Management of Infusion Pumps in the Lower Mainland of British Columbia

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Abstract—**Infusion pumps are used by clinical staff to deliver medications and fluids intravenously to patients. Each of the 27 hospitals in the Lower Mainland of British Columbia has a fleet of Alaris™ infusion pumps, and these pumps are often shared among the units of each hospital. There are several challenges associated with the management and support of a mobile pump fleet, namely: perceived pump shortages, misplaced pumps across hospitals (i.e. mixing of pump fleets following patient transfers), and difficulties associated with identifying, locating, and tracking specific pump modules due for preventative maintenance. This project sought to discover, document, and critically assess hospital-level processes for pump redistribution across units, return of pumps following patient transfers between hospitals, and local management of preventative maintenance logistics by Biomedical Engineering Technologists. Recommendations are provided to improve each of these processes.**

Keywords— **Asset Management, Preventative Maintenance, Infusion Pumps, Pump Redistribution.**

I. Introduction

The BD Alaris™ infusion system is a modular platform used for intravenous (IV) therapy. This system is controlled by a PC Unit (PCU), which is wirelessly connected to a hospital's network. Different infusion modules can be connected to a PCU to customize IV therapy. The three most commonly employed modules are the Large Volume Pump (LVP), Syringe, and Patient-Controlled Analgesia. Up to four modules can be simultaneously attached to one PCU. PCUs and modules will henceforth be referred to as "pumps."

Pumps are the most prevalent medical device supported by the Lower Mainland Biomedical Engineering (LMBME) Department in British Columbia. LMBME maintains over 18,000 pumps, which corresponds to ~17% of all devices that are supported by LMBME. Due to the modular and mobile nature of these devices, there are many challenges associated with pump fleet management and support. Namely:

- *Perceived pump shortages* have been reported by the clinical staff at several hospitals. It is hypothesized that these shortages result from issues with the cleaning and redistribution processes within hospitals rather than a lack of equipment to meet demand.
- *Mixing of pumps across hospitals ("Misplaced pumps")* due to a lack of device repatriation following patient transfers. This situation makes it more difficult to locate specific pumps. Mixed pump fleets may also pose patient safety concerns due to different drug library configurations, which can contribute to medication errors.
- *Sustaining Preventative Maintenance (PM) compliance*. Pumps due for PM need to be identified, transported, and tracked at each hospital. As PM completion rates increase, it becomes progressively challenging to locate the remaining pumps that require PM.

This project sought to discover, document, critically assess, and provide recommendations to improve: a) *Site-level processes for pump redistribution* in Lower Mainland hospitals, b) *Processes for returning pumps following patient transfers* between sites, and c) *Local management of PM logistics by Biomedical Engineering Technologists (BMETs)* pertaining to a hospital's pump fleet.

II. Methods

Three distinct approaches were conducted to help fulfill the objectives of this project, namely: site investigations of seven major hospitals in the Lower Mainland, analyses of data obtained from the Alaris™ Systems Manager (ASM), and the creation of a PM Calculator tool.

A. Site Investigations

A total of seven hospitals were investigated via in-person site visits, during which BMETs, asset managers, and pump cleaning and distribution staff were interviewed. These seven hospitals were chosen based on their high acuity and large size, a high likelihood of patient transfers between them, and well-established processes in place to manage the pump fleet. Pump redistribution processes for the region's largest hospital (873 acute beds) were also observed for two days.

B. Data Analyses

Concomitant to the site investigations, data from the ASM was analyzed to evaluate pump movement and utilization rates for 13 hospitals in the region. Inventory data from LMBME's Computerized Maintenance Management System (CMMS) was integrated into the ASM analyses via Microsoft® Excel®. Two types of reports were downloaded from the ASM for six consecutive weeks: "PC Unit Connection History" and "Device Historical Utilization."

The "PC Unit Connection History" reports include key pump analytics, e.g. the facility in which the pump was last connected, pump serial numbers, the PCU state (current state, disconnected, or communication error), when each PCU last connected to the network, etc. These reports were collected daily at 7 AM, 12 PM, and 5 PM. The first collection point corresponds to a time before the Operating Rooms have begun to operate. The second point represents the period of peak utilization rates, and the last point accounts for pump utilization following the afternoon discharge of patients.

The "Device Historical Utilization" reports detail the number of PCUs that were used throughout a day at a defined frequency (e.g. hourly). Importantly, the ASM can only store this information for seven days at a time. Hence, these reports were collected every six days to prevent loss of data, and the data was exported in time increments of one hour.

C. PM Calculator

A PM Calculator was developed in Microsoft® Excel© to aid BMET Supervisors in scheduling PM based on BMET availability. The goal of this platform is to help enhance PM compliance across hospitals. The tool outputs daily and weekly PM targets (overall, and per BMET) based on the number of BMETs and devices at a hospital and the hours required to PM all the devices. The calculator also outputs a monthly PM target, which is distributed proportionally to the number of workdays in each month. This feature is also used to track PM compliance. Each month, BMET Supervisors input the actual number of pumps that underwent PM, and the remaining number of devices due for PM is automatically and proportionally redistributed into the following months. The PM Calculator was implemented in LMBME's CMMS to allow for the relevant calculations to be based on historical PM data and to include a real-time PM compliance tracker.

III. Results

A. Site-Level Processes for Pump Redistribution

Pump workflow was found to be similar for all sites and followed the typical patient flow in a hospital (Figure 1). The majority of the observed sites had two staff members dedicated to the cleaning and distribution of pumps per shift. For the largest investigated site, this meant that two staff members were responsible for covering over 39 clean utility rooms and 45 soiled utility rooms per shift.

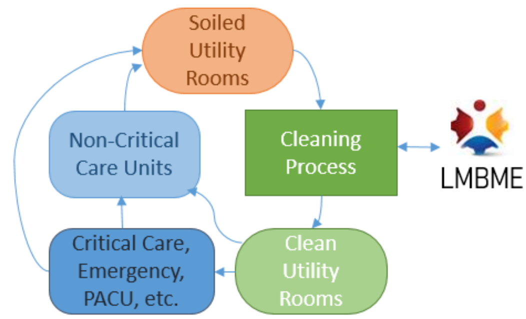

Fig. 1 Typical pump workflow within a hospital.

All investigated sites adopted a PAR (Periodic Automatic Replenishment) stock system. A PAR level, which is the minimum number of pumps needed in each unit to meet its daily operational demand, was designated for each hospital unit based on the experience of the local pump cleaning and distribution team and the clinical staff. Signs were posted in clean utility rooms to inform hospital staff of unit PAR levels. Depending on the hospital size, the cleaning and distribution teams performed 2-5 sweeps a day to monitor unit PAR levels and to locate soiled pumps for cleaning and redistribution. PAR levels were not reviewed regularly.

All surveyed sites had common pumps shared across multiple clinical units as well as some units with dedicated devices. Among the units sharing a common pool of pumps, critical care, emergency, and post-anesthesia care units (PACU) required the most pumps. These pumps often moved with a patient throughout their hospital stay (from critical to non-critical care until discharge). Hence, *pumps primarily accumulated in soiled utility rooms in non-critical care areas*. Among the units with dedicated pumps, leukemia/bone marrow transplant, dialysis, and infusion clinics required the most pumps. Due to their stationary nature, these pumps were cleaned only once a day, and PAR levels were not monitored in these areas. Pumps moved from these units only when due for PM or upon malfunction. In these instances, they were immediately replaced with a functional pump.

Clean utility rooms of critical care, emergency, and PACU were replenished with higher priority in the early morning (since most patients that required new IV therapy were admitted via emergency or for surgeries). Non-critical care areas were monitored shortly thereafter, as several soiled pumps became available for cleaning in these units due to patient discharges the previous night. LMBME became involved in this workflow when a device malfunctioned or needed PM, and typically only dealt with clean pumps.

An additional contribution factor for idle pump time was noted during the site visits. Sometimes, 1-2 idle LVPs were attached to a PCU alongside LVPs being used for treatment.

B. Processes for Returning Pumps Following Patient Transfers

There were Standard Operating Procedures for device repatriation following patient transfers between hospitals. Additionally, the data analyses demonstrated that ~4% of LMBME's pump fleet was consistently misplaced across the region. To aid in the identification of misplaced devices, some sites labelled their pumps with a corresponding hospital abbreviation.

C. Local Management of PM Logistics by BMETs

To accomplish PM tasks, BMETs typically retrieved pumps in the early morning from clean utility rooms in critical care units. This approach was chosen because these areas have additional pumps available during this period, which enhanced a BMET's chance of locating a pump due for PM.

To aid in locating pumps due for PM, several sites tagged pumps with colour-coded stickers. The colours of these stickers represented the year of last PM completion. Some BMETs also included PM completion month on this sticker.

D. Data Analyses

The results of the data analyses were important in understanding pump movement dynamics across sites and pump utilization rates within sites.

The "PC Unit Connection History" analyses outputted:

a) *Pump utilization rates*, which corresponded to the number of online pumps in the ASM (in "current state" status but not necessarily infusing) divided by the inventory data from CMMS. This approach likely overestimated utilization rates since not all online devices were infusing. The peak pump utilization rate was 55% for a particular site, and the average pump utilization rate across all 13 sites was ~30%.

b) *LVP:PCU ratios* of pumps in use compared to pump inventory data. Several sites had a net negative value when comparing inventory information with average utilization ratios of LVPs to PCUs.

c) *The number of LVPs attached to a PCU*. Overall, high acuity areas required more LVPs attached to a PCU than non-critical areas. For some sites, four LVPs were attached to a PCU in non-critical care, which was seldom needed for treatment purposes.

d) *The number of pumps last seen online more than one, three, and six months ago*. These results allowed for the observation of possible equipment loss, which was anecdotally associated with pumps not seen online for more than three months. For most sites, ~5% of the pump fleet was last seen online more than three months ago.

e) *The serial numbers of PCUs and modules that do not belong to a site*. These misplaced devices were automatically highlighted in red during the analyses to allow for filtration by colour in Microsoft® Excel®. This step helped LMBME to repatriate devices during a remediation project.

f) *"Misplaced Matrices,"* which showed the number of misplaced pumps from each site and their current location, representing pump movement dynamics across hospitals. Importantly, modules only appeared in the ASM when connected to a PCU. Hence, these matrices likely underestimated the number of misplaced devices. Nevertheless, at least ~4% of LMBME's pump fleet was misplaced across the region.

The "Device Historical Utilization" reports detailed the number of PCUs in use across 24 hours and over one week. This information allowed for data-driven decision-making regarding the best time and weekday to search for pumps due for PM and to perform PM tasks. For all sites, PCU utilization was lowest at the beginning of each day, increased around 8:30 AM, and reached its peak between 11 AM and 2 PM. Thereafter, utilization decreased to a level slightly higher than at the beginning of the day. Additionally, Sundays were the days with the least amount of PCUs in use, followed by Saturdays, then Mondays.

IV. Discussion and Recommendations

Based on the results of the site investigations and data analyses, several recommendations can be made to improve pump redistribution practices, pump return following patient transfers, and the management of PM logistics.

A. Site-Level Processes for Pump Redistribution

The manual monitoring of PAR levels performed by pump cleaning and distribution staff is challenging and inefficient, especially across large hospital sites. These inefficiencies aggravate idle pump time and reduce pump availability for clinical use. Ideally, *additional full-time employees should be working on cleaning and distribution teams* to enhance the frequency of PAR level monitoring and pump cleaning, which would result in reduced pump idle time. Moreover, a *periodic review of PAR levels* is suggested, preferably yearly. PAR levels should match historical utilization rates, foreseeable increase in demand for pumps, and daily variations in patient influx.

Another potential solution to improve pump redistribution processes would require the *implementation of RTLS (Real-Time Locating System) technologies* to automate pump location monitoring. Knowing in advance which utility rooms have the most pumps due for cleaning would prevent staff from spending hours walking around a hospital to locate such pumps. RTLS would also allow for real-time device visibility. Without real-time device visibility, average utilization rates of mobile devices were reported to be ~42%, which is considered low and costly [1]. Real-time device visibility can improve pump utilization rates by up to 20% in the first few months of implementation [2]. RTLS technologies also reduce equipment shrinkage, enhance the availability of equipment, and improve staff productivity [2]. If RTLS is cost-prohibitive, bar code scanners could be considered.

Idle LVPs attached to PCUs also reduced overall pump availability. It is believed that PCUs stored with a pre-determined number of attached LVPs may contribute to this issue, since clinical staff may refrain from detaching excess LVPs from a PCU in case they require these modules in the future. Thus, the installation of *shelves for separate pump storage* in clean utility rooms is recommended. In this way, clinical staff would be encouraged to only take as many LVPs as they need for each patient, increasing pump availability to other staff.

B. Processes for Returning Pumps Following Patient Transfers

To help identify misplaced pumps and improve repatriation rates, it is recommended to label devices with the home site abbreviation. This practice makes it easier for BMETs to leverage clinical staff and distribution teams in identifying misplaced pumps. These two groups see pumps multiple times a day, and cleaning and distribution teams can bring misplaced pumps to Biomed for device repatriation.

Additionally, data analysis can be used to determine the number of pumps and which devices from a given hospital that are currently located elsewhere ("*Misplaced Matrices*"). This approach can help BMET Supervisors in their efforts to repatriate pumps e.g. for remediation or recall purposes. If implemented, RTLS or bar code scanning could also facilitate this process by triggering a warning to Biomed when a misplaced pump is identified.

C. Local Management of PM Logistics by BMETs

A lack of consistency in PM logistics management was identified across the surveyed sites. Hence, a new sticker system to track PM completion was recommended to be uniformly adopted (Figure 2). PM completion stickers help BMETs to spot pumps requiring PM and allow for the engagement of distribution teams and clinical staff in this process. The PM reminder functionality inherent to the pumps can also be activated for clinical staff to identify pumps due for PM.

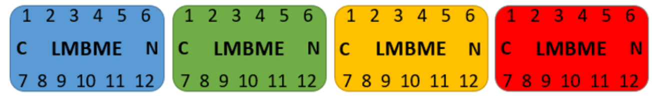

Fig. 2 Colour-coded PM stickers. Each colour represents a calendar year, repeated every four years. The numbers represent the month that PM was last completed and should be punctured accordingly. The "C" and "N" markings pertain to PCUs. The "C" is punctured when its battery is conditioned, and the "N" indicates that a new battery was installed that year.

The PM Calculator could be used by BMET Supervisors as a guideline for distribution of the PM workload, as well as a tracker of PM completion to monitor PM compliance. To achieve weekly PM targets, BMETs should aim to conduct their work on Mondays or weekday mornings (periods of lowest pump utilization within their working hours). Lastly, if RTLS was used to monitor the number of pumps in utility rooms, BMETs would know where to extract pumps due for PM without disrupting clinical practice.

V. Conclusions

The management of pumps in healthcare settings can become very challenging if not done proactively. In the Lower Mainland, several areas of improvement related to pump management were identified. Suggestions for improving pump management were presented based on evidence gathered from site investigations, data analyses, and the use of a PM calculation tool. LMBME sites are working to implement the recommendations described herein while monitoring improvements via the daily collection of data from the ASM for tracking and trending purposes. We are also continuously applying this work to coordinate remediation projects related to device alerts (risk management). It is believed that the outcomes of this project and implementation of the suggested recommendations will result in improved pump management processes across the Lower Mainland of British Columbia.

Conflict of Interest

The authors declare that they have no conflict of interest.

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