Worth the Effort?
Closed-Loop Infusion Pump Integration with the EMR

Dan C. Pettus and Tim Vanderveen

Disclosure: The authors are employees of CareFusion, which holds many patents, including those associated with clinical device operating parameters. They also were employed by the predecessor companies that were involved in developing modular smart intravenous (IV) infusion safety systems and the associated wireless connectivity. This article reports their firsthand experience of what it took, and their understanding of what hospitals need to know, to achieve reliable, scalable, repeatable, closed-loop IV infusion pump integration with the electronic medical record (EMR). The article is based on their combined 50-plus years of experience in IV infusion safety and on a series of recent interviews with thought leaders and senior personnel at early-adopter healthcare organizations.

The leading cause of patient harm is medications, which account for almost 20% of medical injuries.[1] Intravenous (IV) infusion errors, which involve high-risk medications delivered directly into a patient's bloodstream, have been identified as having the greatest potential for patient harm.[2-6] Many hospital administrators think that the combination of computerized provider order entry (CPOE) and barcode medication administration (BCMA) protects patients from serious adverse drug events (ADEs)—but neither CPOE nor BCMA safeguards patients against many types of IV infusion errors (Figure 1).

Darren Dworkin, vice president of enterprise information systems and chief information officer of the Cedars-Sinai Health System in Los Angeles, says, "There's no one thing that you can do to prevent errors. We have lots of data that show that having invested and implemented CPOE and BCMA significantly improves medication safety, but we also have data that show we still have room to improve to get to zero IV drug therapy errors. We need to find a way to fix that by tackling the whole problem."

IV infusions present the greatest medication safety challenges because of their high potential for harm and how they are administered. For an oral solid, intramuscular injection, or eye drops, administering a dose is a one-point-in-time event. For an IV infusion, administration is a process that continues over time and may involve many

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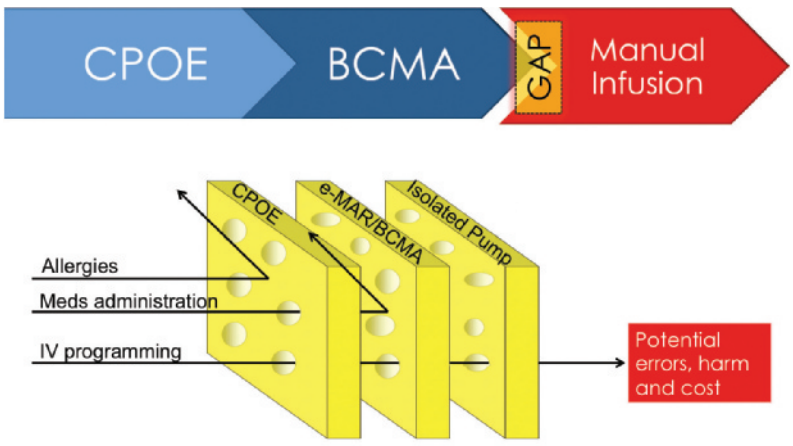


Figure 1. CPOE, BCMA and IV Infusion Errors

dosage adjustments (titrations) based on patient response.[7] A single wrong keystroke in programming the pump can result in a 10- or 100-fold overdose with possibly tragic results ("death by decimal").

The dose error reduction system (DERS) in what have become known as "smart" infusion pumps was developed to alert the caregiver or prevent infusion if the pump programming exceeded hospital-established limits on the medication. While DERS has been shown to help avert potentially serious errors,[2] many infusion-related errors are still not addressed. A 2003 observational, prospective investigation at a 725-bed, tertiary-care, academic medical center in Chicago collected data from 8 a.m. to 5 p.m. on all IV infusion pumps in use on inpatient care units. Of 426 medications infusing through an IV pump, 285 (66.9%) had one or more administration errors (examples, Table 1). Of 389 documented errors, 37 were "rate deviation" errors. Only one error would have been prevented by smart pump technology available at that time without additional interface and software capabilities.[8]

Entered on the IV pump	The CPOE medication order
Heparin infusing @ 200 Units/hr	1,300 Units/hr
Hydromorphone 1 mg/mL @ 2 mg every 15 min prn	No new order written upon transfer to ICU.
Amiodarone 0.5 mg/min	Order was written five days prior: Amiodarone 1 mg/min X six hrs, then 0.5 mg/min x 18h. No continuing orders written past the first 24 hr.
Hydromorphone 1mg/mL @ 0.5mg every 15 minutes prn	Hydromorphone 0.2mg/mL @ 1 mg every 15 minutes. (This discontinued order was erroneously copied upon transfer to ICU.)

Table 1. IV Infusion-Order Discrepancies: Order Compared to Infusion[8]

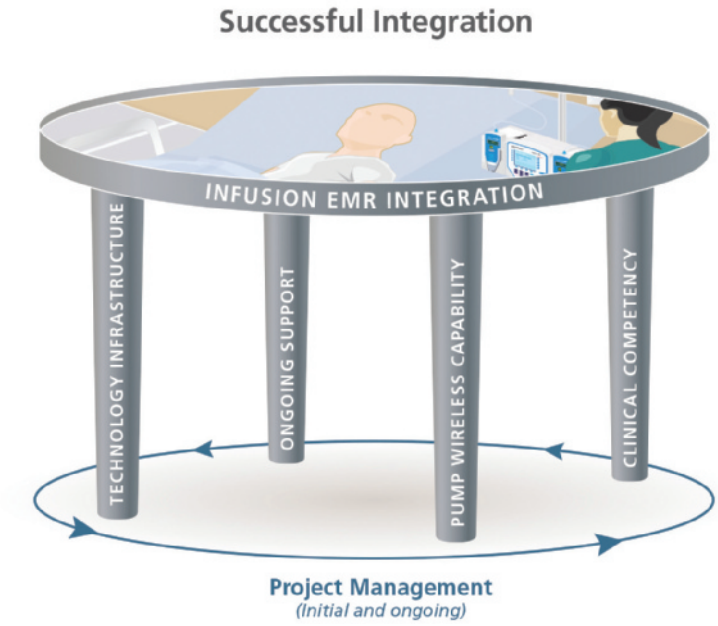


Figure 2. Vendor Strengths for Successful Infusion-EMR Integration

A follow-on study in 2010 showed that 24% of drug infusions and 42% of fluid infusions had discrepancies between CPOE orders and smart pump programming.[9] In addition, a nurse might not know that an order had been discontinued or have the most recent laboratory results. Moreover, a nurse might choose not to engage the safety software. To overcome these obstacles and address the complexity of IV therapy requires an integrated approach.[8] A recent report from the ECRI Patient Safety Organization database shows that 75% of the reported infusion programming errors could have been averted with successful pump integration.[10]

Steve Miller, chief information officer at Oklahoma Heart Hospital (OHH) in Oklahoma City, says, "We felt that the best way to improve high-risk infusion safety would be to free nurses from the burden of manual programming, yet keep them involved in the process, using their clinical expertise to verify the programming before infusion can begin."

As the authors noted in a 2011 AAMI *Horizons* article, the integration of infusion devices into hospitals' health information technology (IT) and EMR can greatly improve safety, quality, and productivity.[11] Michelle Mullins, director of clinical systems at OHH, says, "We now have four validations of the infusion order—the physician, the pharmacist, the nurse and the autoprogramming of the pump—which eliminates the potential errors one can make when manually programming an infusion."

If infusion interoperability with the EMR solves so many issues, why is it not widely implemented in most hospitals today? There are several reasons. Most importantly, infusion pump-EMR integration is bidirectional, which is very different from other types of device-health IT connections. An integrated, closed-loop system both listens and talks to the pumps. Since health IT and infusion pumps were created independent of each other, much work must be done to harmonize the two systems. Communicating

effectively is far more challenging than simply being connected.

The last decade has seen many experiments and pilot studies with infusion interoperability. The lessons learned from these early adopters showed the need for different thinking on the part of the infusion vendor. Moving from a few pilot-test infusion pumps to repeatable, enterprise-wide EMR interoperability mandates a whole new set of capabilities. For integration to be successful, infusion pump and health IT vendors must incorporate four foundational strengths: technology infrastructure, pump wireless capability, clinical competency, and ongoing support (Figure 2). Without these capabilities, there are many points at which full, house-wide infusion pump-EMR interoperability can fail (Table 2).

At some institutions interoperability already has gone beyond small-scale pilot studies to scalable, sustainable, reliable systems in house-wide clinical use. Yet, as ECRI points out, integration can be "complex, difficult, and costly."[11] As we also noted in 2011, achieving the ultimate goal of a fully integrated infusion safety system presents both cultural and technological challenges. However, when such changes are embraced, the results are very much worth the effort.

In this article we describe the current challenges, the fundamental capabilities required to meet these challenges, lessons learned ("what we didn't know we didn't know"), and the results and evaluations of early-adopter and current, house-wide implementations. A capabilities checklist is provided at the end of this article to assist hospitals in forming the type of long-range partnerships needed to successfully implement IV infusion-EMR interoperability.

"There's not a biomed engineer on the planet that alone with their skills can get this done," Dworkin says. "And no matter how much the IT folks think they know, there's not an information technology professional alone who can do this. It's really going to take the marriage of the two of them."

1. If the lower levels of connectivity such as wireless bandwidth and server sizing are not able to scale and sustain acceptable performance.
2. If the technology is difficult to install and support.
3. If the communication protocols require the use of security-threat methods such as user datagram protocol (UDP) or broadcasts.
4. If the pump wireless protocols are not optimized for roaming and receive-sensitivity that allows for patient mobility.
5. If the pump is demoted to basic infusion with no DERS protection for complex multi-ingredient medications.
6. If pump interoperability does not include syringe connectivity with the EMR, especially in a children's hospital.
7. If the pump implementation cannot scale to cover all patient rooms at multi-hospital systems.
8. If the pump vendor does not have the resources or skills to engage with the hospital health IT-application specialists and hospital pharmacists to align the master formulary with the DERS dataset.
9. If the pump vendor does not have the resources or skills to understand BCMA workflow and provide education with ongoing training.
10. If the pump company does not have interface engineers on staff and available 24/7.
11. If the pump company does not provide ongoing, sustaining support with staff interoperability specialists.
12. If the pump company has not demonstrated they have transformed their offering from an interoperability engineering experiment into a commercially comprehensive, repeatable capability.

Table 2. House-wide Infusion Pump Interoperability: Possible Failure Points

IV Infusion Auto-Programming

In the mid-1990s, clinicians and engineers envisioned the day when infusion pumps would be programmed automatically, and several patents were filed describing what eventually would become bidirectional interoperability. This vision predated CPOE, barcode medication systems, wireless device connectivity, and "smart" infusion pumps with drug libraries and DERS.

Following the 1999 publication of the Institute of Medicine's *To Err is Human*, the stage was set for hospitals to begin aggressively addressing medical errors, especially those involving medication. In the early 2000s CPOE, EMR and BCMA were beginning to be implemented by early-adopter hospitals. In addition, the first smart infusion pumps were being introduced. However, the BCMA systems focused on the administration of tablets, capsules, and injections—essentially discrete "events." As mentioned earlier, since most IV infusions are a "process," the early BCMA systems did not function well for infusions.

In 2002 a leading BCMA vendor[a] and an early smart pump vendor[b] combined forces

to co-develop an integrated BCMA-infusion system that would address the most critical, highest-risk medication errors by auto-programming the smart pump with infusion parameters in the physician's order. In addition, this BCMA-infusion system would automatically document the administration process. Rather than requiring nurses to manually program the pumps and document the infusions, the new system only required them to confirm both programming and documentation. This pioneering new infusion system took advantage of the introduction of infusion-pump wireless connectivity and the expanded capability of BCMA to include IV infusion orders.

In December 2003 infusion pump auto-programming and auto-documentation went live in an intensive care unit (ICU) at Ohio Valley General Hospital in Pittsburgh, PA. Barcode scanning of the IV bag triggered the transfer of programming information from the pharmacy directly to the pump. The integrated system eliminated the need for manual documentation by automatically sending infusion data to the electronic medication administration record (eMAR)

The new systems were in use for more than a year. Results confirmed that integrating the technologies reduced the risk of programming errors, as shown by a 12% decline in averted medication errors documented by continuous quality improvement (CQI) data from December 2003 to April 2004.[12] Nevertheless, fundamental challenges remained with regard to clinical scope, technology platform, analytics, and expertise.

The real-world clinical experience at Ohio Valley made possible in-depth analyses of what worked and what did not (Table 3). The knowledge gained was a primary part of the strategic plan for going forward. *[Other companies also conducted early implementations of smart pump-EMR interoperability, but the authors have little knowledge of these and cannot report on what was learned and put into practice.]*

- Fundamental differences between real-world vs. laboratory environments must be addressed by system design and architecture.
- Both large-volume and syringe pump interoperability with the EMR are needed to extend the benefits of auto-programming and -documentation to more care areas, such as the neonatal ICU and pediatric ICU.
- All drug datasets—IV orders, master formulary and DERS—must match.
- Expertise with regard to both BCMA and drug formulary workflow is essential.
- Strong field support for initial integration and continued interface maintenance are essential.
- Wireless design and infrastructure make a critical difference to achieve
  - Short latency times
  - Reliable connectivity
  - Minimal "load" on the network
- Successful implementation and use require multidisciplinary, ongoing vendor support

Table 3. Lessons Learned from Early-adopter IV Infusion-EMR Integration

	All hospitals	300-399	400-599	>600 beds
CPOE	79%	86%	97%	91%
BCMA	76%	89%	85%	84%
Smart Pumps	78%	94%	91%	96%
EMR	87%	94%	97%	92%

Table 4. Medication Safety Technologies: Have or Have Budgeted[13]

Integration Readiness

Medication safety technologies continued to evolve, and by 2011 the vast majority of larger hospitals had the foundational technologies of CPOE, BCMA, smart pumps, and EMR either already in place or budgeted (Table 4).[13] Almost a decade after the implementation at Ohio Valley General Hospital, the technologies, software applications, regulatory approvals, and multidisciplinary teams were in place to provide scalable, sustainable, reliable smart pump-EMR integration for house-wide clinical use.

Current Smart Pump-EMR Implementations

Oklahoma Heart Hospital

OHH is a 145-bed, adult cardiac care hospital in Oklahoma City, OK. Ranked in the top 1% of hospitals nationwide for patient satisfaction, OHH was the first all-digital hospital in America totally dedicated to the care of heart patients. In 2012 OHH became the first hospital to integrate a modular smart infusion system[c] with an advanced EMR.[d] Table 5 shows preliminary results achieved at OHH.

Brent Fivecoat, a nurse at OHH, says, "When you scan everything, it's all right there

on the screen. You know what dosage you're supposed to be giving, you know the drug is right, you know the dose is right. It's nice peace of mind."

Children's Hospitals and Clinics of Minnesota

Pediatric hospitals present perhaps the greatest IV infusion medication safety challenges, as clinicians order, distribute, and administer high-risk medications to patients ranging from 400-gm neonates to 150-Kg adolescents. Children's Minnesota, a non-profit, 347-bed, tertiary-care, high-acuity facility, is the first pediatric hospital system to achieve BCMA-smart pump-EHR interoperability to help protect both large-volume and syringe IV infusions (Figure 3).

In March 2012, following a six-week pilot study in the pediatric ICU (PICU), BCMA-smart pump-EMR integration[c,d] went live at Children's Minnesota's Minneapolis campus, and at the St. Paul campus by the end of the year. Infusion pump auto-programming and documentation are being used in critical care units, medical-surgical units, the emergency department, and surgical services. Jeffery Fleming, clinical and informatics pharmacist at Children's Minnesota, points out, "The nurses are not keying anything; all they're doing is validating that 'Yes, these are all the correct pieces of information.'"

The smart-pump vendor worked with Children's Minnesota to develop a detailed plan for managing every step of the months-long efforts required for implementation (Figure 4). "You need to have somebody that really understands both sides of it in regards to the pumps and the EMR," Fleming says. "Especially if they have a team that can come in and help you do it or at least advise you to help you through those problems, because they have other sites where they have already worked through those issues." At "go-live," pump vendor staff were on the unit 24, then 20 hours per day. The vendor also supplied ongoing technical and clinical support.

Results from a six-week pilot test in the PICU showed significant safety gains following smart pump-EMR integration. Manual programming was significantly reduced, and auto-programming was adopted at a higher rate than had occurred with

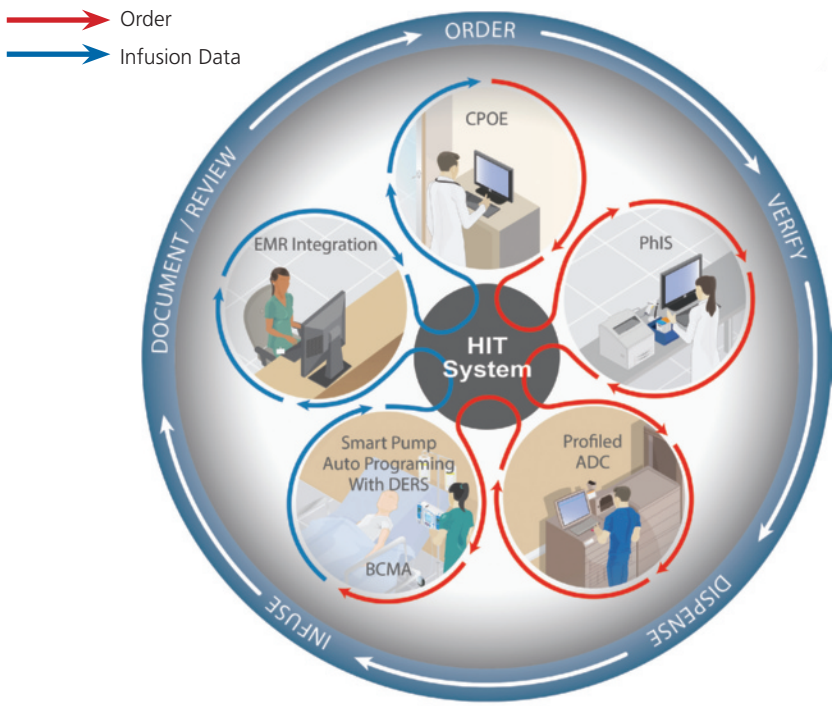


Figure 3. Smart Pump-EHR Interoperability in Integrated Medication Safety System

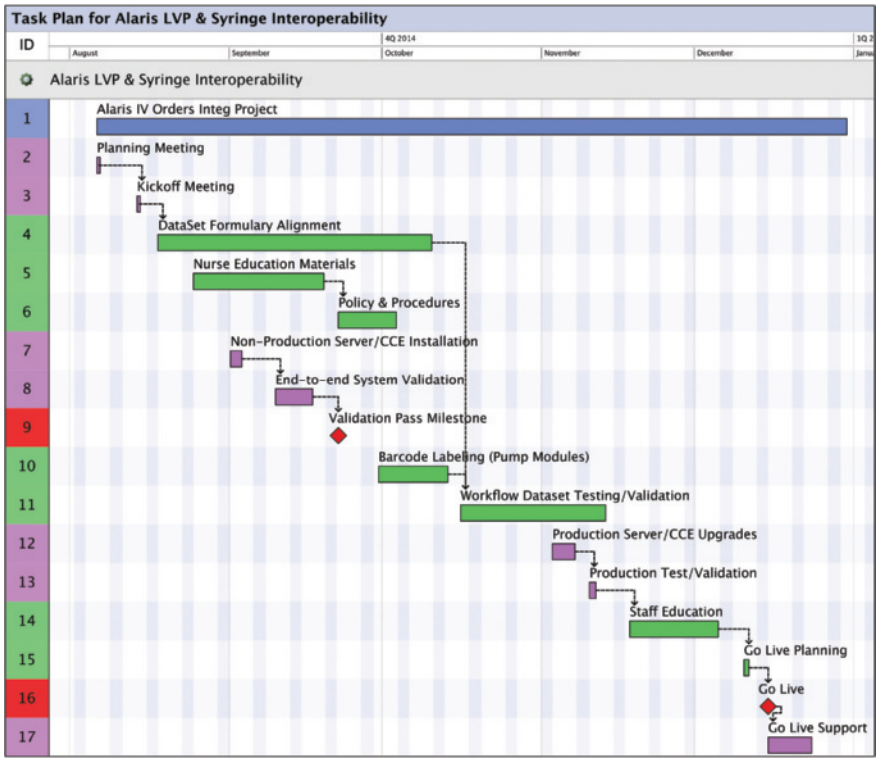


Figure 4. Detailed Project Management Plan

Auto-ID (an earlier system that populated infusion parameters from dispense information, not the EMR). Adoption of smart pump-EMR auto-programming continued to improve with time and advances in technology (Figure 5).

Improved nursing satisfaction is evident in the high rate of adoption of auto-programming. "The positive attitude of our nursing staff for the BMCA and auto-programming comes from seeing the errors they're catching, seeing all that information populate the pump and realizing the safety benefit," Fleming says. "It's to the point where they're unhappy when they're unable to send an autoprogramming message to the pump, for whatever reason. They want to know why and they want it fixed, so the next time they can do it with autoprogramming."

The success at these pioneering hospitals has led to a significant uptake in the number of new smart pump-EMR integrations to take place in coming years, with an additional 75 hospitals now contracted for closed-loop smart pump-EMR interoperability implementations. The reminder of this article will address what has changed and what is needed to cross the chasm from experimentation to commercial availability.

What You Need to Know Now

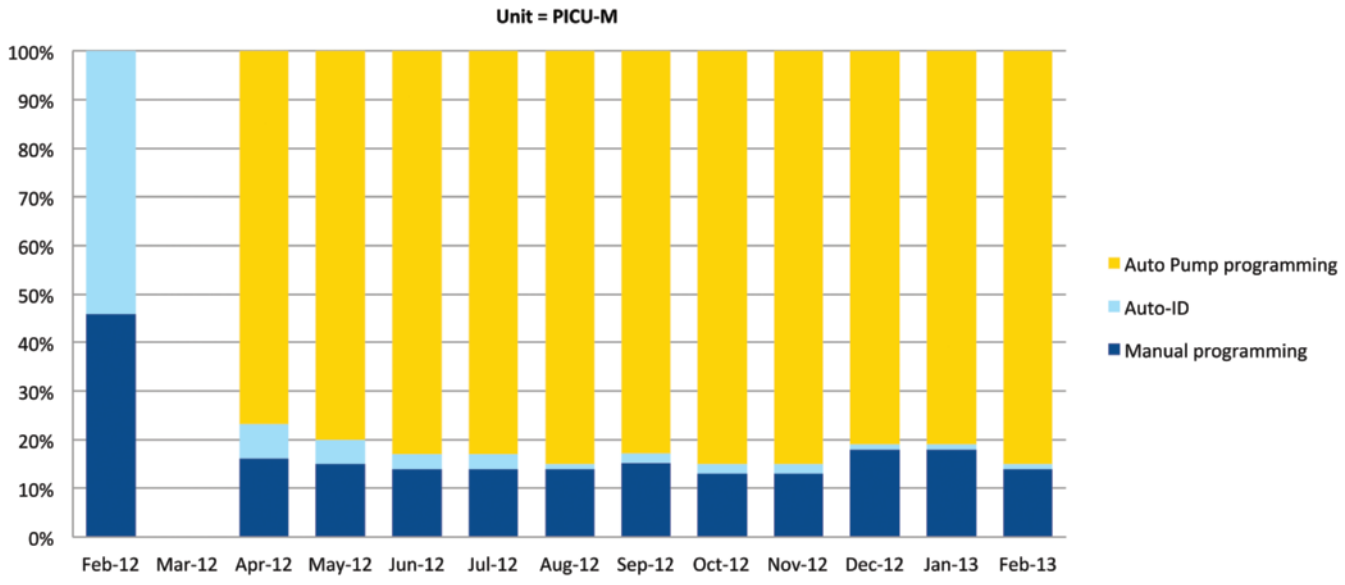
Just transmitting data from an EMR to a pump is not that difficult. All other factors involved are important—the clinical scope, the technology platform, the data analytics capabilities, and the level of expertise the vendor provides to meet all the demands of a large-scale integration.

"At this point we tend to differentiate between vendors and products less on the basis of the core features of the medical device itself and more in terms of the package," Dworkin says. "The differentiation is in the extra features on top of the device itself, such as its ability to communicate wirelessly, to operate in a secure open network, and to interact with an EMR. That evaluation is usually the first step in the selection process and how we decide whether to take a closer look at a piece of technology."

Clinical scope

Implementing auto-programming only for large-volume pumps is not enough.

Syringe pump interoperability is especially critical in neonatal intensive care units (NICUs) and PICUs, where patients are especially vulnerable to medication errors because of their weight-based dosing and the very small margin for error. The pump safety software is needed to protect all types



Auto-ID = earlier system that populated infusion parameters from the IV medication-label dispense information, not from the electronic health record

Figure 5. Programming Method of DERS-protected Infusions

of infusions, including critical multi-ingredient infusions such as chemotherapy and total parenteral nutrition (TPN). An infusion safety system also has to be able to safeguard patients independent of the health IT system, without compromising any of the DERS protection.

Technical Platform

To achieve robust, house-wide connectivity, much more is required than just a better interface engine. Wireless network design and components need to meet challenges such as fast roaming and short latency (turnaround) times, maintaining connectivity while requiring minimal bandwidth, providing the necessary security for data, and offering sophisticated analytics to help maximize a hospital's return on investment and promote the highest levels of compliance and safety.

Latency

While latency times are not that important when it comes to drug-library updates, near real-time activities, such as auto-programming require extremely short wireless-latency times for reliable performance and successful nursing adoption. The time from initiating the IV order on the EMR to actual programming of the pump should be no more than 10 seconds, with three seconds or less as ideal.

Reliable Connectivity

Reliable, scalable connectivity is absolutely necessary. Otherwise, products will perform sporadically or potentially cause other wireless applications such as BCMA, voice over Internet protocol (VoIP), and workstation on wheels (WOW) systems to perform poorly. Off-the-shelf (OTS) solutions have proved to be less than ideal for handling large numbers of medical devices at the scale required for house-wide systems integration.

For example, the transmission control protocol (TCP) delivered with OTS products is not designed for medical device integration. TCP is a poor link method for attempting to reduce data traffic when there may be periods of little or no wireless traffic, as with well-designed IV wireless connectivity. This causes a standard TCP link to be broken, thereby forcing re-association. To solve this problem, a device connection management protocol (DCMP) was developed specifically for infusion pump communications. The resulting low-bandwidth architecture allows the pump wireless communication to be "quiet" when no activity is needed, yet maintain a consistent connection status. The low bandwidth requirement (Figure 6) allows large numbers of pumps to be integrated without disruption to network performance and possible failure of other systems.

Roaming

Efficient fast roaming is required for a device to switch channels, access points and even controllers for the newer light-weight access points. Ineffective roaming algorithms can cause devices to require re-authentications to the network, increasing the load on the authentication server, as well as on the wireless network itself.

Wireless Bandwidth Requirements with On-Site Test Results

Most hospital wireless systems are based on standards that were never designed to support today's enormous demand for the mobile healthcare appliances used by clinicians. The challenge is to meet the need for near real-time clinical systems integration, yet keep bandwidth use to a minimum. Bandwidth utilization of the DCMP protocol

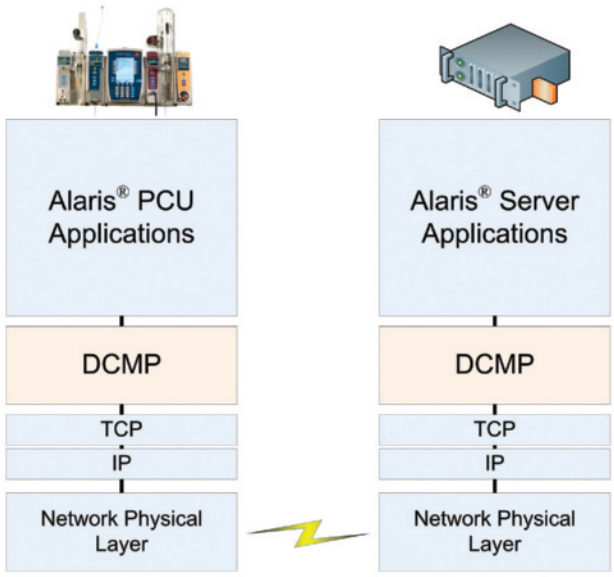


Figure 6. Device Connection Management Protocol (DCMP)

was validated at three different 300- to 400-bed hospitals. All wireless infusion devices were in patient use. Results confirmed that in all three settings, even under peak transfer conditions, DCMP infusion pumps placed negligible load on the wireless data network (Figure 7).

Security

Confidential data need to be protected on the device, during transit, on the server and via client applications. IT departments should consider implementing best practices based on industry experience, as indicated below:

- An ideal wireless infusion pump system would not use communication and discovery methods such as UDP and broadcasts to transmit data to and from the device, because these could lead to security breaches.
- Using OTS operating systems in the infusion pumps may expose a hospital to potentially destructive computer viruses.
- All communications to and from the device should be able to support the latest and most robust wireless authentication and encryption standards, in order to minimize the likelihood of data compromise while the data are in motion.
- Server management and client connections should be supported via the hospital's active directory services to minimize the number of sign-ons that need to be memorized, as well as to allow the IT team to manage the rights and roles of users across the functions of the applications.

Preliminary pre/post analysis of total infusion trends

47% decrease in high-risk overrides
23% decrease in instances of severe harm
12% increase in total DERS-protected infusions
43% reduction in reprogrammed infusions*

Table 5. Oklahoma Heart Hospital – Results

Expertise

Partnerships and Collaboration

Smart pump-EMR interoperability involves a complex integration of software applications happening in near real-time at the patient's bedside. The many different parts and technologies involved can make it challenging to diagnose and resolve issues in a timely manner. A vendor needs to be able to provide both initial and ongoing support in enterprise integration and interfacing solutions. Necessary support personnel include project managers, clinical consultants, pharmacy consultants, field and network engineers, clinical practice consultants, clinical infusion data consultants, IT/clinical applications analysts, biomedical staff, informaticists, and clinical education specialists.

Dworkin says, "We have in development an active program to integrate our EMR[e] with our smart infusion pumps.[c] That is only happening because we have both vendors at the table and ourselves. It's as tactical as weekly calls to track the progress of the project. Unless we brought the teams together, there was no way we were going to be able to take advantage of the technology that was available and, more importantly, the technology that is emerging. So we created the Clinical Engineering and Device Integration Team."

Pharmacy

The hospital formulary, CPOE, BCMA, smart pump and EMR drug datasets must be aligned for an infusion order to automatically program a pump. Securing agreement on standardized orders and drug datasets can be

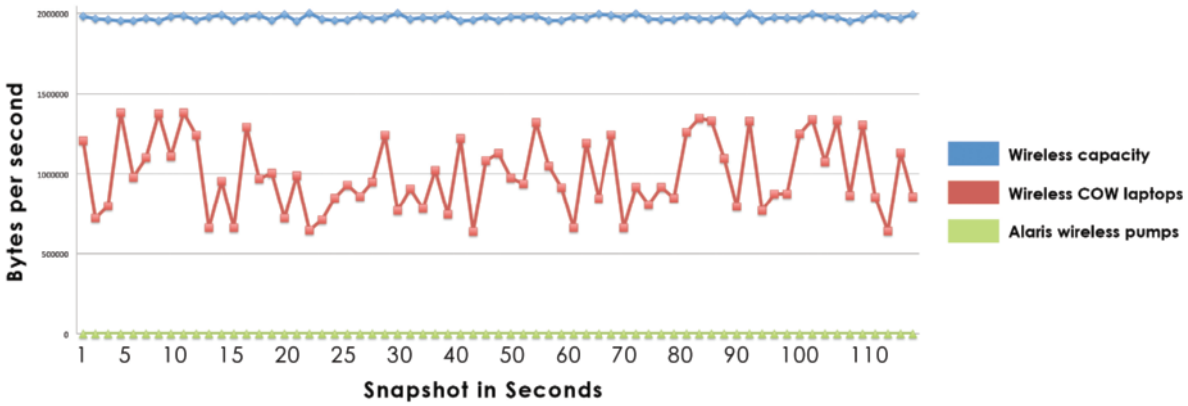


Figure 7. DCMP: Validated Bandwidth Utilization

a complex, time-consuming task involving medical, pharmacy, nursing, biomedical, and IT expertise. The pump vendor's implementation team needs to include people with the necessary medical, pharmacy, and nursing expertise to help hospital staff accomplish this alignment.

Nursing

Onsite observation of clinical practice enables informatics staff to understand clinical issues and workflow considerations. In many cases, there is a difference between what a hospital thinks is happening and what actually is happening. "Something that surprised all of us was how differently nurses administer medications," Fleming says. "If you have five nurses on one unit, you have the potential of them doing it five different ways. Five more units and you've got 25 different ways. Integration really helped to standardize that. Another benefit is that we can build 'order sentences' for all of our medications and standardize everything across our institution."

Mapping nurse processes helps ensure that the system will support all types of IV infusions—small-volume syringes, large-volume infusions, and rapid dosing adjustments based on a patient's condition. "If you're doing a critical titration and really having to observe the patient's response, you don't have to worry about documenting every rate change as you do it—you can keep your focus on the patient," says Marthea Putnam, RN, Children's Minnesota PICU. "Then, when the patient is stable, you can go to the documentation screen, highlight the data you want, and sign it into the EMR with one click. You can also go back and relate the medication dosing to the patient's vital signs, knowing that you have accurate documentation."

Education

Observation of current nursing practices is also an important first step in planning educational efforts. The vendor needs to provide a robust education program that can help take nurses through the conceptual process and support hands-on experience. The vendor should also provide flexible education tools, so nurse educators and other staff can utilize their existing methods to train all parties in the process of infusion-EMR integration.

IT Specialists

Success with infusion pump-EMR integration requires a shift in traditional medical-device expertise, especially when it comes to understanding the role of enterprise-wide IT systems. "Medical-device manufacturers need to augment their teams with the right IT professionals," Dworkin emphasizes, "so that when a hospital comes at them with a shared team with a multitude of skills across the spectrum, there is somebody for them to work with."

Project Management

Expert project management and technical engineering resources are necessary to successfully complete the necessary installation, configuration, and testing steps, following a structured approach aligned with the EMR vendor and the hospital. Dworkin points out, "You're talking about a tremendous amount of change and a more complicated type of change, because it involves people, process, and technology. It's hard enough to just move one of those. To have to move all three of them together is even more difficult."

Successful implementation and ongoing use of BCMA-smart pump-EMR integration depends on having highly qualified partners. The suggested questions and proof points shown in Table 6 are designed to help hospitals assess vendors with regard to their ability to provide the necessary clinical scope, technology platform, data analytics, and professional support.

Conclusion

"We've broken new ground and shown what's possible," says Bobbie Carroll, RN, MHA, senior director for patient safety and clinical informatics at Children's Minnesota. "While this is not the first time barcodes have been used to match medications with patients, it is the first time they have been used to pre-program both large-volume and syringe infusion smart pumps in a children's hospital. This really opens a new era in IV medication safety in helping protect our most vulnerable patients."

Research has shown that to take IV medication safety to the next level, IV infusion safety systems have to be integrated with other medication-safety systems.[7,8,10] Not only is smart pump-EMR integration more than worth it for safe and efficient medication management—it is a requirement.

In both critical and noncritical care areas, integration helps reduce error-prone manual infusion programming, streamline nursing workflow, and ensure accurate and timely capture of infusion data. With smart pump-EMR integration there are no more "holes" around IV medication management. Instead, smart pump-EMR integration encompasses the patient in full-loop IV medication management that improves both safety and quality (Figure 3). Dworkin says. Miller affirms, "The patients' well-being is the number one thing—making sure they're safe, making sure that they can get the care that they need as quickly as possible. Using automation to help do that is key." ■

Footnotes

a. McKesson Automation, Inc. (Pittsburgh, PA)
b. Alaris Medical Systems Inc, now CareFusion (San Diego, CA)
c. Alaris System, with Guardrails Suite MX software, CareFusion (San Diego, CA)
d. CareAware Infusion Suite with Millennium EHR, Cerner Corporation (Kansas City, KS)
e. Epic Systems Corporation (Verona, WI)

Vendor 1	Vendor 2	Vendor 3	Clinical scope
○	○	○	Are large-volume and syringe pumps integrated with the EMR today?
○	○	○	Does the infusion pump continue to protect the patient using DERS after the initial auto programming even with complex multi-ingredient medications
Vendor 1	**Vendor 2**	**Vendor 3**	**Technical platform**
○	○	○	What communication method does the system use to optimize bandwidth utilization and minimize TCP overhead issues?
○	○	○	Does the system provide fast roaming?
○	○	○	What are the average latency times from order to pump programming?
○	○	○	Can the platform support your entire enterprise through a single interface on a single server?
○	○	○	Can both large-volume and syringe pumps be integrated with the EMR in a single implementation?
○	○	○	Has a qualified third-party validated commercial security technology and procedures?
○	○	○	Will the pump limit RF output on infusion device to lowest power necessary?
○	○	○	Did the infusion system vendor implement server-hardening techniques? How?
○	○	○	Will the pumps function clinically and perform "store and forward" in the event of network disruption?
○	○	○	Will the infusion system leverage existing hospital Active Directory services?
○	○	○	Can your infusion solution support multiple types (modalities and channels) to share a single, secured, wireless connection?
○	○	○	Has your infusion platform vendor validated wireless claims with on-site testing?
Vendor 1	**Vendor 2**	**Vendor 3**	**Sustaining support**
○	○	○	Will the infusion system vendor provide 24/7 remote server health and monitoring?
○	○	○	Are support personnel vendor employees or third-party personnel?
○	○	○	How many of the vendor's wireless infusion channels are already commercially installed and operational? How many are integrated with EMR and BCMA?
○	○	○	Will the infusion vendor supply expert resource as part of the implementation in project management, formulary management, nurse workflow, IT integration and clinical engineering?

Table 6. Capabilities Checklist

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