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Using Smart IV Infusion Pumps Outside of Patient Rooms

Best practices for maintaining safety and efficacy.

ABSTRACT: The COVID-19 pandemic has created unique challenges for health care workers, who have demonstrated dedication, collaboration, and innovation in response. In this article, the authors describe an important nursing innovation they employed at Montefiore Medical Center in the Bronx, New York, during the spring 2020 COVID-19 surge: the relocation of smart IV infusion pumps outside of patient rooms. The goals of this innovation were to improve delivery of care, conserve personal protective equipment, limit the spread of the virus, and protect staff from exposure. The authors discuss the initial concerns that arose regarding the safety and efficacy of this practice; the research they conducted with other colleagues in nursing, pharmacy, infection control, and patient safety in the face of scant clinical literature relevant to the difficult circumstances the pandemic created; and the strategies they ultimately employed to ensure that this practice maintained safety and efficacy.

Keywords: COVID-19, IV tubing, nursing innovation, smart IV infusion pumps

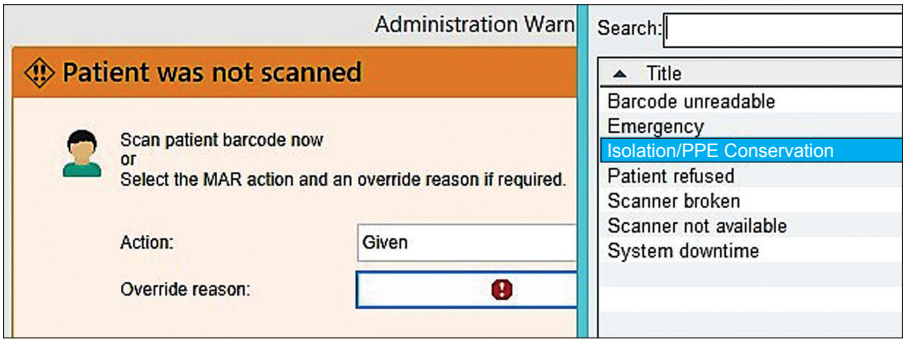
New York City, which saw its first case of COVID-19 on March 1, 2020,[1] quickly became the epicenter of the nation, while the Bronx emerged as the city's hardest hit borough, with the highest number of COVID-19 hospitalizations and related deaths per 100,000 population.[2] From the week of March 8, 2020, to the week of March 29, 2020, New York City weekly case counts rose from an average of 274 to an average of 5,132 cases per day.[3] At Montefiore Medical Center's three campuses, all located in the Bronx, internal hospital data indicated that from March 16, 2020, to April 15, 2020, ICU capacity increased by 143% from 106 to 258 ICU beds, and the medical center saw a 7,200% rise in our COVID-19 census from 15 to 1,095 cases.

The new normal. Montefiore's health care workers were pushed to their limits caring for this uniquely challenging patient population who had unrivaled acuity and need for respiratory support. Treatment protocols were developed and optimized in real time as knowledge—factual, conceptual, experiential, and procedural—evolved. New guidelines and procedures arrived daily, adding to the cognitive burden for health care workers and requiring rapid changes to daily workflow.

Elective procedures were halted, and entire hospital units were reconfigured to increase available staff and space for patients with COVID-19. Post-anesthesia care units (PACUs), cardiac catheterization labs, ambulatory infusion and procedural centers, operating rooms, as well as telemetry and

step-down units were transformed to accommodate an ICU level of care. To accommodate nonventilated patients, physical therapy gyms, conference rooms, and visitor lounges were converted to patient care areas. Such procedures as proning patients became commonplace throughout the system. Although this presented a steep learning curve for staff, efficiency and optimal safety were achieved with the help of a dedicated proning team.

Figure 1. Electronic Documentation of Patient Identification



Cohorting two to four patients with COVID-19 in the same room was widely employed to accommodate the rising number of COVID-19 admissions. Each patient encounter required personal protective equipment (PPE) and hand hygiene upon entering and leaving the room. The clinician donned an N95 mask, performed a seal check, applied a face shield over it, then gowned and gloved. Performing hand hygiene and applying PPE took approximately two minutes and removing it took just over a minute.

Demand for PPE increased exponentially given the number of patients being cared for and the number of times nurses entered patient rooms. Applying the requisite PPE became a daunting task. Nurses reported stepping outside of patient rooms only to hear the pump alarm, indicating the need to return to the patient's bedside. Sometimes the infusion was completed while the nurse was still in the room, necessitating a call to a colleague to bring a replacement medication.

Against this backdrop, innovation became a survival strategy, often referred to as "building the plane while flying it." The severity of patients' acute respiratory distress syndrome (ARDS) coupled with forceful coughing required ventilator settings that caused patients to struggle, necessitating unusually high doses of sedatives. For some patients, the sedative infusions were running at such high doses that IV infusion bags needed to be changed every two to three hours.

Relocating IV infusion pumps. In April 2020, the U.S. Food and Drug Administration endorsed the use of "hardware, software, or design modifications implementing the capability for remote monitoring and remote manual adjustment of infusion parameters," and recommended that this exist "for the duration of the public health emergency, in order to help foster the wider availability of devices for patients in need of continuous infusion therapy, and to help reduce healthcare provider exposure to patients affected by COVID-19."[4]

Colleagues across the nation shared their experiences with COVID-19 surges on social media to help health care providers in other areas deliver more efficient, safer patient care. They began describing how they had moved IV infusion pumps outside of patient rooms in order to

- conserve PPE for which demand had increased exponentially.
- limit the spread of the virus throughout their centers.
- protect staff from exposure.

Nurses and pharmacists at our medical center reached out to our infection prevention and control department to request permission to implement this new practice and sought guidance from our patient safety experts on how to proceed. Initially, as described by colleagues at other hospitals, the practice was being used only in ICUs with glass doors through which patients could be readily visualized, but with the COVID-19 surge, the practice was soon adopted in ICUs without glass doors. Collaboratively, we reviewed the existing science in an effort to develop a safe and effective approach.

The biggest problem we encountered was that clinical literature on the topic was limited. Through our literature search we found some recommendations concerning the practice,[5,6] but were unable to locate any evidence-based standardized procedures, without which some practices would inevitably introduce preventable safety threats. Our first challenges were to ensure that the patient population whose IV pumps would be moved was appropriate and to develop criteria to determine when a pump outside the room would enhance safety and when it would be detrimental.

This article describes our early missteps and the ultimate success our medical center achieved when, in response to the several challenges COVID-19 presented, we adopted the innovative practice of

moving IV infusion pumps outside of patient rooms. This practice has been found to conserve PPE; reduce staff exposure to COVID-19; and support a timely response to alarms, thereby improving efficiency of patient care.[6] We discuss our findings concerning best practices and identify gaps in the clinical literature that need to be addressed for optimal safety when it becomes necessary to place pumps outside of patient rooms.

PATIENT CRITERIA

Appropriate candidates for relocated IV pumps included patients who were mechanically ventilated and those who were heavily sedated with high-rate infusions requiring frequent pump adjustments.

Since some local hospitals had reported errors when more than one pump per room was allowed in the hallway for cohorted patients, we restricted the number of IV pumps in the hallway to one person per room.

Excluded from consideration for a hallway pump were patients receiving blood products, who required more frequent nursing assessment; those receiving patient-controlled analgesia, which they controlled from pumps within their room; and patients who were cognitively aware and able to get out of bed, as their mobility increased the risk of tripping over the extended tubing.

These patient criteria were designed to guide safe practice, not to negate the need for clinical judgment. Patient stability was a relative indicator of patient appropriateness. Unstable patients who required a greater number of physical assessments, procedures, or medication changes would require longer nursing intervals in the room and more interventions at the bedside. Once patients stabilized and had fewer intense, more predictable care needs, nursing time inside the room could decrease and it was safe to place pumps outside the room. Nurses were empowered to make the decision about the most appropriate location for the pump based on individualized patient care needs.

PATIENT IDENTIFICATION

Avoiding room entry also eliminated the normal procedure for scanning the patient identification bracelet.

One clinical report suggested using a two-person check to confirm the patient's barcode.[7] Upon patient arrival, one patient identification bracelet was attached to the patient's wrist and a second was attached to the pump or taped to the inside of the glass door for easy scanning. Two nurses would independently verify that the information on the bracelet attached to the pump or window matched the patient's demographic profile. The bracelet on the pump or window was then scanned as a proxy for patient identification prior to medication administration.[7]

The issue of proxy barcode scanning, however, caused spirited debate in our organization, which had worked aggressively to eliminate duplicate sources of patient identification, such as bracelet books, prior to the COVID-19 surge. Practice standards were rigorously enforced, and the only acceptable barcode scanning method was using the identification bracelet attached to the patient. Recognizing that barcode scanning of the patient was not possible with pumps outside the room, nursing leaders and frontline staff had lively discussions about patient safety concerns that could arise when scanning a bracelet that was not attached to the patient.

Ultimately, we decided to revert to a manual process of identifying patients' pumps by putting a sign on the pump with the name and birth date of the patient receiving infusions through that pump. To ensure truthful and accurate documentation, nurses were provided the option of overriding barcode scanning, selecting as the reason "Isolation/PPE Conservation" (see Figure 1). Nurses, uncomfortable with inaccurate documentation, expressed appreciation for the change.

Through our literature search and experience, we identified no single best practice for patient identification when using IV pumps outside patient rooms. In determining how to achieve optimal patient safety, organizations must establish processes that support their values. Organizations that determine bracelets can be safely scanned outside of patient rooms might implement a two-person check that uses both identifying bracelets attached to patients as well as patient identifiers attached to the window or wall.[7]

Avoid attaching bracelets to pumps, which move in and out of patient rooms, as staff may scan the pump when they are inside the room rather than the bracelet on the patient. Best practice would ensure that electronic documentation accurately reflects whether the patient's bracelet is attached to the patient or in an alternate location.

PATIENT PROXIMITY TO THE DOOR

For some patients, the head of the bed was adjacent to the door opening, while for others, the door was closest to the bottom of the bed. In such cases, to reduce the distance from the head of the bed to the door—and thus reduce the required tubing length—staff would reverse the bed's positioning in the room.

LOCATION OF OUTLETS

In some ICU rooms, outlets were not close enough to the door to enable moving the pumps out into the hallway. When holes were drilled into the walls to permit connecting a pump in the hallway to an electrical outlet inside the room, the room would no longer be a closed space, and clinicians in the hallway would be required to wear N95 masks.

Several units in our medical center, however, including PACUs, EDs, and older ICUs with cubicles, lacked rooms with doors and the following processes had already been established to accommodate clinicians caring for patients within these open spaces:

- Areas lacking doors were labeled as red zones.
- Staff were required to wear N95 respirators when working in red zones.
- Entrances to red zones were marked with red tape on the floor as a visual reminder that staff were required to don an N95 respirator prior to entry.

Units in which holes had been drilled into walls of patient rooms to connect a hallway pump to an electrical outlet within the room were thus similarly designated as red zones, even if holes had been drilled into the wall of only one patient's room.

Nurses expressed that keeping pumps outside of patient rooms was worth the trade-off of having to wear an N95 respirator while working in a red zone.

SAFETY CONCERNS ABOUT TUBING ON THE FLOOR

Our literature search indicated that at least some hospitals allowed IV tubing to be placed on the floor,[6,8] which raised safety concerns among many of our clinicians.

At one hospital, nurses covered tubing on the floor with incontinence pads, secured at each connection, as a visual reminder to reduce the risks of tripping on or dislodging tubing.[6] They further ensured that no Y-site connectors were on the floor.

Blake and Giuliano emphasized that lengthening the IV tubing between the patient and the pump would introduce a gravitational gradient for the infusion to overcome, possibly reducing the flow rate to an undetectable degree.[9]

Covering tubing with incontinence pads, though intended as a visual reminder to reduce the risk of tripping, might actually increase the risk that staff would not see the tubing and would walk on or roll a portable device, such as a radiograph or dialysis machine, over it, thus disrupting flow through IV lines and compromising tubing integrity, introducing the additional risk of central line–associated bloodstream infection (CLABSI).[7,8]

DOOR CLOSURE

The Centers for Disease Control and Prevention had mandated that patient doors be closed for patients with COVID-19.[10] In a report by Shah and colleagues, when ICUs at a New York teaching hospital relocated IV pumps outside of patient rooms to limit exposure and facilitate patient care, tubing was passed through a gap between the double doors to be affixed without kinking and maintained off the floor.[7] Infection control staff preferred that method over closing the glass doors over the tubing, and nursing staff routinely checked tubing for damage and mechanical impediments.[7]

We were unable to locate any data on the potential for visually undetectable micro ruptures resulting from doors being closed over tubing placed on the floor or on the impact of compression by a door on flow rate accuracy. In the absence of reliable data to support the safety of tubing under closed doors, our medical center chose to keep tubing off the floor and leave doors to patient rooms ajar.

ALTERNATIVE PLACEMENT OF TUBING

Of the many safety concerns raised over relocating IV pumps outside of patient rooms, keeping the tubing off the floor was an easy fix. At our medical center, to secure the tubing off the floor, minimizing the risk of CLABSI and eliminating tripping hazards, we used a StatLock securement device (see Figure 2) to attach the tubing to the door frame or wall. To suspend the tubing, we attached a tourniquet used for blood draws to a surface within the room or looped the tubing over an object in the room. The door had to be left ajar to accommodate this practice.

FLOW RATE ACCURACY

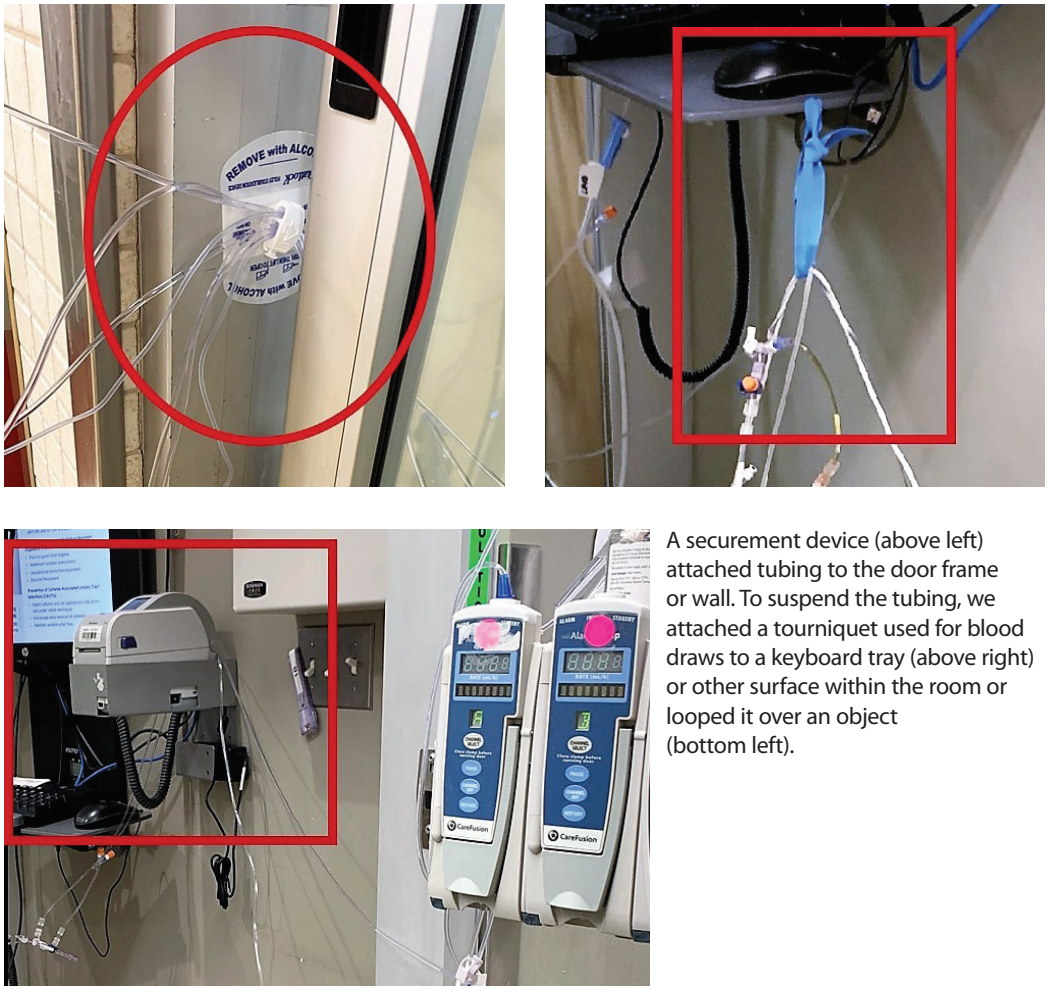
For pumps to reach outside the room, the tubing from the patient to the pump had to be extended, either by using extension tubing or by connecting several sets of regular tubing. On some units, a single set of extension tubing was not enough, but increasing the tubing length would increase resistance in the line and reduce the flow rate, which was an important consideration for such critical medications as vasopressors, sedatives, and antibiotics. To maintain rate accuracy, patient safety administrators recommended using a 20-gauge or larger IV catheter when possible and, in accordance with pump manufacturer guidelines, hanging IV medications at least 20 inches above the top of the pump module (see Figure 3).[11]

When administering secondary medications, the secondary infusion was placed at least 20 inches above the top of the pump module, with the primary infusion placed below the secondary infusion. This ensured that the pump manufacturer's specified 9.5-inch distance between primary and secondary infusions was maintained. Clinical literature specifying that infusions should be hung at least 20 inches above the pump made no recommendations about distance between primary and secondary infusions.

CONSIDERATIONS REGARDING TUBE VOLUMES

When selecting the length of the tubing, it was important to consider the medication being infused as well as the patient's volume status. The longer the tubing, the greater the chance that more drug would remain in the tubing following infusion and the greater the risk the patient could receive a bolus of a high-risk

Figure 2. Strategies for Securing Tubing Off the Floor



A securement device (above left) attached tubing to the door frame or wall. To suspend the tubing, we attached a tourniquet used for blood draws to a keyboard tray (above right) or other surface within the room or looped it over an object (bottom left).

medication during flushing. In the case of intermittent infusions, to ensure patients received the complete dose, staff were instructed to follow the infusion with an amount of plain diluent equal to the volume of solution the tubing could hold. For example, if administering an intermittent antibiotic infusion of 50 mL through extension set tubing with a volume of 37 mL, upon completion of the antibiotic, the nurse would infuse 37 mL of a compatible plain IV solution at the same infusion rate as the antibiotic. This ensured that the full drug dose reached the patient and no residual that could harm the patient remained. When the volume to be infused was completed, the pump alarm would alert the nurse to cap off the intermittent line or resume a continuous infusion.

Priming and flush volumes. Increasing the tubing length also increased the volume needed to prime and flush the lines. Adequate flushing was important to ensure the patient received the total dose at the intended rate, especially for intermittent infusions and bolus doses. Manufacturer-prepared adult flushes normally range from 5 to 10 mL. With increased tube length, the total flush volume could now be as high as 67.3 mL when using three syringe tubing sets with one LivaNova IV infusion set, for example. This was concerning because many COVID-19 patients had ARDS and were at increased risk for fluid overload and renal failure. To mitigate this risk, we provided multiple configuration options for extending pump tubing and their respective total volumes. Standardizing the tubing configuration across the institution was impractical, as many tubing sets were in short supply and the types of tubing available varied across the units. Staff were advised to configure the tubing in the most volume-efficient way using available supplies and recommended priming and flush volumes (see Table 1).

OCCLUSION ALARMS

In April 2020, the independent nonprofit ECRI noted in a medical device special report that extending tubing could affect the frequency of occlusion

alarms.[5] After testing several large-volume infusion pumps with 20 feet of microbore tubing, the report noted that occlusion alarms were delayed at flow rates below 5 mL/hour and more frequent at flow rates above 300 mL/hour. Nurses therefore could potentially receive no indication of occlusions for infusions set at lower flow rates and receive excessive nuisance alarms for infusions set at higher flow rates, adding stress to an already stressful environment. The manufacturer of our medical center's pumps recommended that clinicians change the pump's occlusion pressure limits with each pump set up.[11]

Given that flow rates less than 5 mL/hour and higher than 300 mL/hour are infrequent in adults, our patient safety administrators deemed the manufacturer's recommendation unnecessary and rejected it out of concern over the potential for errors. Another hospital did raise occlusion limits on IV pumps from 300 to 500 mmHg to overcome resistance to flow rates and fluid viscosity and to prevent unnecessary occlusion alarms from interfering with vital continuous infusions.[7] They did not report on staff adherence, frequency of errors, or any reduction in nuisance alarms after implementing the practice, however, so there were no available data to support it.

CONTROLLED DRUG ACCESS

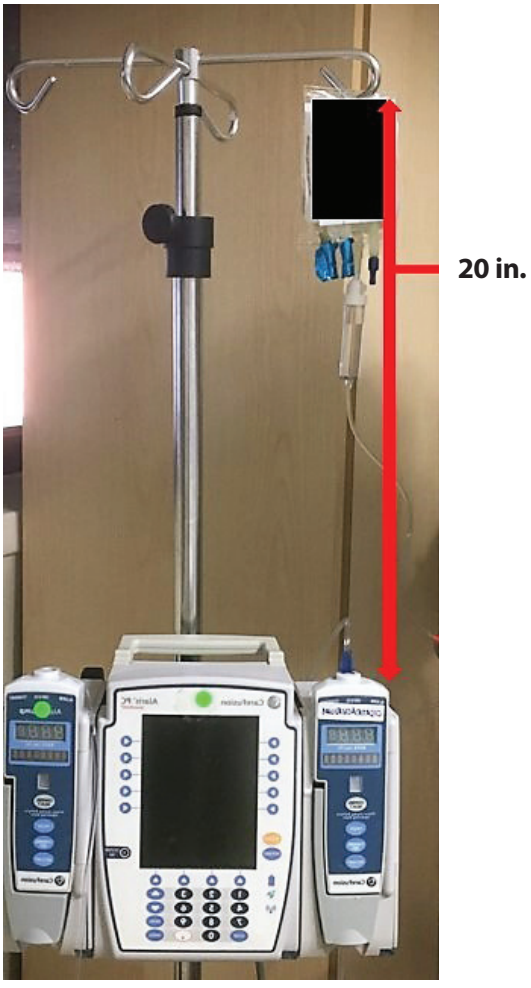
The demand for controlled substance–specific pumps overwhelmed the supply, necessitating the use of standard infusion pumps to infuse controlled substances.

Hallways were crowded due to the increase in patient volume, the large number of IV pumps required per patient, the amount of other equipment needed for patient care, and the increased staffing level required to care for patients, making it difficult to avoid physically bumping into IV pumps. To manage the threat of accidental rate change from a pump bump and to ensure drug security, nurses were instructed to activate the tamperproof feature included in the pump software. We use the BD Alaris pump, which contains a panel that locks the settings so they cannot be changed unless unlocked; this provides the necessary safeguards for controlled substances. As this feature is not normally used, directions about activation were electronically disseminated to the staff. Even with the pump lock activated, nurses can see the selected parameters and respond to pump alarms.

MEDICATION AND EQUIPMENT SHORTAGES

Despite efforts to preemptively identify all potential issues related to moving pumps outside of patients' rooms, several unanticipated challenges arose. The greatest of these was shortages of both medication and equipment. The vast number of intubated, heavily sedated patients increased the demand for tubing, pumps, and medications among all area hospitals, creating supply chain disruptions.

Figure 3. Recommended Infusion Bag Position



The infusion bag should be hung at least 20 inches above the pump according to pump manufacturer guidelines.

Use of sedatives and analgesics soared. Because the COVID-19 population often presented with severe ARDS, they required unprecedented high doses of sedatives such as propofol (Diprivan) and analgesics such as fentanyl to maintain oxygenation and ventilator synchrony. For propofol, which requires that tubing be changed every 12 hours and any unused drug product discarded to prevent organism overgrowth in the event of undetected contamination, our internal hospital data indicated an increased use of almost 500% over baseline. The numbers of heavily sedated patients and extension sets per patient were enormous. Furthermore, some extended tubing sets held up to 135 mL of fluid, a greater volume than entire bags of some of our commonly used drug infusions. When fentanyl was discontinued, the amount of waste could be 3.2 to 64 mL depending on the tubing used. Our internal hospital data indicated that

Table 1. Manufacturer-Recommended Priming and Flush Volumes

Configuration Options	Priming and Flush Volumes
3 Smiths Medical syringe tubing sets	3.3 mL without filter set 4.6 mL with filter set
3 to 4 Baxter extension sets	11.7 to 15.6 mL
1 B. Braun extension set (146 in.)	22 mL
2 BD Alaris syringe tubing sets and 1 standard infusion set	28.2 mL without filter set 29.5 mL with filter set
2 BD Alaris standard infusion sets	52 mL
1 LivaNova perfusion set (96 in.)	64 mL

Note: For the priming and flush volumes for one set, see the manufacturers' instructions.

fentanyl use had increased more than 700% over baseline, and for a brief period our institution's entire supply was depleted, requiring us to transition to a less ideal analgesic. Retrospectively, we hypothesized that drug conservation was a missed opportunity for slowing shortages. One of the lessons we learned for the future is to develop processes that use the full drug volume in the tubing.

FEWER BEDSIDE ASSESSMENTS

We recognized that having pumps outside of patients' rooms created fewer bedside assessments. While vital sign assessments could be accomplished by placing monitoring equipment within view of a glass door or at the bottom of beds that could be seen from the doorway, IV line assessments required the inspection of IV sites. Standards were modified to allow staff to assess IV sites for dressing integrity and infiltration during the repositioning of prone patients, whose heads needed to be turned every two hours. It was not, however, always possible to check subclavian IV sites in prone patients. When IV site assessments weren't possible, staff were advised to be alert to pump alarms that might indicate line dislodgment or occlusion and to be attentive to patients who have an unexpected response to an infusion or who demonstrate signs of clinical decompensation. If a patient's change in condition coincided with the use of additional extension sets and the relocation of the pump, staff were instructed to eliminate the extra tubing and return the pump to the bedside.

GAPS IN CLINICAL LITERATURE

Spikes in CLABSIs during COVID surges. McMullen and colleagues and Nori and colleagues have reported spikes in the number of CLABSIs during COVID-19 surges.[12,13] Likewise, our medical center saw CLABSI rates rise during these surges. The reasons are poorly understood but several hypotheses have been proposed. The introduction of the extra tubing has been identified as a potential contributor. We could not determine whether failure to follow manufacturer recommendations regarding the frequency of propofol tubing changes or the disposal of any unused drug every 12 hours was a factor in the spikes of CLABSIs we saw.

Changing the tubing down to the patient connection required room entry. At our medical center, tubing changes were omitted when more pressing patient care priorities prevented the completion of this time-consuming task. The frequency with which such omissions occurred and their impact on CLABSI rates are unknown. Prone positioning was a barrier to adequate assessment of dressing integrity. The prone position potentially increased pressure on insertion sites that were hidden from view. Pressure on nonintact skin, such as IV insertion sites, causes inflammation at the sites, potentially contributing to CLABSI development. Some prone patients had pooling of oral secretions creating a moist environment near the dressing. Prolonged use of central lines and increased use of femoral sites are well-established CLABSI risk factors. Among the patients who developed a CLABSI, it was impossible for us to identify the subsets who had IV pumps outside of their rooms, were being proned, or were receiving propofol through a central line. Documentation triggers for automated reporting of identified CLABSI risk factors should be considered for future analysis.

Tubing integrity. Whether tubing integrity is maintained when tubing is compressed inside a closed door needs to be verified before it can be recommended as a best practice. The risks of leaving patient doors ajar less than one-eighth of an inch and drilling holes into walls need to be quantified so that recommendations can accurately balance patient care needs and employee safety.

Changing pump pressures. The burden of changing pump pressures and the benefits to rate accuracy and occlusion alarms need to be investigated to determine the necessity of this practice change. While this is a theoretical risk discussed in the clinical literature, our staff did not notice

increases in alarms when this practice wasn't followed. Blake and Giuliano reported that when increased system resistance occurs in peristaltic pump technology, such as the BD Alaris pump used in our medical center, flow rate is likely to decrease, but the pump continues to display the intended flow rate so the reduction is undetectable.[9] This conceptual safety threat needs to be further investigated so that the clinical risks can be quantified.

CONCLUSION

Determining best practices for IV pumps outside of patient rooms is ongoing. Unresolved issues, such as understanding the factors that contribute to increased CLABSIs and establishing the clinical significance of extended tubing sets on the accuracy of drug delivery rates, require further research. It's hoped that a standardized approach that supports clinical decision-making, minimizes drug shortages, optimizes patient outcomes, and improves work efficiency under such difficult circumstances as were created by COVID-19 may be developed. ▼

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