Application of "Human Factor Analysis and Classification System" (HFACS) Model to the Prevention of Medical Errors and Adverse Events: A Systematic Review

Abstract

Hospitals, as one of most important subsectors in human societies, are responsible for providing safe and effective medical services to clients. But sometimes these hospitals are the source of injury and death in patients by creating medical errors. In this systematic review study, the application of human factor analysis and classification system (HFACS) method in the classification of medical errors was investigated. Major electronic databases including Scopus, Web of Science, and MEDLINE were searched. All studies that investigated the application of HFACS method for coding, causation, and classification of medical errors and adverse events conducted from 2001 until February 2021 were included. A total of 108 articles were found. Due to duplication, 18 studies were removed from the review list. After reading the titles and abstracts, 50 of these publications were excluded because they had objectives different from this review. The remaining 40 publications were retrieved for further assessment. Of these, 28 publications were excluded because it did not meet the inclusion criteria. Finally, 12 articles remained for the final systematic review. We found that in 65% of the selected studies, preconditions for unsafe acts have been the major causal level of medical errors and adverse events. In the majority of the studies, communication and coordination, adverse mental states, physical environment, crew resource management, and technological environment have also been recognized as the most important causal categories in this study. As a result, to prevent medical errors and adverse events, the main focus should be on controlling the preconditions for unsafe acts including personnel factors, operator conditions, and environmental factors.

Keywords: *Adverse event, health care system, human factor analysis and classification system, medical error, patient safety*

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Introduction

Health care system (HCS) is one of the most important and vital systems of society. This system consists of different sectors in different countries. Hospitals are among the major subsets of this system and play a key role in human's health. The mission of hospitals is to provide safe and effective medical services for the referring patients. However, sometimes hospitals become the origin of harms, and despite the advanced technologies and cares, medical errors cause different complications and death, and impose a lot of costs on patients and society. So, in the present world, supplying the patients' safety and preventing the medical errors and adverse events in hospitals is a global issue. Investing in increase in patients' safety can result in significant financial savings.[1,2]

According to the definition proposed by the Joint Commission on Accreditation of Healthcare Organizations, a medical error refers to an unwanted action that is done due to negligence, and results in an unfavorable outcome in medical processes. In other words, a medical error is an action or decision that does not corresponds to HCS standards. HCS standards are rational and planned decisions that should be made by authorities based on due conditions and requisites. A medical error may result in an adverse event or not.[2] An adverse event is characterized by three conditions: (1) the incident should be unfavorable, unwanted, unexpected, and unpredictable; (2) doctors, nurses, the hospital, or the health system should be somehow involved in that; and (3) it should cause an actual or potential damage to the patients, their companions, their family, or in general, the health

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system. Adverse events are sometimes preventable and sometimes unpreventable.[3]

According to World Health Organization report, every year 421 million patients are hospitalized in the world, and about 42.7 million cases of complications are reported in the hospitalized patients during the hospitalization period. Based on conservative estimations, the latest data suggests that patient damage is the 14th major cause of deaths all over the world. In high-income countries, 1 patient out of every 10 patients is damaged while receiving hospital care.[4] Various factors are involved in patient's safety, which are directly and indirectly related to medical errors. Currently, the most important area in patient's safety is medication error and side effects of drugs.[5,6] Meanwhile, some hospital wards such as intensive care unit are especially at risk of system failures and equipment deficits.[7]

Regarding the significance of this issue, over the recent years, international health institutions have paid attention to patient's safety and safety promotion in HCS. To promote the reliability of HCS, there should be improved methods for detecting and perceiving adverse and unfavorable events and quasiincidents.[8] However, unfortunately, the expected reliability has not been realized yet.[9] One of the methods that have been recently used for analyzing and detecting the causes of medical errors and adverse events is human factor analysis and classification system (HFACS). This method was introduced by Chapel and Wigman (2001) for modifying the deficiencies of Swiss Cheese method.[10] Having analyzed hundreds of incident reports, HFACS was specifically developed for defining the underlying internal deficiencies and filling the gap between the theories and practices in Swiss Cheese method. The main difference between HFACS and other incident cause models is that this model observes the role of management and organization as part of the safety system. This major advantage of HFACS is that rather than detecting an error, it aims to seek out the causes of the error. HFACS has a hierarchical structure that consists of 19 causal categories classified into four levels. These four levels include unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational effects.[11]

Over the recent years, researchers have paid attention to HFACS to identify the human and organizational factors involved in medical errors and adverse events. This method has so far been used in different sectors and HCS processes, and several studies have suggested it as an alternative for other traditional methods such as root cause analysis (RCA). The present study aims to investigate the studies that have used HFACS for analyzing and detecting the cause of medical errors and adverse events.

Methods

Theoretical framework

From the perspective of safety and human factors engineering, the study of human error in the workplace is not a new issue. James Reason (1990) and Shappell and Wiegmann (2001) have suggested that errors occur at four levels: (a) unsafe acts that indicates the actions of the operator; (b) preconditions for unsafe acts that expresses environmental factors contributing to the error; (c) supervision that indicates the management actions affecting the operator; and (d) organizational influences that includes culture, policies, and procedures of the organization that affect the operator.[10,12] According to Reason, humans are inherently prone to error, and system processes are often affected by latent weaknesses.[13] To counter this situation, organizations create redundant defensive barriers to prevent errors. Although the use of this procedure is effective, but each barrier has its own inherent weakness that overall degrades the quality of the system and makes it vulnerable to failure.[14] This model is known as Swiss cheese and states that any barriers has a weakness that can lead to human error and damage to the system.[14] This model is widely used today in risk assessment and safety management in various types of organizations such as health, aviation, marine, mining, etc.[13-17]

The model consists of several layers that are similar to Swiss cheese and define the cavities in Swiss cheese as defects in each of these layers. This model introduces unsafe practices as the main and direct cause of accidents. It then states the cause of unsafe acts at three levels: preconditions for unsafe act, unsafe supervision, and organizational effects.[14] Although Reason's theory provides a framework for traditional accident investigation, it lacks the specificity to be applied within the real world and fails to identify the exact nature of the cavities in the cheese. In a way, the type of failures that occur at each level is not fully detailed, and this model has no practical application. In order for the model to be used systematically and effectively as an analysis tool, the holes in the cheese must be clearly defined.[8]

Human factors analysis and classification system

Due to the shortcomings of the Swiss cheese model, Chapel and Wigman proposed the "HFACS" to bridge the gap between theory and practice of the Swiss cheese method. The HFACS method is specifically designed to define latent and active defects in the Swiss cheese model that can be used as a research tool.[10]

The HFACS is a commonly used tool for analyzing human factors issues associated with accidents across a variety of industries, including aviation, railway, shipping, mining, manufacturing, and healthcare.[18-27] HFACS consists of causal categories under each of Reason's four levels of error causation. Each of the categories consists of nanocodes that represent specific human behaviors or system situations that may lead to errors. The causes of an adverse event are systematically identified and assigned to 1 or more of the nanocodes. This rigor creates standardization of the investigative process and allows systematic analysis of common causes of adverse events.[10] The structure of the HFACS is defined in four levels in a hierarchical manner. 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. Included within these four levels (also called tiers), are 19 causal categories.[1] Each of these causal categories, as they appear at each level are depicted in Figure 1 (white boxes) and summarized in Table 1.

Methodology

This study is a systematic review that has investigated the use of classification system and analysis of human factors in categorization of medical errors. The inclusion criteria include the revision of previous HCS-related studies that have used HFACS for coding, cause analysis, and categorization of medical errors and adverse events. All the studies published since the introduction of HFACS in 2001 were investigated in this research. The papers that have not observed HFACS in coding and cause analysis of medical errors were excluded from the present study. This study was approved by Ethics Committee of Isfahan University of Medical Sciences, Isfahan, Iran (Committee's Reference Number: IR.MUI.RESEARCH.REC.1400.371).

Searching strategy

Searching and retrieving the papers

Electronic search in reliable databases and review of the selected papers references were used for extracting the appropriate resources.

Electronic search of databases

In the present review, the required data was collected from the papers published in four databases up to February 2021. The databases included the following:

- Web of science (ISI)
- PubMed (Medline)
- Scopus
- Google Scholar.

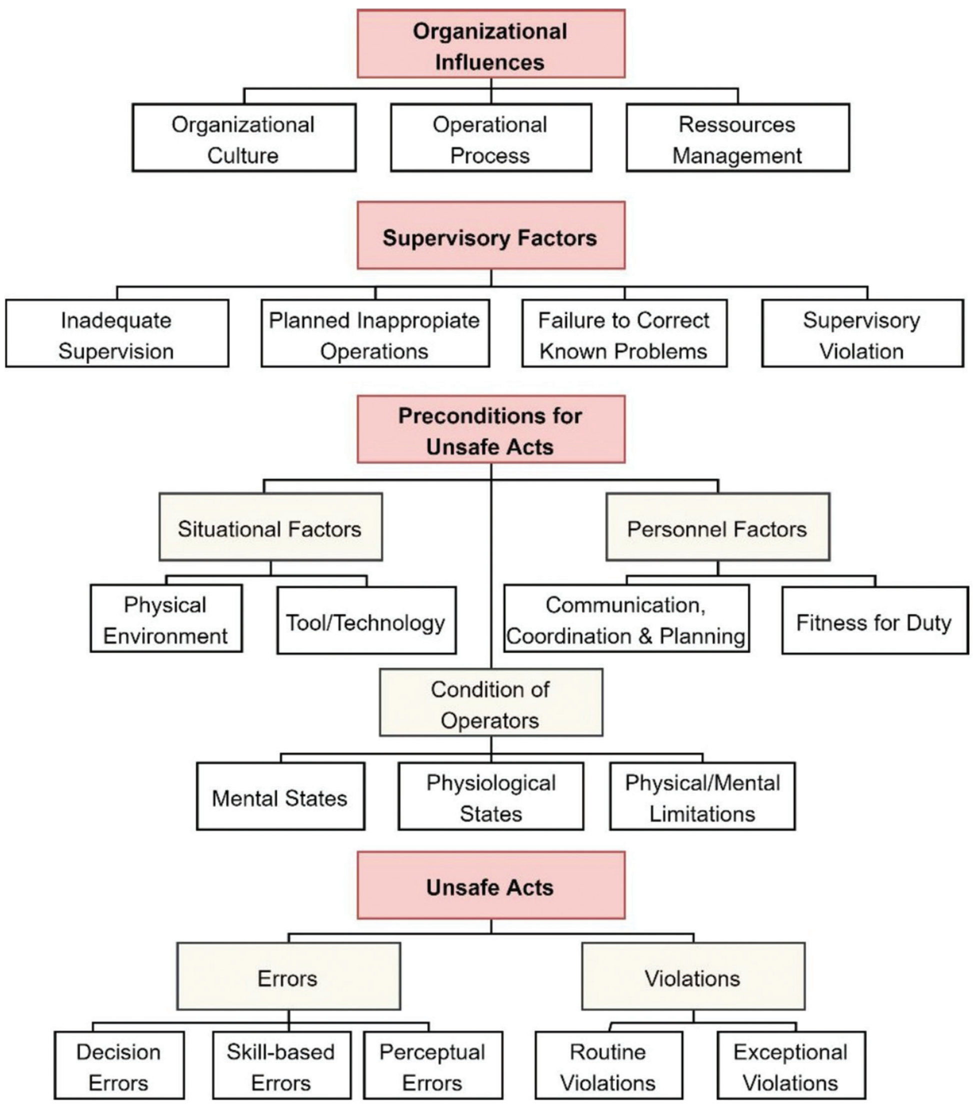

Figure 1: The HFACS framework

Table 1: Description of the HFACS categories

Organizational influences
Organizational climate: Prevailing atmosphere/vision within the organization including such things as policies, command structure, and culture
Operational process: Formal process by which the vision of an organization is carried out including operations, procedures, and oversight among others
Resource management: Management of necessary human, monetary, and equipment resources
Unsafe supervision
Inadequate supervision: Oversight and management of personnel and resources including training, professional guidance, and operational leadership among other aspects.
Planned inappropriate operations: Management and assignment of work including aspects of risk management, crew pairing, operational tempo, etc.
Failed to correct known problems: Those instances when deficiencies among individuals, equipment, training, or other related safety areas are ‘‘known” to the supervisor, yet are allowed to continue uncorrected
Supervisory violations: The willful disregard for existing rules, regulations, instructions, or standard operating procedures by management during the course of their duties
Preconditions for unsafe acts
Environmental Factors
Technological Environment: This category encompasses a variety of issues including the design of equipment and controls, display/interface characteristics, checklist layouts, task factors and automation
Physical Environment: Included are both the operational setting (e.g., weather, altitude, terrain) and the ambient environment, such as heat, vibration, lighting and toxins
Conditions of the Operator
Adverse mental states: Acute psychological and/or mental conditions that negatively affect performance such as mental fatigue, pernicious attitudes, and misplaced motivation
Adverse physiological states: Acute medical and/or physiological conditions that preclude safe operations such as illness, intoxication, and the myriad of pharmacological and medical abnormalities known to affect performance
Physical/mental limitations: Permanent physical/mental disabilities that may adversely impact performance such as poor vision, lack of physical strength, mental aptitude, general knowledge, and a variety of other chronic mental illnesses
Personnel Factors
Communication, coordination and planning: Includes a variety of communication, coordination, and teamwork issues that impact performance
Fitness for duty: Off-duty activities required to perform optimally on the job such as adhering to crew rest requirements, alcohol restrictions, and other off-duty mandates
Unsafe acts
Errors
Decision errors: These ‘‘thinking” errors represent conscious, goal-intended behavior that proceeds as designed, yet the plan proves inadequate or inappropriate for the situation. These errors typically manifest as poorly executed procedures, improper choices, or the misinterpretation and/or misuse of relevant information
Skill-based errors: Highly practiced behavior that occurs with little or no conscious thought. These ‘‘doing” errors frequently appear as breakdown in visual scan patterns, inadvertent activation/deactivation of switches, forgotten intentions, and omitted items in checklists often appear. Even the manner or technique with which one performs a task is included
Perceptual errors: These errors arise when sensory input is degraded, as is often the case when flying at night, in poor weather, or in otherwise visually impoverished environments. Faced with acting on imperfect or incomplete information, aircrew run the risk of misjudging distances, altitude, and decent rates, as well as responding incorrectly to a variety of visual/vestibular illusions
Violations
Routine violations: Often referred to as ‘‘bending the rules” this type of violation tends to be habitual by nature and is often enabled by supervision/management that tolerates such departures from the rules.
Exceptional violations: Isolated departures from authority, neither typical of the individual nor condoned by management

First, the keywords were extracted from medical subject headings of PubMed, and all the synonyms of medical errors were also included in keywords. Then, the extracted keywords were combined by “AND” and

"OR" to explain the searching strategy. The search strategy in the PubMed database is presented below as an example: ((HFACS) OR ("Human Factors Analysis and Classification System")) AND ((Medical Mistakes) OR (Medical Error) OR (Medical Mistake) OR (Wrong Procedure Errors) OR (Wrong-Procedure Error) OR (Omission Medical Error) OR (Omission Medical Errors) OR (Medical Error of Omission) OR (Wrong Site Surgery) OR (Surgical Errors) OR (Surgical Error) OR (Critical Medical Incidents) OR (Critical Medical Incident) OR (Medical Critical Incident) OR (Medical Critical Incidents) OR (Wrong Patient Surgery) OR (Wrong-Patient Surgeries) OR (Never Event) OR (Never Events) OR (Medical Errors of Commission) OR (Medical Error of Commission) OR (Commission Medical Error) OR (Commission Medical Errors) OR (Patient Harm) OR (Patient Safety) OR (Diagnostic Errors) OR (Misdiagnosis) OR (Diagnostic Blind Spot) OR (Health Services) OR (Missed Diagnosis) OR (Missing Diagnosis) OR (Medication Errors) OR (Drug Use Error) OR (Drug Use Errors) OR (High-Alert Medication Errors) OR (Healthcare Near Miss) OR (Healthcare Near Misses) OR (Health Care Sectors) OR (Healthcare Sectors) OR (Healthcare Sector) OR (Healthcare Industries) OR (Health Care Industry) OR (Health Care Industries) OR (Healthcare Markets) OR (Health Personnel) OR (Health Care Providers) OR (Healthcare Workers) OR (Healthcare Worker)).

Other resources

For access to additional articles, reference lists of the selected papers were assessed, and the papers that had not been already retrieved were extracted and used.

Results

The results of reviewing the resources

A total of 108 articles were found. One hundred and two articles were obtained from the electronic search of databases, and six studies were extracted from the references lists of the selected articles. 18 studies were removed from the review list due to duplication. Out of the remained papers, 50 papers were excluded due to their irrelevant title and abstract. Meanwhile, 28 papers were excluded due to lack of the inclusion criteria. Finally, 12 papers remained for the systematic review. Among these 12 papers, 2 papers investigated trauma and emergency department, 2 papers investigated medication errors, 6 papers investigated operating room and surgery, and 2 papers investigated medical errors that occur in hospitals. Figure 2 presents the search flowchart. Also, Table 2 presents the summary of the findings.

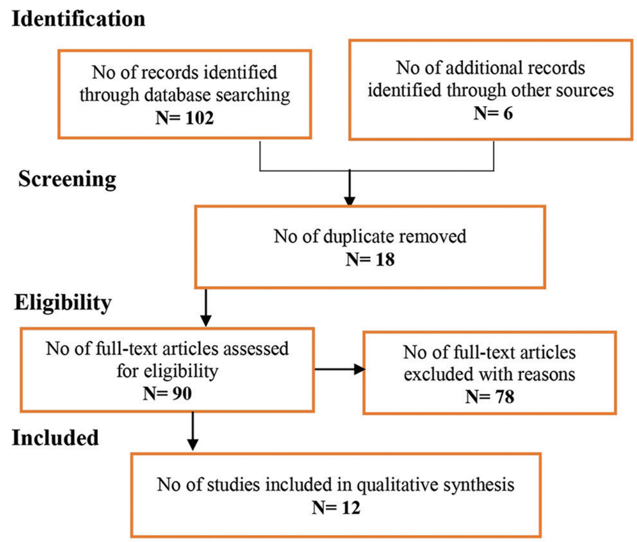

Figure 2: Flow of information through the different phases of the systematic review

The use of HFACS in different parts of the hospitals

The use of HFACS in the process of anesthesia and surgery

One of the main issues that has been so far investigated by HFACS to detect the causes of medical errors is the process of anesthesia and surgery in operating room. Cohen *et al*.[28] (2017) have used this method to identify human errors involved in the process of surgery. The results showed that the most common human factors involved in medical errors in both hospitals are related to the preconditions of unsafe actions. In another study, Cohen *et al*.[29] (2018) investigated systemic vulnerability in the process of surgery. In general, among the 910 major incidents, 592 cases were analyzed by HFACS, and 726 causal factors were identified accordingly. The most frequent causal level was related to the preconditions for unsafe act (60%). ElBardissi *et al*.[30] (2007) used HFACS in the form of a questionnaire to investigate the factors involved in medical errors that occur in operating rooms. The results showed that unfavorable planning at the level of unsafe supervision is the most important factor from the viewpoint of the personnel. Skill-based errors were prioritized at the next level. Souders *et al*.[31] (2020) used HFACS to determine the causes of adverse events and the difference in reporting medical adverse events by male and female surgeons. According to the study of 171 adverse events reported by surgeons, 50% of the incidents are related to unsafe acts, 39% of the incidents are related to preconditions for unsafe acts, 5% of the incidents are related to unsafe supervision, and 6% of the incidents are related to organizational effects. Thiels *et al*.[32] (2015) investigated the human and organizational factors involved in the occurrence of 69 medicals adverse events by HFACS. The results showed that among the identified factors, the most frequent factors are related to preconditions for unsafe acts (*n* = 296) and unsafe acts (*n* = 260), while half of them were related to individual mental factors. Neuhaus *et al*.[33] (2018) used HFACS to analyze 50 incidents recorded in critical incidents reporting system of anesthesia

Table 2: Selected literature for the application of HFACS to cause analysis of medical errors and adverse events

Setting	Authors (year)	Aim	Sample Size (Events)	Most Important Causal Level	Percentage of cases	Most Important Causal Category (Percentage)	Ref.
Operating Room and Surgery	Souders *et al*., (2020)	Gender differences in the reporting of medical events by male and female surgeons	171	Unsafe Act	50%	Not provided	[31]
	Neuhaus *et al*., (2018)	Applying the HFACS to critical incident reports in anaesthesiology	50	Unsafe Acts were identified in 94% of the reports Preconditions for Unsafe Acts were identified in 92% of the reports	-	Decision Errors and Skill-based Errors Personnel factors (Communication and coordination) Environmental factors (Technological environment)	[33]
	Cohen *et al*., (2018)	Using HFACS-healthcare to identify systemic vulnerabilities during surgery	592	Preconditions for unsafe acts	60%	Skill-Based errors (28.2%) Tools/Technology (27.9%) Communication, coordination (25.2%)	[29]
	Cohen *et al*., (2017): study 1	Coding human factors observations in surgery	878	Preconditions for unsafe acts	99%	Adverse mental states (39%) Physical environment (30%) Communication, coordination, and planning (25%)	[28]
	Cohen *et al*., (2017): study 2	Coding human factors observations in surgery	4233	Preconditions for unsafe acts	99%	Adverse mental states (41.5%) -Communication, coordination, and planning (31%) Physical environment (20.5%)	
	Thiels *et al*., (2015)	Surgical never events and contributing human factors	69	Preconditions for unsafe acts	47%	Cognitive factors (18%) Decision Errors (16.4%) Technological environment (11.7%)	[32]
	ElBardissi *et al*., (2007)	Application of the HFACS methodology to the cardiovascular surgery operating room	-	Unsafe Supervision	-	Inappropriate operations (Planning) Skill-based errors	[30]
Medication Process	Widyanti and Reyhannisa, (2020)	HFACS in the evaluation of outpatient medication errors	200	Preconditions for unsafe acts	39.3%	Performance-based error (10.6%) Mental awareness (10%) Psychological condition of workers (9.2%)	[35]
	Hsieh *et al*., (2019)	The investigation of human error analysis in adverse drug events	25	Organizational influence	41%	Organizational process (19.4%) Organizational climate (12.4%) Adverse mental states (8.7%)	[34]
Emergency and Trauma Department	Hsieh *et al*., (2018)	Application of HFACS, fuzzy TOPSIS, and AHP for identifying important human error factors in emergency departments	35	-	-	Inadequate supervision Decision Errors Adverse mental states Crew resource management	[36]
	Cohen *et al*., (2018)	Proactive safety management in trauma care: applying the HFACS	1057	Preconditions for unsafe acts	92%	Communication, coordination, and planning (60%) Adverse mental states (25%) Physical environment (10%)	[37]

Contd...

Table 2: Contd...

Setting	Authors (year)	Aim	Sample Size (Events)	Most Important Causal Level	Percentage of cases	Most Important Causal Category (Percentage)	Ref.
Hospital Complex	Sadeghi *et al*., (2014)	RCA of hospital accidents with HFACS	88	Preconditions for unsafe acts	37.8%	Organizational Process (14.8) Adverse mental states (13.6%) Crew resource management (11.4%)	[38]
	Diller *et al*., (2014)	HFACS applied to healthcare	105	Unsafe Act	49.8%	Communication, coordination, and planning (26.2%) Decision Errors (24.9%) Routine Violations (15.8%)	[8]

ward of operating room. They found that unsafe acts (94% of cases) and preconditions for unsafe acts (92% of cases) have the major roles in the occurrence of incidents.

The use of HFACS in medication

One of the most important hospital processes with a high rate of medical errors is medication. Over the recent years, this process has been analyzed by researchers to detect the causes of errors by HFACS. Hsieh *et al*.[34] (2018) investigated the human errors involved in medication errors and identified the cases of errors in 25 incidents. RCA and HFACS were used to identify the causal and root factors involved in medical errors. The results showed that in the 25 investigated incidents, 222 errors could be classified into 4 causal levels of HFACS. The most frequent causal errors were related to organizational effects (41%). Preconditions for unsafe acts (24.3%) and unsafe supervision (23.2%) were the next prioritized factors. According to the results, unsafe acts constitute only 11.5% of the factors. Widyanti *et al*.[35] (2020) investigated outpatient pharmacological errors and tried to detect the causes of these errors. According to the results, such errors were mainly related to the respectively prioritized factors of preconditions for unsafe acts (39.3%), organizational effects (22%), unsafe supervision (20%), and unsafe acts (18.7%).

The use of HFACS in trauma and emergency departments

The people affected by occupational or nonoccupational incidents and patients with severe and sudden complications are usually hospitalized and treated in trauma and emergency departments. Due to the severe conditions of the referring patients, medical errors and adverse events are usually unavoidable in these wards. Regarding the special conditions of these wards, researchers have used HFACS to detect the cases of these incidents. Hsieh *et al*.[36] (2018) used HFACS to identify the most important factors involved in human errors that happen in emergency departments of Taiwan. The results showed that improper human resource management, decision making errors, inadequate control, and unfavorable mental situation were the most important factors involved in human errors in emergency wards. Cohen *et al*.[37] (2017) conducted a study to classify the human and organizational factors involved in medical errors occurring in trauma wards. The results showed that the majority of the identified factors were related to preconditions for unsafe acts (91.95%). Meanwhile, 7.75% of the causes were related to unsafe acts and 0.18% of the causes were related to organizational effects.

The use of HFACS in the analysis of hospital incidents

Application of HAFCS to detecting the causes of medical incidents has not been limited to any specific ward, and researchers have applied this method to the whole hospital or health system. Sadeghi *et al*.[38] (2014) conducted a study for root analysis of errors by HFACS. Among the studied incidents, 88 human errors were extracted by HFACS and categorized into different levels of this method. The results showed that 18.2% of the causes were related to unsafe acts, 38.7% of the causes were related to preconditions for unsafe acts, 14.7% of the causes were related to unsafe supervision, and 28.4% of the cases were related to organizational effects. Meanwhile, Diller *et al*.[8] (2014) investigated the use of HFACS in health care sectors. They found that 40.6% of the factors identified by HFACS were related to unsafe acts, 49.8% of the factors were related to preconditions for unsafe acts, 4% of the factors were related to unsafe supervision, and 5.6% of the factors were related to organizational effects.

Discussion

Historically, the medical community has put its focus on identifying and reducing medical errors by analyzing the adverse events. Although this approach has been generally effective in reducing medical adverse events, there are still some cases of medical error-related deaths in HCS. The most important measure that can promote patient safety in HCS is to identify the human and organizational factors involved in patient injury.[28] Over the recent years, HFACS has been used as a reliable tool for analyzing and detecting the causes of medical adverse events. According to the analysis of the results, in 65% of the papers, preconditions for unsafe acts have been reported as the main cause of medical errors and adverse events. Unsafe act was also the main cause of medical errors in 20% of papers. As well as, the causal categories of "adverse mental states" and "communication, coordination, and planning" with range of 8.7% to 41% and 25% to 60%, respectively, were the most important and most frequent causes of medical errors in papers. The causal categories of preconditions for unsafe acts have been reported as the main causes of medical errors. This finding is not surprising given that preconditions often manifest as observable events that usually occur in the immediate environment in which work is performed. Other variables such as unsafe supervision and organizational effects are more diffuse, acting as latent conditions that occur outside the workplace, which subsequently influence medical performance later via preconditions. It is difficult to discover these causes, especially when assessors have not received sufficient training in identifying them.[28,39]

Preconditions for unsafe acts usually constitute the first level of the underlying deficiencies of a system that may remain latent for a long time before playing their role in the adverse events. In HFACS, these preconditions are classified into three classes: Personnel factors, operators' condition, and environmental factors. Personnel factors refer to the communication, coordination, and planning and fitness for duty. The operators' condition refers to the adverse mental states, adverse physiological states, and physical conditions of operators that can lead to the occurrence of unsafe acts. Meanwhile, environmental factors include the physical environment and technological environment.[1]

One of the causal categories of preconditions for unsafe actions is the operator's condition such as the mental, physiological, and physical conditions of operators, and personnel factors such as the personnel's communication and coordination.[32] In the majority of the studies, communication and coordination, adverse mental states, physical environment, crew resource management, and technological environment have also been recognized as the most important causal categories in this study. Cognitive factors are considered as a subset of preconditions for unsafe acts that are significantly involved in the occurrence of medical errors. Communication errors are considered as errors that are directly related to cognitive factors. Cognitive factors may be related to the increased number of patients in a ward, complexity of working procedures, the use of complex technologies, and the increased number of team members with different characteristics.[40] Promotion of cognitive factors may lead to the employees' negligence of the working procedures and instructions.[41] The mental workload may be affected by the composition of the working team, the interaction of the people and technologies, time pressure, individual tiredness, etc.[40] The first step to affect the mental workload is to promote the employees' awareness of cognitive factors and other factors involved in medical adverse events in all occupational layers of hospitals. Some measures should be taken to reduce the mental workload, and these measures can include patient and personnel scheduling, managerial chain supply, information technology, education, and independent performance.[32] Although it is not possible to reduce the mental workload under real conditions, the workload can be shared among more people to reduce the pressure imposed on the people.[32] This goal can be achieved via effective interaction between the team members and preservation of sustainable teams.[40] In general, it seems that targeting for the interventions to deal with cognitive factors and team resource management and also other cognitive biases can lead to a reduction in errors and an improvement of the patient's safety.[32]

Adverse mental states include the periods of time during which people are affected by confusion and distraction. Environmental factors include inadequate space, placement issues, inefficient architecture, poor arrangement, and improper location of the equipment. Communication, coordination, and planning includes the ambiguous relationships, unnecessary relationships and deficient coordination (inefficient teamwork, poor planning).[28] Education of human resource management, checklists, multidisciplinary team training, group training, simulation, and scenario-based training can be used to modify inefficient communications and coordination.[42-45] Technology-related problems can also be solved by redesigning methods such as automation.[29] The other cause of human errors at this level is the complexity of medical staff tasks. In addition to patient care, these staff may be involved in fighting other situations such as responding to patients' sudden demands, getting prepared for surgery, patient education at the time of discharge, academic studies, etc., So, medical personnel's working hours are usually long, and increasing the speed of performing the tasks may lead to human errors.[36] It should be noted that in some cases, individual factors can be considered related to organization or supervision factors. For example, as tiredness can lead to an error, the causes of tiredness should be also specified. For example, is tiredness caused by lack of human force? In this condition, organizational level is considered as an important factor involved in medical errors. Also, tiredness may be caused by long working shifts. In such cases, tiredness is due to unsafe supervision that has led to the employees' working long shifts. Based on the statements, the mentioned factors should be observed in classifying and determining the causes of adverse events by HFACS.[34]

One of the aspects of the present study is to differentiate between the causes of medication errors and other errors. Hsieh *et al*.[34] (2019) reported the organizational influences as the main causal level (41%). Widyanti *et al*.[35] showed that after the preconditions of unsafe actions, organizational influences have been the most significant factor. As a cause of medical errors, organizational deficiencies are usually paid less attention to at the highest levels of the organization. It is so difficult to identify these deficiencies, unless there is a clear understanding of the organizational framework and a reliable structure is used for studying the adverse events. Meanwhile, organizations usually do not pay enough attention to the causal categories of this level due to the legal problems that can probably occur in the organization.[1] Nevertheless, it seems that there are different conditions in the area of medication errors. According to studies, medication errors are closely related to deficient working processes. For example, drug distribution system is considered as a noteworthy factor in the occurrence of medication errors, and it is closely related to organizational and systemic factors. Deficient medication error reporting system is also a considerable factor in the increase of such errors. Modification of the reporting system requires the managers' intervention for creation of proper reporting systems.[46] The organizations' actions can play a significant role in the improvement of medication error-related policies. For example, risk management and safety programs cannot enable the medical personnel to recognize the properties of all drugs, particularly the drugs that are rarely used (e.g., La Ferrum, Digoxin) and the drugs with multiple usage (e.g., Demerol, Piton-s). It is the responsibility of organizations (e.g., nursing department) to raise attention to these situations and provide medical staffs with solutions rather than expecting the medical staff to take the blame when the adverse drug events occur. Once organizations take responsibility, the frequency of adverse drug events can be reduced and patient safety would be enhanced.[34] Budgetary constraint is another deficiency in organizations, potentially leading to drug errors and even other errors. If the hospital is private and decision makers adopt profit-based management approaches, it is necessary to control the operational costs and reduce them to achieve the income goals of the hospital. Controlling and reducing the operational costs of hospitals may be effective in the quality of medical cares and the risk of medication errors.[34]

The results of reviewed articles showed that HFACS can be used as a reliable observation tool for detecting the medical errors and adverse events. The results of this method can help managers to take purposive interventions to reduce the human force-related problems involved in the errors. This method can be used for identifying and controlling the human, supervision, and organizational factors that can lead to error and crisis in the future. In other words, instead of solving problems after their occurrence (passive approach), HFACS can be used as an active method for observing different causes of medical errors – from personal problems to organizational deficiencies to unsafe supervision – and subsequently planning purposive interventions that can reduce adverse events and patients' harms in the future.[28]

In the present study, all the papers that have analyzed and classified the causes of medical adverse events are investigated to extract comprehensive information about the situation of errors and medical adverse events in different hospital processes. We recognize some strengths and limitations of this study. A strength is that in the literature search, several languages were eligible, allowing inclusion of non-English literature. Also, our search strategy was comprehensive and search term development was supported by a research librarian. One of the limitations of the study was the incomplete coding of causal levels and causal categories in some studies and led to the exclusion of articles from this systematic review. However, the results of this study suggest that HFACS has limitations in detecting the causes of medical errors. Regarding the currently used adverse events reporting systems, the use of HFACS is accompanied by some constraints. For example, the medical errors and adverse events that are reported voluntarily are usually reported by the frontline personnel. These people have a limited knowledge of how to identify and detect the errors. So, the recorded data is focused on the events rather than their causes. This may lead to inaccurate reporting. In more complex cases, it is not known whether the frontline managers are experienced enough to study these incidents, or if some of them will try to modify and update the content of reports or not. As a result, HFACS is not able to take into account the effect of the currently used adverse events reporting system on the results. Currently, in most health systems and hospitals, untrained people are working in the frontline of dealing with adverse events. As a result, the reports usually include deficient description of the incidents and are affected by the untrained reporters' biases.[29,37]

Another issue that should be considered in this area is the use of HAFCS in a retrospective manner. Researchers believe that retrospective use of HFACS should be accompanied by the consideration of some constraints.[8] First, at the time of recording the facts, there may not be proper questions for identifying the causes of a specific behavior. Second, in the medical errors and adverse events recorded beyond the HFACS framework, other causal categories may also be involved in the occurrence of adverse events that have not been studied by the assessors. Third, higher levels of causal category (including unsafe supervision and organizational influences) may be involved in the occurrence of adverse events. However, these causes may have not been emphasized in the recorded adverse events. As a result, HFACS can be used as a prospective method in HCS. In the case of adopting a prospective approach, this method can be effective in identifying human and systematic errors and especially help towards a systematic classification of the errors involved in medical adverse events.

Conclusion

The analysis of the results showed that in 65% of the selected studies, preconditions for unsafe acts have been the major causal level of medical errors and adverse events. In the majority of the studies, communication and coordination, adverse mental states, physical environment, crew resource management, and technological environment have also been recognized as the most important causal categories in this study. As a result, to prevent medical errors and adverse events, there should be focus on controlling the preconditions for unsafe acts including personnel factors, the operators' conditions, and environmental factors. The results of this study suggest that HFACS can be used as a reliable observation tool for identifying the errors and medical adverse events. The results of this method can help managers to take purposive interventions to reduce the human force-related problems involved in the errors. This method can be used for identifying and controlling the human, supervision, and organizational factors that can lead to error and crisis in the future.

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Author's contributions

H.D designed this systematic review. M.J performed the literature search and analysis of the data. Also, drafted and wrote the final manuscript. E.H and N.K was involved in the design and assisted revising the final manuscript. All authors read and approved the final version of this article.

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Conflicts of interest

There are no conflicts of interest.

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