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Evaluation of Use of Electronic Patient Controlled Analgesia Pumps to Improve Patient Safety in an Academic Medical Center

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Abstract. Patient controlled analgesia (PCA) and Patient-controlled epidural analgesia (PCEA) pumps are methods of pain control with complex smart infusion devices and are widely used in hospitals. Smart PCA/PCEA pumps can be programmed with the dose and rate of medications within pre-set ranges. However, adverse effects have been reported associated with these pumps' use. In this paper, we describe a prevalence observational study where observers used an electronic data collection tool to record pump settings and medications with PCA pumps, corresponding medication orders to identify errors. The results showed that there were many labeling and tubing change tag errors, which were a violation of hospital policy. A few potential harmful medication errors were identified but no critical errors. Study results suggest the importance of a standard process of PCA pump use. Next steps include implementing a safety bundle for improving PCA practice to support safe and effective pain management.

Keywords. Smart pump, smart infusion pump, patient safety, patient controlled analgesia, patient controlled epidural analgesia

Introduction

Patient controlled analgesia (PCA) and patient-controlled epidural analgesia (PCEA) pumps are methods of pain control with complex smart infusion devices that are widely used in hospitals. Dose and rate of medications can be programmed into Smart PCA/PCEA pumps. The embedded drug library provides alerts to the clinician if a dose is programmed outside of a predetermined safe dosing range. The pump also allows patients to control their pain in an effective and safe manner. However, adverse events have also been reported associated with PCA/PCEA pump's use[1]. Although pain control medications are vital for patients who are in pain, these medications can cause critical harms to patients if these pumps are not used in a proper way due to use of

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high-risk narcotic drugs. Despite safety functions of smart PCA/PCEA pumps, some risks of using smart pumps are still persistent.

One previous study by Hicks, et al.[2] reviewed medication errors associated with PCA pumps in a national reporting database for a period of five years. The majority of errors occurred during drug administration and human factors were the main cause of errors. In general, safety reports help us to understand gaps in patient safety related to nursing practice. However, voluntary reporting systems have been criticized for inherent under reporting[3]. While near-miss error reporting is encouraged at our hospital, we believe that many near miss errors or potential adverse events may not be reported through the incident reporting system. The purpose of this prevalence study was to explore the frequency of errors associated with the use of PCA/PCEA pump use including near miss and potential errors.

In this study, we conducted a prevalence observational study to collect data about medication errors and practice deviations. Tubing tags while using smart pump during the administration phase to identify the key issues related to the use of smart PCA/PCEA pumps across a large academic medical center. Observers recorded pump settings and medications infusing on PCA/PCEA pumps using a web-based data collection tool which was developed on the Research Electronic Data Capture (REDCap)[4] database. Findings were compared to provider's orders to identify any medication errors. The goal of this study was to identify errors and practice deviations and to inform a strategy for improving nursing practice related to the use of PCA/PCEA in hospital settings.

1. Methods

1.1. Operational Definitions of Medication Errors for Data Collection

Medication error is defined as an error occurring at any stage in the medication–use process including prescribing, transcribing, dispensing, administering, or monitoring. In this study, we focused on the administration phase with use of PCA/PCEA pumps. Medication errors targeted for data collection are summarized in Table 1.

1.2. Study Setting/Samples

This study was conducted at a 793-bed tertiary care academic medical center, in Boston, Massachusetts. All patients on controlled analgesia (PCA) and Patient-Controlled Epidural Analgesia (PCEA) pumps in all inpatient care units were included. Two registered nurses were trained as observers and collected data using an electronic data collection tool on four different days to collect medication data, which were hanging at the patient bedside. The data collection tool was developed based on a previous study conducted by Husch et al.[5], which allowed a rapid assessment, or prevalence study of the frequency and types of intravenous (IV) medication errors. This tool has been used in multiple sites in the U.S. and has been validated as a standardized form to identify medication errors using smart pumps.

Table 1. Definition of medication errors for data collection.

Error Type	Definition
1. Wrong Dose	The same medication but the dose is different from the prescribed order.
2. Wrong Rate	A different rate is displayed on the pump from that prescribed in the medical record. Also refers to weight based doses calculated incorrectly including using a wrong weight.
3.Wrong Concentration	An amount of a medication in a unit of solution that is different from the prescribed order.
4.Wrong Medication	A different fluid/medication as documented on the IV bag label is being infused compared with the order in the medical record.
5. Known Allergy	Medication is prescribed/administered despite the patient had a known allergy to the drug.
6. Omitted Medication	The medication ordered was not administered to a patient.
7. Delay of Rate or Medication/Fluid Change	An order to change medication or rate not carried out within 4 hours of the written order per institution policy.
8. No tubing tag	A color-coded tubing change tag with date was not attached per institution policy.
9. Incorrect Rate on Label	Rate documented on the medication label is different from that programmed into the pump. Applies both to items sent from the pharmacy and floor stocked items.
10. Patient Identification Error	Patient either has no ID band on wrist or information on the ID band is incorrect.
11.Unauthorized medication	Fluids/medications are being administered but no order is present in medical record. This includes failure to document a verbal order.

1.3. Data Collection Procedure

After securing Institutional Review Board approval, nurse observers visited all patient care units and looked for PCA/PCEA pumps on four separate days in 2013. Observers checked the medications hung at the bedside, pump settings (including dose, 4 hours dose limit, lockout intervals, and rate), and recorded observations in the data collection tool. One patient could have more than one medication, and all PCA/PCEA pumps and medications hanging were recorded. To recover identification errors, presence of a correct patient identification (ID) band and name verification were recorded for each patient. Tubing change tags for PCA/PCEA pumps were also included for data collection. After finishing data collection at the bedside of each patient on each unit, observers looked up patient records and compared orders prescribed in the electronic medical record with the medications that were observed at the bedside. In order to confirm that an error was present, both observers had to agree that an error was made. If an error was identified that had the potential to cause harm, the staff nurse caring for that particular patient was discreetly informed so that it could be corrected as warranted. Each error was rated using the National Coordinating Council for Medication Error Reporting Prevention (NCC MERP) INDEX[6] (Table 2). Observers entered all data on the data collection tool.

Table 2. NCC MERP harm index[6].

(A) Capacity to cause error
(B) An error occurred but did not reach the patient
(C) Errors unlikely to cause harm despite reaching the patient
(D) Errors that would have required increased monitoring to preclude harm
(E) Errors likely to cause temporary harm
(F) Errors that would have caused temporary harm and prolonged hospitalization
(G) Errors which would have produced permanent harm
(H) Errors that would have been life threatening
(I) Errors that would likely have resulted in death

2. Results

2.1. Frequency, Type and Potential Severity of Errors

During the four days of data collection period, total of 108 patients in all inpatient wards were included and 137 medications were observed. Frequency, type and potential harm rating of errors were summarized in Table 3. Violations of hospital policies regarding tubing tag practices was the most frequent error type (89.8%). Excluding policy violation errors, a total of 5 medication errors were identified (error rate 3.6 %).

Table 3. Frequency, type and potential harm rating of errors.

Type of error	# of errors	Frequency per medication observations(n = 137) *	NCC MERP severity rating		
			C	B	A
Tubing not tagged according to policy	123	89.8	123		
Unauthorized medication	3	3.8	3		
Rate deviation	1	0.7	1		
Omission	0	0.0			
Pump setup error	0	0.0			
Incorrect information on label	0	0.0			
Incorrect medication	0	0.0			
Patient identification error	0	0.0			
Total	127				

2.2. Tubing Tag Practice deviations

According to the hospital policy for nursing practice, all IV medications including PCA/PCEA medications should have tubing tags that include the date the tubing was hung. However, only 10% of medications had tubing tags attached. In 89% of cases, there was no tag attached and in one case, a tag was attached but did not include the date (0.7%).

2.3. Unauthorized Medication

Three medications out of 137(3.8%) did not have corresponding medication orders in the electronic patient record, but were administered to patients. Details of these unauthorized medication errors are summarized in Table 4. One of unauthorized medication errors was associated with a discontinued medication that was still connected to the patient. Observers interviewed the nurse caring for the patient and found out that it was her intention to leave the PCA medication hanging until the patient finished eating (Case 1, in Table 4). Another error was related to an order that was changed over the phone with the pharmacist however; the order was not changed in the order entry system (Case 2). In the last case, Bupivacaine was running on PCEA pump and no active order was found in the system. This error happened due to an expired order and there was no new order for the same medication at the time of the observation (Case 3).

2.4. Wrong Rate Error

One medication error regarding wrong rate was identified (0.7%), and Bupivacaine was running at 6mL/hour instead of 4mL/hour. Also, the 4 hour dose limit was set as 48mL instead of 40mL as prescribed in the order entry system. After finding this discrepancy, observers notified the patient's nurse, and the nurse changed the setting after confirming with a doctor. While the order had been changed in the provider order entry system, the nurse did not realize that the order was different from the current setting of the pump and the medication was running at the setting consistent with the previous order.

2.5. Patient Identification Errors

There were no errors with regard to adherence of using patient ID bands or identification errors.

2.6. Potential harms of errors

All errors we found fell into NCC MERP category "C": Errors unlikely to cause harm despite reaching the patient. Labeling and tubing practice deviations were mostly rated as "C". Some examples of error cases with potential harms are summarized in Table 4. Based on cause of errors, intervention plans for preventing errors were identified.

3. Discussion

In this prevalence study, we found that over 89% of medications administered using PCA/PCEA pumps had some types of errors present. The most common error was missing tubing tags per hospital policy. The definition of an administration error was expanded from any oversight errors to deviations from policy. The previous study recognized that this expanded definition would identify events that had the capacity to contribute to patient harm8. In this study, we included these policy violations to assess the potential harm of medication errors using smart pumps.

Table 4. Examples of errors with potential harms.

Case #	NCC MERP	Type of error	Medication and dose infusing via IV pump	Medical record order	Intervention plans for preventing errors
1	C	Unauthorized medication	Fentanyl 250mcg/25mL at demand dose 20mcg, 4 hours limit dose 350mcg, lockout 7 min was running(observed at 04-25-2013 10:14)	Medication order was discontinued at 8:20 but still connected and programmed to patient. RN was waited for patient to eat before stopping PCA.	N/A
2	C	Unauthorized medication	Hydromorphone 25mg/25mL at demand dose 0.3mg, max dose 8mg, lockout 7min was running (observed at 06-14-2013 12:18)	No active order (spoke with RN and pain service increased the setting this AM. No order was written for that per RN. PCA come down this afternoon. Original order was 06-13-2013,4:50, demand dose 0.2mg max dose 3 mg, lockout 7 min	Provide educations (online course about safety risks, face to face feedback per unit level)
3	C	Unauthorized medication	Bupivacaine 0.125%, continuous dose 6mL, demand dose 2mL, max dose 48mL, lockout 20min. (observed at 05-09-13, 12:39)	No active order for the new setting	Implement electronic notification to the clinicians on the eMAR when the order expires/changes in CPOE.
4	C	Wrong rate	Bupivacaine 0.0625% continuous dose 6mL, demand dose 2mL, max dose 48mL, lockout 20min. (Observed at 06-14-2013, 11:58) Checked the order as start administrating time was 06-13-2013, 21:06. We told RN and she didn't realize that the order was different.	Bupivacaine 0.0625%, continuous dose 4mL, demand dose 2mL, max dose 40mL and lockout 20min	Implement medication "order change" alerts

3.1. Tubing Tag Errors

Attaching tubing tags are important process of medication administration to help nurses to systematically track and change tubing regularly to prevent infections/contamination. Although tubing tags were mostly attached to other IV medications, the majority of the PCA/PCEA lines did not have tubing tags attached. After interviewing nurses, some of them did not know that the tubing tag policy applied to PCA/PCEA tubing. As an intervention plan, update the tubing and medication labeling policy that is compliant with the Joint commission standards will be implemented. By working closely with hospital leadership, our project team will educate nurses to maintain better compliance with safe nursing practice that is consistent with policy.

3.2. Critical Error Preventions

Unauthorized medications and rate deviation errors were the most critical errors in this study. These errors can occurred even with current smart pump systems are in place. In the future, if a closed loop system for IV medication administration is implemented, the system would be able to detect discrepancies between pump settings and prescribed orders. One of these errors observed in this study occurred when clinical staff changed settings first and intended to enter the order at a later time and the order was never entered into the electronic order entry system. This situation can cause critical errors in a busy clinical environment. A closed loop system that wirelessly programs the smart infusion pump based on a computerized provider order, may be a desirable feature to decrease the incidence of medication administration errors related to PCA/PCEA pump programming. For now, we can educate clinical staff to comply with safe practices

though education and feedback on current practice and the potential harms associated with breaches in safe medication practices. Next steps for our hospitals is to implement "change order" alerts in eMAR and provide education to nurses about the tubing taking policy, Additionally, to work with nurses to identify the contributing factors that lead to the more critical PCA errors identified in this study and to identify the best interventions to eliminate these errors.

3.3. Practice improvement

Based on study results, intervention plans are identified (Table 4). These intervention plans will be implemented as a safety bundle for improving smart pump practice. We are in the process of implementing this bundle and we will conduct post-intervention data collections after six months intervention of the safety bundle.

4. Conclusion

This study sought to add to the knowledge regarding PCA-related medication errors by using a prevalence observational data collection method to identify errors associated with PCA/PCEA pumps. Medication errors using PCA/PCEA pumps were investigated in an academic medical center and the risks were evaluated. This study was important because it provided a means to evaluate both medication errors and potential errors which may be underreported in hospital-based incident reporting systems. A few high-risk medication errors were found and violations of hospital policy for tubing tags were common.

The results from this study can be used to help to improve safety of administration process. Further investigations of contributing factors that cause high-risk errors are needed.

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