Effect of Patient Acuity of Illness and Nurse Experience on EMR Works in Intensive Care Unit

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Abstract. The objective of this study is to analyze the impact on the nurse's process time during the electronic medical record (EMR) charting task in an intensive care unit (ICU). The dynamic uncertainty of clinical tasks in the ICU can make it difficult for nurses to take care of critically ill patients. According to the literature, EMR documentation is one of the tasks on which nurses spend most of their time during the shift. To understand and improve the EMR documenting process, a time & motion study was conducted in a medical ICU at the University of Missouri Hospital. Data was collected on processes and standard times of every EMR activity performed by ICU nurses. Based on the results of this study, hierarchical task analysis (HTA) charts were developed and analyzed nurse's workflow during EMR documentation. After that, a simulation model was developed for documenting in the EMR in an ICU.

Keywords: Electronic medical record systems · Simulation · Patient acuity level Nurse experience

1 Introduction

An intensive care unit (ICU) is one of the most complex and dynamic places in a hospital. Healthcare providers must perform various clinical tasks while managing patient health records. Moreover, they must spend time to understand how to use IT technologies in their work areas. IT technologies have been increasingly influencing the healthcare sector [1]. IT systems such as the electronic medical records (EMR) were introduced to improve the safety and quality of care, in part by helping the healthcare professionals' carry out their tasks more efficiently. However, most studies have noted a substantial increase in the time spent documenting when using an EMR due to the high demand of documenting patient-related data [2]. Overall healthcare professionals are confronted with an increasing need for high quality and timely patient-oriented documentation [3]. This study considers the documentation done by nurses as the implementation of the EMR system was found to have a higher influence on nurses' documentation time than

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the physicians' [2]. It is important to understand how nurses perform documentation in the ICU to guide improvements in the quality of healthcare delivery processes as nurses perform multiple tasks associated with the daily monitoring of patients. To improve the process of EMR documentation, the factors that increase process time and decrease throughput should be identified and eliminated from the existing process. Various studies in the past identified multiple factors. In this study, we considered patient acuity level and nurse experience as two primary factors impacting the nurse's process times on EMR documentation. To further understand and improve the EMR documentation process, a time and motion study was conducted in a medical ICU at the University of Missouri Hospital. Through the study, we identified the detailed steps of the documentation process conducted by ICU nurses. Multiple hierarchical task analysis (HTA) charts were developed using the data from the time and motion study. According to the research done by Parameshaewara, Kim [4], an HTA chart can provide detailed information regarding the various decisions and steps of the nurse's workflow in an emergency department. A simulation model was then developed using the HTA charts from the time and motion study. The simulation model was used as a tool to understand the workflow and measure the process time during EMR documentation in an ICU.

2 Literature Review

Nursing documentation has been viewed as a vital part of the nurse's work since the time of Florence Nightingale [5]. Studies carried out by Hendrich [6] and Hefter [7] have shown that nursing documentation consumes a tremendous amount of time during a shift. In a paper documentation system, illegible handwriting, manual data entry, and searching for lab results, orders, or patient records are some of the issues that can result in inefficient workflow and poor productivity [8]. Hence, the documentation task has transitioned from traditional paper-based systems to electronic medical record (EMR) systems. EMR systems can increase the quality and efficiency of patient care, and support healthcare professionals in their daily task [3].

Despite the benefits, EMR systems still have several drawbacks (e.g., spending longer time for EMR documentation) [9]. The study done by Hripcsak, Vawdrey [10] found that the nurses spent a significant amount of time documenting in EMRs. The time and motion study carried out by Bosman [11], Bian, Wade [12], also showed that the documentation time was significantly increased due to the EMR system. Researchers have tried to identify the factors impacting documentation time in EMR systems. According to Bradshaw [13], access to the EMR system from a patient's room could be one of the influential factors of EMR documentation. The study identified that using the EMR system present in the patient's room by the bedside had increased the documentation time. Bosman, Rood [14] found that the type of content documented also had an impact on the documentation time. The study of complexities in nursing documentation done by Cheevakasemsook, Chapman [15] had identified three direct and three indirect factors affecting the documentation time using multiple methods such as in-depth interviewing; participant observation; nominal group processing; focus group meetings; time and motion study of nursing activities; and auditing of completeness of nursing

documentation. The three direct factors were interruptions in documentation, incomplete charting, and inappropriate charting while the three indirect factors identified were limited nurses' competence, ineffective nursing procedures and inadequate nursing staff development. The factors identified by these studies are directly related to EMR systems or nurses. Among all the factors identified in previous studies, our study focusses on the patient's morbid conditions and the nurse's competence, which is associated with the nurse's experience level.

2.1 Patient Severity

Analyzing and predicting the mortality and morbidity of the patients is of rising importance in the healthcare system [16]. The systems that analyze and predict the mortality and morbidity rates provide information to healthcare personnel about the condition of the patient. These systems can be used as a comparative approach for assessment of performance in an ICU [16]. There are many scoring systems to predict the mortality and morbidity rates. Among them, we used Sequential Organ Failure Assessment (SOFA) score and Charlson Comorbidity Index (CI) in this study. The combination of both scoring systems can accurately evaluate the seriousness of patient's conditions.

SOFA describes the time course of multiple organ dysfunctions using a limited number of routinely measured variables [17] and considers the organ dysfunction into account while calculating the prediction rates. The SOFA score is primarily used to assess critically ill patients in ICU [18]. The SOFA score is composed of scores from six organ systems (respiratory, cardiovascular, hepatic, coagulation, renal, and neurological), graded from 0 to 4 according to the degree of dysfunction/failure [19]. The reliability of the SOFA score to predict mortality is complicated by different derivatives of the SOFA score such as the Fixed Day SOFA and Delta Sofa Score. The Fixed Day SOFA score can help in comparing mean organ dysfunction in the trials while Delta SOFA allows comparing the trajectory of organ dysfunction from the baseline in the trial arms. Other SOFA derivatives contain the score at the day of death or discharge, or the mean or maximum score during the ICU stay.

The Charlson Comorbidity index is designed to classify prognostic comorbidity in longitudinal studies [20]. It is used in various studies to classify patients based on the influence that the comorbid conditions have on the overall survival of the patient. The CI scores provide a readily applicable, valid and straightforward method for evaluating the risk of death from the comorbid disease. This index also includes the consideration of the seriousness and the number of comorbid diseases.

2.2 Nurse Experience

The other factor in this study, nurses' competence, can be associated with the nurse's experience. Cheevakasemsook, Chapman [15] by the interviewing process found out that some nurses were unable to create a nursing plan while some nurses felt their charting was dubious due to lack of confidence. These factors are a result of lack of proper training and experience for the nurses. Benner [21] interpreted skill acquisition and clinical judgment between the high experience and low experience nurses. The study

showed that the high experience nurses were able to change their perception of the nature of the situation and act accordingly in response to the new situation. Thus, this study considers nurses' experience as one of the important factors for increasing in the documentation time as we assume that the highly experienced nurse may perceive more details in an unfolding situation which they document in the EMR.

3 Methodology

3.1 Time and Motion Study

The time and motion study was conducted in the Medical intensive care unit (MICU) at the University Hospital, University of Missouri, Columbia [22]. The MICU had 18 single patient rooms and a reception area located at the center. Eleven nurses participated in the study voluntarily, and three to four nurses were observed on each observation day during the day shift hours (7:00 am to 7:30 pm). The volunteer nurses were all registered nurses and had at least 1-year experience of working in an ICU. The nurses were well informed about the time and motion study and the information collected about the nurses and the patients were kept confidential. Two observers observed the volunteer nurses on the observation day. The observation was conducted one day per week for thirteen weeks. The observers recorded the start time and end time of each task done by the nurses in an observation form and made notes for any special events that took place. To minimize the Hawthorne effect, the observer maintained a considerable distance from the participants and did not initiate any conversation with the nurses. To ensure patient privacy, the observers did not enter the patient room.

From the data collected using the time and motion study, the nurses were aggregated into four groups. The groups were created based on the illness severity level of the patients assigned to the nurse and the nurse's experience level. A HIGH patient severity level indicates that the patients assigned to the nurse had high SOFA score. The SOFA score is considered to be high if the value is larger than the threshold value of 8.6 and the CI score is considered to be high if the value is greater than the threshold value of 7.3. The threshold values are the mean values of the SOFA and CI scores for the collected data set. Based on regression analysis, it was identified that the SOFA score was more significantly influential than the CI score. Thus, the SOFA score was considered as patient's illness severity level. The nurse experience is considered to be HIGH if the nurse had experience working in an ICU for more than 2 years. Based on the threshold values, the four groups are shown in Table 1.

Table 1. Four groups based on patient severity level and nurse experience

Group number	Patient severity level	Nurse experience level
1	HIGH	HIGH
2	HIGH	LOW
3	LOW	HIGH
4	LOW	LOW

3.2 Data Analysis

The time and motion study data was combined with the EMR system logs called the Real-Time Measurement Systems (RTMS) data to obtain a more detailed view of nurses' documentation workflow. The RTMS data provides detailed information of the usage of the EMR system. From the RTMS data, it is possible to identify the section of the EMR system that was accessed to carry out charting and the time taken for each charting. The RTMS data also gives information related to which computer was used, a number of clicks that the nurse made during the charting and the moving distance of a mouse pointer. By combining the RTMS data and the observation data, we were able to analyze the accurate view of how the nurses used EMR systems.

3.3 Hierarchical Task Analysis (HTA)

The hierarchical task analysis (HTA) technique was used to create a view of the EMR charting process in the MICU. The HTA chart revealed the ICU nurses' EMR charting pattern by systematically breaking down the nurse's charting procedure into different task levels and goals. The HTA chart consists of high-level tasks and subtasks, and each level of tasks has its own goals and sub-goals. Once the goals and sub-goals were identified, a plan was created for each level of tasks. The plan helps in identifying the order in which each subtask needs to be carried out to achieve the goal of the high-level task. The plan also states the conditions that need to be satisfied to perform the subtasks. Figure 1 shows the HTA for the EMR charting process up to level 2. The top-level goal of the HTA chart is to complete documenting in the EMR system. The multiple subgoals must be completed to achieve the goal shown in level 1, and the subtasks in level 2 need to be achieved based on the given conditions to meet each subgoal. Here, the plan 0 shows how the tasks in level 1 need to be carried out to achieve the top-level goal. Plans 1, 2, 4, 5 shows how the subtasks in level 2 need to be carried out to achieve the goals of level 1. This way, the HTA chart helps us identify the different requirements of each task associated with the EMR process. Based on the description of the HTA chart, a simulation model using discrete event simulation was developed to analyze the impact on the nurse's process time during EMR documentation in ICU.

3.4 Simulation Model

The simulation model was developed using the HTA chart and further breaks down a high-level goal into a chain of tasks. The simulation model helped us to improve our understanding of the EMR charting process that is currently being followed by the nurses in the ICU. The simulation model was developed using the Micro Saint Sharp software. The simulation model is similar to HTA chart wherein, all the goals of a particular level are to be completed to move to lower level goals in the model. The simulation model shows the step by step procedure that the nurses follow to chart on the EMR system. The timing information used in the simulation model was obtained from the RTMS data in the form of mean time and standard deviation. The main purpose of modeling was to determine the different factors that influence the time taken by the nurses to document

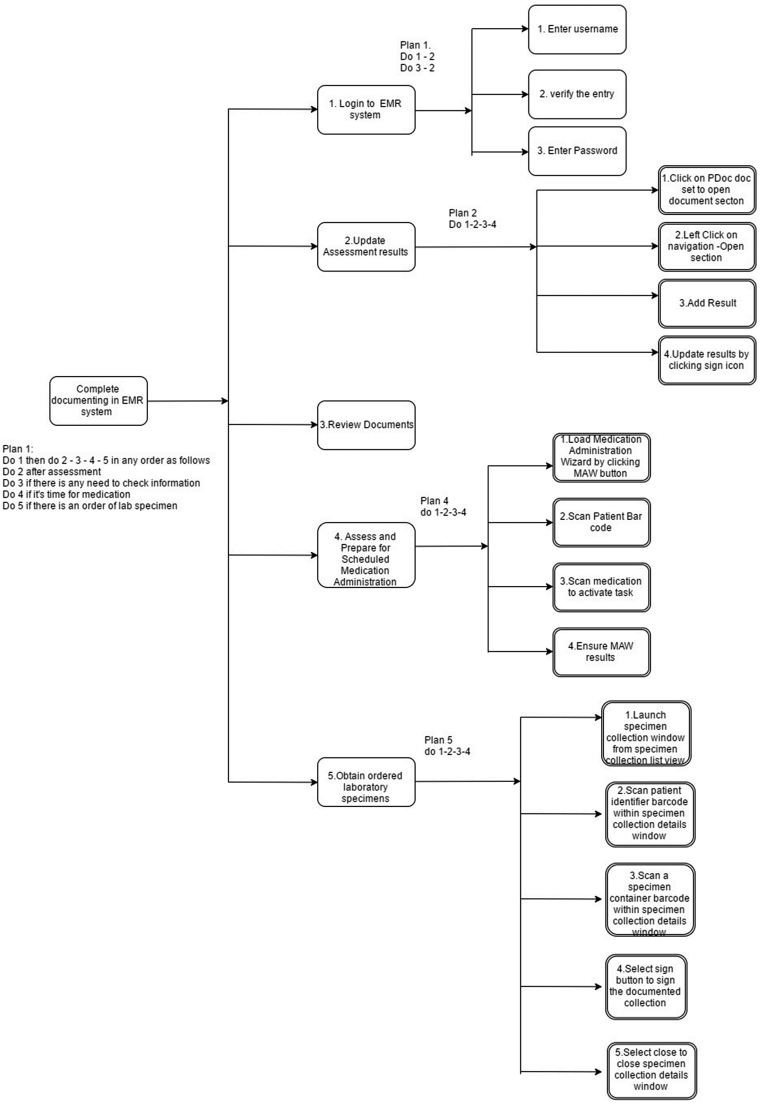

Fig. 1. HTA chart for EMR process

on the EMR system. Figure 2 shows a screenshot of the ICU nurse's discrete event simulation model for EMR documentation.

The simulation model shown in Fig. 2 consists of networks and tasks that represent the charting process. Each method in the model represents a human task and is considered as a node. In the model, the nodes are connected by arrows to denote the sequence in which the tasks were performed. The simulation model allowed us to create a real-time scenario of the nurse's documentation process on the EMR system and conduct experiments to determine the factors influencing the documentation time.

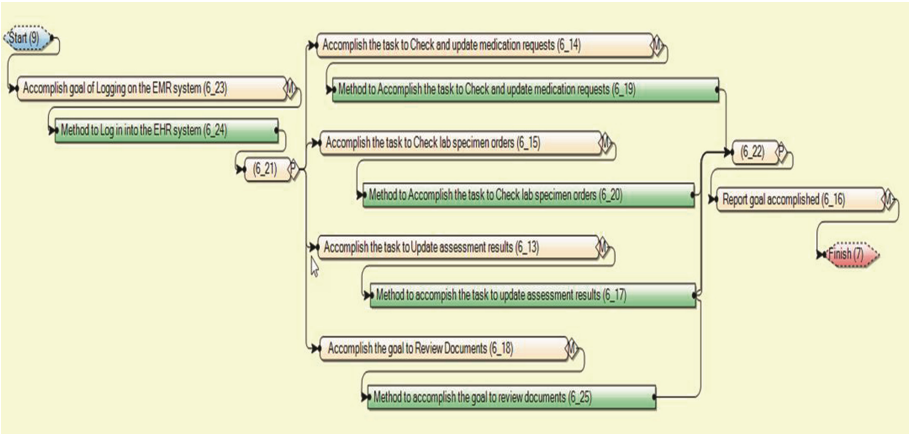

Fig. 2. ICU Nurse's discrete event simulation model to document on EMR system

4 Results

The simulation model was executed to collect the EMR documentation time per a task. According to the RTMS data, the ICU nurses used the EMR system 49.2 times during the 12-h day shift. Based on this, we assumed that average frequency of accessing the EMR system was 1,476 times per month. Hence, the simulation was run 1,476 times, and the simulation results were collected. After that, a one-way ANOVA was conducted to compare the effect of patient severity level and nurse experience on EMR documentation time between the groups. The interval plot from the ANOVA analysis is shown in Fig. 3.

The ANOVA analysis showed that there was the significant effect of patient severity level and nurse experience on EMR documentation time at $p < .05$ [$F(44.12)$, $P < 0.001$]. The mean process time of EMR documentation was significantly longer for Group 1 and Group 3 followed by Group 4 and Group 2 (Group 1 and Group 3 $\gg$ Groups 4 $\gg$ 2). To identify the impact of patient severity level and nurse experience on the content charted, Fischer test was conducted for each type of charting and the four groups. The interval plots for the analysis is shown in Fig. 4.

The analysis showed that the patient severity level and nurse experience had a significant impact on the content being charted. For assessment, the mean process time for EMR documentation was significantly longer Group 1 followed by Group 3, Group 2 and Group 4 (Group 1 $\gg$ Group 3 $\gg$ Group 2 $\gg$ Group 4). For review documents, the high experience nurses took significantly longer time than the low experience nurses (Group 1 and Group 3 $\gg$ Group 4 $\gg$ Group 2). For medication, Group 3 nurses took longer time than Group 1, Group 4, Group 2 (Group 3 $\gg$ Group 4 and Group 1 and Group 2). The next section discusses more in-depth about the impact of patient severity level and nurses experience on each type of charting carried out by the nurses.

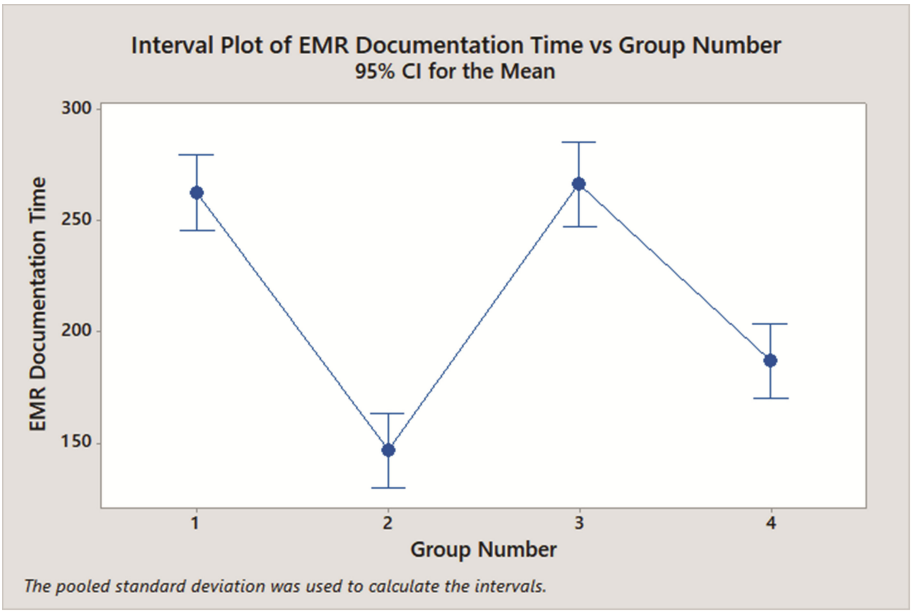

Fig. 3. Interval plot for the time taken to document on EMR system (secs).

5 Discussion and Conclusion

The ANOVA results from Fig. 2 showed that the high experienced nurses charted for a significantly longer time on the EMR system than the low experienced nurses. The more experienced nurses used the EMR system after they conducted multiple assessments whereas the less experienced nurses documented after each assessment. When the more experienced nurses recorded multiple assessment results together, they must handle more information during the EMR documentation compared to the low experienced nurses. It resulted in spending longer time for the EMR charting. On the other hand, the low experienced nurses documented a small amount of data based on the specific predefined charting steps because they were not fully adopted in the EMR environment. According to the previous study [23], the user's clinical experience can significantly influence the pattern of the EMR usage. Also, Moody and Slocumb [24] found that the user's experience level related to an EMR system played a significant role in the EMR documentation. Although the EMR system is designed to fit its intended purpose, nurses must take time to learn the system [25]. For that reason, the nurses showed the different patterns of EMR documentation based on their experience level.

According to the group comparisons (see Fig. 4), for the groups 1 and 3, the average time of documenting medication request, reviewing documents and lab specimen information were significantly different from the time taken by the nurses in groups 2 and 4. However, for the assessment charting, both the nurse experience level and the patient severity level significantly influenced the documentation time. It means that the patient

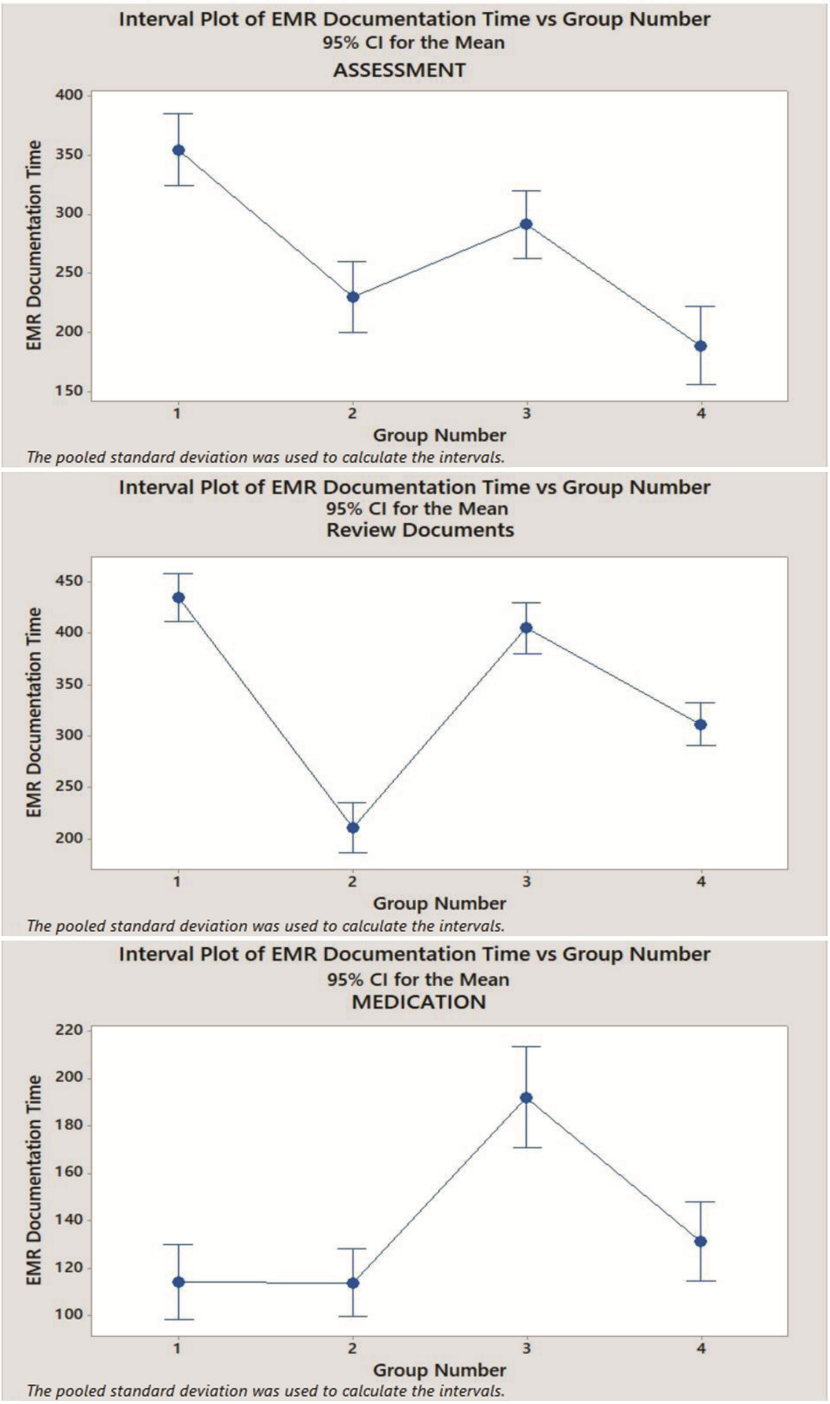

Fig. 4. Interval plots for the different content charted on the EMR system.

severity level had an impact on the assessment charting while all other charting were influenced only by the nurse experience level.

The assessment charting section in the EMR system is where the nurses chart all the results of the assessment conducted during the shift. The nurses performed "initial assessment" at the beginning of the shift. After that, "focused assessment" was performed every hour until the end of the shift. The nurses in group 1 spent longer time to documenting the assessment results because of more results to be charted in the EMR system.

For documenting administered medication in the EMR system, the nurses of groups 3 and 4 took longer time than the nurses of groups 1 and 2. We presume that, when a patient was very sick, the medications that the patient usually took at home were discontinued as they were too sick to take them and were restarted when they became less sick. Thus, the nurses assigned to less severe patients spent longer time in medication administration section. This documentation time is also related to medication requests, and that is the reason why the nurses who assigned in the group 4 showed a significantly longer overall EMR documentation time than the group 2 (see Fig. 3).

6 Limitations and Future Research

There are some limitations in this study. First, nurse's interruption was not considered in our simulation model. Although the ICU nurses experience multiple interruptions during their shift, we did not include the EMR process deviations caused by interruptions in the model. Another limitation is that the model did not consider the workflow variations caused by nurse's workload and emergency situations. The nurse's workload and urgent situations can significantly impact the process time and nurse's care flows in ICU. Hence, for future study, we will expand our simulation model to include the components related to interruptions, nurse's workload, and emergency situations to identify the impact on EMR works in ICU.

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References

1. Haux, R., et al.: Healthcare in the information society. A prognosis for the year 2013. Int. J. Med. Inform. **66**(1), 3–21 (2002)
2. Poissant, L., et al.: The impact of electronic health records on time efficiency of physicians and nurses: a systematic review. J. Am. Med. Inform. Assoc. **12**(5), 505–516 (2005)
3. Ammenwerth, E., Spötl, H.: The time needed for clinical documentation versus direct patient care. Methods Inf. Med. **48**(1), 84–91 (2009)
4. Parameshwara, N., et al.: NGOMSL simulation model in an emergency department. In: Proceedings of the 2016 Winter Simulation Conference. IEEE Press (2016)
5. Iyer, P.W., Camp, N.H.: Nursing Documentation: A Nursing Process Approach. Mosby Inc., St. Louis (1999)

6. Hendrich, A., et al.: A 36-hospital time and motion study: how do medical-surgical nurses spend their time? Perm. J. **12**(3), 25 (2008)
7. Hefter, Y., et al.: A time-motion study of ICU workflow and the impact of strain. Crit. Care Med. **44**(8), 1482–1489 (2016)
8. Mador, R.L., Shaw, N.T.: The impact of a Critical Care Information System (CCIS) on time spent charting and in direct patient care by staff in the ICU: a review of the literature. Int. J. Med. Inform. **78**(7), 435–445 (2009)
9. Saarinen, K., Aho, M.: Does the implementation of a clinical information system decrease the time intensive care nurses spend on documentation of care? Acta Anaesthesiol. Scand. **49**(1), 62–65 (2005)
10. Hripcsak, G., et al.: Use of electronic clinical documentation: time spent and team interactions. J. Am. Med. Inform. Assoc. **18**(2), 112–117 (2011)
11. Bosman, R.J.: Impact of computerized information systems on workload in operating room and intensive care unit. Best Pract. Res. Clin. Anaesthesiol. **23**(1), 15–26 (2009)
12. Bian, D., et al.: A novel virtual reality driving environment for autism intervention. In: Stephanidis, C., Antona, M. (eds.) UAHCI 2013. LNCS, vol. 8010, pp. 474–483. Springer, Heidelberg (2013). https://doi.org/10.1007/978-3-642-39191-0_52
13. Bradshaw, K.E., et al.: Computer-based data entry for nurses in the ICU. MD Comput. Comput. Med. Pract. **6**(5), 274–280 (1989)
14. Bosman, R., et al.: Intensive care information system reduces documentation time of the nurses after cardiothoracic surgery. Intensive Care Med. **29**(1), 83–90 (2003)
15. Cheevakasemsook, A., et al.: The study of nursing documentation complexities. Int. J. Nurs. Pract. **12**(6), 366–374 (2006)
16. Juneja, D., et al.: Comparison of newer scoring systems with the conventional scoring systems in general intensive care population. Minerva Anestesiol. **78**(2), 194–200 (2012)
17. Vincent, J., et al.: The SOFA score to describe organ dysfunction/failure. On behalf of the Working Group on Sepsis-Related Problems of the European Society of Intensive Care Medicine. Intensive Care Med. **22**(7), 707–710 (1996)
18. Frohlich, M., et al.: Which score should be used for posttraumatic multiple organ failure? - Comparison of the MODS, Denver- and SOFA- Scores. Scand. J. Trauma Resusc. Emerg. Med. **24**(1), 130 (2016)
19. Vincent, J.-L., et al.: Use of the SOFA score to assess the incidence of organ dysfunction/failure in intensive care units: results of a multicenter, prospective study. Crit. Care Med. **26**(11), 1793–1800 (1998)
20. Charlson, M.E., et al.: A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J. Chronic Dis. **40**(5), 373–383 (1987)
21. Benner, P.: Using the Dreyfus model of skill acquisition to describe and interpret skill acquisition and clinical judgment in nursing practice and education. Bull. Sci. Technol. Soc. **24**(3), 188–199 (2004)
22. Song, X., Kim, J.H., Despins, L.: A Time-Motion Study in an Intensive Care Unit using the Near Field Electromagnetic Ranging System. In: Proceedings of the IIE Annual Conference. Institute of Industrial and Systems Engineers (IISE) (2017)
23. Miller, L., et al.: Novice nurse preparedness to effectively use electronic health records in acute care settings: critical informatics knowledge and skill gaps. Online J. Nurs. Inform. (OJNI) **18**(2) (2014)
24. Moody, L.E., et al.: Electronic health records documentation in nursing: nurses' perceptions, attitudes, and preferences. Comput. Inform. Nurs. (CIN) **22**(6), 337–344 (2004)
25. Leonard-Barton, D.: Implementation as mutual adaptation of technology and organization. Res. Policy **17**(5), 251–267 (1988)