

Original Paper

Environmental Factors Contributing to Medication Errors in Intensive Care Units



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ABSTRACT

Introduction: Medication errors are one of the most common types of medical errors. In Intensive Care Units, because of its special circumstances, the risk of such errors is increasing. There are several causes for the medication errors of nurses, including environmental factors.

Objective: The current study aimed at determining environmental factors contributing to medication errors based on the perceptions of ICU nurses.

Materials and Methods: The current analytical cross-sectional study was conducted on 281 nurses working in special care units ICU of hospitals affiliated to Guilan University of Medical Sciences in 2014. Nurses' perspectives of environmental factors were investigated using a two-part researcher-designed questionnaire. The collected data were analyzed using Exploratory Factor Analysis (EFA).

Results: Two factors with a predictive power of 68.32% remained as the most important environmental factors. The first factor explained 36.47% of the total variance of medication errors and the second factor explained 31.84%. The first factor consisted of three variables of "poor lighting", "high noise levels", and "inappropriate room temperature", while the second factor included the variables of "high number of patients", "lack of equipment for injection and drop-rate setting", and "inadequate space for medication preparation". Among these variables, poor lighting with a factor loading of 0.89 was reported as the most important environmental factor contributing to medication errors.

Conclusion: Since poor lighting, high noise levels, and inappropriate room temperature were determined as the most contributing environmental factors to medication errors, it is recommended that managers and authorities of hospitals prevent and mitigate medication errors and improve patient's safety by modifying environmental conditions.

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Highlights

- Medication errors are one of the most common types of medical errors.
- In Intensive Care Units (ICUs), due to the special circumstances, the odds of these errors is increasing.
- Medication errors of nurses are contributing to several factors, including environmental factors.
- Two factors were observed as the most important environmental factors.
- The first factor comprises poor lighting, high noise levels, and inappropriate room temperature.
- The second factor comprises a high number of patients, lack of equipment for injection and drop-rate calculation, and inadequate space for medication preparation.

Plain Language Summary

Medication errors are one of the most common types of medical errors. In Intensive Care Units (ICUs), due to special circumstances, the risk of these errors is high. Medication errors of nurses are related to several factors, including environmental factors. Since a disease need to be diagnosed in order to find a remedy for it and on the other hand, the factors associated with medication errors in different centers vary according to the resources and management of that center, identifying the most important environmental factors associated with medication errors can help provide ways to reduce their re-occurrence. In this regard, this study aimed to determine environmental factors related to medication errors based on the perceptions of ICU nurses. For this purpose, 281 nurses working in ICUs of hospitals affiliated to Guilan University of Medical Sciences in 2014 were selected for the study and their perceptions of environmental factors were surveyed using a two-part researcher-designed questionnaire. Two factors were remained as the most important environmental factors. The first factor consisted of three variables of “poor lighting”, “high noise levels” and “inappropriate room temperature”, while second factor included the variables of “high number of ill patients”, “lack of equipment for injection and droplet volume calculation”, and “inadequate space for medication preparation”. Among these variables, poor lighting was reported as the most important environmental factor contribute to medication errors. It is recommended that managers and authorities of hospitals, should prevent and mitigate medication errors and improve patient safety by modifying environmental conditions.

Introduction

One of the most common types of medical errors is medication administration errors [1], which is referred to any preventable harm due to inappropriate medication use [2]. In the United States, medication errors harm 1.5 million patients annually [3], are responsible for the death of 7000 patients [4], and treatment of these harm costs \$42 billion dollars annually [5]. In Iran, although there is still no statistics on medication error rate, experts speculate that its level is very high and increasing complaints of people against physicians and nurses and their referring to the Medical Council and courts can be a proof of this claim [6].

Since medicines are widely used in hospitals, it is expected that a large number of treatments are affected

by medication errors [7]. It should be noted that the process of clinical pharmacology is performed as a team [8]. Although physicians and pharmacists are responsible for the first two phases of the medication process [9], but the final phase called “medication administration” is mainly performed by nurses [10], since they are the largest group of health care teams [11] mainly dealing with medication orders [12] and spending more time with the patients [13]. Thus, they are at higher risk of committing medication errors [14].

The incidence of medication errors in sectors such as emergency rooms and Intensive Care Units (ICUs) is higher due to a large number of patients [15, 16]. In particular, patients who admitted to ICUs receive medications mostly through their veins [17] that often requires calculation of infusion drop rate [18]. On the other hand, these patients are mostly in poor condi-

tion or unconscious and unable to monitor and report adverse drug reactions. Therefore, there may be more medication errors in such sectors that can have serious consequences [19]. According to the available studies in the world, 78% of the total serious medical mistakes in these sections are contributing to medication errors [19]. Medication errors of nurses can lead to various problems such as increased death rate, increased hospitalization duration and medical costs [20]. Nurses are also affected by these errors and the legal complaints can jeopardize their career and life [21].

Several factors contribute to nurses' medication errors, including environmental factors [10]. From a systematic point of view, the nursing work environment is a complex environment [8]. Work environment includes working conditions, organizational climate, or occupational characteristics [22]. Physical aspects of the work environment (e.g. poor lighting) can cause errors in reading medication labels, also poor thermal and acoustic aspects can potentially increase the number of medication errors by creating stress in the staff and is effective in the performance of nurses [23]. On the other hand, in a crowded and noisy work environment, the probability of interruption and distraction increases [24].

The complex environment full of equipment and alarm sounds are other environmental factors accounted for medication errors in ICUs [25]. Mahmood et al. reported following environmental factors: lack of private space in the working area, the inappropriate design of the nursing unit, inadequate space in medication charting area, the small size of the medication room, using defective equipment for medical supplies, and inappropriate location of the nursing stations [26]. Also, Brunetti indicated that proper design of the work environment can prevent medication errors [27].

It seems that disclosing the hidden environmental factors of medication errors, which were studied generally before could be effective in this regard. Determination of the nurses' perspective in this issue as the responsible group for medication administration can provide the best picture of environmental factors of medication errors. In this regard, the current study aimed at investigating environmental factors of medication errors among nurses working in ICUs of hospitals affiliated to Guilan University of Medical Sciences.

Materials and Methods

The current analytical cross-sectional study was conducted on all nurses working in special care units of

hospitals (n=17) affiliated to Guilan University of Medical Sciences. After obtaining permissions from the Research Deputy and approval of the Ethics Committee, the researcher referred to the hospitals from February to April 2014. Then, after introducing and obtaining the subjects' consent, explaining the study objectives and how to respond to the questionnaire, and finally ensuring about the confidentiality of information, the questionnaires were distributed among the study subjects. The subjects were recruited by the census method. In this regard, out of 363 nurses, 11 head nurses that did not have any roles in medication administration, 41 nurses due to inadequate experience, and 22 due to long-term sick leave were excluded from the study (n=289). In the end, 281 complete questionnaires were collected (8 nurses did not respond to the questionnaire). The selected subjects had at least a bachelor degree and 6 months of work experience in ICUs.

The data collection tool was a researcher-designed questionnaire composed of two parts; first part had four items investigating individual characteristics (Gender, age, marital status, educational level) and 12 items about occupational characteristics (overall work experience, work experience in ICUs, the number of work shifts per 24 hours, the number of working days per week, the number of patients treated in each work shift, the type of work shift, the type of employment, the number of active beds in the unit, the hours of working overtime in a month, working in multiple jobs, in-service training on pharmacotherapy, and the type of ward). The second part of the questionnaire was about environmental factors contributing to medication errors from nurses' point of view (unsuitable lighting, so much noise, unsuitable room temperature for staff, drug-shelf arrangement, the number of sick patients, insufficient equipment for injection and drop-rate set, and not enough space for medication preparation). In this section, nurses were asked to prioritize the above factors based on their importance ranging from 1 (the most important) to 7 (the least important).

The content validity of the questionnaire was tested and verified according to previous similar studies, and opinions of 15 nurses specialized in the field of education and care in ICUs. Its test-retest reliability was also examined in a preliminary study on 20 nurses during two weeks ($r=0.474$, $P<0.05$). The collected data were analyzed in SPSS V. 19. To describe individual and occupational characteristics, we used descriptive statistics (frequency, percentage, mean, standard deviation). To evaluate environmental factors, we used Exploratory Factor Analysis (EFA). For this purpose, first, the Kaiser-

Meier-Olkin (KMO) sampling adequacy index (>0.5) and the Bartlett test of sphericity were calculated for the variables that their results confirmed sampling adequacy. After ensuring the possibility of performing EFA (correlation scores were greater than 0.5), Varimax rotation was conducted to determine the most important environmental factors associated with medication errors.

Results

The individual and occupational characteristics of the study participants are presented in Table 1. In performing EFA, KMO index was 0.780 and Bartlett's test of sphericity was reported 630.597 ($P=0.0001$). The results of final common environmental factors contributing to medication errors from the nurses' perspective show 6 remained variables on the diagonal of the correlation matrix table with commonalities more than 0.5 (Table 2).

After studying the anti-image correlation matrix values and commonalities less than 0.5 and based on rotated factor matrix table and established conditions of the complex structure, the variables that were less correlated with other variables were excluded from

the analysis due to their impact on the predictive power of the model. In the end, after varimax rotation, two factors with eigenvalues of greater than 1 remained as environmental factors contributing to medication errors with a predictive power of 68.32% (Figure 1). The first factor with an eigenvalue of 2.693 explained 36.47% and the second factor with an eigenvalue of 1.137 explained 31.84% of the total variance of medication errors (Table 3).

The factor matrix before and after rotation showed that two environmental factors could predict medication errors, according to nurses' point of view. Before rotation, the variable "drug-shelf arrangement" was removed from the model due to the reduction of maximum predictive power. The two remained factors comprised 6 variables: first factor consisted of three variables of "poor lighting", "high noise levels", and "inappropriate room temperature", while the second factor included the variables of "high number of patients", "lack of equipment for injection and droplet-rate set", and "inadequate space for medication preparation". According to the nurses' perspective, of these 6 variables, poor lighting with a factor loading of 0.891 was reported

Table 1. The individual and occupational characteristics of the studied ICU nurses

Characteristics		N (%)
Gender	Female	272(96.8)
Age (year)	30-40	165(58.7)
Marital status	Married	218(77.6)
Educational level	Bachelor	270(96.1)
Overall work experience (year)	5-10	141(50.2)
Work experience in ICU (year)	<2	148(52.7)
Number of work shifts per 24 hours	1	238(84.7)
Number of working days per week	4-6	246(87.5)
Number of patients treated in each work shift	3-4	132(47)
Type of work shift	Rotating	238(84.7)
Type of employment	Contractual	116(41.3)
Number of active beds in the unit	>10	155(55.2)
Overtime hours per month	<50	183(65.1)
Working in multiple jobs	No	258(91.8)
In-service training on pharmacotherapy	No	185(65.8)
Number of receiving medication education	<3	272(96.8)
Type of ward	ICU	158(56.2)

Table 2. Commonalities of environmental factors contributing to medication errors from nurses' point of view

Variable	Initial	The Variance Explained by Each Variable
Poor lighting	1	0.797
High noise levels	1	0.719
Inappropriate room temperature	1	0.681
A high number of patients	1	0.551
Lack of equipment for injection and drop-rate calculation	1	0.769
Inadequate space for medication preparation	1	0.584

as the most important environmental factor contributing to medication errors (Table 4).

Discussion

According to the results of the current study, poor lighting was the most important environmental factor contributing to medication errors from the nurses' point of view. It was consistent with the results of Shahrokhi et al. [28]. However, in the study by Bijani et al. poor lighting was reported as the least important factor of medication errors [29]. Farzi et al. determined the reasons for medication errors in ICUs, but the lighting was not considered as an effective environmental factor [17].

Perhaps the reason for this inconsistency was the difference in the quality and type of lighting and the structure of the medication room in the studied units. According to previous studies, a suitable light has no shadows or glare, which can be useful to minimize medication errors [30]. One of the standards of medication

administration by nurses is that drug name and its label should be checked and read three times [31].

Based on the results of the current study, the high noise level was another environmental factor contributing to medication errors from nurses' point of view, which was in agreement with the findings of Mahmood et al. [26] but against the results of Bijani et al. [29]. The probability of interruption and distraction increases in a crowded and noisy environment [24], which affects the concentration during drug preparation [9]. Perhaps differences between the current study findings and those of Bijani et al. was due to a large number of ICU active beds in the current study (>10). These active beds along with advanced and specialized equipment cause a lot of noise. With this respect, nurses reported high noise level as one of the factors influencing medication errors.

In the current study, the room temperature was reported as another important environmental factor according to the nurses' point of view. The temperature

Table 3. Distribution of the final cumulative variance percentage after varimax rotation of environmental factors contributing to medication errors from nurses' point of view

Environmental Factors	Initial Eigenvalues			% Rotation Sum of Squared Loadings		
	Total Variance Contributing to the Factor	Percentage of Variance Explained	Percentage of Cumulative Variance	Total Variance Contributing to the Factor	Percentage of Variance Explained	Percentage of Cumulative Variance
1	2.963	49.378	49.378	2.189	36.479	36.479
2	1.137	18.943	68.321	1.911	31.842	68.321
3	0.756	12.601	80.922	-	-	-
4	0.436	7.270	88.191	-	-	-
5	0.404	6.738	94.930	-	-	-
6	0.304	5.070	100	-	-	-

Table 4. Factor matrix of environmental factors contributing to medication errors before and after varimax rotation

Variable	Factors Before Rotation		Factors After Rotation	
	1	2	1	2
Poor lighting	0.890	0.029	0.891	0.051
High noise levels	0.785	0.234	0.806	0.262
Inappropriate room temperature	0.770	0.265	0.733	0.288
High number of patients	0.516	0.348	0	0
Lack of equipment for injection and drop-rate calculation	0.152	0.717	0.156	0.725
Inadequate space for medication preparation	0.107	0.868	0.090	0.872
Not enough space for medication preparation	0.359	0.676	0.338	0.685

of the ICU should be 22-26°C [32]. Inappropriate thermal conditions in the environment can lead to stress in nurses and in turn increase medication errors, which can affect their performance [23].

The lack of equipment for drug injection and drop-rate setting were other environmental factors associated with medication errors from nurses' point of view, which were consistent with the results of some other studies [9, 33, 34]. However, in the study by Habibabadi et al. it was observed that the lack of appropriate equipment for medication administration was less important in medication errors for nurses. The availability of appropriate equipment and environment can result in rendering high-quality services [35]. Since hospitalized patients in ICUs require multiple drugs and accurate calculation of drug dosage, droplet or infusion rates [36], differences in findings can be due to differences in the

resources and equipment available in different treatment centers and their organization.

Another important environmental factor of medication errors in the current study was the high number of patients. It was in agreement with some studies [25, 37]. Very ill patients in critical conditions are admitted to ICUs in order to be under continuous care, evaluation, and monitoring of their vital organs. Although one nurse is usually assigned for caring one patient in the ICU, sometimes two nurses are required to care for one seriously ill patient [32]. With regard to the existing conditions, some experts believe that this kind of care is not possible in most cases and with the increase in the number of patients in these sectors, the odds of medication errors increases.

Lack of adequate space to prepare medication was the least important environmental factor of medication errors in the current study. It was consistent with the findings of Mahmood et al. [26] but inconsistent with those of some other studies [38, 39]. The physical arrangement of ICU can be related to medication errors [9]. In addition, inadequate space or allocating of common space to prepare medications causes the employees to interact with each other, and thus distract them while they are preparing and giving drugs to the patients.

Since poor lighting, high noise levels, and inappropriate room temperature were determined as the most contributing environmental factors to medication errors, it is suggested that further studies assess the relationship between the physical standards of working environment and the rate of medication errors. It is also recommended that managers and authorities pay attention to the proper design of ICUs. The results of the current study can provide information about the

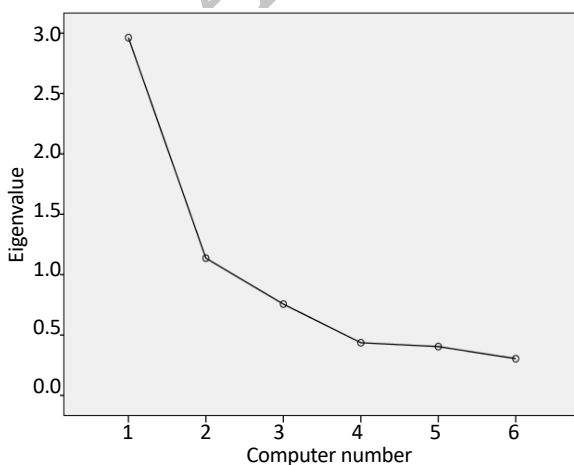


Figure 1. Scree plot of environmental factors contributing to medication errors

environmental problems in the ICUs to the hospital managers. Therefore, by considering the environmental factors of medication errors, they can take steps to design strategic planning, budget allocation, staff training, equipment, and facilities, and eventually improve the safety of patients. Also, the findings of the current study call for spending more hours identifying the environmental factors associated with medication errors in the nursing curriculum.

Since the data collection in the current study was performed by a questionnaire, physical and psychological problems of nurses may have affected their responses, which can be considered as a limitation of the study.

Ethical Considerations

Compliance with ethical guidelines

The Research Ethics Committee of Guilan University of Medical Sciences have approved this article (Code: 9056) on March 12, 2014.

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Authors contributions

Designing the study: All authors; Implementing the study: Roya Kaboodmehri; Statistically analyzing: Ehsan Kazemnejhad Leili, Roya Kaboodmehri; Interpreting the study data, drawing the conclusion, writing the first draft: All authors; Editing the manuscript: Roya Kaboodmehri, Farideh Hasavari; and Supervising the whole study procedure: Farideh Hasavari.

Conflict of interest

The authors declared no conflict of interest.

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