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Medication administration errors in adult patients in the ICU

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Abstract *Objective*: To quantify the incidence and specify the types of medication administration errors from a list of error-prone medications and to determine if patient harm resulted from these errors.
Design: An observational evaluation.
Setting: Five intensive care units (ICUs) in the United States.
Patients and participants: Eight hundred fifty-one patients who were at least 18 years of age and admitted to surgical, medical or mixed ICUs during a 3 month period were included.
Interventions: None.
Measurements and results: A list of error-prone medications was adapted from the literature and evaluated for medication errors and patient harm. Of 5,744 observations in 851 patients, 187 (3.3 %) medication administration errors were detected. the therapeutic classes most commonly associated with errors were vasoactive drugs 61 (32.6 %) and sedative/analgesics 48 (25.7 %). The most common type of error was wrong infusion rate with 71 (40.1 %) errors. Twenty-one errors did not reach the patient and 159 reached the patient but did not result in harm, increased monitoring or intervention. Five errors required increased patient monitoring and two required intervention. None of the errors resulted in patient death.
Conclusions: This multicenter evaluation found fewer medication administration errors than the published literature, possibly due to the varying observational techniques and pharmacist involvement. Lorazepam and wrong infusion rates are associated with errors that occurred frequently, resulted in the greatest potential for harm and were common oversights in the system. These errors should be considered potential areas for betterment in the medication use process to improve patient safety.

Keywords Adverse drug event · Preventable events · Prescribing and medication administration errors · Independent observation approach · High-alert medications

Introduction

The incidence and consequence of medical errors have received renewed media attention since the Institute of Medicine (IOM) published the findings of its Committee on Quality of Health Care in America in 1999 [1]. The IOM report discussed the substantial portion of medical errors related to medications and made a number of recommendations for improving patient safety. The report acknowledged that no single activity would solve the complicated problems that were described.

As discussed in portions of the IOM report, the terminology associated with medication-related problems is confusing and attempts have been made for standard-

ization [2, 3]. For example, an adverse drug event (ADE) has been defined as patient injury resulting from a medication [3]. From this definition it is apparent that not all ADEs are preventable; those that are preventable are part of a much larger category of events referred to as medication errors [4].

Prescribing and medication administration errors are two types of preventable events that have been the focus of investigations concerning medication errors.[5] Much of what is known about medication errors is derived from a series of investigations by the ADE Prevention Study Group, which used daily, prospective chart reviews (and, to a lesser extent, voluntary reporting) to study ADEs [6, 7, 8, 9, 10]. With regards to medication errors, the ADE Prevention Study Group researched the causes, incidence and costs of errors associated with actual or potential ADEs. Therefore, errors with "minimal potential for injury" were excluded [6]. Medication administration errors accounted for 34% of all preventable ADEs in the combined intensive care unit (ICU) and non-ICU settings under investigation [6]. The top three types of administration errors were wrong dose (27%), wrong technique (14%) and wrong drug (12%); the remainder of the errors was spread over a variety of categories [7]. More errors were found in medical ICUs (19.4 per 1000 patient days) compared to either surgical ICUs or non-ICU settings (8.9–10.6 per 1000 patient days), but any differences in the type or severity of errors between the ICU and non-ICU settings were not discussed. Overall, it seems likely that the ADE Prevention Study Group, given the possibility of underreporting and inadequate documentation, underestimated the true incidence of medication administration errors. Furthermore, the manner of data collection used by the Study Group would be unlikely to detect errors unknown to nurses who were administering the medications (e.g., errors in the infusion rate).

Similar to the information obtained by the ADE Prevention Study Group, evaluations of medication errors in the ICU setting have focused on prescribing errors using voluntary reporting systems and chart reviews and are therefore subject to similar limitations [11, 12, 13, 14, 15, 16, 17]. The use of independent observers for medication error reporting has the potential for increasing our understanding of medication administration errors. Few such studies have been conducted in the ICU and all were performed outside the United States [18, 19, 20]. The results of these studies are difficult to compare given the varying definitions of errors and the manner in which the results were reported (e.g., error rate per patient, error rate per number of observed events). However, a couple of observations may be noted: there were no fatal errors in any of the investigations and, with the exception of one study [20], no serious complications.

Given the lack of published information on medication administration errors in the adult ICU, an evaluation of errors using an independent observer approach was conducted. The primary purpose of this evaluation was to determine the incidence, type and severity of medication administration errors in adult ICUs. Additionally, the information will be used to improve patient care in each of the participating institutions by increasing awareness and monitoring of specific error-prone medications. Dissemination of this information may help to improve patient care at other institutions in a similar manner, as well as serve as an impetus for additional evaluations in this area.

Table 1 Error-prone medications (adapted from MR Cohen [21])

Epinephrine, norepinephrine, esmolol and other vasoactive drugs specified
Midazolam, lorazepam and other benzodiazepines specified
Digoxin
Dopamine, dobutamine
Heparin, specified low-molecular-weight heparins
Warfarin
Magnesium sulfate
Insulin
Morphine, fentanyl and other opioids specified
Propofol
Cisatracurium, vecuronium and pancuronium
Potassium chloride, potassium phosphate, hypertonic sodium chloride

Materials and methods

Institutions

The participating institutions were tertiary-care teaching facilities that ranged from 200 to 800 beds. Surgical, medical and mixed ICUs were included for a total of 100 ICU beds. The nurse-to-patient ratio varied somewhat from institution to institution but was approximately 1:1.5. Institutional Review Board approval was obtained at each of the participating centers. In order to ensure patient confidentiality, all patient and institutional identifiers were excluded from the data prior to collation and analysis.

Error-prone medications

The Institute for Safe Medication Practices has generated a list identifying "high-alert medications" that was utilized as a starting point to target medications that have been associated with an increased likelihood of errors [21]. The list was expanded, based on local use patterns identified by the pharmacists involved. The medications selected for evaluation are listed in Table 1. Only targeted medications were monitored.

Table 2 Type and severity of medication administration errors (adapted from The National Coordination Council for Medication Error Reporting and Prevention [24])

Major divisions	Subcategories	Description
Medication error	Dose omission	Dose not received by patient
	Improper dose	Any dose given other than that prescribed
	Wrong strength/ concentration	Any strength/concentration given other than that prescribed
	Wrong drug	Any drug given other than that prescribed
	Wrong dose form	Any dose form given other than that prescribed
	Wrong technique	Inappropriate administration technique
	Wrong route	Any administration route other than that intended
	Wrong rate	Any administration rate other than that intended
	Wrong time	Dose given more than 60 min before or after intended
	Wrong patient	Dose given to patient other than that intended
Error, no harm	Category B	Error, but medication did not reach patient
	Category C	Error reaches patient, but no harm Error reaches patient, but not administered
	Category D	Error occurred, resulted in increased patient monitoring, but no harm to patient
Error, harm	Category E	Resulted in need for therapy or intervention, caused temporary harm
	Category F	Resulted in initial or prolonged hospitalization and temporary harm to patient
	Category G	Resulted in permanent harm
	Category H	Resulted in near-death event (anaphylaxis, cardiac arrest)
Error, death	Category I	

Pilot project

Data were collected for a 1-week period of time at one institution to test the evaluation materials used (e.g., data collection sheets, and definitions of types and severity of errors). The evaluation materials were subsequently sent to the other pharmacists for review and comments. After ensuring a consistent approach to documentation, data collection was begun.

Independent observers

With one exception, pharmacists participating in this evaluation were the observers at their own institutions. The exception occurred at one institution where the pharmacist trained pharmacy students to perform the evaluation. All of the pharmacists were ICU specialists and members of the CPP section of SCCM. Since this was not an interventional study, no attempt was made to insure that there was consistency with regards to the amount of time the pharmacists spent performing their clinical activities in the various ICUs, apart from the data collection procedures associated with this evaluation. Similarly, no attempt was made to delineate the daily nature of the pharmacists' work in the ICUs.

All observers used a standard set of definitions related to medication errors, which included explanations of the various types and severity of errors (Table 2). Similarly, all observers used a data collection form that detailed the information to be obtained.

Data collection

Data were collected for 3 months (non-consecutively and generally limited to weekdays, depending on the discretion of the observers) from July to October 1999 on patients at least 18 years of age who were admitted to one of five ICUs in the United States. Intravenous and oral medications were included and only regularly scheduled medications were monitored (i.e., no as needed or one-time orders). Data collection occurred twice daily, once in the morning and once in the afternoon, on every patient in the ICU. Each time data were collected on an individual patient it was considered an observation, so patients had two observations per day for intravenous and oral medications unless they were discharged prior to the afternoon observation.

Type and severity of errors

For the purposes of this evaluation, a medication error was defined as "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" [2]. This definition allowed for the classification of the root cause of error into one of the following categories: dose omission, improper dose, wrong strength/concentration, wrong drug, wrong dosage form, wrong technique, wrong route of administration, wrong rate, wrong time and wrong patient (Table 2) [22, 23].

Patient outcomes regarding medication errors were assigned to predefined categories, selecting the highest level of severity that applied. The National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) has developed taxonomy for medication errors [24]; this was used as the basis for the categories utilized during this study. Three major divisions of errors (no harm, harm and death) were further subdivided into eight subcategories (Table 2).

Error identification

The observers identified possible errors by verifying the use of the appropriate drug product, dose (e.g., milligram/kilogram), infusion pump rate, medication concentration, time of administration and absence of incompatibilities. Nursing personnel were not informed

of the observations being recorded; it was not expected that the observers' activities would be questioned since the institutions involved were used to having pharmacy personnel reviewing charting materials and performing other clinical activities.

The daily census of the unit was recorded in order to report the total number of patients under observation, as well as the number of patients who were receiving targeted medications. Patients who were discharged but subsequently re-admitted to the ICU were followed as new admissions. An error that was identified was corrected in the manner usually employed by that institution.

Data analysis

The data were entered and analyzed using Microsoft Excel version 4.0. Descriptive statistics were used to evaluate the data collected.

Results

Targeted medications for 851 patients were evaluated with a total of 5,744 observations. One hundred and eighty-seven errors were detected and indexed. Table 3 lists the errors categorized according to harm. Five observations were associated with an error that resulted in increased patient monitoring, but caused no patient harm (category D). Two of these instances involved the administration of an incorrect dose secondary to a miscalculation of an infusion rate. Although the events involved different medications (lorazepam and fentanyl), in both instances the concentrations were double that of the hospital standard resulting in twice the amount of desired medication being administered to the patient. Another miscalculation of an infusion rate of dobutamine resulted in increased hemodynamic monitoring. The remaining two category D observations involved a heparin infusion that had been incorrectly discontinued and several dose omissions of digoxin resulting in an observed sub-therapeutic serum level.

Two medication errors associated with lorazepam involved the need for therapy or intervention and caused temporary harm (category E). In the first situation a neuromuscular blocking agent, pancuronium, was administered instead of the prescribed lorazepam infusion. The second error occurred when a chemically paralyzed patient was supposed to receive lorazepam every 4 h as prescribed. However, the medication administration record erroneously listed the lorazepam as "every 4 h, as needed."

Approximately equal in observed occurrence and most frequently associated with orally administered medications were the types of errors related to improper dose, dose omission and wrong time (Table 4). A portion of the data reviewed did not specify observed errors into a particular category of error type.

Table 5 lists the medications associated with errors. After grouping the targeted medications according to therapeutic classes, vasoactive drugs were involved in the highest number of errors (61/187, 32.6 %) specifically epinephrine. Sedative/analgesics were the second most common (48/187, 25.7 %) with lorazepam leading the therapeutic class.

Table 3 Severity of errors (adapted from The National Coordination Council for Medication Error Reporting and Prevention [24])

Type (major division)	Number of errors (%)
Category B	21 (11)
Category C	159 (85)
Category D	5 (3)
Category E	2 (1)
Total Errors	187

Table 4 Types of errors

Type	Number of errors (%)
Dose omission	27 (14.4)
Improper dose	22 (11.7)
Wrong strength/concentration	4 (2.3)
Wrong drug	1 (0.6)
Wrong dosage form	0
Wrong route of administration	0
Wrong infusion rate	75 (40.1)
Wrong time	26 (13.9)
Wrong patient	0
Not specified	32 (17.1)

Discussion

The incidence and significance of medical errors in the institutional setting has been described in the medical literature over the past decade, but has recently received particular attention in the lay press following the release of the IOM report titled "To err is human" [1]. As mentioned in the IOM report, *medication* errors account for only a portion of all medical errors; the exact percentage is difficult to quantify due to the different methods of reporting errors. Most of the prospective data concerning medication errors has focused on prescribing errors [11, 12, 13, 14, 15, 16, 17], except the work published by the ADE Prevention Study Group [6, 7, 8]. There is a paucity of published information relative to other types of medication errors, in particular the second most commonly occurring, medication administration errors [5, 7]. Medication errors are associated with adverse drug events that can be costly and potentially harmful [8], therefore it is important to study the incidence, types and consequences of medication administration errors.

In contrast to prescribing errors, it is difficult to intercept many types of administration errors. In the ADE Prevention Study Group's research only 0–2 % of medi-

Table 5 Number of errors and observations

Agent	Error/ observations (%)	Error/ total errors (%)
Epinephrine	17/214 (7.9)	17/187 (9.0)
Potassium chloride	4/59 (6.8)	4/187 (2.1)
Magnesium	6/112 (5.4)	6/187 (3.2)
Digoxin	29/496 (5.8)	29/187 (15.5)
Lorazepam	26/572 (4.5)	26/187 (13.9)
Norepinephrine	9/208 (4.3)	9/187 (4.8)
Heparin	20/576 (3.47)	20/187 (10.7)
Midazolam	3/92 (3.3)	3/187 (1.6)
Dobutamine	11/341 (3.2)	11/187 (5.8)
Fentanyl	4/138 (2.9)	4/187 (2.1)
Low-molecular-weight heparin	6/225 (2.7)	6/187 (3.2)
Other vasoactive agents (e.g., phenylephrine)	9/357 (2.5)	9/187 (4.8)
Morphine	8/367 (2.2)	8/187 (4.2)
Vecuronium	2/92 (2.2)	2/187 (1.0)
Dopamine	14/667 (2.1)	14/187 (7.4)
Esmolol	1/50 (2.0)	1/187 (0.5)
Cisatracurium	4/209 (1.9)	4/187 (2.1)
Propofol	6/336 (1.8)	6/187 (3.2)
Insulin	5/348 (1.4)	5/187 (2.6)
Other opioids (e.g., hydromorphone)	1/75 (1.3)	1/187 (0.5)
Pancuronium	1/91 (1.1)	1/187 (0.5)
Warfarin	1/119 (0.8)	1/187 (0.5)

cation administration errors were intercepted [6, 7]. In the hospital setting when a prescribing error occurs, there are at least two other health professionals (pharmacist and nurse) who see the order and hopefully identify the mistake. A pharmacist reviews the order during the processing and distribution stage, while the nurse oversees the administration phase. In institutions with a multidisciplinary approach to patient care the pharmacist and nurse are involved in the ordering process (e.g., during physician rounds), which provides another opportunity to prevent potential errors. For pharmacists such responsibilities have demonstrated a 66% decrease in adverse drug events in the ICU setting [10].

Unfortunately, the system checks relative to prescribing are not in effect for the administration step of the medication use process; most commonly only a single nurse is involved in the actual administration of a medication. There are methods of adding additional checks to the administration portion of the system, albeit with some time commitment from other personnel. For example, internal policies could be created that require medication administration rates for continuous infusions to be calculated by at least two health care professionals. A variety of system changes have been suggested by members of the ADE Prevention Study Group [7].

All published studies focusing exclusively on medication administration errors in the ICU have been performed outside the United States, with the majority involving pediatric patients [20, 25, 26, 27, 28]. The study conducted in France by Tissot et al. appears to have involved adult patients, however patient ages were not specified [20]. This prospective evaluation in a medical ICU used an observation technique to identify medication errors. The observers were two pharmacy residents who each followed a randomly selected nurse for approximately 6 h a day excluding nights and weekends. The residents observed the preparation and administration of medications by nurses for 30 days within a 2-month period. There were 2009 observations in 26 patients, detecting 132 (6.6%) errors. The major types of errors were wrong dose (38), wrong rate of administration (29), inappropriate preparation (24) and incompatibility issues (19). While none of the errors resulted in death, 26 were deemed potentially life-threatening; 10 of these were due to preparation errors, 5 due to dosing errors and 5 due to incompatibilities. These results are difficult to compare to those of the ADE Prevention Study Group because the categorization of errors differs, however wrong dosing was predominant in both studies [7, 20].

There are a variety of similarities and differences between our evaluation and that of Tissot et al. [20]. In common were the ICU environment, the types and definitions of errors and the use of pharmacy personnel as independent observers. However, the pharmacists in our study were active members of the health care team who provided clinical advice. Pharmacist participation during physician rounds and the distinct differences in observation techniques may account for the discrepancy in the incidence of errors. A limitation to the Tissot et al. study was the observation of a relatively small number of nurses and patients [20]. Despite some of the differences in the manner of evaluation, the major types of errors (wrong dose and rate of infusion) found in our evaluation were similar to those reported by Tissot et al. [20], as well as other published evaluations [13, 15, 16, 19].

The difficulty in providing continuous monitoring for evaluating medication errors is a limitation of existing studies, as well as ours. Even if trained independent observers were available to follow nurses 24 h a day, there would still be issues related to interpretation of the results. For example, the behavior of the nurses could change if they knew they were being monitored and the number of errors might be underestimated. In an attempt to provide as much consistency as possible in our study, we standardized the definitions and data collec-

tion; there were still 30 errors documented but not described. Additionally, observation periods were arbitrary at the various institutions. It is clear that further research is needed in this area, although the best method of data collection will continue to be a complicated issue.

Another factor that must be considered when interpreting the results of this evaluation relates to the possible differences in the amount and type of daily clinical pharmacy ICU services provided by the pharmacists at their respective institutions. All of the pharmacists considered themselves ICU specialists with clinical responsibilities that included some degree of input into the decision-making process relative to medications. However, no attempts were made to change or delineate the usual daily routines of these specialists. This is an important limitation of this evaluation, since there are published data that demonstrate a decrease in the number of ADEs with increased pharmacist involvement in the ICU setting. Therefore, it is possible (if not likely) that the varying level of day-to-day pharmacist involvement in the ICUs included in this evaluation influenced the number and types of errors found at the various institutions.

When evaluating the literature on medication errors and applying it within specific institutions, a suggestion would be to use the failure mode effect and criticality analysis (FMECA) [29]. The FMECA is a systematic assessment of a process or product to determine the potential for failures. Using this theory, but realizing the literature has already identified failures, errors can be assessed that would be most relevant based on the following characteristics: occurrence, severity and unlikelihood of detection. Using this study as an example, a medication with frequent errors, greatest severity and ease of going undetected would be lorazepam. Using this same theory and applying it to the process, the rate of infusion error occurring most commonly was associated with the most interventions and was undetected most frequently based on the high occurrence. Since lorazepam and rate of infusion errors seem to be most significant using the FMECA criteria, it would be a reasonable starting point for evaluating the medication use process within institutions.

In conclusion, our evaluation complements the literature on medication errors in the ICU by providing information from a multi-institutional perspective focusing on the medication administration phase. Using an observational technique for identifying errors we found a 3.3 % incidence, which is less than comparable studies, possibly due to varying methods of observation and pharmacist participation in patient care. When improving patient safety in the medication use process it seems reasonable to identify medications or processes associated with the greatest number of errors, potentially cause the most patient harm and that frequently are an oversight in the system. In this evaluation, lorazepam and the infusion rate errors appear to meet these criteria and should be considered potential areas for improvement within the medication use process.

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