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Trauma Team Performance

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INTRODUCTION

The role of effective teamwork in accomplishing complex tasks is accepted in many domains. Similarly, there is good evidence that the outcome in trauma care depends on effective trauma team performance. Teamwork during trauma care can be deficient in a number of ways (Table 1), and multiple deficiencies may interact to impair team success and patient outcomes. This chapter focuses on understanding, assessing, and improving trauma team performance. Resuscitation of trauma patients is a specialized domain in which critically ill patients are treated in a dedicated facility. The need to train and evaluate the performance of trauma teams has emerged as an important topic over the past decade (1,2). Institutions must establish and continuously validate their team-based trauma resuscitation procedures to assure high quality care. This iterative evaluation must include the review of secondary management, careful delineation of team structure, comprehensive team training, effective support structures, and continuous quality improvement. This chapter reviews the state-of-the-art methodology useful for the trauma team's training, evaluation, and improvement. Emphasis is placed upon essential features and newer techniques, including computer simulation and video-assisted analysis and debriefing.

Team training has a proven history in aviation and military organizations. Recently, these experiences and techniques have been utilized in medicine, including trauma resuscitation and critical care management. Studies of aviation teams revealed failures of coordination, communication, workload management, loss of group situational awareness, and inefficient resource utilization (3–6). Thorough investigation of adverse events occuring during trauma resuscitation revealed similarities to failures discovered in aviation-related mishaps, both tending to be multifactorial and complex (7–11).

Much of health care is performed by interdisciplinary teams: individuals with diverse specialized skills focused upon a common task in a defined period of time and space, who must respond flexibly to contingencies and share responsibility for outcomes. This is particularly true of trauma care. Traditional specialty-centric clinical education programs are deficient in team training, because most assume that individuals acquire adequate competencies in teamwork passively without any formal training. Performance incentives in health care are targeted at individuals and not at teams, as are job and other selection and assessment processes (12). With a few exceptions, risk management and liability data, morbidity and mortality conferences, and even quality improvement projects have not systematically addressed systems factors or teamwork issues. Substantial evidence suggests that teams routinely outperform individuals and are required to succeed in today's complex work arenas where information and resources are widely distributed, technology is becoming more complicated, and workload is increasing (13,14). Nevertheless, our understanding of how medical teams coordinate in real-life situations, especially during time-constrained and crisis situations, remains incomplete.

TEAM DEFINITION AND RELEVANCE IN TRAUMA

One must distinguish between a group of individuals sharing a common task (e.g., a jury) and a team (e.g., a marching band, football team). A team is "a small number of people with complementary skills who are committed to a common purpose, performance goals, and approach for which they hold themselves mutually accountable" (14). Weick and Roberts (15) defined medical teams as "a loosely coupled system of mutually interacting interdependent members and technology with a shared goal of patient care." Katzenbach and Smith (14) argued that any performance situation that warrants a team effort must meet three criteria: (*i*) Collective work products must be delivered in real-time by two or more people; (*ii*) Leadership roles must shift among the members; and (*iii*) Both mutual and individual accountability is necessary. They go on to assert that teams must have a specific team purpose (distinct from that of its individual members), that they have shared performance goals and a commonly agreed upon working approach, and that a team's collective work products are generally used to evaluate the team's performance (14). Others have suggested that smaller teams (5–10 members) are generally more effective than larger ones, partially due to familiarity, cross-checking, and interdependence. According to Weinger, **Effective teams possess five characteristics of success (the five Cs): commitment, common goals, competence, consistency (of performance), and communication (16).**

Team Competence

Team competence is measured across multiple dimensions that include technical, decision, and interpersonal skills.

Table 1 Problems and Pitfalls in Trauma Teamwork

Difficulties coordinating conflicting actions
Poor communication among team members
Failure of members to function as part of a team
Reluctance to question the leader or more senior team members
Failure to prioritize task demands
Conflicting occupational cultures
Failure to establish and maintain clear roles and goals
Absence of experienced team members
Inadequate number of dedicated trauma team members
Failure to establish and maintain consistent supportive organizational infrastructure
Leaders without the "right stuff"

Source: From Ref. 19.

The diversity of team members with complementary skills is a hallmark of many effective teams, particularly when the team is required to adapt to complex and changing circumstances. Acute care medical teams, including trauma teams, typically excel at the first two Cs (commitment and common goal) and explicitly strive for competence, but may be much less successful in their consistency of performance (i.e., ability to sustain best practice at all times). The effectiveness of communication between team members requires persistent efforts from all (17–19). The best trauma teams maintain an intuitive understanding of the evolving processes of events (see discussion in the latter part of this chapter of team situation awareness); they appreciate and expect the unknown; and there is a high level of honesty, respect, and trust between team members (20).

Team Member Conflict Resolution

Conflicts among members are inevitable in every team, and many experts believe that conflict, and its successful resolution, is essential to attaining maximal team performance (13,14). The natural tendency, especially among health-care professionals, is to avoid or gloss-over conflicts. However, doing so can sew the seeds of impaired team performance when the next challenge arises. There are four primary conflicts inherent in teamwork (21): First, tensions occur between individuals and the team as a whole in terms of goals, agenda, and the need to establish an identity (22). Second, to attain optimal team performance, one needs to foster both support and confrontation among team members. If team members are unwilling or unable to challenge each other's decisions respectfully, then there is a real risk of poor team outcomes. A team devoid of conflict leads to "group think" (23) and the acceptance of suboptimal team decisions. Third, daily team activities must balance moment-to-moment performance against the need to continually enhance team learning and individual member development. Finally, the team leader must find a balance between managerial authority, on the one hand, and individual team member autonomy and independence, on the other.

ORGANIZATION OF THE MODERN TRAUMA TEAM

The trauma resuscitation and management system is one of the most demanding in healthcare, incorporating very ill patients, a diverse range of care providers, management decisions based upon clinical evaluation, and complex imaging modalities, all occurring under severe time constraints. The trauma team, which assembles rapidly at unpredictable times, must be prepared for sudden, unique, and chaotic situations involving one or more patients presenting with initially unknown injuries.

The successful management of trauma requires effectively coordinated prehospital care and information management, followed by transfer to a well-organized and well-prepared trauma resuscitation suite (TRS) or operating room (OR), (see Volume 1, Chapter 5). During the trauma resuscitation, the team typically adheres to hospital protocols based on the Advanced Trauma Life Support® (ATLS®) management protocols. In most modern trauma teams, multiple team members have dedicated roles and simultaneously perform separate patient-care tasks (24,25). While more efficient, and leading to more rapid resuscitation, this kind of horizontal structure requires much better team coordination, leadership, and organization (24,26,27). Studies in advanced trauma units have highlighted the difficulties of attaining effective teamwork, noting team breakdowns under dynamic conditions (28).

Trauma teams typically consist of 5 to 10 individuals from several clinical disciplines. Traumatologists, usually general surgeons, anesthesiologists, or emergency medicine physicians serve as team leaders, first responders, or other team members (26). Airway management is commonly performed by anesthesiologists or emergency physicians, with support from a respiratory therapist. Specialized trauma nurses as well as pharmacists, radiological technicians, and other ancillary personnel (e.g., laboratory technician, orderlies, etc.) may round out the team together with residents and medical students. Predefined roles (specific task allocation) and even the physical location (trauma resuscitation room or suite) around the trauma patient are commonly proscribed (Volume 1, Chapter 5).

More generally, medical teams, consisting of a multidisciplinary group of members, might form for a single clinical event (e.g., a specific surgical procedure) or be together for a short defined period (typically a month or so). Not infrequently, some team members are consistent and well defined (e.g., the emergency department team) while others join on an ad hoc basis (e.g., respiratory therapists, pharmacists, anesthesiologists). Thus, a specific group of individuals may only infrequently have the opportunity to work together. This can be true of trauma teams as well, especially given the high workload of trauma care. Further, trauma care is often provided in academic medical centers where the trainees, who comprise much of the trauma team, rotate on and off the service on a regular basis. Research in aviation shows that such "rostered teams" are less effective than more stable "fixed" teams (29). In addition, Simon et al. (30) have shown that rostered teams are less likely than fixed teams to call each other on safety infractions.

The Trauma Team Leader

The resuscitation team leader's functions may include the performance of specific tasks, such as conducting the primary and secondary surveys (Table 2). However, given sufficient personnel, the team leader must assume, as quickly as possible, a supervisory role, prioritizing and delegating tasks and reviewing and overseeing the team's (and patient's) progress throughout the resuscitation (26,31). Studies suggest that trauma teams are less effective when the team leader spends significant time performing procedures rather than delegating them to other team members (27).

Table 2 The Trauma Team Leader's Responsibilities

Know the job (e.g., know ATLS® guidelines cold)
Communicate clearly and effectively
Enhance the team's communication
Foster teamwork attitudes through tangible behaviors
Keep the goals and approach relevant and focused
Enhance the team's knowledge and shared expectations
Build commitment, confidence, and trust
Remain positive and supportive, especially under adverse conditions
Acknowledge and manage your own limitations and those of the team
Strengthen the skills of each team member and of the team as a whole across all performance dimensions: technical, functional, problem solving, decision making, interpersonal, and teamwork
Manage relationships with outsiders and remove obstacles
Create opportunities for others to grow into leadership roles
Lead by example
Reward team performance and discourage individualism that detracts from team performance
Provide constructive feedback and opportunities for practice

Abbreviation: ATLS®, Advanced Trauma Life Support®.
Source: From Ref. 27.

However, the team leader should have recognized expertise in treating trauma patients, and be willing and able to intercede when other team members are not performing up to acceptable standards (also see a list of duties provided in Volume 1, Chapter 5).

The team leader is also responsible for formulating (or at least approving) the definitive treatment plan. Thus, the team leader must quickly assimilate a large amount of disparate information from other team members with personal observations. This leads to an overall assessment, which includes decisions about therapeutic and diagnostic interventions. The leader also communicates with team members, coordinates consultations, makes triage decisions, and ensures that all team members are aware of the evolving situation.

Although skill and experience are valuable for every member of the team, it is particularly critical for the trauma team leader. **Studies show that the presence of a single identified trauma resuscitation team leader leads to a better secondary survey, ATLS guideline adherence, and team coordination (32).** Better team coordination is achieved when the definitive treatment plan is facilitated by a team leader who is an experienced traumatologist. The personality of the team leader has a large impact on team performance. Work by Chidester, et al. (33) led to a broad classification of three personality types of team leaders: "right stuff," "wrong stuff," and "no stuff" (Table 3). Teams led by individuals with the "right stuff" performed better than those led by leaders with "no" or "wrong stuff." In addition, Bowles et al. showed that air crews led by "right stuff" captains performed well with less stress than those led by other personality types (3). Successful team leaders know and emphasize that the goal is team performance rather than individual achievement. Team-oriented behaviors, which do not come naturally in a culture that rewards individualism above teamwork, can be learned and practiced.

Other Members of the Trauma Team

Successful resuscitation and recovery from trauma requires an immediately available multidisciplinary team capable of

Table 3 Team Leader Personality Types

Right stuff	Wrong stuff	No stuff
Active	Authoritarian	Unassertive
Self-confident	Arrogant	Low self-confidence
Interpersonal warmth/empathy	Limited warmth/empathy	Moderate warmth/empathy
Competitive	Impatience and irritability	Noncompetitive
Prefers challenging tasks	Prefers challenging tasks	Low desire for challenge
Strives for excellence	Strives for excellence	Doesn't strive for excellence

Source: From Ref. 3.

evaluating and managing life-threatening injuries. The trauma team leader works closely with these other trained experts in trauma care. All essential team members (e.g., trauma surgery, anesthesiology, surgical critical care, neurosurgery, orthopedic surgery, interventional radiology, and blood banking) must be available 24 hours a day, seven days a week, to provide optimum care and meet the requirements for a level-1 trauma center.

The initial focus of the trauma resuscitation is airway, breathing, circulation, and control of hemorrhage (discussed in Volume 1, Chapter 8). Although the team leader must be cognizant of each of these care goals, the definitive management of each is best delegated to other members. For example, the anesthesiologist is best trained and capable of managing the airway and assessing breathing, and one of the surgical assistants should be employed to control hemorrhage, while other team members place intravenous lines, chest tubes, etc. Although each of the assistants could operate autonomously, the resuscitation will be most effective if each team member's activities are overseen by the team leader.

Trained professionals, with extensive experience in trauma management, will provide better care than novice clinicians. In most busy trauma centers, established professionals both model and teach students and trainees the correct approach. They must balance allowing students and trainees to gain practical experience with close supervision to assure proper patient care. Even trained experts will confront difficult circumstances at times [difficult airway, poor intravenous (IV) access, uncooperative patients, etc.]. However, proper training, rest, and environmental support will help rescuers overcome these obstacles.

HUMAN FACTORS IN THE TRAUMA ENVIRONMENT

Human factors (also called ergonomics) is the study of human interactions with tools, devices, and systems with the goal of enhancing safety, efficiency, and user satisfaction. Human factors emerged as a recognized discipline during World War II. Its use improved military system performance by addressing problems in signal detection, workspace constraints, optimal task training, cockpit design, and teamwork (34). Nearly half a century of research and hands-on experience have produced a substantial body of scientific knowledge about how people interact with each other and with technology. The knowledge and techniques of human factors have been productively applied to enhance performance in a wide range of domains, from fighter planes to the TRS and the trauma OR.

Human factors research on team decision-making in complex task environments is of relevance to trauma team performance (4,35–38). One must carefully consider the impact of the many "performance shaping factors" that can degrade human capabilities (Table 4). One must also understand how best to optimize trauma care (39–42). The environment in the field, in the air, and in the hospital greatly affects and shapes the outcomes of trauma teams. Factors that influence the team's effectiveness include the performance of individual team members, the equipment they use, the TRS and trauma OR environment (e.g., established care process and procedures), and the underlying organizational and cultural factors. For example, distracters such as information overload, noise, spectators, and physical obstacles can be a danger to both the patient and health care professionals. Although there is insufficient space in this chapter to discuss all of the performance-shaping factors of relevance to the trauma team, a few of the more pertinent factors are described in more detail in the following sections.

Table 4 Examples of Performance-Shaping Factors Affecting Trauma Care

Performance shaping factor	Example
Individual factors	Clinical knowledge, skills, and abilities
	Cognitive biases
	Risk preference
	State of health
	Fatigue (including sleep deprivation, circadian)
Task factors	Task distribution
	Task demands
	Workload
	Job burnout
	Shiftwork
Team/communication	Teamwork/team dynamics
	Interpersonal communication (clinician–clinician and clinician–patient)
	Interpersonal influence
	Groupthink
Environment of care	Noise
	Lighting
	Temperature and humidity
	Motion and vibration
	Physical constraints (e.g., crowding)
	Distractions
Equipment/tools	Device usability
	Alarms and warnings
	Automation
	Maintenance and obsolescence
	Protective gear
Organizational/cultural	Production pressure
	Culture of safety (vs. efficiency)
	Policies
	Procedures
	Documentation requirements
	Staffing
	Cross coverage
	Hierarchical structure
	Reimbursement policies
	Training programs

Source: From Refs. 39, 40, 41, 42.

Sleep Deprivation and Fatigue

Extensive literature exists on the adverse effects of sleep deprivation and fatigue on an individual clinician's performance (40,43–46). These studies and other events have led to work hour limits of clinicians in training. Most studies of recurrent partial sleep deprivation have suggested that sleeping only five to six hours a night can lead to performance impairment (47). Sleep loss most acutely degrades performance on tasks requiring vigilance, cognitive skills, verbal processing, and complex problem solving (43,46). Performance decrements begin with a lack of appreciation of the skills being degraded and accumulate with continued partial sleep deprivation. This may be seen in trauma physicians working regularly on recurring call or night shifts. In the early morning hours, after nearly 24 hours without sleep (e.g., at the end of difficult on-call shift), psychomotor performance can be impaired "to an extent equivalent to or greater than is currently acceptable for alcohol intoxication" (49). Two recent laboratory simulation studies, involving sleep-deprived surgeons, demonstrated significant impairment in surgical skill (both speed and accuracy) in a virtual reality simulation of laparoscopic surgery (48,50). Although the impact of fatigue on "team performance" has thus far been sparsely studied, the results may be expected to be similar with trade-offs between the benefits of team compensation and redundancy on the one hand and impaired team communication on the other.

The effect of an individual team member's sleep deprivation (or other performance detractors such as working when ill) on the overall trauma team's clinical performance depends on several factors, including time of day (circadian effects), clinical experience, task demands, clinical workload, and other team members' level of functioning. The current body of evidence suggests that a sleep-deprived or fatigued trauma team will make more errors, be less likely to recover from these errors, and provide lower quality care than a well-rested team. Organizational leaders must, therefore, design work schedules to provide adequate rest periods for the team members.

Stress and Job Performance

Sources of stress that affect job performance include social and physical stressors; the tasks involved, such as mental workload and pacing of activity; as well as individual characteristics such as health, fitness, and personality (51). Personal factors, such as financial concerns or a recent dispute with a spouse, can adversely impact job performance and even increase the likelihood of accidents (52). Training and experience reduce the subjective impact of the stress and workload associated with emergency situations, thus, the value of formal emergency drills, whether in aviation or medicine (53).

In an airline transport study, air crews that had the highest performance experienced less stress than did lower performing teams (3). Thus, undue stress can impair performance and impaired performance can cause undue stress. The take-home message for the trauma team is to: (*i*) identify explicitly and manage the sources of stress for the team and its members; (*ii*) actively train to reduce stress and enhance performance, especially during high tempo, high workload periods (e.g., multiple simultaneous trauma resuscitations), and (*iii*) include risk reduction and fatigue countermeasures as part of every clinical debriefing.

Environmental Factors (e.g., Noise, Clutter, Disorganization)

The environment of care contains a number of factors that influence team performance including noise, lighting, temperature, the need for protective gear, clutter, disorganization, and impaired physical access to the patient, or essential tools or equipment, or both. In the interest of brevity, only the effects of noise are discussed in detail. The noise level in acute care environments can be quite high. For example, continuous background noise in the modern OR typically ranges from 75 to 90 dB, and can increase to almost 120 dB (e.g., during high-speed gas-turbine drill use) (39). Although apparently never measured, it is reasonable to assume that sound pressures in the typical trauma unit are similar or louder than those found in surgical suites. In the trauma unit, noise can be generated by multiple conversations, mechanical ventilation, suction, overhead pages, use of medical equipment, and alarms. **High noise levels create a positive feedback situation, where noisy rooms require louder voices and higher volume alarms leading to increased noise levels, missed clinical events, and greater team dysfunction.**

High noise levels interfere with effective verbal communication. This may be important during trauma resuscitations when it is critical for team members to hear clearly other members of the team. High noise levels in trauma units can also detrimentally affect short-term memory tasks, mask task-related cues, impair auditory vigilance (for instance, the ability to detect and identify alarms), and cause distractions during critical periods (39,40). Exposure to loud noise activates the sympathetic nervous system affecting mood and performance. The resulting stress response has been suggested to interact with other performance-shaping factors resulting in impaired decision-making during critical clinical incidents (40).

Interpersonal Communication

Both verbal and nonverbal communication are critical to the success of team performance (6). Failures of team communication lead to medical errors and adverse outcomes (18). In highly complex nonmedical domains that involve teamwork (e.g., aviation crews, submarines), the team has often been together a long time and is well practiced. Effective team communications involve unspoken expectations, body language, traditions, and general assumptions about task distribution, command hierarchies, and individual emotional and behavioral components. A study found failures of adequate communication between clinical care providers in the ICU contributed to medical errors (18). In this study, more than one-third of all patient-care errors reported were associated with failures of verbal communication. These communication failures occurred not only between nurses and physicians, but also between nurses. Similarly, analysis of videotaped trauma team performance showed that highly skilled teams communicated in a variety of ways, many of which were nonverbal and implicit (54). Team coordination breakdowns were manifested by conflicting plans, inadequate support in crisis situations, failure to verbalize problems, and poor delegation of tasks.

Because trauma teams are composed of clinicians from many different disciplines (i.e., physicians, nurses, pharmacists, etc.) with their own norms, expectations, attitudes, and cultures, effective team communication must overcome these barriers. Dutton et al. (55) recently showed that regularly scheduled multidisciplinary "discharge rounds" in a trauma hospital not only facilitated communication but dramatically improved patient flow with a 36% increase in patient volume and a 15% decrease in length of stay.

Team performance can be adversely affected by dysfunctional interpersonal interactions among team members. Such "miscommunication" often stems from a lack of shared expectations, beliefs, or training (56). Thus, trauma teams can enhance their performance by spending more time together, not just during formal training, but also through joint conferences and social events. **Trauma team members must make special efforts to communicate clearly and unambiguously, especially when members of the team are new or less experienced.** Effective team communication is more difficult when some or all of the team are subjected to other stressors, such as sleep deprivation and fatigue.

KEYS TO EXPERT DECISION MAKING FOR TRAUMA

Traditional theories of decision making assume that individuals and teams use a deliberative approach in which they assess the relative risks and benefits of multiple options. However, in the 1980s, researchers began to study the way experienced people actually make complex decisions in their natural environments, or in simulations that preserve key aspects of their environments (naturalistic decision theory) (57). These studies demonstrated that, in contrast to "normative decision theory," experts make real-world decisions through a serial evaluation and application ("trying on") of options that seem appropriate to the apparent situation. Naturalistic decision theory argues that, especially under time pressure in complex task domains (e.g., trauma units), experts recognize situations, or their integral components, as typical or familiar and then respond to each specific situation with appropriate preprogrammed patterned responses. Choosing the first acceptable response that comes to them is called "recognition-primed decision making" (57,58). Thus, competent decision-makers in complex domains are very concerned about quickly assessing and maintaining awareness of the current clinical situation.

Correct Decision Making with Incomplete/Conflicting Data

Expertise is more than simply having extensive factual knowledge—it also includes complementary skills and attitudes. Experts have specific psychological traits (e.g., self-confidence, excellent communication skills, adaptability, risk tolerance) and cognitive skills (e.g., highly developed attention, sense of what is relevant, ability to identify exceptions to the rules, flexibility to changing situations, effective performance under stress, ability to make decisions, and initiate actions based on incomplete data). Clinical experts use highly refined decision strategies such as dynamic feedback, decomposing and analyzing complex problems, and prethinking solutions to tough situations (59).

A key attribute of expertise in trauma care is the ability to anticipate or to predict what might happen to a patient with a particular constellation of injuries given the resources available. Mental simulation, whereby individuals or teams envision (simulate) a possible future clinical event or clinical action before it happens, is essential to gain the expertise to make diagnoses and to perform at a high level during an evolving or future real event. When expert clinicians simulate situations and actions mentally before they undertake them in real life, they save time and improve performance in crucial situations (see simulation section below).

Situation Awareness

One of the most important decision skills in trauma care, where data overload is the rule and the patient's status changes continually, is the ability to recognize clinical cues quickly, detect patterns, and set aside distracting or unimportant data. Situation awareness (or situation assessment) is a comprehensive and coherent representation of the (patient's) current state that is continuously updated, based on repetitive assessment (60). Situation awareness appears to be an essential prerequisite for safe operation of any complex dynamic system. In the case of trauma care, adequate "mental models" of the trauma patient and the associated trauma unit facilities, equipment, and personnel are essential for effective situational awareness. Situation awareness can be divided into three levels (Fig. 1) (60,61) and successful team awareness allows all members to converge on a shared mental model of the situation and course of action (62). **Effective teams adapt to changes in task requirements, anticipate each other's actions and needs, monitor the team's ongoing performance, and offer constructive feedback to other team members (62).** When team members share a common mental model of the team's on-going activities, each will "instinctively" know what each of their team-mates will do next (and why), and they often communicate their intentions and needs nonverbally ("implicit communication").

TEAM TRAINING TECHNIQUES

Team training should be designed based on desired team competencies (behaviors, attitudes, skills, and knowledge) and specific tasks to be trained for. Each training exercise should have explicit learning objectives. Team training exercises are best oriented around realistic scenarios that will address the learning objectives, facilitate team decision-making, and provide specific task training. This section reviews some common team-training approaches, spanning the spectrum from traditional exercises to newer "high tech" techniques, only recently made possible by high-speed computer simulation programs and the evolution of video analysis.

Traditional Team Training Exercises

Application of nonmedical studies on health care team-training methods remains largely invalidated. However, several findings may be instructive to those striving to provide trauma team training. First, training sessions should link the requirements of the task and the environment to the competencies required of team members (63). Second, training that fosters communication of the team leader's evolving picture of the situation to the team can enhance the team's behaviors (64). Thus, team practice should include periodic situation updates by the team

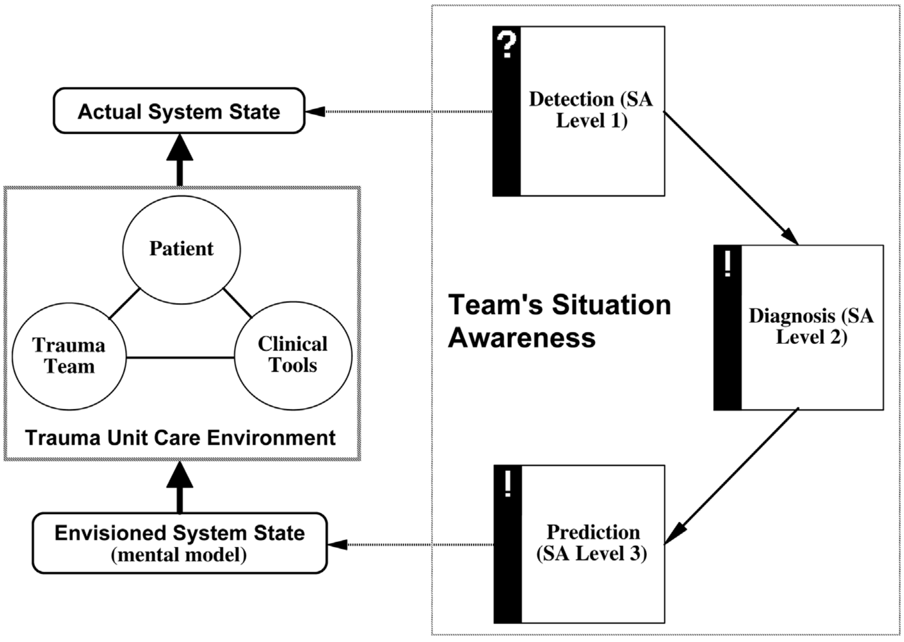

Figure 1 The role of situation awareness in trauma care. Situation awareness consists of three levels: Level 1—detection (perception) of changes in the patient's state, other team members' performance, or the status of equipment or the surrounding environment. Level 2—a diagnosis of the current state of the "system," which includes the patient, the team, and the care environment. This leads to a revised "mental model" used to evaluate the meaning of future changes. Level 3—prediction of future patient/system state leading to the choice of appropriate interventions to optimize patient outcome. *Abbreviation*: SA, situation awareness.

leader. Third, task stressors influence team communication, coordination, and performance strategies. Therefore, training should incorporate methods to build team mental models and provide relevant and meaningful information about the impact of other team members, tasks, equipment, care environment, and the evolving situation. Fourth, teams should practice in simulations or with role-playing in a relevant context. Fifth, training effectiveness should be assessed under both routine and realistic stressful conditions. Finally, training exercises must incorporate ongoing feedback about team performance.

For trauma teams to improve, they must share common performance goals and an understanding of the work to be done together. Teams with shared mental models are more likely to have accurate expectations of the team's needs than those without shared models, thereby allowing them to adjust behavior during stressful situations and to anticipate changing conditions. Three team performance-enhancement strategies that can foster common goals and shared mental models among team members are cross training, team model training, and crew resource management training.

Cross Training

It is challenging to maintain high levels of performance with the frequent turnover of personnel, as is common in academic medical centers. Cross training of trauma team staff in each other's roles provides both flexibility and enhanced team performance. An important benefit of cross training is improved team communication by facilitating development of shared expectations of each other's roles, decision processes, and actions of the team members. Common training regimens (e.g., ATLS) and practice in the tasks performed by other team members enhance knowledge of the team's needs and also promote anticipation and coordination (65). Volpe et al. (66), using a PC-based aircraft simulator, showed that cross training was an important determinant of effective task coordination, communication, and performance. Particularly in high workload situations, cross training by positional rotation can improve team communication, particularly when tasks are highly interdependent (67).

Team Model Training

Team model training (TMT) was developed to enhance indoctrination of combat teams and can be adapted to trauma team preparation (68). TMT evolved in response to concerns that standard measures of team performance were lacking, drills were unsystematic, trainees were overloaded with details, and practice was unguided by feedback. TMT consists of a series of explicit training curricula and feedback-guided experiential learning on PC-based simulators. The goal is to foster collaborative teamwork. Results of TMT education exercises suggest that complex team interactions can be demonstrated and practiced using low-cost, PC-based simulations.

Trauma Crew Resource Management

Trauma Crew Resource Management (TCRM) derives from concepts developed in the aviation industry, called Cockpit Resource Management (CRM). From the days of the Wright brothers to the 1970s, formal training for pilots focused on the technical (stick and rudder) components of flight. In the 1970s, NASA's research showed that many commercial air crashes that occurred were not because of equipment failure or deficiencies of technical piloting skills, but because of failures of communication and teamwork (69,70). In response, the commercial aviation industry initiated a new type of pilot training, which went by the acronym CRM (for Cockpit Resource Management). CRM focused on the interpersonal aspects of flying in a multiperson crew. As the concept matured, the name, but not the acronym, changed to Crew Resource Management, reflecting the fact that safety critical interactions extend beyond the confines of the flight deck (4). By the late 1990s, CRM had evolved through five generations into a highly focused training program with the goal of managing the consequences of human error. Analogously, TCRM training enables trauma teams to effectively harness all available resources to provide the best possible patient care. TCRM facilitates the translation of individual knowledge of what needs to be done into effective team processes and helps to bring structure to the complex and chaotic world of the trauma bay.

TCRM derives from an earlier adaptation of aviation CRM to anesthesiology. Anesthesia Crisis Resource Management (ACRM), an immersive simulation-based training program, was developed by Gaba et al. (53,71) in the early 1990s. The value of ACRM resides in the realistic enactment of scenarios followed by rapid cycle and learner-centered debriefings using video analysis of the clinical team's performance. A preliminary study of the effectiveness of ACRM suggested that trainees learned powerful lessons that they attempted to incorporate into their clinical practice (72). The study coupled in-depth interviews about ACRM training with confidential debriefings about the management of actual serious incidents in patient care after trainees underwent ACRM training. Another study revealed widespread failures in situation awareness and coordination by medical teams and organizational barriers that led to patient harm, further validating the need for this type of training (73). From this pioneering work, one can delineate the essential features of TCRM training courses (Table 5). Additionally, CRM courses have been developed for other specialties, including emergency medicine (74,75) and critical care (76). In the most extensive evaluation of formal teamwork training in a medical setting to date, Morey et al. (77) described the MedTeams Project. A team-based training curriculum based on CRM principles was implemented in nine hospital emergency rooms. Team training of 684 clinicians produced

Table 5 Essential Skills Taught in Trauma Crew Resource Management Courses

Adaptability
Prioritization of tasks
Shared situation awareness and distribution of the workload
Team communication before and after patient arrival
Mobilization and use of all resources in the trauma bay that extends to the OR, intensive care unit, and diagnostic facilities
Performance monitoring and cross-checking of data and team functions
Command, communication, and coordination of feedback
Leadership and the management of the team members' followership
Willingness to challenge each other and conflict resolution skills

Abbreviation: OR, operating room.
Source: From Ref. 122.

statistically significant decreases in clinical errors and improvement in the quality of team behaviors. However, no statistical differences in patient outcomes were seen.

Simulators for Trauma Team Training and Assessment

There are substantial ethical and educational limitations to the use of patients for the clinical training of individuals and teams. The opportunities to learn and practice desired responses to uncommon events or types of injuries are limited, even in a busy trauma center. In fact, actual trauma resuscitations are not optimal training opportunities, because patient care must take precedence over teaching. Moreover, clinical events occur in an uncontrolled setting under stress and time pressure. Societal and regulatory pressures will increasingly limit the use of real patients, especially the critically ill ones, for hands-on clinical training. Simulation has been widely touted as a tool to improve clinical care through enhanced training and evaluation. Simulations can include patient actors (e.g., standardized patients) (78,79), PC-based partial task trainers (80), or full-scale realistic patient simulation (RPS) (81) (discussed below). **Computer simulation of trauma scenarios will become an essential training tool, as it has in almost every other high-risk domain, including aviation, space flight, military operations, nuclear and hydroelectric power generation, ground and sea transportation, and chemical process control (82).**

There are many benefits of medical simulation. Simulations can permit clinicians to learn new or improve old techniques safely and economically without posing harm to patients or to trainees (72,81,83). Simulations can be controlled and modulated according to the needs of a team (84). Decision-making skills can be embedded into the scenario to train for reasoning, metacognition, risk assessment skills, and responsiveness to adverse events. Guided practice with video-based feedback that incorporates measures of performance can be considered managed experience (3). Perhaps, most importantly, lessons taught in a realistic simulation environment may be retained better, on account of the required active learning and focused concentration, the greater emotional intensity of the experience, and its direct association with real-world clinical events (David Gaba, personal communication, 2001). Thus, trauma teams can train, evaluate, and become credentialed providers before participating in actual clinical activities.

Recent literature is beginning to provide evidence for the value of RPS to train and evaluate trauma teams (73,84–87). A study by Holcomb et al. (87) evaluated ten 3-trainee teams before and after a one-month trauma-center rotation, using RPS scenarios. The teams showed significant improvement on multiple measures of technical skill, supporting the face validity of RPS-based technical performance assessment. Lee et al. (88) conducted a prospective randomized controlled trial of surgical interns' trauma assessment and management skills after using either RPS or moulage practice training sessions. RPS-trained interns scored higher on trauma assessment skills and on the management of an acute neurological event.

Value of Realistic Patient Simulators

Realistic patient simulators are fully interactive physical simulations in which the responses of the device to the clinical interventions are scripted to be realistic. In the highest fidelity simulators, the mannequin's response is based on detailed physiological and pharmacological computer models. The goal is for the simulator to respond to clinical interventions in the same way a patient would respond. Thus, the participant interacts with a realistic cognitive and physical representation of the full acute care environment and thereby experiences emotional and physiological responses similar to those experienced in real patient-care situations (89,90). Realistic patient simulators consist of a computer-controlled system and a plastic patient mannequin that generates physiological signals (e.g., electrocardiogram, invasive and noninvasive blood pressure, lung sounds, palpable pulses) and allows for complex airway management scenarios (72,81,89). The mannequin's head contains a speaker so that the trainee can converse with the patient when contextually appropriate. Trainees can also query the operator as needed concerning physical signs not reproduced by the mannequin (e.g., skin color, diaphoresis). There are multiple technical, financial, and methodological issues that affect the design and implementation of RPS-based training programs (81,91). Nonetheless, patient simulators have facilitated study of the response to critical incidents (90), the occurrence of medical errors (89), the role of teamwork (75), and the effects of other factors on clinical performance (91,92).

Importance of Scenario Design

Oser et al. have outlined specific steps for developing simulated scenarios for eliciting team behaviors (93). First, skill inventories and historical performance data are reviewed to identify what should be measured. Identifying the core measurement objectives builds content validity into the scenario. Second, scenarios are created that provide specific reproducible opportunities to observe performance, related to the objectives chosen. Third, performance measures are developed that accurately and reliably assess performance on the objectives. Measures should have the ability to describe what happened (i.e., outcome measures) in addition to describing why certain outcomes were or were not attained (i.e., process measures).

Components of a Simulation-Based Training Course

A typical simulation-based training course will include some kind of pretest, preparatory didactics (lecture, web, or hands-on demonstrations), the performance of one or more standardized scripted scenarios that are videotaped, post-simulation videotape-based debriefing, and a post-training evaluation (of both the trainee and of the training experience) (94). The debriefing is the most important experience, especially when training multidisciplinary teams (82,95,96). Debriefing should occur immediately after each simulation scenario and not uncommonly lasts longer than the scenario itself. Participants debrief together as a team with peers providing feedback.

EVALUATING TRAUMA TEAM PERFORMANCE

Assessing team performance will be key to understanding ways to improve team performance and increase patient safety (Table 6). There is a consistent argument in the literature that team process and outcomes must be distinguished (97). Process is defined by the activities, strategies, responses, and behaviors employed by the team during task accomplishment, while outcomes are the clinical outcomes of the patients cared for by the team. Process

Table 6 Questions to Ask When Assessing a Trauma Team's Performance

Is the team the right size and composition?
Are there adequate levels of complementary skills?
Is there a shared goal for the team?
Does everyone understand the team goals?
Has a set of performance goals been agreed upon?
Do the team members hold one another accountable for the group's results?
Are there shared protocols and performance ground rules?
Is there mutual respect and trust between team members?
Do team members communicate effectively?
Do team members know and appreciate each other's roles and responsibilities?
When one team member is absent or not able to perform the assigned tasks, are other team members able to pitch in or help appropriately?

measures are important for training when the purpose of performance measurement is to diagnose the problems and to provide feedback to trainees. Until recently, the medical community has focused more on outcomes than on process. Medical educators have begun to appreciate the competencies that define effective team process. The key is to identify and measure processes that are directly related to patient outcomes (e.g., successful resuscitation). Measurement tools must be reliable and valid and must distinguish between individual and team-level deficiencies. Most importantly, the results of the assessment must be translatable into specific feedback that will enhance team performance (98).

Paucity of Validated Competency Assessment Metrics

There are a variety of methods to evaluate team performance including debriefing with or without the use of videotaping, simulation with or without standardized patients, and the use of trained observers. Although metrics are available in nonmedical domains, there are very few well-defined validated metrics to assess competency in complex clinical team activities such as trauma resuscitation. No rigorous evaluation studies have been undertaken that relate the training experience with actual clinical outcomes, thereby validating metrics for assessing team performance.

Video Analysis of Trauma Care

Video analysis of team performance is an extremely valuable training tool because it removes any challenge to factual events, helps trainees clearly visualize each event, and can be used as a permanent record or an archive for future educational activities. Beginning with the experience of Hoyt and Shackford (99) in the late 1980s, videotaping and review of resuscitations has become a standard quality assurance method for many trauma centers. Subsequent work has confirmed benefits from improved team education and training, more efficient and accurate QA processes, interventions to improve care processes, and better patient survival (32,100). In a study of simulated anesthetic crises, trainees' review of videotape of the events led to decreases in "time to treat" and workload in subsequent simulations (101). Recently, Scherer et al. (102) found that video-based feedback of trauma resuscitations reduced disposition time by 50%.

However, videotaping of patient care requires overcoming substantial obstacles including medicolegal issues, confidentiality, logistical and resource issues (103,104), and analytical limitations (105). Nevertheless, the ability of multiple instructors to score performance from videotape allows the evaluation of the reliability of performance-assessment metrics. In a simulation-based study, investigators used videotape to validate a systematic rating system of behavioral and clinical markers, with the objective of creating a foundation for team training and assessment programs (106).

EYE TO THE FUTURE

Team training based on CRM principles are being widely disseminated in multiple civilian and military hospitals (77). It would not be surprising for these principles to be incorporated into ATLS and Advanced Cardiac Life Support® (ACLS®) training in the near future. In addition, future team-training programs are expected to incorporate a wider range of educational principles and goals (107). Within a few years, virtually all academic medical centers will have dedicated simulation centers that will increasingly conduct multidisciplinary team-training courses (86).

Increased Emphasis upon Computerized Simulation

Training for rare or dangerous events (e.g., ATLS and ACLS) can and should be increasingly facilitated by computerized simulators (108). The progression toward simulation-based training was recently endorsed by the American College of Surgeons' Committee on Trauma, with their approval of the use of torso simulators during the skills section of ATLS training. Although patient simulators are not currently approved for the assessment-training portion of ATLS, this is likely to occur in the near future. Indeed, patient simulators provide some advantages over moulage actors (e.g., physiological modeling of the scenario and immediate response to therapy) (88).

Patient simulators have been shown to improve both diagnostic and therapeutic decision-making during ATLS training of surgical interns (109). Not only did simulator training speed the acquisition of trauma management skills but, just as importantly, morale was improved. Indeed, the surgical interns participating in the study deemed the simulation training to be worthwhile, and also attributed to the simulation training their improvement in both self-confidence and individual competence (109).

A separate observational study showed that simulators were effective in training junior surgery residents during their critical care rotation (110). Three scenarios were tested. None of the residents successfully completed the first scenario. Subsequent performance improved in previously neglected areas. Although the simulators were useful in identifying the residents with large knowledge deficits, the greatest utility was in evaluating deficiencies in the training program itself (110).

Military and civilian prehospital personnel may benefit from simulation training as well. Currently available hospital-based scenarios can be easily modified to include variations in light, sound, available assets, and numbers of casualties. In addition, simulations can be linked together to replicate mass casualty events, and these simulations can be used to evaluate the management decisions of larger teams and commanders from remote locations (87).

Incorporating Military and Aviation Industry Lessons

Besides placing increased emphasis on computerized simulators for rare event training, the trauma community could significantly improve resuscitation team training by looking to Crew Resource Management (CRM) and other team-training strategies that have already been developed in other domains. The tactical decision making under stress (TADMUS) project, conducted in the surface vessel community of the U.S. Navy, has produced a number of useful tools and lessons learned, which are applicable in health care (107). Based on our experience, as well as a review of the literature, we make the following recommendations for trauma and critical care team training.

First, the health care community should develop a standard set of generic teamwork-related knowledge, skills, and attitude competencies. These competencies would represent the core elements of successful teamwork in health care. This would begin to establish a common language for describing teamwork in health care.

Second, instructional designers should look beyond aviation CRM training to all available training research and tools. For example, Salas and colleagues (66) have compiled an extensive collection of principles and guidelines for assertiveness training, cross-training (66), stress management training (111), and team self-correction (112). Current medical team training programs rely almost entirely on classroom-based or simulator-based training methods, rather than choosing from a variety of instructional strategies to complement the specific training content. With few exceptions, new advances in training technology—such as computer-based partial-task training, low-fidelity simulations, embedded training, scenario-based training, high fidelity robotic and virtual reality training—have rarely been used, despite growing evidence regarding their effectiveness (113). Recent advances in training theory—such as the effect of pre- and post-training factors on training outcomes, the effect of practice schedules on skill acquisition and retention, and the critical role of individual differences in shaping trainees' motivation—have similarly been ignored (68,113–115).

Third, many experts believe that, in the next 5 to 10 years, all clinicians will be required to train and be credentialed on simulators before practicing on patients. Indeed, computer-based simulations were formally introduced for certification by the U.S. Medical Licensure Examination (USMLE) in November 1999 as the official Step 3 Primum® exam (116). It is likely that these exams will soon evolve into full simulation scenarios and may one day be conducted in simulation centers. Indeed, simulation centers have already been used for remedial training of anesthesiologists by the New York Society of Anesthesiologists Committee on Continuing Medical Education and Remediation (117). In addition, physician graduates of an ATLS course recently demonstrated more improved technique and function, following a simulator session than those who did not receive such training (118). Similarly, physicians, nurses, and respiratory therapists (all ACLS certified within two years of their simulation training) showed improved ACLS task-completion rates ($p = 0.001$) following simulator training (119).

More intriguing is the advancing sophistication of virtual (or immersive) reality simulation. Future trauma teams may practice in a virtual world of animated three-dimensional patients and care environments while interacting with simulated clinical tools that provide realistic tactile feedback (see, for example, virtual reality training environments provided by "hit lab research" (120).

Finally, video review of patient care continues to gain popularity for training as well as quality improvement (102,104,121). It would not be surprising for all care areas to ultimately be continuously monitored with audio, video, and physiological data capture to facilitate on-going performance improvement as well as adverse event analysis (analogous to aviation's cockpit flight recorder). Fostering effective teamwork will remain a focus of healthcare performance improvement because the resulting attitudes, skills, and behaviors are essential to establishing a culture of safety and quality.

SUMMARY

Teams make fewer mistakes than do individuals, especially when all team members know their individual responsibilities as well as those of the other team members. However, simply bringing individuals together to perform a specified task does not automatically ensure that they will function as a team. Trauma teamwork depends on a willingness of clinicians from diverse backgrounds to cooperate toward a shared goal, to communicate, to work together effectively, and to improve. Each team member must be able to: (*i*) anticipate the needs of the others; (*ii*) adjust to each other's actions and to the changing environment; (*iii*) monitor each other's activities and distribute workload dynamically; and, (*iv*) have a shared understanding of accepted processes, and the knowledge of how events and actions should proceed.

Teams outperform individuals especially when performance requires multiple diverse skills, time constraints, judgment, and experience. Nevertheless, most people in health care overlook team-based opportunities for improvement because training and infrastructure are designed around individuals. Teams with clear goals and effective communication strategies can adjust to new information with speed and effectiveness to enhance real-time problem solving. Individual behaviors change more readily on a team because team identity is less threatened by change than are individuals. Behavioral attributes of effective teamwork learned on the trauma team, including enhanced interpersonal skills, can extend to other clinical arenas.

Turning trauma care experts into expert trauma teams requires substantial planning and practice. There is a natural resistance to move beyond individual roles and accountability to the team mindset. One can facilitate this commitment by: (*i*) fostering a shared awareness of each member's tasks and role on the team through cross-training and other team-training modalities; (*ii*) training members in specific teamwork skills such as communication, situation awareness, leadership, followership, resource allocation, and adaptability; (*iii*) conducting team training in simulated scenarios with a focus on both team behaviors and technical skills; (*iv*) training trauma team leaders in the necessary leadership competencies to build and maintain effective teams; and, (*v*) establishing and consistently utilizing reliable methods of team performance evaluation and rapid feedback.

ACKNOWLEDGMENTS

Dr. Barach would like to acknowledge the administrative support of Roxanna Araya. The author's time on this project was supported in part by the American Heart Association (grant #0330274 N) and a contract from the Agency for Health Care Research and Quality (AHRQ, Rockville, MD, U.S.A.).

Dr. Weinger would like to acknowledge the editorial support of Karen Ruberg and Kelly Vo. The author's time on this project was supported by grants from the AHRQ (R01-HS11521 and P20-HS11750) and the Department of Veterans Affairs (HSR&D IIR 20-066; Washington, D.C., U.S.A.).

KEY POINTS

- Effective teams possess five characteristics of success (the five Cs): commitment, common goals, competence, consistency (of performance), and communication (16).
- Studies show that the presence of a single identified trauma resuscitation team leader leads to a better secondary survey, ATLS guideline adherence, and team coordination (32).
- Human factors (also called ergonomics) is the study of human interactions with tools, devices, and systems with the goal of enhancing safety, efficiency, and user satisfaction.
- High noise levels create a positive feedback situation, where noisy rooms require louder voices and higher volume alarms leading to increased noise levels, missed clinical events, and greater team dysfunction.
- Trauma team members must make special efforts to communicate clearly and unambiguously, especially when members of the team are new or less experienced.
- Effective teams adapt to changes in task requirements, anticipate each other's actions and needs, monitor the team's ongoing performance, and offer constructive feedback to other team members (61).
- Trauma Crew Resource Management (TCRM) derives from concepts developed in the aviation industry, called Cockpit Resource Management (CRM).
- Computer simulation of trauma scenarios will become an essential training tool, as it has in almost every other high-risk domain, including aviation, space flight, military operations, nuclear and hydroelectric power generation, ground and sea transportation, and chemical process control (81).
- Video analysis of team performance is an extremely valuable training tool because it removes any challenge to factual events, helps trainees clearly visualize each event, and can be used as a permanent record or an archive for future educational activities.

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