Medication Errors Attributed to Health Information Technology

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ABSTRACT

The use of health information technology (HIT) has evolved over the past decade. Although the application of HIT can help improve safety and quality, if not implemented well it can have devastating consequences on patient safety. A total of 889 medication-error reports listed HIT as a factor contributing to the event submitted to the Pennsylvania Patient Safety Authority between January 1 and June 30, 2016. The three most commonly reported event types were dose omission (n = 123), wrong dose/overdosage (n = 97), and extra dose (n = 95). The most common HIT systems implicated in the events were the computerized prescriber order entry system (CPOE; n = 448), the pharmacy system (n = 251), and the electronic medication administration record (eMAR; n = 250). To identify and prevent errors attributed to HIT, organizations can encourage frontline staff to report errors or near miss errors due to HIT so they can be analyzed and systems improved. (Pa Patient Saf Advis 2017 Mar;14[1]:1-8.)

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INTRODUCTION

In 2009 under the Health Information Technology for Economic and Clinical Health (HITECH) Act, billions of dollars were offered in incentives for healthcare providers to adopt an electronic health record (EHR).[1,2] The hypothesis was that an EHR could prevent errors, enhance patient safety, and improve efficiency. It would accomplish this by eliminating transcription errors due to illegible orders or poor quality faxes, using clinical decision support to detect possible contraindications to therapy based on allergies or drug interactions, and making all patient records available in one centralized location. Technologies that target each point of the medication-use process have been developed to reduce the likelihood of errors reaching the patient.[3] These technologies include computerized prescriber order entry (CPOE) systems, pharmacy information systems, automated dispensing cabinets (ADCs), barcode medication administration (BCMA), and "smart" infusion pumps, which incorporate dose error reduction systems with comprehensive drug libraries containing information on usual concentrations, dosing units, and dose limits.

Unfortunately, the introduction of technology to improve patient safety has led to new, often unforeseen types of errors. Between January 2010 and June 2013, 120 health information technology- (HIT-) related sentinel events were reported to the Joint Commission.[4] The majority of errors were attributed to the human-computer interface (33%), workflow and communication (24%), and clinical content (23%).[4]

The use of technology in the healthcare setting has increased dramatically in the past decade. In a survey of pharmacy directors in U.S. hospitals, more than 97% of the 325 respondents indicated their hospitals had implemented either a partial or complete EHR, 84.1% use CPOE systems, and 93.7% have BCMA technology.[5]

Sittig and Singh describe four main causes of errors due to health information technology: the system is unavailable (e.g., downtime), the system malfunctions, the system is used incorrectly, or the system does not interact properly with another system component.[6] Patient safety is not improved by merely implementing HIT.[1] The technology is part of a larger sociotechnical system, which relies not only on hardware and software functionality but also people, workflow, and processes.[1] For this reason, it is important to design a system with an intuitive user interface to minimize the risk for human error.[7] Users should be able to easily enter and retrieve data and share information with other healthcare professionals.[1] When systems are designed without these considerations in mind, patients are subject to undue risk.

In 2015, a new question was added to the Pennsylvania Patient Safety Reporting System (PA-PSRS) reporting form: "Did Health IT cause or contribute to this event?"[8] Pennsylvania Patient Safety Authority analysts had not previously explored HIT-related medication events identified by answers to this question. With this analysis of HIT-related medication errors reported to the Authority, analysts sought to characterize contributing factors and identify appropriate system-based risk reduction strategies to help facilities identify and mitigate risk and minimize potential patient harm.

METHODS

The HIT-related question was introduced into PA-PSRS in April 2015.[8] Based on data from the Pennsylvania Patient Safety Authority 2015 Annual Report, a 45% increase occurred in the number of HIT-related medication error reports received between the second (n = 274) and fourth quarters (n = 397) of 2015.[8] In light of the changing nature of facility usage and completion of these questions during 2015, the latest six-month period of data available was evaluated, including data from January 1 through

June 30, 2016 (n = 889). The reporting facilities provided the following information regarding the event: medication name, event type, harm score (adapted from the National Coordinating Council for Medication Error Reporting and Prevention [NCC MERP] harm index),[9] event description, HIT systems involved, equipment or device function, and ergonomic factors that may have caused or contributed to the event.

RESULTS

HIT-related errors occurred during every step of the medication-use process (Figure 1). The majority of errors, 69.2% (n = 615 of 889), reached the patient (harm score C through I; Figure 2). Eight (0.9%) errors resulted in patient harm (harm score E through I), with three of these reports involving high-alert medications, medications that bear a heightened risk of patient harm if used in error. More than one-third of all the reports (35.2%, n = 313 of 889) involved medications on the *ISMP List of High-Alert Medications in Acute Care Settings.*[10] Insulin, anticoagulants, and opioids, which are all considered high-alert medications, comprised three of the top five drug categories involved in events (Figure 3).

Of the 889 events, the three most commonly reported event types aside from "other," which accounted for 20.9% (n = 186) of events, were dose omission (13.8%, n = 123), wrong dose/over dosage (10.9%, n = 97), and extra dose (10.7%, n = 95). According to an analysis of the event descriptions, the most common cause of omissions was that the system did not work as expected or was unavailable due to downtime (8.1%, n = 10 of 123). The following is an example of a reported error resulting from an unplanned downtime of HIT:*

> *During an extended, unplanned downtime, the nurse missed giving*

_____
* The details of the PA-PSRS event narratives in this article have been modified to preserve confidentiality.

Figure 1. HIT-Related Medication Errors by Medication-Use Process (N = 889)*
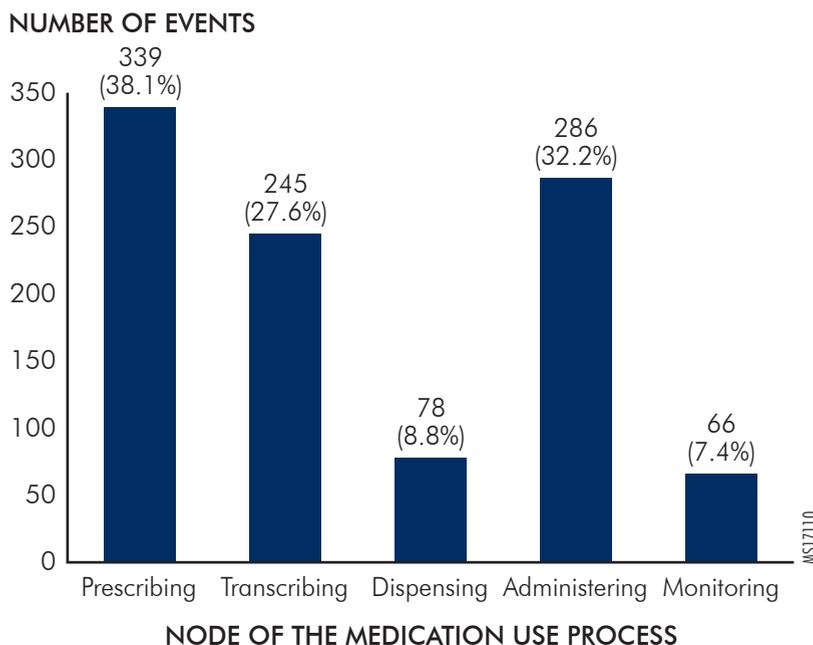
NUMBER OF EVENTS

MS17110

NODE OF THE MEDICATION USE PROCESS

Note: Data reported through the Pennsylvania Patient Safety Reporting System, January 2016 through June 2016.

* Percentages may add up to more than 100% as reporters could select more than one medication use process per report.

> *a midnight dose of medication. The nurse was unfamiliar with paper MAR [medication administration record] and hand[written] documentation.*

The most common cause of wrong dose/over dosage events was an incorrect weight documented (11.3%, n = 11 of 97). For example:
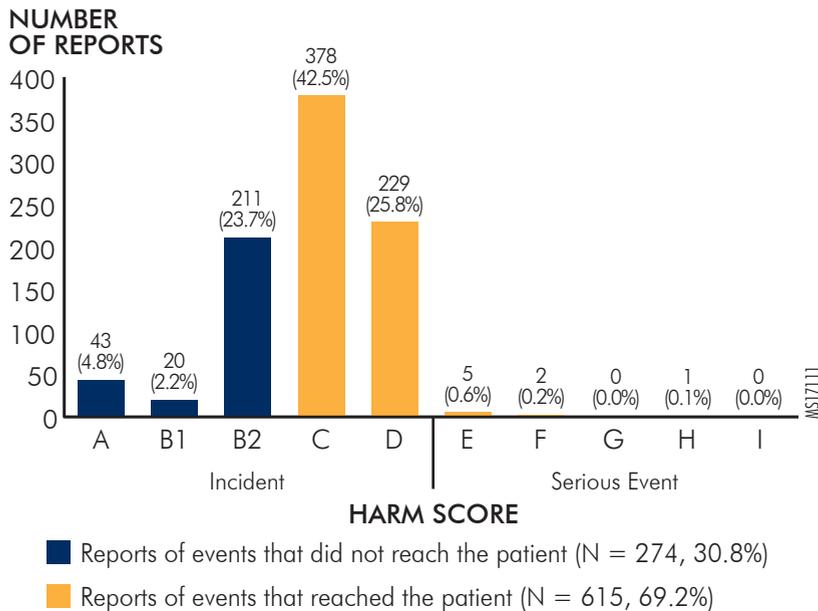
> *Determined that the patient's weight was incorrect. It was entered as 148 kg; after asking nurse to verify, the corrected weight was entered on [the following day] as 46 kg. [It was] realized that a one-time weight-based Lovenox® [enoxaparin] dose was given [based on] the incorrect weight.*

Free-texted instructions in a separate field from the sig or instructions field may be overlooked by other practitioners and may lead to communication of contradictory

instructions. Prescribers free-texting instructions as either a communication order or as a component within a medication order describing when to hold or discontinue a medication (11.6%, n = 11 of 95) was the most common cause of patients receiving extra doses of medication, as can be seen in the following example:

> *[The patient's] INR [international normalized ratio] was elevated at 4.0. The physician was notified and a message was entered, but the warfarin was not discontinued. Medication given prior to receiving report from the nurse and prior to orders being verified by the nurse. The medication dose was not discontinued in MAK [medication administration check] [system] d/t [due to] order being entered as message.*

Figure 2. Harm Scores for HIT-Related Medication-Error Events (N = 889)

NUMBER OF REPORTS

HARM SCORE

■ Reports of events that did not reach the patient (N = 274, 30.8%)

■ Reports of events that reached the patient (N = 615, 69.2%)

Note: Data reported through the Pennsylvania Patient Safety Reporting System, January 2016 through June 2016.

Figure 3. Most Common Medication Classes Involved in HIT-Related Medication Error Events (N = 889)
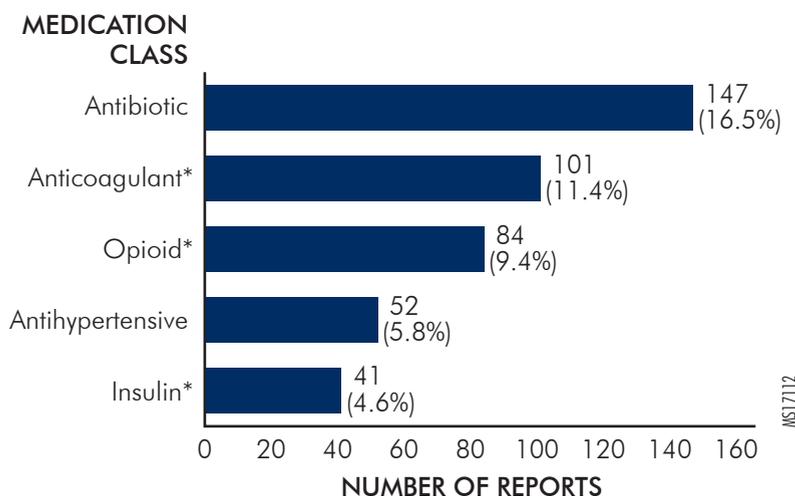
MEDICATION CLASS

NUMBER OF REPORTS

Note: Data reported through the Pennsylvania Patient Safety Reporting System, January 2016 through June 2016.

* High-alert medication

Analyzing the reports classified as "other," analysts found that 22.6% (n = 42 of 186) were either a delay or omission in therapy.
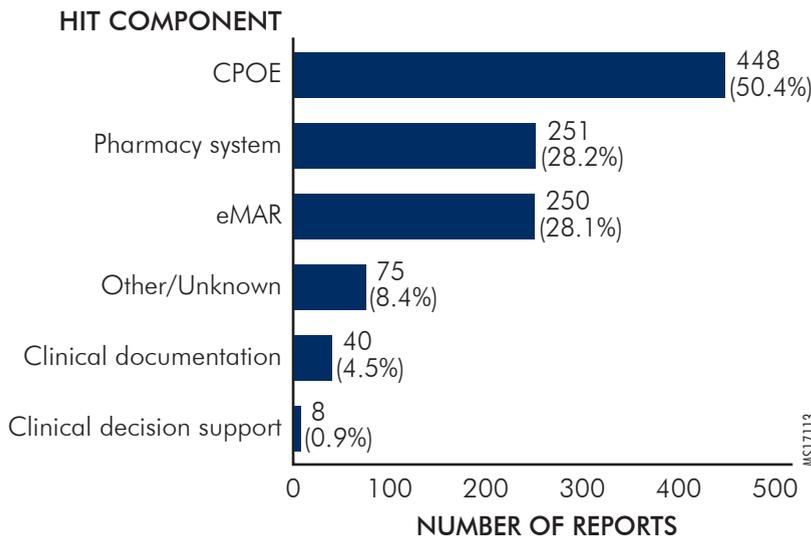
Reporters were able to select the HIT component involved in the event. Half (50.4%, n = 448 of 889) of the event reports listed the CPOE system as a contributing factor, while the pharmacy system and the eMAR were each mentioned in just over a quarter of the event reports (Figure 4). Other EHR components, including the clinical documentation system and clinical decision support system, were implicated in 13.8% of events.

The CPOE system was cited most often as an HIT component that contributed to the top three error event types. It contributed to more than half of dose omissions, extra doses, and wrong dose/over dosage events (Figure 5). The pharmacy system and eMAR were also frequently involved in these events. With respect to ergonomics, data entry or selection errors accounted for almost half (48.9%, n = 219 of 448) of all CPOE events.

Fifty-six errors were identified as "communication" issues within the EHR. The majority (69.6%, n = 39 of 56) were due to a prescriber free-texting instructions in the order comments field, which is a separate field from the sig or instructions field, and the contradictory instructions were overlooked by the pharmacist or nurse. More than a third of the free-text orders (35.9%, n = 14 of 39) specified when to hold or discontinue the medication, which is a workaround that prescribers may use instead of modifying the end date within the CPOE medication order. The second most common place in the EHR that prescribers provided additional order instructions was in the "communication order" or "nursing communication order" section of the medical record as demonstrated in this report:

The patient had chest pain and a recent stent. The physician ordered a heparin bolus. He told the nurse the patient needed a heparin drip. The

Figure 4. Number of Events by HIT Component Involved (N = 889)*

HIT COMPONENT

HIT Component	Number of Reports
CPOE	448 (50.4%)
Pharmacy system	251 (28.2%)
eMAR	250 (28.1%)
Other/Unknown	75 (8.4%)
Clinical documentation	40 (4.5%)
Clinical decision support	8 (0.9%)

NUMBER OF REPORTS

MS17113

Note: Data reported through the Pennsylvania Patient Safety Reporting System, January 2016 through June 2016.

CPOE, computerized prescriber order entry system; eMAR, electronic medication administration record

* Percentages add up to more than 100% as reporters could select more than one HIT component per report.

physician placed the heparin drip as a nursing miscellaneous [communication]. This entry does not drop the order, allow documentation, or open the automated dispensing cabinet. He told the nurse that he was unable to enter the order. There was a delay in the start of the heparin drip due to this issue. The heparin bolus was given at 1730. The drip was started at 1820.

In all, 26 alerts within 21 reports fired for providers, pharmacists, and nurses. Of the reports that indicated multiple alerts had been generated, some described situations in which the same alert fired for multiple disciplines (e.g., prescriber and pharmacist) who accessed the patient's order. Only three of the alerts actually caused the healthcare provider to change the original course of action. Twenty-one of these alerts (80.8%) did not cause the

provider to modify their original order as illustrated in this example:

> *Order for aspirin came through for pharmacist approval. Order was for aspirin 65,610 mg. Physician was made aware of error and corrected to be 81 mg. She explained that she just reordered the medication as entered in the home med rec [medication reconciliation] (was entered as 810 tablets daily). She did ignore/override the maximum dose warnings.*

In four of the cases (from three different hospitals), the report explicitly mentioned that alerts for prescribers had been disabled by the health system.

There were 26 reports that specifically mentioned that no alert fired, which suggests that healthcare professionals depend on alerts for important information. One such report stated:

> *Patient was given 650 mg PO Tylenol® [acetaminophen] about*

an hour after having received IV Ofirmev® [acetaminophen]. There was no alert in computer system that PO Tylenol should not be given within a certain timeframe of Ofirmev having been given. No adverse outcome to patient reported.

About one-third (30.8%; n = 8 of 26) of the reports stated that no alert fired, resulting in the patient receiving an extra dose of medication.
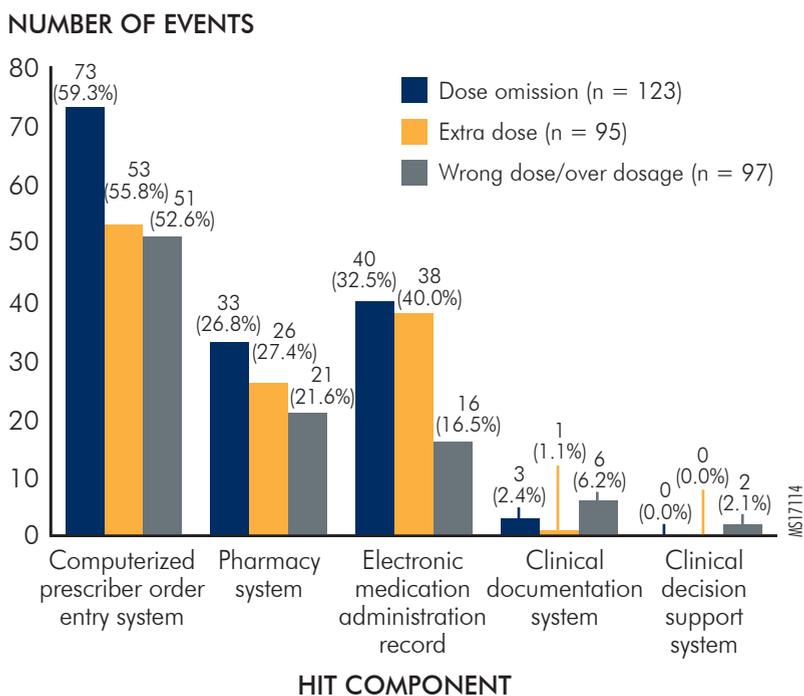
DISCUSSION

Errors due to HIT spanned across all HIT components, including the CPOE system, pharmacy system, electronic medication administration record (eMAR), clinical documentation system, clinical decision support system, ADC, and BCMA system. There were many causes for HIT-related errors, and they were unique depending on the context in which the system was used. Errors occurred when the system was not used as intended, did not work as expected, and because the systems often did not communicate seamlessly, which was evident by the number of errors that occurred during transitions of care.

Surprisingly, the point in the medication use process where errors occur today (see Figure 1) is very similar to where they occurred in 1993, before the widespread implementation of HIT. Bates et al. reported that most errors occurred during the ordering (49%) and administration (26%) stages, which is what was found in this analysis.[11]

Similar to what the Office of the National Coordinator (ONC)[7] reported in 2014, data entry and selection errors, which are dependent on human interface with technology, were the most commonly reported HIT-related errors (39%) in the PA-PSRS data. From a sociotechnical perspective, HIT-related errors can be exclusive to IT, such as errors due to substandard drop-down menus (e.g., too many drug options listed very closely together), or HIT can contribute to an error that existed with

Figure 5. HIT Components Involved in Most Common Event Types of HIT-Related Medication Errors*

NUMBER OF EVENTS

Legend:
- Dose omission (n = 123)
- Extra dose (n = 95)
- Wrong dose/over dosage (n = 97)

Bar values:
- Computerized prescriber order entry system: 73 (59.3%), 53 (55.8%), 51 (52.6%)
- Pharmacy system: 33 (26.8%), 26 (27.4%), 21 (21.6%)
- Electronic medication administration record: 40 (32.5%), 38 (40.0%), 16 (16.5%)
- Clinical documentation system: 3 (2.4%), 1 (1.1%), 6 (6.2%)
- Clinical decision support system: 0 (0.0%), 0 (0.0%), 2 (2.1%)

MS17114

HIT COMPONENT

Note: Data reported through the Pennsylvania Patient Safety Reporting System, January 2016 through June 2016.

* Percentages may add up to more than 100% as reporters could select more than one HIT component per report.

paper charts but is more likely to occur with HIT, such as errors due to distractions or multitasking.[12] In addition to data entry, human interface errors occurred when practitioners overlooked information (e.g., missed comments free-texted in the administration field of a medication order) or did not actively seek out information (e.g., did not give a medication if the eMAR did not prompt them it was due).

LIMITATIONS

As with all reporting systems, the type and number of reports collected depend on the degree to which facility reporting is accurate and complete. Although the narrative fields of the reports are helpful in discerning what happened during the event, they often do not contain all of the HIT-related contributing factors. Event descriptions did not always clarify how the event deviated from the standard operation or specify the make or model of the HIT system, and reporters often presumed the reader would be familiar with the technology and processes used in the facility.

Lack of a unified, standardized reporting system across all facilities may be another limitation. Unless hospitals used the PA-PSRS system or another system with a PA-PSRS interface (that included the HIT-related question), HIT-related events, or answers to all of the HIT-related questions, may not have been captured in PA-PSRS.

Another limitation is that only six months of data was selected for analysis. This could have introduced a seasonality bias because the data analyzed was from January to June 2016, which correlates with the second half of an academic year. By this time of the year, residents and other students are familiar with the HIT systems used in the hospital and may be aware of the technology's limitations.

STRATEGIES

The event reports analyzed reveal that errors due to HIT are multifactorial and highly complex. It is important that healthcare organizations and technology vendors continue to work with frontline and informatics staff to address technology-related issues that would improve the usability of the system. Consider the strategies listed below, which are based on events reported to the Authority, current literature, and observations from the Institute for Safe Medication Practices.

General

— Encourage individuals to report unsafe conditions, near misses, and errors due to HIT so these concerns can be analyzed and ameliorated.[4]

— Conduct a root-cause analysis using information from the individual(s) involved in the events along with IT staff members who are knowledgeable and can address IT system vulnerabilities.[2]

— Provide training to new staff members unfamiliar with the technology and make sure they are competent before allowing them to use HIT for patient care.[2,13]

— Monitor technology usage metrics such as system downtime, number of alert overrides, and the number of medication orders submitted through CPOE.[2]

— Identify workarounds that staff are using to address system flaws.[2] Correct these system flaws so the

workarounds can be eliminated, and be sure to inform staff when changes in the system have been made.

— Reduce the need for manual human interface with the computer by allowing systems to communicate seamlessly.[13]

— Use tall man letters on computer screens to help differentiate look-alike medication names.[14,15] Avoid displaying look-alike names next to one another in computer drop-down lists, and consider differentiating look- and sound-alike drugs by including their purpose (e.g., hydrOXYzine [antihistamine] and hydrALAZINE [vasodilator]).

— Use easy-to-read, larger size, sans serif fonts in electronic systems.[14]

— Allow only metric measurements of patient weight (i.e., kilograms or for low-birth-weight infants, grams), and include a field that displays the date the weight was collected.[14]

— Ensure that there are well-designed downtime procedures in case of software or hardware malfunctions and that all appropriate personnel receive training.[16]

— Determine the character limits of the medication name and other related fields in the electronic systems, infusion pumps, and other related technologies used in the organization. Assess and review how these systems may truncate information or lines to make sure any break in the line does not lead to the absence of important drug information or possible misinterpretation.

CPOE/Pharmacy System

— Triage phone calls and limit distractions to providers, pharmacists, and nurses when ordering medications or completing other crucial tasks.[12,13]

— Use standardized order sets within the EHR to guide prescribers to select appropriate drug therapy and

doses, to prevent medication errors.[4] The order sets can include ancillary orders that facilitate safe medication practices, such as a daily INR when warfarin is ordered.

— Eliminate alerts in the system that are clinically irrelevant, to prevent alert fatigue.[2,17]

— Work with prescribers to include the indication for the medication within their orders.[14,18]

— Limit the ability to order medications using a combination of both discrete and free-text fields, because these could contradict each other or lead to misinterpretation.[14]

— Provide a mechanism to facilitate safe order entry of complex medications (e.g., electrolyte solutions) or drugs that require a variable dose schedule (e.g., steroid tapering) so that orders include all required elements and appear clearly and in a logical sequence.[14]

eMAR

— When the dose of the medication differs from the available strength, list the amount needed for the dose on the eMAR (e.g., propranolol 5 mg [½ × 10 mg] tablet). This information should be displayed on the same line in the eMAR.[14]

— List the drug name, patient-specific dose, route, and frequency on the first line of the medication administration record and the available concentration and any directions on how to prepare the dose below it.[19]

ADC

— ADCs should be located in an area of limited foot traffic, where a minimum number of distractions is the norm.[16]

— Configure all ADCs to dispense in a pharmacy-profile mode. Use of a "profiled" ADC ensures that the pharmacist will validate the new

medication order in the pharmacy system prior to the medication being accessed by the nurse. Do not allow users to select medications using the inventory mode, except in an emergency.[16]

— Display the time the last dose was removed from the ADC on the ADC screen display. Medications appear to the user as unavailable, until the correct time frame for administration. If the practitioner determines it is necessary to select a dose of a medication prior to its scheduled administration time, then additional strategies (e.g., an independent double-check for high-alert medications and documentation of rationale for the override) are needed.[16]

— Store each medication and strength in an individual lidded ADC compartment that opens only when the specific medication is selected.[16]

Smart Infusion Pumps

— When developing pump libraries, limit entries to a single concentration for each drug, if possible.[20]

— Standardize dosing nomenclature for each drug within each library (e.g., do not include multiple dosing methods for the same drug in the drug library, such as mcg/min and mcg/kg/min). The dosing method in the pump should match the display on the CPOE screen, pharmacy label, and eMAR.[20]

— Set hard dose limits to avoid catastrophic events.[20]

— Use data captured by smart pumps (e.g., number of infusions programmed using the drug library, number of soft stop overrides, number of times an alert resulted in the reprogramming of an infusion) to evaluate smart pump use, identify opportunities for improvement, and take action to correct problems.[20]

– Consider integrating smart pumps with the EHR system to improve usability and decrease reliance on manually transferring information from one system to the other.[21,22]

CONCLUSION

It is clear that ongoing HIT system surveillance and remedial interventions are needed. Oftentimes, failures in the HIT systems are attributed to human error, which hinders the investigation into secondary causes of the patient safety event such as limitations in software interoperability, usability, and workflow processes.[1] The interaction between clinician and software is a key component that is to be taken into consideration when trying to improve the safety of HIT. Incident reports can provide valuable information about the types of HIT-related issues that can cause patient harm, and ongoing HIT system surveillance can help in developing medication safety interventions.[12] Efforts to improve HIT safety should include attention to software interoperability, usability, and workflow.[2,12] The relationship between clinician and software includes complex interactions that must be considered to optimize HIT's contribution to medication safety.

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PENNSYLVANIA PATIENT SAFETY ADVISORY

THE PENNSYLVANIA PATIENT SAFETY AUTHORITY AND ITS CONTRACTORS

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