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Intelligent Infusion Technologies

Integration of a Smart System to Enhance Patient Care

ABSTRACT
Medication errors, particularly intravenous therapy-related errors, still continue to occur, despite implementing newer technologies such as "smart pumps" to help avoid causing harm to patients. The Institute of Medicine report *To Err Is Human*, published in 1999, brought the problem of medication safety into the spotlight with a focus on improving the drug delivery systems of parenteral medications. The objective is to use this knowledge to help reduce errors, thereby promoting the best possible result for patients—no harm. Achieving this goal is not out of our reach, and with the execution of various point-of-care medication delivery systems, we are on the way to a safer practice.

Key words: barcoding, EMAR, IV medication errors, nursing, patient safety, point-of-care delivery systems, smart pumps

Every year, there are an estimated 1.5 million preventable adverse drug events (ADEs), including 7000 deaths.[1] Among serious medication errors, about one-third occur at the ordering stage of the medication process, another third occur during medication administration, and the remaining third occur in about equal numbers during the transcription and dispensing stages.[2]

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According to the US Food and Drug Administration, between 2005 and 2009 there were 56 000 reports of infusion pump incidents. Included in these statistics were 710 deaths, which resulted in the recall of 87 infusion pumps.[3]

Approximately 20% of high-alert medications, when used in error, have an even higher risk for causing harm.[4] Anticoagulants, opiates, insulin, and sedatives remain among the high-alert medications, and the inappropriate use of these can account for upwards of 50% of all preventable ADEs.[5] Medications are an important constituent in treating and managing many diseases and conditions; however, if used incorrectly or inadvertently, they are also capable of bringing harm to the very people who are already the most vulnerable.

As a hospitalized patient, the likelihood of receiving an intravenous (IV) medication as part of treatment is quite high, somewhere in the 90th percentile.[6] That is a sobering statistic, and given the preventable drug error rate, how can a patient feel safe?

The Joint Commission has specific guidelines that outline the processes hospitals should follow in the management of medications. This can vary depending on the services and treatments each facility provides; the goal, however, is to make this a framework for a safe and successful system, with patient safety being the end point.

There are multiple steps included within the process of medication ordering to the end point of the patient bedside. Several technologies, including various point-of-care systems, have been designed to reduce the risk of serious medication errors during the different stages. These include automated dispensing cabinets (ADCs), bar coding, computer order entry, electronic medication administration records (EMARs), and smart pumps. The individual characteristics of each technology are beyond the scope of this article; however, a brief description of each will be provided.

AUTOMATED DISPENSING CABINETS

Introduced in the 1980s to hospital pharmacies, ADCs can be described as computerized drug storage devices that are typically located near the point of care[7] so that nurses have timely access to the medications needed for each patient and the pharmacists are able to restock easily. The ADCs are linked to a patient's profile, and after the practitioner has ordered the appropriate medications through computer order entry, on the pharmacist's review, they become accessible to the nurse for administration. Some of the benefits of ADCs are in the practical aspects of medication processing. These include tracking user access and dispensing medications in real time, supporting security measures to minimize narcotic diversion, restricting individual or high-alert medications, and allowing greater control of drug capture and medication inventory.[7]

As with all technologies, the ADCs come with their limitations, such as the overriding drug feature.[8] It is not uncommon that in emergent or code situations, a drug is needed that is not part of a patient's profile. Because many steps are required to have a drug ordered, the quickest way to access this medication is to override the drug in the ADC, which will dispense it immediately. If the turnaround time for pharmacy approval of a drug is slow or the clinician order entry is not done in a timely manner, nurses may override the system to get the medication faster, which defeats the ADC's purpose. It is worth pointing out that not all drugs are accessible via the overriding feature and, in that case, would need to be taken from the code cart for emergency situations.

Errors can occur during the stocking and restocking process, and placing an incorrect medication in the cabinet or in the wrong drawer will increase the likelihood of an error. The placement of medications within the cabinet to keep look-alike or sound-alike medications from being stored together will also help minimize the removal of the wrong drug from the drawer. Most ADCs are designed with one large drawer that opens to display multiple bins with various medications. Some bins are equipped with blinking lights, signaling where the appropriate drug is located. For example, a green flashing light will tell the nurse where the correct drug is housed, and if the wrong bin is opened in error, a red light will flash accompanied by an alarm signaling that there is a problem. This, however, is not a standard feature for all ADCs.

BAR CODING

Bar coding is an inventory control system used to prevent error within the drug administration process. The bar codes enable a nurse to precisely administer medications while documenting the administration electronically, in real time.

The idea of implementing a bar code system in a hospital setting is to increase quality and safety for patients by improving the accuracy of medication administration.

Ideally, before the drug gets to the nurse, the hospital pharmacy ensures that each drug is labeled with a unique code before it is distributed to the ADC or to the floor where the patient is located. If the medication is not bar coded by the manufacturer, the hospital's centralized repackaging center will add a bar code prior to its distribution.[8]

At the bedside, along with a scanner and laptop computer equipped with EMAR software, the nurse verifies his or her identity by scanning the hospital identification and then scans the patient's identity bar code and the appropriate medication. Once the user has scanned the patient wristband and the medications to be given, the software verifies that the correct medication and dosage ordered is administered at the correct time, assuming that the patient has the correct wristband on to link to his or her patient profile. If, in the process of scanning, the bar codes do not match up, the EMAR software will send a signal to the laptop screen indicating that there may be a problem. The nurse will then have to identify why there appears to be a discrepancy with administering the medications.

Some hospitals have a drug storage and retrieval system that allows restocking of the medications to the ADCs, using bar code scanning. It is also notably helpful for managing inventory.

The limitations of bar coding include technical issues related to the scanner and its identification of the precise bar code. The bar codes on the medication packages, bottles, or IV bags are not always amenable to scanning because of either the functionality of the actual scanner or an issue with the bar code itself. Another potential problem is the positioning of the bar codes on the patient wristband. Sometimes the bar codes are difficult to read, making it nearly impossible to scan. This is not a perfect system and can lead to workarounds such as manual entry of the patient's identification and the drug being administered, thereby defeating its purpose.

COMPUTERIZED PRESCRIBER ORDER ENTRY

Computerized prescriber order entry (CPOE) is an electronic way to order treatments for patients, including medications, radiologic testing, home care services, and referrals, most often in combination with the electronic medical record. In analyzing data related to ADEs, the ADE prevention study group noted that throughout the medication process, there was a higher incidence of errors stemming from the ordering stage than from any other.[9]

Leape et al[2] performed a systems analysis of ADEs among a sample of hospitalized patients and found that the majority of events occurred during the ordering and administration stages (39% and 38%, respectively). Twelve percent of events occurred during the transcription and verification stage, and 11% of events occurred during the pharmacy dispensing stage. Lack of knowledge about the drug and lack of information about the patient were the 2 most common attributable causes to ADEs identified in this study. Bates et al,[9] in their analysis of the incidence of both actual and potential ADEs, found similar results. Of the actual ADEs that were considered preventable, 49% occurred during the ordering stage, 11% occurred during the transcription stage, 14% occurred during the dispensing stage, and 26% occurred during the administration stage (Table 1).[9]

The CPOE system requires that the medication orders include drug name, dose, route, frequency, and indication of *pro re nata* (as needed) orders.[8] Other applications have been used as an adjunct to CPOE to provide additional support to clinicians. For example, at Brigham and Women's Hospital (BWH) in Boston, Massachusetts, an application called Nephros was introduced, which assists with dosing drugs that are nephrotoxic and renally toxic.[10] Gerios, another application, addresses the issue of ordering initial medication doses that could potentially be too large for the elderly population. This can help avoid drug-related complications, such as mental status alterations.[11]

ELECTRONIC MEDICATION ADMINISTRATION RECORD

EMAR is an electronic version of the conventional patient chart that contains specific information, including (but not limited to) patient medications, allergies, medical history, and demographics. This is most often used along with bar code verification, providing real-time information at the bedside. It eliminates the need for the manual transcription of orders, which reduces the rate of transcription errors. EMAR was designed to be linked in with pharmacies, clinical lab systems, smart pump IV systems, and other resources to access evidence-based guidelines.[8]

This system has the ability to prompt nurses to document those parameters associated with administering medications. These include pain scales, blood pressure readings, and a patient's weight. It also sends alerts for overdue medications and for those drugs that were discontinued by the order clinician.

TABLE 1

Adverse Drug Events During the Medication Process

Task	Bates Analysis of Medical Errors Occurring, %	Leape's Analysis of Actual Preventable Adverse Drug Events, %
Clinician ordering	39	49
Dispensing from pharmacy	11	14
Transcription	12	11
Nurse administration	38	26

Adapted from Leape et al[2] and Bates et al.[9]

SMART PUMPS

Smart pumps are medical devices used to deliver IV fluids, including nutrients and medications, into a patient's body in a controlled manner.[12] These devices are designed to house a drug library with the hospital's specific drug formulary, warning the user of potential unsafe drug errors. Smart pumps are set up to continuously display the name of the medication, dose, and rate of infusion. These pumps come with a safety net, storing drug information and making calculations while referring to the dosing parameters.[13] The pumps are also configured to allow for infusions within different types of patient populations, such as pediatrics, obstetrics, oncology, and intensive care units. They allow for the standard concentrations, maximum and minimum loading doses, and bolus limits. If an inputted dose is too high or too low based on these drug standards, an alert will sound to allow the user to double-check that the number entered is correct.

Although smart pumps have provided additional safety measures in the administration of IV medications, they are not foolproof. Errors related to IV medications are the leading cause of life-threatening ADEs[14] because they often involve "high alert medications"[15] and are the least likely to be caught before being administered to the patient.[6] IV medications have an immediate onset, and their effects are extremely difficult to reverse once administered.

One study in 2005 found that the most common reason for administering the wrong infusion dose was the erroneous programming of the IV pump.[16] Limit setting is part of the unique technology of smart pumps. The lower limit is the lowest dose that triggers an alert, and, on the flip side, the upper limit is the highest programmed dose that will set off an alert. Hard dose limits are critical in preventing infusion errors because they are fixed and cannot be changed by the user of the pump. Soft limits are also part of the alert system; however, these can be changed or overridden by the user.[17]

EVALUATION OF A POINT-OF-CARE SYSTEM

As a staff nurse working at BWH in Boston, Massachusetts, the author was able to take part in the rollout of a technology system implemented to increase patient safety from the pharmacy to the bedside. This system used ADCs, EMARs, bar coding, CPOEs, and smart pumps. These technologies were implemented to better improve the safety of medical care within a hospital setting.

BACKGROUND

BWH is a 793-bed teaching hospital, located in Boston's Longwood Medical area. It is an affiliate of Harvard Medical School and one of the founding members of Partners Healthcare System.

It has been ranked on *U.S. News & World Report*'s honor roll of America's best hospitals for 18 consecutive years, and in 2010 it ranked 11th. BWH was also recently recognized by the University Health System Consortium for being 1 of 5 top-performing academic medical centers in the country in a special quality and safety benchmarking study.[18]

The author is one of 2800 nurses employed by BWH, and her experience speaks to her time on the cardiac step-down unit. This point-of-care system was a 10-month rollout that started in November 2004 and was completed in August 2005 and involved the majority of the inpatient units, with the exception of the emergency department, procedural areas, and the oncology floors. Nurses were on the forefront of this new system, and extensive training was required in order to use the laptop/EMAR system, bar code scanners, and smart pumps efficiently and effectively. "Super users" were available to help 24 hours per day, 7 days a week. These nurses, information system analysts, and pharmacists were all extensively trained to provide support and troubleshoot the glitches. Using the applications took time and patience, but practice makes perfect (or almost), and the learning curve became less frustrating and more accepted. This was the new way to provide care for the patients, and in the end, safety came first.

The day-to-day problems became less apparent, and even the laborious scanning of medications, which in theory seemed to be the most straightforward task but proved otherwise, also made work flow more efficient. As with any new technology system, the workarounds to bypass safeguards became a recognized way of accomplishing the tasks at hand. The reasoning behind this was multifactorial, but ultimately it is faster to manually enter the drugs rather than using the bar code and scanning feature. Another reason was simply that this was a new way of working, and the glitches were not always straightforward, which could become time consuming. For example, manually entering in the medication and patient identification bracelet, rather than scanning, was becoming part of practice for some. The override feature to manually enter some information was allowed by the system, but it was certainly not meant to take the place of scanning.

Another issue involved not scanning the entire quantity of medication required for the order. For example, for an order written for 60 mg of furosemide po [by mouth], the drugs were dispensed by the ADC as 20-mg tablets. Therefore, 3 separate tablets would be needed. Nurses, instead of scanning each individual tablet 3 times, were scanning the same 20-mg furosemide pill 3 times, which was incorrect. The system was designed to scan each tablet, one by one, for accuracy.

Smart pumps were yet another part of the point-of-care system, and although these were in existence by the year 2000, significant upgrades were made, especially with the execution of the new wireless system. The safety feature of the drug library was instituted to prevent errors related to drug dosage; however, if a nurse bypasses the library, the margin for error becomes much higher. Selecting the wrong drug to infuse or the incorrect dose is more likely to occur, which can then lead to an ADE.

Now, with wirelessly connected pumps, doses ordered in CPOE would be verified by the pharmacy and, in turn, updated in EMAR. The IV fluid or medication ordered is scanned by the registered nurse (RN), as is the patient identification band. This registers in real time in EMAR, and the patient's medication profile shows that the specific medication is running at the correct dose, at the right time. EMAR also tracks the length of the infusion and, once complete, asks the RN to document it. For continuous infusions, such as with dopamine, verification in EMAR is needed every 4 hours, to indicate that the correct dose and medication is being given to the right patient. Orders written to increase or decrease the dose are also documented in EMAR.

CONCLUSIONS

The pharmacy and nursing departments performed studies once the execution of this system was complete. The pharmacy department demonstrated an 85% reduction in dispensing errors with the implementation of bar code scanning. This also represented a 63% decrease in potential ADEs.[19] Poon et al[20] documented a 41% reduction in nontiming administration errors and a 51% reduction in potential drug-related adverse events associated with this type of error by the implementation of both medication verification and bar-coding technology being introduced into EMAR. Errors in the timing of medication administration fell by 27%. No transcription errors or potential drug-related adverse events related to this type of error occurred. The nursing department at Brigham and Women's Hospital also examined nurses' satisfaction with the new bar code and scanner system by comparing satisfaction levels before and after its introduction. They used a 6-point Likert scale, with 1087 nurses' satisfaction scores assessed in 3 areas—safety, efficacy, and access. The satisfaction levels prior to the system implementation showed that nurses were satisfied with the existing systems (average Likert score = 4.1). After the conversion, nurses were more satisfied (average Likert score = 5.1).[21]

The implementation of a comprehensive point-of-care system can reduce discrepancy at all levels during the medication process, thereby making drug administration safer for patients, which is the ultimate goal. As nurses at the bedside, we are often the last line of defense for patients. The success of a system such as this needs to incorporate the technological advances, but it also requires a collaborative effort by all involved to help ensure that patients receive the best possible care.

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