The Human Factors: Errors and Skills

1

Case Study

During an afternoon shift, two hemodynamically unstable patients are admitted to the cardiac ICU (CCU), one immediately after the other. The resident physician's attempt to stabilize both patients nearly overwhelms him. Because of this, he is unable to give adequate attention to a third patient being anticoagulated with warfarin who had several episodes of coffee-ground emesis during the previous 2 h. After finally stabilizing the two new admissions, the resident prepares for an upper endoscopy, but the third patient suddenly becomes hemodynamically unstable. The patient has a recent hemoglobin value of 6.9 g/dL.

With a working diagnosis of acute upper gastrointestinal (GI) bleeding, the patient receives several peripheral IV lines. Crystalloid infusions are started. Six units of crossmatched packed red blood cells (PRBCs) are ordered from the blood bank. Coincidentally, the blood bank is short of personnel and unusually burdened by multiple orders for blood products. The 6 units of PRBCs are sent together with 2 units of PRBCs for another patient in the CCU. The blood products arrive in the CCU while one of the two recently admitted patients is still being stabilized. After a quick glance at the bag containing the PRBCs, the resident asks the nurse to start the blood transfusion. Within minutes of starting the first infusion of blood, the patient complains of dizziness and shortness of breath and deteriorates rapidly. The resident then focuses his complete attention on the treatment of this patient.

Severe and generalized erythema and edema, together with hemodynamic instability and respiratory distress, indicate a severe anaphylactic reaction. Influenced by a comment from a nurse concerning the transfusion, the physician suspects a transfusion error and stops the infusion immediately. The patient is then anesthetized and intubated. Controlled ventilation is difficult due to severe bronchospasm. Under high-dose continuous infusion of

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catecholamines, aggressive volume resuscitation, and administration of corticosteroids and histamine receptor antagonists, the resident manages to stabilize the patient's hemodynamic situation and to improve the bronchospasm. During the following hours, the patient develops severe disseminated intravascular coagulation (DIC) leading to uncontrollable upper GI bleeding. Despite massive transfusion with coagulation factors and blood products, the patient dies several hours later as a result of his uncontrolled bleeding.

Despite maximum therapeutic efforts by motivated caregivers, an intensive care patient suffered harm from a medical error and died several hours later as a consequence of a transfusion reaction. At first glance, the cardiology resident is most likely to be identified as the responsible agent. After all, he was the person in direct contact with the patient, he gave orders for the transfusion, and he did not adhere to standard treatment protocols, thus displaying negligence in the transfusion process. A closer look, however, reveals additional factors that contributed to the adverse event: a workload that overwhelmed the resident with several patients requiring a rapidly executed high level of care, staff shortage in the blood bank, the simultaneous arrival of packed red blood cells (PRBCs) for two different patients, and the acceptance of final responsibility for the transfusion on behalf of the nurse. None of these factors alone would have been able to compromise patient safety. Taken together, however, the factors combined and managed to breach the defensive barriers within the system. The unlikely temporal combination of several contributing factors on different levels within an organization created a condition where a one single moment of inattention by the resident triggered a deadly outcome. The human error, while quite obvious, was only one link in a longer chain of circumstances.

Faulty individual actions represent only one aspect of human factors in a medical high-stakes environment. It is often overlooked that the remarkable ability to rapidly detect, diagnose, and treat a medical emergency or critically ill patient is rooted in human factors. Healthcare providers can only perform successfully in critical situations because the human factors enable them to do so. Far more often than not, healthcare professionals provide safe and efficient patient care even under unfavorable circumstances.

1.1 Human Factors in Healthcare: The Problem

More than a decade ago, the Quality of Healthcare in America Committee of the Institute of Medicine (IOM) issued a report "To Err Is Human: Building a Safer Healthcare System" (Kohn et al. 1999), which examined the quality of the US healthcare delivery system. The results of the study were alarming and stirred up healthcare systems all around the globe: Year after year, a staggering figure of

44,000 people, and perhaps as many as 98,000 people, died in US hospitals as a result of preventable medical error. Even when using the lower estimate, the number of deaths attributable to preventable medical errors exceeded the mortality rate of severe trauma, breast cancer, and HIV.

The IOM report spurred patient safety initiatives around the globe and triggered an unparalleled endeavor to identify medical errors and design interventions to prevent and mitigate their effect. One of the main conclusions of the report was in diametrical opposition to hitherto existing assumptions within the healthcare community; that is, the majority of medical errors were not a result of individual recklessness or incompetence, but instead were caused by faulty systems, processes, and conditions that predictably led people to make mistakes or failed to help prevent mistakes. The idea of a "systemic approach" to safety was no novelty in a number of other high-stakes industries, but it was a relatively new notion in healthcare. A sizable body of knowledge and successful experiences from other high-risk industries had proven that mistakes can best be prevented by systematically designing safety into processes, moving away from a culture of blaming individuals, and seeking to become open organizations where the best and most reliable solutions to problems were valued regardless of *who* came up with the best ideas.

Five years after the Institute of Medicine's call for a national effort to make healthcare safer, an appraisal of progress warranted cautious optimism as the groundwork for improving safety seemed to have been laid successfully: The tone of conversation in healthcare had changed, attitudes and organizations had been impacted, healthcare leaders had learned a great deal about safety, and competence and knowledge of safety practices had increased. The authors did note, however, that progress was frustratingly slow (Leape and Berwick 2005).

Upon nearing the report's 10-year anniversary, this pioneering spirit has given way to disillusionment; despite a flurry of activity during the first years following the publication, efforts to reduce the harm caused by the medical care system are still too few and fragmented. Little appears to have changed as significant barriers are still encountered when attempting to track progress (Mathews and Pronovost 2008). In most countries, neither a national entity nor a systematic process exists to promote, measure, and track patient safety. Despite a decade of work, there is little reliable evidence that we are any better off today than at the turn of the century when the IOM report was written (Jewell and McGiffert 2009). There is some cause for optimism, however. It is found in the growth of simulation in healthcare, an increased emphasis on teamwork, improved technology such as nearly fail-safe medical administration regimens, improved error reporting systems, and enhanced investigation of errors. One anecdotal finding by the authors is that the phrase *patient safety* has crept into daily use in our healthcare institutions. The technology and culture are changing, but ever so slowly. Challenges remain ahead of us. One of the areas that promises significant results in terms of patient safety and performance improvement is understanding how humans work in stressful environments and then designing our systems and training regimens to accommodate the strengths and weaknesses of the people who function within our healthcare systems.

1.2 What Are the "Human Factors"?

1.2.1 Differing Definitions of "Human Factors"

By the beginning of the twenty-first century, it was common knowledge that human behavior dominates the risk to modern socio-technical systems. We owe this insight to the relentless efforts over four decades of interdisciplinary research groups from the field of cognitive sciences, social psychology, organizational behavior, anthropology, sociology, and reliability engineering. They have been studying aspects of the way humans relate to the world around them with the vision that operational performance and safety in the workplace will be improved through the application of an understanding of human factors in the design of equipment, systems, working methods, and training. The generic term *human factors* has several meanings (Fig. 1.1):

- The *human factors sciences* comprise a variety of scientific traditions mostly rooted in engineering, work science, and psychology. The human factors sciences study anatomical, physiological, psychological, and social aspects of workers in their working environment with the objective of optimizing safety, comfort, and efficiency. It elucidates the interaction of environmental, organizational, and job factors with human and individual characteristics that coincide to influence behavior at work that effect health and safety.
- The application of the theoretical principles, data, and methods to design, development, and deployment of tools, machines, systems, jobs, environments, and services in order to optimize human well-being and overall system performance (for our purposes, system performance includes patient safety) is called *human factors engineering* (HFE) also known as *ergonomics*.
- From a *science of humanities* point of view, human factors are physical, psychological, cognitive, and social properties of an individual that influence interaction with

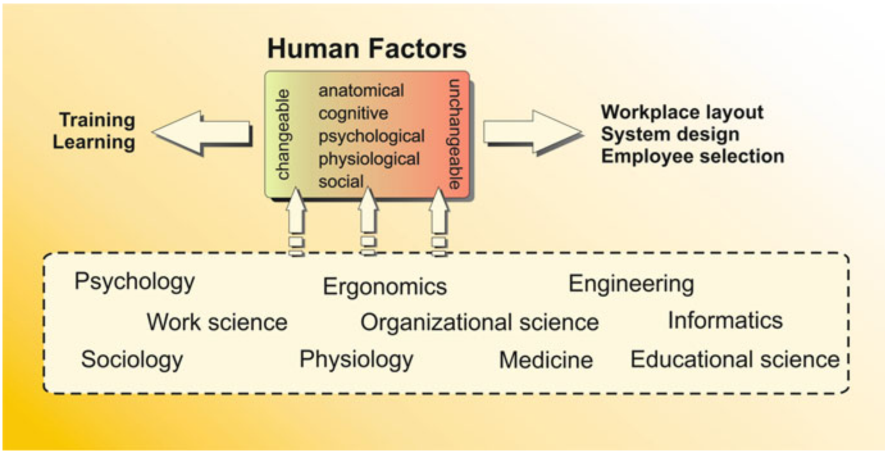

Fig. 1.1 Human factors as scientific discipline and field of application. Some human factors are amenable to training and learning interventions, whereas others can only be addressed by systemic changes

the environment and with social and technological systems. Colloquially, the term *human factors* is often used to differentiate human cognitive or behavioral properties from “technical factors,” e.g., design, usability, etc., of systems, machines, and equipment. However, this perspective fails to consider a central issue of human factors because it is not the examination of isolated human properties but rather the *interaction* of humans with their social and technological environment and the way organizational factors influence daily practice and managing critical situations.

- Some aspects of human action regulation (e.g., information processing, decision-making, motivation, emotions, task execution; Chap. 4) and of teamwork can be changed by learning processes and are therefore amenable to training and learning interventions. Other human properties (e.g., basic mechanisms of perception, regulation of attention, fatigue, somatic stress response, personality, etc.), in contrast, cannot be altered by means of learning interventions. Instead, systemic interventions such as workplace layout, system design, and employee selection help to address these shortcomings. Widespread generic terms for the human factors amenable to training interventions are *nontechnical skills* and, less often used, *soft skills* and *para-technical skills*. However, labeling these skills as “nontechnical” seems rather unfortunate, as many communication techniques can and should be learned like any other skills (Chap. 12).

1.2.2 Facts and Fictions: Misconceptions of “Human Factors” in Healthcare

Interest in human factors has increased across healthcare communities worldwide. It is now widely accepted that support of the cognitive and physical work of healthcare professionals and human-centered workplace design help to enhance patient safety. However, there is a growing concern among human factor specialists that there has been an inadequate integration of human factors principles and methods into healthcare, leading to several basic misconceptions (e.g., Carayon et al. 2012; Catchpole 2013; Russ et al. 2013). These misconceptions are not of a mere academic nature but likely hinder healthcare improvement and slow the integration of human factors into healthcare:

- Despite embracing the notion that “safety is a system problem” and the widespread rhetoric of a “systemic approach,” the focus within healthcare continues to be on the person and his or her behavior. Superficially, the person-centered approach (e.g., “naming, blaming, shaming”) has been abandoned – people are no longer pilloried in public. However, as the response to failure often consists of “re-educating” people, making “human factors training” mandatory, and warning them to be “more diligent,” other contributing factors that contributed to an incident are less likely to be fully taken into account and adequately addressed. Ultimately, if the understanding of *human factors* is reduced to *human failure*, the term is only a semantic surrogate for “blaming” (Catchpole 2013).
- A preferred strategy in healthcare is to achieve patient safety by means of right behavior and well-defined processes. This strategy, however, neither identifies

nor removes system hazards, nor does it incorporate human factors engineering design principles to optimize specific work system elements. One of the main reasons for that might be found in the loose relationship between developer, industry, and user. In addition, training is easier to implement and less expensive than changes in the work environment.
- The end user of a system, medical device, or healthcare information technology (IT) – physicians, nurses, paramedics, and patients – is normally not part of the conversation of designers and human factors specialists. This partly explains why established principles of human factors engineering regarding the implementation of medical devices, management, employee working conditions, training, and design are rarely followed (Carayon et al. 2012).

Because this book is mainly directed at healthcare professionals in acute patient care who want to ensure safe patient care even under emergency conditions, the focus of the following chapters will be on psychological and organizational human factors. However, we deem it necessary to emphasize that these human factors have to be addressed in the broader context of how care is delivered within each unit, clinical site, and culture. Only with those considerations in mind will we achieve the desired good results of our collective thoughtfulness.

1.3 Levels of Human Factors

It took the healthcare community a long time to begin to integrate these findings into daily practice. It started to happen after healthcare's close resemblance with other high-risk socio-technical systems had been realized and accepted. In these domains, the analysis of catastrophic breakdowns of high-hazard enterprises (e.g., Three Mile Island, Bhopal, Cernobyl, *Challenger*) revealed a recurrent pattern: 70–80 % of the accidents were not caused by technological failures but instead were the result of inadequacies in problem solving, faulty decision-making, and substandard or nonexistent teamwork.

The remarkably high percentages of human factors-related mishaps are not surprising, considering that people design, build, operate, maintain, organize, and manage these systems. For this reason, human factors sciences address critical issues such as

- *Physical characteristics* (e.g., the negative impact of noise on concentration)
- *Cognitive characteristics* (e.g., perception, attention, information processing)
- *Social/behavioral characteristics* (e.g., in the context of leadership and group process)
- *Engineering and design* (e.g., equipment, physical work environment, task design, work processes, and organizational structures)

The central theme of human factors sciences is that individuals are an integral part of healthcare systems and that their abilities and limitations must be accounted for when optimizing the overall system's performance.

Another central tenet is that human error, in contrast to prevailing assumptions, is not the same as negligence, sloppiness, incompetence, or lack of motivation on the part of the healthcare provider. On the contrary, serious errors are often committed by highly motivated and experienced people (Amalberti and Mosneron-Dupin 1997). Most of the time, human error is the result of normal cognitive processes interacting with systemic factors.

Despite the results from industrial accident investigations, the healthcare community has been slow to participate in discussions of human factors-related errors. Public scrutiny of medical errors was avoided for the sake of reducing exposure to litigation. Only in the past two decades has the medical community begun to find ways to take a broader and more exacting look at medical error. As a result of the increasing openness, the 70–80 % contribution of human error as trigger for incidents and accidents has been confirmed for the medical high-stakes environment (e.g., Cooper et al. 1978; Hollnagel 1993; Reason 1997; Williamson et al. 1993; Wright et al. 1991).

The assessment that the interaction between normal cognitive processes and systemic factors are responsible for critical situations is also true for the dynamics of accident causation in the ICU case study presented earlier in this chapter: A multitude of organizational factors (e.g., human resource allocation, lack of supervision, staff qualification; Chaps. 14 and 15) were hidden as latent failures within the system for a considerable time until they combined with other factors and local triggering events (Chap. 3). The unforeseen combination of factors opened a window of accident opportunity. All those latent factors then needed only a moment of inattention by a healthcare professional to trigger the accident.

In order to fully understand human error and its implications for effectiveness and safety in complex systems, an understanding of the basic principles of human cognition and its effect on individual and team behaviors is indispensable. The same principles apply to management and organizational levels, and on an even larger scale, to the political and legal framework of the healthcare system (Fig. 1.2).

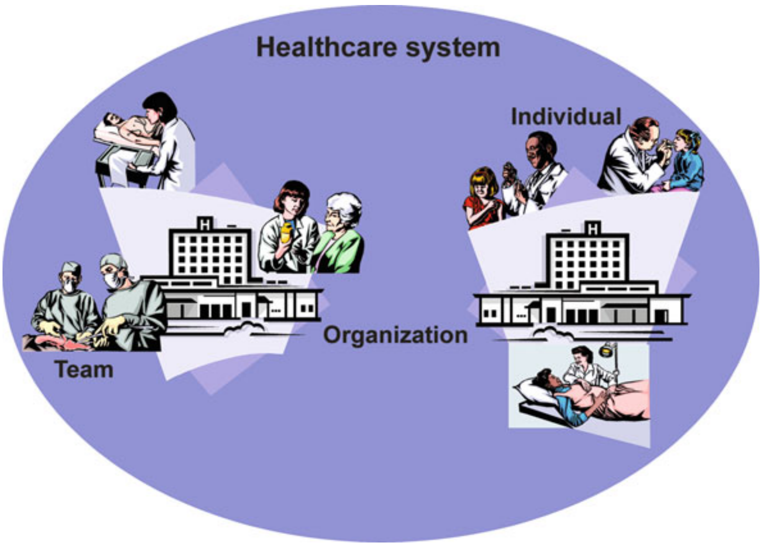

Fig. 1.2 The different levels of patient care that human factors research addresses

1.3.1 The Individual

Although human error can manifest in various ways, there are nevertheless only a few cognitive principles that contribute to these failures. These principles can be identified on the level of perception, information management, and decision-making, but we also must consider emotion and motivation. Some examples that are further explained in Chaps. 4, 5, 6, 7, 8, 9, and 10 are as follows:

- Behavior always follows the "psycho-logic" of action regulation (Chap. 4). There is no such thing as a "purely rational" action.
- Humans do not perceive reality. Instead, humans "construct" their worldview.
- Thinking and reasoning can be related to two distinctively separate cognitive systems developed through evolution ("dual-process account of reasoning"; Chap. 6). One system processes information unconsciously and is associative, effortless, and rapid ("System 1"), whereas the other process is rule based, analytic, controlled, demanding of cognitive capacity, and slow ("System 2").
- Heuristics and cognitive bias lead to a rapid and unconscious termination of the decision-making process. Once the decision is made, the result is not usually cross-checked by conscious thought.
- Humans tend to adjust information to fit their preferred or usual mental model instead of challenging their current point of view. Data is consciously and unconsciously selected and distorted to fit present assumptions.
- Humans try to defend their feeling of competence at nearly any cost. More important than the solution of a problem, as vital as it may be for the patient, may be the necessity of feeling that the situation or a relevant aspect of it is under control.
- Problem solving and decision-making are impaired by many factors.

In the case study, the physician's perceptual error – he did not notice the wrong name on the blood packs – is obvious. Errors in information processing, attentional deficits, and failure in teamwork are not easily observable (Chap. 4).

Besides the aforementioned principles, which are part of the normal human cognitive fabric, we can identify other human factors that cannot be altered by means of learning interventions but which nevertheless contribute to incidents and accidents. These unchangeable factors have to be taken into account, and workplace layout as well as social and technical elements of the system have to be designed to support employees in their daily tasks.

1.3.2 The Team

Compared with an individual, teams represent a larger pool of cognitive resources and can contribute a substantial amount of information, situational models, and proposed courses of action. In addition, all team members can shoulder workload. The physician in the case study lacked this kind of support.

The presence of others, however, can sometimes degrade performance of an individual team member. If basic principles of a successful team process are neglected, or if teams are under stress, internal team dynamics can develop that lead to lower performance (Chaps. 11, 12, and 13). In such a case, the following occurs:

- Team members tend to conform their opinion to the majority in the team.
- Legitimate concerns are not articulated, and criticism is withheld due to perceived hierarchy, obsessive deference to authority, or when a team member is afraid to appear wrong.
- Misunderstanding may result from the use of ambiguous terminology.
- Groups tend to centralize and speed information flow and decision-making when external pressure arises.

In the case study, leadership and communication were flawed. Moreover, the team was not able to share workload well because not enough staff were available. These causation factors show how dependent team performance is on organizational factors.

1.3.3 The Organization

Healthcare delivery is one of the largest and most complex systems in Western culture. The system is composed of subsystems (e.g., prehospital emergency medical service, hospitals, outpatient clinics, manufacturers) with each having a distinct culture and differing financial, technical, and human resources. A common paradox within healthcare organizational goals is to deliver safe patient care and medical excellence versus economy and cost reduction.

In the case study, examples of organizational factors influencing the transfusion error include staffing of the ICU and blood bank as well as the hierarchical culture that prevented the nurse from challenging perceived unsafe decisions.

Organizations can influence the cost and quality of healthcare by influencing the following variables (Chaps. 14 and 15):

- Structure and processes
- Equipment and technologies
- Human resource management
- Teamwork and leadership
- Communication
- Organizational culture

1.3.4 The Healthcare System

Healthcare organizations operate within a political and legal framework that limits the scope for organizing patient care. The influence of these factors is more difficult to trace than individual or organizational factors, but the data presented in the following section shows their large-scale importance. Some of the factors beyond the influence of individual healthcare organizations are:

- The increasing economic pressure on high costs within healthcare
- The funding of healthcare systems (e.g., general taxation, social health insurance, voluntary or private health insurance)
- Work time regulations
- Regulations enacted by governments
- Professional development and the cost associated with training healthcare providers

1.4 Errors in Acute Patient Care

In the mid-1980s, several interdisciplinary research groups started to investigate the issue of human error in medical high-stakes environments. Because of concern about rising costs of litigation and because anesthetists understood that their task characteristics have much in common with those of more widely studied groups in industrial high-risk settings (e.g., pilots, process control), they were the first to initiate collaborations with human factors specialists (e.g., Cooper et al. 1978; Currie 1989).

The past decade has witnessed an increased awareness of the link between normal human decision behavior with suboptimal care and adverse events, which in retrospect are often termed "human error." As clinical decision-making is the most important characteristic of a healthcare provider in an acute care setting and as some kind of decision-making inevitably precedes deliberate action, emergency physicians and anesthesiologists have taken great interest in understanding cognitive and affective dispositions on the quality of decision-making (e.g., Croskerry 2003, 2008; Stiegler and Tung 2013). Contrary to the tacit assumption that the skills associated with decision-making are acquired during postgraduate training and as a natural byproduct of daily clinical work, evidence seems to underscore the fact that the diagnostic process is systematically influenced by heuristics and biases for novices and experienced clinicians alike (Kahneman 2003).

Because the characteristics of the high-stakes medical work environment challenge human problem solving, decision-making, and teamwork considerably (Chap. 2), it is natural to expect the likelihood for diagnostic errors and active failures in acute patient care (e.g., the OR, ICU, and the emergency dept) to be higher than the error rate in routine task environments (e.g., on the ward).

A large body of scientific work is emerging, but a comprehensive overview on errors in acute patient care is not well established. On one hand, too many issues surrounding the identification of errors and adverse events are still unresolved. For example, we do not know the best form of data collection and reporting. To exhaustively track errors, it is not clear what methods are best or are available with our political and legal environment, e.g., retrospective chart reviews, mandatory reportings, solicited voluntary reportings, surveillance systems, or a direct observation approach (Handler et al. 2000)? Thus, the available data comes from a very heterogeneous and idiosyncratic picture. Given the differing methodological approaches to understanding errors, it is impossible to draw completely accurate conclusions about the "real" magnitude of the problem.

It is worth noting that human behavior is often studied using social and behavioral research paradigms. While behavioral research shares a rigorous process and seeks to show causation in its research design, this is often impossible because real-life settings (such as one might need to use to determine types and frequencies of errors) do not allow for enough control to make causation statements. Thus, the social and behavioral scientist depends on an accumulation of evidence shown through a number of studies to be able to identify a phenomenon. In other words, the behavioral scientist often has to rely on a "preponderance of evidence" in order to understand and name a conclusion.

It is with these limitations that we present the following data; neither do they claim completeness nor do they provide an entirely adequate picture of the problem. What we can do is to give the reader an idea of the nature and scale of errors in acute care medicine. What all the publications have in common is that they do not allow for any definitive conclusion as to whether the frequency of errors increases when healthcare providers have to manage critical situations as compared with routine procedures.

1.4.1 Errors in the Prehospital Emergency Medical Service

Prehospital Emergency Medical Service (EMS) is characterized by constantly changing environments, uncertainty, time pressure, and performance in ad hoc teams. Literature on the nature of adverse events in EMS is relatively scant and tends to be focused on the *appropriateness of on-scene performance* and on errors related to skill performance issues. Authors have reported that the majority of events relate predominantly to errors in clinical judgment: the *unreliability of the primary diagnosis* as compared with the discharge diagnosis, as well as the *paramedics' lack of sound ability to determine medical necessity of ambulance transport*.

Skill performance issues included failed out-of-hospital endotracheal intubations (Wang et al. 2009); drug-related errors such as unfamiliarity with drugs due to infrequent use of the medication, dosage calculation errors, or incorrect dosage given; and nonadherence to guidelines or standardized treatment protocols.

Severe diagnostic errors included unrecognized life-threatening conditions, underestimation of the severity of injury, and an on-site diagnosis different from the discharge diagnosis. The majority of data seems to confirm the unreliability of prehospital diagnoses for adult patients and variances from national prehospital medical care strategies (e.g., physician based: Arntz et al. 1996; EMS/paramedic system: Buduhan and McRitchie 2000; Enderson et al. 1990; Esposito et al. 1999; overview in Bigham et al. 2012). For the treatment of the pediatric population, however, some need for further improvement and training of healthcare providers seems to remain (e.g., Esposito et al. 1999; Peery et al. 1999). Current data analyses question the practice of paramedics' determining whether patients require ambulance transport or not (Rittenberger et al. 2005; Brown et al. 2009).

Table 1.1 Incidence of diagnostic and therapeutic errors in prehospital emergency care

Incidence of error	References
22.7 % of out-of-hospital endotracheal intubations fail	Wang et al. (2009)
Incidence of hypoxia (SpO_2 < 90 %) and hypotension (SBP <90 mmHg) during on-site rapid sequence induction is 18.3 % and 13 % of patients, respectively	Newton et al. (2008)
Self-reported incidence of medication administration errors in 9.1 % of patients	Vilke et al. (2007)
Medical team's scene diagnostic accuracy of spinal injury was 31 %	Flabouris (2001)
8–24 % of all injuries in adult trauma patients are missed	Buduhan and McRitchie (2000), Linn et al. (1997)
Overlooked injuries in the prehospital setting comprised predominantly injuries to the abdomen (17 %), the pelvis (15 %), and the chest (12 %)	Helm et al. (2013)
Pediatric medication dosing errors by emergency medical services (EMS) paramedics occurred in 34.7 % of drug administrations	Hoyle et al. (2012)
9 % of trauma deaths were deemed preventable and 16 % of pediatric trauma patients received inappropriate care	Peery et al. (1999)
Only 36 % of the patients who met criteria for anaphylaxis had epinephrine administered by emergency medical services (EMS)	Tiyyagura et al. (2014)
The incidence of missed injuries in pediatric trauma is 20 %	Esposito et al. (1999)
Severe errors of assessment by the prehospital emergency physician ("Notarzt") occurred in 3 % of cases	Arntz et al. (1996)
EMS on-scene evaluation misdiagnosed 28 % of stroke/TIA patients	Kothari et al. (1995)

Adverse events and near misses appear to be common among EMS providers but, as in other healthcare domains, the culture discourages sharing this information. Confidential interviews revealed that many EMTs felt that substantial departures from existing protocols were common reasons for the occurrence of errors, as well as lack of standardization across EMS units and healthcare facilities. Incompatibilities between equipment were also cited as likely sources of adverse events (Fairbanks et al. 2008).

The question of whether or not emergency medical services care carries an inherently higher risk for committing an error then the provision of patient care in familiar working situations (i.e., in-hospital) has still to be answered. An overview of errors in the EMS is given in Table 1.1.

1.4.2 Errors in the Emergency Department

The emergency department (ED) presents a unique combination of widely divergent patient characteristics, a broad range of illness severity, and variation in practice settings and protocols that distinguish it from "classical" medical disciplines in other acute medical care specialties (Cosby and Croskerry 2009). These characteristics increase the potential for error or patient harm.

First, many *patients* arrive at the ED rather unprepared as they have had an unexpected encounter with trauma or acute illness: ED patients usually do not carry a concise summary of medical problems or a list with current medication with them, nor does the emergency physician necessarily have access to medical records or to referring physicians.

As the illness is seen only through a small window of focus and time, nurses and physicians often rely mainly on communication with the patient and employ quick diagnostic and disposition procedures. Communication itself may be difficult as patients may be fearful, uncooperative, unconscious, or without personal identification. Many patients who seek care in an ED are at increased risk of adverse events because of the serious nature of their illness: In the face of possible acute medical decompensation, there is a lower margin for error and patients who have reached a point of diminished reserves are less likely to tolerate missteps in their management. Despite this need for carefulness, time constraints, emergent problems, and high acuity force clinicians to make decisions with incomplete information and uncertainty, and they must work in a team environment that depends on others to perform as expected.

One of emergency medicine's distinctive features is that there are no limits to the potential number of patients or the types of illness facing the emergency physician at any one time. The large number of possible differential diagnoses contributes to the element of diagnostic uncertainty and may be responsible for the high rate of errors attributed to diagnostic errors (Thomas et al. 2000). In few other workplace settings, and in no other areas of medicine, task complexity, time constraints, and decision density are as high, and the pace of work is as unremitting and uncertain as in an ED. The necessity to handle multiple demands, to constantly reassess allocation of resources, and to prioritize attention to competing demands facilitates errors in care delivery. In addition, constant interruptions (Chisholm et al. 2000), a quick turnaround of patients with insufficient time to be thorough, and inadequate supervision (Hendrie et al. 2007) aggravate the problem.

Because many EDs around the world are not subspecialized, emergency healthcare providers are confronted with nearly any type of injury or disease. This complexity causes the pediatric population to be at higher risk than adults: Staff without specialized pediatric training and with little experience are expected to provide adequate patient care to infants and children, often without the supplies necessary for handling pediatric emergencies (IOM 2006). As EDs in many large cities are overcrowded and operate at or near full capacity, even a multiple-car highway crash can create havoc in an ED. A major disaster with many casualties would be something that many hospitals do not have adequate capacity to handle.

Because of the complex nature of task performance and the complex decision-making that has to be made in a time-compressed environment, teamwork plays an important role in detecting and preventing adverse events. For example, active failures in trauma patient care include problems arising from the interaction of the trauma team with the patient or other team members (Schaefer et al. 1994). Table 1.2 shows some of the typical teamwork-associated problems and errors encountered in the ED.

Table 1.2 Incidence of diagnostic and therapeutic errors in the emergency department (ED)

Incidence of errors	References
The incidence rates of adverse events and near misses are 4.1 % and 5.4 %, respectively. 37 % of the adverse events were judged to be preventable	Camargo et al. 2012
8.6 % of patients experienced a preventable medical error with a twofold higher incidence during higher levels of ED crowding	Epstein et al. (2012)
Literature review shows 1.3–39 % incidence of missed injuries and delayed diagnoses. 15–22.3 % of patients with missed injuries have clinically significant missed injuries	Pfeifer and Pape 2008
3.5 errors per patients with spinal/cerebral injury are committed; errors contribute to neurological disability	McDermott et al. (2004)
2–3 % of patients with acute myocardial infarction or unstable angina are not hospitalized after presenting at the ED	Pope et al. (2000), McCarthy et al. (1993)
3 % of all adverse events occur in the ED; a high rate is associated with negligence in diagnostics	Kohn et al. (1999)
Per adverse event, an average of 8.8 teamwork failures occur	Risser et al. (1999)
27 % of patients with acute myocardial infarction were missed in the ED due to absence of chest pain or lack of ST elevation in the ECG	Chan et al. (1998)
23 % of all airway management cases show performance deficiencies	Mackenzie et al. (1996)
Diagnostic errors occur in 25 % of all admitted patients	O'Connor et al. (1995)
5.9 % of all trauma patient deaths were considered preventable. The most common single error was failure to appropriately evaluate the abdomen	Davis et al. (1992)
In 9 % of patients, injuries are missed during the initial work-up	Enderson et al. (1990)

1.4.3 Errors in the Intensive Care Unit

Critically ill patients require high-intensity care and may be at especially high risk of iatrogenic injury. The underlying comorbidities, acute organ dysfunctions, and the complexity of care processes make this specialty vulnerable and prone to error.

Many reports confirm the notion that adverse events and serious errors involving critically ill patients are common and often life threatening (e.g., Ahmed et al. 2013; Rothschild et al. 2005). Root causes for errors in the ICU are found in the serious nature of the underlying disease as well as in structural, technical, and organizational deficiencies of the unit. Many studies ascribe adverse events to the chaotic arrangement of tubes and lines, limited physical access to the patient, poor lighting, ambient noise, frequent interruptions, insufficiently labeled drugs, medication errors at the administration stage (Valentin et al. 2009), and to problems with medical devices (e.g., Donchin and Seagull 2002; Sanghera et al. 2007). In addition, workload – as measured by the patient to nurse ratio, the occupancy rate, and the ratio of beds per nurse – and poor coordination and communication between physicians and nurses have been shown to be responsible for a multitude of adverse drug events and treatment errors: The case report is one example of the complexity within the intensive care unit. Recently, a review of critical incident studies in the ICU identified a series of contributory factors associated with the lack of specific teamwork skills (Reader et al. 2006). Table 1.3 illustrates the magnitude of the problem of errors in the ICU.

Table 1.3 Incidence of diagnostic and therapeutic errors in the intensive care unit

Incidence of errors	References
In 26.8 % of ICU patients, one or more errors occurred, the most common being insulin administration error. The experience of more than two adverse events was associated with a threefold increase in the risk of ICU death	Garrouste-Orgeas et al. (2010)
1 % of critically ill patients experience permanent harm or die because of medication errors	Valentin et al. (2009)
15 % of ICU patients suffer from adverse drug events (ADE) and medication errors. The most frequent preventable ADE occurred in the prescribing (71.1 %)	Benkirane et al. (2009)
During the first 7 days of hospitalization, 55 % of all high-risk newborn infants have one or more errors. The most frequent error was associated with medication use (84.2 %)	Lerner et al. (2008)
36.1 % of emergency neonatal interhospital transfers had one or more adverse events. 67 % were perceived as being due to avoidable human errors	Lim and Ratnavel (2008)
Adverse drug events occur in 3.6 events per 100 orders; 81 % are considered clinically important	Buckley et al. (2007)
One error for every five doses of medication administered (20 %)	Kopp et al. (2006)
20.2 % of critically ill patients suffer from adverse events	Rothschild et al. (2005)
15 % of patients suffer consequences from an error; 92 % are judged as avoidable	Graf et al. (2005)
13–51 % of all critical incidents pose a major threat for patient safety	Beckmann et al. (2003), Donchin et al. (1995)
One of 10 new patients in ICU is transferred to ICU because of a previous treatment error	Darchy et al. (1999)
The rate of preventable adverse drug events in ICUs is nearly twice the rate of non-ICUs	Buckley et al. (1997), Beckmann et al. (1996), Wright et al. (1991), Giraud et al. (1993)
63–83 % of all critical incidents can be attributed to human error	Cullen et al. (1997)
31 % of all ICU patients suffer iatrogenic complications during their stay in the ICU	Donchin et al. (1995)
For the ICU as a whole, about 1.7 errors per patient per day occur. Twice a day a severe or potentially detrimental error is committed	Donchin et al. (1995)
The majority of adverse events were errors in medication (15–60 %)	Donchin et al. (1995), Giraud et al. (1993)
One of every three errors in ICU is caused by communication problems	Giraud et al. (1993)

1.4.4 Errors in Anesthesia and Postoperative Patient Care

The induction and maintenance of anesthesia, without having any therapeutic benefit in itself, has always been a potentially harmful undertaking. The use of highly potent drugs and the associated loss of consciousness and vital functions bears the risk of harming patients. Beginning in the mid-1950s, anesthetists were the first in healthcare to begin to systematically address the issue of the incidence and nature of perioperative adverse events (Beecher and Todd 1954). The increased insight into the contribution of anesthesia to perioperative morbidity and mortality has led to considerable improvement in the safety and quality of anesthetic patient care. As a consequence of its leading role in the prevention and detection of medical error and in pioneering a patient safety movement, the IOM report referred to anesthesiology as the model for addressing patient safety (Kohn et al. 1999). As a result of major improvements in technology, equipment failure has become a rare event. Nowadays, adverse drug events, circulatory events, problems with airway management, and pulmonary complications are among the most frequent critical situations. Patients in the postanesthesia care unit (PACU) can experience an adverse event from a residual sedative or anesthetic effect, persistent muscle-relaxant effect, inappropriate fluid management, allergic reaction, and upper airway obstruction. Human error plays a significant role in these critical situations and accidents (Table 1.4). Human

Table 1.4 Incidence of diagnostic and therapeutic errors in anesthesia and postoperative patient care

Incidence of errors	References
In a sample of voluntarily reported PACU medication errors, harmful errors were present in 5.8 % of the sample, which included two patient deaths	Hicks et al. (2007)
Retrospective analysis reveals a 0.01 % incidence of medication errors without serious adverse events. In 42 %, syringe swap was the leading cause	Sakaguchi et al. 2008
2.1 % of incidents reported to a National Patient Safety Agency resulted in severe harm or death	Catchpole et al. (2008)
Critical incidents occur in 2.5 % of all pediatric anesthesia cases	Marcus (2006)
The most common presenting problems are related to respiratory/airway issues (43 %), cardiovascular problems (24 %), and drug errors (11 %). Contributing factors included error of judgment (18 %), communication failure (14 %), and inadequate preoperative preparation (7 %)	Kluger and Bullock (2002)
29 % of all critical incidents lead to a major physiological disturbance and require management in intensive care unit	Kluger and Bullock (2002)
A drug administration error occurs at a rate of 1 in 133 anesthetics. Incorrect doses (20 %) and substitutions (20 %) with i.v. boluses of other drugs are the most common errors	Webster et al. (2001)
4 % of all incidents are caused by the patient's unpredictable reactions; 69–82 % of all critical incidents could have been avoided	Arbous et al. (2001)
0.2 % of all patients in the PACU need emergency reintubation; 70 % are directly related to anesthesia management	Mathew et al. (1990)
31–82 % of all incidents are caused by human error, 9–21 % by technical failure	Cooper et al. (1978), Kumar et al. (1988), Currie (1989), Chopra et al. (1992), Webb et al. (1993), Buckley et al. (1997), Arbous et al. (2001), Bracco et al. (2001)

error in anesthesia occurs on the individual level (e.g., judgment) as well as on the interpersonal level (e.g., communication failure) and the organizational level (e.g., standards for preoperative management).

1.5 The Human Factors: Skills for Acute Patient Care

Poor outcomes do occur, but what is perhaps surprising given the complex circumstances of critical situations is that good outcomes happen as often as they do. Human factors are behind faulty systems, processes, and conditions as well as active unintentional failures of healthcare providers. Yet it should not be overlooked that human factors, the way people think and feel and interact with each other and their environment, are an essential resource for safe patient care: Like Janus, the two-faced god of Roman mythology looking in opposite directions, human factors, too, provides both the potential to trigger and the skills to master a critical situation (Fig. 1.3). As a result, human factors should never be equated with "risk factors." Each time mindful healthcare professionals detect, diagnose, and correct a critical situation or an error before it has an opportunity to unfold, it is human factors that prevent patient harm (Fig. 1.4). Correct performance and systemic errors are two sides of the same coin, or, perhaps more aptly, they are two sides of the same cognitive balance sheet (Reason 1990).

There is a growing interest in human factors skills as being crucial for delivering safe and high-quality patient care but which are not directly related to traditional clinical expertise. A growing body of research has shown how critical these skills have become. Safe and successful acute care clinicians must have good *interpersonal skills*, such as communication, teamwork, and leadership, and good *cognitive skills*, such as situation awareness, planning, decision-making, and task management. The

Fig. 1.3 The human factors and the two faces of Janus. Similar to the god of Roman mythology, the human factors have two opposite aspects: They combine to trigger critical situations and at the same time provide the skills to master them

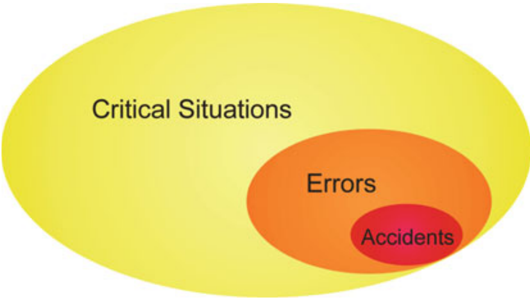

Fig. 1.4 Human factors prevent adverse events. Because healthcare professionals detect critical situations and errors before these can cause accidents, the human factors provide a vital resource for patient safety

aviation industry was among the first to recognize that technical proficiency in pilots was not enough to guarantee safe flight operations and then to identify the most relevant human factors, communication, and teamwork skills (Wiener et al. 1993). Training programs were introduced that taught and reinforced these skills as a set of countermeasures against error. Because the workload profile of anesthetists shows similarities with pilots (i.e., high intensity at task initiation and completion, monitoring for most of the time, and rapid response to critical events), this approach to incorporating human factors, communication, and teamwork skills was adopted for medical care in a high-stakes environment (e.g., Gaba et al. 1994). Because there is increasing evidence that these skills may not extrapolate directly from aviation to the clinical high-stakes environment, several research groups have begun to identify and validate the specific skills important for safety in different high-stakes medical domains (Aggarwal et al. 2004; Flin et al. 2008; Flin and Maran 2004; Fletcher et al. 2003; Reader et al. 2006; Taylor-Adams et al. 2008; Yule et al. 2006).

The resident from the case report, too, experienced both sides of human factors: After having triggered the transfusion reaction, the management of the critical situation was up to him as well. As the critical situation unfolded, he had to manage the emergency by effectively utilizing and coordinating all available resources and team members. In addition to his clinical acumen, he suddenly needed a broad variety of additional skills:

- Rapidly detect and diagnose the nature of the emergency situation.
- Resist the emotional strain caused by the awareness that he himself had triggered the adverse event.
- Call for help.
- Make good decisions under time pressure.
- Know his environment and the resources available.
- Set priorities.
- Lead a team.
- Reassess the situation and dynamically make changes in his plan.

The case study demonstrates another important lesson: Despite maximum effort, the patient suffered irretrievable harm from the adverse event. Even when clinicians have a broad range of human factors and teamwork skills, and although the best technology and medicines are available, even the best emergency care can sometimes still fail to save a patient's life.

One way to understand the relationship between clinical and human factors and teamwork skills is that of a conversation: Clinical skills provide the context-specific vocabulary; human factors and teamwork skills are the grammar that enables a meaningful interaction. The following chapters should be regarded as a kind of "grammar" to help healthcare providers of every profession and specialty engage in a constructive conversation with each other and with the critical situation. The most frequent "grammar errors" will demonstrate possible pitfalls and will hopefully sharpen the providers' focus. The conversation, however, is made difficult by certain characteristics that distinguish emergency situations from any other situation in healthcare. We explore these characteristics in this book.

1.6 "The Human Factors": In a Nutshell

- Human factors are physical, psychological, cognitive, and social properties of an individual that influence interaction with the environment and with social and technological systems.
- Some human factors (e.g., information processing, decision-making, communication, task execution) are amenable to training and learning interventions. Other human properties (e.g., basic mechanisms of perception, regulation of attention, fatigue, somatic stress response, personality, etc.) are unchangeable and have to be addressed by systemic interventions such as workplace layout, system design, standard operating procedures, and employee selection.
- If the understanding of human factors is reduced to human failure, the term is only a semantic surrogate for "blaming."
- The central dogma of human factors sciences is that individuals are an integral part of healthcare systems and that their abilities and limitations must be accounted for when designing and optimizing overall system performance
- Human behavior dominates the risk to modern socio-technical systems: 70–90 % of all errors are due to human factors and teamwork failures.
- The mortality rate of preventable medical error exceeds the number of deaths attributable to severe trauma, breast cancer, and HIV.
- Available data on error in acute care medicine provides a heterogeneous picture. Effective generalizations are limited by limitations on study designs outside of the laboratory and the local and unique structures of healthcare organizations and systems.
- The most frequent human errors in acute healthcare include judgment errors, communication failures, and lack of teamwork.
- Human factors provide the potential to trigger critical situations as well as the skills to master them.
- Human factors skills necessary to manage critical situations include interpersonal skills (e.g., communication, teamwork, leadership) and cognitive skills (e.g., situation awareness, planning, decision-making, task management).

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