

Achieving Outcomes With Innovative Smart Pump Technology

Partnership, Planning, and Quality Improvement

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ABSTRACT

Background: A 5-time designated Magnet academic medical center partnered with its infusion systems supplier to successfully integrate 1327 smart pumps across 45 departments with an aggressive 3-month timeline. The team also achieved quality improvement (QI) outcomes through increased drug library compliance and decreased alerts with their new technology.

Problem: This large academic medical center needed to implement innovative wireless infusion pump technology in a short time frame.

Approach: The approach involved a strong partnership from the medical center and the supplier, with extensive planning and collaboration among the clinical nurse specialists and consultants from both organizations to accomplish QI goals. Lean principles were also followed to enhance efficiency and accountability.

Outcomes: Quality improvement outcomes included 100% drug library compliance across all 6 intensive care units, a decrease in pump alert rates from 4.18% to 0.79%, and a decrease in pump programming correction rate from 0.36% to 0.06%.

Conclusions: A partnership led to a large implementation being completed efficiently across an academic medical center. Through these joint efforts, quality of care was improved within a short period of time.

Key words: drug library compliance, infusion systems, Lean, smart pumps, technology

Implementing smart pump technology is challenging due to the complexity of this technology and all the hospital departments that impact its use. Despite widespread adoption, smart pump implementation has varied success rates, with reported low compliance with drug library use and high incidence of dosing alerts.¹⁻⁴

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After selecting an innovative smart pump platform with 2-way wireless communication and real-time infusion management reporting software, this academic medical center was faced with the challenge of successfully integrating 1327 of these pumps into clinical practice across 45 departments within an aggressive 3-month timeline. This article describes how a successful transition to innovative smart pump technology was accomplished through a strategic partnership with the smart pump supplier, the use of Lean principles to guide the process, and defined quality improvement (QI) metrics to measure performance. The smart pump integration was viewed as more than a technology implementation; it was treated as a continuous QI project.

To implement such a complex technology across a large medical center, it was determined that the Lean methodology would be used to optimally guide this process. The principles of Lean emphasize standardization, elimination of excess inventory, reduction of unwanted variation in processes, and continuous identification of QI.^{5,6} The current health care system is

challenged to deliver increasingly complex services without waste or error.

This article describes how the hospital and the supplier used the principles of Lean to plan and execute a successful transition to innovative smart pump technology. The Lean process made it possible to achieve this project in a short period of time, while also accomplishing significant quality initiatives around drug library development and improved drug library compliance. Teamwork from both the hospital and intravenous pump supplier was vital in achieving these quality initiatives. The team leaders were defined by roles within each organization. After the installation of the infusion devices, joint review of the infusion data and associated practices led to improved drug library compliance and reduced dosing alerts.

METHODS

Establishing the project charter

The smart pump project was initiated with a hospital-supplier kickoff meeting where a project charter was created to define the scope, timeline, key milestones, and stakeholders. The scope of the project entailed not only the implementation of the new pumps but also a plan for integrating the wireless technology and related software, building the drug library, training the staff, and ensuring optimal use. The project completion goal was pump implementation 3 months later. There were 4 quality metrics established to guide our plan and measure performance: (1) train 80% of staff members by the implementation date; (2) achieve 95% drug library compliance across the 6 intensive care units (ICUs); (3) reduce drug library dosing alerts; and (4) reduce pump-related medication errors.

Defining roles and responsibilities

Project team leaders from the hospital and the supplier, including the departments of nursing, pharmacy, information systems, clinical engineering/infusion systems, logistics, Lean Performance Improvement (PI) team members, and the hospital's Center for Professional Development, Innovation and Research, which encompasses the clinical nurse specialists and clinical nurse educators (CNS/CNE), were involved in the process. The meeting's purpose was to introduce project team leads, establish goals and objectives, identify key milestones, and determine the prerequisites needed for successful implementation

within the 3-month timeline. These meetings offered a full view of how each team was progressing, and if additional resources were needed, the Lean PI Green Belt facilitators could escalate the request.

Team lead roles and responsibilities and their alignment across the 2 organizations are shown in Table 1. Project leads facilitated meetings and led the project to fruition, with guidance and support from Lean PI Black Belt mentors and the supplier's clinical and sales managers. Project leads included the Lean PI Green Belt project facilitators (CNS and clinical pharmacist) and the supplier's project team captains (clinical nurse consultant and clinical pharmacist). Green Belt facilitators were responsible for helping develop the project charter, defining the project scope, performing a stakeholder analysis, establishing the financial baseline, establishing and verifying financial metrics, validating data, and analyzing data for root cause. Roles and responsibilities were established on the basis of current Lean team status and then roles within each group, which were predefined within job descriptions.

The information systems teams were responsible for securing laptops, installing software, building 2 servers, setting up user access to install and review drug library and data management software, and ensuring that the infusion system technology was compatible with the hospital's information technology systems. The clinical engineering, logistics, and infusion systems teams were responsible for receiving and preparing infusion pumps and related equipment, uploading the drug library and pump configuration files, applying the real-time location service (RTLS) tags, and coordinating the delivery, storage, and setup of all pumps and poles on the clinical units.

Both the hospital and supplier clinical experts were jointly responsible for developing the drug library and pump configuration, revising protocols, creating educational tools, and developing and executing the education plan, which included creating online registration, assigning and tracking eLearning, securing rooms and facilitating classroom training, and tracking infusion system outcomes. Core to this group was their ability to influence organizational systems to achieve quality, cost-effective, patient-focused outcomes. Change within a health care organization is most effective when the decision making is shared and nursing collaborates with other disciplines. These collaborative qualities of the CNS/CNE

Table 1. Smart Pump Implementation Project Team Roles and Primary Responsibilities

Hospital	Pump Supplier	Primary Responsibilities
Executive sponsor	Executive sponsor	Project oversight
Operational sponsor	Operational sponsor	Project leadership <ul style="list-style-type: none"> • Steer project • Ensure team participation • Ensure timeline met
Lean PI Green Belt project facilitators: <ul style="list-style-type: none"> • CNS • Clinical pharmacist 	Project team captains: <ul style="list-style-type: none"> • Clinical nurse consultant • Clinical pharmacist 	<ul style="list-style-type: none"> • Facilitate project meetings • Lead drug library build • Lead education plan
Lean PI mentors	Clinical and sales managers	Guide facilitators/captains
The Center for Professional Development, Innovation and Research: <ul style="list-style-type: none"> • CNS • Clinical nurse educators 	Clinical Services department: <ul style="list-style-type: none"> • Clinical nurse consultants • Nurse educators 	<ul style="list-style-type: none"> • Library development • Protocol revision • Develop/deliver education • Track outcomes
Super users	N/A	<ul style="list-style-type: none"> • Drug library validation • Unit-based resource
Information systems	Information technology	<ul style="list-style-type: none"> • Software installation and data management
Clinical engineering and logistics	Infusion systems specialists	<ul style="list-style-type: none"> • Pump file upload • Equipment setup, delivery, storage

Abbreviations: CNS, clinical nurse specialist; N/A, not applicable; PI, Performance Improvement.

role heavily influenced this project from initiation to completion.

Building an effective drug library

The smart pump’s dose error reduction software is a hallmark of its safety features. Using this software, hospitals are able to customize and standardize preparations and dosing parameters across the health system. Smart pump libraries include standardized concentrations, clinical advisories, loading and bolus dose features, soft- and hard-dosing limits, and alerts to guide practice and serve as a double check for users. However, creating a standardized and effective smart pump drug library can be challenging due to the many customization options and the diversity of drug delivery across various patient populations and hospital departments. As such, drug library compliance is a widespread barrier to smart pump adoption, with compliance rates as low as 15% to 46%.^{1,2,7,8}

The reasons for opting out or bypassing the drug library are varied, with alert fatigue as a contributing factor.^{3,9} To encourage consistent use of the dose error reduction software, it is critical to create a library that incorporates safety

with clinical workflow. To ensure this was accomplished, 4 key steps were incorporated to ensure engagement and ownership of all stakeholders. First, a multidisciplinary team was created, which included CNS/CNEs, consultants, staff nurse super users, administrators, pharmacists, and physicians.

Second, nursing and pharmacy project leads held weekly drug library review meetings, ensuring that all team members participated optimally and that timelines were met and any variances communicated appropriately. These project leads collaborated with the multidisciplinary team to build the drug library, consulted with other clinical resources, revised protocols, developed educational materials, and clinically validated the drug library.

Third, to aid the build of the drug library data set, the team gathered all pertinent hospital protocols and clinical guidelines and made them readily available during all drug library review meetings. This included protocols on pharmacy and nursing drug administration (anticoagulation, thrombolytics, insulin, pain, anesthesia), standardized order sets, loading and bolus dosing, and infusion pump administration. The team

consulted drug references, computerized physician order entry systems, the electronic medication records, and the pharmacy system to ensure accurate and consistent entry of drug names and drug limits across these systems. They also reviewed recent and/or common intravenous medication errors and high-risk infusions that could potentially be addressed through clinical advisories.

Fourth, a key component of the drug library development process was ensuring that parameters and workflow were consistent with clinical practice while optimizing safety, minimizing risk for error, and maximizing end user compliance. Prior to implementation, it is critical that the drug library be reviewed by end users, both to ensure it is safe and clinically relevant and also to minimize the number of drug library changes after implementation. This review was accomplished through the Drug Library Validation Workshop, where clinical end users (super users/expert contributors) came together for a hands-on review of the drug library construct and pump configuration options.

The workshop took a total of 8 hours and was designed to ensure the pump drug library that was created primarily by pharmacists matched nursing practice in each department. Each session included individuals who would become clinical super users from like departments to collaborate and reach consensus on drug library parameters. All 45 clinical departments were represented. The Drug Library Validation Workshop was jointly facilitated by the hospital CNS/CNE and pump supplier clinical nurse consultants and included pharmacy and nursing team leaders. The facilitators began by explaining the purpose and process to be addressed. They then provided observations and guidance throughout the sessions, collected feedback, and discussed potential library changes. Workshop participants received copies of their respective department library, feedback forms, and infusion pumps preloaded with the library and configuration. The clinical end users addressed every drug in their respective department library, validating the drug location, naming convention, preparation, dosing limits, loading/on-demand bolus, and clinical advisory as applicable. The drug library team leaders were available during the sessions to address any facility-specific policies and to revise the library as appropriate. Throughout the workshop, end users were actively engaged in

the development process, gaining insight into and ownership as super users for the subsequent training, implementation, and “go-live” follow-up.

TRAINING AND IMPLEMENTATION

Training

Once the drug library was complete, the next goal was to educate the end users on how to use the new pumps. One of the largest project tasks was to create and implement an education plan for 1500 registered nurses (RNs). The goal was to educate 80% of the hospital's RNs by pump implementation. Product training on pump and implementation was successfully accomplished with eLearning, simulation-based classroom training using clinical scenarios, and support from super users. Following the completion of eLearning assigned to all staff members, the nurses participated in scenario-based classroom education on the smart pump, held over 6 days in 2 concurrently timed sessions. The average class length was 1 hour. This education was offered at various times to accommodate RNs working off shifts. Education was provided on the external components of the pump, the power supply, and how to program the pump with intravenous solutions and dose-based drugs using realistic clinical scenarios. Overall, the supplier provided twenty 1-hour classes per day over 6 days, for a total of 120 training hours, plus an additional 6 days of 24-hour rounding and follow-up support. At the conclusion of the scheduled classes, 1391 (93%) RNs had been educated on the smart pumps, exceeding the 80% target.

Implementation

A multidisciplinary team was organized with the goal of seamlessly transferring pumps to the nursing units. The CNS/CNE leadership group assisted with the pump transfers according to a structured time frame developed by the team leader. There were 3 key stages to implementation process.

Stage 1: Pump distribution. In the 24 hours prior to implementation, the clinical engineering team began the staging process for new pump delivery. All 1327 smart pumps and poles were transferred from an off-site warehouse to the hospital staging area where they were stacked on large metal carts or placed on intravenous poles to facilitate transfer.

Concurrent with the pump delivery, the clinical engineering team used RTLS to locate pumps currently in patient use and determine the number of pumps in each respective patient care area to ensure an appropriate number of pumps were taken to each floor. This improved efficiency on implementation day. The clinical engineering team grouped pumps according to nursing units to facilitate transfer flow. Priority was given to procedure areas (operating room, infusion areas) to avoid any delay in start times by delivering and setting up the new pumps the night before.

Stage 2: Central command center. A central command center was set up in anticipation of the implementation of the new pumps, with a chart identifying all of the units to be visited, the number of pumps to be taken to each unit, and turnaround time (measured from the time the pump left the staging area to the time the old pump was returned to the staging area). At 7 AM, nursing leadership and team members met in the command center where multifaceted teams were assigned to deploy the 1327 infusion pumps. The clinical engineering team and the Lean PI facilitators led the implementation, recording all of the units to be visited, the number of pumps to be taken to each unit, the time the team left for that unit, and the time they returned.

Stage 3: Deployment teams. There were 4 deployment teams consisting of hospital and pump supplier CNS/CNE, consultants, nursing directors, and infusion system specialists. Their role was to assist with swapping new pumps for old pumps on the nursing unit in a safe and efficient manner, support nurses in their clinical practice, and foster safe patient care. In addition to swapping pumps, the CNSs, consultants, and educators also provided guidance to the staff on programming sequences and use of the drug library. As each team finished, they reported back to the command center where the commander instructed them which department to visit next.

Hospital-supplier partnership was a key factor throughout these stages of implementation. All 1327 pumps were rolled out in only 4 hours 13 minutes. Following implementation, the staff raised minimal concerns during clinical rounds and unit-based practice council meetings, supporting the conclusion that the quality of the ed-

ucation and the engagement of the staff throughout the project had been viewed as successful.

RESULTS

Drug library compliance

The project charter set a project completion goal of 3 months from kickoff meeting to pump implementation, which was achieved. Using the Lean principles, the drug library standardization and development phase was completed in only 9 weeks, significantly shorter than the 4- to 14-month smart pump drug library development timelines reported in the literature.^{2,7,10,11}

The next critical step was to optimize the use of the new technology to ensure the highest level of safety was employed to maximize the value of the investment. Because alert fatigue and drug library noncompliance negatively affect successful outcomes and quality care, the tracking of compliance and dosing alert incidence was made part of a detailed analysis of smart pump data provided by the supplier. Drug library compliance was measured through direct observation and a real-time reporting application (pump supplier's software), which provides visibility to each department's smart pump infusions. Thus, pharmacy and nursing were immediately aware of any infusions being programmed outside of the drug library, allowing them to intervene appropriately. Real-time unit-based audits conducted 2 months following implementation revealed a 100% compliance using the drug library across all 6 ICUs.

However, retrospective data from the other nursing departments revealed that they were bypassing the drug library 34% of the time. Using data analysis and staff feedback, the reasons for bypassing the library were identified. Twenty-one percent of the secondary infusions were programmed outside the drug library because the staff perceived these infusions to be low risk. Some infusion limits were perceived as too restrictive, so drug library dosing limits were adjusted to minimize potential alert fatigue and associated noncompliance. These changes, in addition to reinforced education on drug library use during an annual skills validation, allowed the hospital to document a continual increase in housewide drug library use and an overall decrease in alert incidence.¹²

Alert reduction

Smart pump alerts release a visual and audible warning if a user attempts to program outside

of the hospital-defined dosing limits. In an environment with a high incidence of alerts that contribute to alert fatigue, clinicians may ignore the alerts, perceiving them and the drug library as noncredible, which can result in noncompliance. Alert frequency during the first month of new technology use was recorded at a rate of 4.18% (2467 alerts occurred across 59 049 drug library deliveries). This rate continued to decrease over the next 3 months to an alert frequency of 1.16%, which was consistent with the pump supplier's national alert frequency average of 1%.¹³ By the sixth month of pump usage, the alert rate had dropped to only 0.79% (1764 alerts across 222 472 drug library deliveries).

Upon receiving a dosing alert on the pump, the clinician can respond by either overriding the soft limit, which is a limit created in the library that can be overridden but a warning is given to the clinician that this is outside of the norm, correcting the dose or rate entered, or aborting the programming to make another parameter change, such as selecting a new drug, care area, or delivery mode. The pump data revealed that alert responses were 66% overrides, 26% aborts, and 8% corrections. The pump supplier provided a detailed analysis of alert response data including the first 3 months of smart pump use to identify why these infusions were associated with high alert rates and provided recommendations to reduce alerts and optimize drug library use.¹³ The override analysis targeted the top 10 infusions that contributed to 71% of total overrides during the 3-month study period. The override incidence of 66% was in par with or better than other studies reporting 61% to 95% overrides.^{12,14-16} The majority of soft limit overrides were a result of appropriate dose titration that could be resolved with limit adjustments. For example, increasing the heparin soft maximum limit from 1500 to 1800 units per hour would eliminate 54% of associated overrides, increasing the propofol ICU soft maximum from 50 to 100 $\mu\text{g}/\text{kg}/\text{min}$ would eliminate 71% of associated overrides, and increasing the phenylephrine soft maximum from 180 to 300 $\mu\text{g}/\text{min}$ would eliminate 100% of these overrides.

The analysis also identified 2 potential practice issues associated with overrides. The first was selection error. Clinicians sometimes selected the wrong drug entry when multiple entries for the same infusions were available in the

drug library. Examples included selecting the basic heparin entry and overriding the soft maximum limit when the heparin deep vein thrombosis/pulmonary embolism entry should have been used and selecting the piperacillin/tazobactam "extended" infusion for a standard infusion and overriding the soft maximum limit.

The second potential issue was bolus dosing. There were 2 epinephrine overrides that appeared to be attempts to deliver a bolus dose by increasing the infusion rate, rather than using the bolus feature with built-in safety limits. Another example involved an insulin infusion; when the clinician attempted to increase the rate from 10 to 910 units per hour, the hard maximum of 40 units per hour could not be exceeded, so the clinician exited the drug library to deliver a 4-mL bolus and then reprogrammed the insulin infusion in the drug library. This is an example of how drug libraries help improve patient safety in infusion devices.

Error reduction

Alert responses that are classified as corrections may simply serve as a double check for the clinician, or they may represent corrected programming errors or averted medication errors. The first month following implementation, the correction rate started at 0.36% (211 dose corrections across 59 049 infusions) and steadily decreased over the next 3 months to a rate of only 0.06% (109 corrections across 174 830 infusions) (Table 2). The low number of corrections reflected appropriate dosing by the clinicians coupled with a very low incidence of programming error. Other studies have calculated correction/reprogramming rates of 0.4% to 1.74%.^{2,4}

Analysis of the dose corrections identified specific dosage attempts that could have resulted in a medication error or even an adverse drug event. Top infusions associated with dose corrections included heparin, phenylephrine, and potassium chloride piggybacks (KCL IVPB). With heparin, there were 13 dose corrections that could have resulted in both over- and underdosing. Had these dose corrections not been made, the drug could have been infused at the previous erroneous rates, potentially causing patient harm along with associated cost to this harm. These 13 averted medication errors for heparin alone represented a potential \$113 750 in savings (at \$8750 per error) during the first 3 months of technology use.^{17,18} For example, heparin was

Table 2. Drug Library Deliveries, Alerts, and Corrections

Month	Drug Library Deliveries	Alerts	% Alerts	Corrections	% Corrections
Jan	58 991	2467	4.18	211	0.36
Feb	97 335	1898	1.95	128	0.13
Mar	106 617	1895	1.78	173	0.16
Apr	174 830	2027	1.16	109	0.06

initially programmed at 3150 units per hour and corrected to 1300 units per hour. Phenylephrine had 19 dose corrections, including an attempted dose of 266.7 $\mu\text{g}/\text{min}$ that was corrected to 53.3 $\mu\text{g}/\text{min}$. Finally, KCL IVPB had 33 corrections. For example, a KCL 50-mL infusion start was attempted at 200 mL per hour but could not exceed the hard maximum of 100 mL per hour and was corrected to 100 mL per hour.

CONCLUSION

This large teaching hospital successfully implemented new state-of-the-art smart pump technology in an expedient and efficient 3-month conversion process. The Lean PI team facilitators and mentors together with the CNS/consultants facilitated positive change and practice improvements. At the outset, the team not only identified joint metrics for success but also identified accountability and ownership for measuring and communicating these metrics. The intravenous pump supplier provided meaningful pump data analytics that included baseline clinical indicator data, suggested interventions, and documentation of process improvements. This teaching hospital's outcomes demonstrated improved nursing practice through increased use of the drug library and improved patient safety through reduction of dosing alerts. The hospital then used this project outcome as an example of improved quality of care and nursing practices to support its renewal certification for Magnet status.

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