Identifying and prioritizing of human errors in the anesthesia process of hospital using the extended CREAM technique: a case study

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ABSTRACT

Introduction. Anesthetizing a patient is one of the most important and vital processes in the operating room that in the case of Human error (HE) can endanger the patient's life. Therefore, this study was conducted aims to identify and evaluate HEs in operating room, anesthesia staff with the Cognitive Reliability and Error Analysis Method (CREAM).

Methods. In this study, the tasks and sub-tasks related to the anesthesia process were analyzed using the HTA technique. Then, using extensive CREAM, HEs in the tasks of anesthesia technicians were identified and evaluated.

Results. The highest CFPi was associated with "Examination of the patient in terms of the need for artificial respiration", "Carrying out special care for critical patients", and "Placing arterial lines in intensive care, emergency, and other departments". The highest in Cognitive function was execution error and the Generic failure type was the action of the wrong type.

Conclusion. This job is prone to HEs due to the variety of tasks and high stress. Therefore, the presence of experienced people and increasing the number of human resources can be effective in reducing workload and preventing errors. Moreover, providing smart and modern equipment seems important and necessary.

Keywords: human error, anesthesia, operating room, CREAM

Word Count – Words: 4746

Introduction

Human error (HE) is the deviation of human performance from set rules and tasks that goes beyond the acceptable level of the system and has adverse effects on system performance (ref). Studies have shown that HE is responsible for more than 90% of accidents in workplaces [1]. Hospital environments are complicated working systems and occur HE due to a variety of tasks, workload, fatigue, defects in information processing, and defects in decision-making [2]. Medical error is one of the most common health-threatening errors that affect patient care and can occur in various forms such as errors in diagnosis, medication, nursing care, surgery, etc. [3,4]. It can also lead to increased mortality, length of hospitalization, and treatment costs. According to statistics, more than 98,000 deaths yearly occur in American hospitals due to medical errors, and a large portion of these cases is related to medication [5]. Medication errors are common in the healthcare system, when accidental administration of the wrong medication occurs in the operating room, it can cause serious injury or even death to the patient [6]. The results of a study in Canada showed that about 30% of anesthesiologists have experienced at least more than one medication error [7]. The results of the study by the Japan Society of Anesthesiologists (JSA) on the anesthesia method in 1999-2007 showed that the most errors included overdose (25%), substitution error (23%), and omission error (21%) [8]. In a Norwegian study, 63 (0.11%) were related to medication errors, out of which 3 were classified as serious [9]. According to the study of Alsulami et al., the prevalence of drug errors in Middle Eastern countries including Iran, is estimated at 7 to 90% (10), which indicates the possibility of a high rate of HE in Iran's healthcare system [11,12]. The high rate of these errors in healthcare settings is a significant challenge that threatens patient safety, while almost half of the cases can be prevented with routine standards of care [13,14]. The results of Cooper et al.'s showed that 82% of preventable errors in anesthesia are related to HE [15]. Several studies have been done on HE in different units of the hospital including nurses, intensive care units, laboratories, etc. [16,17]. Whereas according to the HE assessment studies in the operating room, the highest error has been reported in the process of anesthesia [18]. However, few studies have evaluated the HE of operating room staff using human reliability Assessment (HRA) techniques [19,20]. Moreover, specific research on anesthesia staff in the operating room, especially in Iran has not been conducted so far. While the highest number of errors is reported in the process of anesthetizing the patient [19]. HRA has been successfully used in a number of safety-critical areas and can estimate HE probabilities based on socio-technical factors affecting human performance [21]. Therefore, anesthesia process errors in the operating room are a prime candidate for using model-based approaches such as HRA. One of the valid approaches for HRA is the cognitive reliability and error analysis method (CREAM), which is used to identify and evaluate HEs. The CREAM was presented by Eric Hollnagel in 1998. This method is one of the second-generation techniques of the HRA process, and its characteristic is to focus on the cognitive aspects of human behavior [21]. The main advantage of CREAM is its systematic structure for defining and quantifying HEs both error prediction and event analysis [22]. Considering the importance of identifying HEs in the anesthesia process, in this study the extensive CREAM technique was used in order to identify and evaluate the HEs of anesthesia staff in the hospital operating room.

Methods

This study was a case study that was carried out in an anesthesia staff operating room in a hospital. In order to implement the plan after coordinating with the hospital units, anesthesia specialists were used to analyze the tasks of anesthesia experts and identify the errors of this profession. Inclusion criteria included having at least one year of work experience in the anesthesia in the operating room, faculty members of the anesthesia department, and if they did not want to cooperate, they were excluded from the study. In this study, first, the medication process was selected as a critical issue based on the opinions of experts, specialists, and experienced people in the nursing and medical departments. The process was evaluated by the extended CREAM technique, the stages of the study were as follows:

2.1. Analyzing the Process Using Hierarchical Task Analysis (HTA)

In order to carry out this study, the CREAM error analysis technique has been used with an emphasis on human cognitive reliability. The first step before implementing the technique is to determine critical jobs and tasks. Analysis of job tasks was carried out using Hierarchical Task Analysis (HTA). The purpose of job task analysis is to provide a detailed picture of job activities in a system and analyze the performance of the tasks it is responsible for. To perform a job analysis, there are various methods. One of these methods that is mostly used to identify HEs is the hierarchical job analysis method, which was developed by Ant et al. (1971). This technique by Stanton and Young (1999) was used in nuclear power plants and chemical factories. The CREAM technique was first used by Rollnagel in 1998. This technique is one of the methods of evaluating human reliability, which can predict errors with a retrospective method. This technique does the classification of errors in the form of error types, the error causes and describes errors. [5,7].

Determining cognitive failure probability (CFP): CFPs are identified for each job task. Table 1 shows CFP related to 4 types of cognitive functions in a dependent model. The purpose of identifying CFP for each job task is to address the important types of errors expected for each task. In general, knowing the nature of the task and the characteristics of working conditions is preferable in choosing the type of cognitive failure.

Table 1. Generic cognitive failure types

Cognitive function	Generic failure type		CFP_0
Observation error	O 1	Wrong object observed	0.001
	O 2	Wrong identification	0.007
	O 3	Observation not made	0.007
Interpretation error	I1	Faulty diagnosis	0.02
	I2	Decision error	0.01
	I3	Delayed interpretation	0.01
Planning error	P1	Priority error	0.01
	P2	Inadequate plan	0.01
Execution error	E1	Action of wrong type	0.003
	E2	Action at wrong time	0.003
	E3	Action on wrong object	0.0005
	E4	Action out of sequence	0.003

	E5	Missed action	0.003

Quantitative estimation of CFP: Using the following formula, the CFPi task is estimated and determined [5,7].

$CFP_i = CFP_0 \times 10^{0.25\beta}$

Performance influence index β determined by common performance conditions (CPCs) Table 2

Table 2. Working conditions affecting the user performance of CPCs (common performance conditions)

CPC name	**Level**	**Performance influence index, β**
Adequacy of organization	Very efficient	-0.6
	Efficient	0
	Inefficient	0.6
	Deficient	1.0
Working conditions	Advantageous	-0.6
	Compatible	0
	Incompatible	1.0
Adequacy of MMI and operational support	Supportive	-1.2
	Adequate	-0.4
	Tolerable	0
	Inappropriate	1.4
Availability of procedures/plans	Appropriate	-1.2
	Acceptable	0.0
	Inappropriate	1.4
Number of simultaneous goals	Fewer than capacity	0
	Matching current capacity	0
	More than capacity	1.2

Available time	Adequate	-1.4
	Normal	0
	Temporarily inadequate	1.0
	Continuously inadequate	2.4
Time of day	Day-time (adjusted)	0
	Night-time(unadjusted)	0.6
Adequacy of training and preparation	Adequate, high experience	-1.4
	Adequate, low experience	0
	A little inadequate	1.0
	Inadequate	1.8
Crew collaboration quality	Very efficient	-1.4
	Efficient	0
	Inefficient	0.4
	Deficient	1.4

After calculating the quantitative CFP uses the formula for each of the sub-tasks, using the formula presented in Table 3 and based on the dependence between sub-tasks, the quantitative probability of total cognitive failure (CFPt) is calculated for the main task.

Table 3. The formula for calculating the total cognitive failure of the main task

Logic relation between sub-tasks	**Dependence between sub-tasks**	**Total Cognitive failure probability, CFP_t**
Only failure of all sub-tasks would fail the task (parallel subtasks)	High dependence	$Min(CFP_i)$
	Independent/low dependence	$\Pi (CFP_i)$
Failure of one sub-task leading to failure of the task (sequential subtasks)	High dependence	$Max(CFP_i)$
	Independent/low dependence	$\sum (CFP_i)$

Results

In this study, the main tasks and activities in the anesthesia process were examined. In general, the anesthesia process includes 5 main tasks, which are: Routine duties of an anesthesia expert, Patient reception anesthesia process, bringing the patient to consciousness, Recovery, and Other tasks of an anesthesia expert. The routine tasks of an anesthesiologist before admitting a patient, accepting the patient, performing the anesthesia process, bringing the patient to consciousness, recovery, and other tasks assigned to the anesthesiologist including intubation in the other units of the hospital. Such as ICU, maternity unit, corona patient unit, etc. In these 5 main tasks, 50 different activities were identified, of which 39 activities are related to anesthesia technicians or bachelors, and 11 activities are related to anesthesiologists. Based on these activities, 53 cognitive activities were identified and determined. The highest number of cognitive failures in anesthesia technicians or bachelors was related to execution error and the lowest was related to observation error. The highest number of cognitive failures in anesthesiologists was related to observation error and the lowest was related to execution error (Figure 1). The highest CFPi was associated with "Examination of the patient in terms of the need for artificial respiration", "Carrying out special care for critical patients", and "Placing arterial lines in intensive care, emergency, and other departments" (Table 4). The highest in Cognitive function was execution error and the Generic failure type was the action of the wrong type (Table 5). The cause of the errors from the anesthesia workers' point of view is mainly high workload and fatigue, as well as in some cases inexperience and organization failure.

Figure 1. Type and percentage of cognitive function of anesthesia workers

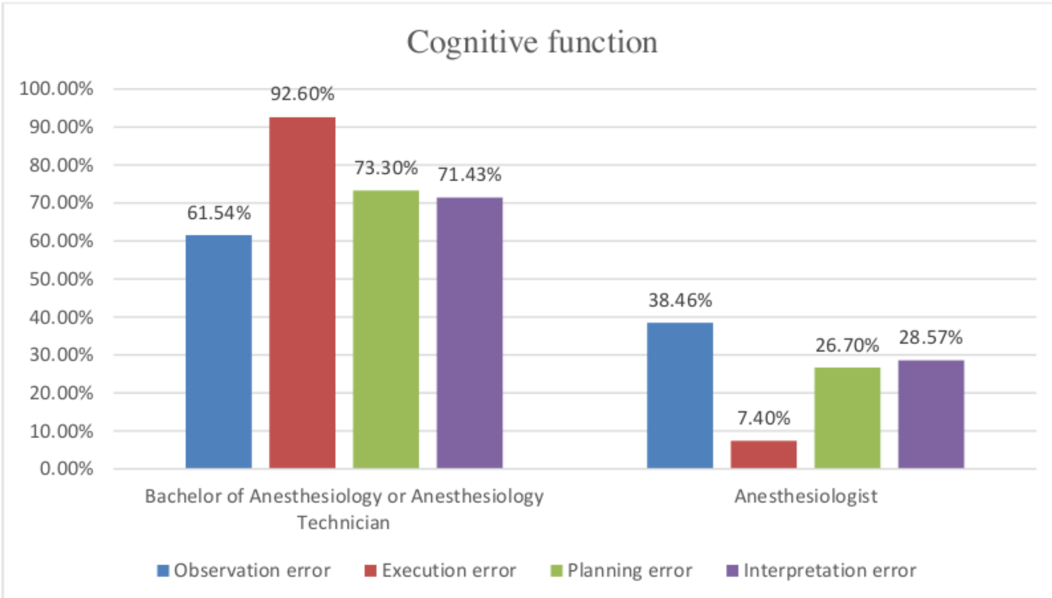

Table 4. Description of tasks and error probability of anesthesia staff in the operating room

Row	Task	Sub-task	CFP0	β	CFPi	CFPt
1	Routine duties of an anesthesia expert	Receive orders and work plans from the supervisor of the operating room	0.01	-1.2	0.0050	0.0140
		Preparing all the tools required for anesthesia according to the surgery list	0.01		0.0050	
		Control of anesthetic gases to avoid the instead of each other use (wrong use)	0.001		0.0005	
		Ensuring the health and efficiency of anesthesia machines and tools before starting each work shift (including anesthesia devices, suction, monitors, pulse ox meters, etc.) and reporting any defects or malfunctions to the supervisor	0.007		0.0035	
2	Patient reception	Guiding the patient to the surgery bed and accompanying the patient from the beginning to the end of the surgery and giving explanations about anesthesia	0.01	-0.6	0.0071	0.0311

		Monitor vital signs and report abnormalities	0.001		0.0010	
		Creating an intravenous line (IV)	0.003		0.0030	
		Consulting with the head of the anesthesia department and deciding on the type of anesthesia (general-regional) according to the patient's condition and the results of the tests.	0.01		0.0100	
		Consultation of the supervisor with the anesthesia team and decision on the amount and type of medicine required by the patient	0.01		0.0100	
3	**Anesthesia process**	Preparing drugs and other necessary equipment for anesthesia	0.01	-3.6	0.0013	0.0243
		Providing drugs and anesthesia tools to the doctor	0.0005		0.0005	
		Anesthetizing the patient throughout the surgery and following up with the patient until the end of the surgery in terms of anesthesia	0.003		0.0030	
		Helping the anesthesiologist in various matters, including anesthesia, cardiac and pulmonary resuscitation, etc.	0.01		0.0100	
		Helping the anesthesiologist in various matters, including anesthesia, cardiac and pulmonary resuscitation, etc.	0.003		0.0030	
		Injecting drugs, blood, or blood products into the patient according to the order of the anesthesiologist	0.003		0.0030	
		Continuous cardiac and respiratory care of the patient during the operation	0.0005		0.0005	
		Patient anesthesia monitoring during surgery	0.003		0.0030	
4	**Bringing the patient to consciousness**	Injecting awakening drugs and bringing the patient to consciousness	0.003	0.4	0.0038	0.0238
		Examination of the patient in terms of the need for artificial respiration, and examination of the patient's condition in terms of blood gases in the intensive care units	0.02		0.0200	
5	**Recovery**	Carrying out special care for critical patients	0.02	2.4	0.079	0.0795
		Reduce postoperative pain	0.000		0.0005	

				5			
6	expert	Other tasks of an anesthesia	Performing the on-call task in the surgical department during emergencies	0.01	1	0.0178	0.0543
			Placing arterial lines in intensive care, emergency, and other departments	0.02		0.0355	
			Anesthesia and intubation monitoring when sending the patient to other hospitals	0.001		0.0010	

Table 5. Type of cognitive function and frequency of potential cognitive errors of anesthesia workers

Row	**Cognitive function**	**Generic failure type**	N (%)
1	Execution error	Action of wrong type	18(%31.03)
2	Programming error	Priority error	9(%15.52)
3	Programming error	Inadequate plan	6(%10.35)
4	Observation error	Wrong object observed	5(%8.62)
5	Execution error	Missed action	3(%5.17)
6	Observation error	Wrong identification	3(%5.17)
7	Execution error	Action on wrong object	3(%5.17)
8	Interpretation error	Faulty diagnosis	3(%5.17)
9	Observation error	Observation not made	3(%5.17)
10	Execution error	Action out of sequence	2(%3.45)
11	Interpretation error	Decision error	2(%3.45)
12	Interpretation error	Delayed interpretation	1(%1.73)
Total			58(%100)

Discussion

Human error in treatment processes, especially in the process of anesthetizing the patient, can cause the patient's life to be endangered. Therefore, this study was carried out with the aim of investigating human errors in this process and in the jobs the technician and bachelor of anesthesia, and anesthesiologist. The results of Liberman et al. in 2020 regarding non-routine events in anesthesia care showed that 173 non-routine events occurred, of which 69.4% affected the patient and 12.7% caused the patient injury. The most common incidents affecting the patient include the cardiovascular system, airways, human factors, drugs, and equipment [23]. In a study conducted by B Cooper et al. in 2002 in the United States, preventable errors in anesthesia were investigated. The results showed that most of the preventable accidents involved human error (82%) [15]. It is necessary to mention that a specialized study has not been done in these tasks and most of the studies have examined human error in the operating room in general. Some of the main tasks related to anesthesia have also been investigated, which compared with their results in this study. The results of Asgari et al.'s study on operating room staff using the HEART method showed that the highest probability of error in the activities of the anesthesia bachelors and anesthesiologists was related to performing resuscitation [20].

The highest CFPi was associated with "Examination of the patient in terms of the need for artificial respiration", "Carrying out special care for critical patients", and "Placing arterial lines in intensive care, emergency, and other departments" while in the study of Mohammadfam et al. on the vital processes of the hospital using the extensive cream technique, the results showed that the highest CFP is related to the "CPR process at the stage of ordering the start of CPR by anesthesiologists (0.0891)", "giving medication at the stage of calculating the drug dose and determination of prescription methods (0.0796)", as well as "tracheal intubation method in the stages of pulmonary and respiratory monitoring of patients and observation of vocal cords and larynx (0.0350)". Considering the critical consequences of human errors in the selection processes, it seems necessary to review the quality of the roles and responsibilities of each member of the medical group and provide specialized hospital processes [24]. And in the study of Asgari et al., in the study of human error in the operating room jobs in Golpayegan city, using the HEART method, resuscitation by a bachelor of anesthesia and an anesthesiologist had the highest probability of error. Cutting the eye and removing the lens by an ophthalmologist, and cutting and removing a part of the intestine by a general surgeon was the next most likely to cause errors [20]. In a study B Cooper et al. the most common human error included interruption of breathing communication, inadvertent changes in gas flow, and drug administration errors. Only 14% of accidents are reported due to equipment failure. Other factors related to accidents include insufficient communication between personnel, haste or lack of caution, and distraction [15]. The results of Liberman et al.'s study show that the most common incidents affecting the patient in the non-routine process of anesthesia include the cardiovascular system, airways, human factors, drugs, and equipment [23]. The study of human errors of cardiac special care nurses using the CREAM technique showed that in the tasks of "adjusting and applying a shock DC in necessary cases", "recording data in the comprehensive hospital system", and "announcing the code and starting cardiopulmonary resuscitation" the probability of human error was high [24]. Aldossary and colleagues in a study investigated medication errors among anesthesiologists in Saudi Arabia. The results showed that 69% of anesthesiologists have experienced a medication error at least once. The two main reasons for the occurrence of these errors have been reported as haste and heavy workload. Most errors occurred in people with little work experience. In this study, the re-examination of drug and syringe labels with color codes is the most effective strategy to reduce errors. 77% considered the fear of forensic issues as the most common obstacle to not reporting medication errors [25]. Fasting et al investigated medication errors in anesthesia and the effect of colored syringe labels. The results showed that 63 cases of refereeing errors were registered. Errors included wrong syringe exchange, wrong muscle relaxant injection, wrong drug dosage, and wrong judgment injection. 3 cases of serious errors and 27 cases of moderate errors have been classified. Although judgmental errors in anesthesia are rare, they have the potential to cause serious complications. Choosing the wrong syringe usually happens in syringes of the same size, and color coding usually does not reduce this error. Considering that muscle relaxants have lasting side effects, preventive measures should be taken from this group of drugs [9]. In a study conducted by Cheragi et al., in Iran regarding medication errors in nurses, the results indicate that the most common types of errors reported are drug dosage and injection rate errors, and the most common causes are the use of the abbreviated name of the drug instead of the full name or the use of the similar name. The most important cause of the medical error is the lack of pharmacology. And most nurses do not report the error. And it is recommended that managers should show a positive reaction so that nurses are encouraged to report errors [2]. The study of Gorgich et al. in Zahedan showed that the medication error in nursing students was related to the error in calculating the amount of medication. And the most common cause of error is due to fatigue caused by workload [4]. The study of the errors of the anesthesia personnel by Kavousi et al. using the FMEA method revealed that most error was related to the process of anesthetizing the patient by the anesthesia resident. The highest frequency of error root causes was related to human errors and organizational errors, and the lowest error was related to technical errors. The same color of drugs may cause mistakes in emergency cases [9]. Aldossary and colleagues have reported that the two main causes of medication errors in anesthesiologists are haste and workload. Most errors occurred in people with little work experience. Fear of forensic medicine is the most common obstacle to not reporting medication errors [24]. Other studies have attributed anesthesia errors to insufficient communication between personnel, carelessness, and distraction [12]. The results of Asgari et al.'s study showed that more fatigue and negligence are reported to be the cause of human error. High workload and sleep disturbance have caused fatigue [20]. In the study of Mohammadfam et al., the cause of human error with the SHERPA method in the process of cataract surgery is mentioned. In our study, most error was related to human error of execution error, and the cause of the error was mainly reported to be high workload and fatigue. The result of the study on the performance of the employees of the performance room in Shiraz showed that the errors were mainly of functional and skill type [24]. In Kazaoka et al.'s study, a lack of experience in nurses was reported as the cause of human error [26]. The study of Mohammadfam et al. was carried out to identify and evaluate human errors using the CREAM technique. The incidence of human error in cardiac intensive care unit nurses is due to doing two or more tasks at the same time and the time of doing the work. The first one can occur due to the simultaneous multi-tasking of the nurse, especially when the unit is busy. The second factor, which represents the work shift, shows the irregularity of the shifts mentioned [24].

During the coronavirus epidemic, when the treatment staff is under more job stress, the probability of these errors will be higher. Due to the fact that the anesthesia personnel work with the face, mouth, and lung area, in some cases it causes more stress in the anesthetizing work. For example, intubation of the trachea of a coronavirus patient in the intensive care unit of the coronavirus or some patients who visit the operating room may be carriers of the coronavirus. Therefore, the possibility of errors due to stress can increase in these conditions. Studies have shown that stress is also one of the causes of human error [1]. Also, highly stressful jobs are more likely to cause burnout, and the occurrence of medical errors and the quality of providing medical services to patients are also affected by stress [15]. Among the limitations of this study are the limited access to anesthesiologists and the fear of reporting errors.

Conclusion

Considering that the anesthesia process is prone to HE, training should be done to increase awareness and prevent these errors. Employing experienced people and increasing the number of operating room personnel can be effective in reducing workload and fatigue and preventing errors. Also, it is suggested to review the drug and syringe labels with color codes as the most effective strategies to reduce medication errors. Providing intelligent and advanced equipment that prevents HEs to a large extent seems to be an important and necessary solution. Also, policies based on non-punishment should be implemented to encourage employees to report errors.

Conflicts of Interest: The authors declare no conflict of interest.

Ethical Clearance: This study was approved by Ardabil University of Medical Sciences with ethical code: IR.ARUMS.REC.1400.158.

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