A Literature Review: The Role of Bar Coding and Smart Pumps in Patient Safety at Intensive Care Unit

Hanan Mohammed Mohammed

Assistant Professor of Medical-Surgical Nursing Department, Faculty of Nursing, Ain Shams University, Egypt

Abstract Medication safety in hospitals depends on the successful execution of a complex system of scores of individual tasks that can be categorized into five stages: ordering or prescribing, preparing, dispensing, transcribing, and monitoring the patient's response. Many of these tasks lend themselves to technologic tools. Over the past 20 years, technology has played an increasingly larger role toward achieving the five rights of medication safety: getting the right dose of the right drug to the right patient using the right route and at the right time. While several of these technologies may incur significant upfront and maintenance costs, the net impact over time may be reduced overall institutional costs and improvements in work efficiency. Examples of technologic tools commonly seen in many hospitals today include computerized provider order entry (CPOE) with decision support and automatic dispensing carts, also known as medication dispensing robots. While outside the scope of this Perspective, it is important to emphasize that many non-technologic interventions, such as clinical pharmacists on physician rounds, can be equally effective in improving medication safety.

Keywords Bare Coding, Smart Pumps, Safety, Intensive Care Unit

1. Introduction

Research has shown that most medication errors are made by providers during the prescribing stage. These errors are often intercepted by pharmacists, nurses, or colleagues, or by the use of CPOE. Dispensing errors are primarily committed by pharmacy staff, though many are intercepted by nurses prior to administration. In a single-center study, undetected pharmacy dispensing committed by pharmacy technicians and not intercepted by hospital pharmacists occurred in 0.75% of doses. This rate translates to over 1200 errors per year in a 500-bed hospital. Since nurses often act as the last line of defense in the medication use process, administration errors at the point of care often lack additional safety nets and as such are infrequently caught [1].

Smart intravenous (IV) infusion pumps have been developed to mitigate errors that occur at the administration stage. These errors have the greatest potential for life-threatening harm because of the dangers of 10- to 100-fold errors in IV medication doses, especially with high-risk medications such as insulin, heparin, propofol, and vasoactive medications. Smart IV infusion pumps have drug libraries with standardized concentrations for commonly used drugs, which allow them to provide point-of-care decision support feedback for excessively high or low rates

and doses (Figure 1). These devices may be programmed to provide "soft" alert feedback, which allows overrides, and "hard" alerts that cannot be overridden. For example, a pump that is programmed with an uncommonly high insulin infusion rate of 20 units per hour may trigger an alert requiring the nurse to confirm this dosage before permitting an override, while an alert for a rate of 200 units per hour should be a "hard" stop that cannot be overridden. Drug libraries may be unit specific, with unique rules for individual clinical areas such as pediatrics, obstetrics, and critical care. Additionally, the use of certain IV medications may be prohibited outside certain clinical areas (such as prohibiting the use of neuromuscular blocking agents outside of intensive care units [ICUs] and operating room settings) [2].

Despite these features, using an earlier iteration (2002) of smart pump technologies, we found that while smart pumps prevented several life-threatening adverse drug events, we were unable to demonstrate a significant reduction in serious medication errors. We concluded that many of the potential benefits of pumps were missed because of the pump design and previously unforeseen clinical practices that included violations. The earlier pump design made it difficult to access the limited-size drug library and resulted in either an inability to find the drug in the library or intentional bypasses of the library's decision support features. Hard alerts were not instituted, and nurses frequently overrode the soft alerts. These pumps did not allow nurses to administer medication boluses. In part for this reason, nurses created numerous workarounds that

resulted in potentially dangerous practice violations [3, 4].

Figure 1. The smart pump is programmed by using the drug library, which determines if the medication dose and rate are within predefined acceptable limits

Although recent pump designs have corrected several of these usability and drug library limitations, Nuckols and colleagues found that many preventable IV medication adverse drug events (ADEs) in ICUs were still not prevented with slightly more current infusion pump technologies (2003). They concluded that integration of smart pumps with CPOE, real-time vital sign alerts or laboratory results, and automated closed-loop drug titration hold promise for patient safety. It appears that we are making progress but still have not yet designed the "genius" infusion pump [5].

2. From "Dumb" to "Smart" Pumps

The first programmable IV infusion pumps came into use more than 40 years ago. Being able to program a specific rate and volume made modern infusion therapy possible; but these "dumb" pumps could accept any infusion rate from 0.1 to 999 mL/hr or higher. Programming 54 instead of 5.4, 800 instead of 8, or entering the volume as the rate could each deliver a fatal dose. Compared to medications delivered via other routes, IV medication errors are twice as likely to cause patient harm. For the next three decades, the potential for pump mis-programming and other errors remained a critical issue [6].

In the late 1990s a technological breakthrough — electronically erasable programmable read-only memory (EEPROM)—made it possible to develop "smart" pumps with safety software that could be customized to a hospital's specific care areas and patient types. The customized software generated an alert or prevented infusion altogether if pump programming exceeded the hospital-established limits. The widespread implementation of such pumps significantly improved IV medication safety. In more than 10 years since their introduction, smart pumps

have [7]:

- Fostered development of drug dose limits.
- Promoted standardization of concentration and dosing units.
- Allowed hospitals to configure pumps to match applications.
- Provided a "treasure trove" of infusion data.
- Documented many "good catches" of prevented programming errors.
- Uncovered high degree of variation in infusion practices.
- Identified human factors issues/opportunities for manufacturers.
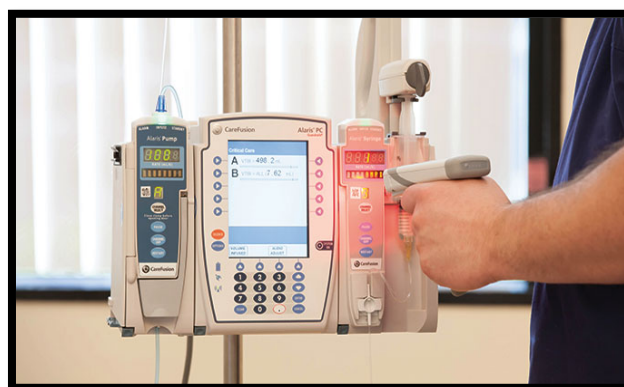- Promoted wireless connectivity/server applications.

Figure 2. Infusion Auto-Pump Programming Using Barcode Scanning

While smart infusion pumps alone may prevent pump programming errors, they cannot prevent giving the wrong drug or the wrong concentration, or giving the drug to the wrong patient. In a large multicenter study that included 24 hospitals, Barker found an administration error rate of 11%, excluding wrong-time errors [8]. An observational British study found IV administration errors in 42% of doses; IV boluses that were infused at an excessive rate were especially common. Recent tragic events in two leading hospitals underscore prevailing systematic deficiencies in the medication system. In both cases, errors led to the wrong concentration of IV heparin being administered, resulting in 1000-fold overdoses. These errors were responsible for the deaths of three newborn infants at Methodist Hospital in Indianapolis in 2006 and placed the premature twins of actor Dennis Quaid at life-threatening risk at Cedars-Sinai Medical Center in 2007. These overdoses most often occur in settings where heparin vials of different concentrations are stocked in patient care areas, allowing them to bypass pharmacist checks [9].

Bar-coded medication administration (BCMA) coupled with an electronic medication administration record (eMAR) targets errors that occur at the drug dispensing, transcription, and administration stages. BCMA provides point-of-care verification of the correct patient and medication. When electronically linked to CPOE, this medication system also electronically tethers the administration to the medication

order. The BCMA system includes a single-unit dose bar-coded medication package that is scanned prior to dispensing from the pharmacy. Prior to administration, the medication package is scanned by the nurse using a handheld barcode scanning device to confirm the right medication (Figure 2) [5].

Figure 3. Barcoded Medication Administration

Next, the patient's wristband is scanned, verifying that the drug to be administered is the correct medication, for the correct patient. The nurse then scans her bar-coded identification badge, which electronically records the medication administration in the patient's eMAR. Portable laptop computers provide nurses with real-time eMARs and can provide alerts for late or missed medications as well as links to drug reference information and medication administration guidelines. Assessing the impact that technology has on the workflow of end-users is critical. A recent study by Poon and colleagues found that prior to implementation of BCMA, nurses spent 26.5% of their time on medication administration. This changed little after BCMA implementation (24.5%). In a survey of nursing satisfaction associated with BCMA/eMAR technology, nurses preferred the technology to prior medication administration systems. Additional trials evaluating the impact of this technology on reducing medication errors at the administration stage are currently near completion [10].

Although costs associated with implementation of BCMA/eMAR technology are considerable, cost-benefit analysis of a home-grown BCMA dispensing system showed favorable results. In this study, researchers analyzed costs associated with preventing pharmacy dispensing errors. The study found that within 4¼ years of development and implantation, or within 1 year of becoming fully operational, the system surpassed the break-even point to a positive financial return on investment. An obstacle to universal dissemination of BCMA is the lag in availability of bar-coded single-unit dose medications from pharmaceutical manufacturers, which requires some institutions to repackage and bar code those drugs not yet available in the single-unit dose format [11].

Unintended and usually undesirable consequences of health care technologies may result from technical defects but more commonly are due to design flaws related to human factors and real world use, unexpected or unaccounted cultural and behavioral interactions, and inadequate training and implementation. Examples of such unintended consequences are detailed in a recent study of workarounds or practice deviations associated with BCMA. Koppel and colleagues found that nurses overrode alerts for 10.3% of medications charted. They identified 15 types of workarounds (e.g., affixing patient ID barcodes away from the patient and carrying pre-scanned medications on carts) and 31 different causes for the workarounds (e.g., unreadable medication barcodes, unreadable or missing patient ID wristbands, and battery failures) [12].

3. From "Smart" Pumps to "Intelligent" Systems

A major limitation has been that even with connectivity, infusion pumps typically operate in insolation—not assigned to a particular patient, not aware of the intent of therapy, unaware of caregiver proximity, and unable to interact with other safety technologies. Wireless connectivity and direct communication with BCMA, the hospital information system (HIS), and other systems can overcome these shortcomings and elevate the current smart pumps to the new level of "intelligent" infusion system [13]. Fully developing and implementing such systems will take time, but the impact will be dramatic [6].

The 2011 American Society of Health-System Pharmacists National Survey showed that in the intervening eight years, the vast majority of hospitals had implemented or budgeted for the foundational technologies of CPOE, BCMA, smart pumps, and electronic medical records (EMRs) (Pedersen et al., 2012). Almost a decade after Ohio Valley General Hospital's implementation, the technologies, software applications, regulatory approvals, and multidisciplinary teams were in place in most large hospitals to implement scalable, sustainable, reliable smart pump-EMR integration for house-wide clinical use [9].

4. Possible Starting Points

Several factors make infusion pumps an ideal starting point for interoperability: the very large number of devices

in a typical hospital, the critical importance of the drugs being infused, the growing base of wirelessly connected pumps already installed, and their uniquely bidirectional information transfer, both from and to the pump. A few hospitals have already implemented closed-loop systems that integrate BCMA, smart pumps, and the electronic medical record (EMR), as described below. But other entry points are also possible. For example, one hospital might decide that interfacing the smart pump and BCMA systems is the highest priority, while another might choose to work on sending alarms directly to the patient's clinician. An ultimate goal is to connect and monitor all infusion-related systems in a type of "air traffic control" surveillance that would automatically flag any critical, infusion-related situation that requires immediate attention [14].
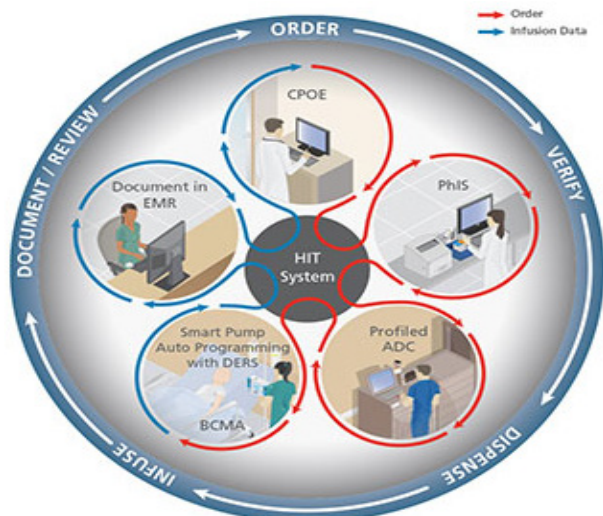

Figure 4. Fully Integrated, Closed-Loop, Medication Safety System

5. Conclusions

The adoption of smart infusion pump and BCMA technology is still early, with recent estimates indicating rates of hospital adoption of 44% and 23%, respectively. Nurses are considered the front line of patient defense in detecting patient deterioration and protecting patients by recovering errors caused by other clinicians. Despite this vital charge, until recently nurses had few if any safeguards between them and the patients to prevent medication administration errors. New technologies now provide tools for clinicians to enhance safety throughout the medication use process.

REFERENCES

[1]   Aspden P, Wolcott JA, Bootman JL, Cronenwett LR. Preventing Medication Errors. Washington, DC: National Academies Press; 2007.

[2]   Kaboli PJ, Hoth AB, McClimon BJ, Schnipper JL. Clinical pharmacists and inpatient medical care: a systematic review. Arch Intern Med. 2006; 166: 955-964.

[3]   Healthcare Information and Management Systems Society. US EMR Adoption Model(SM). Retrieved April 18, 2014 fromhttp://www.himssanalytics.org/hc_providers/emr_adopt ion.asp.

[4]   Cina JL, Gandhi TK, Churchill W, et al. How many hospital pharmacy medication dispensing errors go undetected? Jt Comm J Qual Patient Saf. 2006; 32: 73-80.

[5]   Cescon DW, Etchells E. Barcoded medication administration: a last line of defense. JAMA. 2008; 299: 2200-2202.

[6]   The Joint Commission. (2013, April 8). Medical device alarm safety in hospitals. Sentinel Event Alert, 50. Retrieved from http://www.jointcommission.org/assets/1/18/SEA_50_alarm s_4_5_13_FINAL1.PDF.

[7]   Nuckols TK, Bower AG, Paddock SM, et al. Programmable infusion pumps in ICUs: an analysis of corresponding adverse drug events. J Gen Intern Med. 2008; 23(suppl 1): 41-45.

[8]   The Joint Commission. (2013). National Patient Safety Goals Effective January 1, 2014. Hospital accreditation program. Retrieved from   http://www.jointcommission.org/assets/1/6/ HAP_NPSG_Chapter_2014.pdf.

[9]   Pedersen, C. A., Schneider, P. J., & Scheckelhoff, D. J. (2012). ASHP national survey of pharmacy practice in hospital settings: Dispensing and administration—2011. American Journal of Health-System Pharmacists, 69(9), 768-785.

[10] Hurley AC, Bane A, Fotakis S, et al. Nurses' satisfaction with medication administration point-of-care technology. J Nurs Adm. 2007; 37: 343-349.

[11] Russell, R. A., Murkowski, K., & Scanlon, M.C. (2010). Discrepancies between medication orders and infusion pump programming in a paediatric intensive care unit. Quality and Safety in Health Care, 19(Suppl3), i31-5. doi: 10.1136/qshc.2009.036384.

[12] Koppel R, Wetterneck T, Telles JL, Karsh BT. Workarounds to barcode medication administration systems: their occurrences, causes, and threats to patient safety. J Am Med Inform Assoc. 2008; 15: 408-423.

[13] Survey investigates role of pharmacy in technology use in hospitals [press release]. Bethesda, MD: American Society of Health-System Pharmacists; February 24, 2008. Available at: http://www.ashp.org/s_ashp/article_press.asp?CID=168&DI D=2037&id=24262.

[14] Vanderveen, T. (2013). Intravenous infusion medication safety: The vision becomes reality. Patient Safety & Quality Healthcare, 10(2), 24–30. Retrieved from http://www.psqh.com/marchapril-2013/1598-intravenous-inf usion-medication-safety-the-vision-becomes-reality.htmlfusi ng Patients Safely: A Future Vision.