

IV Medication Safety Software Implementation in a Multihospital Health System

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Abstract — A number of technological advances are becoming incorporated into institutional pharmacy practice in order to reduce the frequency and severity of medication errors. One of these has great promise. They deal with intravenous (IV) medication safety systems, wherein customized drug software is interfaced with “intelligent” infusion pumps. This paper describes the implementation and initial evaluation of Hospira’s *MedNet* decision support infusion software in a five-hospital health care system in Pennsylvania. All of the steps are reviewed (identification of stakeholders, evaluation of software capabilities, evaluation of institution-specific practices, decisions regarding standard operating procedures, writing of the drug libraries, and preparation for “going live”) in detail. In addition, the initial results of the system are described, especially with respect to potential medication errors avoided. The well-documented medication error avoidance potential of such systems has proven useful in a clinical setting.

Key Words — IV medications; safety system implementation; safety software

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Technology is essential for improving the safety of the medication-use process by avoiding medication errors. Computerized prescriber order entry (CPOE), robotic drug dispensing, pharmacy-controlled drug-cabinet access, and bedside bar-code medication verification are important technologies in this regard,¹⁻⁵ but they do not address the issue of intravenous (IV) infusion programming errors.

Although infusion pumps have made complex IV medication

administration possible, general-purpose pumps can be associated with errors because of the extremely wide range of possible rates (0.1 to 999 mL/h) and patient weights (0.6 to 300 kg). Without safeguards, administration errors are likely to occur, potentially characterized by manifold overdoses and mixups in programming dose, flow rate, and bolus or loading doses.⁶

Medication errors associated with high-risk-of-harm drugs have the greatest potential to cause sig-

nificant patient harm. Many of these drugs are delivered by IV infusion, and administration is the step most vulnerable to error.⁷ The introduction of an IV medication safety system (a computerized IV infusion system with facility-defined drug libraries with dosing limits) can help reduce the risk of IV infusion administration errors. It can also provide data on the medication errors averted by its use.

In general, IV medication safety systems have various platforms wherein monitoring and administration are contained in a single bedside system. The programming can be interfaced with large-volume pumps, syringe pumps, PCA pumps, and pulse oximetry/end-tidal CO₂ sensors. One interface for all administration devices greatly simplifies staff education, reduces the complexity of programming, and enhances ease of use. This design also maximizes equipment use.

System software allows the drug library database to be linked to all devices and tests the “reasonableness” of the intended administration before it is started. The entire drug library is formatted according to clinical care area (CCA) such that each area’s library contains drugs specific to that area’s patient population (eg, adult critical care, adult medical-surgical, obstetrics, pediatrics [in various weight ranges]). Each drug library entry contains various

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drug-infusion parameter sets (eg, drug name, diluent, drug concentration, and maximum/minimum/bolus dose limits). Limits are set to correspond with patient condition, age, and weight for adults and children. If a programmed dose is outside of the “approved” limits, an alert is provided. Alerts can be “hard” or “soft,” the latter can be overridden, while the former cannot. Alerts can also be provided to prevent duplicate therapy. These devices require institutions to develop standardized concentrations, dosing units, and limits for drug indications and areas of use specific for their patient populations and prescribing practices.

These systems can log programming alerts and overrides. They also provide data on serious potential medication errors, which could have caused patient harm, however were averted. If a hospital has wireless capabilities, real-time queries of the system can report information on infusion rates, drugs being administered, and whether or not a library is being used. In wired systems, data can also be downloaded periodically to a specific computer for analysis.

Using data from a pooled analysis of IV medication safety systems in 18 institutions (425,000 patient days), it was estimated that this type of system can avert 1.1 potentially life-threatening and an additional 1.5 probably significant IV programming overdoses per 1,000 patient-days in a typical 350-bed hospital.⁸

We describe the multidisciplinary, collaborative approach used by Crozer Keystone Health System (CKHS) to implement and evaluate an IV medication safety system.

CKHS

CKHS comprises five hospitals in Delaware County, Pennsylvania (800 beds). The hospitals are community (450 beds) or community/teaching-based (350 beds). Three Pharmacy and Therapeutics (P&T) Committees service the five hospitals. The formularies are similar, with policies and procedures varying between hospitals. There were ten CCAs in which the use of an IV medication safety system was considered to be of greatest potential value: pediatrics, neonatology, adult critical care, pediatric critical care, medicine/surgery, obstetrics/gynecology, burn, trauma, hematology/oncology, fluids/anti-microbials, and anesthesia.

The current CKHS medication error policy is non-punitive in nature. Errors are reported to managers via incident reports after which patients/prescribers are notified. In addition, if IV administration is suspected to be involved in the error, the infusion pump is sequestered in order to retrieve relevant data from the pump log.

Both hospital accreditation and in-house medication errors with high-risk IV drugs (eg, opioids, insulin, total parenteral nutrition) led to our focus on IV medication safety at CKHS. After a trial of three IV pump systems, our health system chose the *Med-Net* software system, which was loaded on the *Hospira Plum A+* IV infusion pumps.

IMPLEMENTATION

Successful implementation of the IV medication safety system involved the following steps:

- Identification of stakeholders
- Evaluation of software capabilities
- Evaluation of institution-

specific practices

- Decisions regarding standard operating practices (SOP) (systems, procedures)
- Preparation of drug libraries
- Preparation for “going live”

Several steps proceeded concurrently and, in some cases, out of this exact sequence. The ideal sequence is illustrated above. An optional, but valuable step, is to pilot the facility-prepared drug libraries on a limited number of units prior to facility-wide implementation. This allows modifications in the system with feedback from nursing and pharmacy staff without having to change out modified drug libraries on every infusion pump in use.

Identification of Stakeholders

Crucial stakeholders included hospital administration, nursing, pharmacy, and biomedical engineering departments, prescribers, and select existing multidisciplinary committees. Hospital administrators were key to implementation, since they provided financial and personnel support. Although not directly involved, they had to be updated frequently on progress and timelines. As the end user of the product, the active participation of the nursing staff was essential. Nurses also provided anecdotal information needed to make decisions in the absence of quantitative data (eg, prescriber practices, most common medications in a given area). Pharmacy’s expertise in medications made it a vital player, providing data on the most common medications and concentrations dispensed, managing the hospital formulary on a day-to-day basis, writing the drug libraries, and coordinating implementation. From the staff pharmacists who knew global ordering practices best, to the clinical phar-

macists who wrote and proofread libraries in their areas of expertise, to managers responsible for the implementation, editing, and maintenance of the libraries—all levels of pharmacy skill sets were used. Biomedical engineering was essential, as this department is responsible for the up- and down-loading of the IV infusion pump information. They also take care of pump maintenance. Prescribers had the least direct involvement in the process, since most of the necessary information was already available in hospital formulary documents. However, they were counseled on the process and consulted on specific situations, especially those instances involving hard limits. All facets of the process were overseen by the governing P & T committee, composed of mainly, and chaired by, prescribers. Time and resource constraints mandated use of existing multidisciplinary committees to facilitate implementation. At our institution, the Clinical Medication Safety Committee (comprised of pharmacy, nursing, hospital quality assurance [QA], and system QA members) was responsible for coordinating pump implementation and evaluating any data retrieved from the pumps. Reporting to the president, this committee had the authority needed to make key decisions in the process. As previously mentioned, the three P & T committees played a role, as did the Critical Care and Pediatrics/Intensive Care Nursery committees and the Nursing Practice Council (latter for dissemination of information at the staff nurse level).

Evaluation of Software Capabilities

Once it was decided to use the *MedNet* software, certain key parameters were ascertained in

order to facilitate writing of the drug libraries. These included the software's capabilities in terms of number of CCAs, number of medications per CCA, number of characters available in each field, options for rate delivery, and delivery precision. The first two parameters were important starting points, helping in the organization of the libraries and the identities of medications to be included/excluded. The number of characters parameter was important for the design of drug labels and CCA titles. In some instances, the limitation on the number of characters required us to use either brand names or abbreviate longer names, such as ampicillin/sulbactam. The bibliography of the CCA title abbreviations and drug labels had to be disseminated to all involved individuals to minimize the potential for confusion. The options for rate delivery were critical in deciding how to write rule sets. Delivery precision is most important for pumps used in pediatric and neonatal patient populations. As we were changing from syringe pumps with precision to two decimal places to an infusion pump with precision to one decimal place, this difference in precision had to be acceptable to the prescribers and mandated education of all involved individuals.

Evaluation of Institution-Specific Practices

A well-written and organized hospital formulary facilitates data collection for this step in the process. Decision making was greatly assisted by having the following items readily available: standard drug concentrations, IV infusion administration guidelines (including recommended rates, IV access types, monitoring parameters, etc), and sample order

sheets/protocols. These data frequently dictated how certain drugs were listed and on which units they could be used. Having these guidelines in place before implementing the software made for a very smooth transition.

Decisions Regarding SOP

Once data gathering was completed, it was time to make decisions regarding standard operating practices, both IV system specific and policy and procedure specific. These decisions, when possible, should be made by a multidisciplinary committee. Examples of key software system decisions to be made included:

- How are medications organized, and what are the rule sets governing them?
- Who has editing privileges for the libraries?
- How many CCAs will be used?
- Which medications will be listed in each CCA and in which order?
- What are the rule sets for each drug?
- Will medications be listed by generic or brand name?
- Will there be any upper or lower hard limits?
- Are there any medications “on the horizon” for formulary evaluation prior to the next scheduled library update?
- How will “look-alike, sound-like” medications be listed?

At our institution, it was decided that only the manager of quality assurance and drug safety and health system pharmacy director would have library editing privileges. Any edit suggestions are to be made solely to the manager. Currently, there are more than 250 different medications configured into 10 CCAs. With this volume, it

<i>Drug Name</i>	<i>Drug Amount</i>	<i>Drug Unit</i>	<i>Diluent Amount</i>	<i>Diluent Unit</i>	<i>Dosing Unit</i>	<i>Lower-Hard Limit</i>	<i>Lower-Soft Limit</i>	<i>Upper-Soft Limit</i>	<i>Upper-Hard Limit</i>	<i>Clinical Care Area</i>
No drug selected	NONE	mg	NONE	mL	mL/h	NONE	NONE	NONE	NONE	
Maintenance fluid	NONE	mg	1,000	mL	mL/h	1	5	499	999	ICU
Amiodarone (bolus)	150	mg	100	mL	mg/min	NONE	NONE	15	NONE	ICU
Amiodarone	750	mg	375	mL	mg/min	NONE	0.5	1	NONE	ICU
Calcium Gluconate	1	g	100	mL	mL/h	NONE	50	100	NONE	ICU
Calcium Gluconate	2	g	100	mL	mL/h	NONE	NONE	50	NONE	ICU
DOBUTamine	500	mg	250	mL	mcg/kg/min	NONE	1	40	NONE	ICU
DOPamine	400	mg	250	mL	mcg/kg/min	NONE	1	20	NONE	ICU
Gentamicin	NONE	mg	100	mL	mL/h	NONE	200	200	NONE	ICU
Midazolam	NONE	mg	NONE	mL	mg/h	NONE	0.5	15	NONE	ICU

Figure 1. Sample of MedNet library; example of 10 medications out of 99 total in the Critical Care Clinical Care area.

was felt that having more than one editor at a time would increase error potential.

Selecting which medications to add to the libraries was made on the basis of several inputs. Nursing and clinical pharmacy staff responsible for units represented by specific CCAs provided anecdotal feedback while, at other times, quantitative data could be used. Medications were listed in alphabetical order by generic name. After piloting the system on four nursing units, it was decided to add upper-hard limits for potassium chloride, vancomycin, and lipids. Tall man lettering, in accordance with current institutional practices, was used for “look-alike, sound-alike” medications.

Examples of key procedural decisions to be made included:

- Which CCA covers which nursing unit(s)?
- How will patient transfers between units be handled?
- Which committee(s) must approve drug libraries?
- Will use of the libraries be mandatory?
- What is the procedure for sequestering pumps in the

case of a suspected medication error?

- Will formulary rules override pump library entries?

Many of the procedural decisions, such as patient transfers and pump sequestration, were addressed in nursing policies and procedures.

Preparation of Drug Libraries

The actual writing of a drug library requires incorporating all of the information gathered into a series of data entries for a specific drug (ie, entering a specific drug into a CCA and adding drug-specific parameters including concentration, rate, and limits into the database). The database software prompts each step in the entry process.

Using collected data, drug libraries were created followed by a review of each library by nurses and clinical pharmacists responsible for the appropriate CCA. In some instances, such as the burn and neonatal units, prescribers also reviewed libraries at this stage. In both of these units, some limits were based more on anecdotal standards of practice or prima-

ry literature rather than reference sources. These situations required prescriber approval. After receipt of feedback and revisions had been made, drug libraries were forwarded to the applicable P & T committee for review and approval. A sample drug library is illustrated in Figure 1.

Preparation for “Going Live”

Education of the involved individuals was a must at this step. The health system nursing education department used a combination of live demonstrations, “train the trainer” symposia, and written materials to ensure a smooth transition. Education was also provided to pharmacy, prescribers, and biomedical engineering staff. Our institution piloted the system in four different types of CCAs prior to facility-wide implementation. This testing allowed us to refine the education process for the balance of facility staff.

RESULTS

At CKHS, a data download was performed in the summer of 2004, approximately 2 to 3 months post-implementation. At

Table 1. Medications Identified in Critical Catches

Ampicillin
Clindamycin
Eptifibatide
Labetalol
Morphine
Nicardipine
Oxytocin
Phenylephrine
Total Parenteral Nutrition (TPN)

that download, over 8,000 infusion data sets were available representing a period of 3 to 14 days of data depending on the acuity of the unit. The overall compliance with the *MedNet* software was 46%. Compliance was defined as a medication being administered with the drug library being used according to institutional policy. Of the 8,471 infusion datasets evaluated, there were 226 (2.6%) alerts and overrides captured, with 25 (0.3%) of these resulting in programming changes. The evaluation was taken one step further. Programming changes that actually resulted in a change in rate from the original entered rate were termed critical catches. We had 10 (0.1%) such critical catches. Examples of programming changes that were not critical catches included a nurse being stopped by a limit and saying “no” (she did not want to proceed) but, with the next keystroke, she proceeded with the original rate that had been entered. Table 1 lists the medications involved in the critical catches, with some medications appearing multiple times.

Some incidents (such as morphine) exceeded the upper limits, while others (such as TPN) were slower than recommended which

could have resulted in the patient not receiving sufficient amounts of drug. Not all critical catches or programming changes represented potential harm to the patient; however, they did give further insight about changes in practice. For instance, oxytocin was not a critical catch, but was flagged as being one of the 25 programming changes mentioned above. In these examples, the dose being administered was therapeutically correct, but the trend alerted the group to the need for further streamlining of the oxytocin program to decrease potential for errors. For example, having the alerts from the pumps assisted in having multiple hospitals and physician groups come to an agreement on standard concentrations and possible implementation of a preprinted order form for oxytocin. We found that the pumps assisted our facilities with better formulary enforcement, since having a finite number of entries in the pumps requires streamlining standard concentrations.

Other interesting findings in the evaluation included the compliance rates by time of day. Compliance with using *MedNet* software, instead of choosing no drug selected, was down at the times of shift change. The units with the highest rates of compliance were the neonatal and the obstetric/gynecology units. It is hypothesized that this occurred due to the closed nature of these units and the use of a relatively small number of medications. The most common medications selected throughout the health system included maintenance fluids, oxytocin, heparin, and total parenteral nutrition solutions.

Nursing was made aware of the data extracted, and they were asked how the libraries, or the

pumps, could be better used. After receiving this feedback, some modifications were made to the libraries to increase efficiency. For instance, examples of noncompliance included nurses choosing “no drug selected,” because he or she was administering medications which were not part of the drug library or the CCA that was being used for the patient. This was not only a patient safety concern, but this also falsely lowered the compliance rates. Because of these findings, the format in which antimicrobials were listed was changed. Some of the premixed medication options were further streamlined. Bolus options for medications not previously included were added. With ongoing feedback from the nursing staff, it is hoped that a user-friendly drug library can be maintained.

CONCLUSION

Throughout the implementation process, lessons were learned as time proceeded. The need for education and interdisciplinary support was a constant theme throughout implementation. Making a technology change such as this cannot be done unilaterally, or it will not succeed. There was, as expected, some resistance to change; however, the ability to provide better patient care overcame resistance to implementation.

Ultimately, patient safety was impacted by this implementation. The critical catches were each incidents, which either had the potential to cause harm directly or indirectly, or they showed trends towards changes in standard practices. When analyzing the numbers, it is important to realize that the 10 critical catches represent, at most, a 14-day time period. This extrapolated over a year has a sig-

nificant impact on patient safety and overall health care costs. Ongoing education and data evaluation of the IV medication system will continue to increase compliance rates and in turn patient safety.

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