Program Description
This journal supplement will focus on the use of technology to proactively prevent medication errors. The estimate of 44,000 to 98,000 annual patient deaths due to adverse medical events (AMEs) is often quoted in the literature and prevention of medication errors continues to dominate the health-system quality improvement environment.

In tackling the medication error problem, high tech infusion technology is often considered, but requires planning to implement. Additionally, the data available from such technology is robust, but may be overwhelming. Without a clear strategy, the data may not reach its full potential to assist health professionals in improving patient care.

Learning Objectives
The target audience for this program is pharmacists and nurses in health-system settings. At the completion of this activity, the participants will be able to:

- Describe the lessons learned from facilities that have implemented and are maintaining intelligent infusion technology
- Outline the process of developing drug libraries, including drug libraries for specialty patient populations
- Explain the use of data reports from intelligent infusion technology in improving compliance, medication administration practices and quality of care
- Devise strategies for the clinician and administrator in using intelligent infusion technology to optimize patient care

Faculty/Funding
Burnis D. Breland, MS, PharmD, FASHP
Director of Pharmacy
Columbus Regional Healthcare System
The Medical Center, Inc.
Columbus, Georgia

Kelly A. Michienzi, PharmD
Clinical Pharmacy Coordinator
Women & Children’s Hospital of Buffalo
Buffalo, New York

This program is supported by an educational grant from Hospira, Inc.

Advance Patient Safety with Intelligent Infusion Technology

Accreditation
Pharmacists: ProCE, Inc is accredited by the Accreditation Council for Pharmacy Education as a provider of continuing pharmacy education. ACPE Universal Program Number 221-000-09-013-H05-P has been assigned to this home-study program (initial release date 3-14-09). This program is acceptable for 1.5 contact hours (0.15 CEUs) in states that recognize ACPE providers. The program is provided at no cost to participants. Statements of credit will be issued online at http://www.ProCE.com/ upon successful completion of the post-test (≥ 70% correct). No partial credit will be given.

Nurses: Nurse CE is provided for this journal supplement through collaboration between ProCE, Inc and Wild Iris Medical Education, Inc. Wild Iris Medical Education, WSNA CEARP Provider number PA-5/Feb/11, is an approved provider of continuing education by the Washington State Nurses Association, an accredited approver by the American Nurses’ Credentialing Center’s Commission on Accreditation. California Board of Registered Nursing Provider #12300. This activity provides 1.5 contact hours of nurse CE credit.

Release Date: 03-14-2009
Expiration Date: 02-23-2012

Faculty Disclosure
It is the policy of ProCE to require the disclosure of the existence of any significant financial interest or any other relationship a faculty member or a sponsor has with the manufacturer of any commercial product(s) discussed in an educational presentation. Dr. Breland and Dr. Michienzi report serving as faculty for Hospira-funded educational programming.

Please note: The opinions expressed in this program should not be construed as those of the CE provider. The information and views are those of the faculty through clinical practice and knowledge of the professional literature. Portions of this program may include the use of drugs for unlabeled indications. Use of drugs outside of labeling should be considered experimental and participants are advised to consult prescribing information and professional literature.

This program is supported by an educational grant from Hospira, Inc.
Table of Contents

Safety First: Smart Pumps in Action ......................................................... Page 2
by Burnis D. Breland, MS, PharmD, FASHP

Continuous Commitment to Safety ....................................................... Page 8
by Kelly A. Michienzi, PharmD

Authors

Kelly A. Michienzi, PharmD is a clinical pharmacy coordinator at Kaleida Health, Women and Children’s Hospital of Buffalo, where she serves as co-chair of the pediatric pharmacy and therapeutics subcommittee. Dr. Michienzi’s primary practice is in neonatal and pediatric critical care. She maintains the adult and pediatric drug library as well as the standard concentrations for Women & Children’s Hospital of Buffalo.

Dr. Michienzi is an adjunct clinical instructor and preceptor for the State University of New York at Buffalo School of Pharmacy and Pharmaceutical Sciences, and precepts for Lake Erie College of Osteopathic Medicine pharmacy students and Kaleida Health residents.

She is a graduate of the State University of New York at Buffalo, School of Pharmacy and Pharmaceutical Sciences. Dr. Michienzi completed an ASHP accredited pharmacy practice residency from Kaleida Health, Buffalo General Hospital.

Burnis D. Breland, MS, PharmD, FASHP is director of pharmacy at Columbus Regional Healthcare System in Columbus, Georgia, where he also directs the pharmacy residency programs. In addition, Dr. Breland serves as affiliate clinical professor in the department of pharmacy practice at Auburn University and preceptor for the University of Georgia and Mercer University Schools of Pharmacy.

Prior to assuming his current position with Columbus Regional in 1984, he was the associate director of pharmacy and an assistant professor of clinical pharmacy practice at the University of Mississippi Medical Center.

Dr. Breland is a member of the American Society of Health-System Pharmacists (ASHP), the Georgia Society of Health-System Pharmacists (GSHP), the Mississippi Society of Health-System Pharmacists, the American Pharmacists Association, and the Georgia Pharmacy Association (GPhA).

He is co-chair of the GSHP legislative affairs committee, member of the GPhA board of directors, and member of the GPhA governmental affairs committee. He currently serves as the chair of the VHA Georgia Pharmacy Advisory Council. He has served as delegate or alternate delegate to the ASHP House of Delegates for the state of Georgia for many years, and was recognized as a fellow of ASHP in 1991. He has served as a board member for the GPhA.

A recipient of the 2005 Innovative Pharmacy Practice Award from the Georgia Pharmacy Association, Dr. Breland also received the ASHP’s Best Practices Award in 2002 and the John W. Webb Lecture Award from the ASHP and Northeastern University in 2006.

Dr. Breland received a BS degree in pharmacy and a MS degree in hospital pharmacy from the University of Mississippi. His doctor of pharmacy degree was awarded by the University of Tennessee at Memphis. In addition, Dr. Breland completed an ASHP accredited residency in hospital pharmacy from St Luke’s Episcopal, Texas Children’s Hospital, Texas Heart Institute in Houston, Texas.
To improve safety in the medication administration process, addressing medications that are delivered intravenously (IV) and which provide the highest risk to patients can result in life saving critical catches. At our hospital, the Medical Center of Columbus Regional Healthcare Center located in Columbus, Georgia, we sought to address and correct these IV medication management issues through the implementation of intelligent infusion devices. Our goal in using intelligent infusion devices, or smart pumps, was to improve the quality of care by establishing safety limits and standardizing optimum administration processes.

The Medical Center, a 413-bed community teaching hospital, offers highly specialized acute care services, plus the region’s only advanced maternity services and a neonatal intensive care unit, a full service pediatrics program, and a pediatric intensive care unit. We also are a Level II trauma center, serving 13 Georgia counties and offer many other medical-surgical services, including a large oncology center. We have a large family practice residency program, and this year, we had nine pharmacy residents. Additionally, we are a disproportionate share hospital operating in one of the lowest income areas in the state of Georgia; therefore we run an extremely thin net margin.

**Pump Features**

In 2006, we implemented intelligent infusion devices in our institution. These infusion devices provide precise delivery of medication, and when configured with their software system, offer a drug library containing dosing limits with the potential to prevent severe or even fatal medication errors at the bedside. With the correct use of smart pumps, we can now ensure greater safety in the IV route of drug administration.

Some basic administration features we looked for in our smart pumps were positive valving, set based flow protection, an air-trap management system, and back priming for air elimination. Additional features we value are automated piggyback bag delivery, automated concurrent delivery, keypad lockout via toggle switch, programmable standby settings, multi-step delivery, loading dose automation, and programmable delayed starts. The pump can be programmed to use exact dose, rate, and volume parameters for specific medications. TALLman lettering specific to each institution is employed to distinguish between look-alike and sound-alike drugs. On the final display screen, the clinician is asked to confirm medication type, dosing, and variable rate information instructions for entries on both lines A and B, so that primary and secondary infusions are under the umbrella of the medication safety limits. User-defined soft and hard lower and upper limits for each medication are programmed into the drug library. If the medication is being dosed without limits in operation, a special symbol appears on the confirmation screen visible to the clinician before final confirmation is requested.

**Drug Library**

One of the most important steps in the successful use of infusion devices is the creation of a comprehensive drug library. The library must contain the safety data for all IV medications used, including name, concentration, minimum and maximum infusion rates, and minimum and maximum bolus infusion rates per specified time, all with appropriate dosing. The specifics of dosing and infusion rate can be customized to the hospital’s individual clinical care areas (CCAs).

Initially, in our hospital, we started with broad CCAs, such as a med/surg grouping that included multiple patient care areas. We soon realized these groupings were too broad as they did not allow us to track an individual unit’s compliance rates or use of the pump. For example, usage varied greatly between the emergency department and a standard med/surg unit, but we were not able to capture these differences as they were grouped in the same CCA. As a result, we chose to customize the libraries to individual patient care areas, such as pediatrics, neonatology, outpatient cancer center, and specific ICUs. The pump provides storage of individual drug libraries for up to 18 CCAs, allowing us to track an individual unit’s pump usage, which greatly increases the value of the data we collect. Each library contains user-defined dosage limits, both soft and hard, based on clinical evidence, literature, and institutional best practice standards that can be updated and accessed via the software.

Establishing the safety limits within the drug library to meet the patient needs within each CCA is critical in order to maximize patient safety. I recommend establishing both soft and hard upper and lower limits. The soft limits drive system alerts that act as warnings, which the user can override or edit with confirmation. The hard lower and upper limits cannot be overridden. There is a “no drug selected” menu option on the pump that allows for infusion without programmed limits. This may be used, for example, in the case of an emergency administration of critical drugs initially infused at a very high rate, such as norepinephrine. These hard and soft limits, both upper and lower, are at the heart of the pump’s ability to avert fatalities and must be tailored to meet the needs of each individual CCA in your institution.

The software system was equipped with a drug library template that we proceeded to customize. We consulted the literature and asked other institutions to share their drug libraries with us. We discovered that many hospitals are not assigning safety limits in their library, often due to internal disagreements over what the number should be. Our own experience has taught us that establishing some limit is better than no limit in terms of quality patient care. At the very least, a hard upper limit – even one that is set very high – can preclude a triple digit entry when a double digit was
intended. While the different pumps offer various capabilities, the basic options include establishing a full-limit set that specifies milligram dose per time interval, a more limited set that might establish volume infusion rates only, or a label only (or a no limit) set for drugs such as cefazolin that can be safely pushed when necessary.

Building the Drug Library
Building the drug library can be a challenge. Do not underestimate the amount of time necessary to tailor the library to the needs of your specific patient populations. While there is currently no clearinghouse of drug libraries available, your vendor may be able to assist you in building a template, and reaching out to other institutions to discuss their library development process can be very helpful.

Essential to creating an effective drug library is having the pump in hand and using it when you are building or improving the libraries. By previewing exactly what the users will see, you can prevent flaws from being built into the system. Another key step is to understand your institution’s drug usage patterns. Create a list of all drugs that are normally infused and then review how they are used in different care settings. For example, we learned that our ICU quite often starts nicardipine infusions at a higher dose than our soft upper limit. We chose to retain the soft upper limit so as to alert the user that while they can start at this dosage, they must keep in mind where they are in the dosage range.

When building the library, avoid dosing conflicts within your own system. For example, we originally established an upper soft limit infusion rate for phenytoin at 25 mg/min with an upper hard limit of 50 mg/min at the direction of our ICU pharmacists. However, with our loading doses, we were using 1000 mg/100 mL with a label instructing the clinician to infuse it in 20-30 minutes, which exceeded our upper soft limit. This practice would conflict with the upper soft limit warning. To resolve this, we raised our upper soft limit to 40 mg/min. It is imperative that hospital drug dosing and usage patterns do not conflict with established safety limits. This causes general confusion, especially for nurses at the bedside. We have learned to research the literature; understand the drug usage patterns of our institution; and ask for input from our users, including nursing, critical care medicine, emergency medicine, oncology, pediatrics, and anesthesiology. Only then do we review and recheck all of our dosing data. Our library is a continuous quality improvement process that we work hard on because we know it prevents errors and saves lives.

Monitoring the Drug Library
It should be pharmacy’s responsibility to continually monitor the library and make necessary revisions and additions. Such scrutiny will keep the library operating accurately and efficiently and build user confidence. The pumps offer a wonderful opportunity for on demand data collection. You can view how the pumps are being used throughout the institution or in individual patient care areas. With these pumps, every keystroke is recorded allowing you to review practice patterns and examine previous events in minute detail, which can sometimes reveal surprising data.

In addition to reviewing the reports for system inefficiencies, solicit recommendations about safety limits from all departments. All recommendations for changes to the drug library database should be heard whether they come from pharmacy, nursing, anesthesiology, or medicine. Ask clinicians to describe their frustrations and what they feel must be changed. In our hospital, the upper soft limits for the drug meropenem were originally set so low that every time it was used the limit was exceeded. If there is no good reason to keep the limits intact, then by all means change them. The open-ended question to clinicians should be “What do you see in our medication dosing parameters that should be changed?”

We use our hospital’s Pharmacy and Therapeutics (P&T) Committee as the final authority on changes. In most cases, we worked the issue out ahead of time, and presented it to the P&T Committee not so much for input as for final validation. Nonetheless, it is key to establish procedures for updating the libraries.

We update the drug library periodically according to need—if we see a need to improve a situation in a particular CCA, then we make adjustments. We use a wireless system for the updates, which I strongly recommend. Using wireless communication, every pump that is plugged into a power outlet (not just running on battery), automatically receives the update. The pump notifies the user of the availability of a new library and the user can accept the update when the pump has finished an ongoing infusion (or at another convenient time). The update takes about five to seven minutes to complete. With a wired system, updates tend to be very infrequent because they are so cumbersome to download. While wireless updates are simple to accomplish, remember to alert nursing when an update is scheduled.

CQI Reports
Real-time reports and data gathering are available through the smart pump’s software, which provides advanced data transfer technology to create benchmarks, and monitor, evaluate, and improve the IV medication delivery process. The on demand reports are a vital component of patient safety solutions and identify therapeutic trends, drive quality improvement initiatives, and monitor and measure implemented changes. The reports, which can be scheduled and sent via email, provide the following:

- Show compliance with safety software
- Show clinicians’ responses to alerts
- Review whether dosing limits are clinically appropriate
- Identify current practice trends
- Demonstrate maximization of pump functionality
- Identify operational improvement opportunities
- Review pump utilization and drug library status

Reports on asset tracking, asset utilization, and infusion status provide the physical facts of the pump: when and where was it last used and whether it is currently running.

There are clinical reports, such as those that present an infusion sum-
mary that provide very detailed information about each medication being administered (Fig 1).

These drill down reports are crucial because they provide a summary of drug library utilization, including:
- Frequency of programs and alerts
- Breakdown of clinicians’ responses to alerts
- Specifics of overrides and edits
- Clinical safety and workflow efficiency implications
- User response at the final confirmation delivery screen

Some of the most useful reports are those that provide override variance detail and edit variance detail as they communicate when an override or change in the entry for the hard and/or soft upper and/or lower limits of a medication occurs. The reports detail the CCA, the medication, the date, and the time the alert occurred. Presently they are not interfaced with the patient medical record, but we hope to have this connection in the future.

Reading these reports is a study in improving the efficiency and safety of our drug administration practices. How many instances of alerts or actual edits of medication dosages are occurring? Are the soft limit alerts frequent enough, as well as founded in good pharmacology and therapeutics, to justify changing the drug library’s parameters for a particular medication? The goal is to avoid a situation where the limits are constantly overridden, as this will eventually become a habit, making the limits meaningless. We should change the drug library rather than allow regular overrides of the limits.

When we first implemented the pumps, we simply used the old TKO (to keep open) rate of 40 mL/hr as the lower soft limit for intravenous fluids (IVF). Because of the accuracy of these pumps and their ability to go down to single digit numbers, we discovered that we were frequently overriding the lower soft limit. So we changed the soft limit to 10 mL/hr in the drug library to keep all of us from getting in the habit of overriding an alert.

For antibiotics, we initially had one entry, whether the agent was cefazolin, piperacillin/tazobactam, meropenem, gentamicin, etc. We now have information on each specific agent (Table 1). Safety limits for a low-risk antibiotic such as cefazolin will differ from high-risk agents, and we wanted our nursing staff to become accustomed to using individual antibiotic names. Our infectious disease pharmacists, after viewing

Table 1

<table>
<thead>
<tr>
<th>Antibiotic</th>
<th>Lower Hard</th>
<th>Lower Soft</th>
<th>Upper Soft</th>
<th>Upper Hard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doxycycline 100 mg/250 mL</td>
<td>63 mL/hr</td>
<td>75 mL/hr</td>
<td>150 mL/hr</td>
<td>200 mL/hr</td>
</tr>
<tr>
<td>Gentamicin ODD 100 mL</td>
<td>60 mL/hr</td>
<td>75 mL/hr</td>
<td>200 mL/hr</td>
<td>250 mL/hr</td>
</tr>
<tr>
<td>Gentamicin Conventional 50 mL</td>
<td>50 mL/hr</td>
<td>100 mL/hr</td>
<td>150 mL/hr</td>
<td>200 mL/hr</td>
</tr>
<tr>
<td>Meropenem 100 mL - 140 mL</td>
<td>33 mL/hr</td>
<td>40 mL/hr</td>
<td>280 mL/hr</td>
<td>300 mL/hr</td>
</tr>
<tr>
<td>Piperacillin/ tazobactam 50 mL 2.25 g and 3.375 g</td>
<td>12.5 mL/hr</td>
<td>20 mL/hr</td>
<td>120 mL/hr</td>
<td>125 mL/hr</td>
</tr>
<tr>
<td>Piperacillin/ tazobactam 100 mL 4.5 g</td>
<td>25 mL/hr</td>
<td>40 mL/hr</td>
<td>200 mL/hr</td>
<td>220 mL/hr</td>
</tr>
<tr>
<td>Linezolid 300 mL</td>
<td>125 mL/hr</td>
<td>150 mL/hr</td>
<td>300 mL/hr</td>
<td>500 mL/hr</td>
</tr>
</tbody>
</table>
Inappropriate Safety Limits of Specific Medications

Phenytoin is a medication that should not be infused too quickly because the patient can experience pain as well as adverse events such as arrhythmias. With such medications, appropriate limits must be established. For phenytoin, our upper soft limit is 40 mL/min, and our upper hard is 50 mL/min. These limits are very well defined in the literature.

Another medication that should not be infused too quickly is the antibiotic, levofloxacin, so we need upper hard limits to avert adverse effects. However, levofloxacin is a medication that also needs lower soft limits because if it is infused too slowly over too long a period of time it never reaches maximum plasma concentrations and therefore the maximum antimicrobial effect is lost. See Table 2 for the safety limits for levofloxacin in our drug library.

With heparin, a very critical drug, we initially concentrated on the upper soft and hard limits, but neglected to establish soft and hard lower limits. Focusing only on the upper limits for heparin can lead to missing low dose errors that may result in therapeutic failures and patient harm. Reviewing our usage reports revealed problems with not setting these lower safety limits. For example, we found errors where the pump was set at “7” and the user assumed they were setting the pump at 7 mL/hr; in actuality they were setting the pump at 7 units/hr. To avoid this problem, we instituted a lower soft limit of 700 units/hr and a lower hard limit of 100 mL/hr (Table 3).

We also found prescribing errors while monitoring infusion reports. When we looked at the override variance detail report, we saw that our neurology patients in the emergency department were being given a sub-therapeutic dose of heparin. After discussions and research, the dosing practices of heparin in this population were changed. The report helped us identify an opportunity to improve drug therapy in a critical care population.

Although standardization, when possible, is one of our goals, we still want our clinicians thinking about infusion rates. There are occasions when we choose not to change a limit that may be commonly overridden. For nicardipine, the override variance detail report showed us that the soft upper limit of 10 mg/hr programmed into our drug library was routinely overridden for 12 mg/hr infusions. After review by pharmacy, nursing, and medicine, we decided not to change the soft upper limit of 10, in spite of the many overrides (Table 4). We felt it was prudent for the user to be reminded with this drug, that the dosing was in the upper limit of the normal dosing range.

Critical Catches

We use propofol, a high-risk drug, on a routine basis. We consulted with anesthesiology to add an upper hard limit that they would not expect to exceed. What we came up with was an upper hard limit of 250 mcg/kg/min. Hopefully, the need never arises to infuse at that level, but if a clinician inadvertently enters 50 instead of 50 that error will be caught because of this upper hard limit. We strongly believe upper hard limits are life saving and should be in the drug library for all medications, even for those agents for which upper limits are difficult to determine.

For potassium infusion rates, the edit variance detail report showed a 200 mL/hr rate instead of the intended 20 mL/hr rate. This mistake was avoided because the drug library had an upper hard limit of 175 mL/hr. Adding or subtracting a zero is critical and can be caught through the use of upper hard limits (Table 5).

Compliance

At our institution, we started with an overall pump compliance rate of 35% in all of our CCAs. In other words, the pumps were being used appropriately just over one third of the time. After one year, we achieved a 55% compliance rate, and in November 2008, at the two year mark, we achieved a compliance rate of 96.6% (Fig 2). This increase reflects the hard work of our staff in improving the libraries. With better libraries, nursing became more compliant and nurses encouraged each other to use the pumps. We publicized some of the critical catches to the staff and they were impressed. Our oncology center has always been the CCA with the highest compliance rate, partially because of the critical nature of the medications and the natural caution required for their delivery. In addition, the oncology pharmacists extended a significant effort determining each medication and its appropriate dosing, container volume and overfill.

<table>
<thead>
<tr>
<th>Dose</th>
<th>LHL</th>
<th>LSL</th>
<th>USL</th>
<th>UHL</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 mg/50 mL @ 50 mL/hr</td>
<td>25 mL/hr</td>
<td>50 mL/hr</td>
<td>700-1500 units/hr</td>
<td>400 units/hr</td>
</tr>
<tr>
<td>500 mg/100 mL @ 100 mL/hr</td>
<td>50 mL/hr</td>
<td>100 mL/hr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>750 mg/150 mL @ 100 mL/hr</td>
<td>50 mL/hr</td>
<td>100 mL/hr</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Safety Limits for Levofloxacin (concentration dependent antimicrobial effect)

<table>
<thead>
<tr>
<th>Dose</th>
<th>LHL</th>
<th>USL</th>
</tr>
</thead>
<tbody>
<tr>
<td>700-1500 units/hr</td>
<td>400 units/hr</td>
<td>1500 units/hr</td>
</tr>
<tr>
<td>2500 units/hr</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Safety Limits for Heparin

LHL= Lower Hard Limit
UHL= Upper Hard Limit
Concentrating on high-risk medications, such as heparin, and stressing the safety features of having hard and soft limits for these drugs can increase compliance. With drill downs on individual medications, you can monitor all of the patients receiving that medication and identify trends. Individual CCAs can be audited and real-time feedback given to the nurse manager and staff about the findings and the importance of the pump and the drug libraries. The importance of feedback from the front-lines cannot be stressed enough. If you spend time rounding, you will understand the clinician’s problems and limitations when using the pump. We take our reports to a monthly nursing directors’ meeting whose attendees include the directors of medical/surgery, women and children’s health, intensive care units, etc, and we discuss compliance and quality and how the two are linked. These reports are integrated into our current CQI processes and can result in medication standardization.

Table 4

<table>
<thead>
<tr>
<th>CCA: 8ICU</th>
<th>Override Variance Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medication/Concentration</td>
<td>Alert Date/Time</td>
</tr>
<tr>
<td>Nicardipine 25 mg/250 mL</td>
<td>4/13/2008 00:16:46</td>
</tr>
<tr>
<td>Nicardipine 25 mg/250 mL</td>
<td>4/13/2008 00:39:21</td>
</tr>
<tr>
<td>Nicardipine 25 mg/250 mL</td>
<td>4/13/2008 00:39:25</td>
</tr>
<tr>
<td>Nicardipine 25 mg/250 mL</td>
<td>4/13/2008 00:39:43</td>
</tr>
<tr>
<td>Nicardipine 25 mg/250 mL</td>
<td>4/13/2008 00:39:55</td>
</tr>
</tbody>
</table>

Table 5

<table>
<thead>
<tr>
<th>Critical Catches for Propofol and IVF</th>
<th>Edit Variance Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCA: 7ICU</td>
<td></td>
</tr>
<tr>
<td>Medication/Concentration</td>
<td>Alert Date/Time</td>
</tr>
<tr>
<td>Propofol 1000 mg/100 mL</td>
<td>3/20/2008 23:30</td>
</tr>
<tr>
<td>CCA: CHLD</td>
<td></td>
</tr>
<tr>
<td>Medication/Concentration</td>
<td>Alert Date/Time</td>
</tr>
<tr>
<td>IVF w/ KCL 1000 mL</td>
<td>3/26/2008 7:48</td>
</tr>
</tbody>
</table>
Conclusion
We have seen how the critical catches with an intelligent infusion system can be life saving. We can improve the quality of IV administration by establishing a degree of standardization, incorporating safety limits, and implementing optimum administration processes. The pump has made this much more possible.

We have received great value from our investment in smart pumps. Because these safety systems help catch potentially severe or even fatal medication errors at the bedside, they provide an excellent return on investment.

Implementation Tips

- There are often concerns about whether the newest drug library is being downloaded on the pump. To remedy this, we use the asset tracker software, which indicates which pumps have been updated. We can monitor the updating process and observe which pumps have yet to be revised. We have even discovered a few pumps on the report that are no longer in the institution!

- One challenge when building a library is addressing medications that could be used at different infusion rates based on different patient populations. For instance, in labor and delivery, oxytocin may have one set of dosing parameters and yet another in post-delivery. This is true of many medications. One safety solution is to have use-based medication entries in the drug library that fit each unique clinical situation.

- Emergency departments should have access to all CCA drug libraries, because they see all types of patients—from pediatric to geriatric patients. The choice of library should be displayed on the screen and the pump will employ the chosen library.

Figure 2

Trend Reports - Drug Library Compliance
November 2007 to November 2008
The 220-bed Women and Children’s Hospital in Buffalo, New York is part of Kaleida Health, a five hospital health care system. The majority of our beds are pediatric, including a 20-bed pediatric intensive care unit (PICU), which is also a regional trauma center. There is a 64-bed neonatal ICU, which admits more than 700 patients a year, 200 of whom are transported from other facilities in an eight county area surrounding Buffalo. We are also a designated high-risk obstetrics center with fetal maternal medicine consultations and a hotline, so we are concerned with adult as well as pediatric patients.

Our primary concern when dispensing intravenous (IV) medications to a predominantly pediatric population is consistent accuracy in weight-based dosing. To this end, we need drug delivery products that enhance patient safety, reduce IV-infusion errors, and increase clinician productivity. At the Women and Children’s Hospital we found all of these capabilities with an intelligent infusion pump, and we went live with these smart pumps in February 2008.

At the center of the pump’s safety system is the software, which offers clinicians programmable drug libraries specific to the clinical care areas (CCAs) or patient populations defined by each individual hospital. Our infusion device has the capacity for up to 40 different CCAs with up to 400 medications per care area. To ensure safety software compliance, the pump requires the selection of a CCA drug library when turned on and programmed.

Multidisciplinary Approach to Drug Library Development
The drug library development process requires a significant effort. Creating and revising the drug library is a continuous process, driven by input from the multidisciplinary team, pump report data, and other quality data, such as incident reports. The multidisciplinary team charged with creating our initial drug library was composed of pharmacists; nurses, including nurse educators, nurse managers, and transport team members; and physicians, including department chairs and anesthesiologists.

We found the input of our nurse educators to be particularly valuable as they shared not only their extensive clinical experience, but also their ability to create education programs that encourage clinicians to make the right decisions. All transport team members who occasionally use smart pumps during patient transport also required education on pump functions and drug library updates.

We also had some key physicians involved in the evolutionary process of the drug library. The co-chair of the hospital’s Pharmacy and Therapeutics Committee (P&T) is an attending physician in our PICU and a toxicologist, in other words a physician-pharmacologist. When disagreements arose as to dosing limits within the library, we would consult with the P&T committee or department chairs. Anesthesiologists are an important group to consider when creating a drug library. They are end users but, unlike other clinicians involved in the process, they are often the prescriber, dispenser, and administrator as well. Keep in mind that vendor consultants are a good source for tips of what has worked well in drug libraries in other hospitals.

Increase Library Compliance
In the spring of 2007, the Institute for Safe Medication Practices (ISMP) issued a report highlighting how smart pumps are not smart on their own. Emphasizing that drug library compliance is often very poor – as low as 30% to 50% – the report cited the following reasons for such low compliance rates:

- Falsely low perceptions of risk
- Failure to make timely corrections to the drug library for alerts that are not credible
Extra steps involved to use technology

Time pressures and clinical emergencies

Cultures supporting at-risk behaviors including technology work-arounds

After conducting extensive education during the implementation phase, we went to the front lines on rounds to see what actually prevents clinicians from using the infusion devices correctly. We found that one way to increase compliance was a very selective ordering of the institution’s medications within the library, starting first with the most common medications and their indications. Keeping the library current was also important to our staff, so we now update our drug library quarterly.

Another means to increase compliance is to make it easy to do right and hard to do wrong. With some pumps, when the device is initially turned on, the user has the option of using the pump with the drug library or in basic mode without the protections of the drug library. With other devices, once the pump is turned on the drug library is the default setting and it is somewhat difficult to opt out to use the basic mode.

Publicizing “good catches,” or situations in which the library’s hard and soft limits were lifesaving, is key. Let staff know what adverse events were prevented by using the pump. We want our staff thinking, “This could have been my patient, it could have been me that made that error.” Communicating the direct positive result of using the smart pumps to the staff will have a positive effect on the compliance rate.

Since we first started using the infusion devices ten months ago, our compliance rate with the drug library has ranged from 92% to 99%. Rather than becoming complacent, we are now looking at ways to achieve a 100% compliance rate (Fig. 2).

Creating a Drug List

Once the multidisciplinary team has been selected, formation of a drug list for the drug library is a necessary first step. Sources for creating a list include:

- Continuous infusions
- Standard concentration list
- Stat log/fill list
- Nursing requests
- Sample libraries from vendors if available
- IV medication policy
- Intermittent doses

When creating a drug list, determining how to represent diverse patient populations within the same unit can be a challenge. We addressed this problem via creative naming and ordering. We also use TALLman lettering with look-alike sound-alike drugs. The importance of this approach is very evident when medications are listed alphabetically in the drug library.

Our medication order form requires all prescribers to include an indication for the prescribed agent, and this is particularly imperative for those drugs that have indication-dependent dosing parameters. In clinical practice, for example, the insulin used for pediatric diabetic ketoacidosis is different from that used to treat certain overdoses. Therefore, different soft and hard limits for each separate indication must be set in the drug library.

In a hospital with neonatal, pediatric, and adult patients, establishing varied — but limited — standard concentrations is key. In our hospital, each pump has a drop down menu listing available concentrations. Because not all concentrations are appropriate for all CCAs, it is important that your library match your standard of care and your policy on standard concentrations. For example, in our NICU the smart
pump menu lists the most commonly used IV fluids/medications first, starting with total parenteral nutrition (TPN). If fentanyl is chosen in the NICU, the four approved concentrations will appear on the dropdown menu. In the PICU, only two approved concentrations will appear (Table 1).

**Standardized Dosing**

Standardizing dosing units is another challenging task. Vasopressin provides a good example of these challenges as it has multiple dosage options and indications. Initially, we decided to include all the various dosing options in the library, so nursing would have a safe way to check the dose via the soft and hard limits no matter how it was prescribed.

Our goal was to provide multiple dose checks per medication, including a rate check and a dose per kilogram check, while always maintaining a cap on total dose. Nursing voiced concerns that the multiple options for vasopressin made it confusing and difficult to choose the right indication. The simplification of the vasopressin dosages was on the agenda of a PICU quality assurance meeting that included the prescribers and nursing personnel. At that meeting, all involved decided upon one method for dosing vasopressin for each of its indications. With our next revision of the drug library, the nurses will see fewer options for this medication (Table 2).

With the listings of IV fluids in the pump, nursing actually requested more explicit and detailed options. They wanted each fluid to be specifically labeled to indicate whether it was a central line, a central line with heparin, an arterial line, etc. Nursing even requested multiple library entries for dextrose 5%.

We received feedback from anesthesiologists that the concentration they needed was not in the drug library. We could argue that they should be using standard infusions, but at the same time, we wanted them to have appropriate limits on each infused medication. In addition to listing the hospital approved standard concentrations, entries for anesthesia medications allowed input of the concentration (i.e., mg per mL). We have primarily set soft limits for anesthesia, but soon we will have to commit to hard limits to avoid keystroke errors.

**Increasing Usability**

In our continuous customizing and refining of the drug library, our goal is always to make the pumps easier to set up, manage, and monitor and hopefully to achieve the ultimate goal of greater safety in the administration of IV medications throughout our hospital. While our smart pumps represent a quantum leap in terms of ease of use, we wanted our drug library to be user friendly as well.

One step in this process was to identify and minimize useless alerts. In our first library, we had an alert at the end of a syringe infusion, indicating there was still volume to infuse, which was a nuisance to the staff. The option for the delivery at the end of infusion was changed from KVO to “none” for medications given via a syringe. This setting was adjusted during the revision of the first drug library to eliminate the every two minute KVO Call Back alert. The limits on antibiotics were also adjusted to accommodate those (i.e. cefazolin) that may be delivered over 15 minutes (previous limits were based on 30-minute infusions).

The drug library must mirror the standard of care in your institution, not just in small overrides, but also in medication doses in general. We continue to require nurses to conduct a safe dose check prior to drug administration. The safe dose check is NOT replaced by the drug limits programmed into the library. The library’s soft limits have to encompass the majority of patients, but allowances must always be made for outliers titrated for specific patients and represent the hard limits programmed into the pump.

We customized our pump settings, such as alarms and brightness by CCAs. Our PICU nurses wanted the lights on all the time, while the floor nurses preferred to have the lights out at night. We also customized our report capabilities by CCA. We have five different pediatric floors, and

<table>
<thead>
<tr>
<th>Drug</th>
<th>Indication</th>
<th>Dosing Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vasopressin</td>
<td>Diabetes Insipidus</td>
<td>milliUnits/kg/hr</td>
</tr>
<tr>
<td>Vasopressin</td>
<td>Shock (milliUnits)</td>
<td>milliUnits/kg/min</td>
</tr>
<tr>
<td>Vasopressin</td>
<td>Shock ADULT</td>
<td>Units/min</td>
</tr>
<tr>
<td>Vasopressin</td>
<td>GI Bleed (milliUnits)</td>
<td>milliUnits/kg/min</td>
</tr>
</tbody>
</table>

**Table 1**

<table>
<thead>
<tr>
<th>NICU</th>
<th>PICU</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 mcg/1 mL</td>
<td>20 mcg/1 mL</td>
</tr>
<tr>
<td>10 mcg/1 mL</td>
<td>50 mcg/1 mL</td>
</tr>
</tbody>
</table>

**Table 2**

**Standardized Dosing Units for Vasopressin**

**Advancing Patient Safety**

I 2009

**Pharmacy Purchasing & Products**
all five have identical drug libraries. However, each library is identified separately because data is easier to combine than to separate. This allows the nurse educators and managers to learn what is going on in their unit and what educational points should be highlighted.

Additionally, we built a code CCA in the drug library. In an emergency, the code responder will need to access critical care medications, such as epinephrine and dopamine, which would not be in the general pediatric floor CCA library. Rather than scrolling through the entire ICU library and parsing through antibiotics and neuromuscular blockers, the medications are quickly available in the code drug library. It is also important to create a training CCA. While learning, nurses should hit hard and soft limits on purpose to see how the pump operates. With a training CCA, that data will not skew the actual patient data stored in the pump.

Our NICU and PICU chose different libraries and have different dosing parameters. In the NICU, patients are weighed in grams, in the PICU, in kilograms. Even though weight is entered in two different ways, the pump checks the dosage using kilograms and adjusts accordingly. The PICU enables the bolus function off the primary, whereas the NICU does not allow it. Other functions vary between these units, and the drug library is customized to accommodate such variations. (Table 3)

**Avoiding Common Errors**

Knowing what infusion errors occur at your site and why will allow you to design the drug library to avoid common errors. For example, we knew from incident reports that our TPN and intralipid rates were sometimes inadvertently interchanged. To address this we made the intralipids in NICU weight based with a daily maximum of 4 g/kg/day, although we still allow programming in mL/hr. Should the nurse enter the dose in mL/hr and accidentally put in the TPN rate, the pump would back calculate and give a soft and hard limit as well. In reviewing our pump reports, this error was avoided over 40 times in July and August alone, making for a nice return on investment (Table 4).

Because the PICU uses different concentrations of dopamine than the NICU, a challenge arose with concentration per milliliter versus total medication and total volume. We found that nurses were choosing 800 mcg/mL...
because the dopamine bag was labeled 800 mg/250 mL. To resolve this we removed the two lower concentrations from the PICU library. Should a lower concentration be required, it is available in the NICU drug library, but must be obtained from the pharmacy.

Catches in the First Week

During our first week using the new pump, we were called to the PICU because of some difficulties with intravenous immunoglobulin (IVIG). We had our old pumps on standby in case anything was to go wrong. The new pump caught a decimal error. The ordered and programmed infusion rate was 0.8 mL/kg/min instead of the correct rate of 0.08 mL/kg/min. Because the technology was new to us, the users assumed it was the pump, not the medication order that was incorrect. The order was corrected and the infusion was safely administered.

We also had a critical catch with insulin. Our library has an upper hard limit of 0.2 units/kg/hr for our pediatric diabetic ketoacidosis patients, although it is not inappropriate to start a younger patient at 0.05 units/kg/hr. One user accidentally programmed in 0.5 units/kg/hr, a decimal error that would have caused a tenfold overdose. We have also caught subtherapeutic doses of heparin and life-threatening high doses of remifentanil (Table 5).

Challenges of the Multi-campus Health System

We are a multi-campus health system with both adult and pediatric sites. Because the Women and Children’s Hospital also has adult patients, we need to have the same limits for the same patient populations across the health system. To achieve this, I have access to both the adult and pediatric libraries and the pharmacist who maintains the adult library also has this dual access.

Wireless Technology as an Imperative

Given the significant investment of time and energy required to develop and build a drug library, it is imperative that the library gets to every pump in a timely fashion. Using biomedical engineering to update each pump individually is incredibly labor intensive. Pushing the drug library wirelessly, on the other hand, is relatively effortless. In addition, with wireless technology, data is available in real time, allowing you to run daily reports of “no drug selected” entries, or query high-risk medication alerts, schedule the frequency of reports, etc.

Conclusion

During our first week with the new pump, we anxiously anticipated the success of the drug library. Now nurses are asking about adding medications that are not in the drug library. They are requesting tighter hard limits on certain medications, and they want to see the real-time data. They have discovered what a great tool these pumps can be in the total quality assurance process. They realize the value of the data available from these pumps to the ongoing improvement of patient care.

Reference:
Continuing Education Exam

1. The intelligent infusion devices are useful in preventing medication errors due to:
   a. Infusion of medication at too high of dose
   b. Infusion of medication at too fast of rate
   c. Infusion of medication at too low of dose
   d. Infusion of medication at too slow of rate
   e. All of the above

2. Although many departments may participate in the development of the drug library (or medication safety limits), the one department that must assume responsibility is:
   a. Internal Medicine
   b. Nursing
   c. Pharmacy
   d. Clinical Engineering
   e. Risk Management

3. When setting safety limits for high risk medications with highly variable doses (for example, propofol), the best approach is to:
   a. Not set an upper hard limit at all
   b. Set neither an upper soft or upper hard limit
   c. Set an upper hard limit that is higher than is normally needed clinically but that would catch extra digit entry errors
   d. Double the soft upper limit
   e. Have the user call the pharmacy before setting the pump if the limit is above the upper soft limit

4. When administering antimicrobial agents using the intelligent infusion device, the drug library should be set:
   a. To administer all doses over a one hour time period
   b. Without safety limits since some antimicrobials may be given via IV push
   c. To allow the user to select the rate of infusion based on clinical urgency of need
   d. To allow infusion of the agent within a specified time frame that assures the dose is not infused too slowly when a concentration dependent antimicrobial agent is administered, but not too fast so as to cause dose-related adverse side effects
   e. All of the above

5. Monitoring intelligent infusion device data reports is useful in quality improvement because:
   a. Reports showing frequent overrides may reveal inappropriately set safety limits
   b. Edit reports may indicate near misses which may be opportunities for additional staff education
   c. Inappropriate medication prescribing practices may be recognized and corrected
   d. Inappropriate variations in medication administration practices between clinical care areas may be detected
   e. All of the above

6. Various mechanisms are utilized to improve compliance with use of intelligent infusion devices including:
   a. Involvement of all stakeholders in the planning, education, and implementation process
   b. Strong support from nursing and pharmacy leadership
   c. Use of a continuous quality improvement approach related to the drug library to improve user efficiency and develop optimum medication safety limits
   d. Patient care area specific, real time audits with feedback to users and management
   e. All of the above

7. Advantages of developing the drug library by individual clinical care areas include:
   a. Each area may have their own listing of medications according to their practice patterns
   b. Data reports provide area specific information which is valuable in driving pump compliance
   c. It requires less time to develop the library
   d. a and b are correct
   e. All of the above are correct

8. Drug library compliance may be low because of:
   a. Low perceptions of risk
   b. Time pressures
   c. Limits that are not credible
   d. All of the above

9. Increasing drug library compliance may be achieved by:
   a. Listing most commonly used medications first
   b. Keeping information regarding prevented errors and catches confidential amongst the drug library development team
   c. Updating the drug library quarterly
   d. a and c

10. Advantages of having location or nursing unit based clinical care areas include:
    a. All patients on the same unit are likely to be the same
    b. Reports and subsequent education can be specific to the unit in need
    c. It prevents the unnecessary sharing of data between units
    d. All of the above

11. Drug library development should be done exclusively by a pharmacist.
    a. True
    b. False

12. Members of the multidisciplinary drug library team should include:
    a. Physicians
    b. Nurses
    c. Pharmacists
    d. All of the above

13. The advantage of a training clinical care area is that it:
    a. Allows nursing to experiment and override limits for educational purposes without skewing reports of infusions used in patient care
    b. Provides the pharmacist in charge of the drug library with data for disciplinary action
    c. Increases the number of clinical care areas in the drug library
    d. Guarantees pumps will be used appropriately
    e. All of the above

14. Knowledge and understanding of infusion errors that have occurred in your institution is important because:
    a. The medications identified in incident reports should be excluded from the drug library
    b. Drugs previously involved with errors and adverse events are statistically unlikely to be repeated
    c. Infusion errors will not get reported once intelligent infusion device reports are utilized
    d. Incident reports can provide insight into which medications require the most attention in the drug library
    e. All of the above

15. Advantages to wireless technology include:
    a. Real time reports of drug library compliance and edits
    b. Easier drug library updates
    c. Drug inventory tracking
    d. a and b