



**Institute for Safe  
Medication Practices**

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# Effective Approaches to Standardization and Implementation of Smart Pump Technology

A CONTINUING EDUCATION PROGRAM FOR PHARMACISTS AND NURSES

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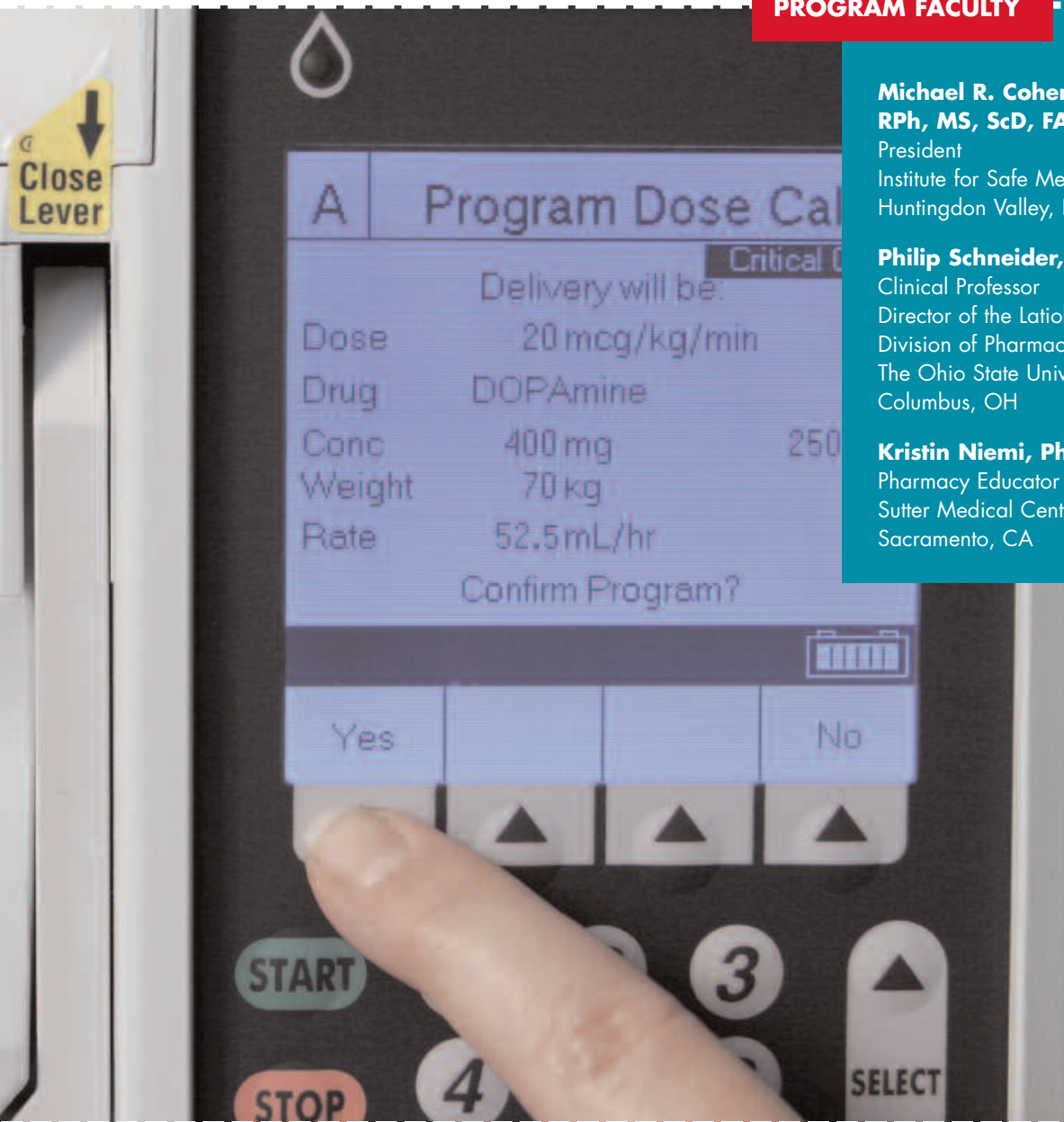
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## LEARNING OBJECTIVES

### After studying this monograph, the reader should be able to:

1. Describe the recommendations of the 2006 Institute of Medicine (IOM) report on preventing medication errors that relate to infusion therapy and “smart” pump technology.
2. Discuss the current state of smart pump use in U.S. hospitals.
3. Understand the role of smart pump technology in preventing medication errors.
4. Create a plan for smart pump implementation, including defining scope of use, development of drug libraries, providing education, and conducting maintenance and monitoring.

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# Impact of Smart Pump Technology and Findings from the 2006 IOM Report on Preventing Medication Errors

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The 1999 Institute of Medicine (IOM) report *To Err Is Human: Building a Safer Health System* accelerated efforts to prevent errors and improve quality of care. In 2003, Congress directed the Centers for Medicare and Medicaid Services (CMS) to contract with the IOM for a comprehensive study of drug safety and quality issues.

In 2006, *Preventing Medication Errors* was published. The objectives of the report were to conduct a comprehensive evidence-based literature review on medication safety, provide specific guidance to consumers, providers, payers, and other key stakeholders on high priority prevention strategies, and help identify national agendas for medication error reduction.

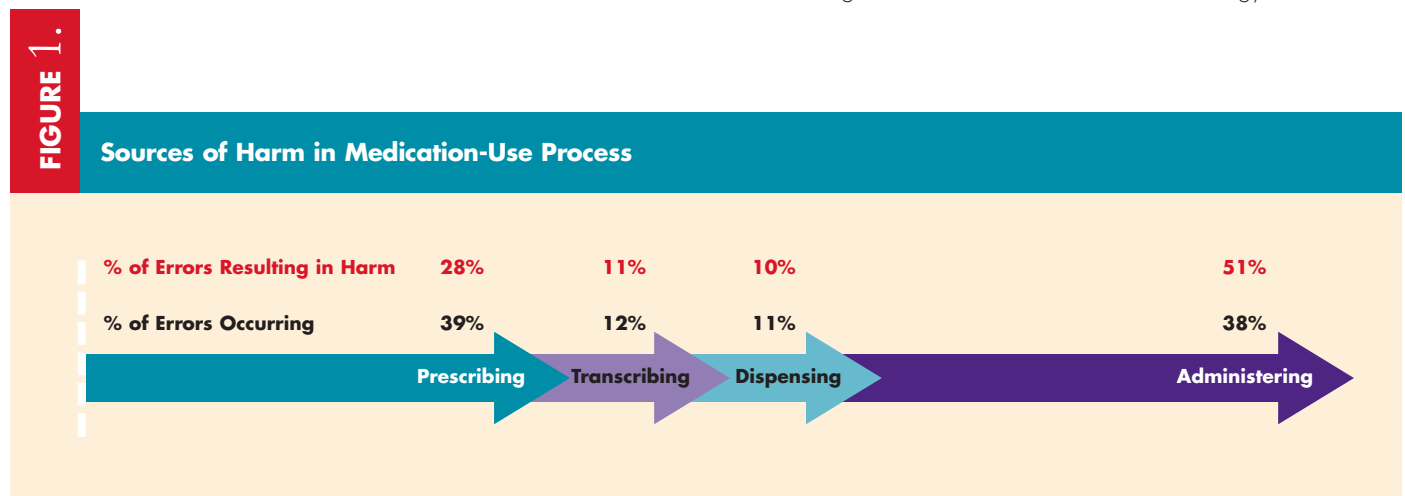
The intention of the report was to investigate all aspects of medication safety, including the impact of technology in averting some of the 1.5 million preventable adverse drug events that occur in U.S. hospitals each year. The committee's major recommendations included widespread adoption of healthcare information technology by healthcare facilities.

## WHERE HARM OCCURS IN THE MEDICATION-USE PROCESS

When discussing the benefits of medication management technology, it is useful to focus on where the greatest improvements can be accomplished. In 1995, Leape, Bates, and colleagues published findings from a study (see Fig. 1) in which they audited the medication-use process and identified where medication errors take place and the degree of harm associated with those errors (*JAMA* 1995; 274: 35-43).

The researchers found that most errors occur during the prescribing and administering of medications. It is clear the most harmful errors happen during administration, which is why the Institute for Safe Medication Practices (ISMP) has placed special focus on this area of medication use.

ISMP has identified several drugs and drug categories that can be considered 'high alert'—those more likely to result in patient harm when involved in an administration error. Some recommended prevention methods include standardizing commercially available concentrations, preparation in the pharmacy when commercial concentrations do not exist, and setting dose limits in medication-use technology.



## ROLE OF TECHNOLOGY IN PREVENTING MEDICATION ERRORS

Many technologies have been developed to prevent errors from occurring at different points in the medication-use process, from the time a patient history is taken all the way to medication administration and monitoring. Technology can provide high-level error-prevention strategies, including constraints, forcing functions, automation, and standardization.

Available technology includes wireless handheld devices for recording patient histories, computerized physician order entry (CPOE) systems, robotic dispensing systems, “smart” pumps, and bar-code point-of-care administration. Surveys undertaken by ISMP and the American Society of Health-System Pharmacists show that bar code and smart pump technology is increasingly being used for drug administration management.

[Medication-use] technology can provide high-level error-prevention strategies, including constraints, forcing functions, automation, and standardization.

The 2006 IOM report on preventing medication errors strongly recommends that “...all healthcare organizations immediately make complete patient information and decision support tools available to clinicians and patients.” This includes making effective use of well-designed technologies, providing access to comprehensive reference information concerning medications, assessing the safety of medication use through active monitoring, and subjecting prescriptions to evidence-based and current clinical decision support.

An important aspect of this recommendation is the suggestion that prescribers have plans in place to prescribe medications electronically by 2008, and that all prescribers order prescriptions and all pharmacies receive them electronically by 2010.

## INCREASING USE OF SMART PUMPS

Several statements were made in the IOM report advocating use of specific technologies, such as smart infusion pumps, as a way to deliver safer care. Findings from ISMP Medication Safety Self Assessments® for Hospitals, which were conducted in 2000 and 2004, suggest that smart pumps are becoming increasingly common. In 2000, virtually no facilities reported use of smart pumps. In 2004, approximately 30% had employed the technology.

The use of smart pumps was a widely recommended intervention in the IOM report. More rigorous testing was suggested, based on a controlled trial of smart pumps in which Rothschild and colleagues (*Crit Care Med* 2005; 33(3): 533-40) found that while smart pump implementation identified errors, the rate of errors did not change.

One reason for this finding may have been the fact that the pumps involved in the study at that time were designed in such a way that it was easy for users to override the set limits and bypass the safety software. As a result, they were not engaging maximum dose limit warnings. Pump software today is more advanced, and offers the capability of preventing users from bypassing important set dose limits.

A 2005 study (*Am J Health Syst Pharm* 2005; 62(5): 917-20) found the most common reason for administering the wrong infusion dose was the incorrect programming of the intravenous (IV) infusion pump. This step in the medication-use process was associated with the highest criticality index. A dramatic reduction in the percentage of pump-related errors was seen after the facility implemented an IV pump with enhanced safety features.

Another reported problem with the use of infusion pumps has been key bounce. Key bounce results from pressing once on a pump’s number key and getting an unintended repeat of that same number. This occurs when the key is softly or partially pressed for a time, or if programming a pump from an odd angle. Errors also have resulted from accidentally hitting a number key twice, or intentionally hitting the key twice because the corresponding number did not appear immediately on the screen.

## ADDITIONAL IOM RECOMMENDATIONS

Another recommendation in the 2006 IOM report addressed industry and government collaboration to establish standards for drug-related health information technologies. The report proposed that the Agency for Healthcare Research and Quality (AHRQ) lead the effort to organize safety alert mechanisms by severity, frequency, and clinical importance to improve their value and acceptance.

The IOM also advised that improved labeling is needed for communicating medication information to practitioners and consumers. Approximately 30% of the medication errors reported to the United States Pharmacopeia-ISMP Medication Errors Reporting Program relate to labeling and packaging. The Food and Drug Administration needs to develop guidance statements to clearly convey to the industry the expectations for safe labeling practices and drug nomenclature.

Oversight by the regulatory organizations and payers in order to motivate adoption of technologies that can reduce medication errors also was proposed by the IOM. State boards of pharmacy were urged to undertake more quality improvement activities and accreditors of professional education to require more education in medication-related areas. In addition, CMS was called upon to evaluate strategies for delivering medication therapy management to patients. Organizations that acquire medication technologies should be recognized publicly and acquire preferred provider status. They also should be given an increase in pay for performance, which has already been implemented as part of Medicare legislation.

## SUMMARY

Recommendations from the IOM's 2006 report *Preventing Medication Errors* encourage healthcare organizations to make complete patient information and decision support tools available to clinicians and patients. In addition, they were urged to adopt technology that allows practitioners to communicate medication-use information and measure the safe use of medications with active monitoring.

The IOM report emphasizes that well-designed technology, such as smart pumps, has a definite role to play in enhancing patient safety and preventing medication errors and advocates its use. Recent research from ISMP and other organizations shows that smart pump technology is increasingly being used for drug administration management. ■

## Key Points/Recommendations from the 2006 IOM Report on Preventing Medication Errors Include:

- All healthcare organizations should immediately make complete patient information and decision support tools available to clinicians and patients.
- Many medication errors resulting in patient harm involve IV infusion devices, with the most common cause of these errors being incorrect programming.
- To deliver safe drug care, healthcare organizations should make effective use of well-designed technologies...these include smart pump technology.
- Industry and government should collaborate to establish standards affecting drug-related health information technologies.
- Oversight by regulatory organizations and payers should utilize incentives to motivate the adoption of practices that can reduce medication errors and ensure that providers have needed competencies.

# Technology-Related Findings from ASHP's Surveys of Pharmacy Practice in Hospitals and Other Studies

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Every year the American Society of Health-System Pharmacists (ASHP) conducts a national survey of pharmacy practice in hospital settings, which facilitates tracking and analysis of major trends, including the use of technology. Results reveal the gaps between our vision for the future of pharmacy practice and its current state.

One important area that needs to be addressed in order to move pharmacy practice into the future is the reduction of errors in drug prescribing and administration.

## **SURVEY METHODS**

The ASHP national survey focuses on what practices are in place to improve the safety of medication use. It captures data on the role pharmacists play in managing and improving the six steps of the medication-use process: prescribing, transcribing, dispensing, administration, monitoring, and patient education. Each year, two of the six steps are assessed, and the cycle repeats every three years.

Healthcare organizations are looked at in a number of different ways in the survey. One of the primary distinguishing characteristics is hospital size. Survey distribution is designed to yield a statistically valid sample for each size category, which allows for accurate determinations on what practices are in place in hospitals based on the number of staffed beds.

Utilization of the Dillman method, which involves contacting potential respondents up to six times in order to gather the information requested by the survey, has allowed ASHP to achieve an impressive 50% response rate.

## **ADOPTION OF MEDICATION SAFETY TECHNOLOGIES**

The ASHP survey measures and evaluates the extent to which medication safety technologies are being adopted along different points in the medication-use process.

### **Prescribing and Transcribing**

The Institute of Medicine (IOM) report *Preventing Medication Errors* recommends that there be a plan for computer prescriber order entry (CPOE) by 2008 in every health system, and electronic prescribing be implemented by 2010. Because CPOE shifts responsibility for the entry of medication orders to the prescriber, system interfaces are important. The system often needs to be linked with electronic medical records, which in most hospitals may not be very robust, if they exist at all.

As a result, we found in the first ASHP national survey that the implementation of CPOE systems had been relatively small—only 2% were implementing the technology. The percentage has increased slightly, but the present data still points to less than 10% of hospitals and health systems having adopted CPOE.

Larger institutions have a substantially higher rate of adoption than smaller hospitals. This is no surprise given the expense of these systems and the infrastructure support that is necessary to maintain them.

### **Dispensing**

There also are technologies that allow for improved safety and reduction of errors at the dispensing step of the medication-use process. Pharmacy can be justifiably proud in having developed a systems-based approach to dispensing medicines, as evidenced by the use of unit dose drug distribution and creation of sterile medicines through IV admixture programs.

According to ASHP’s national survey, U.S. hospitals have achieved full adoption of at least one innovation in drug distribution—unit dose systems—but the adoption process occurred over a span of twenty years. The question is whether pharmacy should wait twenty more years to fully implement technologies for which evidence exists suggesting the potential to improve medication safety.

Currently, robotic distribution systems attempt to further improve the system-based approach to error prevention by applying technology to a centralized unit dose program. Robotic distribution requires that medications be bar coded, which is an expensive investment.

Other technologies include automated compounding devices, which are used for large volumes as well as preparing syringes. These devices utilize technology that improves the efficiency and accuracy of admixture processes. In addition, automated dispensing cabinets allow medications to be stored closer to the patient but shift some of the responsibility for dispensing medications from pharmacists to nurses.

The use of these technologies has had an impact on drug distribution. As patients become more acutely sick in hospitals, there is an interest in reducing waiting times and getting medications more quickly to the patient care areas, to the nurse, and to the bedside. Many pharmacies have moved to a decentralized philosophy that positions medications closer to the bedside. Most hospitals still maintain a centralized system as part of the unit dose philosophy, but that number is decreasing as technology facilitates decentralization.

### Administration

A pivotal study published in 1995 (*JAMA* 2005; 274: 35-43) showed that approximately 38% of reported errors that resulted in adverse drug events occurred during drug administration, and only 2% of potential adverse drug events could have been intercepted and prevented with the systems that were in place.

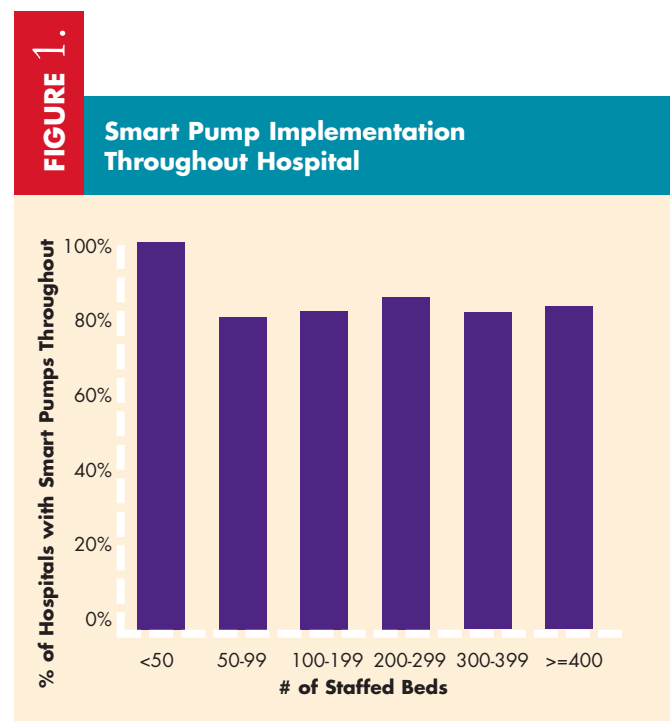
In analyzing data from the ASHP national survey, it is safe to say that hospitals and health systems need to look at adopting technologies that provide safety at the point where an error is much less likely to be intercepted—errors proximal to the bedside or errors in drug administration. In more recent years, there have been substantial innovations in drug administration systems. For example, bar-code medication administration (BCMA) systems have been developed to “hardwire” safe medication practices and provide electronic documentation as well as decision support.

In 2002, the adoption of BCMA reported in the ASHP national survey was less than 2%, or relatively similar to the adoption of CPOE systems. In 2006, well over 10% of participants reported the adoption of BCMA. According to the survey, this technology is being adopted most rapidly by middle sized hospitals. One reason could be that larger hospitals are preoccupied with CPOE systems. Middle sized hospitals may prefer BCMA as a technology that requires less change in physician practice.

“Smart” pumps—infusion devices with drug libraries and decision support—are another technology that provides an additional medication safety check at the point of care. Errors associated with intravenous medications arguably have the greatest potential to cause harm to patients; there is less protection when you give a drug intravenously than when you give it through the oral route. Nurses certainly value the assistance with dose calculations and the alerts that are provided by smart pump technology.

According to ASHP’s national survey, hospitals that have smart pumps in place are using them virtually hospital-wide, rather than only in the ICU, pediatrics, or areas where there might be high-risk patients (see Fig. 1).

In the 2005 survey, the documented adoption rate was approximately 40%. Out of all the technologies explored by the survey, smart pumps are the least tied to hospital size. Smart pumps



appear to apply to hospitals irrespective of how large they are, and are similarly diffused in all but the smallest organizations.

One of the important aspects of the smart pump is the drug library. It is important that nurses utilize this decision support tool and refrain from bypassing it. In the survey, we asked hospitals whether they had institution-specific drug libraries in place. In 2005, at least 60% or more of responding hospitals were using drug libraries.

## DIFFUSION OF INNOVATIONS

It is in our best interests to encourage a faster rate of adoption of new safety technologies than what has been seen to date. In his book *Diffusion of Innovations*, Everett Rogers presents a construct that is useful in helping determine the factors that decide how rapidly new technology such as smart pumps is embraced.

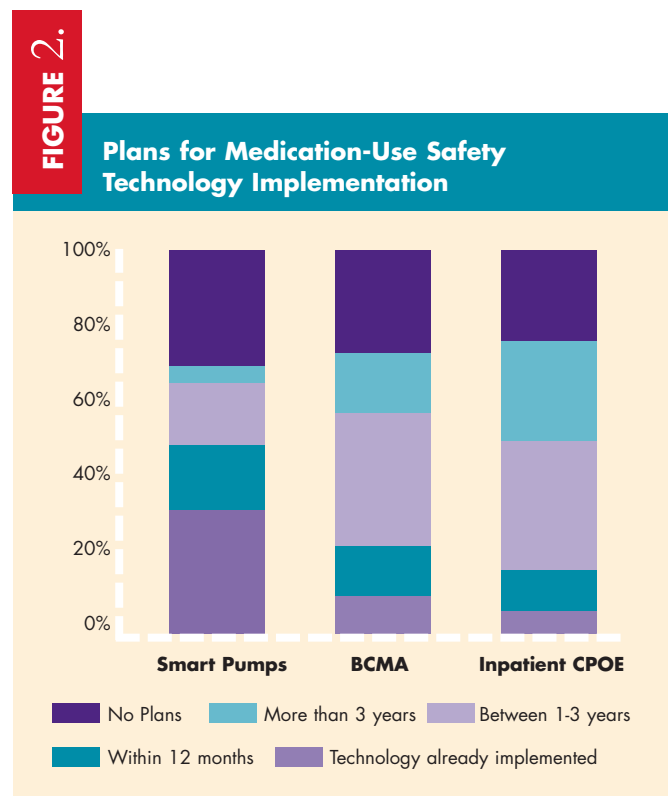
Rogers points out not every innovation is adopted at the same rate. Innovations can be divided into categories—a category 1 innovation is adopted the fastest in the shortest period of time, an innovation 2 takes slightly longer, and an innovation 3 takes the longest. If we look at medication safety technologies in this way, a smart pump is an example of an innovation 1, a bar-code system is an example of a category 2 innovation, and CPOE is an example of a category 3 innovation.

*Diffusion of Innovations* emphasizes that innovations do not sell themselves; they often require a great deal of persuasion. Rogers offers two main ways to speed the process. The first is to choose to begin with the right innovation—find sound technology that can be implemented more quickly. For instance, if you choose to implement CPOE, which is a category 3 innovation in the categories previously described, you should be aware that a substantial implementation timeframe will be involved.

We have asked pharmacy directors what kinds of technologies they used and what kinds they were planning to implement in the future, which helps get at the diffusion rate of medication safety innovations. With this particular sample group, approximately 30% had smart pump technology, 10% had bar-code administration technology, and 7% had CPOE systems (see Fig. 2).

More respondents were interested in implementing smart pumps within the next twelve months than the other two technologies. The next highest priority was bar-code administration within one to three years, and then CPOE systems.

Rogers' second piece of advice regarding speeding up the adoption of innovation is to find and support innovators. Once the right technology is selected, the next step should be to find



individuals in your organization who are thought leaders, and make sure that they are supportive of the effort. One possibility is to have them conduct a beta test or pilot study with the technology to identify problems in advance and therefore be better positioned to champion its use.

Having the assistance of early adopters or innovators in developing decision support and gaining organization-wide acceptance of the project can be invaluable regardless of which technology you are implementing.

## SUMMARY

The ASHP National Survey of Pharmacy Practice in Hospital Settings provides a sense of the status of current pharmacy practice and progress toward embracing new medication-use technology. Of all the technologies covered by the survey, smart pumps were the least tied to organizational size. Hospitals that have smart pumps in place are using them hospital-wide instead of only in designated patient care areas.

The principles of innovation diffusion presented by Everett Rogers can help healthcare organizations decide what type of medication-use technology to adopt and achieve successful implementation. ■

# Case Study of Smart Pump Implementation

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The implementation of new medication-use safety technology, which often falls to pharmacy, can present a challenge to healthcare professionals' traditional roles. The Sutter Medical Center Sacramento (SMCS) experience in implementing "smart" infusion pumps provides a comprehensive overview of the key steps, challenges, and benefits.

SMCS is a 500-bed facility in Sacramento, CA, that features a children's hospital within the hospital. In some settings, such as the operating rooms, it is normal to have a 2 kg pediatric patient in one suite and a 70 kg adult patient in the next suite.

One challenge for the SMCS pharmacy educator was to give an inservice for new nurses on the "rule of six." It quickly became clear that due to the wide range of prescribing practices, no amount of education could ensure adoption of the safety measures needed to utilize the rule of six in preparing and administering continuous infusions in pediatric patients. It was simply an unsafe practice.

As a result, SMCS decided to tackle standardizing both drug concentrations and prescribing styles. The implementation of smart pumps followed from that process. Smart pump technology was rolled out in the pediatric program in 2004 and in the adult patient population in 2005.

Every successful implementation project has a plan. SMCS's plan centered on analyzing the scope of the project, identifying the stakeholders, addressing implementation issues, and conducting follow-up maintenance and monitoring.

## STEP 1: ANALYZE SCOPE OF IMPLEMENTATION

The first questions to ask when implementing smart pump technology in your organization are *where are the safety checks* and *what are you going to include in the new technology?* Implementation with other technology systems enhances the effectiveness of the smart pump. For example, the pump needs to work with standard concentrations, bar codes, electronic medical records and computerized prescriber order entry (CPOE) systems.

SMCS wanted to maximize use of its new smart pumps. It was decided to implement the pumps in conjunction with standard concentrations for continuous infusions that would provide greater safety at that point in the medication-use process. Specific intermittent infusions and chemotherapy were excluded from use in smart pumps, as SMCS did not have bar coding, CPOE, or electronic medical record systems operational during the implementation phase.

## STEP 2: IDENTIFY THE STAKEHOLDERS

Once the scope of implementation is defined, it must be decided *who is going to use the technology?* From the beginning, different perspectives from nursing staff need to be considered. A clinical nurse specialist can reveal how the drugs are used, staff end users can discuss how the pump actually works, and physicians can provide insight into prescribing styles for multiple dosing units that may need to be considered during programming. Nurse educators also play an important role in the implementation process, since they often will be called upon to explain the decision-making process.

Anesthesiologists are one important end user group. To make a successful smart pump drug library for anesthesiologists,

### Key Stakeholders in Pump Implementation

- Pharmacy
- Nursing
- Physicians (key items only)
- Information technology
- Biomedical engineering
- Executive sponsor
- Pharmacy and therapeutics committee

it is important to know what drugs they use, how they use them, and what dosing limits are actually being utilized.

Also include IT professionals in the process. Information technology staff needs to know about available servers and interfaces. The biomedical engineering department needs to be involved in determining how the pumps interact with the software.

Conflict between the different stakeholders can be resolved in most cases. But if consensus cannot be reached, having a previously-designated executive sponsor can help solve disagreements. In addition, the hospital pharmacy and therapeutics committee should be aware and supportive of the implementation process.

### **STEP 3: ADDRESS IMPLEMENTATION ISSUES**

The next phase in getting smart pump technology operational is to deal with the key steps involved in implementation, including developing standardized concentrations, creating drug library subsets, and setting dosing limits.

#### **Developing Standardized Concentrations**

There are many clinical benefits to smart pumps, but the main safety strategies are right at the point of care, so it is important to standardize concentrations. In order to know what concentrations are needed, it is necessary to identify which patient populations are being treated. At SMSC, we identified five groups—the adult cardiac patients, pediatric cardiac patients, NICU patients, decreased renal function/restricted fluid patients, and shock/trauma patients.

Smart pumps may provide additional benefits from a clinical perspective. SMSC was able to adopt the philosophy of separating medication delivery from fluid delivery as part of its smart pump implementation. The goal was to use the least amount of fluid necessary to deliver the medication; clinicians prefer to keep both adult and pediatric post-operative cardiac patients slightly fluid restricted. Prior to introduction of smart pumps, orders were frequently written for double strength dopamine and dobutamine, and double or quadruple strength epinephrine or norepinephrine.

In looking at concentrations at SMSC, it was found that when an order was written for double strength of dopamine in a 2.6 kg patient, it was actually the same concentration as the adult normal dopamine concentration. For a 5.3 kg patient, a double strength of dopamine was equivalent to 800 mg in 250 mL bag. From this finding, it was determined anyone over 5 kg could actually receive 800 mg of dopamine in a 250 mL bag.

This philosophy was applied to many other infusion standardizations. Previously, clinicians were changing drug orders to address fluid issues in restricted patients. Now prescribers can order the drug, the dose, and the route instead of a concentration,

and the pump helps calculate the rate. A maximum concentration protocol exists and is reserved for cases involving truly fluid-restricted patients, where clinicians write a maximum concentration that is applied to all the vasopressors listed in the patient's current medication profile.

When standardizing concentrations, it is important to maximize use of commercially available products. Affiliated hospitals should be encouraged to adopt the standard concentrations used by the facility that has implemented smart pump technology, since it enhances patient safety. SMSC conducts more than 400 transfers in one year just in the NICU; placing patients on facility-defined concentrations allows clinicians to focus all their attention on clinical issues.

#### **Creating Drug Library Subsets**

Another important step in smart pump implementation is the creation of useable drug libraries. SMSC realized that patient care areas had to be defined in order to create library subsets for specific groups of patients.

SMSC grouped adult patient populations by those who were using similar medications—critical care, medical/surgical, telemetry, and maternal/newborn/obstetrics. Neonatal and pediatric patients were grouped by weight—less than 5 kg, 5–40 kg and greater than 40 kg. The advantage of grouping pediatric patients by weight is that only the concentrations used with the weight-specific group are entered into the library, as opposed to entering all available concentrations.

One essential point to keep in mind when creating drug library subsets is that patients move from one care area to another. If a small number of patient care areas is defined in the library, transferring patients between units is easier, although the drugs may not be as customized. It is up to the practitioners controlling the process to decide what size subsets work best for their particular patient population.

#### **Setting Dosing Limits**

Dose limits also have to be addressed as part of smart pump implementation—dosing units are fixed and cannot be changed by the nurse at the pump. So concerns such as weight-based versus standard dosing, same doses but different prescribing styles, and different indications requiring different doses will all need to be addressed.

One way SMSC has addressed the weight-based versus standard dosing issue for code drugs is by creating a software program which integrates patient weight, drip concentrations, and dosing units. Every time a patient comes into the hospital, they get a code dosing sheet. Clinicians can go to any computer, enter the

patient's name and weight, and hit "code sheet." If the patient is less than 35 kg, the pediatric dosing guidelines automatically appear. If the patient is greater than 35 kg, the clinicians are asked whether they need the adult or pediatric guidelines.

See Fig. 1 below for a sample dosing guideline sheet. These are some of the drugs given at the bedside, and dose units would appear in pump drug libraries for nurses to select.

When setting alert limits on smart pumps, the lower limit is the lowest dose that triggers an alert for the end user. Lower limits are not required on every medication contained in the smart pump library. Upper limits are the high doses that trigger an alert. A soft limit is an alert that is displayed but can be overridden. A hard limit is an alert that is displayed but cannot be overridden. See Fig. 2 for a sample report on programming alerts. The pumps utilized by SMSC offer the option of activating hard stops on lower and upper limits.

A non-standard entry occurs when individualized medication dosing needs to be entered by the nurse. This situation is more error-prone because it increases the number of data entry points on the device. Standardization is vital for maximization of pump safety potential. The more concentrations that are standardized to fit certain patient care areas, the fewer incidences there will be of non-standard entries by end users.

The end goal needs to be considered when picking dose limits for smart pumps. The most common goal is to prevent a tenfold dosing error. Limits can also be used to define narrow therapeutic windows (e.g., drotrecogin alpha), support specific hospital policies, define true maximums (hard limits), and create clear IV line labels to prevent mix-ups. Remember that healthcare professionals can suffer from 'alert fatigue'—so it is not wise to overuse limits and warnings or they may begin to be ignored.

**FIGURE 1.**

**Sample Pediatric Dosing Guidelines for Continuous Infusions**

Drug	Dose Range	Mixing Instructions	Reference Dose
<b>Alprostadil (PGE1)</b>	0.04–0.1 mcg/kg/min	2500 mcg in 250 mL	6.7 mL/hr = 0.05 mcg/kg/min
<b>Amiodarone</b>	5–15 mcg/kg/min	450 mg in 270 mL	8 mL/hr = 10 mcg/kg/min
<b>Dobutamine</b>	2–20 mcg/kg/min	1000 mg in 250 mL	3.3 mL/hr = 10 mcg/kg/min
<b>Dopamine</b>	2–20 mcg/kg/min	800 mg in 250 mL	4.2 mL/hr = 10 mcg/kg/min
<b>Epinephrine</b>	0.05–1 mcg/kg/min	8 mg in 250 mL	4.2 mL/hr = 0.1 mcg/kg/min
<b>Esmolol</b>	50–250 mcg/kg/min	2000 mg in 100 mL	6.7 mL/hr = 100 mcg/kg/min
<b>Isoproterenol</b>	0.05–1 mcg/kg/min	2 mg in 250 mL	16.7 mL/hr = 0.1 mcg/kg/min
<b>Lidocaine</b>	20–50 mcg/kg/min	2000 mg in 500 mL	6.7 mL/hr = 20 mcg/kg/min
<b>Milrinone</b>	0.25–0.75 mcg/kg/min	20 mg in 100 mL	3.3 mL/hr = 0.5 mcg/kg/min
<b>Nitroglycerin</b>	0.5–10 mcg/kg/min	50 mg in 250 mL	6.7 mL/hr = 1 mcg/kg/min
<b>Nitroprusside</b>	0.5–10 mcg/kg/min	50 mg in 250 mL	6.7 mL/hr = 1 mcg/kg/min
<b>Norepinephrine</b>	0.05–2 mcg/kg/min	8 mg in 250 mL	4.2 mL/hr = 0.1 mcg/kg/min
<b>Phenylephrine</b>	0.1–0.5 mcg/kg/min	20 mg in 250 mL	1.7 mL/hr = 0.1 mcg/kg/min
<b>Vasopressin</b>	0.25–10 milliunits/kg/hr	5 units in 500 mL	1.1 mL/hr = 0.5 milliunits/kg/hr

**FIGURE 2.**

**Sample Report on Programming Alerts**

Medication	Frequency (# Infusions)	Total Alerts	Soft Limit Alerts			
			Override	Edit	Confirm	Edit
<b>Cardizem (diltiazem)</b>	135	11	11	0	134	1
<b>Diprivan (propofol)</b>	232	2	2	0	231	1
<b>DOBUTamine STD</b>	8	0	0	0	8	0
<b>DOPamine STD</b>	219	6	5	1	217	2
<b>Heparin</b>	64	2	1	1	64	0
<b>Insulin</b>	129	17	17	0	127	2
<b>KCl 20 mEq/100 mL</b>	10	10	7	3	10	0

**FIGURE 3.**

**Sample Override Report**

Medication/ Concentration	Rule Set	Limit Programmed	Limit Violated	Initial Value	Final Dose
<b>Amiodarone Loading (mg/min)</b>	Bolus Dose Amount	100 mg	LOWER SOFT	50	150
<b>Amiodarone Loading (mg/min)</b>	Bolus Dose Time	00:15	UPPER SOFT	2:00	00:15
<b>Bumetanide 6 mg/250 mL</b>	Dose Rate	2 mg/hr	UPPER SOFT	5	20.83
<b>Calcium Chloride 1 gm/50 mL</b>	Dose Rate	320 mL/hr	UPPER SOFT	500	50
<b>DOPamine 800 mg/250 mL</b>	Dose Rate	20 mcg/kg/min	UPPER SOFT	50	7.03
<b>Vancomycin 1 gm/250 mL</b>	Dose Rate	250 mL/hr	UPPER SOFT	500	167

## Creating Strategies for Large Dose Ranges

If the dosing range is set to capture greater than tenfold dosing errors, it will be difficult to set effective limits. Consider patient care area stratification as a way to help deal with large dose ranges. For instance, higher limits can be set for drugs used in the anesthesia patient care area compared to drugs used in the ICU patient care area for ventilated patients.

Patient stratification also can be achieved by creating individual drug library medication entry labels that appear on the selection screen. For example, separate entry labels can be generated for “methotrexate” versus “methotrexate—high dose.” The “methotrexate—high dose” entry would feature higher limits than the “methotrexate” entry.

At SMSC, this strategy was utilized for heparin. Heparin is used for pediatric patients to maintain the patency of infusion lines; this practice is not used in adults. An entry was created for therapeutic “heparin” and another entry for “heparin line open.” The “heparin line open” entry featured tight limits, to differentiate it from the therapeutic “heparin” entry.

In addition, it is important to separate entries in the library for bolus administration. If this is not done, dosing limits will need to be set high enough to include both the bolus and the maintenance rate, which eliminates the protection of maintenance rate limits. Ensure that your pumps can efficiently change from maintenance dosing to bolus dosing, and if they cannot, consider what effect that the bolus dosing is going to have on limits.

## STEP 4: PROVIDE APPROPRIATE EDUCATION

Education is crucial for successful implementation of smart pumps. Pharmacy and nursing should collaborate on creating learning opportunities that ensure staff competency, focusing on key smart pump operations. Plan for education near implementation day, and make sure that all nurses are included.

Education follow-up needs to be conducted post implementation to ensure that the drug library is actually being used. This can be achieved by downloading data from the smart pumps to verify how often the libraries are being used by nursing staff.

## STEP 5: CONDUCT REGULAR MAINTENANCE AND MONITORING

Planning for smart pumps obviously does not end with implementation. Budgeting for future upgrades and maintenance needs to be taken into consideration from the start. New medications and commercially available products are constantly emerging and should be evaluated for potential use.

Pump monitoring capabilities also should be utilized. Numerous reports can be generated from the smart pump data. Overrides can be reviewed very specifically, down to checking each program entry—such as an incorrect rate entered, the alert that came up, and the practitioner’s response.

Events can be looked at individually and overrides can be analyzed by time of day to monitor and evaluate workflow issues. See Fig. 3 for an example of an override report that can be generated.

In addition, reports can identify medications that have high incidences of alerts and can be utilized to detect process problems that need to be addressed or alerts that have not been set correctly.

Once SMSC staff downloaded data reports, excessive overrides on medications used as part of pump training and teaching were identified. These overrides most likely involved both education sessions at the bedside as well as actual programming events. Therefore, the data could not be used to prove what was happening because it was contaminated with the teaching data. SMSC now isolates teaching pumps to keep the patient data separate.

SMSC also found that the practice of priming tubing could look like an override. Nurses actually prefer to use smart pumps during a code situation, because the extra few seconds for data entry is worthwhile in terms of providing safety checks. However, during a code situation, drips are often begun at a high rate to get the drug to the patient as quickly as possible, so it appears on the report as an override.

## SUMMARY

As a first step in smart pump implementation, determine the scope of smart pump use that is most appropriate for the organization’s patient population and technological capabilities and needs.

Multidisciplinary team preparation for implementation also is key. Infusion concentrations need to be standardized, drug libraries for patient care areas designed carefully to ensure maximum safety, dosing limits properly defined, and all staff educated on pump use. Even after implementation, team members need to be vigilant about maintenance and monitoring, and take advantage of the extensive monitoring capabilities of smart pumps to continue to hone their system. ■

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# Self-Assessment Questions

To take the continuing education (CE) test, please go to the ISMP website ([www.ismp.org/smartpumpce/default.asp](http://www.ismp.org/smartpumpce/default.asp)) and complete the answer sheet and evaluation. A passing grade of 70% is required to qualify for CE credit. Upon successful completion of the test, you will be able to print your CE certificate. If online access is not available, please mail the completed test along with your name, address, and contact information to: ISMP, c/o Continuing Education, 1800 Byberry Road, Suite 810, Huntingdon Valley, PA 19006. You can contact ISMP directly at 215-947-7797.

**1. Which part of the medication-use process is most error prone?**

- a) Prescribing
- b) Dispensing
- c) Administering
- d) a and d

**2. The 2006 Institute of Medicine (IOM) report *Preventing Medication Errors* calls for:**

- a) All healthcare organizations to immediately make complete information and decision support tools available to clinicians
- b) Healthcare organizations to make effective use of well-designed technologies to deliver safe drug care, such as “smart” pumps
- c) More rigorous testing of smart pumps
- d) All of the above

**3. The most common reason for administering the wrong infusion dose is incorrect programming of the pump.**

- a) True
- b) False

**4. According to the American Society of Health-System Pharmacists (ASHP), most hospitals that have smart pumps are using them in:**

- a) ICU
- b) Pediatrics
- c) Oncology
- d) Hospital-wide

**5. The 2005 ASHP National Survey of Pharmacy Practice in Hospitals showed that smart pumps are being similarly diffused in all but the smallest organizations.**

- a) True
- b) False

**6. According to Everett Rogers’ model of innovation diffusion, smart pumps are an example of an:**

- a) Category 1 Innovation
- b) Category 2 Innovation
- c) Category 3 Innovation
- d) None of the above

**7. Errors are least likely to be detected at which step in the medication-use process?**

- a) Prescribing
- b) Dispensing
- c) Administration
- d) Monitoring

**8. Which of the following medication safety technologies is most likely to be implemented in hospitals within the next 12 months?**

- a) CPOE
- b) Robotic dispensing
- c) BCMA
- d) Smart pumps

**9. Common preparation steps for smart pump implementation include:**

- a) Standardization of continuous infusion concentrations
- b) Defining patient care areas
- c) Accommodation of all different prescribing styles
- d) a and b

**10. A soft limit in a smart pump is:**

- a) Adjustable by the nurse at each pump
- b) Standard for all pediatric patients
- c) An alert that can be overridden
- d) Not recorded in pump database

**11. Dosing units (i.e. mcg/kg/min or mcg/min) are important elements in smart pump implementation because:**

- a) Dosing units need to be entered each time the pump is used
- b) Dosing units cannot be changed by the end user of the pump
- c) Dosing units should be prescriber specific
- d) Dosing units are the same for all patient care areas



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