

Stakeholder perceptions of smart infusion pumps and drug library updates: A multisite, interdisciplinary study



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Purpose. Results of a questionnaire-based study to evaluate smart infusion pump end users' perceptions and understanding of the drug library update process are reported.

Methods. The Indianapolis Coalition for Patient Safety, Inc., in partnership with the Regenstrief Center for Healthcare Engineering, conducted a 33-item electronic, cross-sectional survey across 5 Indiana health systems from May through November 2017. Interdisciplinary participants identified for survey distribution included nurses, pharmacists, biomedical engineers, administrators, and medication safety officers. The survey assessed the following domains: patient safety, the drug library update process, knowledge of drug libraries and the update process, and end-user perceptions.

Results. A total of 778 submitted surveys were included in the data analysis, with a large majority of responses (90.2%) provided by nurses. The use of drug libraries for ensuring patient safety was deemed extremely important or important by 88% of respondents, but 36% indicated that they were unsure of whether drug libraries are updated on a routine basis in their health system. Approximately two-thirds agreed that the current update process improves quality of care (65.0%) and patient safety (68.1%). Moreover, 53.3% agreed that the current drug library update process was effective. However, less than 10% responded correctly when asked about the steps required to update the drug library. Furthermore, only 18% correctly indicated that when a pump is on it may not necessarily contain the most up-to-date version of the drug library.

Conclusion. A survey of 5 health systems in Indianapolis identified several end-user knowledge gaps related to smart pump drug library updates. The results suggest that these gaps were most likely due to a combination of the 2-step update process and the fact that the current drug library version is not easy to find and/or user-friendly and it is unclear when an update is pending.

Keywords: infusion pumps, medical informatics, patient safety, surveys and questionnaires

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Medication safety remains a critical issue for healthcare providers to address. In a 2006 publication by the Institute of Medicine (now called the National Academy of Medicine), it was reported that at least 1.5 million people are harmed by medication errors each year.¹ Of those medication errors, approximately 400,000 in the hospital setting were considered preventable; that

figure translates to 1 medication error per patient per day and higher healthcare costs.^{1,2} In the acute care setting, medication-related errors involving intravenous infusions have the greatest potential to cause significant harm to patients.³⁻⁹ Schnock et al.⁸ found that as many as 60% of i.v. infusions were observed to have 1 or more errors associated with their administration. Another

study, by Lyons and colleagues,⁹ found that 10% of all i.v. infusions involved an error and half involved a medication administration, procedural, or documentation discrepancy.

One goal of the formation of regional public/private patient safety coalitions such as the Indianapolis Coalition for Patient Safety, Inc. (ICPS) is to improve medication safety. ICPS provides a forum for Indianapolis-area hospitals to share information about best practices and to work together to solve patient safety issues. Having identified an opportunity to improve patient safety related to smart infusion pumps (smart pumps), ICPS formed an initiative-specific working group called the Smart Pump Safety Workgroup in January 2013.¹⁰

Smart infusion pumps can help clinicians detect and reduce medication errors and have been widely adopted by hospitals around the country.¹¹⁻¹⁴ Equipped with dose-error reduction systems, smart infusion pumps help prevent medication errors by using predefined drug limit settings programmed in the smart pump's drug library.¹⁵⁻¹⁸ The drug library contains preset safety parameters for drug dosing limits, concentrations, infusion durations, and dosing units. A warning or alert appears, typically visually and audibly, when an infusion is programmed outside of these preset parameters.¹⁹ However, to achieve these patient safety benefits, it is critical to ensure that the drug library is routinely updated with the most current parameters.

It is recommended that the drug library and corresponding preset safety parameters be regularly reviewed and updated to reflect the needs of each healthcare institution.^{10,20} This process is especially pertinent in today's healthcare environment given the numerous ongoing drug shortages and frequent introductions of new agents. Wireless smart infusion pumps are designed to support drug library dissemination from a central network server to allow automatic downloads of updated files. The complete drug library update

KEY POINTS

- End users' knowledge and perceptions of smart pump drug library updates in relation to pump update delays were previously unknown.
- The results of a cross-sectional survey conducted across 5 health systems in Indianapolis revealed that most end users recognize the positive impact of drug libraries on patient safety; however, several knowledge gaps related to the update process were identified.
- There is a need for an interdisciplinary culture of safety surrounding proper use of smart pumps to ensure timely updates of drug libraries and associated strategies to accomplish this aim.

requires a 2-step process: (1) a wireless download of the new drug library after it is released on the central network server and (2) performance of a series of manual keystrokes on the pump display to restart the device and complete the installation of the new drug library.^{21, 22} Although the wireless download is automated, this does not guarantee completion of updates on the smart pump, and significant delays in the update process have been discovered.²³ Research has shown that it may take days or even weeks for the new drug library to be installed on all smart infusion pumps within a hospital.²⁴⁻²⁶ Using an out-of-date drug library on a smart pump can lead to medication errors due to incorrect drug dosing limits.²⁷ Although a smart pump can still function normally without an updated drug library, there may be negative consequences for not using the most current library.²⁸

Through collaboration between ICPS and researchers at Purdue University, gaps were identified in the process for ensuring timely smart pump drug library updates. In a recent study of infusion pump update delays using infusion alert data from 2015-2016, substantial drug library update delays were observed among all but 1 of 12 health systems (including 5 ICPS member systems), with median delays ranging from 22 to 192 days.²³ The study showed that health systems should be aware of the magnitude of the problem of smart pump update delays and the consequent potential for unexpected problems that can result in patient harm.

To understand how a health system can improve the process of smart pump drug library updates, we conducted a multisite study to assess nurses', pharmacists', biomedical engineers', and other health professionals' knowledge and perceptions of smart pump updates in several health systems in Indianapolis. All systems included in the study were using BD Alaris smart pumps (Becton, Dickinson and Company, Franklin Lakes, NJ), so there was no cross-vendor comparison. The purpose of the study was to evaluate perception and understanding. Specifically, we aimed to assess (1) the perceptions of stakeholders (nurses, pharmacists, biomedical engineers, and others) regarding the smart pump, the pump drug library, and the library update process, (2) associations between nurses' expertise level and smart pump knowledge, and (3) nurses' perceptions of the effectiveness of the content and method of distributing information regarding drug library updates in their own organizations.

Methods

Study design. A cross-sectional survey was conducted across 5 health systems in Indianapolis from May through November 2017. The study was sponsored by the Indiana Clinical Translational Sciences Institute Community Health Engagement Program and approved by local institutional

review boards. The survey was cocreated through a community-based participatory research partnership between academic researchers and community representatives from ICPS. Specifically, the survey was iteratively refined with community partners through focus groups that reviewed survey content, length, flow, applicability across disciplines, ease of use, and reliability.

Final survey. The final survey was conducted electronically and contained a study information sheet and 33 questions. The first section focused on demographics (a participant's primary health institution, job experience, job roles, and primary patient care unit or practice area) and interactions with patients and smart pumps. The main section of the survey focused on 3 themes: (1) the perceived relationship between the pump drug library and patient safety, (2) procedural knowledge of the drug library update process, and (3) the effectiveness of current processes for updating the drug library. Questions and other survey items were primarily in Likert scale or multiple-choice format. Likert scale responses were collapsed when appropriate.

Data collection. The final survey was implemented in REDCap (Research Electronic Data Capture), a secure, Web-based application designed to support data capture for research studies.²⁹ REDCap was used to electronically disseminate the survey to 5 ICPS member health systems (Community Health Network, Eskenazi Health, Franciscan Health, Indiana University Health, and St. Vincent) representing community hospitals, safety net hospitals, faith-based organizations, and academic medical centers. Of the 5 health systems included, 1 system had implemented infusion system interoperability prior to survey completion. To ensure that the study contained diverse data, members of the participant health systems' leadership were encouraged to forward the survey links to staff members who were either frontline users of smart infusion

pumps or were involved with management and preventative maintenance of smart pumps. An interdisciplinary audience was identified for survey distribution: nurses, pharmacists, biomedical engineers, administrators, and medication safety officers. In an effort to obtain a heterogeneous sample, additional demographic information was not utilized to target study participants. However, details regarding participants' backgrounds and expertise (e.g., patient care unit or practice area, years of professional experience, use of smart infusion pumps as part of daily workflow) were collected.

Statistical analysis. Data management and analysis of survey responses were completed using RStudio (RStudio, Boston, MA) and Microsoft Excel (Microsoft Corporation, Redmond, WA). Comparative analysis strategy was used to identify similarities and differences in participants' perception and knowledge. A power calculation was not performed, as the analysis involved a convenience sample dependent upon the number of survey responses.

Results

Background information and demographics. A total of 833 surveys were collected from 5 health systems over the study period. Of the total of 833 survey participants, 778 (93.4%) completed the demographics section and were thus included in the data analysis. Other missing data points did not exclude a survey from analysis. After data collation and analysis, health-system names were removed and identification numbers (1 through 5) randomly assigned in order to deidentify the results.

Table 1 describes survey participants' practice roles and level of expertise (years of professional experience and experience with smart pumps). The majority of respondents were nurses (90.2%), likely because in a hospital there are many more nurses than pharmacists, biomedical engineers, or professionals serving in the other targeted roles. Among the respondents,

39.3% had 11 or more years of professional experience, and 40.4% had less than 5 years of experience with smart pumps. In addition, 82.9% of participants indicated that they programmed smart pumps in their current role. Table 2 provides a breakdown of patient care units and practice areas in which survey participants most frequently reported serving. Additionally, the majority of respondents (83.3%) were full-time employees, defined as persons employed by the health system for 30 hours or more per week; 92% indicated that they typically had direct interaction or contact with patients.

Drug library updates and patient safety.

Among survey respondents, drug libraries on smart infusion pumps were rated as extremely important or important in ensuring patient safety by 88%, but 36% indicated that they were unsure if their hospital system updated the drug library on a routine basis. When asked "How often does your health system update the drug library (Guardrails) (as you recall)?" 43.2% of respondents gave no response, 27.1% were unsure, and 17.4%, 8.6%, 1.3%, and 2.2% answered "every month," "every quarter," "twice a year," and "once a year," respectively, while less than 1% answered "other." In response to question 1 of survey section 3 (see eAppendix), 43% of participants indicated receiving information, training materials, or newsletters about drug library updates monthly (19%) or quarterly (24%), with 39% answering "none" or providing no response.

When survey respondents were asked to indicate their level of agreement with a posed statement regarding the clarity of their institution's policies surrounding the updating of drug libraries (eAppendix, section 2, item 1), there was a nearly equal distribution of affirmative, neutral, and negative responses: "strongly agree" and "agree" combined, 33.2%; "neither" (agree nor disagree), 33.2%; and "disagree" and "strongly disagree" combined (24.2%). Despite this result, over half of respondents (53.3%) agreed or strongly agreed that the

Table 1. Demographics and Experience of Survey Respondents^a

Survey Item	No. Responses per Health System					Total
	System 1	System 2	System 3	System 4	System 5	
Professional role						
Registered nurse	101	54	152	328	49	684
Advanced practice nurse	3	1	2	4	1	11
LVN or LPN	0	0	3	2	0	5
Nurse anesthetist or anesthesiology nurse	0	0	0	2	0	2
Pharmacist, medication safety officer, or patient safety officer	0	0	7	42	4	53
Biomedical engineer	0	0	3	5	0	8
Other	3	1	1	10	0	15
Total	107	56	168	393	54	778
Length of professional experience (yr)						
≥11	48	27	67	149	15	306
5–10	34	9	44	92	13	192
<5	26	20	57	151	26	280
Total	108	56	168	392	54	778
BD Alaris smart pump user?						
No, not typically	7	9	38	72	7	133
Yes, part of current role	101	47	131	319	47	645
Total	108	56	169	391	54	778
Length of BD Alaris smart pump experience (yr)						
≥11	40	19	47	87	4	196
5–10	38	15	58	146	5	262
<5	30	21	64	156	44	314
No response	0	1	0	4	1	6
Total	108	56	169	393	54	778

^aLVN = licensed vocational nurse, LPN = licensed practical nurse.

current drug library update process was effective (eAppendix, section 3, question 3). Approximately two-thirds of respondents agreed that the current drug library update process improved quality of care (65.0%) and/or patient safety (68.1%). The posed statement that elicited agreement from the highest proportion of respondents (73.0%) was “Current use of drug library prevents medication errors.”

Drug library update process.

The process of updating the smart pumps’ drug library was studied in a series of survey questions. If survey

participants indicated the correct response regarding the required steps for updating the drug library of a BD Alaris smart pump, they were then queried as to the last time they intentionally updated the pump drug library (section 2, question 4.A). A majority of respondents (56% in aggregate) indicated that they could not recall, selected the response option “Someone else is responsible for updating the pump,” or gave no response. Among those who answered that question, there was no clear consensus regarding recent completion or ownership of the drug library

update process. Of the respondents who indicated an active role in programming smart infusion pumps, 51.6% indicated that they never visually confirm that pumps are programmed with the most recent drug library. While 37.3% of survey participants agreed that the process for updating the drug library does not take much time, nearly half (46.7%) neither agreed nor disagreed with a posed statement that the process for updating the drug library was time intensive, providing instead a neutral response. Although 33.4% agreed that the current workflow for drug library

Table 2. Primary Patient Care Units or Practice Areas of Survey Respondents^a

Unit or Practice Area	No. Responses per Health System					Total (% of All Unit or Area Types)
	System 1	System 2	System 3	System 4	System 5	
ICU (any type)	22	2	26	59	15	124 (15.9)
Obstetrics	8	49	16	24	0	97 (12.4)
Pediatrics or neonatal ICU	4	1	5	68	2	80 (10.3)
Medicine unit (nonsurgical)	11	0	12	37	19	79 (10.1)
Surgical or postsurgical unit	8	0	19	41	2	70 (9.0)
Emergency department	0	0	11	47	0	58 (7.4)
Oncology or infusion center	24	0	8	22	4	58 (7.4)
Other	6	3	27	21	1	58 (7.4)
Step-down or intermediate ICU	13	1	15	17	8	54 (6.9)

^aICU = intensive care unit.

updates was easy to follow, 46.7% gave a neutral response.

Knowledge of drug library updates. Recognizing that survey participants represented divergent health systems, a series of items related to the stakeholders' knowledge of drug library updates and the resultant impact on patient safety were included in the survey. Less than 10% of all nurses who participated in the survey responded correctly when asked about the steps required to update a BD Alaris drug library. In addition, only 18% correctly indicated that a pump that is turned on may not necessarily contain the most up-to-date version of the drug library. When queried as to whether the pump alerts the end user if it does not contain the current version of the drug library, one quarter indicated the correct response ("no"). These same results did not vary significantly when analyzed in terms of nurses' expertise level in terms of either years of work experience or use of smart pumps.

Stakeholder perceptions. Pump stakeholders were also surveyed as to their perceptions regarding general practices surrounding smart pumps (e.g., policies, workflow, medication errors, and effectiveness of pump updates) (section 2, question 7). Survey participants' level of agreement with a series of posed statements related to the

impact of library updates on medication safety and the process for updating pumps was assessed with a numerical 5-point Likert scale (1 = "strongly disagree," 5 = "strongly agree"). End users more uniformly agreed with statements related to the impact of smart pumps on patient safety ("Current use of drug library (Guardrails) prevents medication errors" and "Current drug library update process improves patient safety"), with lesser agreement with statements regarding the overall update process itself ("Current policy for updating drug library is clear" and "Current workflow for updating drug library is easy to follow").

Discussion

Over 800 respondents from 5 Indianapolis-based health systems submitted responses to a survey focusing on the use of smart infusion pumps, specifically knowledge of, the process of, and the safety implications of drug library updates. While a wide variety of disciplines and end users were targeted for study inclusion, the vast majority of survey responses were provided by nurses who indicated use of smart pumps as a part of their daily work. Despite over 80% of participants indicating daily use of smart pumps in their current roles, the survey results revealed an overall lack of understanding

of the process required to update the drug library, the cornerstone of the safety software embedded in the device. Nearly 90% of survey participants recognized the importance of smart pump drug libraries in ensuring patient safety. Over 50% of respondents believed that the current drug library update process was effective; however, approximately 40% indicated a lack of knowledge related to their institution's update process, and only 30% were able to articulate the frequency of updates. These results supported previous findings regarding significant delays in updating drug libraries described by DeLaurentis and colleagues.¹²

Regarding communication of infusion pump-related patient safety initiatives, the survey results indicate that a wide variety of strategies are used by health systems, with regular newsletters (via email) and team briefings being the most prevalent. When questioned as to the frequency with which end users receive information, training materials, or newsletters regarding drug library updates, 39% of survey participants indicated that no such information or training is provided or gave no response. When the results for this survey item were compared by institution, respondents who reported that their health systems conduct culture-driven, consistent smart

pump—related safety initiatives, such as a monthly “pump safety day” event, were more likely to report receiving such information and/or training, with fewer responses of “none.” Establishing smart pump-related safety strategies should be a priority for all health systems and could improve end users’ overall knowledge and/or awareness of the drug library update process.

As evidenced by the survey results, there is an overall lack of knowledge about smart pump drug libraries. Several alarming gaps were identified in several areas, including (1) understanding of the time requirements and overall ease of the drug library update process, (2) knowledge of the correctness of the drug library version in use, (3) the importance of visually confirming the pump’s drug library version upon programming, and (4) knowledge of when the latest drug library update was completed. Illustrating these gaps, the vast majority of respondents gave a neutral answer in response to posed statements holding that the drug library update process does not take much time and that the steps for proper completion are easy to follow; this led us to believe that respondents provided a neutral response due to lack of knowledge on how to update the drug library. Additionally, when asked to recall the last time they initiated a drug library update, the majority of respondents (70% of all those who self-identified as pump end users) provided no response, supporting our belief that there is a lack of knowledge or engagement related to the process of drug library updates.

In an effort to assess whether end users’ perception of the drug library update process, as described above, aligned with their comprehension, a series of knowledge-based questions were asked of all survey respondents. The results identified significant deficits regarding (1) steps required to update the drug library, (2) knowledge of whether a pump always contains the most up-to-date version of the drug library, and (3) knowledge of whether the pump alerts the end user if it does

not contain the current version of the drug library. Furthermore, in response to these crucial knowledge issues, almost half of nurse respondents indicated that they were “unsure/not sure.” To ameliorate these deficiencies, we strongly urge manufacturers of smart pumps to consider a more user-friendly design and a visual cue on the pump in order to streamline the drug library update process for end users.

Study strengths. Numerous strengths can be delineated from a review of our study’s design, broad scope of study participants, and overall outcomes. Study participants’ perceptions were captured from a multicenter survey inclusive of a broad workforce from an array of hospital types, including academic-affiliated, community-based, faith-based, and county hospitals. Within those diverse hospital settings, the survey captured individuals from a wide variety of patient care areas and with varying years of experience. Furthermore, participants were a good representation of pump users, with a majority having direct patient care and serving in the role of nurse, which mirrors that of the typical workforce that utilizes the smart infusion pump. Lastly, our survey validated assumptions about nursing staff perceptions of the importance of drug libraries and their impact on patient safety while identifying several knowledge gaps related to the process and policies for drug library updates.

Study limitations. Our study had a number of limitations relating to survey distribution, survey completion, and the study participants. In order to maximize the number of potential participants and due to the heterogeneity of the survey sites, distribution of the surveys was left to the discretion of site-specific leaderships. As a result, it was impossible to calculate the overall survey response rate due to lack of knowledge of the total number of recipients. One study site used a contracted service to perform smart pump updates, which could have introduced a confounding factor;

however, a cursory review of the results indicated that this did not have an impact on the overall results. Lastly, not all respondents completed all survey questions, which resulted in a category of “blank” responses. Unfortunately, there was no way of knowing the reason for such responses (i.e., lack of knowledge versus inadvertently skipping a question), so these results were acknowledged or excluded from the final analysis.

Study implications. Our results reinforce the importance of creating an interdisciplinary culture of safety surrounding proper use of smart infusion pumps to ensure timely updates of drug libraries and to implement strategies to accomplish this aim. Until those aims are achieved, the patient safety impact and intended benefits of smart infusion pumps and drug libraries will not be fully realized. Further research to address these findings is warranted.

Conclusion

A survey of 5 health systems in Indianapolis identified several end-user knowledge gaps related to smart pump drug library updates. The results suggest that these gaps were most likely due to a combination of the 2-step update process and the fact that the current drug library version is not easy to find and/or user-friendly and it is unclear when an update is pending.

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Disclosures

The authors have declared no potential conflicts of interest.

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