



## SPECIAL ARTICLE

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## Implementing barcode medication administration and smart infusion pumps is just the beginning of the safety journey to prevent administration errors

La implementación de la administración de medicamentos con código de barras y las bombas de infusión inteligentes es sólo el comienzo del camino seguro para prevenir los errores de administración

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## Abstract

**Introduction:** Healthcare-related technology has been widely accepted as a key patient safety solution to reduce adverse drug events by decreasing the risk of human error. The introduction of technology can enhance safety and support workflow; however, it does not eliminate all error types and may create new ones. Barcode medication administration and smart infusion pumps are two technologies utilized during medication administration to prevent medication errors before they reach the patient.

**Objective:** This article reviewed different error types with barcode medication administration and smart infusion pumps and examined how these errors were able to occur while using the technology. Recommendations for preventing these types of errors were also discussed.

**Conclusion:** Hospitals must understand the technology, how it is designed to work, which errors it is intended to prevent, as well as understand how it will change staff workflow. It is essential that metrics are set by hospital leadership and regularly monitored to ensure optimal use of these technologies. It is also important to identify and avoid workarounds which eliminate or diminish the safety benefits that the technology was designed to achieve. Front line staff feedback should be gathered on a periodic

## Resumen

**Introducción:** La tecnología sanitaria se ha convertido en la solución más aceptada para reducir los eventos adversos provocados por los medicamentos, minimizando los posibles errores humanos. La introducción de la tecnología puede mejorar la seguridad y permitir una mayor eficiencia en la clínica. Sin embargo, no elimina todos los tipos de error y puede crear otros nuevos. La administración de medicamentos con código de barras y la utilización de bombas de infusión inteligentes son dos estrategias que pueden emplearse durante la administración de medicamentos para evitar errores antes de que estos lleguen al paciente.

**Objetivo:** En este artículo se han revisado diferentes tipos de errores relativos a la administración de medicamentos con código de barras y las bombas de infusión inteligentes, y se ha examinado la forma en la que se producen dichos errores al emplear la tecnología. También se exponen las recomendaciones encaminadas a evitar este tipo de errores.

**Conclusión:** Los hospitales deben comprender la tecnología, su funcionamiento y los errores que pretende evitar, así como analizar de qué manera cambiará los procesos clínicos. Es esencial que la dirección del hospital establezca las métricas necesarias y las monitoree regularmente para garantizar el uso óptimo de estas tecnologías. También es importante

## KEYWORDS

Barcode; Infusion pumps; Medication errors; Technology; Patient safety; Adverse drug events; Medication systems.

## PALABRAS CLAVE

Código de barras; Bombas de infusión; Errores de medicación; Tecnología; Seguridad del paciente; Eventos adversos por medicamentos; Sistemas de medicación.



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basis to understand any struggles with utilizing the technology. Leaders must also understand that even with full implementation of technology, medication errors may still occur.

## Introduction

For patients, medications offer many benefits from effectively managing chronic conditions such as hypertension, asthma, and diabetes to providing a key role in the treatment of acute conditions such as infection, pneumonia, myocardial ischemia, and congestive heart failure. Despite the many benefits of medications and healthcare providers' expertise in using them effectively, medication errors remain a serious healthcare concern that practitioners must consider. A medication error can be tragic and costly in both human and economic terms. Administering the wrong drug or dose, mistaking a drug with another drug that has a look-alike name or package, giving medications at the wrong time or at the wrong infusion rate, entering the wrong dosing weight into an infusion pump, selecting the wrong drug or patient from a drop down list, are all slips that happen every day, to all types of practitioners, and in all practice settings<sup>1</sup>.

There have been many estimates on the incidence and cost of medication errors. Elliott *et al.* analyzed 36 studies that reported medication error rates in primary care, care homes, and secondary care at various stages of the medication pathway and found error rates ranging from 0.2% to 90.6%. They also reviewed four UK studies on the cost of medication errors in specific settings, which ranged from €67.93 per intercepted error of inhaler medication to €6,927,078.96 for litigation claims associated with an anesthetic error<sup>2</sup>. In the US, adverse drug events account for nearly 700,000 emergency department visits per year and 100,000 hospitalizations. Nearly 5% of US hospitalized patients experience an adverse drug event, making them one of the most common types of inpatient errors, and it is estimated that about half of adverse drug events are preventable<sup>3</sup>. Recognizing that unsafe medication practices and medication errors are a leading source of preventable harm in healthcare settings around the world, and at a global estimated cost of \$42 billion USD annually, in 2017, the World Health Organization (WHO) initiated the third WHO Global Patient Safety Challenge: *Medication Without Harm*. The aim of *Medication Without Harm* is to reduce avoidable medication-related harm by 50% globally in the next 5 years<sup>4</sup>.

Given the well-documented high frequency of medication errors, their potential to cause significant patient harm and increased healthcare costs, makes medication error prevention a priority for all practitioners. To address the many factors that can lead to a medication error, the introduction of healthcare-related technology has been widely accepted as a key patient safety solution to reduce adverse drug events by decreasing the risk of human error. Technology examples include computerized order entry systems with clinical decision support, automated dispensing cabinet storage units, robotic dispensing systems, compounding workflow systems that utilize barcode verification, smart infusion pumps, and barcode scanning of medications during administration. The introduction of technology can enhance and support workflow, improve efficiency, provide decision support, improve accuracy, improve quality of care, and help avoid errors; however, it can also create new types of errors. Instances of misuse and disuse, often to work around issues with the technology system, have been well documented<sup>5</sup>. Although the benefits of healthcare technologies are also well documented<sup>1</sup>, it must also be noted that information technology to support clinical decision making does not replace human activity but rather changes it, and at times in unintended or unanticipated ways. Errors can also be caused by over-reliance and trust in the technology or when users bypass safety features programmed into medication use technologies to provide warnings of possible unsafe conditions or errors<sup>5,6</sup>.

identificar y evitar desviaciones en los procesos que puedan eliminar o disminuir los beneficios de seguridad para los que fue diseñada. De igual forma, es necesario recopilar periódicamente las opiniones del profesional que la utiliza para detectar los posibles problemas que pudieran surgir. Sin embargo, la dirección debe ser consciente de que incluso con la implementación completa de la tecnología pueden surgir errores a la hora de administrar la medicación.

Barcode medication administration (BCMA) and smart infusion pumps are two technologies utilized during medication administration to prevent medication errors before they reach the patient. This article will review different error types with barcode medication administration and smart infusion pumps and examine how these errors were able to occur while using the technology. Recommendations for preventing these types of errors will also be discussed.

## Barcode medication administration

Leape *et al.* found that errors originating in the administration phase of the medication use process were the second most prevalent and nearly equivalent to the number of errors that originate during prescribing<sup>7</sup>. Unlike the prescribing phase, which comes early in the medication use process and is followed by several verification checks, once a medication has reached the administration phase, the nurse is the last healthcare practitioner who can stop an error from reaching the patient.

The goal of BCMA is to ensure the right medication is administered to the right patient at the right dose, and by the right route, at the right time<sup>8</sup>. Barcode technology is well established in industries outside of the healthcare sector and barcode verification prior to medication administration is standard practice in the US<sup>9</sup> with a growing presence in hospitals outside the US. Despite data that supports improved accuracy when BCMA is added<sup>10,11</sup>, several studies have demonstrated workarounds that limit the safety benefits<sup>12,13</sup>. The use of BCMA technology is considered a high-leverage strategy, but similar to other healthcare technologies, practitioners must be cautioned against overreliance. While BCMA plays an important role in medication safety, it will not eliminate all types of administration errors and it cannot replace clinical judgment.

The following describes how workarounds, poor workflow, and technology limitations when using barcode medication administration may allow errors to occur.

## Performing a verification barcode scan after administration

In some cases, medication errors have resulted when nurses decide to obtain and administer medications to patients before they carry out the barcode verification step. In this situation the decision support of a wrong patient, wrong drug, wrong dose, or timing warning alerts too late for the nurse to take corrective action<sup>14</sup>.

The main safety intent of barcode scanning is defeated when scanning occurs *after* drug administration to the patient. This practice, referred to as "back scanning," is sometimes used by nurses who feel it is a more efficient workflow to scan all the patient's doses *following* administration. In organizations where barcode scanning compliance is monitored, reports are not always able to differentiate if a medication was scanned *after* administration. Furthermore, if the scan time and administration time are the same, there is no way to know from a report whether the medication was scanned immediately before administration or immediately after. It is best to take a proactive step and observe the barcode medication administration process to see if the workaround of back scanning is happening before it leads to an error. If back scanning occurs, make necessary system changes to assist nurses in avoiding this practice and educate nurses about the risks associated with back scanning. It is important for organizations to monitor medication and patient scan rates, medications with a readable barcode, barcode scan rates

by ward, nurse, and time of day to identify potential barriers to barcode medication administration.

## Misunderstood messages

When preparing to administer medications to patients, a nurse may not have easy access to view their barcode medication administration device. They may not be looking at the verification scanning screen where warning messages appear. Since most barcode scans issue a sound, this may cause nurses to accept the sound as confirmation that the medications are correct for their patient<sup>5</sup>.

Until more advanced barcode medication administration scanners are available, presently, regardless of whether the correct medication or patient has been scanned or an associated warning has alerted, the same audible beeping sound is heard during scanning. Failed verification of the right medication or right patient is communicated through error messages displayed on the medication administration record or hand-held device screen. Unfortunately, some nurses have mistakenly relied on the sound of the beep alone to signal verification of patient and medication, in particular when the computer or hand-held device screen is not easily visible. If a nurse's computer is on a mobile cart or in a stationary location, it may be difficult or impossible to get to the patient's bedside. Nurses may not recognize that a key safety strategy during drug administration is to have the patient's medication administration record at the bedside and visible during medication administration. Medical equipment as well as visitors may also provide obstacles which make it more difficult to move a mobile device next to the patient bed. Whether you are in the planning stages for bedside barcode scanning or already a user of this administration technology, hospitals need to identify conditions throughout the entire medication administration process that may result in absent or poor visibility of the full medication administration record. Organizations should give thought to devices that will be used by nurses to view medication administration records and to scan patient identification bands and medications prior to administration. It is also a good strategy to educate nurses about the difference between the audible beep with a registered scan and actual verification of the correct patient and medication when using barcode technology.

## Barcode verification cannot catch all administration errors

There are limitations to the type of errors that barcode verification technology can detect. Although it can warn practitioners and help avoid many potential errors, there are some errors that originate during administration that it will miss. If a nurse scans the correct medication, but administers it by the wrong route, barcode verification will not catch that error. A patient may have a medication ordered to be given intranasally, barcode verification will not alert if the nurse gives this medication orally. If an ampule or vial of a medication to be given intravenously contains more than the patient's ordered dose, some barcode verification systems may issue a warning to give a partial amount; however, it cannot warn the nurse if they draw out and administers the incorrect dose or volume.

Wrong route errors and errors where a partial dose must be withdrawn from an ampule are two administration error types that may be difficult or impossible to prevent using barcode verification technology. In the case of a wrong route error, the nurse will receive affirmation that they have the correct medication and are giving it to the correct patient; however, verification of the route of administration must be done manually by reviewing the medication administration record. Although some barcode medication administration systems will prompt nurses when a dose is different from the package size scanned, in cases where a partial dose needs to be withdrawn from an ampule or vial there is nothing that prevents the nurse from drawing up more or less than the intended dose or in some cases perhaps withdrawing and administering the entire contents of the ampule or vial<sup>16,17</sup>. When the medication administration process is enhanced by the addition of barcode technology, practitioners may begin to over rely on the system, incorrectly thinking it can catch all errors. Some users may forget that manual verification checks (e.g., cor-

rect route, correct dose volume) also need to occur prior to administering a medication to a patient.

## Scanning identification barcodes that are not attached to patients

As a workaround to scanning patient identification bands worn by patients, a nurse might choose to print extra barcode patient identification bands and use these to verify the correct patient during medication administration. Some nurses have felt uncomfortable waking a sleeping patient to scan their identification band. Nurses may not want to place an identification band on a small neonate for fear of causing skin breakdown or they may want to avoid placing a barcode band on the affected limb of a burn victim. In these cases, the extra barcode identification bands are sometimes kept at a nurse's workstation but may also be affixed to a patient's hospital bed, treatment chair, or hospital room door<sup>18</sup>.

Scanning a patient identification band that is not attached to the patient defeats the safety benefit of barcode medication administration technology. Nursing staff may not recognize that it is unsafe to scan surrogate identification bands and this practice may lead to an error reaching the patient. This workaround will not be apparent when reviewing barcode administration metric data; therefore, it is necessary for managers to observe the medication administration process in order to identify this risky behavior and coach staff to understand that for their safety and for the technology to reduce the risk or wrong patient errors, it is imperative that during medication administration only the identification band attached to the patient be scanned. In addition, to identify potential identification band workarounds some organizations have limited the number of staff who can print additional identification bands and regularly monitor which bands have been requested for reprinting. Similarly, nurses may create a shortcut by keeping medication barcodes that were removed from previously used drug packages on a clipboard, at their workstation, posted somewhere in the ward, or on their computer monitor and scan those instead of the barcode on the medication dose they are administering to the patient. This, too, creates unnecessary risk as the medication administered may not match the surrogate drug barcode that was scanned. Detectability of this error type would be low and identification of this work around is important so that managers can coach staff towards the safer workflow of scanning the package of the medication that will be given to the patient.

## Barcode labels affixed to wrong medications

In order to fully implement barcode medication administration and maximize the safety benefits of this technology, each medication must have a scannable barcode. Not all manufacturer-supplied medications contain a barcode, therefore, the pharmacy dispensing process may involve manual application, relabeling, or repackaging of drugs, in order to add a barcode label. Some pharmacy technologies barcode verify that the correct medication has been selected during the dispensing process; however, use of these technologies in the hospital setting is very limited. Most pharmacies will select medications for dispensing using a manual process. At times, pharmacies have applied barcoded labels to the wrong drugs and dispensed these incorrect medications to the wards. The detectability of these errors may be low since the added barcode label may cover all or some of the original product information. Additionally, when a nurse scans the pharmacy applied barcode label, the medication administration system would not signal a wrong drug warning even though the label was attached to the incorrect drug.

When barcodes are manually applied to medications, a process must be in place to verify that the correct label is applied to the correct product. This may involve an independent double check by a second practitioner, or it might involve use of barcode technology verification to ensure the correct barcoded label is applied to the correct product<sup>9</sup>.

Table 1 summarizes the priority safety practices that are recommended to be implemented by hospitals in order to achieve the maximum benefit of BCMA<sup>1,15,20</sup>.

**Table 1.** Top 10 priority safety practices for barcode medication administration (BCMA)<sup>1,15,20</sup>

1. Implement BCMA in all medical surgical, intensive care, and labor and delivery wards.
2. Ensure all medications have a scannable barcode.
3. Collect metrics and set a goal of achieving 95% compliance with scanning patients and medications.
4. Have a mechanism (e.g., paper/electronic form, help desk, email) for staff to report BCMA issues or challenges.
5. Conduct real-time observations and monitor for workarounds like back scanning or scanning identification bands not attached to patients.
6. Add an independent double check or use technology to barcode verify barcodes are manually applied to the correct medication.
7. Have nursing and pharmacy leaders meet regularly to review BCMA data and address issues and challenges.
8. Share safety success stories such as how many wrong drug and wrong patient scans were caught each month.
9. Educate nurses that the audible scanner beep only means a barcode has been scanned.
10. Communicate to all practitioners the type of errors that will not be caught using BCMA.

## Smart infusion pumps

Smart infusion pumps should be the standard of care when administering intravenous medications and fluids in healthcare. The computer software on these pumps, which is what makes them “smart”, allows the pump to help catch and prevent catastrophic misprogramming errors.

How we infuse intravenous medications has come a long way; from calculating drip rates and counting drops, to using electronic infusion pumps to deliver milliliter per hour rates, to wired smart pumps with a drug library and dose error reduction software systems (DERS), to wireless smart pumps with drug libraries and DERS, to smart pump interoperability with electronic health records (Figure 1)<sup>21</sup>. The recent advancement of interoperability applies bidirectional communication between the infusion pump and the electronic health record (EHR). After associating a pump with a patient in the EHR, infusion information from the medication order flows over to the pump and certain pump information flows back to the EHR for documentation. The number of steps needed to program the pump are significantly decreased while safety is increased by removing the number of button presses and facilitating documentation of information back into the EHR<sup>21</sup>.

DERS warns users of potential over- and under-dosing of medications and fluids by checking the programmed information against the preset facility limits. Leaders of the drug library need to establish soft and hard limits on dose, duration, and concentration for each medication and IV fluid in the drug library. Soft limits are warnings that can be overridden by clinical staff; these alerts warn users that the programmed infusion is running outside the normal range. Hard limits are warnings that cannot be overridden by staff; these limits provide a forcing function stopping an infusion from being programmed and run outside of facility-established parameters<sup>22</sup>.

As with all technology, time and attention must be devoted to implementation of smart infusion pumps as well as ongoing maintenance. Since the drug library is a critical component of the DERS, users should be encouraged and have a way to report when medications are missing from the library or when other issues with smart infusion pump programming occur. The safety goal of smart infusion pumps is to prevent the inadvertent administration of an infusion at the wrong rate or dose. As with BCMA, workarounds can also occur while using smart infusion pumps<sup>23</sup>. Organizations should monitor compliance metrics for use of the drug library and the data should be reported to hospital leaders. While smart infusion pumps play an important role in medication safety, they will not eliminate all types of administration errors and it cannot replace clinical judgment.

The following describes how workarounds, poor workflow, and technology limitations when using smart infusion pumps may allow infusion errors to occur.

## Smart infusion pump not used when available

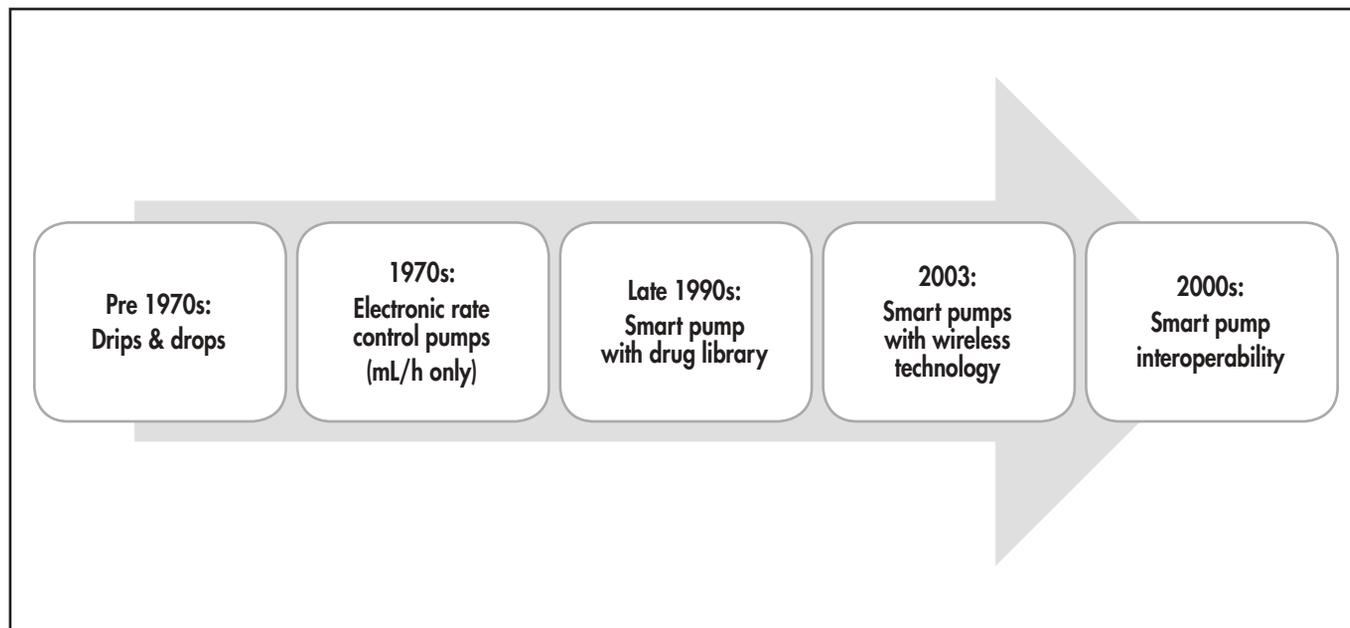
Even when smart infusion pumps are available in a facility, there are times when staff may choose to administer medications without any electronic infusion device, via gravity. There are some clinical conditions where you may need to infuse medications and fluids via gravity (e.g., when the rate needed to be infused is greater than what the pump can deliver), but there are more times where a controlled rate is needed to prevent infusion reactions and adverse drug reactions (e.g., potassium chloride, phenytoin, vancomycin).

The safety advantages of smart infusion pumps cannot be realized if the technology is not used. Organizations should assess medication infusion needs to ensure they have enough pumps for their facility and couple that with a functional pump distribution process so nurses and other practitioners have reliable access to these devices. The expectation should be clear that all infusions will be run on a pump with DERS (continuous infusions, intermittent and secondary infusions, IV bolus doses and loading doses, patient controlled analgesia infusions and epidural/nerve block infusions). To address and remove barriers that preclude smart infusion pump use, department managers and leaders should round on wards to observe how infusions are being administered and interview staff to understand limitations<sup>22</sup>. Monitor use of smart infusion pumps with DERS by routinely reviewing the library compliance metric which shows the number of times infusions were run using the library compared to the total number of infusions run on the pump.

## IV tubing mix-ups

There are limitations to the types of errors that the DERS of a smart infusion pump can detect and prevent. When setting up or changing more than one infusion at a time, swapping IV tubing in the pump is one of those types of errors. During medication administration, nurses can perform a barcode verification scan to ensure the patient and infusions are correct based on the patient’s medication administration record; however, if the tubing of one medication is placed in the infusion pump that was programmed for a different medication, an error will occur. Even with the added benefit of interoperability with the EHR, this error type can still happen. Unfortunately, the detectability of an infusion tubing mix-up

**Figure 1.** History of infusion pump technology. Where did we start? Adapted from: Vanderveen<sup>21</sup>.



is low and often occurs only after the error has reached the patient and caused harm.

Full utilization of medication safety technology does not prevent all errors. As long as there is still a human element to a process, there is opportunity for human error. To help prevent infusion tubing mix-up errors during medication administration, staff should trace the IV tubing from the IV bag/bottle, through the infusion pump all the way to the insertion site on the patient to ensure that infusions are set up correctly<sup>24,25</sup>. An additional safe practice strategy is to trace infusion tubing any time an IV line is accessed. Sharing stories of errors of this type help staff understand the error potential while using smart infusion pumps. Periodic evaluations of the medication administration process by nurse leaders should include IV line tracing.

### Pump from a different hospital

As patients transfer from one hospital or care setting to another, their infusion pumps may travel with them. If the infusion pump is the same manufacturer, make, and model, as those used at a receiving facility, it may easily get mistaken as one belonging to the receiving facility's fleet. This, however, can pose a great safety risk. Smart infusion pump drug libraries are built based on each specific facility's standards of practice. Using a pump from a facility other than your own may cause a gross over- or underdose to a patient. For example, an infusion that is dosed as µg/min at one facility may be dosed as µg/kg/min at another facility. The detectability of this error type may be low since infusion pumps from the same manufacturer, but different hospitals can look nearly identical.

Hospitals should have a standard policy and procedure on how to handle equipment transferred into the hospital with patients<sup>22</sup>. A process should be in place whereby any pump found to be from another facility is removed from use, quarantined, and sent back to the hospital or organization to which it belongs.

### Inverting numbers during pump programming

Some medications are ordered, prepared, dispensed, and administered based on a standard concentration; however, there are other drugs that are dosed in a manner that does not support a standard concentration or dose. For example, hospitals may prepare a standard infusion concentration for a drug like DOPamine, but a drug like iron dextran will

be dosed differently based on patient specific parameters. The DERS limits built into smart infusion pump drug libraries for medications whose concentrations and doses vary among patients need to warn of potential over and under-infusion but at the same time remain flexible enough to allow doses and drug concentrations for many different patient parameters. For drugs without standard concentrations, the infusion pump library requires entry of the patient's total dose and infusion volume for each administration. It may be easy, during this manual programming, for a nurse to invert numbers representing the total dose and total volume. For example, if a nurse enters a dose of 1,500 (mg) in the fluid volume field and the diluent volume of 250 (mL) in the dose field, this could cause the medication to infuse much faster than intended. Depending on how the library limits are set up, the smart infusion pump may not alert the nurse to the misprogramming error.

Facilities should evaluate the DERS limits on medications that do not have a standard dose and/or concentration built out in the library and add in hard minimum concentration limits. Soft limits provide alerts that advise a user that the programmed amount is about to be infused outside organization-established parameters; while hard limits are a non-overridable forcing function that prevents a medication from being programmed outside organization-established limits<sup>22,26</sup>. Another way to prevent this type of transcription error is to utilize pump interoperability. If information from the order is able to be sent directly over to the pump, then the opportunity for misprogramming the concentration is significantly decreased or eliminated.

### Using the pump as an alarm clock

Some nurses have utilized the routine practice of programming the smart pumps with a limited duration to act as a reminder (or like an alarm clock) to come back and assess the patient's IV access points. This practice coupled with not utilizing the pump's DERS can cause unintentional misprogramming errors. Infusion pumps do not automatically know what is being infused and cannot provide any safety checks for possible misprogramming if an infusion is run outside of the drug library. For example, if a medication is programmed to infuse at 5 mL/hr with a volume to be infused of 100 mL the pump will default to a 20 hour infusion; however if a nurse attempts to change the duration to two hours to alert as a reminder to come back and check on the patient, the infusion pump will change the rate from 5 mL/hour to 50 mL/hour. While some drug libraries may

**Table 2.** Top 10 priority safety practices for smart infusion pumps<sup>22,24-26</sup>

1. Ensure there are enough pumps for the facility along with a functional pump distribution process.
2. Set the expectation that all infusions are run on a pump with DERS (continuous infusions, intermittent and secondary infusions, IV bolus doses and loading doses, patient controlled analgesia infusions and epidural/nerve block infusions).
3. Monitor pump compliance metrics with goals set at 95% for both library compliance and/or pump auto programming.
4. Have a standard policy and procedure on how to handle equipment transferred into the hospital with patients (e.g., infusion pumps).
5. Any time an IV is accessed and during shift-to-shift handoffs, trace the IV tubing from the IV bag all the way to the insertion site at the patient to ensure that infusions are set up correctly.
6. Ensure there are hard minimum concentration limits in the drug library for drugs that do not have standard concentrations.
7. Implement smart pump - electronic health record interoperability.
8. Do not use pump programming as an opportunity to set a reminder for other clinical activities.
9. Have leaders round on wards to observe how infusions are being administered and help remove any barriers precluding pump and drug library use.
10. Share error stories with staff to help them understand the impact of the safety technology.

DERS: dose error reduction software systems.

be able to alert to this error based on library DERS soft and/or hard limits, other pump drug libraries may not be able to detect the error. This error type often goes unrecognized until there is patient harm or the infusion completes sooner than expected.

Staff should not program pumps like an alarm clock as it may cause unintended consequences. An expectation should be set that the smart pump drug library will be used for all infusions, including fluids. Organizations should regularly monitor the drug library compliance rate for both medications and fluid infusions with a set goal of 95%<sup>22</sup>.

Table 2 shows the safety practices that are recommended to be established by hospitals to optimize the safe implementation and use of smart infusion pumps<sup>22,24,26</sup>.

## Conclusion

Healthcare technology has had increasing implementation rates due to its ability to improve safety, accessibility, and prevent medical errors. Using medication administration technology, specifically barcode medication administration and smart infusion pumps with dose error reduction software, helps detect and prevent medication errors before they reach a patient. However, studies have also shown that new technology may introduce new types of errors. Hospitals must understand the technology,

how it is designed to work, which errors it is intended to prevent, as well as understanding how it will change staff workflow. In order to achieve maximal benefits from its use, implementation of these technologies needs to be accomplished in a meaningful way. For these reasons, it is essential that metrics are set by hospital leadership and regularly monitored to ensure optimal use. It is also important to identify and avoid workarounds which eliminate or diminish the safety benefits that the technology was designed to achieve. Front line staff feedback should be gathered on a periodic basis to understand any struggles with utilizing the technology and communication of system issues evaluated or corrected should be conveyed back to staff. Hospitals should seek out information about administration technology safety risks and take action to prevent similar errors. Leaders must also understand that even with full implementation of technology, medication errors may still occur.

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## ANNEX. Definition of terms

**Adverse drug event:** An adverse drug event (ADE) is defined as harm experienced by a patient as a result of exposure to a medication. The occurrence of an ADE does not necessarily indicate an error or poor quality care. Preventable adverse drug events result from a medication error that reaches the patient and causes any degree of harm. It is generally estimated that about half of ADEs are preventable. A certain percentage of patients will experience ADEs even when medications are prescribed and administered appropriately; these are considered adverse drug reactions or nonpreventable ADEs<sup>3</sup>.

**Medication error:** A medication error is any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient, or consumer. Such events may be related to professional practice, health care products, procedures, and systems, including prescribing, order communication, product labeling, packaging, and nomenclature, compounding, dispensing, distribution, administration, education, monitoring, and use<sup>27</sup>.

**Smart pump:** An infusion pump with integral computer software that is, at a minimum, capable of: 1) maintaining a drug library of standard medication concentrations, which when enabled, is used to support dose calculations and alert the user to incorrect orders, calculation errors, or programming errors, that would result in significant over- and under-delivery of a medication or fluid; and 2) capturing administrative infusion data in a systematic, objective manner to support improvement in safe medication administration. If the programmed dose is outside the preset limits, the pump alerts clinicians and can either require confirmation before beginning delivery (soft limit) or not allow delivery at all (hard limit)<sup>22</sup>.

**Smart pump interoperability:** Also referred to as smart infusion pump integration, refers to technologies that enable the creation of an electronic connection between an infusion pump channel and an EHR system. This connection allows the pump channel, the patient, and the medication order to be associated with one another<sup>22</sup>.

**Barcode scanning technology:** The use of optical machine-readable representation of data found in barcodes on medication packages and patient identification bands to verify that the correct patient is receiving the correct medication, the correct solution or ingredient is selected prior to compounding a preparation, or the correct medication is retrieved from or stocked in the correct storage location. The process involves the use of a barcode scanner, an electrical device that can read and output printed barcodes to a computer<sup>28</sup>.

**Medication use process:** A complex process that comprises the sub-processes of medication prescribing, order processing, dispensing, administration, and effects monitoring<sup>1</sup>.

**Workaround:** A bypass of an organization's systems and processes to accomplish an activity; a way to circumvent or temporarily 'fix' perceived workflow hindrances to meet a goal or achieve it more readily<sup>29</sup>.