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## **Successful Implementation of Intelligent Infusion Technology in a Multihospital Setting: Nursing Perspective**

Lisa Longshore, MSN, RN, CNP  
Timothy Smith, BSN, RN, CRNI®  
Michelle Weist, PharmD, BCPS

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# Successful Implementation of Intelligent Infusion Technology in a Multihospital Setting

## Nursing Perspective

### ABSTRACT

Complexities of today's medications and greater use of high-risk medications place the patient at an increased risk for nursing errors. The purpose of this case report is to present, from a nursing perspective, the successful experience of a multihospital healthcare system's quest to decrease or eliminate medication administration errors through implementation of intelligent pumps. This case report focuses on the vital role that nursing services played, including the selection of pumps, development of the drug library, education of end users, and strategies employed to achieve a high compliance rate. Also described are the ongoing educational efforts, lessons learned, and specific results in intercepting significant medication administration errors.

(ADEs) occur in the United States each year.<sup>2</sup> This report outlined a comprehensive approach to decreasing the prevalence of these errors, such as encouragement of patient involvement in their own healthcare and increased use of new technology.

Technological advancements and complexities of today's medications have made it even more difficult to medicate patients correctly and have contributed to risks of nursing errors.<sup>3</sup> Over the last 40 years, the number of medications available for prescribing has increased 10-fold. This includes an increase in high-risk intravenous (IV) medications with narrow safety margins (ie, "high-alert" medications) that are associated with a large potential for patient harm. Often these drugs involve complicated protocols and procedures, which in turn carry an increased risk of drug, dose, and route errors in the administration stage.<sup>4</sup> This is especially concerning because the medication administration step is the most vulnerable in the medication-use process since there are no or limited checks for nursing.

Delivery devices were not capable of providing safety features in medication administration. That technology is now available. This case report will demonstrate how an organization was able to incorporate and implement new technological advances that promote patient safety.

Intravenous high-risk medications are usually administered through infusion pumps. Although IV infusion pumps improve the accuracy and continuity of IV drug administration, these devices continue to be involved in a large number of ADEs that occur annually in the United States. These ADEs are largely attributed to calculation errors leading to inappropriate pump programming<sup>5-7</sup> and thus are costly and can result in significant morbidity and, occasionally, mortality. Over the last 20 years, the Food and Drug Administration has received several hundred reports of incidents involving infusion pumps, and many of these have led to patient deaths.<sup>8</sup>

**M**edication errors occur frequently and universally. In 1999, the Institute of Medicine first brought attention to this subject by reporting that more than 1 million medication mishaps occur each year, causing 98,000 patient deaths, more than caused by vehicle accidents, breast cancer, or AIDS.<sup>1</sup> In 2006, the Institute of Medicine follow-up report reaffirmed the findings and concluded that at least 1.5 million preventable adverse drug events

**Author Affiliations:** Jewish Hospital of Cincinnati (Ms Longshore, Mr Smith), and Health Alliance (Ms Weist), Cincinnati, Ohio.

**Corresponding Author:** Lisa Longshore, MSN, RN, CNP, Jewish Hospital of Cincinnati, 4777 E Galbraith Rd, Cincinnati, OH 45236 (lisa.longshore@healthall.com).

At many institutions, nurses are paving the way to decrease or eliminate medication administration errors through a new generation of IV infusion pumps, known as “intelligent pumps,” that use wireless medication safety software.<sup>9</sup> The key feature of this software is that customized drug libraries can be developed. A drug library is a list of parenteral medications, their admixture concentrations, and software functionality that provides point-of-care decision support for overly high or low IV infusion rates. The device prompts the user to choose a medication from the library, confirm the selection, input a volume to be infused, and input an infusion rate or dose. For all medications selected from the library, the keypad entry of an infusion rate in milliliters will automatically calculate the equivalent dose in units, milligrams, or micrograms. The intelligent pump will alert the nurse if institution-defined parameters (ie, drug dose, dosing unit, dosing rate, or drug concentration) are outside of preestablished limits.<sup>5</sup> In addition, intelligent pumps have free-flow protection that prevents unintentional overdelivery of fluids or medications.

When the IV pump project started, of the 7 goals identified in the 2004 National Patient Safety Goals of The Joint Commission, 5 related to medication administration.<sup>2</sup> These goals may be positively impacted by implementing an intelligent pump system, but only if a high rate of compliance is achieved. For example, the second goal is improving the effectiveness of communication among caregivers, which can be achieved, in part, by standardizing abbreviations, acronyms, and symbols pertaining to medications. The third goal is improving safety when high-alert medications are used. The other goals relate to improving the safety of pumps and the effectiveness of clinical alarm systems that include infusion pump alarms. Also, the Joint Commission recommends healthcare institutions conduct proactive risk-management activities that will identify system weaknesses, predict the outcomes of these weaknesses, and adopt system changes to minimize the potential for patient harm. The specific implementation of the intelligent IV pumps was presented by one of the hospitals in a healthcare system (ie, the beta site) as a performance improvement project for The Joint Commission based on the 2006 goals. Today, medication safety continues to be a concern in the 2009 National Patient Safety Goals, with Goal 3 being “Improve the safety of using medications,” which is specifically related to sound-alike/look-alike medications, labeling medications, and reducing harm due to anticoagulant therapy. Some solutions are provided with the safety features that are embedded into the intelligent technology of IV pumps, such as capital lettering for high-alert drugs and hard and soft limits that alert the end user of infusion therapies that are out of the average range.

This article discusses, from a nursing perspective, a multihospital healthcare system’s quest to decrease or eliminate medication administration errors through the implementation of a new generation of IV infusion pumps, known as intelligent pumps, that use wireless medication safety software.<sup>9</sup>

## BACKGROUND: CLINICAL SITE

The multihospital organization is an integrated healthcare delivery system that includes teaching, acute care, and rehabilitative hospitals. These facilities offer a range of medical and surgical services, including a level I trauma center; AirCare helicopter transport services; cardiac care services; women’s health services (including a level III perinatal center); neurological services; oncology, blood, and bone marrow transplant services; orthopedics; and behavioral medicine as well as primary care. Nursing services use a patient-centered care approach where each nurse is responsible to provide care and IV therapy to their assigned patients.

## SELECTION AND PLANNING

Several challenges existed that encouraged the organization to implement pumps with safety software. The most pressing challenge was the advanced age of the legacy IV pumps; most pumps were between 11 and 14 years old and in need of repair. The healthcare system was using 5 different models of IV pumps, which became problematic since 2 models were upgradeable but required the purchase of increased memory. In addition, the cost of the repairs of the existing pumps had increased and was significantly impacting budgets.

Another challenge was the prevention of IV medication errors to ensure patient and family well-being. Published studies show that nursing errors are often underreported, and effective ways are lacking to encourage nurses to actively report errors.<sup>3</sup> Since drug administration errors represent the majority of medication errors, the legacy pumps could not intercept errors before they occurred, nor could they assist the nursing and hospital administrations to aggressively discover and address errors, especially with “high-alert” medications.

A systemwide, multidisciplinary expert task force (composed of clinical nurses from each hospital, as well as pharmacy, information technology, bioengineering, and supply chain representatives) was convened to perform an assessment of possible replacement technologies. The clinical nurse, also referred to as the clinical lead for that hospital, was chosen for this project based on her or his expertise in the field of IV therapy. The clinical leads served as the “subject-matter experts.”

The published literature was reviewed, evaluated, and presented to the task force. The task force determined that the fleet of IV pumps across the healthcare system should be replaced at once with IV pumps with intelligent technology. The task force garnered support for the project through presentations at multiple forums and set criteria for pump selection, including considerations for a wireless platform.

A return on investment (ROI) analysis with evidence to support the need to purchase intelligent pumps with safety technology was completed to support such a large capital expense. As part of the ROI, nursing services conducted a systemwide needs assessment analyzing fiscal components, as well as process improvement through standardization and streamlining. Specific analyses included IV tubing set use and the process of cleaning, storing, and delivering IV pumps. A major percentage of pump damage occurs during the cleaning and delivery process. The doors on the devices can break during the cleaning process. Damage also occurs as devices are transported from one area to another, either by dropping them or by banging them against doors and walls, especially when trying to deliver too many devices at a time to a nursing area. Conducting the assessment was a vital component in evaluating supply and demand, developing the best process for cleaning and delivering the pumps, and validating the need for new devices.

Administrative personnel from the multihospital-system task force, including the chief executive officer, chief operating officer, chief information officer, as well as chief nursing officers and senior vice presidents, were involved in reviewing and approving the proposal. The leadership was in full support of implementing this safety technology and remained involved throughout the selection and implementation process.

Nurses were an integral part of the team that reviewed all marketed intelligent IV pumps, and all levels of nurses were included in the process. After viewing vendor presentations and spending hands-on time with the various pumps, nursing management interviewed other hospitals that had already purchased and implemented the intelligent pumps to determine their level of satisfaction. Nursing management also used that opportunity to glean any recommendations or tips from the other hospitals regarding implementation processes.

## IMPLEMENTATION AND RESOURCES

A medication administration team (MAT) with representatives from nursing, pharmacy, and information technology from each hospital was appointed and charged with implementing the intelligent IV infusion pump system. Several standardized systems/processes

relating to medication administration were already in existence across all hospitals, which facilitated the implementation procedure (Table 1). A Web site was created to post materials relevant to IV drug administration. Nursing services assumed pivotal roles within this committee (Table 2).

The MAT conducted a failure modes and effects analysis to identify high-risk situations that could hinder a successful switch from the current to new technology. A plan for IV pump report generation and review was outlined prior to implementation, and expectations were set. The goal for adherence to safety software use for each hospital was established as 85%. The goal of 85% was determined to account for the emergency situations in which one could not take the extra time to program the pump using the drug library (it does require a few extra keystrokes). The 85% also considered the emergence of new IV drugs or formulary changes that would not show up in the drug library until the next drug library update. Although intelligent pumps have great promise for the future, technological and nursing behavioral factors must be addressed if these pumps are to achieve their potential for improving medication safety.<sup>10</sup> The additional steps needed to program a medication in the drug library increases the time spent in delivering medications. New technology can present challenges to existing nursing practices and may

### TABLE 1 Integration of Existing Standardized Systems/Processes Analysis

Standardized systems already exist  
 Clinical information system (IDX Lastword® Enterprise Clinical System)  
 Computer-generated MAR  
 Pharmacy compendium  
 System-wide formulary

Standardized additional aspects related to medication administration  
 Standardized concentrations  
 IV push medications by unit  
 Continuous infusions by unit  
 Guidelines for IV medication administration  
 Guidelines for oncology medication administration  
 Standardized policies  
 IV medications and solutions approved for administration by nurses  
 IV medications via infusion device or gravity, safe administration

Abbreviations: IV, intravenous; MAR, medication administration record.

## TABLE 2 Nursing Roles and Responsibilities Within MAT

Defining infusion pump deployment strategy
Ensuring patient safety software usage and compliance
Reviewing and modifying current intravenous infusion policies and procedures
Providing feedback to other teams
Providing feedback on building the drug library
Coordinating clinical education program
Reviewing and approving vendor in-servicing process and content
Ensuring approval of all defined clinical care areas and final library
Ensuring ongoing successful drug library updates to infusers

require breaking down old beliefs while changing the culture. However, such technology may also potentially save time by freeing clinicians to engage in other tasks that would be expected to result in safer care.<sup>10</sup> Staff feedback analysis, in addition to the hard limits now provided by intelligent infusion pumps, can be potential solutions to the successful adoption and correct use of the pumps' safety features.

The MAT was charged with decision making related to the drug library. As the drug library is built, it is important that all key players are included; for example, pharmacy is needed to ensure that guidelines in the delivery of the medications are followed, and nurses currently involved in administering IV medications are needed for their knowledge of day-to-day ordering patterns.

The intelligent pump has a customizable drug library. There are clinical care areas within the pump that are referred to as CCAs. Each CCA has its own drug library that is based on the scope of practice for that nursing floor. For example, cardiac drugs are not in the medical/surgical CCA since the delivery of these drugs requires telemetry. The nurse who is working with a patient on telemetry will choose the "telemetry" CCA. All of the CCAs display on the first screen once the pump is turned on. The nurse must then choose the CCA needed for that patient. This allows every pump to be used in every setting. When a patient is transferred to another setting, the same pump can be used by changing the CCA to correlate with the patient's level of care. See Table 3 for a complete list of CCAs.

Another step in building the drug library was deciding on pump default settings (eg, IV piggyback vs continuous, to keep vein open vs rate, and PSI [pounds per square inch]). Using preestablished standardized concentrations, continuous infusion grid tables, and reports generated by IDX Lastword<sup>®</sup> Enterprise Clinical System, the pharmacists and nurses developed the CCA-specific drug libraries. Incorporating a training CCA that enables the staff to view icons and make errors is beneficial to keeping the data accurate during the training period.

The libraries were then reviewed and approved by the MAT. It was essential that a systemwide drug library be developed. In doing so, a standard of care was established for IV drug administration and efficiencies obtained by supporting a single drug library. Drug library updates were scheduled according to the implementation plan for each hospital so that identified problems could be corrected prior to subsequent

## TABLE 3 Clinical Care Areas

CCA
BMTU
ED
Hemodialysis
Hospice
ICU/PACU
Med/Surg
NICU
OB/L&D
Oncology
OR/Anesthesia
Outpatient
Ped/Nursery
Specialty Units
Step-Down
Telemetry
Training

Abbreviations: BMTU, bone marrow transplant unit; CCA, clinical care area; ED, emergency department; ICU, intensive care unit; L&D, labor and delivery; NICU, neonatal intensive care unit; OB, obstetrics; OR, operating room; PACU, postanesthesia care unit.

implementations. Wireless capability was mandatory to allow this process to occur smoothly and in a timely manner.

## TRAINING

The nurse educator assumes a pivotal role in the implementation process because she or he is involved in patient care and understands how the policies and procedures are accepted into practice. The nurse educator also comprehends the workflow that may identify barriers impacting acceptance of the new intelligent IV pump technology. The nurse educator was involved with all of the MAT meetings from inception and became the “go to” person for any questions related to nursing practice. The nurse educator for a single hospital also designed and implemented the educational plan for the system, and it was the educator’s hospital that went “live” first with the new intelligent IV pumps, becoming a beta site for the system.

To facilitate adherence with IV pump policy, all nursing and pharmacy personnel were required to attend in-service pump training. The benefits of safety technology and the requirement to use the safety software were emphasized. An important aspect of the training program was to recognize and communicate that using safety software may require an increased time commitment to administer each infusion from the already-overworked nurse. A vital realization is that there are no shortcuts to using the safety software and that providing a safer environment to patients is worth the time invested.

One of the methods used to train the clinicians involved was the development of “super user” classes where each nursing unit was represented. The ultimate goal was to achieve acceptance from the nursing staff and have them embrace the technology. During this 2½-hour class, the nurse educator reviewed the roles and responsibilities for the super users (Table 4). After training, each participant was given a “super user” button to advertise the project and to identify themselves as someone for other staff nurses to go to for any concerns or questions. Displaying the button created excitement for the new technology and helped with overall acceptance.

After the super user classes, the nurse educator designed and implemented standard training for the remainder of the nursing staff. Realizing that people learn differently, the nurse educator provided several options of learning styles. Each nurse could choose between an instructor-led class and a self-paced class. Demonstration pumps accompanied the self-paced binder in each of the nursing conference rooms. If opting for the self-paced class, participants were required to successfully set up 3 different types of infusions before completing the class.

## TABLE 4 Super Users’ Roles and Responsibilities

### General

- Attend a training class.
- Assist with general education classes.
- Remind nurses on unit to attend the general education classes.
- Encourage nurses to complete the infusion device learning CD and practice with the demonstration devices that will be located on each unit prior to implementation.
- Act as trainer for those who miss the general education class.
- Act as a general resource for questions that arise with the pumps on the unit and neighboring units.
- Notify unit of super user status.
- Assist pharmacy with questions related to medication infusions on unit.

### Implementation day

- Assist nurses in placing pumps.
- Assist nurses in placing the new devices on patients if programming help is needed.
- Ensure that each pump is changed out.

### Post-“go live” day

- Make sure the drug library is being used.
- Continue to provide support to nurses.
- Report any therapies that are not listed in the drug library.
- If a drug is not listed in the CCA, look at the reference material to see where the drug is located.
- If nurses are getting out of the CCA frequently to find a drug, notify pharmacy that a drug may need to be added to additional CCAs.
- Make sure that all of the devices are plugged in and the doors are kept closed when not in use.

Abbreviation: CCA, clinical care areas.

Maximizing compliance starts in the classroom with the nurse educator emphasizing the importance of compliance with the new intelligent IV pump safety software. Often educators undervalue the extent to which they can influence the success or failure of a project. The educator’s attitude can signal the audience if they do or do not believe in a system, policy, practice, or technology. At this facility, the nurse educator compared using the drug library to other safety measures and stressed that a nurse can jeopardize the safety of the patient by bypassing the drug library.

As staff training progressed, several misunderstandings or challenges were encountered. One such challenge was understanding that when the concurrent mode is used, the maximum rate is 500 mL/h of the 2 rates combined. The other challenge was understanding how medications were administered. For example, nurses were looking for some drugs that did not exist in the drug library, such as trying to administer promethazine on channel B (maintenance IV was on channel A) as a piggyback instead of giving IV push. The nurse educator devoted special attention to explaining these situations.

*Going live* is the term used for the official start of the new intelligent pump technology. The nursing clinical project leader plays an important role during implementation and going live. The leader should be available along with the vendor to assist staff acclimation to the new intelligent IV pumps during the initial days of implementation. The clinical project leader at the multi-hospital system worked as many shifts as possible to ensure an understanding of the impact made on the implementation of this new intelligent IV pump technology impacted the day-to-day operations of the unit.

Numerous practice issues were not identified until after the official “go live” day. One of the most important methods to increase initial compliance was to optimize the use of the drug library and ensure that it functioned easily for the nurse to incorporate in her or his practice. All nurses were encouraged to discuss issues concerning drug libraries during group meetings; for example, staff would report occasions when they experienced difficulty using the pump to meet the needs of their patient. The MAT would dissect whether it was an individual practice issue or whether the library needed to be changed. The nursing clinical project leader developed daily tip sheets to reinforce some of the lessons learned.

It is important to address problems within the drug library; otherwise, nurses may create workarounds. For example, study drugs were being used in the bone marrow transplant patients and were not readily available in the drug library. The staff nurses were selecting alternative line items such as IV antibiotic or IV therapy. An investigational drug line item was added to the drug library and data were captured more accurately.

The demonstration intelligent pumps remained on the floor for 1 month after going live. The demonstration pumps were used by the nursing staff especially if they needed to set up a new infusion or program; they could practice with the demonstration pump before administering the medication to the patient.

Overall, the staff adapted very well to the new technology; however, it was important to continue highlighting the importance of always using the drug library. When the workload was high, some members of the nursing staff felt that it would be permissible to bypass the new pump safety software when administering replacement IV fluids. This was not approved, however, because it was felt that if the staff developed good habits and consistently used the intelligent pump software, they would eventually become more efficient and faster in programming the new pumps when administering other medications. Some nursing staff members believed that the new IV pumps increased their self-confidence while decreasing their anxiety about making IV medication errors, especially when calculations or “high alert” medications were involved.

**Measuring and Increasing Compliance**

Initially, compliance was measured by conducting walking rounds, which provided an opportunity to give immediate feedback to the nursing staff. As more was learned about the vendor-generated reports that were available, the reports were used to track compliance locally. Through the software and wireless component of the intelligent pumps, the designated Web site (password protected) can be accessed to see which areas of the hospital are not in compliance with using the drug library. There are numerous other reports that can be generated, including soft limit edits; all keystrokes involved in a program to identify an error; and drug infusion by medicine or time of day to identify most frequently infused drugs versus the busiest day of the week or time of day.

The infusion device policy, developed by the MAT, stated that the drug library would be used for all infusions. Initial compliance with the intelligent pump software across all campuses was between 68% and 88% (Figure 1). The goal was 85%. Once it was demonstrated that a higher compliance was possible by one of the hospitals, the goal was increased to 90%.

Start Date	Institution	March 07	April 07	May 07	June 07	July 07	Aug 07*	Sept 07	Oct 07	Nov 07
2/26/07	(Beta Site)	68.2	68.2	69.7	71.3	78.3	78.9	82.5	85.1	88.1
3/26/07	Hospital B		69.5	71.4	69.3	79.4	86.7	86.4	83.9	75.2
5/21/07	Hospital C				75.2	78.6	78.6	76.4	75.2	73.6
7/30/07	Hospital D					81.7	80.7	81.5	80.1	80.2
8/1/07	Hospital E						85.6	86.2	85.7	84.8
8/27/07	Hospital F						87.6	81.7	81	81.7
<b>Bold: Partial Month Drug Library Update</b>		Highlighted rates adjusted for board upgrade								
		April 4	May 6	July 13				Nov 1		

**Figure 1** Initial compliance rates with drug library and drug library updates.

Each month the data were analyzed and reported to the MAT. The magnitude of errors in the cases in which reprogramming occurred were quantified. Subsequent user action was captured in the device memory. From these data, “significant edits” that may have averted serious adverse events associated with high patient morbidity and mortality were determined. Each month the significant edits were reported back to nurses and discussed during staff meetings. By providing this feedback to the end users of intelligent pumps, they were consistently reminded of the power of the infusion safety software for intercepting administration errors pertaining to real patients. This reporting mechanism has increased staff members’ belief in the value of intelligent pump technology and is an essential component to obtaining and sustaining a high compliance rate. The top-10 medications associated with significant errors are listed in Table 5.

The IV pump project was not submitted to the institutional review board since patient-specific information was not reported. The information was reviewed internally for quality assurance purposes.

## CASE REPORT: BETA SITE HOSPITAL

One of the hospitals was chosen to be the beta site (ie, the initial hospital to implement the intelligent

pump technology). It was a facility that includes open heart recovery, bone marrow transplantation, intensive care, cardiac surgery step-down, orthopedic surgery, and general medical/surgical/telemetry beds. In addition, this hospital had an emergency department and a cardiac catheterization/interventional radiology unit. Clinical care areas were built to complement the areas of specialty.

Predictably, because it was the first hospital that went live, the beta site hospital had the lowest initial compliance rate at 68%, for several reasons. It was difficult to identify the workflow issues that would become barriers to successful use of the drug library with every IV infusion when the library was being created, and not having a “perfect library” fostered the belief among nursing staff that it was appropriate not to use the library, resulting in poor compliance. Increasing compliance became the hospital’s performance improvement project.

Compliance did improve once a second drug library was updated and “pushed.” However, once the staff became comfortable using the new pumps without using the drug library, it became more challenging to compel the staff to embrace it.

As more hospitals started using the new IV pumps with intelligent technology, the MAT started comparing the hospitals. This provided the beta site hospital with more incentive to identify measures to increase compliance, given that competitive edge and the need to show that an ROI was being achieved.

The nursing clinical project leader and the nurse educator for the beta site hospital were assigned the responsibility of increasing compliance by identifying and correcting episodes of noncompliance in real time. With the infusion status report, staff found not to be using the drug library were given immediate feedback, and an assessment was completed to find out if the library was not being used because of a lack of knowledge or the perception that the library was not useful. Both issues were then addressed. For those who perceived that the pump was not useful, discussion would include realistic examples of errors that the pump had prevented, such as insulin not being started at 66 units an hour or heparin at 8000 units per hour.

Members of the nursing staff who were identified as administering IV infusions out of the library on more than 1 occasion were sent to retraining. It was usual for these nurses to express surprise at what they had forgotten from the original training and satisfaction with retraining. The vendor continued to play an important support role by returning to the hospitals to provide additional education for staff. These in-service retraining sessions not only provided educational opportunities but also promoted group discussion to uncover situations that prevented staff from using the drug library. For example, the secondary mode to deliver IV antibiotics is frequently referred to as giving “piggybacks.” When the

### TABLE 5 Top-10 Medications Most Frequently Associated With Significant Errors

Abciximab
Antibiotic piggyback <sup>a</sup>
Eptifibatide
Fentanyl
Heparin
Insulin
Magnesium
Potassium and sodium phosphate
Potassium bolus
Propofol

<sup>a</sup>Antibiotics are listed as 1 entry in the drug library.

secondary mode pops up, “piggyback” is displayed on the screen. Many nurses assumed this was validation that they were using the drug library appropriately, not realizing that “piggyback” was simply the name of the mode. Uncovering this misconception had a positive impact on increasing compliance.

To spark interest, competition was added to the performance improvement project of increasing drug library compliance. The compliance rate for each floor was compared, and the floor with highest compliance received a pizza party. Tactics like this helped nurses hold each other accountable for using the drug library.

When individual units did not meet the goal, the manager was required to develop an action plan for increasing compliance. Compliance reached the goal of 92% in only 5 months after a concerted effort was made to reach the target goal. Individual CCAs identified as not reaching the standard of 92% began completing pump rounds to ensure that all pumps were using the drug library. A stretch goal of 94% compliance was set in July 2008 and exceeded by October 2008 with every major CCA reaching greater than 92% compliance. All of these efforts now have the beta site hospital’s compliance in the 95% range (Figure 2). The efforts to foster use of the drug library and make the drug library user-friendly have truly paid off.

## UPDATES AND WORKLOAD

The drug library was updated 4 times during implementation. The wireless technology of the intelligent pumps

helped facilitate the update of the drug library. A new drug library was developed and sent to each device, and the device stored the upgraded library until the IV pump was turned off. Incorporating the “library install” prompt to display when turning off the pump prevented therapies from being interrupted due to the belief that if the pump was being turned off, it was no longer needed. Once the “install new library” prompt displayed, the user had to choose “yes” to install it. If the user chose “no,” then the library remained in pending status until the next time the pump was turned off. This process is similar to that of a computer waiting for upgrades from existing software programs. Concerns regarding the drug library were forwarded to the Department of Pharmacy Services and added to the agenda for the next scheduled meeting of the MAT. Nursing staff were asked for their input, and the MAT reviewed the staff requests and determined feasibility. Postimplementation, the drug library was scheduled to be updated (“pushed”) twice a year and whenever an urgent need arose. Failure to make the appropriate adjustments in the drug library was considered a failure of the organization.

The overall workload for nursing services initially increased with the implementation of intelligent pumps because of the time needed to program the pump. Unfortunately, it still may be considerably time-consuming, especially when administering a drug located in the middle of the alphabet in a CCA that has several pages of drugs to scroll through. However, most nurses reported that it was worth the extra time commitment to use the software as a second safety check. Seasoned

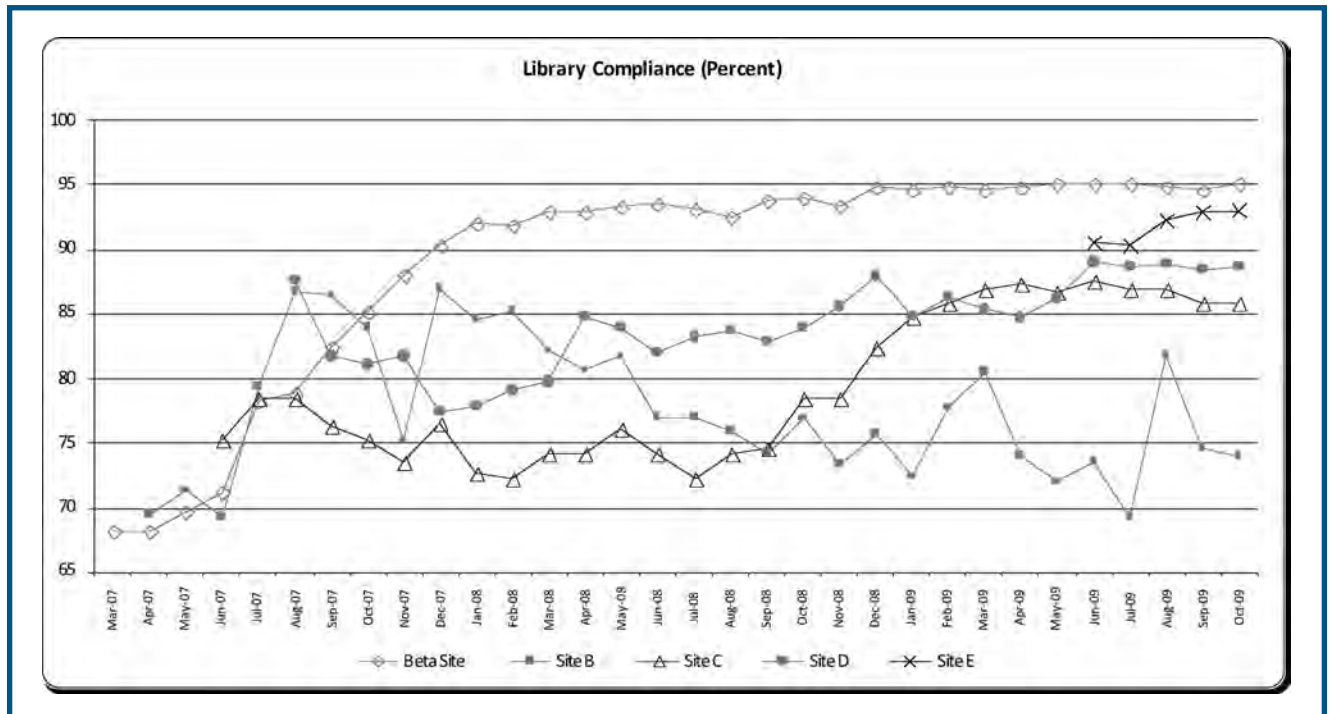


Figure 2 Compliance rates (March 2007-October 2009). Fiscal year is defined from July 1 to June 30.

nurses, who may have been resistant to the technology at first, explained that they were able to save time by preprogramming the pump, leaving it in standby mode, and hitting start when ready to use. New graduate nurses who were exposed to the technology in other roles reported ease of using the pumps. Culture change has occurred within the healthcare system; staff now monitor each other and have been observed teaching students and instructors on the floor how to use the technology. During the last 12 months, compliance was determined to range from 72% to 95% (Figure 2).

## REDUCTION OF MEDICATION ERRORS

During the previous 13-month evaluation period, the study determined that the intelligent pumps averted 680 significant medication alerts, many of which were triggered by high-alert medications. It is important to note that averting significant underdosing of medications in certain patient populations can be as important as preventing overdoses. For example, underdosing of heparin may result in extreme detrimental consequences such as thrombus formation, pulmonary emboli, and even death. For all of these alerts, the users either reprogrammed the device or cancelled the infusions.

The reporting function of the intelligent pump software is also beneficial in the delivery of medications. For example, in the event/alarm report, the nurse can review every key stroke keyed into the pump, which may be valuable in determining when a medication was administered when timing therapeutic drug levels to be drawn. This function is also useful to identify when the drug library was not in use or when a mistake was made.

### Examples of Errors Averted

When the drug library was initially implemented, a mechanism for staff to administer a fentanyl bolus for pain control and sedation was not included. This was discovered when a nurse attempted to bolus fentanyl from the primary bag and inadvertently administered a large dose of fentanyl to the patient. After reviewing this problem, the MAT developed a syringe bolus with appropriate limits on the total amount of drug that could be infused.

Another error uncovered and corrected was administering IV bolus furosemide. This was discovered after staff attempted to increase the rate at which the pump would allow them to administer furosemide during high-dose therapy. This served as an opportunity to reinforce that furosemide should not be administered at a rate greater than 4 mg/min during high-dose therapy.<sup>11</sup>

An example of a significant error that the pump prevented occurred when a nurse inadvertently programmed

a pump to run insulin at 66 units per hour as opposed to the ordered 6 units. Because the nurse used the drug library correctly, the pump would not run until the error was corrected, thus preventing an ADE for the patient and nurse.

## COST ANALYSIS

It has been estimated that each preventable ADE in the hospital setting is associated with an additional inpatient cost of \$8750 (2006 dollars).<sup>2</sup> This accounts only for direct costs and does not estimate indirect factors such as lost earnings or compensation for pain and suffering.<sup>2</sup> Assuming the occurrence of 628 intercepted significant errors annually, the annual cost savings through the prevention of infusion-related ADEs by the use of intelligent pumps with safety software in this multihospital system is conservatively estimated to be \$5,495,000 (2006 dollars), not including any associated litigation costs. This cost savings translates into approximately 83 full-time equivalents (FTEs) per year. Because nursing salaries comprise a large portion of the hospital budget, if money can be saved elsewhere, more nurses may be available at the bedside.

### Management Pearls/Lessons Learned

1. Nurses will use the device that makes them feel most comfortable and competent. To make a technology culture change, it is necessary to replace the entire fleet to promote best practice and not to have the old pumps available.
2. Tracking compliance needs to be considered when creating the CCAs. For example, units providing telemetry should be broken into subcategories. It is impossible to determine accountability when too many nurses are using the same CCA. For example, instead of an overall telemetry CCA, label the CCA as the name of the unit so only 1 unit is using the specific library.
3. Ask staff for their input on which drugs show up on the first page of the drug list. This healthcare system has a page of most frequently used drugs; the remainder of the list is in alphabetical order.
4. It is time-saving for standard IV solutions to be listed as "IV fluids" or "IV fluids with potassium" instead of listing each one separately in the drug library. Also, consider listing antibiotics as either "antibiotic syringe" or "antibiotic piggyback."
5. Place the pump setting in "standby" mode to save settings (settings erase after 4 hours if the pump is turned off) and save the staff time.
6. Add the drug library documentation to the daily patient record. The nurses must document what CCA they are using and if the drug library is in use.

## CONCLUSIONS

Technological advances can assist nurses in the goal of caring safely for patients. However, it requires true dedication of an organization and inclusion of staff at all levels to successfully implement technology to reap the many benefits it has to offer. The successful implementation of new technology allowed staff in this case report to embrace pumps as an adjunct to safe practice through the reduction of medication errors. Even though change is often viewed as difficult, the staff adapted quickly and competently with the adoption of the intelligent pumps. Adding safety features to a busy work environment has decreased the burden and fear of making a mistake. Three years after the first implementation, the nurses still spoke with enthusiasm about the IV pumps.

This multihospital healthcare system made a total commitment by all levels of management and staff to implement the intelligent IV pumps with safety technology throughout each hospital. Adequate training and retraining, if necessary; daily surveillance of compliance; timely drug library updates by the pharmacy; and overall belief in the importance of this technology led to achieving a goal of greater than 92% compliance. Implementing intelligent IV pump technology averted many significant errors and, in turn, resulted in a culture of increased safety for the patients and staff.

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