Different Patterns of Medication Administration Between Inside and Outside the Patient Room Using Electronic Medical Record Log Data

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Abstract. The primary object of this study is to analyze the different patterns of medication administration in a medical intensive care unit (MICU) using an electronic medical record (EMR) log data and how these patterns can be different inside and outside the patient room in terms of average process time. To analyze ICU nurses' workflow related to the EMR documentation, the real-time measurement system (RTMS) data was used, and multiple hierarchical task analysis (HTA) charts were developed. The results revealed that there was no significant different pattern between the medication administration inside and outside the patient room. However, we found a significant difference in medication administration's average process time between inside and outside the patient room. The findings of this study highlight the behavioral differences in performing medication administration in an ICU.

Keywords: Electronic medical record · Medication administration · Health information technology

1 Introduction

An intensive care unit is one of the most complex and dynamic areas in a hospital [1]. According to the study done by Ross, et al. [2], medication errors may cause or lead to inappropriate medication usage. As a result, those errors will affect patient outcomes, increasing patient morbidity, mortality, and costs [3, 4]. The significant errors related to the medication orders in ICUs are prescribing, transcribing, dispensing, and administration [5]. More than 50% of medical errors occur at the prescribing stage and 34% at the administration stage [6]. According to Vazin and Delfani [7] medication errors account for 78% of serious medical errors in an ICU. They state that the most common causes of errors are rule violations, slip and memory lapses, and lack of knowledge. According to a study done by Freedman, et al. [8], the occurrence and scope of medication errors are described by an American Heart Association Scientific Statement. Based on this

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report, improved methods, like automated information systems, are needed to identify and reduce medication errors.

Various strategies could improve the quality of care and operational efficiency. One strategy is improving health information technology, which helps ICU nurses quickly access patient information and support clinical decision-making [9]. Electronic medical record (EMR) is a type of IT system introduced to help physicians and nurses carry out their tasks more efficiently while improving the quality of care, safety, and patient outcome [10]. Despite the advantages of EMR systems, they still have several shortcomings. First, EMR systems generate and process a large amount of digital information regarding a patient's treatment and conditions. EMR systems will increase the spending time on documentation due to the massive amount of the patient conditions and treatment information delivered to nurses, limiting the ability of ICU nurses to provide timely and appropriate healthcare services [11–13].

Although the electronic health record systems should make the medication administration process safer, error rates may increase due to order complexity [14]. According to a study done by Warrick, et al. [15], the rate of new errors, like incorrect selections of multiple dosage options for some drugs, raised after deploying the EMR system in a pediatric ICU.

To advance our understanding of ICU nurses' EMR documentation process, a time-motion study was conducted in a medical ICU at the University of Missouri Hospital. By combining data obtained from the time-motion study and real-time measurement system (RTMS), multiple hierarchical task analysis (HTA) charts were developed to understand ICU nurses' workflow. HTA charts can be used as a tool to show the nurse's workflow [16]. According to the previous study done by Guo, et al. [17], four primary categories, including 1) update assessment results, 2) review documents, 3) medication administration, 4) check lab specimen orders were identified which must be conducted to complete the EMR documentation. In this study, we investigated the patterns of medication administration and how these patterns in EMRs can be different in terms of average process time inside and outside the patient room.

2 Literature Review

One of the most essential and vital parts of nurses' work since the time of Florence Nightingale is nursing documentation [18]. The objectives of documentation in a healthcare system are to ensure continuity of care, provide legal evidence of the process of care, and support evaluation of patient care quality [19]. Further, EMR documentation should help the healthcare team deliver a higher quality of care and evaluate nurses' progress and patients' health outcomes [20]. However, achieving these objectives might be challenging when nurses spend more time documenting due to the large amount of information regarding patients' complex conditions and treatments. While healthcare information technology (HIT) is reducing error inside the ICU, the current EMR system increases the incidence of certain types of mistakes that produce hazard risk related to patient safety and even mortality [21–23]. According to a study done by Bates, et al. [24], incorrect selection of medications similarly spelled appearing nearby the computer screen and physicians writing orders in the wrong electronic record are some of these

errors. Also, healthcare information technology can cause new kinds of errors, specific to the inherent cognitive complexity of human-computer interaction [24]. According to a study done by Vicente [25], inconsistencies in the system, like buttons, menus, and entry fields, may prolong medication order completion time or increase user errors by concealing or misrepresenting stored information. Also, disruption, incompleteness, and inappropriate charting are three major issues of EMR documentation [19]. The quality of nursing care crucially depends on accessing high-quality information related to patient's conditions [26].

In this research, we look deeper into the nurses' workflow related to EMR documentation to discover how medication administration patterns in EMRs can differ in terms of average process time and frequency inside and outside the patient room.

3 Methodology

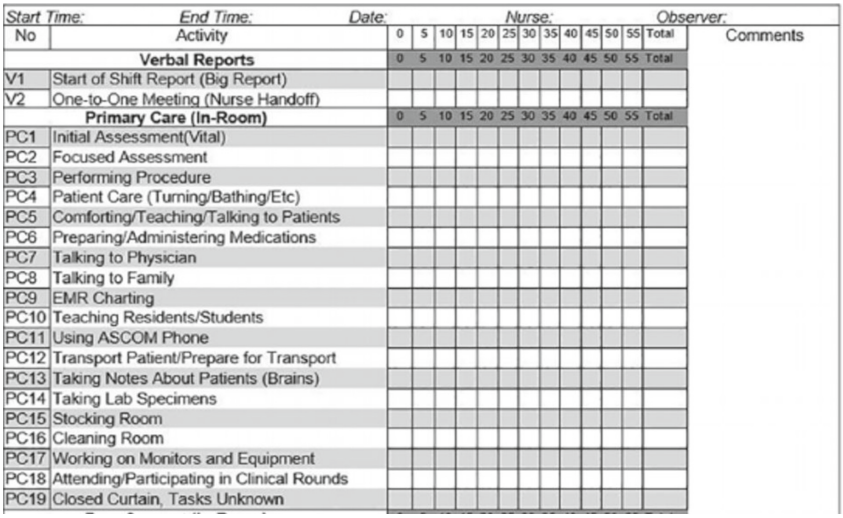
The time-motion study was conducted in the medical ICU (MICU) at the University Hospital, University of Missouri-Columbia. Nine ICU nurses participated in this study, and one to three nurses were observed on each observation day from 7:00 a.m. to 7:30 p.m. for 15 days from 2/17/2020 to 3/11/2020. All participants were registered nurses with a range of 1 to 26 years of ICU work experience. All participating nurses were informed about the time-motion study, and all collected information related to the nurses and patients was kept confidential. To minimize the Hawthorne effect, observers maintained a considerable distance from the participants and did not initiate any conversation with them. Besides, to maintain patient privacy, observers were not allowed to enter a patient room.

The studied MICU had two pods and a reception area in the center of the unit. There were nine single-patient rooms in each pod and a nurse station equipped with computers, monitors, tables, telephones, and a medicine cabinet.

All information related to the nursing documentation in the EMR system were recorded in the Real-Time Measurement System (RTMS) database. In this study, the RTMS log data was used to analyze nursing work patterns related to the EMR charting. All procedures done in this study were approved by the University of Missouri IRB.

Three graduate industrial and manufacturing systems engineering students and one senior undergraduate engineering student collected time and activity data during this study. The observers recorded the start and end time of each task done by ICU nurses and took notes about any special events in an observation form. Figure 1 shows the manual observation form used in this study for a time-motion study.

All nursing activities are categorized into five main groups: verbal report, primary care, peer support, out-of-room activities, and non-nursing activities [27]. RTMS data shows the time and EMR windows related to nurses' documentation. Nurse log ID, login time, number of clicks, pages accessed, every keystroke, and computer name for charting were provided in the RTMS.



Start Time:	End Time:	Date:	Nurse:	Observer:											
No	Activity	0	5	10	15	20	25	30	35	40	45	50	55	Total	Comments
	Verbal Reports	0	5	10	15	20	25	30	35	40	45	50	55	Total	
V1	Start of Shift Report (Big Report)														
V2	One-to-One Meeting (Nurse Handoff)														
	Primary Care (In-Room)	0	5	10	15	20	25	30	35	40	45	50	55	Total	
PC1	Initial Assessment(Vital)														
PC2	Focused Assessment														
PC3	Performing Procedure														
PC4	Patient Care (Turning/Bathing/Etc)														
PC5	Comforting/Teaching/Talking to Patients														
PC6	Preparing/Administering Medications														
PC7	Talking to Physician														
PC8	Talking to Family														
PC9	EMR Charting														
PC10	Teaching Residents/Students														
PC11	Using ASCOM Phone														
PC12	Transport Patient/Prepare for Transport														
PC13	Taking Notes About Patients (Brains)														
PC14	Taking Lab Specimens														
PC15	Stocking Room														
PC16	Cleaning Room														
PC17	Working on Monitors and Equipment														
PC18	Attending/Participating in Clinical Rounds														
PC19	Closed Curtain, Tasks Unknown														

Fig. 1. The manual observation form

4 Data Analysis

In this study, we combined data obtained from the time-motion study and RTMS to develop a hierarchical task analysis (HTA) chart for having a detailed view of the nurses' documentation workflow.

4.1 Hierarchical Task Analysis (HTA) Chart

By combining the data gained from the time-motion study and RTMS system, multiple HTA charts related to EMR documentation were created both inside and outside the patient room. The advantage of HTA chart is to break down a nurses' task into sub-tasks and provide a model for task execution, which helps us better understand ICU nurses'

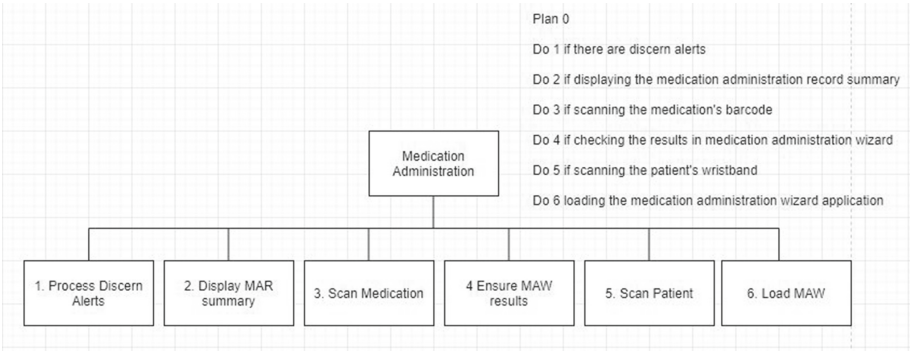


Fig. 2. The HTA chart for medication administration in EMRs

work patterns related to medication administration while doing EMR charting. Figure 2 shows the HTA chart for medication administration in EMRs.

To construct the HTA chart, all nursing tasks related to medication administration inside and outside the patient room categorized into six groups, including 1) process discern alerts, 2) display MAR summery, 3) scan medication, 4) ensure MAW results, 5) scan patient, 6) load MAW. To administer medications, nurses must complete all or a part of the above tasks. Table 1 shows a description of each of the HTA chart tasks.

Table 1. The description of tasks in the HTA chart

Task number	Task name	Description
1	Process discern alerts	The purpose of discern alerts window is to warn of missing patient data such as height/weight or allergies that provide decision support for an order. Also, this window will show nurses any discern alerts regarding the conflictions of a new medication order with the current one. There are several types of discern alerts depending on the nature of the nurses' activity
2	Display Medication Administration Record (MAR) summary	The Medication Administration Record (MAR) Summary is a view-only section that allows nurses to view all active, scheduled, unscheduled, PRN, and continuous medications for a specific patient. The MAR displays the medication orders, tasks, and documented administrations for the specific time frame
3	Scan medication	Scanning a medication's barcode to verify that the nurse is administrating the right medication, at the right dose, at the right time, to the right patient
4	Ensure Medication Administration Wizard (MAW) results	Reviewing and confirming all information related to the medication orders and sign them to store the results in the database
5	Scan patient	Scanning a patient's wristband can automatically show the patient's medications due, medical history, and verify the patient's identity. It also shows all the medications and dosages required or procedure about to be performed based on the records
6	Load Medication Administration Wizard (MAW)	Launching the Medication Administration Wizard (CareAdmin) application by clicking the Medication Administration icon on the organizer toolbar

5 Results

In this study, a one-way ANOVA was conducted to compare the patterns of EMRs for medication administration inside and outside the patient room in terms of average process time (see Table 2). There are significant differences in average process time between inside and outside the patient's room for tasks 1 ($P = 0.010$), 3 ($P = 0.009$), and 6 ($P = 0.038$) (see Table 3). These results will be further discussed in the next section.

Table 2. ANOVA results for the average process time of medication administration in EMRs

Location	Avg process time	StDev	F	P
In-Room	2.789	4.540	24.80	**0.00**
Out-of-Room	3.529	5.280		

Table 3. ANOVA results for the average process time of HTA chart tasks

Task number	Location	Average process time	StDev	F	P
1	In-Room	2.516	4.410	6.72	**0.010**
	Out-of-Room	3.613	5.573		
2	In-Room	1.811	3.163	1.95	0.163
	Out-of-Room	2.155	3.740		
3	In-Room	3.230	4.409	6.82	**0.009**
	Out-of-Room	4.453	6.404		
4	In-Room	3.920	5.673	3.32	0.069
	Out-of-Room	4.791	6.205		
5	In-Room	3.890	6.485	2.13	0.145
	Out-of-Room	4.689	6.195		
6	In-Room	2.283	3.506	4.32	**0.038**
	Out-of-Room	2.856	3.790		

6 Discussion and Limitations

The primary goal of this study was to analyze the different patterns of medication administration using EMR log data in a medical ICU and how these patterns can be different inside and outside the patient room in terms of average process time.

When nurses open the medication orders window by clicking the orders icon on the navigation ribbon at the left side of the EMR, they will see all of the patient's active orders, including medication orders. There are several types of alerts that nurses might see during the medication administration process including:

- An alert may appear when medication is hazardous to handle and requires appropriate personal protective equipment or should not be handled by pregnant or breastfeeding nurses.
- An alert may appear regarding the timing of giving the medication to the patient (too early or overdue).
- An alert may appear in case of the potential drug interaction between the administered medication and other medications that the patient has already taken. In this case, a drop-down box will be shown up with options for resolving the alert.

- An alert may appear regarding parameters under which medication should not be given (see Fig. 3).

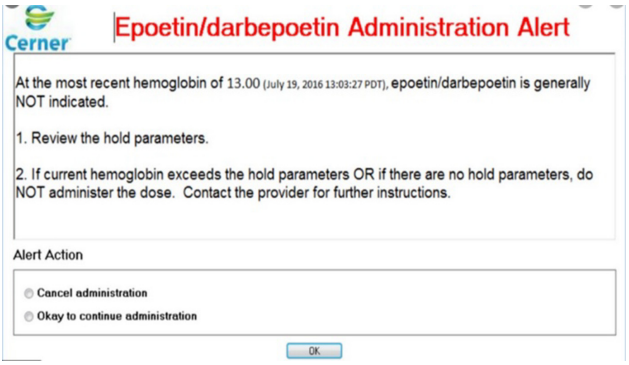


Fig. 3. A screenshot of a discern alerts regarding the medication issue

Table 3 shows a significant process time difference in task 1 (process the discern alerts) between inside and outside the patient room. ICU nurses usually spend more time processing discern alerts while working outside the patient room. One possible explanation might be related to the behavioral preferences of ICU nurses. Typically, ICU nurses prefer to check the potential conflicts between the new and current medication orders while working outside the patient room, because checking and reviewing the patient documentation for processing the discern alerts is a time-consuming process.

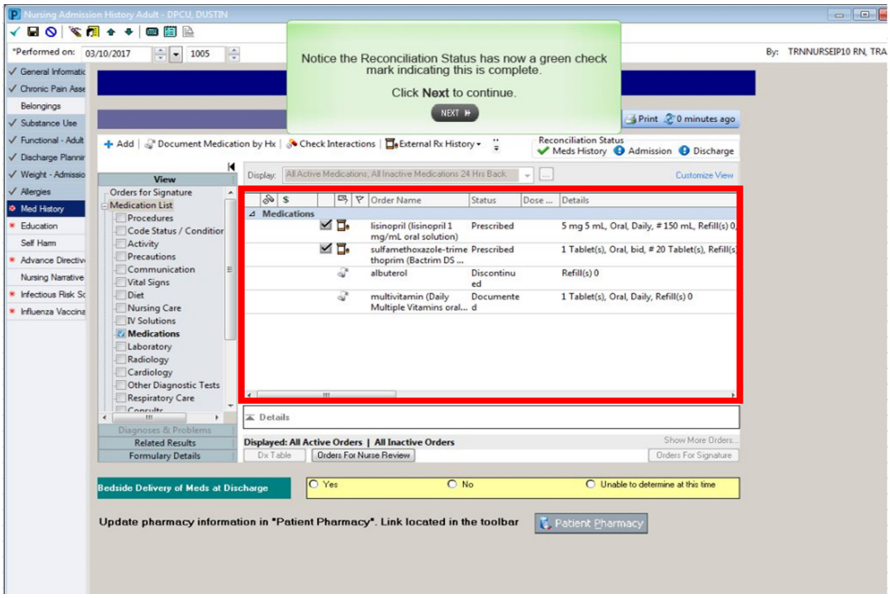


Fig. 4. A screenshot of scanning medication process in medication administration wizard

For task 3 (Scan Medication), ICU nurses need to scan a barcode on the box or a bottle of the medication when they administer and check expiration dates. A successful scan indicates that a medication order matches the results represented on the medication administration wizard (MAW) via a checkmark (see Fig. 4).

If the required dose is more than what has been shown in the system, the nurse needs to scan the medication's barcode multiple times to meet a required dose. Table 3 shows a significant difference in scanning medication between outside and inside the patient room. ICU nurses usually spend more time to scan a medication's barcode while working outside the patient room. One possible explanation could be an additional process time for checking the expiration date of the medicines outside the patient room. Nurses will get medication from medicine cabinets and prefer to check expiration dates outside a patient room while preparing and giving them to patients inside the room. Checking the expiration date of medication will take longer since nurses need to open the medication boxes or look for the medication bottle expiration date.

For task 6, the medication administration wizard (MAW) shows ICU nurses which medication is currently due to be given and scheduled in the future up to 75 min, overdue medication, PRN medication, and any continuous infusions. Also, MAW provides detailed information about each patient's medications (see Fig. 5). According to the results, ICU nurses spend a longer time using the MAW outside the patient room compared to the in-room. One of the ICU nurses' top priorities is preparing and giving the patient medication while doing focused assessments in a patient room. Thus, ICU nurses usually use the MAW to see what medicine is currently due to be given while working inside the patient room. However, they will spend more time using the MAW to check

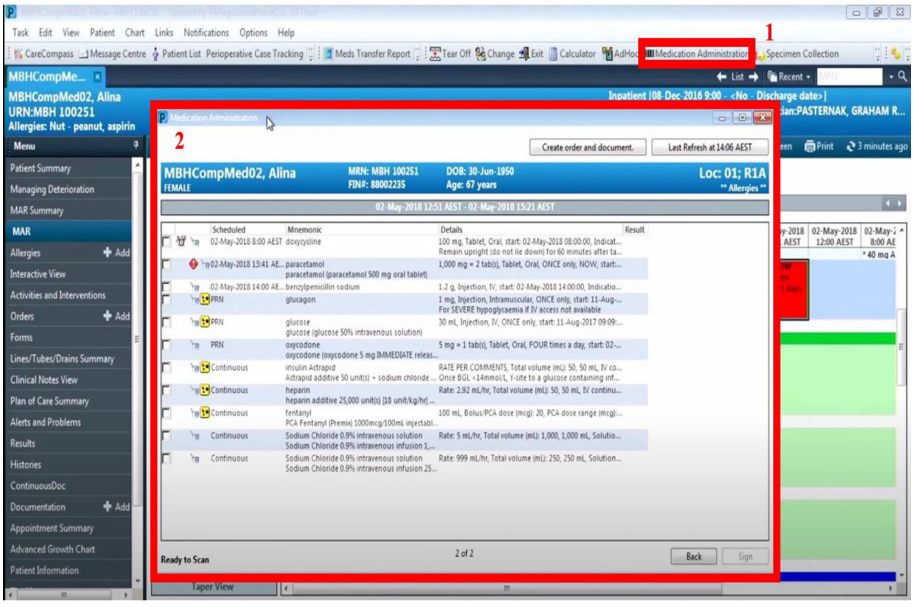


Fig. 5. A screenshot of the medication administration wizard

the medication orders for the future and complete additional medication orders while working outside the patient room. ICU nurses must process more information while reviewing and updating medication orders.

Although the findings of this study revealed some of the patterns related to medication administration inside and outside the patient room, there are several limitations. First, nurses' interruption was not considered when we developed the HTA chart. Even Though ICU nurses experience multiple interruptions during EMR documentation, those interruptions were not included in the data analysis. Also, we only collected data from day-shift nurses. Thus, we recommend including night-shift nurses to compare how their patterns are different than our findings. Another limitation of this study is the small sample size. We only collected the data from nine nurses. It would be better to have more participants for supporting our results in a future study. Lastly, we did not consider the effect of urgent situations, such as surgeries, patient coding. These situations might affect ICU nurses' workflow and process time in the ICU.

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