Evaluation and Management of Human Errors in Critical Processes of Hospital Using the Extended CREAM Technique

Iraj Mohammadfam[1], Saeid Bashirian[2], Zohreh Bakhshi*[1]

1) Center of Excellence for Occupational Health, Research Center for Health science, School of Public Health, Hamadan University of Medical Sciences, Hamadan,Iran
2)Department of Health Education, Faculty of Health, Hamadan University of Medical Sciences, Hamadan, Iran

**Author for Correspondence: bakhshi.ohs@yahoo.com*

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ABSTRACT
Medical errors result in serious and often-preventable problems for patients. Human errors can be used as an opportunity for learning as well as a key factor for patients' safety improvement and quality of patients' surveillance in hospitals. The aim of the present study was to identify and evaluate human errors to help reduce risks among personnel who render health services during critical hospital processes. This cross-sectional study was done in the Besat hospital in Hamedan in 2016. At first, the critical processes were selected via given scores in Delphi method and by multiplying the scores of each of the five criteria including the severity of the consequences caused by error incidence, probability of error, capability of the error detection, task repeatability and type of hospital ward with each other. Determining the risk numbers of each process, three ones were chosen with the largest scores. At the end, the selected processes were analyzed by the method of extended CREAM. The results showed that the highest CFP is associated with the CPR process, particularly in the sub-stage of command of starting CPR by anesthesiologists (0.0891), the one in the giving medicine process is in the sub-stage of calculating of medicine dozes and determining prescription methods (0.0796) and also the one in the tracheal intubation process is in the sub-stages of pulmonary and respiratory monitoring of patients and observing the vocal cords and larynx of patients (0.0350). Regarding the critical consequences of human errors in the selected processes, reviewing the qualities of roles and responsibilities of each of the medical group members and providing specialized introduction for hospital processes seem necessary.

Key words: Human Errors, Critical Processes, Hospital, Extended CREAM

LIST of ABBREVIATIONS
CREAM: Cognitive Reliability Error Analysis Method
HRA: Human Reliability Assessment
MTO: Man-technology- organization
HTA: Hierarchical Task Analysis
CPCs: Common Performance Conditions
CFPt: Cognitive Failure Probability total
CFPi: Cognitive Failure Probability
CPR: CardioPulmonaryResuscitation

INTRODUCTION
Nowadays, the problem of human errors in medical dominion is a critical one and this imposes many unacceptable risks on societies [1]. Medical errors always occur as a result of human's mistakes and weak designation of health-caring systems. These errors are considered as serious, inevitable and perennial threats for patients and health service personnel [2]. An error was defined by the Institute of Medicine report as "the failure of a planned action to be completed as intended or the use of a wrong plan to achieve an aim" [3]. Nowadays, improving the health systems has resulted in massive changes in these systems especially in hospitals. IOM rendered a report about complicating medical errors accompanying improvement of health systems. Based on this report, reduction of medical errors needs a systematic effort in order to establish safety in medical and caring processes [4].

Medical errors create serious problems for patients, while they are often preventable [5]. Losses resulting from them could be dead, problems for patients, economical losses and loss of credit [6]. Based on the report of WHO, of each 10 patients, one suffers from the effect of human errors [7]. According to the report of IOM every year, more than one million injuries and about 44000 to 98000 deaths occur because of medical errors and about 7000 of them are because of wrong prescription of medicine [8].

In the US society, after cardiovascular disorders and cancers, medical errors are the third reason of death. The fourth rank belongs to “death from stroke” which are fewer than the one in the third rank [9]. Some statistics show that human errors result in more than 10 percent of death of patients whose injuries are curable in the US [10].

Furthermore, from the economical point of view, medical errors have direct effects on salaries of physicians and benefits of hospitals. In a study, the salary expense of medical errors in the US in 2008 was estimated 985 million dollars and in 2009 was more than 12 billion dollars. The findings of this study showed that about one-third of injuries during the process of curing patients each year were because of human errors [11].

Studies have shown that 70 percent of medical errors are preventable and 6 percent of them are implicitly and only 24 percent of them are not preventable [12]. Therefore, since most of them are preventable, experts must analyze why they occur and find and execute comprehensive and preventive plans to reduce human errors in hospital processes [11].

Analyzing and studying human errors and using them as opportunities to learn from, is a key factor in trying to improve safety of patients and qualities of taking care of them in hospitals [13]. Therefore, a comprehensive study of critical processes in hospitals for evaluating and managing human errors, using a standard method, seems to be necessary.

This case study was conducted aiming at recognizing and evaluating human errors for reduction of their risks in personnel who render health service during critical hospital processes in the Bethat hospital in Hamadan.

MATERIALS AND METHODS

This cross-sectional study was done in the Besat hospital in Hamadan in 2016 in order to determine human errors by the use of extended CREAM (Cognitive Reliability Error Analysis Method). In this study, at first by reviewing related researches, five criteria including the severity of consequence caused by error incidence, probability of error, capability of the error detection, task repeatability and type of hospital ward were selected to determine critical processes [14,15]. Then, using Delphi method compromising 14 people, the criteria were scored and by multiplying the score of each of the five criteria with each other, a risk score was determined for each hospital process and so the three hospital processes which had the highest risk scores, were selected as the three critical processes. At the end, the three selected processes were analyzed by the method of extended CREAM. The reliability of this method has been confirmed in several studies in Iran. [16,17]

The CREAM, was developed in 1998 by Hollnagel. As a second generation method, CREAM has a detailed theoretical literature and has the feature of concentration on cognitive grounds of human behaviors. Some of the most important advantages of CREAM compared with other techniques of evaluating human errors, may be its systematic structure for defining and stating human errors in numbers both as predicting (predicting human errors) and as looking at the past (analyzing events), hierarchical processes, control model of cognition contextual and definition of the reasons of human errors based on relative factors to humans, technology and organization or MTO model [16].

Based on the principles of this method, the following stages were followed in this study:

1. Analyzing the three selected processes using the Hierarchical Task Analysis (HTA) method: In this step, first the three selected hospital processes were analyzed via the HTA method using observation, interviews with the medical personnel of the hospital and experts and reviewing of relevant documentations. Obviously the reliability of this method has been confirmed in many studies in Iran [18,19]. Structure-wise, HTA separates the desired process to necessary details and numbers for doing that activity. In fact analysis begins in this method: the final goal is taken into account, and for reaching it, the process is divided into steps and sub-steps [20].

2. Evaluating the Common Performance Conditions (CPCs) which are effective on performance in steps of critical processes: At this stage, using field study, interview and observation of documents, the general features of each process and conditions of work which were effective on performances of users were analyzed using the CPCs table which was derived from the extended CREAM method. As a result, the conditions which could improve or reduce the performance or had no effect on it, were determined and their total numbers were calculated for each process. These conditions included nine individuals, the following technical and equipment factors: adequacy of organization, working conditions, adequacy of MMI and operational support, availability of procedures/plans, number of simultaneous goals, available time, time of day, adequacy of training and experience, crew collaboration quality.

3. Determining the control modes in steps of critical processes in the mentioned conditions and determining Cognitive Failure Probability total (CFPt): At this stage, the total number of activities which reduced performance (∑reduced) was subtracted from the total numbers of activities which improved performance (∑improved). The result was used for determining the control modes in the steps of three selected hospital processes in the mentioned conditions. These controls are in four groups regarding increased degrees: scrambled, opportunistic, tactical and strategic. Then with the continuation of control line on the control modes chart, an index called β or the coefficient of control mode were determined. Finally, with this coefficient and the use of CFPt equation (Equation1), CFPt was found out in the desired activity.

$$\boldsymbol{CFPt = 0.0056 \times 10^{0.25\beta}} \quad \text{Eq.(1)}$$

4. Obtaining Performance Influence Index (PII) and identifying Context Influence Index (CII) for each activity: using the results of the basic CREAM, PIIs for each CPC for each step of the three selected hospital processes were found using the database of the relative table. Since there are nine CPCs, nine PIIs were determined for each step of the of the three selected hospital processes. Afterwards, equation 2 was used to calculate CIIs for each step.

$$\boldsymbol{CII = \sum_{i=1}^{9} PII} \quad \text{Eq.(2)}$$

5. Rendering the cognitive demands related to each of sub-steps of selected critical processes: At this stage the cognitive demands related to each of the sub-step of the selected critical processes were determined using related tables to cognitive activities in order to create a cognitive profile for each sub-steps of activities and determine necessary cognitive features and Cognitive Failure Probability total (CFPt).

6. Recognition of possible cognitive errors for each of the sub-steps of selected critical processes: After determining cognitive needs related to each of the selected critical processes, the possible cognitive errors for each of the three processes were determined in four groups: observation, interpretation, planning and execution. Then, basic values (CFP0) of each of them were recognized.

7. Evaluating the Cognitive Failure Probability (CFPi) as quantitative: At this stage, regarding the results of previous stages and using the equation 3 which will be calculated for each step separately and at the end, putting the values of CFP0 for each sub-step in these equations, the final CFP for each sub-stage was calculated [21,22].

$$\boldsymbol{CFP = CFP_0 \times 10^{0.25\,CII}} \quad \text{Eq.(3)}$$

RESULTS

In this study, after reviewing the relevant studies, five criteria were found: the possibility of error occurrence, the intensity of consequences of the event resulting from errors, the capacity of discovering errors, replication of tasks in desired processes and the type of hospital unit for recognition and selection of critical processes.

The desired processes were found based on risk numbers and three processes of CPR, medication and endotracheal intubation were chosen as critical. Their risk numbers are mentioned in the table 1.

Table 1: The risk number in the three selected critical processes

Rank	Process	Unit	Risk number
1	CPR	Operation Room	3600
2	Medication	ICU	2700
3	Endotracheal Intubation	ICU	2700

According to results found out via basic CREAM for CPR, in the step of starting CPR, the CFPt is 0.0315 and the control mode was found to be opportunistic. In two steps of examining patients by doctors and performing primary stages and observing the effect of CPR, this amount was 0.0177 and the one for the opportunistic control and the step of completing forms and recording was 0.0056. The mode of control was found to be a tactical one.

The results obtained via basic CREAM for the process of medication in the step of prescribing medicine revealed that, the CFPt is 0.056 and the control mode was found to be an opportunistic one. This amount was 0.0315 for the two steps of finding and preparing medicine and recognizing and preparing patients. The mode of control was found to be an opportunistic one. In the two steps of doctors' prescription and checking on nurses, CFPt was 0.0177 and their control mode was opportunistic and in the recording step, this amount was equal to 0.0099 and the control mode was tactical.

In the endotracheal intubation process, CFPt of two steps of preparation before intubation and endotracheal intubation by anesthesiologists yielded 0.0177 and their control mode was opportunistic. In the step of doctors' prescription, this amount was equal to 0.0099 and the control mode was tactical. In the recording step, this amount was equal to 0.0056 and the control mode was tactical. Part of results related to basic CREAM for the three selected processes is mentioned in table 2.

The results derived from the extended CREAM method also showed that out of the total of all cognitive errors identified for the three selected hospital processes, 61.5% were related to execution errors, 25% were observation errors, 11.5% were related to interpretation and 2% were related to planning. A sample of these results found out via extended CREAM method is mentioned in table 3.

Observing cognitive demands profile, these activities were recognized for the three selected processes in the following order and percentages, activity of execute (42.3%), record (17.3%), evaluation (9.61%), identification (7.77 %), monitoring (5.77%), verification (5.77%), diagnosis (3.84%), communication (3.84%), observation (3.84%).

Table 2: The summary of results of basic CREAM in the three processes of CPR, Medication and Endotracheal Intubation

Process	Step	CFPt	Control mode
CPR	Starting CPR	0.0315	Opportunistic control
	Completing forms and Documenting	0.0056	Tactical control
Medication	Reviewing of the nurse	0.0177	Opportunistic control
	Documenting	0.0099	Tactical control
Endotracheal Intubation	Endotracheal intubation by doctors	0.0177	Opportunistic control
	Documenting	0.0056	Tactical control

Summary of the CFP for some sub-steps of critical processes under the study is in table 4. In this table, in the first column, the three processes are presented. The second and third columns respectively show the steps and sub-steps of three selected processes. In the fourth and fifth columns, the basic value of Cognitive Failure Probability (CFP0) and Cognitive Failure Probability (CFPi) is provided for each sub-step.

In the CPR process the highest amount of CFPi was in the sub-step of command of starting CPR by anesthesiologist (0.0891) and the lowest amount of CFPi was in the sub-steps of documenting (0.0030). In the medication process the highest amount of CFPi was in the sub-steps of calculating of medicine doses and determining the method of prescription by physicians and recognizing patients (0.0796 and 0.0785 respectively) and the lowest amount of CFPi was in the sub-step of transcribing the prescribed medicine from file to the worksheet of medicine (0.0106). Also in the endotracheal intubation process the highest amount of CFPi was in the sub-steps of pulmonary and respiratory monitoring of patients and observing the vocal cords and larynx of patients (0.0350) and the lowest amount of CFPi was in the sub-steps of Recording efforts and services in HIS system and Recording observations and efforts in nurse’s report (0.0026).

Table 3: A sample of the evaluation results of HRA based on extended CREAM in CPR process

CPR	Sub-Step	Cognitive activity	Cognitive function	Generic failure type	Nominal CFP (CFP0)	CFP Adjusted
CPR1- Examining of patient by doctors and primary efforts	CPR1.1-Touching the carotid and femoral throbs	Diagnosis	Interpretation	I3	0.01	0.0446
	CPR1.2-Giving two deep breaths to patient	Execute	Execution	E2	0.003	0.0134
CPR2- Starting CPR	CPR2.1-The command of start of CPR by anesthesiologist	Communication and Co-Ordination	Interpretation	I3	0.01	0.0891
	CPR2.2-CPR via massaging	Execute	Execution	E2	0.003	0.0267
	CPR2.3-CPR via breathing	Execute	Execution	E2	0.003	0.0267

Table 4: The summary of results of extended CREAM in the three processes of CPR, Medication and Endotracheal Intubation

Process	Step	Sub-steps	CFP0	CFPi
CPR	CPR2- Starting CPR	CPR2.1-The command of starting CPR	0.01	0.0891
		CPR2.2-CPR via massaging	0.003	0.0267
		CPR2.3-CPR via breathing	0.003	0.0267
		CPR2.4-CPR via medicines	0.003	0.0267
	CPR3- Observing the effects of CPR	CPR3.1-Observing Cartoid and femoral throbs	0.007	0.0312
		CPR3.2-Observing the Sine rhythm in ECG	0.007	0.0312
		CPR3.3-Preparing and transferring patients to CCU or ICU	0.01	0.0446
		CPR3.4-Accurate monitoring of patients and watching them closely	0.007	0.0312
		CPR3.5-Transferring bodies to morgues after finding out information	0.01	0.0446
Medication	Med1- Doctor prescription	Med1.1- Getting accurate information about patients like age (children) and weight by doctors	0.007	0.0393
		Med1.2- Calculating medicine dozes and determining methods of prescription	0.02	0.0796
		Med1.3- Recording stages of calculating dosage of medicine and prescription in the paper of doctors' orders	0.003	0.0168
	Med2- Checking by nurse	Med2.1- Getting exact information about patients like age (children) and weight by nurses	0.007	0.0248
		Med2.2- Calculating the medicinal dose for the second time and reassurance of prescription method by nurses	0.02	0.0709
		Med.2.3- transcribing the prescribed medicine from file to worksheet of medicine	0.003	0.0106
Endotracheal Intubation	EIP2-Preparing before intubation	EIP2.1- Putting patients in a suitable positions by nurses	0.003	0.0150
		EIP2.2- Cardio pulmonary monitoring of patients	0.007	0.0350
		EIP2.3- Respiratory support of patients with masks and ambos based on their readiness for tracheal intubation	0.003	0.0150
		EIP2.4-Injecting loosening medicines by nurses according to physicians' instructions	0.003	0.0150
	EIP4-Recording	EIP4.1- Recording efforts and services in HIS system	0.003	0.00267
		EIP4.2- Recording observations and efforts in nurse’s report	0.003	0.00267

DISCUSSION

In recent decades, evaluating and managing human errors were center of attention in various parts of health care. For example, in Al-Hakim *et al.*’s study the goal was recognizing human errors in laparoscopy surgery using the SHERPA method. In total, 86 errors were identified during observation of 12 surgeries performed by 5 experienced surgeons [23]. Also, in a study conducted by Rolston *et al*. in Canada entitled “Analysis of errors in neurosurgery”, results showed that in 25 to 85 percent of total of surgeries, there were mistakes whose only 25 percent of recorded errors were results of methods of surgery. Most errors are the result of the whole health care team [24]. In a study by Hwang *et al*. in South Korea, whose goal was evaluating different levels of team work and its relationship with clinical errors of nurses of hospitals, findings showed that the extent of cooperation and team work in this study was average and it has positive relationship with nurses' error reporting performance [25]. In a study on surgery errors in endoscopy via HRA method which was derived from SHERPA method, done by Joise *et al*. in total, 189 errors were observed in 20 surgeries and out of them, 116 errors were related to intra-step errors and 73 of them were related to inter-step errors of surgeries [26].

These kinds of studies were focused seriously on medical and health centers of Iran in recent years. In a study done by Dastaran *et al*. whose goal was to recognize and evaluate human errors of dentist assistants using the method of SHERPA, 90 errors were recognized and the most percentage of errors were related to performance and the least was of communication type [27]. In a study done by Mazloumi *et al*. in which the goal was to recognize and evaluate human errors of urgency section doctors using the method of SHERPA, 1.56 percent of errors were unacceptably risky all of which were of control types and 53.13 percent of them were unpleasantly risky of which most were the retrieval type. Unpleasant errors were the most and unacceptable ones were the fewest [12]. In a study done by Mohammadfam *et al*. whose subject was the evaluation of human errors in the process of cataract surgery using the method of SHERPA, overall 53 errors were recognized for 14 duties in the process of surgery. Most of them were of an operational type and the fewest were of recovery types. 22.64 percent of them were unpleasant [7]. In a study conducted by Khamarnia *et al*. whose goal was to evaluate human errors in 10 governmental hospitals, results showed that 4379 errors in hospitals were recorded within a year and most of them were related to large hospitals. Nurses committed errors more than other groups. Systematic errors had the largest frequency. There was a meaningful relationship among people who committed errors, the time shift of errors and type of errors and different sections and hospitals [28].

In this study, three hospital processes including CPR, medication and endotracheal intubation were determined as critical processes. Regarding the consequences of human errors during the process of medication including increase in the death toll, incapability of patients and hospital expenses, numerous studies were done regarding this issue [29]. In this study, based on the findings achieved via basic CREAM method for medication process, the largest amount of CFPt is related to prescription and drug administration to patient which was equal to 0.056. In a study done by Ruiz *et al*. after observing medical errors in a neonatal unit of a hospital, it was found out that the largest amount of errors reported was related to drug administration to patient which was equal to 68.1 % and after that the largest amount is the one of prescribed medicines which was equal to 39.5 % [30]. Also, in another study it was found that in the process of medication, most errors occurred at the time of prescription and drug administration to patients [31]. In another study conducted by Port *et al*. whose goal was to observe the prescription of medicine to patients, results showed that 36 percent of errors occurred at the time of giving medicine, 19 percent at the method of consumption of medicine, 15 percent occurred at the time of amount of medicine and 10 percent at the time of prescribing medicine without prior doctors' advice [32].

According to the basic CREAM method, the factors related to a decrease of reliability of performance (CPCs) include: the number of simultaneous goals, available time for doing a task, time of day and adequacy of training and experience. These results in errors were achieved in passing through steps of the medication process and consequently the mode of opportunistic control. Mohammadfam *et al*. in a study to recognize and evaluate nature and reasons of human errors of nurses of CCU in a hospital used CREAM technique and stated that two factors of doing two or more tasks at the same time and the available time to work were the main reasons of errors in performance of nurses [17]. Also, in a study done by Jolaee *et al*. about analysis of occurrence and report of medication errors by nurses and their relations with working conditions in hospitals, the results showed that there was meaningful relationship between medication errors of nurses and their work conditions. In the proper work conditions, there was less probability of medication errors than in improper ones [33]. Results of the study done by Beidokhty *et al*. also showed that illegible orders of physicians, lack of personnel, high workload and overtime work of medical personnel are some factors that affected medication errors [34]. Also, reasons in his study showed that work conditions such as lack of time, lack of personnel, improper facilities and lack of experience results in increase of unsafe clinical activities and the occurrence of clinical errors [35]. The results of this study can be considered in line with the one of the current study.

In the basic CREAM method, the goal is increasing the reliability of performance and decreasing the CFPt for which the control mode must move from opportunistic to strategic [16]. Therefore, regarding the findings in this study, the CPCs can improve and the reliability of performance of medical personnel can increase and the CPCs can decrease via specialized training and also retraining scientific and practical skills, increase of personnel, decrease of overtime work and organizing work shifts.

According to findings achieved via extended CREAM method for the process of medication in the current study, the highest amount of CFPi is related to the step of calculation of medicine dose and determining the method of prescription which was 0.076. In a study done by Taheri *et al*. whose subject was observing medication errors in ICU of children in five experimental hospitals, medication errors in injections were recognized in this order: mistakes at the time of giving medicine equal with 51 to 60 percents, mistakes in medicinal calculations equal with 51 to 60 percents and mistakes in medicine doses was equal to 41 to 50 percents [36].

Also, based on the extended CREAM method, results showed that out of all recognized errors in the three processes of chosen hospitals, the majority is related to execution errors and the least is related to planning. Just as the study of Azadeh *et al*. based on categorizing human errors based on stages of human understandings and the model SRK in the urgency section of a hospital, the repetition of human errors is as follows in this order, behavior based on skills equal to 36.06 percent, behavior based on knowledge equal to 33.69 percent, behavior based on role equal to 15.82 percent and errors related to organization was equal to 8.93 percent [37]. Since errors which reassure behaviors based on skills are often of executive type, we can consider the result of the abovementioned study in agreement with the current one.

CONCLUSION

Regarding the critical consequences of human errors in the selected processes, reviewing the qualities of roles and responsibilities of each member of the healthcare team and providing specialized instructions for hospital processes, providing specialized training and also retraining scientific and practical skills, increasing personnel and reducing overtime works and organizing work shifts in order to reduce human errors in the three selected hospital processes seem necessary.

ETHICAL ISSUES

The Hamadan University of medical sciences ethics committee approved the study protocol.

CONFLICT OF INTERESTS

There are no conflicts of interest.

AUTHORS' CONTRIBUTIONS

All authors equally helped to write this manuscript.

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