Intravenous Medication Administration in Intensive Care: Opportunities for Technological Solutions

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Abstract: Medication administration errors have been shown to be frequent and serious. Error is particularly prevalent in highly technical specialties such as critical care. The purpose of this study was to describe the characteristics of intravenous medication administration in five intensive care units. These data were used within the context of a larger study to design information system decision support to decrease medication administration errors in these settings. Nurses were observed during the course of their work and their intravenous medication administration process, medication order source, references used, calculation method, number of medications prepared simultaneously, and any interruptions occurring during the preparation and delivery phases of the administration event were recorded. In addition, chart reviews of medication administration records were completed and nurses were asked to complete an anonymous drop-box questionnaire regarding their experiences with medication administration error. The results of this study are discussed in terms of potential informatics solutions for reducing medication administration error.

INTRODUCTION

Medication administration errors have been shown to be frequent and serious. A study that involved direct observation of medication administration in 36 hospitals revealed that 19%, or nearly one in five, medications administered involved errors of some kind (1). The authors estimated that 7% of these errors would have resulted in harm to the patient. This amounts to 40 adverse drug events a day in a hospital of 300 beds.

In a description of errors by stage of medication process, Kopp et al. (2) report that lack of drug knowledge was the cause of 10% of errors and slips and memory lapses were responsible for 40% of errors at the administration stage. It is not surprising that some medication administration errors are attributable to slips and memory lapses as healthcare work occurs within an interrupt-driven environment (3) and practitioners often carry on more than one communication task simultaneously (4). In one study of communication in emergency rooms, Coiera et al. (5) found that nearly a third of communications were interrupted, with an interruption rate of 11 per hour. While nurses who have long experience in a setting might be expected to prevent many errors because of familiarity with the drugs, dosages, and patient population, older and more experienced nurses are leaving the workforce (6). Hospitals increasingly rely on novice nurses, transfers among settings, and the use of agency nurses to staff units both here (7) and abroad (8). The implementation of Clinical Decision Support Systems (CDSS) has the potential to assist in the proper administration of medications in the clinical setting.

Relatively little research has been conducted on the use of CDSS to aid decision making in acute care nursing practice (9). Most CDSS studies involving nurses have been targeted at the prescribing and patient management practices of nurse practitioners (10-13). Some attention has been focused on the use of clinical alerts embedded in clinical information systems and has shown them to be an effective mechanism for prompting nurses to remember clinical routines (14), or to provide information regarding a patient's progress on a care pathway (15). Information related to the correct method for medication administration, monitoring, and patient physiological parameters can now be integrated through the use of middleware into information devices at the point of care. The optimum configuration and integration of these alerts into work flow will depend on a thorough understanding of medication administration practice. The purpose of this study was to describe the characteristics of intravenous medication administration in five intensive care specialties as a part of a larger study to design decision support tools for medication administration safety.

METHODS

This descriptive study included observations of intravenous medication administration, review of medication administration records, and collection of drop-box questionnaires related to medication administration error in five intensive care units: Coronary Care (CCU), Coronary Surgical (CICU), Surgical (SICU), Medical (MICU), and Neurological (NICU).

Observations of Administration Process

Data were collected on 553 IV medication administration events over the course of six months. 34 nurses were observed during the course of their work and their intravenous medication administration process was recorded on an electronic data collection tool. The data collection tool allowed rapid coding of workflow in terms of medication event duration, mode (i.e. peripheral, jugular, sub-clavian), delivery (i.e. push, drip, soluset), and the preparation of each medication (i.e. pre-mix, extract from vial, reconstitute, infusion). An administration event was defined as the preparation and administration of one medication to one patient. Data were also collected on the number of medications prepared simultaneously and then administered separately, whether medications were administered immediately or held, any interruptions occurring during the preparation and delivery phases of the administration event, medication order source, references used, and medication calculation methods utilized.

Review of Medication Administration Records

Medication administration records (MAR) of 81 patients across all five intensive care units were reviewed by a nurse familiar with the intensive care environment. Data were abstracted and recorded on the type and number of regularly scheduled medications ordered for each patient.

Error Questionnaire

Paper based questionnaires and a locked collection box were placed in each intensive care unit. A flyer was posted on the box asking nurses to complete the questionnaires and to place them in the locked collection box. The box was placed in each unit for approximately one week. The questionnaire asked nurses two questions: 1. to describe medication errors that they had been involved in or witnessed, and 2. to suggest how these errors might have been avoided.

Protection of Human Subjects

No identifiable patient data were collected. Prior to observation of nurses their written consent to participate in the study was obtained. All information collected was only reported in aggregate. The study was approved by the institution institutional review board.

Data Analysis

Observations of the medication administration process were transferred from the MS Access electronic tool database to statistical software for the calculation of frequencies, percentages, and associations between data collection categories. Data regarding medication orders derived from the 81 MARs were also entered into a statistical database for the calculation of frequencies and percentages. The data on the description of errors from the questionnaire drop box were categorized in two ways: the type of error was categorized as failure to adhere to one or more of the five rights of medication administration practice (right drug, right dose, right person, right route, right time) and by the cause of the error.

RESULTS

Characterization of Medication Administration

On an average day, each nurse administered 13 scheduled medications per patient, of which 7 were either IV medications or IV fluids. Generally, nurses take care of two patients; therefore on average nurses were administering 26 scheduled medications per day. These totals do not include as needed or one time medications and reflect only the number of regularly scheduled medications. The duration of medication preparation and administration ranged from 4.33 minutes for one medication to 42.23 minutes for ten medications, including the administration of blood. Mean administration duration was 6.83 minutes.

The most frequent classification of drugs given across all the intensive care units were anti-infectives (26.2%), gastrointestinal agents (13.5%), electrolytes (11%), and analgesics (6.5%). There was a significant association between the intensive care unit specialty observed and the most frequent classification of drugs given (Chi-square $p<.01$). For example, in the surgical intensive care unit, over 34% of the drugs given were anti-infectives and only 8% were electrolytes. There was also an association between the intensive care unit and the mode of drug administration (Chi-square $p<.01$). Drugs were much more likely to be given through a peripheral intravenous line in the MICU (40%) than other units, and an internal jugular line was used in the CICU 37% of the time and almost never in the CCU (2.6%). These differences mean that nurses who are working across units, or are hired on a temporary basis, may not be familiar with drugs or delivery protocols for

any individual unit and may benefit from decision support.

Nurses were interrupted at least once 65.6% of the time during the preparation and administration of medications. Duration of medication preparation and administration, mode of administration, or the type of medication given was not significantly correlated with the number of interruptions that occurred. However, there was a significant association (Chi-square $p<.001$) between the intensive care unit and the number of interruptions. Interruptions during medication preparation and administration occurred most frequently in the NICU (74%), followed by the CICU (70%), the SICU (66%), the MICU (57%), and the CCU (43.7%).

The nurses sought additional drug information 20% of the time and were most likely to seek information from physicians (7.1% of the time) and other nurses (5.2% of the time) despite the fact that online and print references were available. Print reference material regarding medication administration was utilized 3.4%, pharmacists 2.4%, and online references 1.6% of the time that nurses gave medications.

Over all intensive care units, medication orders were accessed via computer 70% of the time and almost 20% of administered drugs were based on standing protocols. However, there was a significant difference (Chi-square $p<.01$) on the source of medication orders between units. Almost half of the medications given in the CICU (49.2%) were based on protocols and standing orders as opposed to 17.6% in the NICU, 12.5% in the CCU, 5.9% in the SICU and 5.5% in the MICU. When nurses are administering medications based on protocols or standing orders they must independently make a judgment regarding when it is appropriate to administer the medication based on the patient's condition, how much medication to administer, and what patient physiological parameters and adverse effects should be monitored.

Characterization of Medication Error

The drop-box questionnaire data described 22 medication errors. The most frequently reported error was wrong dose (37%), followed by wrong drug (27%), wrong route (22.7%), and wrong time (4%). No errors were reported that involved giving medications to the wrong patient. The absence of such an error may be an anomaly specific to the intensive care environment because of the low nurse/patient ratio.

Nurses often cited lack of experience with the patient population, drug dosage, administration route (i.e. intrathecal), or a stressful and busy environment for the occurrence of error. For example, one adult health nurse related the circumstances surrounding an error she committed: *"I was the only RN working on a peds floor. I didn't know the patients, was in a hurry and gave the wrong med to the wrong patient"*. As another nurse stated *"medication errors seem to happen when there is relatively new staff, in a stressful and busy environment"*. Specific types of errors experienced by the nurses responding to our survey are listed in Table 1.

Table 1. Specific Error Problem Areas

*Pumps programmed incorrectly
*Drug injected too fast
*Drug injected through wrong type of access, oral medication injected
*Similar labeling
*Stressful situation
*Wrong drug taken from drug dispensing machine
*Wrong amount of fluid aspirated from drug vial containing more drug than ordered
*Obtained drug from drug dispensing machine in advance, then order was changed but nurse not aware
*Mixed up hanging IV bags changing dose rate on wrong drug

DISCUSSION

Administration Practices

Using the mean administration duration and an average patient load of two patients per nurse, we can estimate that the average nurse spends almost three hours a day preparing and administering regularly scheduled medications in these intensive care units. Many more, as needed, emergency, and one time medications are also given, therefore 3 hours is the minimum amount of time they are involved in this activity. These nurses spend a significant amount of their time involved in a very risky task where previous observational research has shown error rates of 6.6% (16), 11.7% (17), 19% (1), 28% (2), and 66.9% (18).

The type of medications administered varies across units as does the intravenous delivery access (i.e. peripheral, jugular, sub-clavian). Nurses in these units are frequently drawn from staff of another unit or employed through a temporary agency. The

vacancy rates in the intensive care units included in this study have increased dramatically over the last several years as they have in hospitals nationwide. These issues in conjunction with the fact that these nurses rarely seek out reference materials, but instead rely on other health care workers, who may not always have correct information regarding medication administration, can contribute to the potential for error. Context specific decision support pushed to the point of care could provide information to nurses who may be unfamiliar with drugs given in a particular unit. Short messages intended to address some of the most frequent types of errors such as administration rates, appropriate administration access, and amount of fluid to be delivered could be displayed on a bar code medication administration (BCMA) device after the patient and drug have been scanned at the bedside. Forcing the nurse to acknowledge these messages through system design blocks would provide the right information at the right time to decrease administration errors.

Of particular concern are the reports of errors related to medication dispensing machines. In a study of interruptions to medication administration in medical-surgical units, Givens et al. found that 66% of interruptions occurred when nurses were obtaining medications from automatic dispensing machines (19). In the units included in this study, as in many units, BCMA had not been implemented. There is concern in the nursing community that automatic dispensing machines without the accompanying BCMA have in effect forced the nurse to secure medications for patients independently without the intervention or consultation of pharmacists. This eliminates an additional check that had been in place prior to the implementation of these devices.

Currently, in this setting when nurses access medication dispensing machines for drug extraction they must pick out the correct drug from a drawer that contains multiple drugs and is not individualized by patient. Modifying the automatic medication administration machines so that only the drug to be administered is available for extraction would decrease the risk of nurses taking the wrong drug from the drawer. Also, prompts by the machine for verification of the drug (i.e. shape, color, amount) might add another check that could decrease the possibility that they might administer the wrong drug.

Interruptions

The high rate of interruptions during the preparation and administration of intravenous medications in these intensive care units is alarming. It is interesting that in this study the length of time to prepare and administer drugs, the type of drug given, and the mode of administration were not associated with the number of interruptions that occurred. The only factor that was associated with the number of interruptions was the unit studied. This and the fact that there was quite a range in the number of interruptions between these units (NICU 74% and CCU 43.7%), points to other environmental, procedural, or cultural factors that may be contributing to the number of interruptions. Of particular concern in this study, is that the unit where nurses were most frequently apt to be making decisions regarding medication administration independently (CICU) was also a unit with a very high rate of interruptions (70%).

In a study of interruptions in an Emergency Department, Brixey et al. found that 18% of interruptions for nurses were the result of the unit's physical layout and 14.2% were due to the unavailability of supplies and equipment in the workspace (20). Gurses and Carayon surveyed intensive care nurses on the types of obstacles to work performance they encounter in their practice. The most frequently reported obstacle was a noisy work environment (46%) (21). The reasons for the range in the number of interruptions in these units certainly warrant further investigation.

Decision support alerts pushed to the nurse at key points in the process such as, at the medication dispensing machine, when programming pumps, and when using BCMA devices may decrease the impact that these interruptions have on the incidence of memory lapses that could result in medication administration error. There is the risk that these types of alerts could also interrupt the administration process and compound the problem. However, in a computer-based simulation of operating room scheduling it was found that active interruptions (notifications) providing information regarding the task at hand did not cause the participants to move off task (22). Further research is needed to evaluate the risks and potential unintended consequences of these alerts.

SUMMARY

These data demonstrate that nurses are administering many drugs and multiple drugs at the same time; are often interrupted; and rarely seek information regarding correct administration, even when this information is readily available. In addition, nurses are frequently required to independently make judgments regarding correct drug administration from protocols and standing orders and to self-dispense these drugs without consultation with physicians or

pharmacists. The opportunity for error during the course of drug administration in these nursing units is frequent, and the occurrence of these errors is supported by the questionnaire data collected. This study shows that there are both multiple causes for medication administration error and multiple opportunities for system checks that may help reduce the incidence of these errors.

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