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Improving Patient Safety: Exploring the Causes of Medical Errors Using the HFACS Framework in Hospitals

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A B S T R A C T

Introduction: Attention to patient safety is one of the essential foundations for promoting health services and it is important to identify the factors contributing to medical errors. This paper aims to develop a questionnaire based on the human factors analysis and classification system (HFACS) for the first time.

Materials & Methods: A questionnaire was designed based on the HFACS structure. The Likert scale was utilized to score each item. The contribution of the main levels and sublevels in each error and also the correlation coefficients between different levels of HFACS with the lowest level, referred to as “Unsafe Acts” were determined.

Results: The number of medical errors in the emergency department, intensive care unit (ICU), and Cardiac Care Unit (CCU) were higher than in the other departments. Insufficient supervision, management processes, and adverse mental state achieved the highest scores. Pearson's correlation coefficients show very strong relationships between organizational processes and supervisory violations with routine violations (0.81, and 0.84 respectively).

Conclusion: Organizational failures are the main cause of decreased patient safety and the mental condition of staff has the greatest impact on reducing medical errors.

Keywords: Hospital, HFACS, Medical Errors, Patient Safety

➤ **How to cite this paper**

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Introduction

Nowadays, patient safety is as critical as worker safety, paying more attention to patient safety is one of the essential foundational to promoting health services. In this way, the simplest definition of patient safety can be introduced as “those activities that may reduce the risk of adverse events related to exposure to medical care across a range of diagnoses or conditions” (1). Although the health care system has become more effective, it has also become more complex, with increased use of new technologies, medicines, and treatments. Recent studies have shown that in Australia and the U.S., 16.6% and 3.7%, respectively, of patients who were hospitalized had complications due to medical errors (2). Thus, failure to prescribe medication can cause complications that can be prevented (3). Here, a drug error that may occur in the operating room, can be very problematic in the patient's anesthetic process (4). It is important to identify the factors that contribute to medical errors in certain situations, such as the COVID-19 pandemic.

In a study conducted on 277 surgical procedures, of 3671 prescriptions, 193 drug errors (5.3%) occurred. They also found that 79.3% of them were preventable (5). Developing strategies to achieve the experience from errors occurring in treatment centers requires accurate planning by managers to generate conditions where employees can report errors without worries. Nevertheless, in recent years, several models have been developed to distinguish and reduce human errors (6, 7). One of these methods is the Human Factor Analysis and Classification System (HFACS) framework, which was initially introduced by Dekker as one of the most influential and practical tools to survey different types of incidents (8). This model was initially provided for the analysis and classification of operator errors in aviation and maritime accidents, based on the Reason model, which was introduced to identify human error in air traffic accidents. According to Reason, errors are categorized into two groups, active errors, and latent errors, based on which the active errors occur at the point of contact between a human and some aspect of a larger system. In contrast, latent errors denote less apparent failures of organization or design that contributed to the occurrence of errors or allowed them to cause harm to workers (9).

The structure of the HFACS is defined in four hierarchical levels. The four main levels include unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences. Each level is related to the previous level, and the reasons for the error are arranged from active to latent situations in a hierarchical manner from unsafe acts to organizational influences. A better explanation of the HFACS framework is illustrated in Figure 1 (10).

HFACS is well known as a framework for investigating some fields such as railway accidents (11) as a model to illustrate the roots of errors in mining (12-14), oil and gas (11), construction (15), health care(16), surgical procedures (17), and as a tool for reducing occupational accidents in the shipyard has been used (18).

Boquet et al. described the HFACS system to distinguish the causes of both active errors and latent errors in medical emergencies. In this way, they found that the highest percentage of errors were related to skill-based errors (69%), decision errors (31%), perceptual errors (26%), and violation errors (15%) (19). On the other hand, in a study on 545 incidents in the airline industry using the HFACS method, it was found that Level 1 skill-based errors, Level 2 adverse mental state, Level 3 Inadequate supervision, and Level 4 resource management have been the most effective factor in accidents (20).

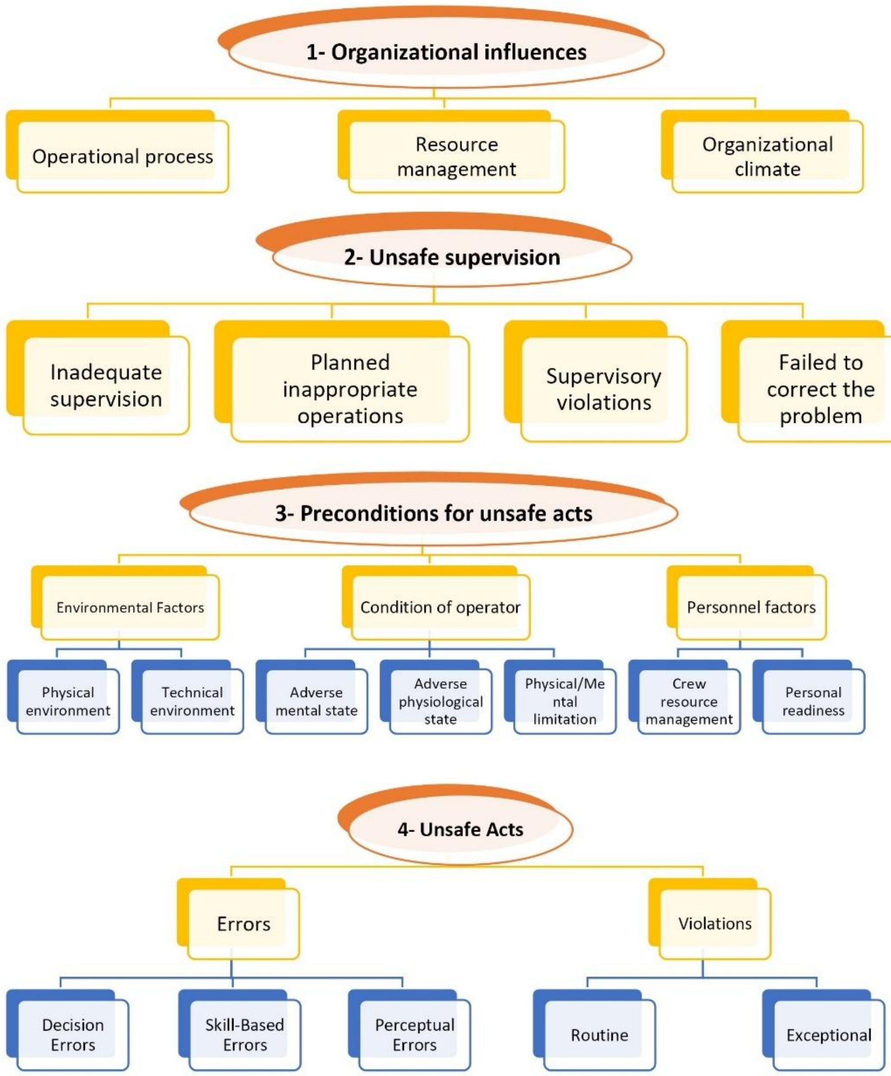

Fig 1. The HFACS framework

Here, it should be noted that when a medical error occurs, an active error could be detected immediately. Nevertheless, are there any latent errors? As long as there are latent causes, even if we remove the causes of the active error, we should expect other errors at other places and times. Now, the HFACS tool has acceptable inter and intra-rater reliability for the assessment of accidents (21), which reveals that this method has the value of training and implementation in the health care system.

As we need the right tools to appropriately identify the causes of both active and latent error, this paper aims to develop a questionnaire based on the principles of the HFACS method to distinguish the main and critical causes of human error in the treatment process as well as to determine causes of the medical errors in a training hospital.

Materials and methods

This study was approved by the IRB of our institution (IR.UMSHA.REC.1397.460) and was conducted in an educational hospital, including more than 1000 patient beds, 3000 medical staff members, and 10,000 employees. The medical errors that occurred from February to April 2020 were analyzed. The hospital's policy is based on the identification and analysis of medical errors to enhance the patient safety policy. To do it, a questionnaire was designed based on the HFACS structure, which contains four main levels, 19 sublevels, and a total of 94 questions.

Both the validity and reliability of the questionnaire were assessed by 10 experts and the medical staff. Besides, to evaluate the reliability of the proposed questionnaire, the content validity method (CVR and CVI indices) was employed. Furthermore, the Cronbach's alpha coefficient was utilized to investigate the reliability of the questionnaire. Based on the study by ElBardissi et al., 359 medical errors were investigated (22).

It is worthwhile to mention that two trained experts through an interview filled out the proposed questionnaires along with doctors and nurses, in an educational hospital. Interviewees should answer each question based on medical errors that they either have carried out or have been witnessing.

To do it, the Likert scale and ranging were utilized to score each question, in which from very low=1 to very high=5. In this way, the contribution of the main levels and sublevels in each accident was specified, as each error usually has more than one cause, and the impact of each cause on the accident is different.

Ultimately, the subgroup scores at each level of HFACS were analyzed using SPSS-21 software. The following formula was employed to calculate the error score.

$$S = \frac{a}{b}$$

Where "a" denotes the sum of the scores given by participants to questions at each level, and "b" means the maximum points of each level (based on the Likert scale). For instance, suppose there are four questions for the skill-based error level, and participants scored five on each of these four questions, so a=4×5=20 and b=4×5=20 (the highest score on the Likert scale was considered five). As a result, the final score of the skill-based error sub-level becomes one (S= 20/20=1).

The sub-level relative score was then measured from the sum of the total scores of the questionnaires. On the other hand, the score of the main level was also achieved from the sum of its relative score of sub-levels. For example, the relative score of the "violation level" was calculated from the sum of the "routine" and "exception" sub-level scores.

In addition, the SPSS software was implemented to elaborate the correlation coefficient between different levels of HFACS and the lowest level (unsafe act), as the level of "unsafe act" is immediately before the error.

Findings

In the following, those questions with CVR and CVI of less than 0.7 were eliminated so that the number of questions decreased from 105 to 94. Meanwhile, in the analysis of reliability, the Cronbach's alpha coefficient was obtained as 0.721. In this study, 42% of participants in this study had more than 5 years 43% had between 5 and 15 years and the rest had less than 5 years of work experience. The most frequent errors were in the emergency department, Cardiac Care Unit (CCU), and intensive care unit (ICU) (31%, 24%, and 32% respectively).

By investigating the questionnaires, it was revealed that each medical error had more than one cause. Besides, the relative score of each main level of HFACS was measured to distinguish the contribution of causes. The results show that the relative scores of "unsafe supervisions" and "organizational influences" are higher than other levels. The organizational influences level contains three sublevels, and the unsafe supervision level includes four sublevels whose relative scores are exhibited in Figure 2

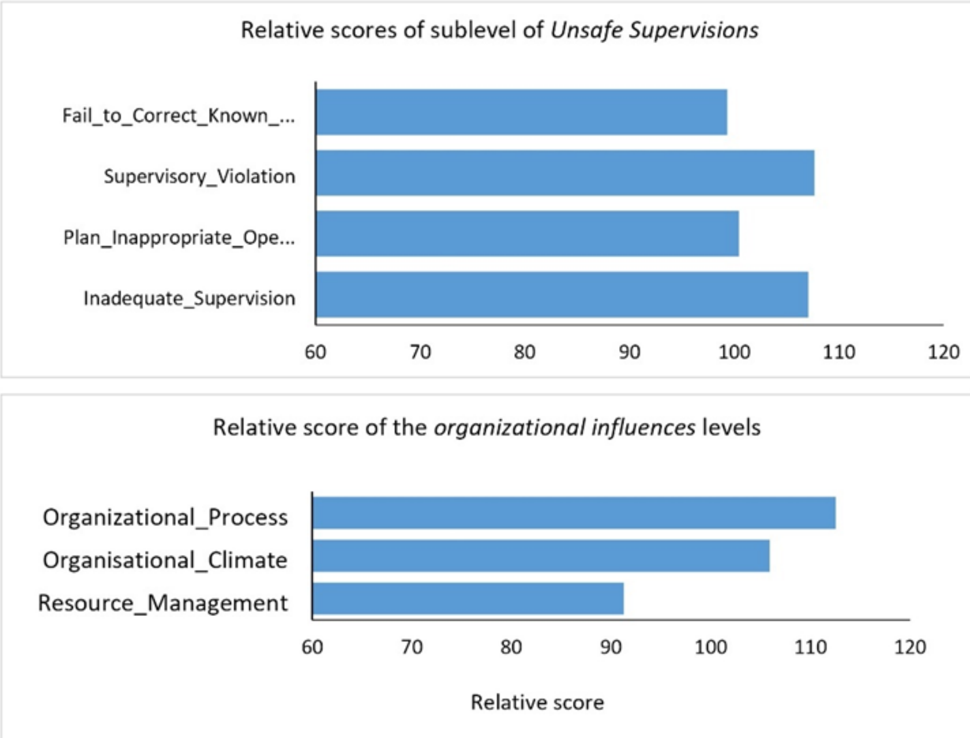

Fig 2. Relative scores of sublevels of organizational influences and unsafe supervision

Based on Figure 2, both the "organizational process" and the "supervisory violation" obtain the highest score. In this regard, to better understand the received experimental results, the relative score of all levels of the HFACS can be observed in Figure 3.

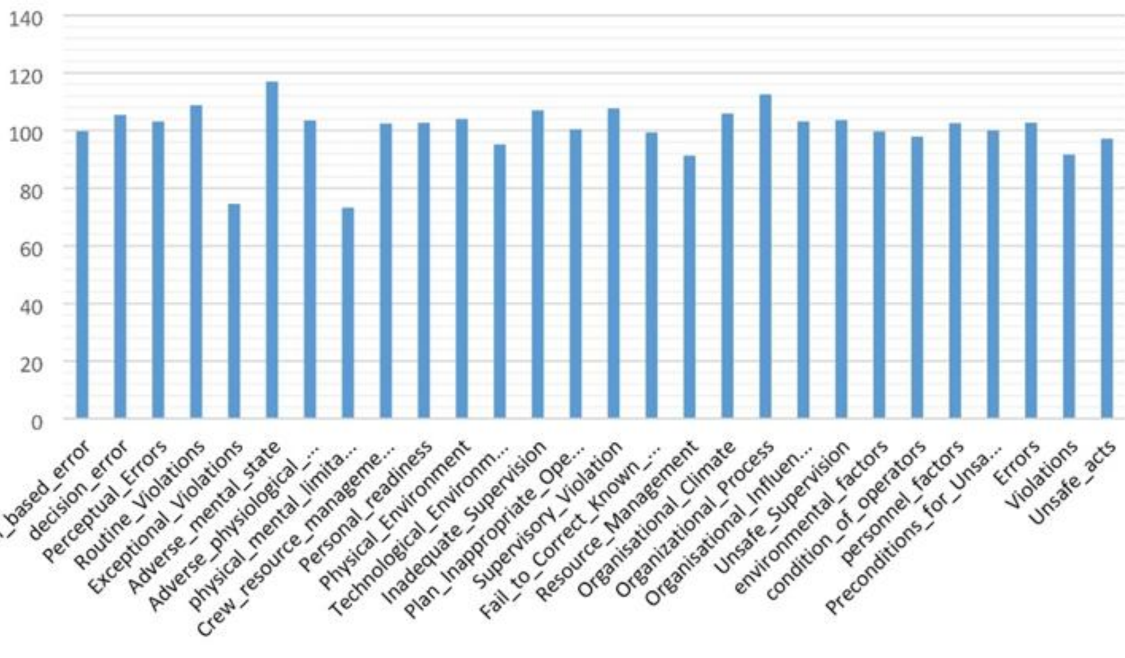

Fig 3. The relative score of all levels of the HFACS.

In the meantime, the Pearson correlation coefficients between the main levels of HFACS are shown in Figure 4.

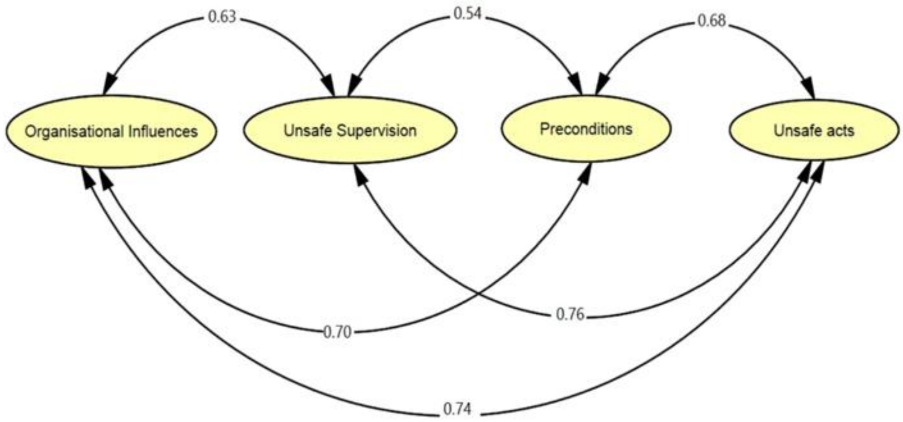

Fig 4. Pearson correlation coefficients between main levels of HFACS.

Here, to explore the relationships between the response's sublevels, Pearson correlation coefficients were estimated, which are listed in Table 1.

Table 1. Pearson Correlation Coefficients between sublevels.

		Unsafe Acts				
		Decision Errors	Skill-based Errors	Perceptual Errors	Routine	Exceptional
Organizational Influences	Resource Management	0.73	0.61	0.66	0.12	0.18
	Climate	0.75	0.70	0.73	0.73	0.65
	Process	0.64	0.66	0.60	0.81	0.80
Unsafe Supervision	Inadequate	NS	NS	NS	0.54	0.41
	Planned	0.81	0.65	0.48	0.55	NS
	Failed to correct	0.42	NS	NS	0.77	0.68
	Supervisory violations	NS	0.54	0.61	0.84	0.33
Preconditions for Unsafe Acts	Environmental	0.31	NS	0.46	NS	NS
	Adverse mental	0.84	0.15	0.55	0.57	0.48

	Adverse physiological	0.21	0.11	0.14	NS	NS
	Physical/Mental Limitations	0.15	0.17	0.20	NS	NS
	Crew resource management	0.71	0.74	0.79	0.33	0.21
	Personal readiness	0.71	0.23	0.15	NS	NS

NS = not significant.

Discussion

In this study, medical errors were assessed using a questionnaire based on the HFACS method, and the causes of medical errors were examined at four main levels (Unsafe Acts, Conditions for unsafe Acts, Unsafe Supervision, and Organizational Influences) associated with 19 subscales.

Recent studies show that the incidence of medical errors is increasing worldwide (23, 24), in most error-reduction approaches have decreased the incidence of accidents in the manufacturing industry (25, 26). Several of these approaches are also practical and applicable in the healthcare system, such as HFACS. According to the obtained results of this study, it can be concluded that the questionnaire provided in this study contains both good reliability and validity.

The initial experimental results revealed that the number of medical errors in the emergency department (34%), the ICU (32%), and the CCU (24%) were higher than the other departments. Westbrook et al., described the causes of more errors in the emergency unit as are mainly as follows: multitasking, and poor sleep (27).

On the other hand, there were no significant differences between the error statistics in different shifts. Meanwhile, the number of nurses' errors was noticeably higher than physicians. This difference could be interpreted due to the overworking of nurses. A study conducted by Macphee et al. examined the impact of nurses' workload on their performance (28). In addition, the results of another survey of 1816 nurses working in South Korea were in accordance with ones of the current research (29).

Relative scores of the main levels of "organizational influences" and "unsafe supervision" achieved the highest scores. According to the proposed questionnaire, the most important organizational effects included follows: low staffing, selection of people on irrelevant criteria, poor equipment management, unrealistic policies, inadequate delegation of authority, poor patient safety culture, and poor reporting culture of the voluntary error. Tang et al., by evaluating patient safety during surgery, found that the organization was highly effective in causing a medical error (30).

Investigation of the questions of the proposed questionnaire also showed that at the level of " unsafe supervision" factors such as inadequate supervision of personnel, irregular work schedules, failure to perform dangerous operations, failure to supervise proper implementation of policies and procedures, failure to correct problems known in the field of patient safety, and so on, are the main and critical causes of medical errors at this level. The results illustrated in Figure 2 which show the relative scores of the sub-levels at the levels of "organizational influences" and "unsafe supervision", demonstrate that insufficient and insecure supervision and management processes achieved the highest scores.

Furthermore, Figure 3 exhibits the relative scores of all HFACS substrates. It should be mentioned that below the level of the "adverse mental state", it achieved the highest score among all sub-levels in the ‘Preconditions for Unsafe Acts’ category. Thus, these results are in accordance with the results of a study of 8597 Canadian nurses. In this regard, Laschinger et al. found that burnout is highly effective in reducing nurses' performance (2006), especially when nurses and doctors work long shifts (31).

In the meantime, the Pearson's correlation coefficients between the four main levels of HFACS in Figure 4 reveal that investigating the causes of medical errors should not be limited to one level, as in complex organizations such as hospitals, a set of factors interact with each other to cause medical error.

Some studies (32, 33) have shown that other organizational factors such as poor patient safety culture, human resource management deficits, and job dissatisfaction directly influence the unsafe practices of physicians and nurses, and may even reduce reporting of errors (34). The Pearson's correlation coefficient between the first, second, and third levels below the fourth level (unsafe acts) in Table 1 shows that there are very strong relationships between "organizational processes" and "supervisory violations" with "routine violations" (Pearson coefficients of 0.81, and 0.84 respectively). In some studies (35), changes in organizational processes have reduced errors.

Moreover, the correlation coefficients between the planned inappropriate operations and adverse mental states are highly correlated with the incidence of decision error and are consistent with similar studies (36, 37).

Conclusion

IBy focusing on the root causes of accidents and their classification in human error detection, the HFACS approach can be employed as an effective and practical tool to investigate human error in the healthcare industry. The results of this study showed that organizational failure is the main cause of decreased patient safety. This becomes even more critical during pandemics.

These organizational deficiencies, such as a lack of proper supervision, inadequate human resources management, unrealistic policies, etc., may lead to preconditions for medical errors and violations. Without correcting these deficiencies, efforts to reduce medical errors and increase patient safety will be fruitless.

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Ethics approval

This study was approved by the Institutional Review Board of Hamadan University of Medical Sciences (IR.UMSHA.REC.1397.460).

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Conflict of interest

The authors declare that there is no conflict of interest.

Authors’ contributions

All authors contributed significantly to the conception, design, data collection, analysis, and writing of the manuscript. All authors reviewed and approved the final version of the article.

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