reduction of medication administration errors by 80.7% (Bonkowski et al., 2013).

BCMA can improve medication safety through several levels of functionality. At the most basic level, the system helps verify that the right drug is being administered to the right patient at the right dose by the right route and at the right time. On admission, patients are issued an individualized barcode wristband that uniquely identifies their identity. When a patient is to receive a medication, the nurse scans their barcoded employee identifier and the patient's barcode wristband to confirm their identity. The Joint Commission has stated that a barcode with two unique, patient-specific identifiers will provide healthcare organizations a system that complies with the 2014 National Patient Safety Goal requirement of obtaining two or more patient identifiers before medication administration (Joint Commission, 2014). Prior to medication administration, each barcoded package of medication to be administered at the bedside is scanned. The system can then verify the dispensing authority of the nurse, confirm the patient's identity, match the drug identity with their medication profile in the pharmacy information system, and electronically record the administration of the medication in an eMAR system.

The use of an eMAR is likely to be more accurate than traditional handwritten MARs. One study showed that by using BCMA, the medication-verification component greatly facilitates the documentation process for nurses and may be an important factor for its acceptance (Poon et al., 2008). In a survey of nurses who worked in a variety of clinical settings, the nurses believed that using barcoding and eMARs at the bedside was more time consuming, but they acknowledged that the extra time was worth it to ensure verification. Saving time on transcribing orders or trying to read handwritten, paper-based medication sheets was seen by many to be a significant positive change (Hurley et al., 2007). Furthermore, the barcode scanner can enable nurses to have greater accuracy in recording the timing of medication administration, as the computer generates an actual "real-time" log of medication administration. Additional levels of functionality can include some of the following features:

- Up-to-date drug reference information from online medication references. This could include pictures of tablets or capsules, usual dosages, contraindications, adverse reactions, and other safety warnings, pregnancy risk factors, and administration details.
- Customizable comments or alerts (e.g., look-alike/sound-alike drug names, special dosing instructions [e.g., 2 tablets = 10 mg]) and reminders of important clinical actions that need to be taken when administering certain medications (e.g., do not crush; respiratory intubation is required for neuromuscular blockers).
- Monitoring the pharmacy and the nurse's response to predetermined rules such as alerts or reminders. This includes allergies, duplicate dosing, over-/underdosing, checking for cumulative dosing for medications with established maximum doses such as acetaminophen.
- Reconciliation for pending or STAT orders (i.e., a prescriber order not yet verified by a pharmacist). The ability of the nurse to enter a STAT order into the system on administration that is linked directly to the pharmacy profile and prevents the duplicate administration of the same medication.
- Capturing data for the purpose of retrospective analysis of aggregate data to monitor trends (e.g., percentage of doses administered late; alerts that were overridden). However, this analysis should *not* be used to assess employee performance, especially if it could lead to punitive action.
- Verifying blood transfusion and laboratory specimen collection identification.
- Increased accountability and capture of charges for items such as unit stock medications.

It is important to understand that the successful implementation of an effective BCMA system "forces" nurses to accept and change some of their long-held practices when administering medications to achieve a higher level of medication safety. When BCMA technology is used correctly, it drives compliance with the proper identification of patients, it documents real-time administration and acts as a double-check. It is also vitally important to its success that affected staff members, and specifically frontline nurses, are involved in all the decisions related to the purchase, education, and implementation of bar code technology. Before embarking on a BCMA implementation, it is critical to anticipate potential failures and develop contingency plans for unexpected results. A study that evaluated the workflow variables related to bedside barcode technology-based medication administration process, the authors concluded that nurses were found to be primarily engaged in tasks performed at the bedside. However, tasks such as retrieving medications and routinely updating patients' vital signs records added workflow blocks to the medication administration process (Dasgupta et al., 2011). And second revealed that the introduction of BCMA in an intensive care unit (ICU) resulted in nursing spending less time on the documentation process and more time conversing with patients during the medication administration process (Dwibedi et al., 2012).

Of course, a stringent testing phase should also be built into the system rollout phase using a technique such as failure mode and effects analysis (FMEA) to proactively address potential sources of breakdowns, work-arounds, or new sources of medication errors. One study noted significant changes to workflow that occurred during the implementation of a BCMA system at VA hospitals that might lead to the use of work-arounds (Patterson, Cook, & Render, 2002). Negative effects and corresponding work-arounds include the following:

- Nurses were sometimes caught "off guard" by the programmed automated actions taken by the BCMA software. For example, the BCMA would remove medications from a patient's drug profile list four hours after the scheduled administration time, even if the medications were never administered.
- Inhibited coordination of patient information between nurses and physicians. Before the BCMA was implemented, the prescriber could quickly review the handwritten MAR at the patient's bedside or in the unit's medication room.
- Nurses found it more difficult to deviate from the routine medication administration sequence with the BCMA system. For example, if a patient refused a medication, the nurses had to manually document the change since the medication had already been documented as given when it was originally scanned.
- Nurses felt that their main priority was the timeliness of medication administration because BCMA required nurses to type in an explanation when medications were given even a few minutes late. Particularly in long-term care settings, some nurses were observed to scan and pre-pour medications for unavailable patients so that they would appear "on time" in the computer record, thereby relying on memory to administer unlabeled medications when the patient returned to the unit.
- Nurses used strategies to increase efficiency that circumvented the intended use of BCMA. For example, some nurses routinely entered a patient's social security number by typing the numbers rather than scanning the patient's barcode wristband, because typing seemed to be quicker. This was especially true if the nurse experienced difficulty in scanning the patient's barcode arm band (i.e., curvature of the barcode on the patient's wrist band on patients with small wrists, or damaged barcodes) (Patterson et al., 2002).

The interaction between nurses and technology at the bedside is important and must be continually evaluated for safety. As previously mentioned, nurses tend to develop work-arounds for ineffective or inefficiently designed systems. Koppel, Wetterneck, Telles, and Karsh (2008) sought to identify reasons for work-arounds and found three categories that capture this phenomenon: (a) omission of process steps, (b) steps performed out of sequence, and (c) unauthorized process steps. The authors identified 15 types of work-arounds, including, for example, affixing patient identification barcodes to computer carts, scanners, doorjambs, or nurses' belt rings; carrying several patients' pre-scanned medications on carts. The authors identified 31 types of causes of work-arounds, such as unreadable medication barcodes (crinkled, smudged, torn, missing, covered by another label); malfunctioning scanners; unreadable or missing patient identification wristbands (chewed, soaked, missing); non-barcoded medications; failing batteries; uncertain wireless connectivity; emergencies. The authors found nurses overrode BCMA alerts for 4.2% of patients charted and for 10.3% of medications charted. The possible consequences of the work-around include wrong administration of medications, wrong doses, wrong times, and wrong formulations. Shortcomings in BCMA design, implementation, and workflow integration encouraged work-arounds.

One medication error reported to ISMP caused by a work-around (overriding an alert), involved a mix-up with an order for digoxin elixir (used for congestive heart failure), which was stocked on the unit as a 0.05 mg/mL, 60 mL multi-dose bottle (usual dose is 0.125–0.25 mg [2.5–5 mL]). The nurse not only misinterpreted the dose of digoxin elixir as 60 mL, but accidentally retrieved a bottle of doxepin (used for depression), which was available as 10 mg/mL (usual dose is 75–150 mg per day [7.5–15 mL]) from unit stock and attempted to administer what she thought was digoxin elixir. This error occurred because she scanned the barcode on the bottle, which generated an error window on the laptop computer screen stating "drug not on profile" and did not investigate the error. The system allowed the nurse to manually enter the wrong medication's national drug code (NDC) number (a medical code set that identifies prescription drugs and some over-the-counter products), ignoring the correct drug NDC number that had been entered by the pharmacy which appeared on the laptop screen and administered