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ISMP

Acute Care
ISMP Medication Safety Alert!®
Educating the Healthcare Community About Safe Medication Practices

Smart pumps in practice: Survey results reveal widespread use, but optimization is challenging

In two recent surveys on smart infusion pump (smart pump) usage in the US, more than 1,000 nurses, pharmacists, and other healthcare professionals provided ISMP with a unique glimpse into the successes, safety concerns, and barriers with the optimization of smart pumps. Most respondents reported widespread use of smart pumps and demonstrated a commitment to employing reliable drug libraries capable of reducing administration errors with parenteral infusions, including pump programming errors. However, respondents were also very candid about their many frustrations and challenges with maximizing this technology, which included significant limitations in pump capabilities, alarm fatigue, and persistent deficiencies related to library use and updates, availability of the pumps, programming workflow, secondary infusions, and pump data analysis.

About Smart Pumps

Smart pumps with dose-error reduction software (DERS) allow organizations to create a tailored library of medications with dosing guidelines by establishing standard concentrations, dosing limits, and alerts (e.g., clinical advisories, soft stops, hard stops). Smart pumps with enabled DERS can detect dosing and programming errors that may harm patients. They can also provide a great deal of data that is useful in improving safe practices, including compliance with using the drug library, alert types and frequency, action taken in response to an alert (e.g., reprogramming), and the frequency of overridden soft stops. The data can also help investigate pump-related errors and identify good catches as well as risky practices such as unnecessary nurse dilution of intravenous (IV) medications.

Respondent Profiles

Between November 2017 and January 2018, ISMP conducted an 18-item smart pump survey for healthcare practitioners, a copy of which appeared in the November 16, 2017 *ISMP Medication Safety Alert!* A total of 618 respondents completed this survey, including nurses (68%) and advanced practice nurses (3%), pharmacists (22%), medication or patient safety officers (3%), and others (4%). Most (65%) were staff-level practitioners working in hospitals (95%) evenly distributed by bed size. Nearly half (42%) of the respondents reported current experience with managing smart pump drug libraries.

Between January and March 2018, ISMP also conducted a 7-item smart pump survey for frontline nurses only, a copy of which appeared in the January 2018 *Nurse AdviseERR*. Most of the items in this survey mirrored some of the key items in the 18-item survey, although the focus was on nursing use of the drug library when programming infusions. A total of 438 nurses completed this survey. Almost all respondents (95%) work in hospitals, in adult medical-surgical units (30%), adult critical care units (26%), the emergency department (ED) (13%), pediatric/neonatal units (7%), labor/delivery/perioperative areas (6%), or inpatient oncology units (5%).

The following is an analysis of the results from *hospital* respondents to either the 18-item survey (n=592), the 7-item survey (n=416), or both surveys (n=1,008).

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For safety, switch from phenol bottles to applicators. Painful ingrown toenails are commonly treated surgically by excising a section of the nail or an entire nail plate after matricectomy (the process of destroying all or part of the base nail portion called the nail matrix). Once destroyed, the portion of the nail that is removed cannot be regenerated and the problem is expected to resolve. During the procedure, local anesthetic is injected into the base or proximal aspect of the toe before the nail matrix is destroyed chemically using phenol.

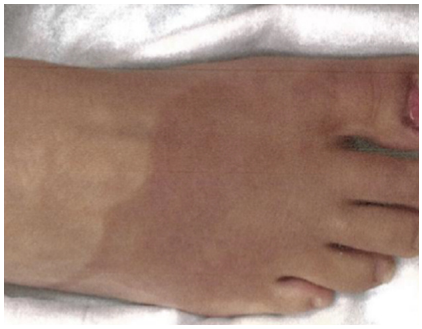

Figure 1a. Area of phenol burn is evident after 1 day.

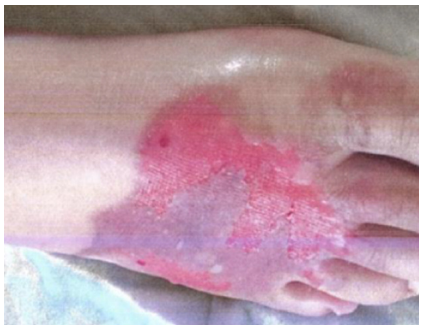

Figure 1b. Significant dermal changes noted after 9 days.

Our sister organization, ISMP Canada, recently conducted a briefing about a 17-year-old patient who was undergoing this procedure, after which a nurse used an unlabeled bowl of clear fluid to cleanse the patient's foot. The patient experienced a burning sensation which led the nurse to realize that phenol solution was in the bowl,

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Results

Scope of use (18-item survey). More than 70% of respondents from larger hospitals with 100 beds or more and nearly half (45%) of respondents from smaller hospitals with less than 100 beds reported using smart pumps for more than 5 years. Another 22% of larger hospitals and 43% of smaller hospitals have been using smart pumps for 1-5 years. Overall, only 4% of respondents reported using smart pumps for less than 1 year, and fewer than 1% reported not using smart pumps at all in their facilities.

High usage of smart pumps was reported when administering IV medications (99%), IV fluids (96%), and blood (93%), with few differences between respondents from different size hospitals. Eighty-three percent of respondents also reported using smart pumps for parenteral nutrition (PN) and patient-controlled analgesia (PCA), although usage was lower in hospitals with less than 100 beds (PN=69%, PCA=74%). Smart pump usage varied among hospitals with less than 100 beds, 100-499 beds, and 500 and more beds for epidural infusions (36%, 57%, 62%, respectively) and syringe infusions (47%, 63%, 80%, respectively). Smart pump usage was lowest with magnetic resonance imaging (MRI) infusions, ranging from 8% in hospitals with less than 100 beds to 29% in hospitals with 500 and more beds. About 3% of respondents reported using smart pumps for other types of infusions, such as nerve blocks, continuous inhalation, and enteral feedings.

At least 97% of respondents reported consistently using smart pumps in medical-surgical units, pediatric units, adult and pediatric critical care units, neonatal intensive care units (NICUs), inpatient oncology units, post-anesthesia care units (PACUs), labor and delivery units, ambulatory infusion units, and EDs. Fewer respondents reported using smart pumps consistently in surgical suites (90%), endoscopy suites (87%), and radiology departments (84%). However, wide variability within these three patient care areas was reported among respondents from different size hospitals. For example, the use of smart pumps in endoscopy suites was reported by only 70% of respondents from hospitals with fewer than 100 beds, compared to 91% of respondents from larger hospitals.

Almost one-third (31%) of respondents who care for neonates and pediatric patients reported using the same smart pumps to administer parenteral infusions and enteral feedings. Most respondents (82%) who reported using different infusion pumps for these purposes also reported the availability of dedicated small volume enteral pumps.

Interoperability (18-item survey). Fifteen percent of respondents have implemented bi-directional interoperability between their smart pumps and electronic health record (EHR) that facilitates pump programming and documentation of the infusion in the EHR. Another 13% of respondents are planning implementation within the next 12 months. Most respondents who reported pump/EHR interoperability said it was available hospital-wide; few respondents reported that pumps were not interoperable in some areas of the hospital, such as the operating room, PACU, oncology unit, cardiac catheterization lab, ED, and/or NICU.

Wireless connectivity (18-item survey). One-quarter (25%) of respondents from hospitals with fewer than 100 beds do not have the infrastructure to wirelessly transfer data to and from smart pumps, while only 10% of respondents from larger hospitals reported no wireless connectivity. Most respondents with wireless connectivity use it to update drug libraries (97%) and obtain reports and data (70%). Pharmacists and manager/director/administrator-level respondents (82%) reported higher use of wireless connectivity to obtain reports than nurses and staff-level respondents (57%). One-third (33%) of respondents use wireless connectivity to track a pump's location within the hospital.

Drug library profiles and updates (18-item survey). Selection of the appropriate drug library when programming a pump is typically based on the patient care area

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not the expected normal saline. Although first aid was provided and a poison and drug information service was contacted, the condition worsened and required additional care at a tertiary healthcare facility with a burn center (**Figures 1a** and **1b**, page 1).

Phenol, also known as carbolic acid, is a hazardous chemical associated with chemical burns when mishandled. Never decant phenol or any other liquid into an unlabeled container used concurrently during surgery or any other procedure. This has often contributed to serious mix-ups between fluids used during surgery and has caused medication error-related tissue injury and death. We are also aware of an incident in which phenol was injected into the toe instead of the local anesthetic. Unfortunately, the hazards of phenol are often not recognized, and processes may not be in place to address safe use.

Pharmacists should determine if phenol is stored and/or used at their facility, whether inside the pharmacy or not. Learn why it is being used and whether alternatives are plausible. Remove unnecessary phenol to prevent future problems. Many hospitals stock bottles of phenol without realizing there are prepackaged phenol applicators (**Figure 2a**) with a small amount of phenol in an ampul-like container (**Figure 2b**) for use during a matricectomy. These are much safer than bottles of liquid phenol and reduce staff exposure to phenol. If phenol is available, be prepared for immediate treatment should the substance be mishandled. Staff in the above case did not know to take proper precautions if an error occurred. Polyethylene glycol 300 (PEG 300) solution should be kept with phenol for decontamination of unintended skin exposure.

Figure 2a. A single phenol applicator holding just 0.175 to 0.2 mL is enclosed in this package.

Figure 2b. Phenol applicator after being removed from package.

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(89%), although about half (47%) of respondents reported that the patient's weight may be used, and approximately one-third (35%) said the library is selected according to the therapeutic drug class. About 6% of respondents noted that the library is differentiated according to patient age groups—adult, pediatric, or neonate. Half (50%) of respondents who manage the pump library reported 1 to 3 library modifications and updates during the past year; another 28% reported 4 to 6 annual updates. Only 17% said that the libraries had been updated more than 6 times in the past year, and fewer than 5% reported no updates.

Engaging the drug library (both surveys). In the 7-item survey, more than three quarters (79%) of frontline nurses who use smart pumps said they use the drug library for IV medications more than 90% of the time. In the 18-item survey, only half (48%) of all respondents reported compliance with the drug library greater than 90% of the time. However, the compliance rates may differ because, in the 18-item survey, all infusions in the drug library, including plain IV solutions and drugs by other routes of administration were included, while in the 7-item survey, nurses were asked to report compliance with using the library with IV medications separately from their compliance with using the library to program plain IV fluids. When asked the reasons for compliance rates lower than 90%, most nurses reported that medications or concentrations were not in the drug library (46% of nurses working in adult care units; 86% of nurses working in pediatric or neonatal units), or that the basic infusion mode was used in an emergency situation (33% of nurses working in the ED; 12% of nurses working in all other areas).

Only 3-5% of respondents in either survey reported using the drug library less than 50% of the time for IV medications. However, up to 45% of nurses who responded to these surveys reported that plain IV solutions are programmed outside the library as a basic infusion more than 50% of the time. In the 7-item survey, reasons for low compliance with using the drug library when infusing plain IV solutions included unavailability of the solution in the library (45%), a perception that it took too much time to program the plain

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Table 1. Error Types Experienced in the Past 12 Months Despite the Use of Smart Infusion Pumps

Error Type	% of Respondents Experiencing Errors			
	18-Item Survey			7-Item Survey
	All (n=592)	Pharmacists (n=128)	Nurses (n=400)	Nurses (n=416)
Secondary infusions delayed/omitted due to roller clamp being closed	62	52	65	41
Wrong rate errors for secondary infusions	36	52	24	13
Dose-rate confusion during pump programming	46	57	39	19
IV line or channel mix-ups	32	33	26	12
Omission of decimal point (e.g., 1.2 entered as 12)	21	37	8	5
Selection of a zero instead of a decimal point (e.g., 1.2 entered as 102)	13	21	5	1
Wrong drug selected or hung	Not asked during survey, but 3% of respondents included examples related to these errors in the "other" category			12
Administered to the wrong patient				3
Infusion attached to the wrong access site (e.g., IV infusion attached to epidural site)				4
I am not aware of any errors in the past 12 months	Not asked during survey, but 80% of respondents selected at least one type of error			41
Other (most frequent examples included weight-related errors, selecting the wrong dosing method, pump failures)	20	14	22	8

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Handling of sterile water bags by materials management increases risk. A close call took place with sterile water for injection that was related to the current shortage of this product in vials. When a hospital's pediatric emergency department (ED) ran out of vials of sterile water, materials management sent a 2 liter bag of sterile water for injection and recommended that the ED staff use it as an alternative to sterile water for injection vials for reconstituting medications. Luckily, a pediatric ED pharmacist noticed the bag and intercepted it before it was used.

The use of sterile water for injection bags for diluting or reconstituting multiple medications in patient care areas would present the same infection control problems that existed when hospitals used intravenous (IV) bags of saline to prepare saline flush syringes. ISMP has also received reports of mix-ups between sterile water for injection, sterile water for irrigation, and other IV fluids in which the sterile water was infused without first making it isotonic. Sterile water for injection is 0 mOsm/L, which can lead to hemolysis and even cause fatalities if administered IV. As early as 2003, we called attention to medication errors with sterile water for injection (www.ismp.org/node/890) and provided prevention recommendations.

The materials management department at this hospital will no longer interchange the vials and bags. Also, inpatient care units can no longer order large volume bags of sterile water. Still, having materials management maintain supplies of sterile water bags for dispensing may create unnecessary risk. As happened in this case, personnel may not be aware of the proper use of this product. Large volume containers of sterile water for injection may be necessary for compounding IV solutions and reconstituting medications in the pharmacy, but these products should only be delivered to and stored in the pharmacy and should be segregated and labeled with warnings to never leave the designated sterile compounding area.

Pharmacy mix-up between polyethylene glycol and propylene glycol. Our sister organization, ISMP Canada, published a report of a pharmacy mix-up that caused propylene glycol to be dispensed to a patient instead of polyethyl-

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Table 2. Most Frequent Challenges Encountered by Respondents Related to Smart Infusion Pumps

Challenges	%	Examples/Comments
Drug library creation, maintenance, and engagement	29	■ Establishing agreement with the drug library (e.g., standard concentrations, dosing methods, agreement across system facilities) ■ Not engaging the drug library, particularly in certain locations (e.g., anesthesia, ED) or when diluting medications ■ Must use basic mode for infusions due to drug shortages ■ Drugs not in the library (sometimes due to limited space), particularly pediatric medications, blood products, drugs used in desensitizing protocols, multiple drugs in a single infusion, intermittent drugs, plain IV solutions, custom concentrations ■ Frequent overrides due to unacceptable soft or hard limits (e.g., oxytocin, small volumes) ■ Untimely updates to the library ■ Library updates not communicated to nurses; dose limit problems not communicated to pharmacy
Technology limitations	14	■ Pumps will not self-prime ■ Keep vein open (KVO) infusion rate is not an option ■ Running description on screen is inadequate ■ Small text font size on screen; no backlight makes viewing screen at night difficult ■ Programming is complex ■ Pump does not consider flush volumes or fluid volume in tubing ■ Pump cannot alert nurse if a secondary infusion is not running ■ Pump malfunctions are frequent (e.g., channel errors) ■ Rate of infusion cannot exceed 999.9 mL/hour ■ Pump updates do not occur in real time; lag time in reaching all pumps ■ Infusion volume deleted when changing pump to new library upon transfer ■ Pump must be shut off to update or change the library when transferring patients
Programming workflow	12	■ Time consuming to engage the drug library (e.g., too many steps, complex) ■ Time consuming to restart the programming if necessary ■ Hard to find drug by scrolling through a large list of generic drugs ■ Barcode scanning challenges ■ Lengthy process to start an infusion for a new patient ■ Difficult to obtain infusion volumes for intake (and output [I & O]) documentation ■ Complex process to reset the pump/select the proper library for transferred patients
Alarms and sensors	10	■ Alarms too sensitive ■ Air in line and upstream occlusion alarms difficult to resolve ■ Alarm fatigue from false alarms
Pump availability	7	■ Pumps never returned to unit after being repaired, cleaned, or transferring patients ■ Problem during high census ■ Untimely repair of pumps, leaving them out of service for long periods ■ Lack of syringe pumps for drugs delivered in smaller volumes due to a drug shortage
Data analysis	7	■ No pump data or no analysis of data ■ Not sharing compliance or error data with frontline staff ■ Unable to extract meaningful data ■ Data not linked to patient, provider, hospital (if multisystem use), or unit ■ No data on basic infusions ■ Cannot tell if changes to limits are needed ■ Compliance data skewed because all drugs are not in the library ■ Insufficient resources to conduct data analysis
Secondary infusions	7	■ Omissions, infusion rate errors, or failure to infuse the total volume ■ Forgetting to open the roller clamp or hang the drug above the primary infusion ■ Forgetting to reprogram the primary infusion after secondary infusion completed ■ Misprogramming primary infusions as secondary infusions ■ Difficulty knowing which infusions are primary and which are secondary
Incorrect programming	5	■ Programming dose as rate; rate or weight as dose; selecting wrong dosing method ■ Forgetting to change the rate of titrated drugs ■ Selecting bolus dose for maintenance infusion ■ Selecting the wrong library based on patient location ■ Forgetting to change the drug library when transferring patients ■ Volume always left in bag at the end of infusion
Wireless connectivity	5	■ No wireless connectivity for certain pumps (e.g., syringe pumps, PCA pumps) ■ Delays in connection
Inter-operability	4	■ Unavailability of resources to maximize interoperability ■ Problems with electronic documentation of the infusion in the EHR ■ Difficulty reading the medication administration record in the EHR

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ene glycol (PEG 3350; **MIRALAX**), resulting in patient harm (www.ismp.org/ext/1). The patient had called a pharmacy to request "polyethylene glycol" in preparation for a colonoscopy. Although not specified in the report, this is often prepared by dissolving the contents of a 238 gram bottle (8.3 ounce) of MiraLAX or generic equivalent PEG 3350 in 2 liters of liquid. Unfortunately, the pharmacist ordered and dispensed propylene glycol. Within hours after ingesting 500 mL of the propylene glycol mixture, the patient developed nausea and vomiting requiring a hospital visit. Propylene glycol is metabolized into pyruvic and lactic acids. At the hospital, the patient was diagnosed with severe metabolic acidosis requiring hemodialysis.

PEG 3350 is used as a laxative while propylene glycol is a solvent used in some pharmacy compounding processes. Propylene glycol is also used as a veterinary product for the prevention and treatment of acetonemia (ketosis). The product is certainly less dangerous than ethylene glycol, a toxic chemical compound still used in many types of antifreeze and other household products. However, as seen in the incident above, propylene glycol can still cause harm if ingested in large quantities.

ISMP Canada mentioned that there was no pharmacist intervention when the product was ordered, packaged, or dispensed—for example, confirmation of the indication with the patient. However, although not stated in the report, this event may be a case of mistaken identity in which the pharmacist ordered the wrong product and failed to detect the error prior to dispensing it. Look-alike, sound-alike product names clearly played a role in this event. Many clinics and physician offices provide patients with colonoscopy instruction sheets that list the brand name MiraLAX along with the generic name, polyethylene glycol 3350. Patients should be encouraged to bring the instruction sheet to the pharmacy to compare it to the actual product dispensed.

Unless absolutely needed for routine compounding, eliminate propylene glycol as a stock item, and assess how it may be listed on wholesaler templates to be

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solution through the library (19%), and nurses were not expected by the hospital to use the drug library for plain IV solutions (10%). The reasons for noncompliance did not vary much between different care locations.

Data analytics (both surveys). Nurses who completed the 7-item survey and healthcare practitioners who completed the 18-item survey were consistent in reporting how often they receive smart pump compliance data. Approximately two-thirds of all respondents who review compliance data said they receive the data either monthly (33%) or quarterly (35%). Approximately 11% of respondents receive compliance data daily or weekly, and about 10% receive it yearly. The remaining respondents receive compliance data every 6 months or less often than yearly. In both surveys, more than half of the respondents reported that compliance data was not available, or they were unaware of how often the data was reviewed. Staff-level practitioners (58%) were unaware of smart pump compliance rates than manager/director/administrator-level practitioners (19%).

Errors (both surveys). More than half of all respondents were aware of at least one error that happened during the prior 12 months despite the use of smart pumps (**Table 1**, page 3). The most common types of errors reported involved secondary infusions, including delayed or omitted secondary infusions caused by a closed roller clamp, or secondary infusions that were administered at the wrong rate. Other types of errors reported included programming errors due to dose-rate confusion, decimal point errors, weight-related errors, and selecting the wrong drug or dosing method in the drug library; IV line or channel mix-ups and tubing misconnections; hanging the wrong drug or solution; and administration of an infusion to the wrong patient.

Biggest challenges (both surveys). Most respondents provided detailed accounts of the significant challenges they face when using smart pumps (**Table 2**, page 4)—more than 700 comments were provided! These challenges clearly fell into familiar categories of known vulnerabilities with smart pumps, the most frequent of which was related to the creation, maintenance, and use of the drug library. Common challenges detailed in this category included difficulty in securing agreement with prescribers regarding the drugs, standard concentrations, and dosing methods, and practitioners who routinely bypass the drug library. The difficulty with keeping the drug library up-to-date during the current drug shortage crisis was also frequently noted. Smart pump technology limitations were another category of challenges often cited by nurse respondents, who provided a myriad of improvements they would love to see in smart pumps, from less lag time when updating pump libraries to reducing the complexity of selecting the correct library when patients are transferred to a different care area. Some of the specified technology limitations were reinforced when describing the challenging workflow associated with programming the pump, including difficulty in finding the correct drug when scrolling through a large list of generic names, and the time-consuming and complex programming process. Challenges that often led to incorrect pump programming or problems with secondary infusions were detailed, particularly challenges associated with flushes and forgetting to restart the primary infusion when the secondary infusion has been administered. Overly sensitive and false alarms, lack of pump availability during times of high census, and problems associated with wireless connectivity and interoperability were also mentioned by dozens of respondents.

Conclusion

Next month, ISMP will be convening a national, invitational summit on smart pumps to update our current guidelines and establish new best practices. We sincerely thank the more than 1,000 healthcare practitioners who completed our surveys. Your thoughtful responses provide a glimpse into the current challenges and barriers to optimizing smart pump use. Overall, the findings from these surveys have helped shape the questions that need to be addressed during the summit. We are confident that your input will be a crucial factor in the summit's success.

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sure it cannot be easily mixed up with polyethylene glycol, if ordered. If the product is necessary, store it with other compounding chemicals, keep it far away from PEG 3350, inform staff about its proper use, and add auxiliary warning labels on the container to prevent confusion with PEG 3350. ISMP Canada also recommended computer alerts if adding products to a patient's profile that are intended for compounding use only, and suggested questioning patients if they request such products.

Special Announcements

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