Journal of Hospital and Healthcare Administration

Research Article

Errors Associated with the Rights of Medication Administration at Hospital Settings

Pearl C. Kim[1], Jay J. Shen[1*], Alona D. Angosta[2], Kaitlyn Frakes[1], Casey Li[3]

[1]Department of Health Care Administration and Policy, University of Nevada Las Vegas, USA

[2]School of Nursing, University of Nevada Las Vegas, USA

[3]Green Valley High School, USA

[*]**Corresponding author:** Jay J. Shen, Department of Health Care Administration and Policy, University of Nevada Las Vegas, USA. Tel: +1-7058955830, Email: jay.shen@unlv.edu

Abstract

Aims & Objectives: To investigate the associations between nurse-related medication errors by examining: (a) the Rights of medication administration and hospital units, (b) the Rights of medication administration and drug classes, and (c) interactions between hospital units and drug classes regarding the Rights of medication administration.

Background: Medication errors are associated with the five Rights of medication administration (right patient, right drug, right dose, right time, and right route), hospital units, and drug classes, however these factors are not often examined simultaneously.

Design & Methods: 1,273 medication error incident files from the risk management departments of five acute-care community hospitals in the southwestern United States were analyzed. Descriptive statistics and the Chi-square test were used in data analysis.

Results: Giving medications at the wrong time was the most frequent cause of error in medical surgical units (54.1%) and intensive care units (51.7%). Errors related to cardiovascular drugs were commonly due to wrong dosages (40.2%) and wrong time of administration (40.2%). In addition, errors related to wrong dosages of antimicrobials were strongly associated with errors in intermediate care units (46.4%) and medical surgical units (52.1%), while wrong dosages of cardiovascular drugs were highly correlated with errors in intensive care units (49.0%) and intermediate care units (50.0%).

Conclusion: Interactions between hospital units and drug classes were found in regard to being associated with the Rights of medication administration, especially with errors in wrong time and wrong dose.

Relevance to clinical practice: To reduce medication errors and improve patient safety, continuing education for nurses regarding basic pharmacology, factors contributing to medication errors such as drug classes and hospital units, and preventing medication errors should be a priority. Medication administration policies and guidelines should be continuously updated and enforced.

Keywords: Health Care Policy; Medication Errors; Nursing; Patient Safety; Rights of Medication Administration

What does this study contribute to the wider global clinical community?

- Provides insights into nurse-related medication errors by examining interactions between hospital units and drug classes regarding the Rights of medication administration.

- Identifies the need to develop education programs targeting specific hospital units and drug classes associated with the Rights of medication administration

- Identifies the need for revised pharmacology guidelines to address potential interactive effects between drug classes and hospital units on medication error.

Introduction

Medication Administration Errors (MAEs) are among the most common medical errors in health care settings. They affect patient safety, mortality rates, length of hospital stays, and related costs [1-3]. Serious, preventable medication errors occur in 3.8 million inpatient admissions and 3.3 million outpatient visits every year in the United States, costing approximately $20.6 billion annually [4]. The Institute of Medicine estimated that approximately 7,000 deaths per year in the US were attributed to preventable medication errors [5].

Background

A medication error is 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. Such events may be related to prescribing, ordering, dispensing, administering, or monitoring the drug" [6]. Nurses are the largest group of health professionals and have the last opportunity to prevent medication errors [7]. It is reported that approximately 64.6% of nurses have committed MAEs. However, 39.9% of medication errors by nurses are not reported, indicating the incidence of nurse-related medication errors is higher than reported [8].

In hospitals, there are five stages of the medication process: ordering/prescribing, transcribing and verifying, dispensing and delivering, administering, and monitoring and reporting [5]. Nurses are involved in all stages of the medication process except ordering/prescribing. Our study concentrated on the "administering" stage and examined nurse-related medication errors [9]. During the administering stage, specifically, Five Rights of Medication Administration (Five Rights) are emphasized in several nursing guidelines to prevent and reduce nurse-related MAEs [10]. They are right patient, right drug, right dose, right time, and right route. Errors associated with these Five Rights may be grouped differently, from Five Rights to 15 Rights however, based on the data collected, we added documentation errors and wrong technique, along with the Five Rights, to create a total of Seven Rights in our study [11].

Studies show that nurse-related medication errors often take place during the medication administration process, such as wrong time, wrong dose, or by omission of the medication [12-14]. These medication errors usually occur in hospital units and are often associated with drug classes. Medical surgical units, Intensive Care Units (ICU), Intermediate Care Units (IMCU), and Emergency Departments (ED) are among the most error-prone hospital units [15-17]. Further, drug classes related to MAEs vary among hospital units, although cardiovascular drugs, antibiotics, electrolytes, analgesics, and anti-diabetics are the most common drugs associated with MAEs [15,18-19].

To find a successful intervention to decrease MAEs, potential causes of MAEs need to be identified. According to the Reason's conceptual model, the causes of MAEs in hospitals are a combination of active failures (e.g. errors caused by individuals via unsafe acts, slips and lapses, knowledge and rule-based mistakes, or violations) and latent conditions (e.g. amount of workload and skill mix, general work environment, communication, and organizational decisions) [20]. As said by the Swiss Cheese Model of system accidents, "the system produces failure when a hole in each slice momentarily aligns and permits trajectory of accident opportunity" [20]. The causes of MAEs in hospitals could be explained from aligning a series of barriers in terms of latent conditions of error-prone hospital units, drug classes, and active failures of the Seven Rights. Many studies have identified the cause of errors in hospital settings however most of them focus solely on one single factor, such as Rights of Medication Administration (Rights), hospital unit, or drug class [15-19].

Nevertheless, medication errors may well be related to multiple factors. For instance, a specific Right may be associated with a certain drug class or a hospital unit. MAEs in more error-prone hospital units may be associated with a particular drug class that is related to certain Rights. From this standpoint, much of the research on MAEs has important limitations. Moreover, most existing studies have been based on subjective, self-reported surveys potentially with inherent reporting bias [21-22]. Others are based on retrospective chart reviews that may affect the validity and reliability of the data [14]. Direct observation is often used in studies and may introduce the Hawthorne effect that nurses being observed may act differently in the presence of an observer [10,12,23]. Studies based on objective incident reports often have very small sample sizes that seriously limit the generalizability of their findings [10,14].

This study, based on medication error incident reports, examined associations between: (a) the Rights and hospital units, (b) the Rights and drug classes, and (c) potential interactions between hospital units and drug class on the Rights.

Methods

Data

Data were extracted from a prior study being described elsewhere [24]. In that study, the case group was the medication error group which included medication incidents and associated nurses. The control group included nurses who did not have medication errors. Medication error incident information was obtained from medication error files kept at the risk management departments of five short-term acute community hospitals in the Southwestern region of the United States [24]. Our study only focused on the medication error case group that included information for 1,276 medication error incidents. After three records with missing values were excluded, the final number of observations was 1,273. The study was approved by a university's institute review board and the Western Institutional Review Board.

Measures

This study examined MAEs during the administration stage, which predominantly falls into the nursing scope of practice [7]. We categorized the Seven Rights according to the administration phases. They were reflected by wrong dose (e.g. wrong infusion), wrong time (e.g. wrong frequency, wrong duration of medication administration, omission of dose), documentation error or wrong documentation (e.g. medication given without order), wrong route (e.g. administration of dose in a different form or doses given in the wrong site), and wrong technique (e.g. exclusion or incorrect performance of a procedure ordered by the prescriber immediately before administration of each dose of medication) [22].

The hospital units where MAEs occurred most often were cardiology, the Emergency Department (ED), Intensive Care Units (ICU), Intermediate Intensive Care Units (IMCU), medical-surgical, and maternity. We followed the Anatomical Therapeutic Chemical (ATC) system to classify drugs as cardiovascular, antimicrobial, endocrine, and neurologic [25]. In addition, consequences of MAEs were grouped into four categories, from the least to the most severe: 1) potential to cause harm, 2) error affected the patient but did not cause harm, 3) need to increase patient monitoring but no harm, and 4) temporary harm but treatment needed.

Results of our classification of the data were summarized using descriptive statistics. Associations of the Seven Rights with hospital units and drug class were examined by the binary analysis using the Chi-square test. Due to small numbers in some hospital units and drug classes (n < 30 for hospital unit and n < 30 for drug class), we only applied the Chi-square analyses on more frequent hospital units, drug classes, and the Seven Rights. They included MAEs related to wrong time/dose, documentation errors, the medical-surgical unit, IMCU, and ICU. Also included were cardiovascular, antimicrobial, and endocrine drug classes, as well as electrolytes. Further, we analyzed medication errors in regard to associations of hospital units, and the Seven Rights and drug class, respectively.

Results

More than half of medication errors occurred during medication administration (84.7%) and 6.2% occurred during the monitoring stage (Table 1). MAEs tended to occur in medical surgical units (34.9%), ICUs (17.4%), IMCUs (13.2%), EDs (7.8%), rehabilitation units (5.9%), and maternity units (3.3%). Relative to medication error consequences, 64.8% of medication errors reached patients, but did not cause harm. High frequencies of MAEs were associated with cardiovascular drugs (21.7%), antimicrobials (19.0%), endocrine/metabolism drugs (11.8%), and electrolytes/nutrition/minerals (11.6%). As for the Seven Rights, wrong time (37.6%) was the most frequent MAEs (Table 1), followed by wrong dose (22.0%), wrong documentation (15.9%), wrong drug (9.3%), wrong patient (7.5%), wrong technique (4.2%), and wrong route (3.5%).

Variables	Frequency	Percent %
Rights of MAE (N=1,081)		
Wrong Time	406	37.6
Wrong Dose	238	22
Wrong Documentation or Documentation Error	172	15.9
Wrong Drug	101	9.3
Wrong Patient	81	7.5
Wrong Technique	45	4.2
Wrong Route	38	3.5
Medication Error by Hospital Unit (N=1,272)		
Medical-Surgical	446	34.9
ICU	222	17.4
IMCU	169	13.2
ED	99	7.8
Rehabilitation	75	5.9
Maternity	42	3.3
Other	219	17.1
Medication Error by Drug Classified by ATS (N=1,277)		
Cardiovascular	277	21.7
Antimicrobial	242	19
Endocrine/Metabolism	151	11.8
Electrolyte/Nutrition/Minerals	148	11.6
Analgesic	119	9.3

Neurologic	61	4.8
Multiple Medications	46	3.6
Genitourinary	42	3.3
Gastrointestinal	41	3.2
Psychiatric	32	2.5
Consequences of Medication Error (N=1,277)		
Error reached patient but did not cause harm	828	64.8
Capacity to cause harm	181	14.2
No harm but increased monitoring needed	134	10.5
Temporary harm, treatment needed	122	9.6
Others	12	0.9
Note: Percentages may not add to 100 due to rounding; MAE, medication administration error; ICU, intensive care unit; IMCU, intermediate care unit; ED, emergency department; ATS, anatomical therapeutic system		

Table 1. Frequency and Percentage of Medication Errors by Hospital Unit, Drug Classification, Consequence to Patient, and the Seven Rights.

More than 50% of MAEs that were a result of medications being given at the wrong time occurred in ICUs and medical surgical units (Table 2). MAEs in the IMCU were usually due to wrong documentation (39.8%) and wrong time (36.3%). MAEs associated with cardiovascular drugs were often due to wrong dose (40.0%) or wrong time (40.0%) (Table 2).

	Rights of MAE (%)		
	Wrong Dose	**Wrong Time**	**Documentation Error**
Hospital Units (N=541, p < 0.001)			
ICU	35.6	51.7	28.6
IMCU	23.9	36.3	39.8
Medical Surgical Unit	21.2	54.1	24.7
Drug Class (N=521, p < 0.01)			
Cardiovascular	40.2	40.2	19.5
Antimicrobials	31.5	59.8	8.8
Electrolytes/Minerals	35.8	49.4	14.8
Endocrine/Metabolism	19.6	42	38.3
Note: All numbers are expressed as a percentage; Percentages may not add to 100 due to rounding; MAE, medication administration error; ICU, intensive care unit; IMCU, intermediate care unit			

Table 2. Hospital Unit and Drug Class by Top 3 of the Seven Rights of MAE.

MAEs caused by antimicrobials being administered at the wrong time tended to occur most often in ICUs (34.8%), IMCUs (41.9%), and medical-surgical units (35.7%) (Table 3). MAEs due to the wrong dose of antimicrobials frequently occurred in IMCUs (46.4%) and medical-surgical units (52.1%), whereas wrong dose of cardiovascular drugs were more likely to occur in ICUs (49.0%) and IMCUs (50.0%). Inaccurate documentation associated with antimicrobials was more frequent in ICUs (100.0%) and medical-surgical units (50.0%). Additionally, wrong documentation with electrolytes/minerals was more likely to be present in IMCUs (50.0%) (Table 3).

Rights of MAE	Drug Classes	Hospital Units (%)			
		ICU	**IMCU**	**Medical-Surgical Units**	**Total**
Wrong Dose	Antimicrobials	5.9	46.4	52.1	35.3
	Cardiovascular	49	50	28.2	39.3
	Endocrine/Metabolism	15.7	3.6	0.1	0.1
	Electrolytes/Minerals	29.4	0	12.7	16
	Total	100	100	100	100
Wrong Time	Antimicrobials	34.8	41.9	35.7	36.6
	Cardiovascular	21.7	25.8	28.6	26.3
	Endocrine/Metabolism	32.6	19.4	13.3	19.4
	Electrolytes/Minerals	10.9	12.9	22.4	17.7
	Total	100	100	100	100
Documentation Error	Antimicrobials	100	25	50	46.2
	Cardiovascular	0	25	25	23.1
	Endocrine/Metabolism	0	0	12.5	0.1
	Electrolytes/Minerals	0	50	12.5	23.1
	Total	100	100	100	100

Total	Antimicrobials	20.4	42.9	43	36.4
	Cardiovascular	35.7	36.5	28.2	32
	Endocrine/ Metabolism	23.5	11.1	10.7	14.5
	Electrolytes/ Minerals	20.4	9.5	18.1	17.2
	Total	100	100	100	100
Note: Percentages may not add to 100 due to rounding; MAE, medication administration error					

Table 3. Hospital Unit by Top 3 of the Seven Rights of MAE and Drug Classes (N = 338)

1. Discussion

Our study shows that wrong time, wrong dose, and documentation errors are the most frequent inaccuracies noted during medication administration. Furthermore, the associations between the Seven Rights and hospital units exist. Errors as a result of administering a medication at the wrong time tend to happen in ICUs and medical-surgical units. ICUs contain potential risk factors for MAEs. Multiple high alert medications are typically given to patients in ICUs in addition to complicated clinical procedures [26-27]. Frequent changes in substances and doses are required in fast paced medical care in ICUs [28]. There are also potential organizational risk factors that include patient-to-nurse ratios [29]. Medical-surgical units have similar potential risk factors in terms of heavy patient loads [18]. Many distractions and time constraints are other risk factors for MAEs in Medical-surgical units [18]. Therefore, MAEs caused by wrong time such as omission of dose tend to happen more in hospital units that require higher attentions.

Our findings also show associations between drug classes and the Seven Rights specifically, cardiovascular drugs, antimicrobials, endocrine drugs, and electrolytes. Errors with antimicrobials are mainly due to wrong time. During a patient's hospital stay, the dosage of antimicrobials must be adjusted by nurses, doctors, or pharmacists based on laboratory test results time by time. Therefore, clear communication among healthcare providers and precise dosage calculations based on updated orders in compliance with protocols, are critical to avoid antimicrobial-related MAEs [30]. MAEs with medication errors relating to electrolytes and endocrine drugs are also highly associated with wrong time. Concentrated electrolytes are the most common MAEs related to electrolytes, however, our study showed omission of doses or medication given at the wrong time is more strongly associated with errors regarding electrolyte administration. Endocrine drugs such as insulin are widely used in critical and intensive care patients in order to reduce morbidity and mortality [31].

Maintenance of optimal insulin concentration is a critical task. These findings are further expanded by examining potential interactions with hospital units. In regard to hospital units, electrolyte-related MAEs due to wrong time tend to happen in Medical-surgical units. It is reported that the frequent need for rapid life-saving responses may contribute to wrong time and documentation errors in medical-surgical units [26]. Our study also showed MAEs with endocrine drugs due to wrong time tend to happen in ICUs. MAEs regarding electrolytes and endocrine drugs may be a result of organizational and environmental factors rather than individual skills or knowledge [13,20,30,32].

Medication given in wrong doses prevails in MAEs. Our study showed MAEs in ICUs and IMCUs tend to happen with cardiovascular drugs as a result of the wrong dose. Insufficient knowledge of correct dosage has been identified as a main cause of MAEs with "high alert" medications such as heparin [13,30,32]. Other research also indicates that more than half of the nurses did not read syringe markings at eye level when mixing medications [10]. Documentation error is prominent with antimicrobials in ICUs and with cardiovascular drugs in IMCUs and Medical-surgical units. Again, frequent changes in dose and substance of antimicrobials and cardiovascular drugs may affect the verbal and written prompts, especially in fast paced hospital units such as ICUs and Medical-surgical units [29].

Our findings indicate that error prone drugs such as cardiovascular drugs, antimicrobials, electrolytes, and endocrine drugs all need frequent dose adjustment and maintenance of optimal concentration. Therefore, it is critical that these medications be administered at the right time with the right dose in order to reduce MAEs. Our study also showed that hospital units with complex medication administration and complicated clinical procedures such as ICUs and Medical-surgical units are more prone to MAEs. Therefore, associations between hospital units and drug classes regarding the Seven Rights revealed from our study suggest that the amount of workload may be one of the aligned holes that allow MAEs as the Swiss Cheese Model of system accidents stated. Without adequate health professionals (e.g., the high number of beds per nurse ratio), fast paced hospital units with complex interventions and increased patient admissions may contribute to nurses not being able to administer medication at the right time and provoke documentation errors [29]. In fact, many studies have identified heavy workload as an important contributor to MAEs [33,34]. Even though our study did not measure the effect of workload on MAEs specifically, our findings may indicate that the high bed-to-nurse ratio is a possible underlying contributing factor to MAEs which merits further research [9]. For example, since antimicrobials are listed as time-critical medications that should be administered at strict time intervals with frequent dose adjustments, we observed that giving antimicrobials at the wrong time is associated with IMCUs and medical-surgical units [35].

Existing research also reports that the low patient-to-nurse ratios in medical-surgical units makes the administration of medications on a strict timeline difficult [10]. Therefore, a heavy workload may indeed be one of underlying causes of the Seven Rights related MAEs that are also associated with drug class, and hospital unit.

The study had limitations. First, data were collected without a predefined medication error tracking form; therefore, variations in categorizing medication errors across different hospital systems existed, which might, to a certain extent, affect the accuracy of assigning root causes of medication errors. In addition, the data were obtained from five hospitals in the Southwestern United States, which limited the generalizability of the results. Future research on "at the time of medication error" as a contributing factor of nurse related MAEs is needed to examine the associations between nurse shifts and incidents of MAEs. Future research should also investigate relationships between the bed-to-nurse ratio/nurse workload and medication errors.

Implications for Nursing Practice and Policy

Medication administration errors due to wrong timing are sometimes inevitable considering the synchronized drug administration timeline, frequent dose changes with antimicrobials, and certain features of hospital units, like inadequate staffing [10]. Use of the Electronic Health Record (EHR), which can alert nurses during the medication administration phase of required dosage changes and drugs that are outside the acceptable administration window, is one approach to avoid wrong-time errors [36]. Although many hospitals are using EHRs, some may not have the means or capability to alert nurses about drugs outside the acceptable administration window, high-risk drug alerts, or drugs that require dosage changes.

Identifying hospital units where medication administration errors frequently occur provide more specific alerts to nurses for avoiding potential medication errors. Strengthening related training and education should then follow, as Huckels-Baumgart and Manser point out that roots of medication error chains include inattention and lack of training [14]. Nursing education on drug classes associated with medication errors with regard to the more frequent Rights provides guidelines for proper medication administration. For example, educational materials in nursing pharmacology curriculums specifically focusing on medication administration errors associated factors (e.g., drug class, hospital unit, and combinations of those factors) will be helpful to reinforce and stress the issue. It is also recommend offering more targeted nursing training and continuing education programs that emphasize medication administration error prevention's knowledge, skills, techniques, and approaches.

Policies and programs should target hospital units and drug classes for reducing medication administration errors with regard to the Seven Rights. The awareness improvement training such as Plan-Do-Study-Act and an educational program developed based on actual reported medication error incidents may enable nurses to reduce preventable medication administration errors and improve patient safety [35].

Since medication administration errors may be caused by combinations of certain latent conditions with regard to hospital units and drug classes, errors related to the Seven Rights may be minimized by alleviating the heavy workload of nurses. Mandated nursing staffing to patient ratio legislation and reduction of workloads should be considered. These have been shown to reduce medication administration errors related to human factors such as fatigue from lack of sleep, working too many hours, and time constraints [10,15,37-38].

Conclusion

This study, collecting more accurate medication error information from hospital's risk management departments, supports previous evidence that medication errors continue to exist in hospital settings and prove to be more common in some units than others. Examining the Seven Rights, hospital units, and drug classes simultaneously enabled us to identify potential factors associated with medication administration errors. Findings from this study may assist hospital administration and staff in developing practical and effective strategies to reduce medication errors and improve patient safety.

Acknowledgement

References

1. Stetina P, Groves M, Pafford L (2005) Managing medication errors a qualitative study. Medsurg Nurs 14: 174-178.

2. Department of Human Services. Sentinel Event Program. Annual Report 2007-08. Building Foundations to Support Patient Safety. Rural and Regional Health and Aged Care Services, Government of Victoria, Melbourne.

3. Australian Institute for Health and Welfare. Medical Indemnity National Data Collection Public Sector 2006-07. Medical Indemnity National Data Collection Public Sector 2009.

4. National Priorities Partnership. Preventing Medication Errors: A $21 Billion Opportunities. 2010.

5. Institute of Medicine. Preventing medication errors. Washington, DC: National Academy Press 2007.

6. National Coordinating Council for Medication Error Reporting and Prevention. About medication errors. 2010.

7. Krähenbühl-Melcher A, Schlienger R, Lampert M, Haschke M, Drewe J, Krähenbühl S (2007) Drug-related problems in hospitals: A review of the recent literature. Drug Saf 30: 379- 407.

8. Cheragi MA, Manoocheri H, Mohammandnejad E, Ehsani SR (2013) Types and causes of medication errors from nurse's viewpoint. Iran J Nurs Midwifery Res 19: 228-231.

9. Frith KH, Anderson EF, Tseng F, Fong EA (2012) Nurse staffing is an important strategy to prevent medication errors in community hospitals. Nurs Econ 30: 288-294.

10. Kim J, Bates D (2013) Medication administration errors by nurses: adherence to guidelines. J Clin Nurs 22: 590-598.

11. Leape LL, Bates DW, Cullen DJ, Cooper J, Demonaco HJ, et al. (1995) Systems analysis of adverse drug events. JAMA 274 :35-43.

12. Barker KN, Flynn EA, Pepper GA, Bates DW, Mikael RL (2002) Medication errors observed in 36 health care facilities. Arch Intern Med 162: 1987-1903.

13. Hsaio G, Ghen I, Yu S, Wei L, Fang Y et al. (2010) Nurses' knowledge of high-alert medications: instrument development and validation. J Adv Nurs 66: 177-190.

14. Huckels-Baumgart S, Manser T (2014) Identifying medication error chains from critical incident reports: A new analytic approach. J Clin Pharmacol 54: 1188-1197.

15. Tang FI, Sheu SJ, Yu S, Wei IL, Chen CH (2007) Nurses relate the contributing factors involved in medication error. J Clin Nurs 16: 447-457.

16. Sheu SJ, Wei IL, Chen CH, Yu S, Tang FI (2009) Using snowball sampling method with nurses to understand medication administration errors. J Clin Nurs 18: 559-569.

17. de Vries EN, Ramrattan MA, Smorenburg SM, Gouma DJ, Boermeester MA (2008) The incidence and nature of in- hospital adverse events: A systematic review. Qual Saf Health Care 7: 216-223.

18. Harkanen M, Ahonen J, Kervinen M, Turunen H, Vehvilainen-Julkune K (2015) The factors associated with medication errors in adult medical and surgical inpatients: a direct observation approach with medication record reviews. Scand J Caring Sci 29: 297-306.

19. Redley B, Botti M (2013) Reported medication errors after introducing an electronic medication management system. J Clin Nurs 22:575-589.

20. Reason J (2000) Human error: models and management. BMJ 320: 768-770.

21. Agency for Healthcare Research and Quality: Patient safety and quality: An evidence-based handbook for nurses; Hughes R, Blegen M. 2008.

22. Dalmolin GRDS, Rotta ET, Goldim JR (2013) Medication errors: classification of seriousness, type, and of medications involved in the reports from a university teaching hospital. BJPS 49: 793-802.

23. Keers RN, Williams SD, Cooke J, Ashcroft DM (2013) Causes of medication administration errors in hospitals: a systematic review of quantitative and qualitative evidence. Drug Saf 36: 1045-1067.

24. Shen JJ, Neishi S, VanBeuge S, Covelli M, Adamek S, et al. (2015) Comparing medication error incidents among foreign-educated nurses and U.S.-educated nurses. JNR 5: 4-10.

25. World Health Organization. The anatomical therapeutic chemical classification system with defined daily doses (ATC/DDD).

26. Wu HF, Yu SU, Lan YH, Tang FI (2012) Medication errors in emergency. rooms, intensive care units and pediatric wards 59: 93-98.

27. Vazin A, Delfani S (2012) Medication errors in an internal intensive care unit of a large teaching hospital in Iran: a direct observation study. Acta Medica Iranica 50: 425-432.

28. Valentin A, Capuzzo M, Guidet B, Moreno RP, Dolanski L, et al. (2006) Patient safety in intensive care: results from the multinational Sentinel Events Evaluation (SEE) study. Intensive Care Med 32: 1591-1598.

29. Camire E, Moyen E, Stelfox HT (2009) Medication errors in critical care: risk factors, prevention and disclosure. CMAJ 180: 936-941.

30. Schaubhut RM, Jones C (2000) A systems approach to medication error reduction. J Nurs Care Qual 4: 13-27.

31. Ellahham S (2010) Insulin therapy in critically ill patients. Vasc Health Risk Manag 6: 1089-1101.

32. Phillips J, Beam S, Brinker A, Holquist C, Honig P, et al. (2001) Retrospective analysis of mortalities associated with medication errors. Am J Health Syst Pharm 58: 1835-1841.

33. Taxis K, Barber N (2004) Causes of intravenous medication errors-observation of nurses in a German hospital. Journal of Public Health 12: 132-138.

34. Treiber LA, Jones JH (2010) Devastatingly human: an analysis of registered nurses' medication error accounts. Quality Health Res 20: 1327-1342.

35. Graudins LV, Ingram C, Smith BT, Ewings WJ, Vandevereede M (2015) Multicentre study to develop a medication safety package for decreasing inpatient harm from omission of time-critical medications. Int J Qual Health Care 27: 67-74.

36. Yang A, Pharm D, Nelson L (2016) Wrong-time error with high-alert medication. Agency for Healthcare Research and Quality: Patient Safety Network.

37. Kopp BJ, Erstad BL, Allen ME, Theodorou AA, PriestleyG (2006) Medication errors and adverse drug events in an intensive care unit: direct observation approach for detection. Crit Care Med 34: 415-425.

38. Roth C, Brewer M, Wieck KL (2017) Using a Delphi method to identify human factors contributing to nursing errors. Nurs Forum 52: 173-179.