Parameters for Edema Associated With Inflammation

When using electrical stimulation to inhibit the formation of edema during the acute inflammatory response, the following recommendations apply:

Waveform. HVPC is the recommended waveform.

Electrode Placement. Negative polarity treatment electrodes should be placed directly over the area of edema, with the dispersive electrode placed over another large flat area that is generally proximal to the area of edema (Fig. 14-4).

Pulse Duration. The pulse width of the device will be fixed by the manufacturer in the range of 40 to 100 μs.

Polarity. The negative polarity electrode should be placed over the area of edema.

Frequency. The pulse frequency is set to 100 to 120 pps.[3]

On:Off Time. Electrical stimulation is delivered continuously throughout the treatment time. This maximizes the amount of charge delivered and thus the attraction of negatively charged particles.

Current Amplitude. The current amplitude should be set to a comfortable sensory level.

Treatment Time. Electrical stimulation is generally applied for 20 to 30 minutes/session but may be used more than once a day.

Parameters for Edema Associated With Lack of Muscle Contraction

When using electrical stimulation to reduce edema associated with lack of muscle activity, the following recommendations apply.

Waveform. A pulsed biphasic waveform or **Russian protocol** is recommended.

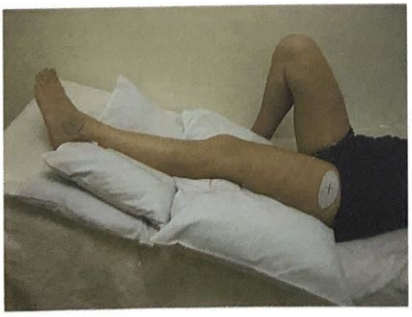

FIG 14-4 Electrode placement to retard acute edema formation at the ankle.

FIG 14-5 Electrode placement to reduce edema in the wrist and hand caused by lack of motion. *Courtesy Mettler Electronics, Anaheim, CA.*

Electrode Placement. Electrodes should be placed on the muscle around the main veins draining the area in the same way as recommended for muscle contractions (Fig. 14-5).

Pulse Duration. When a pulsed biphasic waveform is used, the pulse duration should be between 150 and 350 μsec—sufficient to produce a muscle contraction. When Russian protocol is used, the cycle duration depends on the carrier frequency and is 400 μs.

Frequency. The frequency should be 35 to 50 pps, as used to produce muscle contractions for other purposes.

On:Off Time. An on time of 1 to 2 seconds and an off time of 1 to 2 seconds are recommended to promote muscle pumping.

Current Amplitude. Amplitude should be sufficient to produce a small, visible muscle contraction.

Treatment Time. Electrical stimulation is generally applied for 20 to 30 minutes/session but may be used more than once a day.

IONTOPHORESIS

Iontophoresis is the use of low-amplitude DC to facilitate transdermal drug delivery. The use of iontophoresis was first reported in the early 1900s.[58,59] Iontophoresis is based on the principle that like charges repel, and that therefore a fixed charge electrode on the skin can promote the movement of charged ions of a drug through the skin by "pushing" them away.[60] However, more recent studies suggest that iontophoresis, similar to phonophoresis, may promote transdermal drug penetration primarily by increasing the permeability of the outermost layer of the skin, the stratum corneum, the main barrier to transdermal drug uptake.[61-63] The most common use of iontophoresis in rehabilitation is for application of the corticosteroid antiinflammatory medication dexamethasone. Iontophoresis can provide advantages over oral delivery if the patient is nauseated or vomiting; over nasal delivery, which can leave a bad taste in the patient's mouth and has low bioavailability; and over injections, which can be painful and may cause bleeding, infection, and traumatic injury.

The depth to which a drug is delivered by iontophoresis is uncertain. Most studies have demonstrated penetration to a depth of 3 to 20 mm.[64] For example, when iontophoretic delivery was compared with passive delivery of salicylic acid and lidocaine to rats, it was found that both drugs penetrated 3 to 4 mm below the skin when delivered by iontophoresis if the epidermis was intact, or by passive delivery if the epidermis was removed.[65] Passive delivery is the application of the drug to the skin without additional enhancement. Penetration was negligible with passive delivery when the epidermis was not removed. The authors of this study concluded that iontophoresis allows salicylic acid and lidocaine to penetrate through the stratum corneum. Another study found that lidocaine penetrated to a depth of 5 mm through intact skin in humans with iontophoresis.[66] Sodium ethanolamine and lidocaine could be detected up to 2 cm laterally away from the iontophoresis treatment electrode in the intact skin of rats.[67] Declining drug concentration with distance was thought to be a result of clearance from the site of application by the microcirculation of the skin, leading to systemic uptake of the drug.

For an electrical current to facilitate transdermal drug penetration, the current must be at least sufficient to overcome the combined resistance of the skin and the electrode being used.[68] The amount of electricity used for performing iontophoresis is described according to charge, in milliamp minutes (mA-min). This is the product of the current amplitude, measured in milliamps, and the time, measured in minutes. The number of milliamp minutes depends on the specific electrode being used and is determined by the manufacturer of the electrode. At this time, most manufacturers recommend using 40 mA-min or 80 mA-min for each iontophoresis treatment. Studies have shown effective drug delivery with 40 to 80 mA-min treatments.[69,70]

One can use a number of combinations to achieve the currently recommended 40 mA-min minimum dosage level. For example, a 1-mA current for 40 minutes, a 2-mA current for 20 minutes, and a 4-mA current for 10 minutes all give treatment of 40 mA-min (Table 14-3). In practice, one should set the current amplitude to patient comfort and then adjust the time to produce the desired product. Typical treatment current amplitudes used in research studies are between 1.0 mA and 5.0 mA; however, currently available clinical devices allow a maximum current amplitude of only 4.0 mA to minimize the risk of burns; in general, using a lower current within this range is safest.[71]

To promote continuous delivery of the ionized drug, a direct current must be used for iontophoresis. Unfortunately, this type of current can also produce undesirable chemical changes under the electrodes. Sodium hydroxide, which is caustic, can form under the negative electrode, causing discomfort, skin irritation, or chemical burns.[72] This is known as the *alkaline reaction*. Reducing the **current density** by making the negative electrode larger or reducing the current amplitude will help decrease the risk of local adverse effects. Hydrochloric acid can form under the positive electrode. This is known as the *acidic reaction* and generally is less uncomfortable than the alkaline reaction.

To further reduce the risk of skin irritation, optimize comfort, and provide prolonged drug delivery, iontophoresis delivery systems that have low voltage output and apply an extremely low current for a much longer period of time have recently been developed. These devices have a battery within the electrodes and deliver between 0.1 and 0.3 mA for a period of 1 to 24 hours, delivering a total dose of approximately 40 to 80 mA-min (Fig. 14-6). The battery activates when the drug is applied to the electrode (also called a *patch*), and the patch is applied to the skin. The patch can be worn under clothing and requires no machine or external battery. A recent study demonstrated that this type of iontophoresis delivery increases drug retention in the treatment area because it causes less increase in local circulation.[73,74]

Although the low-voltage patches are more comfortable than traditional iontophoresis delivery, their lower voltage and current may reduce drug delivery because of high skin resistance. To address this, several new devices combining traditional and low-volt technology have been designed. These devices have a small rechargeable wireless dose controller that attaches to a patch containing the drug to be delivered (Fig. 14-7). A few minutes of milliamp

TABLE 14-3 Current Amplitude and Treatment Duration for Iontophoresis Treatment

Current Amplitude, mA	Treatment Time, min	Dose, mA-min
1	40	40
2	20	40
3	13.3	40
4	10	40

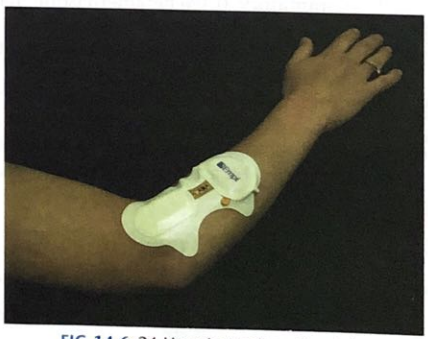

FIG 14-6 24-Hour iontophoresis patch.

FIG 14-7 Hybrid iontophoresis device. *Courtesy Chattanooga, Vista, CA.*

current is applied using a controller at the beginning of treatment to decrease skin resistance. The controller is then removed, and the patch, which then delivers a microamperage level of current, is worn for several hours and turns off automatically after a preset dose of 40, 60, or 80 mA-min has been delivered. These devices may also be used to deliver standard iontophoresis in the clinic or patch-only treatment, which runs without the first few minutes of milliamperage current at the beginning, but for a longer period of time.[75]

Many drugs can be delivered by iontophoresis as long as they can be ionized and are stable in solution, they are not altered by the application of an electrical current, and their ions are small or moderate in size. Different drugs have been used for the treatment of different pathologies (Table 14-4). At this time, the manufacturers of iontophoresis electrodes recommend using iontophoresis only for delivery of dexamethasone or lidocaine. However, the use of other substances, such as acetic acid for treatment of calcific tendinitis or heel pain, has been reported.[76,77] Also, a new iontophoretic delivery system is available by physician order only for delivery of fentanyl to hospitalized patients.[78]

Dexamethasone is a corticosteroid with antiinflammatory effects that is recommended for treatment of inflammatory conditions such as tendinitis or bursitis. Dexamethasone iontophoresis has been found to be more effective than placebo in the treatment of lateral epicondylitis and plantar fasciitis.[79,80] Dexamethasone is delivered by iontophoresis using a 0.4% solution of dexamethasone sodium phosphate. The negative polarity electrode is used to promote penetration of the negatively charged dexamethasone phosphate ion through the skin (Fig. 14-8). Iontophoresis with another corticosteroid antiinflammatory, 0.1% betamethasone, has also been studied but was not found to be significantly more effective than a control intervention for the treatment of trapeziometacarpal wrist arthritis.[81]

Lidocaine is an anesthetic drug. In the past, dexamethasone and lidocaine were delivered together by iontophoresis, with a positive charge used initially to promote lidocaine delivery, followed by a negative charge to promote

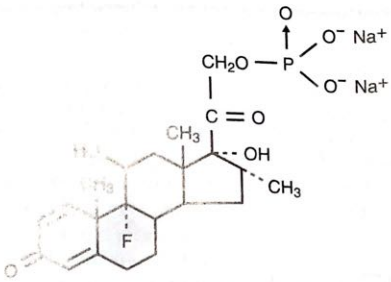

FIG 14-8 The molecular structure of dexamethasone sodium phosphate. Note that the negatively charged dexamethasone phosphate ion is moved across the dermal barrier by iontophoresis using the negatively charged electrode.

dexamethasone delivery.[82] This combined procedure mimicked the combined application of lidocaine and dexamethasone by injection and provided chemical buffering. However, because iontophoresis should not be as painful as an injection, the lidocaine is not needed. Also, newer electrodes are buffered, adding to the safety of the treatment. It is therefore recommended that dexamethasone be delivered alone with the negative electrode only.

One randomized controlled trial found that low-dose lidocaine iontophoresis provided effective topical anesthesia for venipuncture and venous cannulation within 10 minutes in adults and children.[83] The manufacturers of iontophoresis electrodes have recommended lidocaine iontophoresis for local anesthesia in children. The advantage of lidocaine iontophoresis in children is that it is very effective in relieving pain, has been shown to be cost-effective compared with the alternatives, and seems to be well tolerated by most.[84-86]

The delivery of other medications by iontophoresis to control pain and inflammation, such as the nonsteroidals naproxen and ketoprofen and the synthetic opiate analgesic fentanyl, has been studied. Iontophoretic delivery of naproxen was shown to be effective in reducing pain in lateral epicondylitis, and an iontophoretic transdermal system is approved by the FDA to deliver fentanyl for control

TABLE 14-4 Ions Used Clinically for Iontophoresis, Including Ion Source, Polarity, Recommended Indications, and Concentration

Ion	Source	Polarity	Indications	Concentration (%)
Acetate	Acetic acid	Negative	Calcium deposits	2.5-5
Chloride	NaCl	Negative	Sclerotic	2
Copper	$CuSO_4$	Positive	Fungal infection	2
Dexamethasone phosphate	$DexNa_2PO_3$	Negative	Inflammation	0.4
Hyaluronidase	Wydase	Positive	Edema reduction	—
Iodine	—	Negative	Scar	5
Lidocaine	Lidocaine 1:50,000 with epinephrine	Positive	Local anesthetic	5
Magnesium	$MgSO_4$	Positive	Muscle relaxant, vasodilator	—
Salicylate	NaSal	Negative	Inflammation, plantar warts	2
Tap water	—	Negative/positive	Hyperhidrosis	—
Zinc	ZnO_2	Positive	Dermal ulcers, wounds	—

of postoperative pain.[87] Iontophoretic delivery of fentanyl was shown to be more effective than placebo and to have effects comparable with those of intravenous morphine.

Much research has focused on exploring the use of iontophoresis to deliver a wide range of other medications, including insulin, leuprolide, calcitonin analogs, cyclosporine, beta-blockers, antihistamines, triptans for migraines, ondansetron for nausea and vomiting, prednisolone for bronchial asthma, zinc phthalocyanine tetrasulfonic acid for the treatment of cancerous tumors, dexamethasone phosphate for dry eyes, and midazolam for pediatric sedation before the time of surgery.[5,88-93] Also, a product currently available by prescription uses reverse iontophoresis to measure a patient's blood sugar level (GlucoWatch Biographer, Animas Technologies, Westchester, PA). In the future, reverse iontophoresis may provide a noninvasive way of checking the blood levels of other substances, such as urea and homocysteine; this process now requires taking a blood sample and analyzing it in a laboratory.[94,95] The primary challenges facing new applications of iontophoresis are not the ability to deliver drugs through the skin, but rather precise control of the dose (bioavailability) and patient tolerance of the stimulation. Because of limitations of other delivery methods, iontophoresis is likely to be a topic of much future research.

PARAMETERS FOR IONTOPHORESIS

The parameters used for electrical stimulation for iontophoresis are discussed in detail in the following sections and are summarized in Table 14-5.

Electrode Placement and Size. For iontophoresis, the drug delivery electrode is placed over the area of pathology. When a low-voltage patch electrode is used, both negative and positive polarity electrodes are within the same patch. When an iontophoresis unit with wired electrodes is used, the dispersive or return electrode is placed a few inches away from the treatment electrode at a site of convenience over a large muscle belly (Fig. 14-9). The electrode should be large enough that the current density does not exceed 0.5 mA/cm^2 when the **cathode** is used as the delivery electrode, and 1.0 mA/cm^2 when the **anode** is used.[36]

Polarity. For iontophoresis, the drug delivery electrode should have the same polarity as the active ion of the drug to be delivered.

Current Amplitude. For iontophoresis, the amplitude should be determined by patient comfort and should be no greater than 4 mA.

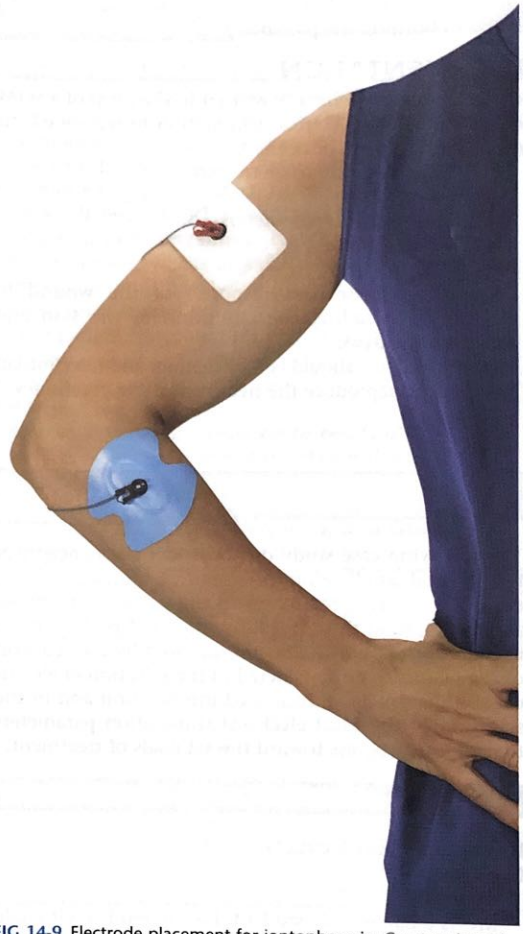

FIG 14-9 Electrode placement for iontophoresis. *Courtesy Iomed, Salt Lake City, UT.*

Treatment Time. For iontophoresis, the treatment time is affected by the current amplitude and should be adjusted to produce a total treatment dose of 40 to 80 mA-min, which is achieved by setting the amplitude to patient comfort and then setting, or having the device select, the treatment time to achieve the desired treatment dose. It is important to check the patient's skin during this treatment because the DC and the small electrodes used for

TABLE 14-5 Recommended Parameter Settings for Electrical Stimulation for Iontophoresis

Parameter Settings/ Goal of Treatment	Waveform	Pulse Frequency	Pulse Duration	Amplitude	Polarity	Treatment Time
Iontophoresis	DC	NA	NA	To patient tolerance, no greater than 4 mA	Same as drug ion (See Table 14-4)	Depends on amplitude, to produce a total of 40 mA-min

DC, Direct current; *NA*, not applicable.

iontophoresis produce a high current density, increasing the risk of burning the patient.

DOCUMENTATION

Documentation is generally written in the form of a SOAP note. When using electrical stimulation to reduce edema or for tissue healing, document:

- The area of the body to be treated
- Patient positioning
- Specific stimulation parameters
- Electrode placement
- Treatment duration
- Patient's response and response of the wound to treatment, including the condition of the skin and surrounding areas.
- The level of detail should be sufficient for another clinician to be able to reproduce the treatment using your notes.

When applying electrical stimulation (ES) to a full-thickness venous ulcer on the left (L) lateral ankle, document the following:

S: Pt alert and oriented ×3. She states she has been keeping her L lower extremity elevated as much as possible because the edema in her L ankle increases with dependent positioning.

O: Intervention: Pt supine with 2 pillows under L leg for elevation. HVPC to L lower extremity ×1 hour. 2 treating electrodes placed periwound, 1 dispersive electrode placed on proximal posterior calf. Frequency 100 pps, negative polarity to treatment area, intensity to sensory level.

Posttreatment: Wound area decreased from 10 × 5 cm on first treatment 3 weeks ago to 8 × 3 cm today.

A: Pt tolerated treatment well. Wound size decreasing.

P: Continue HVPC to L lateral ankle area until wound closes. Change polarity if healing plateaus.

CLINICAL CASE STUDIES

The following case study demonstrates the concepts of the clinical application of electrical stimulation discussed in this chapter. Based on the scenario presented, an evaluation of the clinical findings and goals of treatment are proposed. These are followed by a discussion of the factors to be considered in the selection of electrical stimulation as an indicated intervention and in the selection of the ideal electrical stimulation parameters to promote progress toward the set goals of treatment.

CASE STUDY 14-1

Lateral Ankle Sprain

Examination

History

MC is a 23-year-old student. He injured his left ankle during a soccer game at school. He was seen by the attending physician on the field and diagnosed with a grade II lateral ankle sprain. MC's ankle was packed in ice, and he was sent to the locker room for immediate physical therapy follow-up. The physician instructed MC to use non–weight-bearing crutches to rest the injured ankle.

Tests and Measures

Visual inspection shows the patient holding his ankle in a single position with extreme hesitancy in allowing the therapist to move the joint. Gentle passive ROM (PROM) reveals restrictions in all directions. Active ROM (AROM) is minimal. The lateral talofibular joint is tender to touch, with discoloration indicative of internal bleeding along the lateral surface and an inability to view the lateral malleolus because of swelling. The area is warm to the touch and slightly reddened. The student is otherwise healthy and denies a history of cancer, diabetes, or other significant health problems.

What kind of process is occurring in this patient's ankle? What kind of electrical stimulation would be most useful? What aspects of the patient's injury would electrical stimulation address? What other physical agent may be used along with electrical stimulation?

Evaluation, Diagnosis, Prognosis, and Goals

Evaluation and Goals

ICF Level	Current Status	Goals
Body structure and function	Left ankle pain, edema, and decreased ROM	Control edema and pain Accelerate resolution of the acute inflammatory phase of healing Increase ROM
Activity	Limited ambulation	Increase ambulation
Participation	Unable to play soccer	Return to playing soccer

Diagnosis

Preferred Practice Pattern 4D: Impaired joint mobility, motor function, muscle performance, and ROM associated with connective tissue dysfunction.

Prognosis/Plan of Care

Given the mechanism of injury, an active inflammatory process is most likely occurring. Electrical stimulation using HVPC would be an appropriate choice of treatment because it has been shown to retard the formation of edema during the inflammatory stage of injury. It is also known to help control pain. Nothing in the patient's history indicates a contraindication to using electrical stimulation.

Intervention

Electrical stimulation using HVPC waveform is chosen based on the literature indicating that it is effective

CLINICAL CASE STUDIES—cont'd

at decreasing edema formation after injury (see Fig. 14-4). The following parameters are chosen:

Type	Parameter
Electrode placement	One or two treating electrodes may be used over the swollen, discolored area. (Polarity is negative for treating electrodes.) The larger dispersive electrode is placed proximally over the calf or the quadriceps. This may be based on comfort or other suspected areas of swelling. Ice may be added over the electrodes to further inhibit the formation of edema.
Pulse duration	Generally fixed at 40-100 μs for HVPC
Pulse frequency	120 pps
Mode	Continuous
Amplitude	Sensory ONLY. Ask the patient to state when a tingling or vibratory sensation just begins to occur. Continue to increase the amplitude until it reaches the maximum tolerable level. If a contraction is seen, decrease the amplitude.
Treatment time	30 minutes

Documentation

S: Pt reports severe (9/10) L ankle pain immediately after injuring himself playing soccer.

O: Pretreatment: Pt unable to bear weight. L ankle PROM limited in all directions. Edema and discoloration over lateral L ankle.

Intervention: One treating electrode, negative polarity, place over lateral L ankle; one dispersive electrode on L calf. HVPC at 120 pps, continuous. Amplitude sensory only ×30 minutes.

Posttreatment: Pain 5/10. Mildly increased L ankle PROM. Pt unable to bear weight.

A: Pt tolerated ES well, with decreased pain and increased PROM.

P: Continue treatment 2-3 times daily for 30 minutes. Pt should remain non–weight-bearing and should apply ice and elevation to the L ankle.

CASE STUDY 14-2

Wound Healing

Examination

History

BT is a 72-year-old wheelchair-bound nursing home resident who is referred to you with a stage III pressure ulcer on his left buttock over his left ischial tuberosity. He recently had a right great toe amputation owing to his diabetes and has been recovering slowly. The nursing staff has been debriding and cleaning the wound, monitoring nutrition status, frequently repositioning him, and changing the dressings on his left buttock wound following standard wound care protocols for the past month. Although the pressure ulcer has not increased in depth or size, it has not become smaller or shown other signs of healing. To avoid excessive pressure on his left buttock, BT has been advised to minimize time sitting, including time in his wheelchair. He is therefore very limited in his mobility and cannot participate in most community activities.

Tests and Measures

The patient states that his pain is 6/10.

Pressure ulcer 3 × 4 cm, stage III, left buttock, clean but without granulation tissue. Surrounding skin intact but tender to palpation.

Why would electrical stimulation be beneficial for this patient? What kind of electrical stimulation should be used? What other physical agents might be used?

Evaluation, Diagnosis, Prognosis, and Goals

Evaluation and Goals

ICF Level	Current Status	Goals
Body structure and function	Left buttock pressure ulcer	Control pain, reduce size of ulcer Increase ROM
Activity	Limited sitting tolerance Limited mobility in wheelchair	Increase sitting tolerance Increase mobility in wheelchair
Participation	Limited participation in community activities requiring sitting (e.g., meals, games)	Return to prior level of community participation in group activities requiring sitting, including meals and games

Diagnosis

Preferred Practice Pattern 7D: Impaired integumentary integrity associated with full-thickness skin involvement and scar formation.

Prognosis/Plan of Care

Electrical stimulation would be an appropriate addition to the care BT is already receiving because it can accelerate healing of the wound and decrease pain. BT has no contraindications for electrical stimulation. However, care should be taken when increasing amplitude to ensure adequate sensation in the area because of his diabetes.

Intervention

Electrical stimulation with HVPC can be used to reduce the size and depth of the pressure ulcer, in addition to providing conventional wound care interventions. This

Continued

may help to control some of the pain associated with the ulcer. Recommended parameters are as follows:

Type	Parameter
Waveform	High-volt pulsed current
Electrode placement	One negative electrode may be used in the ulcer. A larger dispersive electrode is placed over the low back.
Pulse duration	Generally fixed at 40-100 μs for HVPC
Pulse frequency	120 pps
Mode	Continuous
Amplitude	Sensory ONLY. Ask the patient to state when a tingling or vibratory sensation just begins to occur. Continue to increase the amplitude until it reaches the maximum tolerable level. If a contraction is seen, decrease the amplitude.
Treatment time	45-60 minutes, 5 days a week

Documentation

S: Pt reports pain and discomfort on left buttocks due to pressure ulcer after great toe amputation and subsequent confinement to wheelchair. Pt alert and oriented ×3. BT states he is taking acetaminophen for the pain.

O: Pretreatment: L buttock pain 6/10, full-thickness stage III wound, 3 × 4 cm, 1 cm deep, clean but without granulation tissue. Surrounding skin intact but tender to palpation.

Intervention: ES with HVPC waveform, 1 negative electrode in wound, 1 dispersive electrode over low back. 120 pps, sensory level 60 min.

Posttreatment: Pt reports decrease of pain to 4/10.

A: Pt tolerated ES with decreased pain.

P: Continue ES 5 days per week for 60 minutes. Monitor closely for wound changes. Change polarity if healing plateaus.

CASE STUDY 14-3

Lateral Epicondylitis

Examination

History

TO is a 42-year-old administrative assistant who is referred to therapy with a diagnosis of right lateral epicondylitis. She usually plays golf and tennis on the weekends and reports that a significant part of her workday is spent typing on a computer. Her pain developed 1 week ago after she participated in an all-day tennis tournament. She now has trouble gripping and shaking hands. If she has to hold things for any period of time, the pain increases, especially if the objects are heavy (e.g., books). She notes that her pain is not resolving and is interfering with her ability to sleep, work, and participate in sports. She has taken the last 3 days off work. She has moderate pain with typing for longer than 10 minutes and moderate pain with gripping. She is not able to play tennis at all because of the pain.

Tests and Measurements

TO states that her elbow pain is consistently 5/10 but increases to 7/10 with any activity. Her grip strength in her involved hand is 15 kg and in her uninvolved hand is 24 kg, as measured by a dynamometer. Her wrist flexion strength is 4+/5 with pain at end-range. Her wrist extension strength is 4/5 with pain. TO is tender to palpation directly over the lateral epicondyle. Her passive ROM is within normal limits. Her active ROM is within normal limits but with pain at end-range of both flexion and extension.

Why is this patient a candidate for electrical stimulation? What type of electrical stimulation would you select and why? What else should be included in her treatment plan? What other physical agents might be helpful?

Evaluation, Diagnosis, Prognosis, and Goals

Evaluation and Goals

ICF Level	Current Status	Goals
Body structure and function	Right elbow pain, weakness, and decreased ROM	Control pain Increase strength Increase ROM
Activity	Limited gripping capacity	Increase gripping capacity
Participation	Unable to work, hold heavy objects, grip without pain, and play tennis	Return to prior level of work activity and tennis

Diagnosis

Preferred Practice Pattern 4E: Impaired joint mobility, motor function, muscle performance, and range of motion associated with localized inflammation.

Prognosis/Plan of Care

Iontophoresis with an antiinflammatory drug such as dexamethasone would be an appropriate treatment for this patient to reduce her pain and inflammation in the lateral epicondyle. This would enable her to participate in active ROM exercises and passive stretching without pain, increasing her functional ability. This patient has no contraindications for the use of electrical stimulation or dexamethasone.

Intervention

With an appropriate prescription from the referring provider, iontophoresis with dexamethasone could be used for this patient.

Recommended parameters are as follows:

- Iontophoresis delivery system: low-voltage patch electrode
- Electrode placement: Negatively charged part of the electrode loaded with the dexamethasone is placed on the lateral epicondyle.
- Polarity: negative
- Treatment time: 14 hours

CLINICAL CASE STUDIES—cont'd

S: Pt reports R lat elbow pain, increased with activity, especially gripping and playing tennis.

O: Pretreatment: R elbow PROM WNL, AROM WNL with pain, grip strength in R 20 kg (L = 24 kg), flex strength 4+/5, ext strength 4/5.

Intervention: Iontophoresis with 0.4% dexamethasone sodium phosphate with active negative electrode over lateral epicondyle using low-voltage iontophoresis patch. Pt to keep patch on for 14 hours at home and then remove.

Posttreatment: Pt able to actively flex and extend without pain.

A: Pt tolerated iontophoresis well with increased ROM and decreased pain. Skin under electrode sites without signs of irritation after treatment. Pt tolerated 15 minutes of pain-free typing posttreatment.

P: Apply ice as needed. Pt given stretching exercises to be done at home 3 or 4 times a day. Pt will monitor pain while typing, stopping before onset of pain, and will complete stretching exercises as needed during typing activity.

CHAPTER REVIEW

1. The ionic effects of electrical currents can be used to facilitate tissue healing by attracting or repelling cells that carry a charge—a process called galvanotaxis.
2. Electrical stimulation applied to chronic wounds may accelerate healing by attracting appropriate cell types to the injured area and increasing collagen production by fibroblasts.
3. The formation of edema associated with inflammation can be reduced using sensory-level electrical stimulation; edema due to lack of muscle contraction can be reduced by using motor level electrical stimulation.
4. Iontophoresis is the delivery of drugs through the skin facilitated by an electrical current of the same polarity as the drug.

ADDITIONAL RESOURCES

Textbooks

Baker LL, Wederich CL, McNeal DR, et al: *Neuromuscular electrical stimulation: a practical guide*, ed 4, Downey, CA, 2000, Rancho Los Amigos Research and Educational Institute.

Gersh MR, Wolf SR: *Electrotherapy in rehabilitation*, ed 2, Philadelphia, 2000, FA Davis.

Robertson V, Ward A, Low J, et al: *Electrotherapy explained: principles and practice*, ed 4, London, 2006, Butterworth-Heinemann.

Robinson AJ, Snyder-Mackler L: *Clinical electrophysiology: electrotherapy and electrophysiologic testing*, ed 3, Philadelphia, 2008, Lippincott Williams & Wilkins.

Watson T, ed: *Electrotherapy: evidence-based practice*, ed 12, Edinburgh, 2008, Churchill Livingstone.

Web Resources

Chattanooga Group: Chattanooga produces a number of physical agents, including cold packs and cooling units, hot packs and warming units, paraffin, and fluidotherapy. The web site may be searched by body part or by product category. Product specifications are available online.

Dynatronics Corporation: Dynatronics produces a variety of physical agents, including electrical stimulation devices.

Empi: Empi specializes in noninvasive rehabilitation products, including iontophoresis and electrical stimulation. In addition to product brochures and protocols, the web site lists references.

Iomed: Iomed sells iontophoresis units and patches. The web site includes product brochures, specifications, and instructions.

Mettler Electronics: Mettler Electronics carries a wide variety of electrical stimulation products.

GLOSSARY

Amplitude (intensity): The magnitude of current or voltage (see Fig. 11-25).

Anode: The positive electrode.

Biphasic pulsed current: A series of pulses where the charged particles move first in one direction, and then in the opposite direction (see Fig. 11-6, *B*).

Cathode: The negative electrode.

Charge: One of the basic properties of matter, which has no charge (is electrically neutral) or may be negatively (−) or positively (+) charged. Charge is noted as Q and is measured in Coulombs (C). Charge is equal to current × time.

$$Q = It$$

Current density: The amount of current delivered per unit area.

Direct current (DC): A continuous unidirectional flow of charged particles. DC is used for iontophoresis, for stimulating contractions of denervated muscle, and occasionally to facilitate wound healing (see Fig. 11-1).

Frequency: The number of cycles or pulses per second. Frequency is measured in Hertz (Hz) for cycles, and in pulses per second (pps) for pulses (see Fig. 11-10).

Galvanotaxis: The attraction of cells to an electrical charge.

Iontophoresis: The transcutaneous delivery of ions into the body for therapeutic purposes using an electrical current.

Monophasic pulsed current: A series of pulses where the charged particles move in only one direction (see Fig. 11-6, *A*).

On:off time: On time is the time during which a train of pulses occurs. Off time is the time between trains of pulses when no current flows. On and off times are usually used only when electrical stimulation

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