Review

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Epidemiology of Medical Errors and Incidents in Emergency Medicine

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RELEVANCE The issues of patient care and quality management have acquired particular relevance in modern healthcare. Improvement in the clinical performance of medical technologies has led to a significant reduction in deaths and complications associated with the disease and side effects of interventions. As a result, the share of additional harm related to the process of providing medical services has become more noticeable. Accurate data regarding the type, frequency and severity of active threats and incidents they cause are needed to reduce the likelihood and severity of additional harm. In this respect, emergency medical care is the subject of special attention and is characterized by the greatest difficulty in terms of obtaining valid and relevant information about deviations associated with health worker performance, equipment operation and patient behavior.

THE AIM OF THE STUDY was to explore the main epidemiological characteristics of medical errors and incidents associated with the provision of emergency medical care.

MATERIAL AND METHODS We present a literature review followed by an analytical study of the epidemiology of incidents and active threats (including medical errors) that precede those incidents in various areas of emergency medical care. By an incident, the authors understood an event with a patient that was more related to the process of providing medical care than to the course of the disease or comorbid conditions which led or could lead to causing additional harm. Active threats included events that subsequently became the direct cause of the incident (medical errors and malpractice, mistakes and deviations in patient behavior, emergency situations in the physical environment). By the "mortality from adverse events", the authors understood the proportion of deaths from adverse events among all hospitalized patients. By the concept of "lethality associated with adverse events", the authors denoted the proportion of deaths from adverse events among all the patients affected by adverse events. The search for information was carried out for the period of 1995–2021 using the following medical databases: MEDLINE; Cochrane Collaboration; EMBASE; SCOPUS; ISI Web of Science. For analysis, we used prospective and retrospective observational studies of high methodological quality, meta-analyses and systematic reviews. For the statistical evaluation of frequency characteristics, indicators of incidence, prevalence, and incidence density were used. The calculation of generalized frequency indicators for large samples was carried out with a 95% confidence interval.

RESULTS The epidemiology of medical errors and incidents depends on the area in which emergency care is provided. For prehospital emergency medical care, there are 12.45 medical errors and 4.50 incidents with consequences for every 100 visits. In emergency departments, one in fourteen patients suffers additional harm which in 10.14% of cases has severe consequences, and in 3.18% of cases leads to unexpected death. In intensive care units, incidents related to the provision of medical care are recorded in every third patient in the amount of 1.55 per 1 patient. Of these, 58.67% of incidents are accompanied by harm, but the fatality associated with the incidents is only 0.77%. The prevalence of patients affected by incidents during the provision of anesthesia for children is almost 2 times higher than for adults (4.79% vs. 2.03%). At the same time, mortality due to anesthesia-related incidents in children is 11 times lower than in adults (0.27% versus 3.09%). The author draws attention to a number of factors contributing to the development of incidents during the provision of emergency medical care. These include environmental complexity, suboptimal configuration of the workspace, technological interface complexity, the effects of acute stress on performers, and organizational vulnerabilities. A special role was assigned to environmental complexity which was studied in detail both in terms of the complexity of the tasks being solved, and in connection with obstacles to solving problems. It was shown that the intensity of the influence of various components of environmental complexity is not the same in different departments providing emergency care. Particular attention was paid to the fact that organizational vulnerabilities reduce the effectiveness of protective mechanisms during the interaction of the human factor with a complex environment.

CONCLUSION The study showed that the provision of emergency medical care is associated with moderately high risks of incidents, including severe and critical consequences for patients. The main factor contributing to the development of incidents is environmental complexity which becomes much harder to counter under the influence of organizational vulnerabilities. Identification and registration of errors and incidents in units providing medical care is difficult due to the short time of contact with patients, the high speed of situation update, and the constant impact of chronic and acute stressors on staff. In this connection, the optimization and improvement of the efficiency of the system for recording errors and incidents in departments providing emergency medical care remains an area for improvement.

Keywords: health care safety, emergency medical care, adverse events, incidents, medical errors

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CI - Confidence interval
IC - Intensive Care

EMC - Emergency medical care
AE - Adverse event
EMS - Emergency medical services

INTRODUCTION

Mistakes, incidents, resulting additional harm (an adverse event) and related issues of patient safety management have lately become the central problem of modern healthcare. Publications of recent years clearly demonstrate the fact that additional harm is an inevitable companion and downside of the process of providing medical care. A meta-analysis of modern publications, including a sample of almost one hundred and ninety thousand patients, showed that every fifth patient encounters a medical error, and every eighth hospitalized suffers additional harm associated with the provision of medical care. Besides, for one out of eighty inpatients, incidents are accompanied by severe harm and quite often lead to permanent disability. One out of 160 hospitalized patients dies from the complications described above. Moreover, deaths caused by adverse events are the cause of every fourth death in hospital and every tenth death in the population of developed countries [1-5].

Emergency medical care, apparently, must have a higher probability of errors associated with the human factor and the severity of the resulting incidents. This is due to the complexity of the environment in which emergency medical care is provided. Such an environment in modern literature is called a high-stakes environment. Under the environment in our article, we will understand the space in which medical care is provided (temporary or permanent workplace) and its technological interface. In this technological interface, the staff, the patient, objects and tools, tasks and technologies for their solving interact. Environmental complexity is always the result of a subjective assessment which depends on the competencies, experience of a particular individual and the requirements of the situation. In modern literature, environmental complexity is considered in two aspects: from the point of view of the complexity of the tasks being solved and taking into account the barriers to problem solving. In terms of the complexity of the tasks to be solved, the high-stakes environment is characterized by:

– instability of the object of transformations (it implies a high rate of changes in the patient's state);
– multitasking;
– monotony (associated with the uniformity of the operations performed to solve one problem);
– heavy technological load (due to a large number of complex technologies used to solve many problems);
– interdependence of tasks;
– high velocity, irreversibility and multiple consequences of a decision;
– delayed effect of many technologies used (many effects become apparent only after a certain time and quite often in another unit);
– high cost of error at all stages of human behavior, when minimal deviations lead to very serious consequences.

In terms of barriers to problem solving, a high-stakes environment has the following characteristics:

– complexity of goals (contains many competing goals, often changing in the course of treatment);
– instability of the environment itself (associated with a high rate of change in key variables: the number and types of patients, the number and competence of team personnel, external conditions, technical factors, etc.);
– uncertainty (associated with the initial lack of information about the object of transformation, the unpredictability of changes in the environment, transient ignorance of the situation);
– non-transparency (implies the ambiguity of most of the information received);
– frequent breaks (associated with the need to constantly switch between tasks and patients);
– migrating stress (characterized by frequent alternation of periods of intense stress with periods of routine activities);
– novelty of the situation (associated with unique situational variables);
– lack of time for decision-making, which reduces the opportunity for thorough information gathering, problem analysis, hypothesis testing and risk assessment;
– information overload (caused by redundancy of information, multiple sources of information and distractions);

– interactive hypercomplexity (associated with the interaction of a large number of performers with different competencies and different qualifications, the need to develop a single mental model, the high interdependence of all components of the technological interface).

Environmental complexity is exacerbated by the scarcity and sub-optimal configuration of the workspace, the complex human-machine interface of the medical devices used, the effects of acute stress on all health workers providing emergency medical care, and multiple organizational vulnerabilities. The latter reduce the cognitive and physical protective resources of the human factor at all levels. Acute stress is always associated with an imbalance between the demands of the situation (saving the patient and medical duty), a specialist's own competencies, available time and resources, as well as the unpredictability and inability to control the workload. Frequent consequences of acute stress are the dominant negative emotions in response to the subjective perception of a higher risk of no effect from the interventions performed and the peril of causing additional harm [6-9].

Thus, conducting research on the epidemiology of adverse events in the provision of emergency medical care, their systemic root causes, the search for effective solutions in order to manage the magnitude of the risk of these events is of particular scientific and practical interest.

RESULTS OF THE STUDY

Analysis of the frequency and severity of errors, incidents and adverse events was carried out for the following areas: prehospital emergency medical care, emergency departments, intensive care units, anesthesiology service.

Prehospital emergency medical care implements a bulk of emergency and urgent measures, as well as assistance in emergency situations. It can be anywhere: on the side of the road, at home, in public and other places. Ambulance teams work in conditions of extremely high initial uncertainty, including those associated with unpredictable and uncontrollable threats from the patient. At the same time, these activities are carried out in conditions of critical time pressure, cramped workspace, and rather limited resource opportunities. Very often, an ambulance team is formed from representatives of various professions (medical workers, firefighters, policemen, etc.), which causes great difficulties in managing the process, in coordinating the activities of an interdisciplinary team and synchronizing mental models. Ambulance workers themselves are at risk of various injuries associated with patient transportation, shift and overtime work, frequent team changes, unfavorable intentions on the part of the patient and his family members, and many other factors [6-8,10,11]. All of the above is a serious risk factor for errors and incidents, most of which are associated with defects in communication and coordination of team activities, patient behavior, equipment failures and environmental factors [6,8,12-15].

The epidemiology of adverse events and errors in the field of emergency medical care is presented in the literature in a very limited and fragmented form. This is due to the fact that the time allotted for the provision of emergency medical care is short and most of the adverse events associated with errors and incidents in the work of ambulance teams occur in a delayed period of time and are diagnosed in emergency departments, and most often in departments of multidisciplinary hospitals [6]. The fixed error rate according to retrospective analysis using global instrumental triggers was 12.45, and the cumulative rate of incidents with consequences was 4.50 for every 100 ambulance visits (Table 1) [16-21].

Table 1

Epidemiology of incidents and medical errors during the provision of prehospital emergency medical care

Author	Number of patients/ambulance trips	Medical errors		Incidents with consequences	
				Absolute number	%
R. Kothari et al., 1995 [16]	86 (diagnosis "stroke")	24	27.91	–	–
H.R. Arntz et al., 1996 [17]	2 033	221	10.87	73	3.59
C.L. Peery et al., 1999 [18]	201	55	27.36	–	–
A. Flabouris, 2001 [19]	(diagnosis "childhood trauma")	135	68.88	30	15.31
G.M. Vilke et al., 2007 [20]	196 (diagnosis "spinal cord injury")	32	9.09	–	–
M.A. Hagiwara et al., 2019 [21]	352	–	–	46	4.26
Кумулятивные частотные показатели	(drug therapy)	332	12.45 (11,25–13,76)*	149	4.50 (3.84–5,26)*

Note:* — 95% confidence interval

Emergency departments are formed as part of large multidisciplinary hospitals and are large receiving and diagnostic terminals where patients are admitted as a result of self-referral, transportation by ambulance and other services. Within a short period of time (3-6 hours) in emergency departments, urgent diagnostic and therapeutic measures are carried out, and then approximately two-thirds of the patients who applied are transferred for observation and (or) treatment to the outpatient clinic unit, and the remaining part is hospitalized in the specialized departments of the round-the-clock hospital. Emergency departments have their own emergency operating rooms, an intensive care unit, emergency services for laboratory and instrumental diagnostics. Depending on the structural characteristics of healthcare in different countries, emergency care is provided either by permanent multifunctional emergency care teams, or teams are formed as needed from narrow specialists of various departments. The main features of emergency department performance are the high uncertainty and opacity of the situation, the multifactorial and multiorgan nature of pathological processes in a large number of incoming patients, the lack of time for decision-making, multitasking and multiple goals, frequent breaks, the impossibility of direct monitoring of delayed effects of medical interventions. Constant overload of diagnostic and treatment units by patients requires proper sorting of patients and their distribution in waiting areas, consistent provision of medical care, taking into account initial severity of injury and disease. The described factors cause the occurrence of incident errors, which likelihood is enhanced by organizational vulnerabilities and a lack of competence among medical personnel [8,22,23,24].

In the overall structure of adverse events, the share of additional harm caused in emergency departments is 5%, and in the structure of life-threatening complications - 17%. One in five adverse events resulting from errors in the emergency department is an infectious complication [25,26,27,28]. On average, there are 1.17 adverse events per 1 patient in an emergency department. The incidence of adverse events is not influenced either by the gender of patients or by the size of the clinic where emergency medical care is provided [29].

Information about adverse events that occur in emergency departments is given in Table 2. The cumulative incidence of adverse events is 7.14%, where the share of cases of severe harm is 10.14%, the share of deaths is 3.18%. Most of the consequences of incidents related to interventions in emergency departments are diagnosed either in hospital departments (where about a third of patients are transferred) or as a result of repeated visits. This is due to the fact that the time spent by the patient in the emergency department usually does not exceed 6 hours. Therefore, personalized accounting of these events is a rather difficult task. There are great risks that most of the incidents and the resulting adverse events will be attributed not to the work of emergency departments, but to the activities of inpatient departments where these patients are subsequently transferred. Apparently, this can explain the fact that the actual statistics of incidents in emergency departments are somewhat underestimated in comparison with the average epidemiological hospital indicators [5,26,27,29,30-36].

Table 2

Epidemiology of incidents and medical errors during the provision of prehospital emergency medical care

Author	Number of patients	Patients with adverse events		Share of patients with adverse events who were seriously harmed		Mortality from adverse events	
		Absolute number	%	Absolute number	%	Absolute number	%
A.M. Wolf et al., 2002 [26]	–	250	–	12	4.80	3	1.20
A.J. Forster et al., 2007 [30]	399	24	6.01	–	–	–	–
M. Soop et al., 2009 [31]	1967	241	12.25	26	10.79	10	4.15
L.A. Calder et al., 2010 [32]	503	43	8,54	2	4.65	1	2.32
S. Tomas et al., 2010 [33]	3642	277	7.61	14	5.05	7	2.52
N. Rafter et al., 2017 [29]	1574	211	13.41	35	16.59	14	6.63
J. Hendrie et al., 2017 [34]	2167	89	4.11	17	19.10	2	2.25
P. Halfon et al., 2017 [35]	1007	127	12.61	–	–	–	–
N. Grossman et al., 2019 [27]	–	240	–	31	12.9	6	2.50
M. Alsabri, 2020 [36]	6519	258	3.96	–	–	–	–
Cumulative incidence	17778	1760	7.14 (6.77–7.53)*	137	10.14 (8.64–11.86)*	43	3.18 (2.37–4.26)*

Note: * — 95% confidence interval

Half of incidents in emergency departments are related to the performed intervention, and one in four of them are related to drug therapy (Table 3) [31,33,35].

Table 3

Medical interventions associated with incidents in emergency departments

Intervention	*M. Soop et al.*, 2009 [31]		*S. Tomas et al.*, 2010 [33]		*P. Halfon et al.*, 2017 [35]	
	Absolute number	%	Absolute number	%	Absolute number	%
Diagnostic procedures	**27**	**11,20**	**99**	**16,13**	**6**	**4,11**
Misdiagnosis	2	0.82				
Late diagnosis	17	7.05				
Incomplete diagnosis	1	0.41				
Incorrectly performed diagnostic intervention	7	2.90				
Drug therapy	**73**	**30.29**	**148**	**24.10**	**45**	**30,82**
Incorrect drug therapy	6	2.49				
Delayed drug therapy	17	7.05				
Incorrect drug dose	16	6.63				
Adverse drug reactions	34	14.12				
Surgeries and any invasive procedures	**119**	**49.38**	**313**	**50.98**	**68**	**46.58**
Unnecessary intervention	6	2.49				
Late intervention	9	3.73				
Incomplete intervention	10	4.15				
Incorrectly performed intervention	94	39.00				
Other interventions (therapeutic procedures related to patient care)	**22**	**9.13**	**54**	**8,79**	**27**	**18,49**
TOTAL	**241**	**100.00**	**614**	**100.00**	**146**	**100.00**

Note: * — the table shows the distribution of shares of the entire pool of adverse events depending on the type of intervention that was the main cause of the adverse event

Intensive care units are the concentration of the most critically ill patients. Some of them come to intensive care units from emergency departments, the other ones - from hospital departments in the event of sudden development of a critical condition. Intensive care units provide intensive specialized medical care using advanced monitoring of vital signs, various methods of physiological organ support and life support during acute organ system failure. Despite the localization of the intensive care unit in a certain geographical space, its activities often extend beyond this space into any unit and any area of the clinic. It should be noted that the rate of renewal of patients in intensive care units is significantly lower, and the period of their stay is longer than in emergency departments. On the one hand, this provides certain opportunities for a full-fledged examination and reduction of the uncertainty contribution to the treatment outcome. But on the other hand, there are a number of specific problems in intensive care units that practically negate the described advantage. Firstly, this is perhaps the highest rate of change in the patient's condition. Secondly, this is the highest multitasking and the need to achieve many hierarchically dependent goals. In no other department and no other service does the patient receive such an interventional and therapeutic load as in intensive care units - an average of 178 manipulations per day per patient. Thirdly, the concentration in the space of the resuscitation bed of a large number of devices, equipment, infusion lines, drains and catheters significantly limits access to the patient and the ability to assess changes in the patient's condition in the background control mode. In addition to the problems described above, the development of adverse events is facilitated by frequent team changes, round-the-clock work or night shifts, communication problems, including those associated with ambient noise. It should be noted that the cost of error and any other active threat in intensive care units is significantly higher than in emergency departments and in the work of the prehospital ambulance service. The

incidence of only infectious complications associated with mechanical ventilation, invasive devices, catheters and drains reaches 30% or more, even in clean rooms. The prevalence of patients in whose treatment medical errors were recorded by prospective studies is 30.55%, while the proportion of diagnostic errors exceeds 40%, and every fourth error occurs in the process of prescribing and distributing medicines. Approximately 3% of errors lead to harm, and patients are informed about errors only in 2.7% of cases [6,37-45].

Information about errors and incidents that occur in intensive care units is given in Table 4. As can be seen from the Table, the prevalence of patients with incidents in intensive care units is 31.82%. The incidence of incidents themselves is on average 49.39 per 100 patients, and the incidence density is 138.20 incidents per 1000 patient-days [46-54].

Table 4

Epidemiology of incidents in intensive care units

Author	Number of patients/patient-days	Incidents			Patients with incidents	
		Absolute number	Per 100 patients (95% CI)	Per 1000 patient-days	Absolute number	Prevalence % (95% CI)
R.K. Resar et al., 2006 [46]	/8841	1450	–	164	–	–
A. Forster et al., 2008 [47]	207	56	27.05	–	40	19.32
A. Pagnamenta et al., 2012 [48]	6404/17 434	2047	31.96	117.41	1727	26.97
P. Merino et al., 2012 [49]	1017	1424	140.02	–	591	58.11
D.A. Garry et al., 2014 [50]	280	104	37.14	–	76	–
K.E. Roque et al., 2016 [51]	355/ 3448	324	91.27	93.96	115	32.39
F.J. Molina, 2018 [52]	94	178	189.36	–	49	52.13
G. Decormeille, 2021 [53]	253	–	–	–	142	56.12
G. Aikawa, 2021 [54]	50/333	19	38.00	57.05	–	–
Cumulative incidence			**49.39** (48.32–50.46)* (4152/8407)	**138.20** (134.30–142.10)* (4154/30 056)	2740	**31.82** (30.84–32.82)*

Note:* — 95% confidence interval

Despite the high incidence rates, mortality and lethality from incidents associated exclusively with the work of the intensive care unit is significantly lower than the average hospital ones - 0.27% and 0.77%, respectively (Table 5). This can be explained by the fact that the main contribution to the fatal outcome is made by incidents caused by the performance of surgical teams and problems emerging in inpatient departments [48,40,50,52].

Table 5

Mortality and lethality associated with incidents in intensive care units

Author	Number of patients	Number of patients with incidents	Lethality		Mortality	
			Absolute number	%	Absolute number	Prevalence % (95% CI)
A. Pagnamenta et al., 2012 [48]	6404	1727	0	0	0	0
P. Merino et al., 2012 [49]	1017	591	9	1.52	9	0.88
D.A. Garry et al., 2014 [50]	280	76	11	14.47	11	3.92
F.J. Molina, 2018 [52]	94	49	1	2.04	1	1.06
Cumulative incidence	7795	2740	21	**0.77** (0.49–1.17)*	21	**0.27** (0.17–0.42)*

Note:* — 95% confidence interval

Analyzing the severity of incidents, it should be noted that, on average, the share of incidents with consequences (causing harm to the patient) is 58.67%. At the same time, the proportion of fatal incidents is

small - 0.61%. For every healthcare-associated death in the intensive care unit, there are 5 major incidents, 22 moderate injuries, and 68 minor injuries (Table 6) [48, 40, 50, 52].

Table 6

Incident severity distribution in intensive care units

Author	Total	Incident Category NCC MERP55									
		CD (without consequences)		E (minimum harm)		F (moderate harm)		GH (heavy harm)		I (death)	
		Absolute number	%	Absolute number	%	Absolute number	%	Absolute number	%	Absolute number	%
A. Pagnamenta et al., 2012 [48]	1727 (patients)	265	15.43	1155	66.88	302	17.47	5	0.29	–	–
P. Merino et al., 2012 [49]	1424 (incidents)	1058	74.30	185	12.99	120	8.43	52	3.65	9	0.63
D.A. Garry et al., 2014 [50]	104 (incidents)	8	7.69	31	29.80	32	30.76	22	21.15	11	10.57
F.J. Molina, 2018 [52]	178	88	49.43	68	38.20	2	1.12	19	10.67	1	0.56
Cumulative incidence	3433	1419	**41.33** (39.69–42.99)*	1439	**41.92** (40.28–43.58)*	456	**13.28** (12.19–14.46)*	98	**2.85** (2.34–3.46)*	21	0.61 (0.40–0.93)*
Incident ratio		**67**		**68**		**22**		**5**		**1**	

Note:* — 95% confidence interval

Figures given in Table 6 demonstrate two important facts. First, the accumulation of minor incidents and incidents without consequences will inevitably lead to the occurrence of cases of severe iatrogenic injury and critical incidents (transition of quantitative changes into qualitative ones). Second, reported critical incidents and major injuries must necessarily correspond to higher rates of new non-consequential and minor incidents. The latter fact is a powerful tool for checking the validity of an organization's existing incident reporting system. The vast majority of incidents in intensive care units (62.63%) are related to drug therapy and interventions, 20.12% - to care procedures, 11.12% - to the treatment plan and 6.13% - to diagnostic procedures (Table 7) [47,49,50,56].

Table 7

Medical interventions associated with incidents in intensive care units

Intervention/ treatment steps	*A. Forster et al.*, 2008 [47]		*P. Merino et al.*, 2012 [49]		*D.A. Garry et al.*, 2014 [50]		*C. Chapuis et al.*, 2019 [56]		Cumulative incidence	
	Absolute number	Share %	Absolute number	Share %	Absolute number	Share %	Absolute number	Share %	Absolute number	Share %
Diagnostic procedures	1	1.79	118	8.29	4	3.85	7	0.87	130	**6.13** (5.19–7.23)*
Drug therapy	12	21.44	355	24.93	18	17.31	526	65.10	641	**30.21** (28.29–32.20)*
Surgeries, manipulations and invasive procedures	24	42.85	558	39.18	20	19.23	86	10.64	688	**32.42** (30.46–34.44)*
Other interventions (therapeutic procedures related to patient care)	13	23.21	323	22.69	23	22.11	68	8.41	427	**20.12** (18.47–21.88)*
Treatment planning	6	10.71	70	4.91	39	37.50	121	14.97	236	**11.12** (9.85–12.53)*
TOTAL	56	100.00	1424	100.00	104	100.00	808	100.00	2122	–

Note:* — 95% confidence interval

Anesthesia during surgeries, minimally invasive interventions and manipulations contain a large number of factors of aggressive impact on the patient's body. This is due to the fact that during surgery in a rather limited

space there is a purposeful use of mechanical ventilation and muscle relaxants, anesthesia, a large number of drugs with a narrow therapeutic range, many invasive devices (lines for infusion, monitoring, etc.), catheters and drains, equipment for carrying out extracorporeal perfusion of organs, controlled hypothermia and many other interventions. The danger of critical deviations associated with the described exposure requires permanent monitoring of the most important hemodynamic parameters and respiratory function, reliable laboratory monitoring of the state of blood and metabolism, timely and effective correction of diagnosed disorders, support of the vital organ functions and prevention of possible complications, adequate pain relief throughout the surgical stage and in the early postoperative period. Extremely limited communication with the patient during most of the anesthesia care significantly complicates the described monitoring [6,57,58,59].

Important conditions for effective and safe anesthesia care are the competence of the anesthesia team, effective communication with the surgical team and other services, and free orientation in the space of the technological interface. There are six stages in the work of an anesthesiologist, and at each stage errors and the development of severe complications are possible: preoperative examination of the patient and premedication, anesthetic induction, maintenance of anesthesia, recovery from anesthesia, transportation to the postoperative ward, maintenance in the ward of postoperative stay. It is necessary to pay special attention to the stage of transportation which should begin only after confirmation of the full readiness of the resuscitation bed and all medical and diagnostic equipment for receiving the patient. And the transportation itself requires adequate cardiac and respiratory activity of the patient, monitoring of central hemodynamics. This is virtually impossible without an invasive blood pressure monitor, transport stations for infusion and transport devices for mechanical ventilation. Unfortunately, data on incidents that occur during the transportation stage are practically not presented in modern literature [6,57,58,59].

It is noteworthy that in the provision of anesthesia care, the proportion of incidents related to equipment is higher than in other areas of medical care. The reasons for these incidents are failures of the equipment itself, lack of preparation and testing of equipment before starting work, poor performance as a result of human-machine interface anomalies, insufficient technical competence of personnel, emergency situations associated with the delivery of medical gases [6,57,58,59,60]. However, the main mistakes and incidents in the provision of anesthesia care are related to the human factor in terms of anesthesia planning and management in the early post-anesthesia period, therapeutic interventions, condition monitoring and nursing care. In this respect, maintaining adequate central hemodynamics, tissue perfusion and pulmonary ventilation, timely and adequate compensation for losses and disorders associated with surgical aggression (blood loss, loss of fluids and electrolytes, external cooling, carbohydrate and electrolyte metabolism disorders, etc.), managing the state of invasive devices and catheters are of particular importance. The majority of human errors and incidents are caused by poor communication and coordination of activities, and drowsiness associated with the necessity to work at night. All the above is exacerbated by exposure to organizational vulnerabilities and distractions [6,57,61,62,63]. A study showed that, on average, one team of surgeons and anesthesiologists during surgery is affected by 111 distractions, of which 33% cause diversion from current activities. In 46% of cases, distractions were associated with excessive communication of the members of the team itself [64]. Quite dangerous in the process of providing anesthesia care is the change of the anesthesia team. Thus, during cardiac surgery, the transfer of anesthesia to another anesthesia team increased perioperative lethality by 43% [65].

The contribution to perioperative lethality from anesthesia-related incidents is not easy to determine. Only a few publications specify the role of anesthetic problems that have become primary or secondary causes of death. While the proportion of deaths associated exclusively with anesthesia is usually in the range of 3-12% and does not exceed 1 case per 100-150 thousand patients. Despite the fact that over the past half century, significant progress has been made in reducing perioperative lethality (by 9 times) and mortality (by 10.5 times) associated exclusively with anesthesia, most of this was achieved through improved medical technologies and quality of medical devices. At the same time, the role of the human factor and organizational vulnerabilities continue to be a significant area for improvement [66,67,68,70].

Information about errors and incidents associated with anesthesia (assuming a significant contribution of anesthesia to their origin) is given in Table 8. The number of incidents per 100 patients and the prevalence of patients with incidents are almost 2 times higher in children than in adults, while mortality and lethality from incidents in children is more than 10 times lower than in adults. In absolute figures, the mortality rate, where a significant contribution was due to anesthesia care, was equal to 1 case per 2500 anesthesia in adults and 1 case per 8000 anesthesia in children [69,71-76].

Table 8

Anesthesia-related incidents

Author	Number of patients/ anesthesia	Incidents			Incidents per 100 patients/ 100 anesthesias %	Prevalence of patients with incidents %	Incident deaths	
		Absolute number	Deaths	Patients			Mortality %	Lethality %
S. Wan et al., 2013 [69]	75 331	2519[a]	no data	no data	3,34[a]	–	–	–
K.E. Munting et al., 2015 [71]	65 985/110 310	3904	45	no data	5,91/3,54	–	0,068	–
T. Saito et al., 2015 [72]	44 915	379	8	379	0.84	0.84	0.018	2.11
A.K. Lipshutz et al., 2015 [73]	63 818	1811[b]	no data	no data	2.83[b]	–	–	–
W. Habre et al., 2017 [74]	30 874/31 127	1637[c]	4[c]	1478[c]	5.30/5.26[c]	4.78[c]	0.013	0.27
P. Agbamu et al., 2017 [75]	1188	73	5	42	6.14	2.22	0.4	11.9
G.D. Williams et al., 2017 [76]	72 384	2689[a]	3	1980	3.71	2.73	0.0055*	no data
Cumulative incidence - adults					**3,51** (3,45–3,57) (11 375/323 621)	**2,03** (1,95–2,11) (2401/118 487)	**0,04** (0,03–0,05) (61/166 557)	**3,09** (1,73–5,36) (13/421)
Cumulative incidence - children					**5,03** (5,06–5,56)** (1637/30 874)	**4,79** (4,56–5,03)** (1478/30 874)	**0,013** (0,011–0,017)**	**0,27** (0,09–0,74)**

Note: a — provision of anesthesia for children; b — incidents without consequences; c — only large and critical pediatric incidents; * — mortality rate was determined based on 54 469 death cases; ** — 95% confidence interval

Most anesthetic incidents are the result of patient-related problems (29.3%) and miscalculations in staff decision-making (23.2%). This was followed by mistakes in the actions of the staff (14.8%), errors associated with impaired coordination in the surgical team performance (14.5%), inadequate preoperative examination (6.9%), the need to switch between tasks (6.1%) , problems in communication (4.8%), lack of competencies (4.5%), haste and time pressure (4.5%), errors and violations in equipment testing (3.2%). The vast majority of miscalculations (81.5%) are caused by the loss of awareness of a rapidly changing situation as a result of misperception, as well as information-processing failures [62,72,75].

The main number of anesthetic incidents occurs at the stages of induction and maintenance of anesthesia (Table 9) [72,74,75].

Table 9

Distribution of incidents depending on the stage of anesthesia care

Author	Incidents (Absolute number)	Premedication		Induction		Maintenance of anesthesia		Recovery from anesthesia		Management in the post-anesthesia department	
		Absolute number	%	Absolute number	%	Absolute number	%	Absolute number	%	Absolute number	%
T. Saito et al., 2015 [72]	379	9	2,37	149	39,31	133	35,09	56	14,77	32	8,44
W. Habre et al., 2017 [74]	1 637*	–	–	403	24,61	627	38,30	509	31,09	98	5,98
P. Agbamu et al., 2017 [75]	73	–	–	40	54,79	24	32,88	5	6,85	4	5,48

Note: * — large and critical incidents

Almost half of the incidents, both in children and adults, have no consequences for the patient. The share of major and critical incidents in children is significantly lower than in adults, which explains the lower mortality and lethality rates given above in children, despite the higher incidence characteristics (Table 10). For one critical adult incident, there are 8 major incidents, 3 moderate incidents, and 11 minor incidents. In children, the distribution is biased towards minor incidents: 3, 17, and 27, respectively [71,72].

Table 10

Severity distribution of anesthesia-related incidents

Author	Total	Incident Category NCC MERP55									
		CD (without consequences)		E (minimum harm)		F (moderate harm)		GH (heavy harm)		I (death)	
		Absolute umber	%	Absolute number	%	Absolute number.	%	Absolute number	%	Absolute number	%
K.E. Munting et al., 2015 [71]	3 904 (children)	1750	44.82	1231	31.53	751	19.23	127	3.25	45	1.15
	Ratio for children	39		27		17		3		1	
T. Saito et al., 2015 [72]	379 (adults)	198	52.24	87	22.95	22	5.80	64	16.89	8	2.11
	Ratio for adults	25		11		3		8		1	

Among anesthetic incidents with consequences, respiratory problems dominate, followed by cardiovascular disorders. The third place is occupied by incidents related to the actions of anesthesiologists (Table 11) [69,71,72,75].

It should be noted that complications of drug therapy presented in Table 11 concern the drug technology itself (drug reactions and allergies). The reason for the aggressive action of most drugs with a narrow therapeutic range is unsafe actions associated with the human factor. Most of these complications are included in the groups of respiratory and cardiovascular complications, as well as related hypoxic damage to the central nervous system. Anesthesiology is the only medical specialty where the prescription, dilution and administration of drugs take place without the consent of any other specialist. Along with a large number of drugs used, this creates favorable conditions for potential errors [77]. Errors associated with the use of drugs during anesthesia are quite often a violation of one or more principles of safe drug therapy: "right patient", "right drug", "right dose", "right time" and "correct route of administration" [78, 79]. In this case, the first place is occupied by errors associated with the introduction of the wrong drug (due to problems with drug identification and labeling). The second place belongs to errors associated with an insufficient dose or overdose of the drug, the third - errors associated with skipping the administration of the drug (omission), the fourth - errors associated with the wrong route of drug administration [75,77,79,80].

Table 11

The main types of incidents in the provision of anesthesia care

Problem type	*S. Wan et al.*, 2013 [69]*		*T. Saito et al.*, 2015 [72]		*K.E. Munting et al.*, 2015 [71]*		*P. Agbamu et al.*, 2017 [75]	
	Absolute number	Share %	Absolute number	Share %	Absolute number	Share %	Absolute number	Share %
Respiratory problems	1757	69.74	211	55.67	851	21.80	22	30.14
Complications of drug therapy	100	3.97	55	14.51	323	8.27	9	12.32
Cardiovascular problems	238	9.45	54	14.25	1164	29.81	25	34.25
Incidents related to anesthetic procedures, insertion and positioning of medical devices	161	6.39	8	2.11	820	21.00	12	16.44
Equipment related problems	183	7.26	25	6.60	329	8.42	5	6.85
Other problems	80	3.17	26	6.87	417	10.68	–	–
TOTAL	2519	100.00	379	100.00	3904	100.00	73	100.00

Note: * — pediatric anesthesia

DISCUSSION

The conducted analysis of the working conditions of various departments involved in the provision of emergency medical care (prehospital care emergency medical services, emergency departments, intensive care units and anesthesiology services) showed the presence of common initial variables: environmental complexity, suboptimal workspace configuration, complexity of the technological interface and the impact of acute stress on performers [6,8,13,22,23,38,42]. The most significant variable is the complexity of the emergency care environment. This environment has been called the high-stakes environment in the literature. A universal approach to the description of a complex environment involves its assessment in terms of the complexity of the tasks being solved and the obstacles to solving problems. Table 12 summarizes the key characteristics of the complex environment for all four areas of emergency care. The most common one is the critical impact of time pressure which leads to a significant decrease in the quality of perception and information processing by reducing the time to test hypotheses. In addition, the lack of time significantly narrows the space of opportunities for critical assessment of the decisions made, the application, along with the treatment, of additional and duplicating functions necessary to prevent errors and incidents. The influence of other elements of the complex environment in different departments is not equivalent, which leads to significant differences in the frequency and severity of incidents, as well as in the quality of accounting for the events themselves. This is largely due to the duration of contact with the patient (meaning the time the patient stays in the area of focus of a certain service), the number of patients who receive medical care in one time interval, the number of simultaneously used technologies, examinations and treatment in the previous period.

Table 12

Characteristics of environmental complexity in various areas of emergency care

Characteristics of the environment	Severity factor			
	Prehospital care emergency medical services	Emergency Departments	Intensive Care and Resuscitation Units	Anesthesiology Services
Environmental complexity in terms of the complexity of the tasks being solved				
Patient uncertainty	++++	+++	++	+
Patient related instability	+	+++	++++	++
Multitasking	+	+++	++++	++
Monotony	++	+	+++	++++
Heavy technological load	+	++	+++	++++
Task interdependence	+	++	++++	+++
High velocity of a decision's consequences	+++	+++	+++	++++
Irreversibility of a decision's consequences	+	++	++++	++++
Multiple consequences of a decision	+	++	+++	++++
High price of a wrong decision	+	++	+++	++++
Delayed effect of technology	++++	+++	+	++
Environmental complexity in terms of obstacles to solving problems				
Multiple goals	++	++	++++	+++
Competing goals	++	++	++++	+++
Goals changing during treatment	+	+++	++++	++
Instability related to environment variables	+++	++++	+	++
Uncertainty related to environment variables	++++	+++	++	+
Environmental opacity (ambiguity of the information received)	+	++	++++	+++
Frequent breaks	+	++++	+++	++
Migrating stress	+	+++	++++	++
Novelty of the situation	++++	+++	++	+
Lack of time to make decisions	++++	++++	++++	++++
Information overload	+	++	++++	+++
Interactive hypercomplexity	+	+++	++	++++

Notes:
+ the factor is present;
++ the factor has a moderate influence on decision-making;
+++the factor has a strong influence on decision-making;
++++ the factor has a very strong influence on decision-making, affecting all previous stages of human behavior.

Research related to the epidemiology of incidents with consequences has shown unequal prevalence of patients with incidents in different areas of emergency medical care. The maximum rates of frequency and severity are observed in intensive care and resuscitation units, the minimum - in anesthesiology and prehospital care emergency medical services. Intermediate values are typical for emergency departments of multidisciplinary hospitals. Unfortunately, the extremely short time of contact with the patient creates great obstacles for identifying the causes and sources of incidents related to ambulance service performance. The initial severity of the disease and the predominant impact of surgical trauma on the patient's body, in addition

to emerging surgical problems, skillfully mask incidents associated exclusively with the anesthetic management itself. That is why the real statistics of errors, frequency and severity of incidents for anesthesiology and prehospital emergency medical services require special attention as well as the development of more reliable methods of identification and verification criteria, including the methodology of global instrumental triggers for the vast majority of clinical cases [11, 14, 25, 45, 81].

From the point of view of the system security model, root causes associated with various sources (the human factor, technology, patient, organization and non-organizational factors) are the basis of errors and incidents. And unsafe actions of people (mostly highly motivated and competent ones) are the result of hazards and vulnerabilities associated with the root causes. Moreover, most incidents arise as a result of the confluence in time and space of many active threats and vulnerabilities [6,57,81-84]. That is why, in order to prevent deviant events in emergency medicine, systemic solutions are required that take into account the influence of the root causes at various levels. These system solutions are usually redundant in relation to the process of providing medical care and require additional time and resources.

CONCLUSION

The analysis of publications on errors and incidents in the provision of emergency medical care revealed an extreme heterogeneity of descriptive statistical indicators in all target groups of departments: from the minimum values (in anesthesiology services) to the peak values in intensive care and resuscitation departments. Nevertheless, for all areas of emergency care, factors have been noted that, along with the threats present in other types of departments and services, determine both the special nature of the complexity of the tasks being solved, and the presence of serious obstacles along the way. This type of environment is called a high-stakes environment, where the cost of error and any deviation is high enough in terms of severe complications and unforeseen death. The special nature of the activities and the catastrophic lack of time for decision-making significantly limit the possibility of obtaining up-to-date information about errors and incidents, as well as the application of well-known and proven effective measures to manage the risks of additional harm in parallel with the treatment process.

FINDING

Emergency medical care is fraught with many threats that cause a high prior probability distribution of errors and incidents. Registration of deviant events in emergency medical units is complicated by the limited time of contact with the patient, many influencing variables, including various technologies and the influence of other teams. The extremely high concentration and interdependence of many root causes, the resulting hazards and vulnerabilities in the high-stakes environment requires a special approach to managing the risks of additional harm.

REFERENCES

1. O'Hagan J, MacKinnon NJ, Persaud D, Echegaray E. Self-Reported Medical Errors in Seven Countries: Implications for Canada. *Healthcare Q*. 2009;12 Spec No Patient:55–61. PMID: 19667778 https://doi.org/10.12927/hcq.2009.20967
2. Thiels CA, Lal TM, Nienow JM, Pasupathy KS, Blocker RC, Aho JM, et al. Surgical never events and contributing human factors. *Surgery*. 2015;158(2):515–521. PMID: 26032826 https://doi.org/10.1016/j.surg.2015.03.053
3. Makary MA, Daniel M. Medical error – the third leading cause of death in the US. *BMJ*. 2016;353:i2139. PMID: 27143499 https://doi.org/10.1136/bmj.i2139
4. Roytberg GE, Kondratova NV. *Meditsinskaya organizatsiya po mezhdunarodnym standartam kachestva: prakticheskoe rukovodstvo po vnedreniyu*. Moscow: MEDpress-inform Publ.; 2018. (in Russ.).
5. Voskanyan Y, Shikina I, Kidalov F, Davidjv D. Medical care safety – problems and perspectives. In: Antipova T. (ed.). *Integrated Science in Digital Age. ICIS 2019. Lecture Notes in Networks and Systems, vol 78*. Springer, Cham; 2019. pp. 291–304. https://doi.org/10.1007/978-3-030-22493-6_26
6. St Pierre M, Hofinger G, Buerschaper C. *Crisis Management in Acute Care Settings. Human Factors and Team Psychology in a High Stakes Environment*. Springer-Verlag Berlin Heidelberg; 2008.
7. Khubutiya MS, Molodov VA, Vasilyev VA, Karasev NA. The Current State and Development Trends of Emergency Medicine Management in Postindustrial Societies. *Russian Sklifosovsky Journal Emergency Medical Care*. 2016;(4):15–20. (in Russ.).
8. Howard IL, Bowen JM, Al Shaikh LAH, Mate KS, Owen RC, Williams DM. Development of a trigger tool to identify adverse events and harm in emergency medical services. *Emerg Med J*. 2017;34(6):391–397. PMID: 28153866 https://doi.org/10.1136/emermed-2016-205746
9. Voskanyan Y, Kidalov F, Shikina I, Kurdyukov S, Andreeva O. Model of Individual Human Behavior in Health Care Safety Management System. In: Antipova T. (ed.). *Comprehensible Science. ICCS 2020. Lecture Notes in Networks and Systems*. Springer; 2021. pp.413–423. https://doi.org/10.1007/978-3-030-66093-2_40
10. Reichard AA, Marsh SM, Tonozzi TR, Konda S, Gormley MA. Occupational injuries and exposures among emergency medical services workers. *Prehosp Emerg Care*. 2018;21(4):420–431. PMID: 28121261 https://doi.org/10.1080/10903127.2016.1274350

11. Patterson PD, Runyon MS, Higgins JS, Weaver MD, Teasley EM, Kroemer AJ, et al. Shorter versus longer shift durations to mitigate fatigue and fatigue-related risks in emergency medical services personnel and related shift workers: A Systematic Review. *Prehosp Emerg Care*. 2018;22(Suppl 1):28–36. PMID: 29324079 https://doi.org/10.1080/10903127.2017.1376135
12. Yadley LE, Donaldson LJ. Deaths following prehospital safety incidents: an analysis of a national database. *Emerg Med J*. 2016;33(10):716–721. PMID: 26984719 https://doi.org/10.1136/emermed-2015-204724
13. Hughes AM, Patterson D, Weaver MD, Gregory ME, Sonesh SC, Landsittel DP, et al. Teammate familiarity, teamwork, and risk of workplace injury in emergency medical service teams. *J Emerg Nurs.* 2017;43(4):339–346. PMID: 28366241 https://doi.org/10.1016/j.jen.2016.11.007
14. Bigham BL, Buick JE, Brooks SC, Morrison M, Shojania KG, Morrison LJ. Patient Safety in Emergency Medical Services: A Systematic Review of the Literature. *Prehosp Emerg Care*. 2012;16(1):20–35. PMID: 22128905 https://doi.org/10.3109/10903127.2011.621045
15. Hohenstein C, Fleischmann T, Rupp P, Hempel D, Wilk S, Winning S. German critical incident reporting system database of prehospital emergency medicine: Analysis of reported communication and medication errors between 2005–2015. *World J Emerg Med*. 2016;7(2):90–96. PMID: 27313802 https://doi.org/10.5847/wjem.j.1920-8642.2016.02.002
16. Kothari R, Barsan W, Brott T, Broderick J, Ashbrock S. Frequency and accuracy of prehospital diagnosis of acute stroke. *Stroke*. 1995;26(6):937–941. PMID: 7762041 https://doi.org/10.1161/01.STR.26.6.937
17. Arntz HR, Klatt S, Stern R, Willich SN, Bernecker J. Are emergency physicians' diagnoses accurate? *Anesthesist*. 1996;45(2):163–170. PMID: 8720889 https://doi.org/10.1007/s001010050251
18. Peery CL, Chendrasekhar A, Paradise NF, Moorman DW, Timberlake GA. Missed injuries in pediatric trauma. *Am Surg*. 1999;65(11):1067–1069. PMID: 10551758
19. Flabouris A. Clinical features, patterns of referral and out of hospital transport events for patients with suspected isolated spinal injury. *Injury*. 2001;32(7):569–575. PMID: 11524091 https://doi.org/10.1016/S0020-1383(01)00071-7
20. Vilke GM, Tornabene SV, Stepanski B, Shipp HE, Ray LU, Metz MA, et al. Paramedic self-reported medication errors. *Prehosp Emerg Care*. 2007;119(1):80–84. PMID: 17169883 https://doi.org/10.1080/10903120601021358
21. Hagiwara MA, Magnusson C, Herlitz J, Seffel E, Axelsson C, Munters M, et al. Adverse events in prehospital emergency care: a trigger tool study. *BMC Emerg Med*. 2019;19(1):14. PMID: 30678636 https://doi.org/10.1186/s12873-019-0228-3
22. Stang AS, Wingert AS, Harting L, Plint AC. Adverse Events Related to Emergency Department Care: A Systematic Review. *PLos One*. 2013;8(9):e74214. PMID: 24069281 https://doi.org/10.1371/journal.pone.007421
23. Mitchel L, Flin R. (eds.). *Safer Surgery: Analysing in the Operating Theatre*. CRS Press; 2017.
24. Gill S, Mills PD, Watts BV, Paull DE, Tomolo A. A Review of Adverse Event Reports From Emergency Departments in the Veterans Health Administration. *J Patient Saf*. 2021;17(8):e898–903. PMID: 32084094 https://doi.org/10.1097/PTS.0000000000000636
25. Panagioti M, Khan K, Keers RN, Abuzour A, Phipps D, Kontopantelis E, et al. Prevalence, severity, and nature of preventable patient harm across medical care settings: systematic review and meta-analysis. *BMJ*. 2019;366:l4185. PMID: 31315828 https://doi.org/10.1136/bmj.l4185
26. Wolf AM, Bourke J. Detecting and reducing adverse events in an Australian rural base hospital emergency department using medical record screening and review. *Emerg Med J*. 2002;9(1):35–40. PMID: 11777869 https://doi.org/10.1136/emj.19.1.35
27. Grossman N, Gratwohl F, Musy SN, Nielen NM, Donze J, Simon M. Describing adverse events in medical inpatients using the Global Trigger Tool. *Swiss Med Wkly.* 2019;149:w20149. PMID: 31707720 https://doi.org/10.4414/smw.2019.20149
28. Zhang E, Hung S, Wu C, Chen L, Tsai M, Lee W. Adverse event and error of unexpected life-threatening events within 24 hours of ED admission. *Am J Emerg Med*. 2017;35(3):479–483. PMID: 27974226 https://doi.org/10.1016/j.ajem.2016.11.062
29. Rafter N, Hickey A, Conroy RM, Condell S, O'Connor P, Vaughan D, et al. The Irish National Adverse Events Study (INAES): the frequency and nature of adverse events in Irish hospitals—a retrospective record review study. *BMJ Qual Saf*. 2017;26(2):111–119. PMID: 26862223 https://doi.org/10.1136/bmjqs-2015-004828
30. Forster AJ, Rose NG, van Walraven C, Stiell I. Adverse events following an emergency department visit. *Qual Saf Health Care*. 2007;16(1):17–22. PMID: 17301197 https://doi.org/10.1136/qshc.2005.017384
31. Soop M, Fryksmark U, Koster M, Hagland B. The incidence of adverse events in Swedish hospitals: a retrospective medical record review study. *Int J Qual Health Care.* 2009;21(4):285–291. PMID: 19556405 https://doi.org/10.1093/intqhc/mzp025
32. Calder LA, Forster A, Nelson M, Leclair J, Perry J, Vaillancourt C, et al. Adverse events among patients registered in high-acuity areas of the emergency department: a prospective cohort study. *CJEM*. 2010;12(5):421–430. PMID: 20880432 https://doi.org/10.1017/S1481803500012574
33. Tomas S, Chanovas M, Roqueta F, Alcaraz J, Toranzo T. Adverse events related to Spanish hospital emergency department care: the EVADUR study. *Emergencias*. 2010;22(6):415–428.
34. Hendrie J, Yeoh M, Richardson J, Blunt A, Davey P, Taylor D, et al. Case-control study to investigate variables associated with incidents and adverse events in the emergency department. *Emerg Med Australas.* 2017;29(2):149–157. PMID: 28118693 https://doi.org/10.1111/1742-6723.12736
35. Halfon P, Staines A, Burnard B. Adverse events related to hospital care:

a retrospective medical records review in a Swiss hospital. *Int J Quality Health Care.* 2017;29(4):527–533. PMID: 28586414 https://doi.org/10.1093/intqhc/mzx061

36. Alsabri M, Boudi Z, Zoubeidi T, Alfaki I, Levy P, Oneyji C, et al. Analysis of Risk Factors for Patient Safety Events Occurring in the Emergency Department. *J Patient Saf*. 2020;18(1):e124–135. PMID: 32853517. https://doi.org/10.1097/PTS.0000000000000715
37. Gawande A. The Checklist Manifesto: How to Get Things Right. New York, N.Y.: Metropolitan Books; 2010. 236 p. [Russ. Ed.: Gavande A. *Chek-list: sistema predotvrashcheniya oshibok*. Moscow: Al'pina Pablisher; 2019]
38. Asadi P, Modirian E, Dadashpour N. Medical Errors in Emergency Department; a Letter to Editor. *Emerg (Tehran)*. 2018;6(1):e33. PMID: 30009235
39. Hussain F, Cooper A, Carson-Stevens A, Donaldson L, Hibbert P, Hughes T, et al. Diagnostic error in the emergency department: learning from national patient safety incident report analysis. *BMC Emerg Med*. 2019;19(1):77. PMID: 31801474 https://doi.org/10.1186/s12873-019-0289-3
40. Shitu Z, Aung M, Kamauzaman T, Rahman A. Prevalence and characteristics of medication errors at an emergency department of a teaching hospital in Malaysia. *BMC Health Serv Res*. 2020;20(1):56–62. PMID: 31969138 https://doi.org/10.1186/s12913-020-4921-4

41. Pham J, Story J, Hicks R, Shore A, Morlock L, Cheung D, et al. National study on the frequency, types, causes, and consequences of voluntarily reported emergency department medication errors. *J Emerg Med.* 2011;40(5):485–492. PMID: 18823735 https://doi.org/10.1016/j.jemermed.2008.02.059
42. Marshall JC, Bosco L, Adhikari NK, Connolly B, Diaz JV, Dorman T., et al. What is an intensive care unit? A report of the task force of the World Federation of Societies of Intensive and Critical Care Medicine. *J Crit Care*. 2017;37:270–276. PMID: 27612678 https://doi.org/10.1016/j.jcrc.2016.07.015
43. Claro C, Krocockz D, Toffoleto M, Padilha K. Adverse events at the intensive care unit: nurses' perception about the culture of no-punishment. *Rev Esc Enferm USP.* 2011;45(1):167–172. PMID: 21445504 https://doi.org/10.1590/s0080-62342011000100023
44. Lilly CM, Cody S, Zhao H, Landry K, Baker SP, McIlwaine J, et al. Hospital Mortality, Length of Stay, and Preventable Complications Among Critically Ill Patients Before and After Tele-ICU Reengineering of Critical Care Processes. *JAMA*. 2011;305(21):2175–2183. PMID: 21576622 https://doi.org/10.1001/jama.2011.697
45. Ahmed AH, Giri J, Kashyap R, Singh B, Dong Y, Kilickaya O, et al. Outcome of Adverse Events and Medical Errors in the Intensive Care Unit: A Systematic Review and Meta-analysis. *Am J Med Qual*. 2015;30(1):23–30. PMID: 24357344 https://doi.org/10.1177/1062860613514770
46. Resar R, Rozich JD, Simmonds T, Haraden CR. A trigger tool to identify adverse events in the intensive care unit. *J Comm J Qual Patient Saf*. 2006;32(10):585–590. PMID: 17066996 https://doi.org/10.1016/s1553-7250(06)32076-4
47. Forster AJ, Kyeremanteng K, Hooper J, Shojania KG, van Walraven C. The impact of adverse events in the intensive care unit on hospital mortality and length of stay. *BMC Health Serv Res*. 2008;8:259. PMID: 19091089 https://doi.org/10.1186/1472-6963-8-259
48. Pagnamenta A, Rabito G, Arosio A, Perren A, Malacrida R, Barazzoni F, et al. Adverse event reporting in adult intensive care units and the impact of a multifaceted intervention on drug-related adverse events. *Ann Intensive Care*. 2012;2(1):47. PMID: 23174137 https://doi.org/10.1186/2110-5820-2-47
49. Merino P, Alvarez J, Martin M, Alonso A, Gutierrez I. Adverse events in Spanish intensive care units: the SYREC study. *Int J Qual Health Care*. 2012;24(2):105–113. PMID: 22190588 https://doi.org/10.1093/intqhc/mzr083
50. Garry DA, McKechnie SR, Culliford DJ, Ezra M, Garry PS, Loveland RC, et al. A prospective multicentre observational study of adverse iatrogenic events and substandard care preceding intensive care unit admission (PREVENT). *Anaesthesia*. 2014;69(2):137–142. PMID: 24443852 https://doi.org/10.1111/anae.12535
51. Roque KE, Tonini T, Melo EC. Adverse events in the intensive care unit: impact on mortality and length of stay in a prospective study. *Cad Saúde Pública*. 2016;32(10):e00081815. PMID: 27783755 https://doi.org/10.1590/0102-311X00081815
52. Molina FJ, Rivera PT, Cardona A, Restrepo DC, Monroy O, Rodas D, et al. Adverse events in critical care: Search and active detection through the Trigger Tool. *World J Crit Care Med*. 2018;7(1):9–15. PMID: 29430403 https://doi.org/10.5492/wjccm.v7.i1.9
53. Decormeille G, Maurer-Maouchi V, Mercier G, Debock S. Lebrun C, Rouhier M, et al. Adverse Events in Intensive Care and Continuing Care Units During Bed-Bath Procedures: The Prospective Observational NURSIng during critical carE (NURSIE) Study. *Crit Care Med.* 2021;49(1):e20–e30. PMID: 33177361 https://doi.org/10.1097/CCM.0000000000004745
54. Aikawa G, Sakuramoto H, Ouchi A, Ono C, Hoshino T, Kido T, et al. Development of the Japanese version of the Intensive Care Unit Trigger Tool to detect adverse events in critically ill patients. *Acute Med Surg*. 2021;8(1):e672. PMID: 34188941 https://doi.org/10.1002/ams2.672
55. NCCMERP taxonomy of medication error. Available at: https://www.nccmerp.org/sites/default/files/taxonomy2001-07-31.pdf [Accessed April 19, 2022].
56. Chapuis C, Chanoine S, Colombet L, Calvino-Gunther S, Tournegros C, Terzi N, et al. Interprofessional safety reporting and review of adverse events and medication errors in critical care. *Ther Clin Risk Manag*. 2019;15:549–556. PMID: 31037029 https://doi.org/10.2147/TCRM.S188185
57. Reason J. Safety in the operating theatre – Part 2: Human error and organisational failure. *Qual Saf Health Care*. 2005;14(1):56–60. PMID: 15692005
58. James RH. 1000 anaesthetic incidents: experience to date. *Anaesthesia*. 2003;58(9):856–863. PMID: 12911357 https://doi.org/10.1046/j.1365-2044.2003.03334.x
59. Gupta S, Naithani U, Brajesh SK, Pathania VS, Gupta A. Critical Incident Reporting in Anaesthesia: A Prospective Internal Audit. *Indian J Anaesth.* 2009;53(4):425–433. PMID: 20640204
60. Mehta SP, Eisenkraft JB, Posner KL, Domino KB. Patient Injuries from Anesthesia Gas Delivery Equipment. a closed claims update. *Anesthesiology*. 2013;119(4):788–795. PMID: 23835591 https://doi.org/10.1097/ALN.0b013e3182a10b5e
61. Sanches I, Teixeira F, dos Santos JM, Ferreira AJ. Effects of Acute Sleep Deprivation Resulting from Night Shift Work on Young Doctors. *Acta Med Port*. 2015;28(4):457–462. PMID: 26574980 http://dx.doi.org/10.20344/amp.5777
62. Arzalier-Daret S, Buléon S, Bocca M, Denise P, Gérard J, Hanouz J. Effect of sleep deprivation after a night shift duty on simulated crisis management by residents in anaesthesia. A randomised crossover study. *Anaesth Criti Care Pain Med*. 2018;37(2):161–166. PMID: 28882740 https://doi.org/10.1016/j.accpm.2017.05.010
63. Neuschwander A, Job A, Younes A, Mignon A, Delgoulet C, Cabon P, et al. Impact of sleep deprivation on anaesthesia residents' non-technical skills: a pilot simulation-based prospective randomized trial. *Br J Anaesth*. 2017;19(1):125–131. PMID: 28974071 https://doi.org/10.1093/bja/aex155
64. Jothiraj H, Howland-Harris J, Evley R, Moppett IK. Distractions and the anaesthetist: a qualitative study of context and direction of distraction. *Br J Anaesth*. 2013;111(3):477–482. PMID: 23592694 https://doi.org/10.1093/bja/aet108
65. Hudson CC, McDonald B, Hudson JK, Tran D, Boodhwani M. Impact of Anesthetic Handover on Mortality and Morbidity in Cardiac Surgery: A Cohort Study. *J Cardiothorac Vasc Anesth.* 2015;29(1):11–16. PMID: 25440620 https://doi.org/10.1053/j.jvca.2014.05.018
66. Wacker J, Staender S. The role of the anesthesiologist in perioperative patient safety. *Curr Opin Anaesthesiol.* 2014;27(6):649–656. PMID: 25233191 https://doi.org/10.1097/ACO.0000000000000124
67. Bainbridge D, Martin J, Arango M, Cheng D. Evidence-based Perioperative Clinical Outcomes Research Group. Perioperative and anaesthetic-related mortality in developed and developing countries: a systematic review and meta-analysis. *Lancet*. 2012;380(9847):1075–1081. PMID: 22998717 https://doi.org/10.1016/S0140-6736(12)60990-8
68. Beattie WS, Culwick MD, Grocott HP. Canadian Anesthesia Incident Reporting System (CAIRS): The Canadian Anesthesiologists' Society's National Patient Safety Initiative. *Can J Anesth.* 2018;65(7):749–756. PMID: 29704222 https://doi.org/10.1007/s12630-018-1141-z
69. Wan S, Siow YN, Lee SM, Ng A. Audits and critical incident reporting in paediatric anaesthesia: lessons from 75,331 anaesthetics. *Singapore Med J.* 2013;54(2):69–74. PMID: 23462829 https://doi.org/10.11622/smedj.2013027

70. Schiff JH, Welker A, Fohr B, Henn-Beilharz A, Bothner U, Van Aken H, et al. Major incidents and complications in otherwise healthy patients undergoing elective procedures: results based on 1.37 million anaesthetic procedures. *Br J Anaesth*. 2014;113(1):109–121. PMID: 24801456 https://doi.org/10.1093/bja/aeu094
71. Munting KE, van Zaane B, Schouten AN, van Wolfswinkel L, de Graaff JC. Reporting critical incidents in a tertiary hospital: a historical cohort study of 110,310 procedures. *Can J Anesth*. 2015;62(12):1248–1258. PMID: 26407581 https://doi.org/10.1007/s12630-015-0492-y
72. Saito T, Wong ZW, Thinn KK, Poon KH, Liu E. Review of critical incidents in a university department of anaesthesia. *Anaesth Intensive Care*. 2015;43(2):238–243. PMID: 25735691 https://doi.org/10.1177/0310057X1504300215
73. Lipshutz AK, Caldwell JE, Robinowitz DL. Gropper MA. An analysis of near misses identified by anesthesia providers in the intensive care unit. *BMC Anesthesiol*. 2015;15(1):93–99. PMID: 26082147 https://doi.org/10.1186/s12871-015-0075-z
74. Habre W, Disma N, Virag K, Becke K, Hansen TG, Jöhr M, et al. Incidence of severe critical events in paediatric anaesthesia (APRICOT): a prospective multicentre observational study in hospitals in Europe. *Lancet Respir Med*. 2017;5(5):412–425. PMID: 28363725 https://doi.org/10.1016/S2213-2600(17)30116-9
75. Agbamu PO, Menkiti ID, Ohuoba EI, Desalu I. Critical incidents and near misses during anesthesia: A prospective audit. *J Clin Sci*. 2017;14(1):18–24. https://doi.org/10.4103/2468-6859.199170
76. Williams GD, Muffly MK, Mendoza JM, Wixson N, Leong K, Claure RE. Reporting of Perioperative Adverse Events by Pediatric Anesthesiologists at a Tertiary Children's Hospital: Targeted Interventions to Increase the Rate of Reporting. *Anesth Analg*. 2017;125(5):1515–1523. PMID: 28678071 https://doi.org/10.1213/ANE.0000000000002208
77. Erdmann TR, Garcia JH, Loureiro ML, Monteiro MP, Brunharo GM. Profile of drug administration errors in anesthesia among anesthesiologists from Santa Catarina. *Rev Bras Anestesiol*. 2016;66(1):105–110. PMID: 25481769 https://doi.org/10.1016/j.bjan.2014.06.004
78. Tobias JD, Yadav G, Gupta SK, Jain G. Medication errors: A matter of serious concern. *Anaesth Pain Intensive Care*. 2013;17(2):111–114.
79. Erdmann TR, Erdmann AC. Why do Anesthesiologists Drug Administration Errors? *SOJ Anesthesiol Pain Manag*. 2016;3(1):1–4. https://doi.org/10.1016/j.bjan.2016.12.006
80. Dhawan I, Tewari A, Sehgal S, Sinha A. Medication errors in anesthesia: unacceptable or unavoidable? *Rev Bras Anestesiol*. 2017;67(2):184–192. PMID: 28038759 https://doi.org/10.1016/j.bjan.2016.12.006
81. Amaniyan S, Faldaas BO, Logan PA, Vaismoradi M. Learning from patient safety incident in the emergency department: a systematic review. *J Emerg Med*. 2020;58(2):234–244. PMID: 31843322 https://doi.org/10.1016/j.jemermed.2019.11.015
82. Abbaszadeh A, Borhani F, Afshar PF, Ajri-Khameslou M. The nature of errors in emergency department and the role of detectors: A qualitative study. *Patient Saf Qual Improv J*. 2019;7(4):137–143. https://doi.org/10.22038/psj.2019.43894.1248
83. Hsieh M, Chiang P, Lee Y, Wang EM, Kung W, Hu Y, et al. An Investigation of Human Errors in Medication Adverse Event Improvement Priority Using a Hybrid Approach. *Healthcare*. 2021;9(4):442. PMID: 33918754 https://doi.org/10.3390/healthcare9040442
84. Midega TD, Filho NC, Nassar AP, Alencar RM, Neto AC, Ferras LJ, et al. Impact of intensive care unit admission during handover on mortality: propensity matched cohort study. *Einstein (São Paulo)*. 2021;19:eAO5748. PMID: 34161436 https://doi.org/10.31744/einstein_journal/2021AO5748

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