfortable, and in a catabolic state before surgery. The typical 70-kg healthy adult will have lost >800 mL of primarily extracellular fluid volume by the end of an 8-h fast (Fig. K-1). As a general rule, deep levels of anesthesia (e.g. BIS <40) should be avoided, and vasopressors should be used to treat anesthesia-related hypotension.

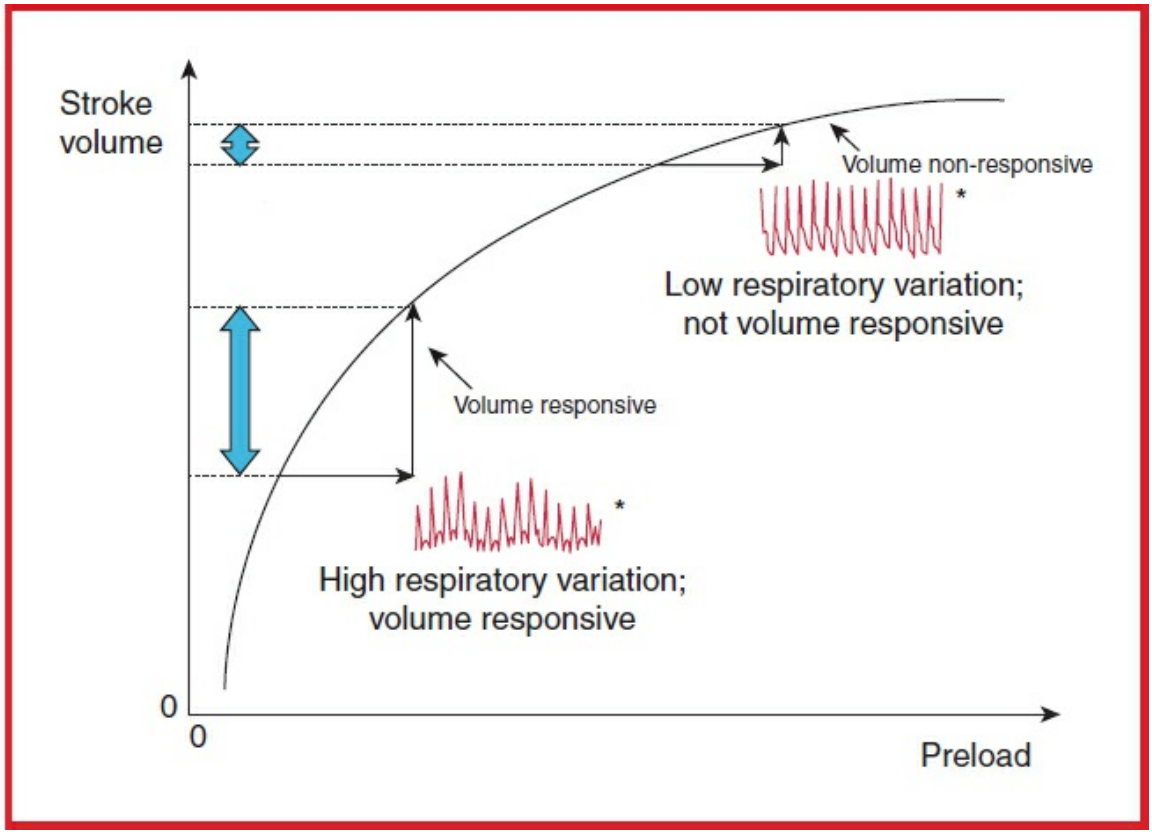

Figure K-1 Frank-Starling relationship with corresponding respiratory variations in the arterial pressure waveform. High respiratory variation in the arterial pressure or in the plethysmographic oximeter waveforms indicates that the patient is on the steep portion of the Frank-Starling relationship. Low

variation indicates that the patient is on the plateau. Cardiac output maximization concepts aim at increasing cardiac output until it reaches the plateau of the Frank-Starling relationship. This goal, as demonstrated on this figure, could be achieved by minimizing respiratory variation in arterial pressure or plethysmographic waveform. (Modified from Rinehart J, Liu N, Alexander B, et al: Closed-loop systems in anesthesia: is there a potential for closed-loop fluid management and hemodynamic optimization? Anesth Analg 2012; 114(1):130–43.)

Parameter	Goal-Directed Strategy	Restrictive (Zero Balance) Strategy
Patient population	Major surgery with potential for EBL ≥ 500 cc or significant fluid shift	Surgery in low-risk patient. EBL < 500 cc
IV fluids*	BSS @ 1–3 mL/kg/h + UO + 1.5 × EBL (or 1 × EBL if colloid used)	BSS @ 1–3 mL/kg/h + 1.5 × EBL
PPV (or SVV)	Give volume if PPV > 10–15% (TV: 8 cc/kg). Use 100–250 cc BSS bolus; repeat prn to keep PPV <11%.	PPV usually not available (no art line)
PVI	May substitute for PPV (less reliable?)	← but probably better than nothing
TEE	Transgastric two-chamber (or midpapillary) view to assess LV cavity size. Normal end diastolic diameter = 45–50 mm ± 4 mm (F < M). Rx small EDV with 100–250 cc BSS bolus prn	Usually not necessary
CO/SV estimating devices	May substitute for PPV when PPV cannot be used	Usually not necessary
HR	Poor predictor of volume status	←
BP	Poor predictor of volume status; Rx ↓ BP 2° anesthesia	←

	with phenylephrine or ephedrine prn	
Urine output	Poor predictor of volume status Goal UO ≥ 0.3 mL/kg/h to avoid AKI	← expect/accept mild oliguria
CVP or PAOP	Poor predictor of volume status	← and usually not available
SvO_2 or $ScvO_2$	Poor predictor of volume status	← and usually not available

*assuming adequate preop hydration.

BSS, balanced salt solution (e.g., LR, Normosol®, PlasmaLyte®). Patients should be euvolemic and carb loaded preop per ERAS guidelines.

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4. Myles PS, Andrews S, Nicholson J, et al: Contemporary approaches to perioperativ IV fluid therapy. World J Surg 2017; 41:2457.

ENHANCED RECOVERY AFTER SURGERY: MULTIMODAL ANALGESIA

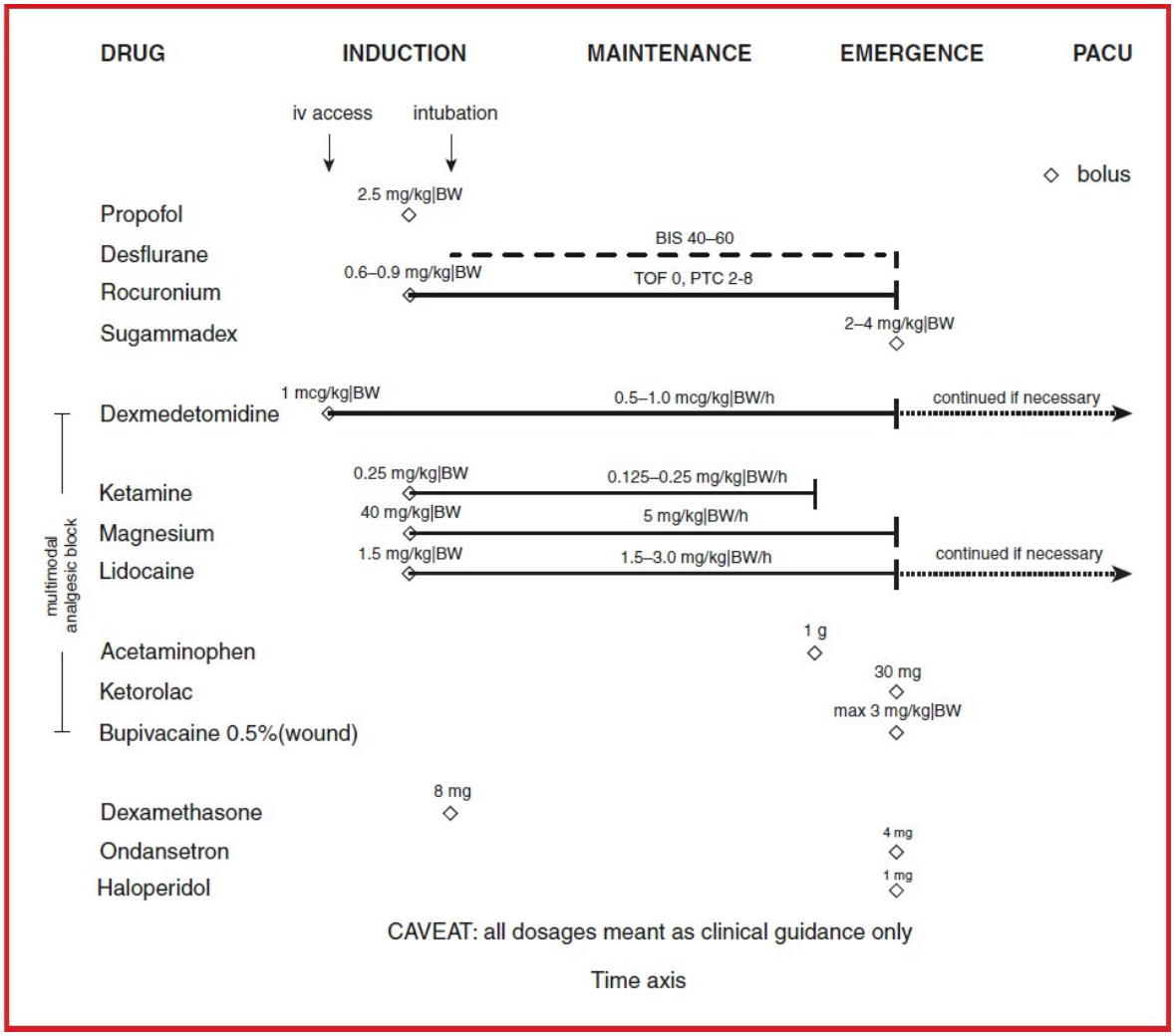

Figure K-2 An example of nonopiate multimodal analgesia/anesthesia. (Adapted from Mauermann E, Ruppen W, Bandschapp O. Different protocols used today to achieve total opioid-free general anesthesia without locoregional blocks. Best Pract Res Clin Anaesthesiol2017; 31(4):533–45. Copyright © 2017 Elsevier. With permission.)

Multimodal analgesia options for a 70-kg patient without specific drug contraindications, undergoing major surgery (see Fig. K-2). Specific analgesic components and doses must be individualized for each patient. (See Appendix C for additional information on perioperative pain management.)

Multimodal Analgesia Options to Consider		
Preinduction	Systemic	Acetaminophen 1000 mg PO Celecoxib 200 mg PO Ibuprofen* 800 mg PO Gabapentin 300–600 mg PO

	Regional	Neuraxial analgesia (e.g., epidural or spinal opiates) or regional/peripheral nerve block
Preincision	Systemic	Ketamine 50 mg iv (especially in opioid-dependent patients) Fentanyl 100–250+ mcg iv
	Local	Local anesthetic infiltration of incision site
Intraop	Systemic	IV opiates (e.g., fentanyl, hydromorphone [low-dose], remifentanil infusion @ 0.05–0.2 mcg/kg/min) Lidocaine infusion 1–2 mg/kg/h and/or ketamine infusion 0.25 mg/kg/h ± $MgSO_4$ 2 g iv (may enhance opiate analgesia) ± Acetaminophen 1000 mg iv q6h
	Regional/local	Whenever possible: continuous regional anesthesia/analgesia Local anesthetic infiltration of incision at closing
Postop	Systemic	Acetaminophen 1000 mg PO q6h Ketorolac* 15–30 mg IV q6h or ibuprofen* 200–800 mg PO q6h or celecoxib 200 mg PO IV opiates (e.g., fentanyl)

	Regional/local	bolus and PCA Tramadol 50 mg PO q4h for breakthrough pain Continuous regional analgesia

*May interfere with platelet function.

Suggested Readings

1. Mauermann E, Ruppen W, Bandschapp O: Different protocols used today to achieve total opioid-free general anesthesia without locoregional blocks. Best Pract Res Clin Anaesthesiol 2017; 31(4):533–45.
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ENHANCED RECOVERY AFTER SURGERY: PEDIATRIC SURGERY

ERAS pathways have become common for adult surgical procedures, especially in bowel, breast, and joint surgeries. These pathways typically employ standardized preop, intraop, and postop medications, fluid management strategies, surgical approaches, patient mobilization, and nutrition optimization to facilitate patient recovery, decrease morbidity, and decrease time to discharge from the hospital. ERAS pathways use opioid-sparing multimodal analgesics, antiemetics, optimal intraop fluid management, and preferred anesthetic method (including neuraxial and regional anesthetic techniques). In randomized controlled trials, these interventions have been shown to decrease morbidity, shorten length of stay, and reduce costs of care after various types of surgeries in adults. ERAS pathways have slowly become more common in pediatric surgical practice, with recent articles detailing their benefits.

Principles of ERAS can be applied to most types of surgical cases. While providing a very hemodynamically stable profile intraop, high-dose intraop and postop opioids represent one of the primary causes of prolonged hospital courses, including postop nausea and delayed return of bowel function after surgery. Therefore, many ERAS protocols emphasize the use of opioid-sparing techniques, including thoracic, lumbar and caudal epidurals; paravertebral catheters; and erector spinae plane catheters for thoracic and abdominal procedures. For unilateral upper and lower extremity procedures, single-shot or continuous nerve catheters are also often used. The use of adjuvants to intravenous opioids is also encouraged, including (when appropriate) intraop ketamine; preop or intraop acetaminophen that is continued postop; preop and

postop use of pregabalin or gabapentin; postop use of NSAIDS including ketorolac ibuprofen, or celecoxib; and the use of low-dose lorazepam or diazepam to treat agitation or for muscle spasm after surgeries likely to cause spasm. When opioids are used, the goal should be to use the lowest effective dose of opioids to adequately control pain and to transition to oral analgesics as soon as the patient can tolerate.

The use of nonpharmacologic therapies at all phases of care, including child life consultation, distraction therapies, preop counseling where appropriate, and parental presence at induction, may help to decrease perioperative anxiety, decrease the patient's stress response, and reduce perioperative opioid requirements. Perioperative acupuncture has been shown to decrease postop pain, nausea, and vomiting and may help to decrease the inflammatory response perioperatively and thereby facilitate patient recovery.

Other principles of ERAS that are applicable to most pediatric surgeries include the optimization of nutrition and of fluid management. Nutrition is optimized by prescribing patients evidence-based diets before surgery or admitting patients the night before surgery to follow a standard feeding protocol, and then encouraging early enteral nutrition and discontinuation of parenteral fluids as soon as practical after surgery. Along with early feeding, it is especially important in postsurgical, hospitalized pediatric patients to start medications to reduce the risk of opioid-induced constipation, especially medications such as senna, bisacodyl, docusate, or polyethylene glycol. To prevent intravascular depletion as well as unnecessary fluids that can cause total body and bowel edema, careful assessment of the patient's fluid status is necessary before and during surgery, and general guidelines for fluid requirements for each surgery should be considered. Some pathways combine these aims by encouraging patients, for example, to continue drinking clear fluids containing electrolytes up until two hours prior to surgery and to minimize fasting to as little as is required for the safe performance of general anesthesia.

An evidence-based guide to antiemetic management is also important, as the two primary causes of unplanned admission after outpatient surgeries are uncontrolled pain and uncontrolled nausea.

The creation of ERAS pathways for specific types of surgery is typically done at each operating site by a careful review of the literature and then collaboration and agreement between surgeons, anesthesiologists, and other stakeholders including nursing staff, nutritionists, physical and occupational therapists, and patients. Inclusion and exclusion criteria of patients for each surgery are created, as are guidelines for both the anesthesiologist and surgeon, and perioperative counseling strategies for patients and

families. ERAS pathways include recommendations for preferred minimally invasive surgical techniques, multimodal analgesics, anesthetic techniques, protocols for maintenance of normothermia, hemodynamic goals, choice of antibiotics, fluid optimization, nutritional management, antiemetic choice, time to mobilization, and goals for discharge of patients. Another necessary part of ERAS pathways is the monitoring of metrics associated with surgical recovery to ensure that the ERAS pathway is enhancing recovery and to allow for further improvements.

Typical ERAS Elements Applicable to Pediatric Anesthetic Care	

Preop	• Allow patients to drink clear, electrolyte-containing fluids until 2 h before surgery.
	• Consider preop administration of oral acetaminophen, celecoxib, and/or gabapentin or pregabalin (see doses in table below).
	• Assess volume status.
	• Discuss with surgeon the use of neuraxial and regional techniques, when appropriate.
	• Assess for how patient comorbidities will affect anesthetic and analgesic choices.
	• Pharmacologic anxiolysis
	  • Midazolam 0.5 mg/kg po (maximum 20 mg) or 0.05–0.1 mg/kg iv (maximum 2 mg)
	  • Intranasal dexmedetomidine (2 mcg/kg)
	• Nonpharmacologic anxiolysis options
	  • Child life consultation
	  • Distraction with music, videos, virtual reality
	  • Preop psychological counseling
	  • Perioperative acupuncture
	  • Parental presence for induction

Intraop	• Attempt to maintain euvolemia with appropriate use of crystalloids and colloids.
	• Use multimodal pain control. Can include the following:
	  • Acetaminophen iv 10 mg/kg (<1 yr old) or 15 mg/kg (1 yr or older)
	  • Dexmedetomidine iv (1 mcg/kg over 15 min if not used preop) or clonidine 1–2 mcg/kg
	  • Ketamine iv (0.5 mg/kg at beginning of anesthetic and then additional 0.25 mg/kg every hour)

	• Ketorolac 0.5 mg/kg at end of surgery • Employ neuraxial and regional techniques when appropriate. • Use appropriate antiemetic treatments. • Employ techniques to maintain normothermia. • Change anesthetic plan based on best management of patient comorbidities.
Postop	• Continue multimodal analgesia. • Use medications to prevent constipation. • Encourage early enteral nutrition and patient mobilization, as appropriate.

Analgesic Adjuvants to Opioids		
Indication or Category	**Medication and Dosage**	**Maximum per Dose**
Skeletal muscle spasm or anxiety. Use only one at a time.	Lorazepam (0.01 mg/kg) q6h iv/po	0.5 mg
	Diazepam (0.1 mg/kg) q8h po	5 mg
Neuropathic pain. Use only one at a time.	Pregabalin (1 mg/kg) q12h po	75 mg
	Gabapentin (5 mg/kg) tid po	300 mg
NSAIDs for general pain (do not use any of these in children <6 mo old). Use only one at a time.	Ibuprofen (10 mg/kg) q6h po	600 mg
	Ketorolac (0.5 mg/kg) q6h iv	15 mg. Do not use for more than 3 d.
	Celecoxib (2 mg/kg) q12h po	100 mg
Acetaminophen	Acetaminophen 10 mg/kg (<1 yr old) or 15 mg/kg (1 yr or older) q6h po/iv	650 mg
Opioid-induced pruritus	Nalbuphine (0.05 mg/kg) q4h iv prn	2.5 mg
Nausea (typically ondansetron as first-line therapy with one	Ondansetron (0.1 mg/kg) q8h iv/po prn	4 mg
	Metoclopramide (0.1	10 mg

alternative medication)	mg/kg) q6h iv/po prn Promethazine (0.25 mg/kg) q6h iv/po/pr prn 25 mg
Constipation treatment and prevention	Bisacodyl 5 mg (3–11 yr old) or 10 mg (>11 yr old) qd pr prn Docusate 10 mg (<3 yr old), 25 mg (3–5 yr old), 50 mg (6–12 yr old), 100 mg (>12 yr old) bid po scheduled or prn Senna 4.3 mg (half tablet, for 2–5 yr old), 8.6 mg (one tablet, for 6–11 yr old), 19.2 mg (two tables, for >12 yr old) qd po scheduled or prn Polyethylene glycol 3350: 4.25 g (<5 yr old), 8.5 g (5–12 yr old), 17 g (>12 yr old) bid po

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APPENDIX L: HIGH-FLOW NASAL CANNULA (HFNC) AND TRANSNASAL HUMIDIFIED RAPID-INSUFFLATION VENTILATORY EXCHANGE (THRIVE)

Erin Bushell, MD

Background	1. Heated and humidified high-flow nasal cannulae (HFNC) have been employed in critical care areas for some time. 2. Use in the OR with apneic, anesthetized patients is more recent. Patel and Nouraei coined the acronym THRIVE when they began using the device in the OR on anesthetized patients and discovered that it significantly extended the safe apnea period. 3. HFNC may be delivered by the ventilator in the ICU or by a stand-alone device. When stand-alone devices such as the Optiflow® (Fisher & Paykel Healthcare) and the Hi-VNI® (Vapotherm®) are used on spontaneously breathing patients, this is usually referred to as HFNC, and when used on apneic patients, this is usually referred to as THRIVE. 4. Blenders are available for these devices and an $FiO_2 < 1$ may be used in spontaneously ventilating patients, but for apneic patients, an FiO_2 of 1 is standard. 5. The devices deliver a totally conditioned gas (37° at 44 mg H_2O/L = 100% saturation), which allows patients to tolerate high flows. 6. Flows can be titrated from 10 to 70 lpm. Even in dyspneic spontaneously breathing patients, this usually exceeds the peak inspiratory flow rate and thus provides noninvasive support for patients with hypoxemic respiratory failure.
Physiologic Principles	Five physiologic mechanisms are involved. 1. Apneic oxygenation:

- First described by Volhard in 1908 as diffusion ventilation, the mechanisms were expanded upon by Draper's notion of a "hemoglobin-oxygen pump" in 1947.
- Given an oxygen consumption of ~200–250 mL/min, this amount of oxygen will move from the alveolus into the blood. However, due to buffering and the high solubility of carbon dioxide, only about 8–20 mL/min of additional CO_2 enter the alveoli. This results in a slight negative pressure in the alveoli and, provided the patient has a patent airway, net movement of oxygen (or whatever gas is in the pharynx) into the alveoli.

2. Positive airway pressure: When the mouth is closed, these devices provide ~1 cm H_2O of positive pressure for every 10 L of flow.
3. Maintenance of FRC: The replacement of alveolar oxygen combined with positive airway pressure maintains FRC, thereby reducing atelectasis and minimizing desaturation due to shunting.
4. Ventilatory exchange: In contrast to true apneic oxygenation where the PCO_2 rises ~2–3 mm Hg per min of apnea, when THRIVE is used, the observed increase in PCO_2 is only about 1 mm Hg per min of apnea. This may be due to synergy between high flow washout and cardiogenic oscillations.
5. Dead space washout: The high flows employed wash out the pharyngeal space, effectively removing all supraglottic CO_2 and thus eliminating this dead space.

Applications/Indications

Included here is a list of the common current applications:

1. Preoxygenation of patients prior to intubation or induction of anesthesia and while securing difficult airways:
   - Three minutes of preoxygenation with HFNC has been shown to be as effective as 10 L via face

	mask. • In obese patients undergoing bariatric surgery, 8 ½ min of preoxygenation with HFNC was superior to face mask and equivalent (with a trend toward superior) to preoxygenation with 7 cm H_2O of CPAP. • In patients undergoing rapid sequence intubation, it allowed for longer apnea time. • It has been demonstrated to significantly improve oxygenation during intubation in the ICU and to optimize oxygenation and intubation conditions during awake fiberoptic intubation. • In contrast to face mask ventilation, it may be continued during efforts to secure an airway, thus further extending the safe apnea time. There are case reports in which it has provided lifesaving maintenance of oxygenation during 30-min periods of apnea while emergency surgical airways were secured. 2. During general anesthesia: • THRIVE has been successfully used as the sole means of oxygenation during general anesthesia for oral and laryngeal surgeries and ECT. 3. During monitored anesthesia care: • The use of HFNC has been described for various procedures such as endoscopy, awake tracheostomies, and awake craniotomies. 4. In critically ill patients: • HFNC has been employed in patients with stridor, acute epiglottitis, hypoxemic and hypercapneic respiratory failure, and heart failure. • HFNC has been used to prevent postextubation respiratory failure and reintubation.
Contraindications	1. Fire risk: THRIVE has been used successfully with laryngeal laser surgery as long as care is exercised to ensure all fuel sources are protected from the laser. THRIVE with an FiO_2 of 1 should not be used in areas near electrocautery. Instead, an FiO_2 of 0.3

	or lower should be used to reduce the risk of fire. 2. Recent sinus surgery or recent transsphenoidal hypophysectomy. 3. Patients who would not tolerate even a modest rise in PCO_2 (e.g., pulmonary hypertensives) should not undergo apneic oxygenation with THRIVE.
Other Considerations	1. Airway patency must be maintained: Laryngeal suspension, jaw thrust, or oral/nasal airways should be used to maintain oxygenation and allow for some ventilatory exchange. 2. Must have sufficient FRC at outset: THRIVE will maintain FRC but cannot expand atelectatic lungs. Therefore, it is best to use in slight head-up position. 3. Use in children: Although THRIVE is effective in extending the safe apneic period in children, early data indicate it may not offer the same degree of ventilatory exchange because the rate of rise of PCO_2 does not appear to be as reduced as it is in adults.

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ABBREVIATIONS

APPENDIX M: ABBREVIATIONS

~	approximately
↓	decrease (e.g. ↓BP = hypotension)
↑	increase (e.g. ↑BP = hypertension)
→	results in, leads to
⇐	see column to the left
2°	secondary to
A-a	alveolar-arterial
AAA	abdominal aortic aneurysm
ABC	argon beam coagulator
ACAS	Asymptomatic Carotid Atherosclerosis Study
ACE	angiotensin-converting enzyme
ACL	anterior cruciate ligament
ACLS	advanced cardiopulmonary life support
ACT	activated clotting time
ACTH	adrenocorticotropic hormone
AD	autonomic dysreflexia
ADH	antidiuretic hormone (vasopressin)

AEC	airway exchange catheter
AED	antiepileptic drugs
AF	atrial fibrillation
AFL	atrial flutter
A/G	albumin/globulin
AH	autonomic hyperreflexia
AI	aortic insufficiency
AKI	acute kidney injury (formerly known as ARF)
ALCAPA	anomalous left coronary artery from pulmonary artery
ALI	acute lung injury
ALT	alanine aminotransferase (SGPT)
AOVM	angiographically occult vascular malformations
A-P	anteroposterior
AR	aortic regurgitation
ARDS	adult respiratory distress syndrome
AS	aortic stenosis
ASA	American Society of Anesthesiologists
ASD	atrial septal defect
AST	aspartate aminotransferase (SGOT)
ATG	antithymocyte globulin
ATLS	Advanced Trauma Life Support
ATN	acute tubular necrosis
AV	arteriovenous
A-V	atrioventricular
AVF	arteriovenous fistula
AVM	arteriovenous malformation
AVN	avascular necrosis
AVR	aortic valve replacement
BAEP	brainstem auditory evoked potential
BAER	brainstem auditory evoked response
BB	bronchial blocker
BBS	bilateral breath sounds

BD	balloon dilation
BE	base excess
β-HCG	β-human chorionic gonadotropin
BMI	body mass index
BMR	basal metabolic rate
BCNU	chemotherapy agent
BOR	branchio-oto-renal (syndrome)
BP	blood pressure
BPD	bronchopulmonary dysplasia
BPF	bronchopleural fistula
bpm	beats per minute
BRCA	breast cancer gene
BSA	body surface area
BSLT	bilateral sequential lung transplantation
BSO	bilateral salpingo-oophorectomy
BSS	balanced salt solution (e.g., LR, Normosol®, Plasma-Lyte®)
B-T	Blalock-Taussig (operation)
BUN	blood urea nitrogen
BVH	biventricular hypertrophy
Bx	biopsy
C-section	cesarean section
C-spine	cervical spine
Ca^{++}	calcium
CABG	coronary artery bypass graft(ing)
CAD	coronary artery disease
CAH	congenital adrenal hyperplasia
CAJ	cricoarytenoid joint
CBC	complete blood count
CBF	cerebral blood flow
CBV	cerebral blood volume
CCAM	congenital cystic adenomatoid malformation
CCU	coronary care unit

CD	Crohn disease
CDDP	cisplatin
CDH	congenital diaphragmatic hernia
CEA	carotid endarterectomy
CHD	congestive heart disease
CHF	congestive heart failure
CI	cardiac index
CK	creatine kinase
CLO	congenital lobar overdistension
cm	centimeter
CMC	carpometacarpal (joint)
cmH_2O	centimeters of water
$CMRO_2$	cerebral O_2 consumption
CN	cranial nerve
CNS	central nervous system
CO	cardiac output
CO_2	carbon dioxide
COPD	chronic obstructive pulmonary disease
CP	cerebral palsy
CPAP	continuous positive airway pressure
CPB	cardiopulmonary bypass
CPD	citrate-phosphate-dextrose
CPK	creatine phosphokinase
CPM	continuous passive motion
CPNB	continuous peripheral nerve block
CPP	cerebral perfusion pressure
Cr	creatinine
CRI	chronic renal insufficiency
CRPS	complex regional pain syndrome (formerly known as RSD)
CRT	cardiac resynchronization therapy
CSE	combined spinal-epidural
CSF	cerebrospinal fluid
CSI	cranial spinal irradiation

CT	computed tomography
CTR	carpal tunnel release
CTS	carpal tunnel syndrome
CUF	continuous ultrafiltration
CUSA	Cavitron ultrasonic surgical aspirator
CV	cardiovascular
CVA	cerebrovascular accident
CVP	central venous pressure
CXR	chest x-ray
d	day(s)
D5W	dextrose 5% in water
D&C	dilation and curettage
D&E	dilation and evacuation
DAPT	dual antiplatelet therapy
DBP	diastolic blood pressure
DC	direct current
d/c	discontinue
DCR	dacryocystorhinostomy
DDAVP	desmopressin acetate
DFT	defibrillation threshold
DHCA	deep hypothermic circulatory arrest
DI	diabetes insipidus
DIC	disseminated intravascular coagulation
DIP	distal interphalangeal (joint)
DJD	degenerative joint disease
DKA	diabetic ketoacidosis
dL	deciliter(s)
DL	direct laryngoscopy
DL_{CO}	carbon monoxide diffusion capacity
DLT	double-lumen tube
DM	diabetes mellitus
DO_2	oxygen delivery

DOE	dyspnea on exertion
DORV	double-outlet right ventricle
DOS	day of surgery
DP	dorsalis pedis
DPG	diphosphoglycerate angiography
DTR	deep tendon reflex
DVT	deep venous thrombosis
d/w	discuss with
Dx	diagnosis
EA	esophageal atresia
EAC	endoaortic clamp catheter
EACA	epsilon-aminocaproic acid
EARC	endoaortic return cannula
EB	epidermolysis bullosa
EBL	estimated blood loss
EBV	estimated blood volume
EC-IC	extracranial-intracranial
ECG	electrocardiogram
echo	echocardiogram
ECMO	extracorporeal membrane oxygenation
ECT	electroconvulsive therapy
ED	emergency department
EDAS	encephaloduro-arteriosynangiosis
EEA	end-to-end anastomosis
EEG	electroencephalogram
EF	ejection fraction
EJ	external jugular
EMG	electromyogram
EMLA	eutectic mixture of local anesthetic
ENT	ear-nose-throat
EP	evoked potentials
EPS	electrophysiologic studies

EPV	endopulmonary vent
ER	emergency room
ERCP	endoscopic retrograde cholangiopancreatography
ERV	expiratory reserve volume
ESC	endocoronary sinus catheter
ESLD	end-stage liver disease
ESRD	end-stage renal disease
ESS	endoscopic sinus surgery
ET	endotracheal
$ETCO_2$	end-tidal CO_2
ETN_2	end-tidal N_2
ETOH	alcohol
ETT	endotracheal tube
EVAR	endovascular aneurysm repair
EVD	endovascular drain (extraventricular catheter)
FAP	familial adenomatous polyposis
FAST	focused assessment with sonography for trauma
FB	foreign bodies
FDP	flexor digitorum profundus (tendon)
FDS	flexor digitorum superficialis (tendon)
FDT	forced duction test
FEIBA	factor B inhibitor bypass activity
FESS	functional endoscopic sinus surgery
FEV_1	forced expiratory volume (in 1 sec)
FFP	fresh-frozen plasma
FHR	fetal heart rate
FIGO	International Federation of Gynecology and Obstetrics
FiO_2	fraction of inspired oxygen
FNA	fine needle aspiration
FOB	fiberoptic bronchoscopy
FOI	fiberoptic intubation
FOL	fiberoptic laryngoscopy

Fr	French (size)
FRC	functional residual capacity
FSP	fibrin-split products
FTSG	full-thickness skin graft
FTT	failure to thrive
FVC	forced vital capacity
g	gram(s)
ga	gauge
GA	general anesthesia
GCS	Glasgow Coma Scale
GDT	goal-directed therapy
GE	gastroesophageal
GERD	gastroesophageal reflux disease
GETA	general endotracheal anesthesia
GFR	glomerular filtration rate
GGTP	gamma-glutamyl transpeptidase (liver enzyme)
GH	growth hormone
GI	gastrointestinal
GIA	gastrointestinal anastomosis
GIFT	gamete intrafallopian transfer
GM-CSF	granulocyte-macrophage colony-stimulating factor
Gn-RH	gonadotropin-releasing hormone
GSW	gunshot wound
GT	gastric tube
GTD	gestational trophoblastic disease
GU	genitourinary
h	hour(s)
HA	headache
H&P	history and physical examination
Hb	hemoglobin
Hb/Hct	hemoglobin/hematocrit

HbA	adult hemoglobin
HbF	fetal hemoglobin
HCC	hepatocellular carcinoma
HCG	human chorionic gonadotropin
HCO_3	bicarbonate
Hct	hematocrit
HELLP	hemolysis, elevated liver enzymes, and low platelet count
HFNC	high-flow nasal cannula
HFV	high-frequency ventilation
Hg	mercury
HIV	human immunodeficiency virus
HLHS	hypoplastic left heart syndrome
HM	hyoid myotomy
Ho	holmium-YAG laser
HPV	hypoxic pulmonary vasoconstrictive (reflex)
HR	heart rate
HSV	highly selective vagotomy
HTN	hypertension
HVA	homovanillic acid
Hx	history
IABP	intra-aortic balloon pump
IBD	inflammatory bowel disease
IC	inspiratory capacity
ICD	implantable cardioverter-defibrillator
ICP	intracranial pressure
ICU	intensive care unit
ID	inside diameter
IE	inspiratory/expiratory
IgE	immunoglobulin E
IHSS	idiopathic hypertrophic subaortic stenosis
II	image intensifier
IIC	intermediate intensive care

IJ	internal jugular (vein)
im	intramuscular
IMA	internal mammary artery
IMF	intermaxillary fixation
iMRI	interventional magnetic resonance imaging
INH	isonicotinic acid hydrazide (isoniazid)
INR	international normalized ratio
IOFB	intraocular foreign body
IOL	intraocular lens
IOP	intraocular pressure
IORT	intraoperative radiation therapy
IPAA	ileal pouch and anastomosis
IPG	implantable generator
IPPV	intermittent positive pressure ventilation
IRDS	infant respiratory distress syndrome
ISS	injury severity score
IT	iliotibial
ITP	idiopathic thrombocytopenic purpura
IUP	intrauterine pressure
iv or IV	intravenous
IVC	inferior vena cava
IVF	in vitro fertilization
IVH	intraventricular hemorrhage
IVP	intravenous pyelogram
IVS	intact ventricular septum
J	Joule
JET	junctional ectopic tachycardia
JI	jejunoileal
JVD	jugular venous distension
K^+	potassium
KCl	potassium chloride

kg	kilogram(s)
KVO	keep vein open
L	liter
LA	left atrium or local anesthetic
LAD	left anterior descending
LAE	left atrial enlargement
LAP	left atrial pressure
LAVH	laparoscopy-assisted vaginal hysterectomy
LBBB	left bundle branch block
LDH	lactate dehydrogenase
LE	lower extremity
LEEP	loop electrosurgical excision procedure
LFT	liver function test
LGL	Lown-Ganong-Levine (syndrome)
LH-RH	luteinizing hormone–releasing hormone
LHSV	laparoscopic highly selective vagotomy
LIMA	left internal mammary artery
LINAC	linear accelerator
LLETZ	large loop excision of the transformation zone
LLD	left lateral decubitus
LLQ	left lower quadrant
LMA	laryngeal mask airway
LMG	laser midline glossectomy
LMP	last menstrual period
LMWH	low molecular weight heparin
LP	lumbar puncture
LR	lactated Ringer (solution)
LRD	living related donor
LSC	laparoscope approach
LTA	lidocaine tracheal anesthesia
LUQ	left upper quadrant
LV	left ventricle/ventricular

LVAD	left ventricular assist device
LVEDP	left ventricular end diastolic pressure
LVEF	left ventricular ejection fraction
LVH	left ventricular hypertrophy
LVOT	left ventricular outflow tract
LVOTO	left ventricular outflow tract obstruction
LVRS	lung volume reduction surgery
m	meter(s)
M	molar
MAC	monitored anesthesia care
MAGPI	meatal advancement glanuloplasty
MAO-B	monoamine oxidase-B
MAOI	monoamine oxidase inhibitor (antidepressant)
MAP	mean arterial pressure
MAPCAs	major aortopulmonary collaterals
MCA	middle cerebral artery
MCKD	medullary cystic kidney disease
MDI	multidirectional instability
MEA	multiple endocrine adenopathy
MED	microendoscopic lumbar discectomy
MEN	multiple endocrine neoplasia
MEP	motor-evoked potential
mEq	milliequivalent
mEqK^+	milliequivalency of potassium
metHb	methemoglobin
mg	milligram(s)
Mg^{++}	magnesium
$MgSO_4$	magnesium sulfate
MH	malignant hyperthermia
MI	myocardial infarction
MICAB	minimally invasive coronary artery bypass
MICABG	minimally invasive coronary artery bypass graft(ing)

µg	microgram(s)
MIDCAB	minimally invasive direct coronary artery bypass
MIDCABG	minimally invasive direct coronary artery bypass graft(ing)
MIF	maximum inspiratory flow
min	minute(s)
mL	milliliter(s)
MLT	microlaryngeal tube
mm	millimeter(s)
$MMEF_{25–75}$	maximum midexpiratory flow
mm Hg	millimeters of mercury
MMPM	multimodal pain management
mo	month(s)
MOGA	mandibular osteotomy and genioglossal advancement
MR	mitral regurgitation
MRA	magnetic resonance angiography
MRI	magnetic resonance imaging
MRSA	methicillin-resistant Staphylococcus aureus
MRT	magnetic resonance–guided therapy
MS	mitral stenosis
MTP	massive transfusion protocol
MUF	modified ultrafiltration
MUGA	multigated acquisition (scan)
MUPIT	Martinez Universal Perineal Interstitial Template
MV	minute ventilation; mitral valve
MVA	motor vehicle accident
MVC	motor vehicle collision
MVD	microvascular decompression
MVO_2	mixed venous oxygen content
MVP	mitral valve prolapse
Na^+	sodium
$NaHCO_3$	sodium bicarbonate
NB	nota bene (note well)

NDMR	nondepolarizing muscle relaxant
Nd:YAG	neodymium-YAG laser
NEC	necrotizing enterocolitis
ng	nanogram(s)
NG	nasogastric (tube)
NIBP	noninvasive blood pressure
NICU	neonatal intensive care unit
NIF	negative inspiratory force
nl	normal
NLD	nasolacrimal duct
NMB	neuromuscular blocker
NMR	nondepolarizing muscle relaxant
NO	nitric oxide
NOAC	new oral anticoagulants
NOE	naso-orbital ethmoid
NORA	non–operating room anesthesia
NPH	neutral protamine Hagedorn (insulin)
npo	nothing by mouth
NS	normal saline
NSAID	nonsteroidal anti-inflammatory drug
NS/LR	normal saline/lactated Ringer (solution)
NSR	normal sinus rhythm
NTE	not to exceed
NTG	nitroglycerin
NTP	nitroprusside
N_2O	nitrous oxide
N/V	nausea and vomiting
OA	osteoarthritis
OATS	osteochondral autograft transfer system
OCR	oculocardiac reflex
OD	outside diameter
OEIS	omphalocele exstrophy imperforate anus spinal defect

OG	orogastric (tube)
OLV	one-lung ventilation
OPCAB	off-pump coronary artery bypass
OPCABG	off-pump coronary artery bypass graft(ing)
OPLL	ossification of the posterior longitudinal ligament
OR	operating room
ORIF	open reduction and internal fixation
ORR	oculorespiratory reflex
OSA	obstructive sleep apnea
O_2	oxygen
O_2 sat	oxygen saturation
P	pulse
PA	pulmonary artery
$PaCO_2$	partial pressure of CO_2 (arterial)
PACU	postanesthesia care unit
PAD	pulmonary artery diastolic
PADP	pulmonary artery diastolic pressure
PAK	pancreas after kidney (transplant)
PAOP	pulmonary artery occlusion pressure
PaO_2	partial pressure of oxygen (arterial)
PAP	pulmonary artery pressure
PAR	postanesthesia room
PAWP	pulmonary artery wedge pressure
PCA	patient-controlled analgesia
PCC	prothrombin complex concentrate
PCEA	patient-controlled epidural analgesia
PCL	posterior cruciate ligament
PCO_2	partial pressure of carbon dioxide
PCV	parietal cell vagotomy
PCWP	pulmonary capillary wedge pressure
PDA	patent ductus arteriosus
PDE	phosphodiesterase

PDPH	postdural puncture headache
PE	pulmonary embolus
PEEP	positive end-expiratory pressure
PEF	peak expiratory flow
PET	positron emission tomography
$PetCO_2$	end-tidal CO_2 partial pressure
PFNS	preservative-free normal saline
PFO	patent foramen ovale
PFT	pulmonary function test
PGE	prostaglandin E
PICC	peripherally inserted central catheter
PICU	pediatric intensive care unit
PID	pelvic inflammatory disease
PIH	pregnancy-induced hypertension
PIP	peak inspiratory pressure
PKP	penetrating keratoplasty
PLIF	posterior lumbar interbody fusion
Plt	platelet
PND	paroxysmal nocturnal dyspnea
po	by mouth
POC	product of conception
POD	postoperative day
POEM	peroral endoscopic myotomy
PONV	postoperative nausea and vomiting
POOP	perineal one-stage operative pull-through
POPE	postobstructive pulmonary edema
PO_2	partial pressure of oxygen
PPH	postpartum hemorrhage
PPI	proton pump inhibitor
ppm	parts per million
PPTL	postpartum tubal ligation
PPV	positive pressure ventilation or pulse pressure variation
pr	per rectum

PRBC	packed red blood cell
prn	as needed
PS	pulmonic stenosis
PSARP	perineal sagittal anorectoplasty
PSSD	postsurgical stress disorder
PT	prothrombin time
PTCA	percutaneous transluminal coronary angioplasty
PTM	posterior tibial muscle
PTS	posttourniquet syndrome
PTSD	posttraumatic stress disorder
PTT	partial thromboplastin time
PUD	peptic ulcer disease
PUV	posterior urethral valve
PVA	polyvinyl alcohol
PVB	paravertebral block
PVC	premature ventricular contraction
PVD	peripheral vascular disease
PVI	pleth variability index
PVOD	pulmonary vascular occlusive disease
PVR	pulmonary vascular resistance
q	query
qd	every day
Q_P/Q_S	pulmonary-to-systemic flow ratio
QRS	QRS complex of ECG
qs	quantum satis (sufficient quantity)
RA	radial artery
RAD	right axis deviation
RAE	right atrial enlargement
RAP	right atrial pressure
RAST	radioallergosorbent test
RBBB	right bundle branch block

RBC	red blood cell
RC	rotator cuff
RCA	right coronary artery
RCP	retrograde cerebral perfusion
RCT	randomized controlled trial
RDS	respiratory distress syndrome
RF	radiofrequency
RFA	radiofrequency ablation
RFT	renal function test
RIND	reversible ischemic neurologic deficit
RLD	right lateral decubitus
RLQ	right lower quadrant
r/o	rule out
ROM	range of motion
ROP	retinopathy of prematurity
RR	respiratory rate
RSD	reflex sympathetic dystrophy (obsolete)
RSI	rapid-sequence induction
RSV	respiratory syncytial virus
RUE	right upper extremity
RUQ	right upper quadrant
RV	right ventricle
RVE	right ventricular enlargement
RVEDP	right ventricular end-diastolic pressure
RVESV	right ventricular end-systolic volume
RVH	right ventricular hypertrophy
RVOT	right ventricular outflow tract
RVOTO	right ventricular outflow tract obstruction
Rx	treatment
SA	sinoatrial (node)
SAB	subarachnoid block
SAD	subacromial decompression

SAH	subarachnoid hemorrhage
SAM	systolic anterior motion
SBE	subacute bacterial endocarditis
SBO	small bowel obstruction
SBP	systolic blood pressure
sc	subcutaneous
SCD	sequential compression device
SCFE	slipped capital femoral epiphysis
SCT	sacrococcygeal teratoma
sec	second(s)
SGOT	serum glutamic-oxaloacetic transaminase
SGPT	serum glutamate-pyruvate transaminase
SI	sacroiliac
SIADH	syndrome of inappropriate antidiuretic hormone
SICU	surgical intensive care unit
sl	sublingual
SLAP	superior labral anterior to posterior
SLE	systemic lupus erythematosus
SLH	subtotal laparoscopic hysterectomy
SLT	single-lung transplant or single-lumen tube
SMA	superior mesenteric artery
SMV	superior mesenteric vein
SNP	sodium nitroprusside
SOB	short(ness) of breath
S/P	status post
SPK	simultaneous kidney/pancreas (transplant)
SpO_2	oxygen saturation measured by pulse oximetry
SPV	systolic pressure variation
SSA	sickle cell anemia
SSEP	somatosensory evoked potential
SSI	surgical site infection
SSRI	selective serotonin reuptake inhibitor
SSS	sick sinus syndrome

S-T	wave of ECG
ST-T	ST-T wave of ECG
STA	superficial temporal artery
STP	sodium thiopental
STSG	split-thickness skin graft
SV	stroke volume
SVC	superior vena cava
S_vO_2	venous O_2 saturation
SVR	systemic vascular resistance
SVT	supraventricular tachycardia
Sx	signs and symptoms
Sz	seizure
T	temperature
T&C	type and cross-match
T&S	type and screen
T/A	tonsillectomy/adenoidectomy
TAAA	thoracoabdominal aortic aneurysm
TAB	therapeutic abortion
TACO	transfusion-associated circulatory overload
TAH	total abdominal hysterectomy
TAPVC	total anomalous pulmonary venous connection
TB	tuberculosis
TBI	total body irradiation
TBSA	total body surface area
TCA	tricyclic antidepressant
TCD	transcranial Doppler
TE	tangential excision
TEA	thromboendarterectomy
TECAB	totally endoscopic coronary artery bypass
TEE	transesophageal echocardiogram (graphy)
TEF	tracheoesophageal fistula
TEG	thromboelastogram

TET	tubal embryo transfer
TEVAR	thoracic endovascular aortic repair
TGA	transposition of the great arteries
TGV	transposition of the great veins
THRIVE	transnasal humidified rapid-insufflation ventilatory exchange
TIA	transient ischemic attach
tid	3 times per day
TIPS	transjugular intrahepatic portosystemic shunt
TIVA	total intravenous anesthesia
TKO	to keep open
TL	thoracolumbar
TLC	total lung capacity
TLH	total laparoscopic hysterectomy
TLIF	transforaminal lumbar interbody fusion
TMJ	temporomandibular joint
TMJD	temporomandibular joint dysfunction
TOF	tetralogy of Fallot, train of force
tPA	tissue plasminogen activator
TPN	total parenteral nutrition
TR	tricuspid regurgitation
TRALI	transfusion-related acute lung injury
TRAM	transverse rectus abdominis muscle (flap)
TSA	total shoulder arthroplasty
TSC	tethered spinal cord
TSH	thyroid-stimulating hormone
TT	thrombin time
TTE	transthoracic echocardiography
TTP	thrombotic thrombocytopenic purpura
TUMT	transurethral microwave thermotherapy
TUNA	transurethral needle ablation
TUR	transurethral resection
TURBT	transurethral resection of bladder tumor
TURP	transurethral resection of the prostate

TUVP	transurethral vaporization of the prostate
TV	tidal volume
TVOR	transvaginal oocyte retrieval
TVT	tension-free vaginal tape procedure
TW airway	Tudor-Williams airway
TWR	total wrist replacement
Tx	transplant
U	unit(s)
UA	urinalysis
UAC	umbilical artery catheter
UBC	unicameral bone cyst
UC	ulcerative colitis
UE	upper extremity
UO	urine output
UPJ	ureteropelvic junction
UPPP	uvulopalatopharyngoplasty
URI	upper respiratory infection
US	ultrasound
UTI	urinary tract infection
UVC	umbilical vein catheter
UW	University of Wisconsin (solution)
V&A	vagotomy and antrectomy
V&P	vagotomy and pyloroplasty
VA	ventriculoatrial
VAE	venous air embolism
VAGM	vein of Galen malformation
VALH	vaginally assisted laparoscopic hysterectomy
VAT	video-assisted thoracoscopy
VATS	video-assisted thoracoscopic surgery
VBG	vertical banded gastroplasty
VC	vital capacity

Vd	volume of distribution
VF	ventricular fibrillation
VIP	vasoactive intestinal peptide
VIPoma	vasoactive intestinal peptide-secreting tumor
VLAP	visual laser ablation of the prostate
VMA	vanillylmandelic acid
VO_2	oxygen consumption
VP	ventriculoperitoneal
VPI	velopharyngeal insufficiency
V/Q	ventilation-perfusion ratio
VRE	vancomycin-resistant enterococci
VS	vital signs
VSD	ventricular septal defect
VT	ventricular tachycardia
VUR	vesicoureteral reflux
WBC	white blood cell
WPW	Wolff-Parkinson-White (syndrome)
W/U	workup
XRT	x-ray therapy
yr	year(s)

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