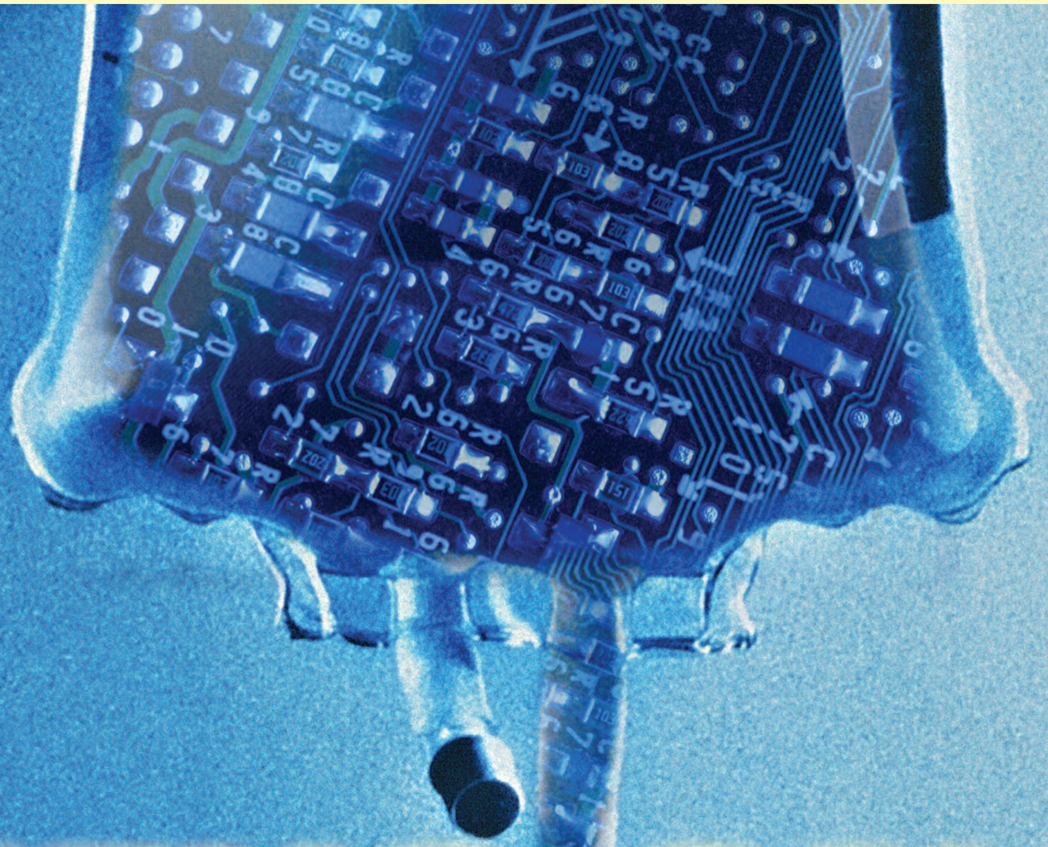

INTELLIGENT INFUSION

Wireless I.V. pumps allow for remote device management, monitoring of medication administration practices, prompt intervention of medication errors, and timely clinical education regarding near misses.

By Linda Morgan, RN, and Lor Siv-Lee, PharmD

Intravenous (I.V.) infusion pump technology has revolutionized administration of I.V. medication—many of which are high potency agents likely to cause injury if misused.[1] Approximately 90% of hospitalized patients receive I.V. medications, the majority delivered by infusion pumps.[2] Although these devices have been responsible for improvements in the accuracy and continuity of I.V. drug delivery, they're involved in 35 to 60% of the estimated 700,000 adverse drug events (ADEs) occurring annually in the United States.[1-3]

Morbidity due to ADEs is costly. Each preventable event in the hospital setting is associated with an additional estimated inpatient cost of $8,750.[4] Assuming the occurrence of 175,000 in-hospital preventable ADEs annually, the cost comes to $15.3 billion.

Medication errors can occur at numerous steps in the process of I.V. medication administration.[5,6] Errors related to I.V. infusion pump programming have the greatest likelihood of causing patient harm.[5] Hence, interventions designed to positively impact these errors should result in substantial reductions in potential and actual patient harm and should receive priority.

A concerted effort to address I.V. infusion pump-related errors has led to the availability of a new generation of I.V. infusion pumps, known as "intelligent" infusion pumps. These devices have the potential to prevent the majority of pump-related ADEs.[7-12] The key feature of intelligent pump technology is software that permits the development of drug-specific libraries or rule sets, which include drug dosing parameters specific to a given clinical care area (CCA) or defined patient population. The programmer is alerted if institution-defined dosing parameters (such as dose, rate, concentration) are outside of preestablished limits.[3]

These devices also have free-flow protection to guard against unintentional overdelivery of I.V. solutions or medications.[13] When these devices are used in conjunction with bar-code technology and standardized infusion concentrations, they support the five "rights" of safe medication administration ("right" drug to the "right" patient by the "right" route in the "right" dose at the "right" time).[13,14] These devices also log data continuously, providing valuable continuous quality improvement (CQI) information.[12] When used in conjunction with wireless technology, data review and intervention can occur in real time.

Table 1. Weighted evaluation tool for I.V. infusion pumps

Disposable requirements

1. Ease of priming tubing
2. Functionality of automated free flow prevention
3. Ease of loading tubing
4. Easy to use I.V. set for gravity infusions
5. In an emergency, set can be removed quickly and safely from pump and set to gravity flow
6. Ease of setting up secondary infusions (bag and syringe)
7. Ease of removing air bubbles
8. Needle-free system was easy to use
9. Product's ability to ensure compliance (doesn't allow direct use of needles)
10. Ability to prevent accidental disconnects (Luer-locking connections)

Technical specifications

1. Ease of programming rate and VTBI (volume to be infused)
2. Ease of programming secondary infusions
3. Ease of changing rate
4. Ease of changing VTBI
5. Ease of clearing volume infused
6. Ease of utilizing numeric keypad
7. Ease of titrating both dose and rate
8. Ease of switching back and forth from drug library to primary
9. Ease of activating and inactivating tamper resistance feature
10. Ease of determining remaining battery power in real time
11. Ease of determining whether pump is on battery or AC power
12. Ease of changing from one drug library to another
13. Ease of reading display in all light conditions and from several angles
14. Easy to understand and act upon troubleshooting messages
15. Ease of clearing nuisance air-in-line alarms
16. Easy to adjust alarm tones
17. Ability of pump to assist in identifying I.V. site/I.V. line status
18. Ease of evaluating alarm/notification of miscalculated dose
19. Ease of evaluating alarm/notification of hard and soft limits
20. Ability to override hard and soft limits

Physical dimensions

1. Ease of transport with regard to weight and flexibility of clamp
2. Actual size of pump
3. Adaptable to current patient environment

Overall infusion pump rating

Devise selection, implementation

Erlanger Health System (EHS) is a tertiary care, not-for-profit, academic facility affiliated with the University of Tennessee College of Medicine. Staff at EHS includes 999 RNs and 124 LPNs. A weighted evaluation tool was created by representatives from the nursing, pharmacy, and biomedical engineering departments to rate each brand of infusion pump. Criteria evaluated included the physical dimensions, technical specifications, disposable requirements (I.V. solutions, I.V. administration sets), ease of programming (primary and secondary infusions), ease of changing programming parameters, and ability to resolve alarm conditions. (See *Table 1*.)

Input was aggregated into six response fields: cost, disposable requirements, physical dimensions, technical specifications, patient safety, and service. The respective weights of the six fields were 20%, 15%, 10%, 25%, 15%, and 15%. Weighed scores were then averaged to provide overall scores used to select the top device.

Draft drug libraries were developed principally by a clinical pharmacy specialist in May 2004 to help streamline implementation once contractual arrangements had been finalized. The safety software can incorporate data for a total of 18 CCAs. Staff nurses from various patient care areas were invited to provide input into the development of the draft drug libraries. The committee felt that tailoring drug libraries to specific patient care areas would result in improved compliance.

Originally, 13 drug libraries were developed. While some CCA libraries contained as few as 10 medications, the ICU CCAs used the software maximum of 150 medications/CCA. Programming parameters for a given drug could vary between CCAs. When an infusion pump was initially assigned to a patient, the CCA had to be designated at that time. If the patient was transferred to another location, the CCA would be changed by the nurse accepting the transfer to reflect the new location of the patient or level of care that the patient required.

Preparation of the drug libraries involved searching and collating the institution's existing I.V. preparation guidelines, policies, and procedures governing medication administration (nursing and unit/patient population specific), and standing order/electrolyte replacement protocols. Preliminary drafts were organized by generic names in alphabetical order. Upon review, nurse managers requested a change to listing by brand names in most cases. The committee agreed that nursing staff would be more comfortable with brand names as opposed to generic names. Each library was organized in the following order: maintenance I.V. fluids, electrolyte replacement, individual nonantimicrobial drugs, then individual antimicrobial drugs. Two drug lists were generated (by brand and generic names), each list being in alphabetical order. Hard and soft dosing limits were established primarily using data provided by drug manufacturers as well as input from clinical specialists based on their areas of clinical expertise and experiences delivering these medications to patients. It was challenging to set limits for every drug since dosing variations are common in clinical practice.

The software program administrator's responsibilities included managing drug library updates, device software upgrades, and data downloads. This position was shared by individuals in biomedical engineering, clinical pharmacy, and nursing, all of whom had upper management positions and vested interests in the functionality of the device and patient safety initiatives while performing their other job responsibilities. A clinical pharmacist handled ongoing library editing, with library review/updating occurring a minimum of twice annually. Review/updating would occur more frequently, if needed, based on the results of analysis of data from the pumps, such as identification of an ADE. Biomedical Engineering was responsible for data uploads and library transfers after completion of revisions. Nursing was responsible for analyzing data retrieved to evaluate compliance with use of the safety software and safe medication administration practices, and providing feedback to nursing staff and other stakeholders.

Stakeholders adopted a policy of virtually 100% compliance with the use of the safety software. Exceptions to this policy were made only in the cases of emergency situations or if medications weren't represented in the existing drug libraries.

A clinical specialist from the vendor trained nursing staffs. Night and day shift "super users," clinicians who received additional device

Strategic planning for wireless infusion technology

- ♦ Ensure that hospital administration supports implementation of intelligent I.V. infusion pump technology in the institution.
- ♦ Perform due diligence.
  –Provide thorough investigation and evaluation of products from several I.V. infusion pump vendors.
  –Involve nursing staff in the device evaluation/selection process.
- ♦ Assess the institution's potential wireless capabilities or existing wireless infrastructure.
  –Complete the development of wireless infrastructure prior to device purchase.
- ♦ Involve staff in the in-service education plan.
  –Carefully select and utilize staff-based "super users" to help ensure successful staff education regarding new technology prior to and during implementation.
- ♦ Plan staff scheduling to insure that all staff members attend educational in-services.
- ♦ Set measurable targets and stretch goals regarding staff compliance with use of the new technology.
  –Obtain staff input in setting the targets.
- ♦ Prepare budget to include expenses to reward staff who reach target and stretch goals. Plan for ongoing educational in-services to occur at 6 and 12 months after initial in-services.
  –Plan focused educational programs based on CQI data reports regarding compliance with the new technology.

training, were utilized as educational resources for staff at the first go-live campus. This location's super users then trained super users from other campuses so that the latter could serve as educational resources. Nurse managers relieved staff on the floors to maximize participation.

Eight CCAs were selected for initial implementation of new pump/software technology: ED, Medicine/Surgery, Oncology, two Obstetrics/Gynecology, locations, Pediatrics, Surgery, and ICU). Subsequently, additional CCAs were selected for initial implementation since the software provides room for library data for up to 18 CCAs. The additional CCAs subsequently added prior to implementation were specific to patient population types across the multiple campuses and/or locations in the complex: Cardiology, Renal Services/Dialysis, Neonatal ICU, two Medicine/Surgery units, and another location's ICU. Following initial implementation (July-October 2005), three CCAs were added in March 2006 (Pediatric ED, Cardiac Catheterization Lab, and ICU [Antimicrobials]).

Results

Implementation of intelligent pump technology was delayed until completion of the institution-wide wireless infrastructure. In June 2005, contractual arrangements were finalized and preparations began for going live. By July 8, 2005, all safety software policies and procedures had been completed and 80% to 95% of nursing inservices had taken place. On July 11, 2005, final approved versions of the drug libraries were ready for uploading into the infusion pumps.

Initial compliance rates were disappointingly low. The Director of Operations scheduled meetings with individual nurse managers of each CCA and had focused meetings to review their compliance results and discuss any barriers that would prevent their CCAs from achieving satisfactory compliance rates. Interventions carried out over several months resulted in a positive trend in compliance rates in all CCAs, culminating in absolute percentage increases in compliance rates (January 2007 data) of 26%, overall. Compliance as a function of the time of the day revealed little fluctuation. Ongoing analysis of data reports yielded some interesting details that addressed the need to revise selected drug libraries as well as evaluate current practices. One example of such an opportunity was to address any conflicting pharmacy department instruction medication labels so that the drug library and label instructions were congruent, and to do this during the library development process.

By the week of December 1 to 7, 2007, noncompliance with use of the safety software had fallen to only 1.2% overall (11,299 total programs). Alerts (hard limit, soft limit edit, and soft limit override) occurred in 0.5%, 0.3%, and 5.5% of programs, respectively. For only one CCA, the noncompliance rate exceeded 1.9%. The range for hard limit and soft limit edit alerts was 0% to 1.2%, and for soft limit override alerts it was 0% to 24%. During this same period, there were a total of 74 hard limit override attempts. Assuming that all 74 attempts would have resulted in ADRs had they been "successful," the potential cost avoidance was $647,500.

Take-aways

In retrospect, many lessons were learned during the implementation process that may improve prospects for higher and sustained compliance rates in the future. Ongoing staff and administration education and reinforcement of that education are key. It also includes involving more end users in the device selection process and in the drug library development to improve their acceptance. This may also potentially reduce the number of subsequent drug library revisions required during the implementation process. Stressing the importance and value of the safety software during the training phase of implementation is also vital to helping clinicians improve medication administration practices and fully participate in patient safety initiatives. One area in which initial education was deficient was among relief pool and agency staff. Realizing this, educational efforts were repeated with this group in October 2006.

While the end user can bypass some aspects of the drug library to program the device, the committee agreed early on that it was appropriate for nurses to make this selection ONLY in case of an emergency or a medication not found in the drug library. With up to 6 months between library revisions, using the "no drug selected" entry may be necessary more frequently than desirable. The only way to reduce such selections is to reduce the maximum interval between library updates.

Another strategy to improve compliance with software use involved making routine unannounced CCA spot checks of pumps delivering I.V. infusions to patients, looking for the ⚠ icon on the screen (indicating that the safety software wasn't in use). This allowed nursing management the opportunity to learn why the clinician wasn't using the safety software and immediately reinforce hospital policy regarding compliance, as well as educate the clinician on correct pump operation. Reporting the results of these spot checks, in addition to sharing pump CQI data with the staff, has resulted in a "healthy competition" between CCAs—and raised compliance rates. Staff can witness firsthand the true value of the software when reports indicate ADEs that have been avoided as a result of its use.

Examples of actual programming errors are anonymously shared with staff to illustrate the value of always using the safety software. For example, an insulin dosage of 1.5 units/hr was prescribed, but a value of 105 units/hr was keyed in. As the upper soft limit of 20 units/hr was exceeded, the clinician was warned and corrected the entry.

Another case involved the use of propofol for sedation in the coronary catheterization lab. A dose of 65 mcg/kg/min was incorrectly keyed in as 665 mcg/kg/min. As the upper soft limit of 200 mcg/kg/min was exceeded, the error was caught and corrected.

Equal emphasis is given to teaching about underdosing errors, as these, too, can have catastrophic consequences. For example, heparin orders were written for 1,200 and 1,000 units/hr, but doses of 12 and 10 units/hr were keyed in. This underdosing could have caused worsening thrombosis. As the keyed values were below the lower soft limit of 700 units/hr, clinicians were alerted to the substantial underdoses and corrected their entries.

The major advantage of wireless technology is the ability to access data in "real time" so that monitoring can be done in a prospective fashion and interventions can take place before ADEs occur. This may improve the retention of corrective measures, especially those involving new technologies. Wireless technology is a tremendous time saver, allowing access to current data immediately, and allowing ready access to data from physically separated institutions (separate campuses of one facility).

Wireless systems can provide bidirectional communication—from server-to-pump and pump-to-server. Server-to-pump communication allows the facility to transfer hospital-specific drug libraries and configure wireless/network operating parameters to pump from a remote location. Pump-to-server communication allows the pump to upload and report all events (program start/stop, dose limit alerts, power state changes, etc.) and alarms to the server as they occur. Lastly, wireless technology allows for remote software upgrades.

Uncompromised care

At EHS, implementation of wireless intelligent infusion pump technology occurred transparently, without any compromise of patient care. Many lessons were learned during implementation that explained the initial suboptimal compliance with safety software use. From these, strategies were developed to increase software utilization rates, resulting in steadily improving compliance rates.

Wireless technology has allowed prospective monitoring, the avoidance of ADEs through prompt intervention, and the timely education of healthcare professionals regarding potential ADEs. As word of the value and the power of the infusion safety software spreads throughout the nursing units, staff members are increasingly believing in its value and reporting that they're uncomfortable using infusion devices without safety software. NM

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