The Human Factor

Optimizing Trauma Team Performance in Dynamic Clinical Environments

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KEYWORDS

- Human factors • Patient safety • Resilience

KEY POINTS

- Equipping team members with a suite of psychological skills to manage stress, attention, and arousal
- Emphasizing specific team-based behaviors that facilitate the creation of accurate and flexible mental models, implicit communication, and adaptive coordination
- Improving awareness of environmental and equipment issues to close the gap between strategy and logistics
- Implementing systems-based initiatives aligned with Safety-II to improve system resilience in the absence of error, based on what went right

Trauma is easy; Trauma teams are hard

—*Anon*

Case 1. *An urban emergency department receives a prehospital trauma alert: a young man with multiple gunshot wounds is en route. The team assembles beforehand, and the attending emergency physician assumes the leadership role. Team members quietly prepare for anticipated key tasks: airway, chest tube insertion, and vascular access. On arrival, the patient is unresponsive, with massive external hemorrhage from a midface gunshot wound plus 2 ballistic injuries within the cardiac box. Amid the chaos, only the recording nurse hears the paramedic's handover report: "unsuccessful intubation attempt, critical hypotension, signs of life in the field." In an attempt to optimize*

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preintubation hemodynamics, the anesthesiologist pushes phenylephrine from a vial she carries in her emergency response kit, an intervention not communicated to either team leader or recording nurse. Airway management is further complicated by mechanical trismus from the ballistic injury. This observation is made by the paramedic team and shared during sign-over, but the team leader is fixated on the cardiac ultrasound. Various individuals offer suggestions regarding next steps, prompting confusion and exasperation with the nurses. A "can't intubate, can't oxygenate" airway is declared by the anesthesiologist, who then requests a surgical airway kit. An open surgical airway tray is brought to the bedside, which is not the percutaneous set-up that the anesthesiologist prefers. Further delays occur after disagreements between the surgeon, emergency physician, and anesthesiologist about the airway approach and who should make the final decision. It is at this point that the respiratory therapist assertively declares that he cannot feel a carotid pulse.

BACKGROUND: THE TROUBLE WITH TEAMS

Trauma is a team sport. Resuscitating a severely injured patient requires the coordination of cognitive, task, and systems-based resources in a dynamic and time-dependent fashion that rapidly exceeds what an individual can bring to bear. Equally challenging is the interaction between individuals within teams during periods of ambiguity, complexity, or high coordination overhead. Trauma resuscitation poses a particular challenge: diagnosis and management occur simultaneously, in step with the ordered execution of team-based tasks and procedural interventions. Trauma teams do not operate in a bubble—the extent to which teams can effectively operationalize a resuscitation strategy is moderated in part by the clinical environment. The decision to insert a tube thoracostomy may be straightforward, yet the ambient environment, crowding, noise, lighting, and functional set-up of key equipment have a significant effect on the ability to complete the procedure quickly, safely, and successfully. A gap between strategy (the plan) and logistics (how that plan is executed) often arises from a lack of consideration for and preparation of the operational environment.[1]

At first glance, the demands of managing team-based challenges during trauma resuscitation seem daunting. Research from performance psychology, team dynamics, organizational theory and systems engineering suggest the opposite is true: the targeted integration of human factors theory can help manage complexity and improve performance in dynamic clinical environments. Standardized paradigms like crisis resource management represent a logical first step but do not help individuals and teams recognize the ambient and circumstantial factors in which implementing those skills might become problematic. For example, the team leader in case 1 was overly task focused during handover and missed important details that may have influenced management. Crisis resource management would identify this as a failure of situational awareness, but to effectively address the problem the analysis needs to go deeper. The team leader ignored task-relevant cues, a feature of hyperarousal that is known to constrain cognition and decision-making capacity.[2] The solution is not to "improve situation awareness" but to recognize the influence of acute stress on performance and apply specific strategies to moderate arousal during periods of high task load.[3] The case can be dissected further to reveal process issues (lack of standardized handover), problems with clinical logistics (availability and accessibility of surgical airway equipment), and team leadership (problematic process of shared decision-making and conflict resolution). Each of these challenges requires a specific response—marginal gains that can sum to major improvements in team performance.[4]

MANAGING COMPLEXITY: SELF, TEAM, ENVIRONMENT, AND SYSTEM

Complexity in trauma resuscitation is a function of the interplay between individuals, teams, their environment, and the system in which health care teams work.[5] Managing complexity involves improving performance at each level and the points at which they intersect. Individual team members are invariably influenced by prior experience and coping strategies, which in turn influences mental posture—the ability to remain flexible, problem-solve, and perform under acute stress. Individuals working in a team environment must employ early and effective cognitive, linguistic, and behavioral strategies to co-orient and effectively direct their efforts toward a shared sense of priorities.[6] A clinical environment that is deliberately and strategically calibrated to align with team and task priorities can facilitate the execution of common goals in a safe and efficient manner. Finally, systems require sufficient flexibility and resilience to minimize and mitigate the impact of human error and capitalize on intrinsic elements that promote and maintain safety. Specific strategies can be used at each level—self, team, environment, and system—to enhance preparation and accelerate performance. Although the behavior of individuals and teams is invariably context bound, the tools described in this article bear relevance to any team, regardless of size, composition, or extent of local resources.

Self: Psychological Skills Training for Trauma Team Members

Optimizing psychological preparation, or fitness to execute, has a profound impact on the performance of individuals and teams.[7] Elite athletes and musicians devote a significant amount of their preparatory work to the acquisition of psychological skills to manage attention and arousal. There is a level of arousal—termed, *ideal performance state*—that is associated with optimal performance: underarousal is associated with a lack of performance effort, whereas hyperarousal can produce chaotic inattention at the expense of execution.[8] The degree of arousal required for optimal performance depends on the task—complex acts can tolerate a lower degree of arousal and vice versa.[8] Few would argue that trauma resuscitation is a complex act, yet in most circumstances individuals do not take steps before, during, and after engaging in active resuscitation to manage hyperarousal to improve performance.

Stress and performance

The effects of stress on performance are determined by an individual's appraisal of task demands compared with available resources, the complexity of the task to be completed, and the relationship between the stressor and the task.[9] Elements of a clinical encounter affect individuals in different ways and to a greater or lesser extent, based on prior experience and coping strategies (both innate and acquired).[10] Stress is highly subjective and varies based on an individual's appraisal of the task at hand and the cognitive, personnel, and system-based resources available to manage it.[11] Individuals can become quickly overwhelmed when task demands outstrip perceived resources; this threat appraisal has a specific cognitive and physiologic footprint that can be identified experimentally[12]—most clinicians recognize this intuitively as a team that is falling apart (**Fig. 1**). The effect of threat appraisals on attention, memory, decision making, and teamwork are outlined in **Table 1**.

Teamwork can also be influenced by stress. As stress increases, teamwork suffers as a result of a narrowing of team perspective, which in turn correlates with impaired team performance.[13] Situations that require attention to multiple tasks and cues are more likely to suffer as a consequence of threat appraisals.[13] As attention narrows, peripheral or less relevant task cues are ignored first, followed by central or task-relevant

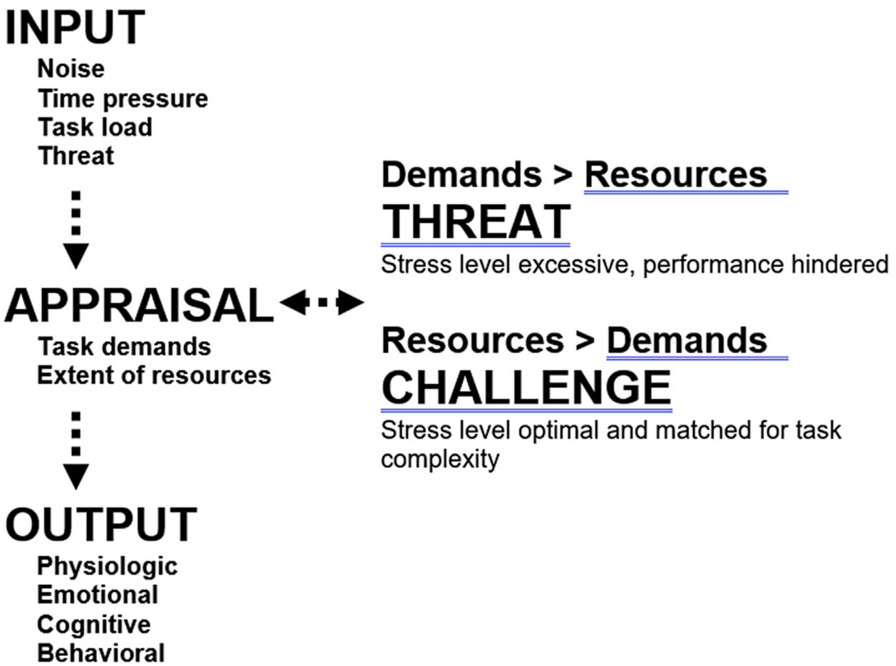

Fig. 1. Two-step cognitive appraisal. Task demands that exceed available resources produce a threat appraisal, which has negative effects on individual and team performance. (*Adapted from* Salas E, Driskel JE, Hughes S. The study of stress and human performance. In: Driskell JE, Salas E, editors. Stress and human performance. Mahwah (NJ): Lawrence Erlbaum Associates; 1996; with permission.)

cues. Accordingly, team performance under stress can be assessed by the extent to which task-relevant cues are identified or ignored.

Specific techniques

Controlled breathing is a simple and powerful tool for managing arousal both prior to and during an acutely stressful event. A series of deep and controlled breaths, in a 4-4-4-4 pattern (4 seconds in, 4 seconds hold, 4 seconds out, and 4 seconds hold) can lower heart rate and blood pressure and attenuate the neurohormonal response associated with threat appraisals.[14] Choosing the correct timing, technique, and duration of a controlled breathing exercise is highly personal and depends on features of the individual and the task at hand. The authors recommend a series of controlled breaths, paired with visualization and self-talk, prior to engaging in a complex or high-stakes procedure and during scheduled pause and reassess moments during resuscitation.

Self-talk and cue words are used to support self-confidence and render a state of focus and clarity. Self-talk can involve brief statements of affirmation and self-reassurance (“You’ve got this,” “You’ve done this before,” and “Slow and steady”) or relate to the specific steps in a given procedure (“I’m going to make a deep incision in the interspace just below the nipple line, all the way down toward the stretcher, as far as my hand will move”). Self-talk can also support cognitive reframing—the active act of identifying and interrupting irrational or disruptive thoughts.[15] Reframing exercises using self-talk include task chunking (breaking up a complex concept or procedure into smaller, more manageable parts) and perfection bashing (separating

Table 1
When things fall apart: impact of the threat appraisal on attention, memory, cognition, and team-based behaviors

Process	Description	Example
Attention	• Selective attention: ignoring task-relevant cues impedes situation awareness (fixation). • Tasks that require attention to multiple sources of input are particularly vulnerable.	Task fixation on an invasive airway maneuver, with subsequent failure to recognize fall in end-tidal CO_2 foreshadowing cardiac arrest
Working memory	• Working memory is constrained. • The ability to shift between multiple concepts held in working memory is impaired.	Simple drug-dose calculations are more error prone.
Decision making	• Over-reliance on heuristics—cognitive shortcuts that can produce errors in decision making • Failure of analytical systems of problem analysis—inability to shift from one hypothesis to another, even in the face of contradictory clinical information	Inability to deanchor from a presumptive diagnosis of hemorrhagic shock, even given a lack of response to blood transfusion and the suggestion of a pneumothorax on bedside ultrasound
Team	• Shift in focus from "we" to "me"—team more likely to make decisions that are based on self-preservation • Degradation of shared mental models of team process, shift toward information-seeking behaviors	Seeking to better understand an ambiguous situation, team members speak over and above one another, contributing to a cacophony of noise that further encumbers team coordination

necessary from non-necessary interventions, or prioritizing key interventions and making a deliberate decision to leave the rest). Cue words may involve a single word or short phrase that can be repeated, silently or aloud, to help the user stay in the moment when task load or complexity seems overwhelming.

Mental rehearsal (also known as psychophysical rehearsal or mental practice) can improve both the learning and performance of technical and nontechnical skills.[16–18] Similar to athletics, warming up with mental practice before a high-stakes event primes key motor/haptic and cognitive/decision-making pathways that allow for a smoother execution of complex mental and physical behaviors.[19] Mental rehearsal is also believed to help mitigate the effects of acute stress on performance and help establish and refine accurate team-based mental models.[18] To be effective, mental rehearsal exercises should be performed in real time, in as much detail as possible, and from an internal perspective, visualizing what the user would see. A scripted guide to mental rehearsal using the PETTLEP mnemonic is summarized in Table 2.

Stress inoculation training is a method of stress preparation that occurs in several discrete stages, in a process similar to cognitive behavioral therapy for phobia habituation.[3] In the first stage, individuals are made aware of the physiologic, emotional, and behavioral effects of acute stress. In the second stage, specific stress management skills are taught with the goal of minimizing the influence of stress on performance. Finally, those skills are applied to increasingly challenging situations to build

Table 2
The PETTLEP script for guided mental rehearsal, or mental preparation

P – Physical	Imagine all relevant physical characteristics
E – Environment	Imagine the environment in which the performance will occur
T – Task	Accurately reproduce all task steps
T – Timing	As much as possible, visualize steps in real time
L – Learning	Update visualization based on learning, experience, and changing task demands
E – Emotion	Conjure emotions that are likely to be experienced during the act itself; avoid debilitative emotions, such as fear, panic
P – Perspective	Visualize from an internal, or first-person, perspective

Adapted from Wright CJ, Smith DK. The effect of a short-term PETTLEP imagery intervention on a cognitive task. J Imagery Res Sport Phys Activ 2007;2(1):1–14.

tolerance and resilience as well as aptitude with skill application. The net effect is the conversion of threat appraisals to challenge appraisals, whereby individuals are functioning with a heightened sense of arousal but in a focused, controlled, and contained manner. Challenge appraisals are associated with improved performance and adaptive behavior under difficult conditions.[20] Stress inoculation training has been shown to improve team-based performance, with effects that are both lasting and generalizable.[21,22]

Overlearning involves repetition of a skill or sequence of skills beyond the point of initial mastery. The goal is to develop unconscious competence or the ability to perform with limited conscious thought.[23] As a stress preparation technique, overlearning can help shift the locus of control from external to internal, thereby maintaining a sense of influence over a series of otherwise chaotic events. This technique is well suited to accelerate competence with procedural skills, especially those carried out in complex high-stakes situations. Simulation-based training facilitates overlearning by allowing for repetition while modifying ambient conditions, context, and level of difficulty. The primary limitation of overlearning is the development of rigid mental scripts and learned motor behavior that lack adaptability and flexibility.

Team: Operationalizing Group Behaviors in Complex Scenarios

Trauma education has traditionally focused on task work—the cognitive and skills-based elements of patient care. Precious little time is devoted to the teamwork: the skills needed for an interprofessional group of experts to function as an expert team in complex and dynamic scenarios. This can be explained in part the pervasive belief that effective team behaviors develop naturally and organically over time, by way of a semirandom process of trial, error, and repetition. This faulty series of assumptions is not mirrored in other high-stakes professions, where team training is front and center in organizational safety culture.[24]

High-performance teams maintain open and flexible lines of communication, use a team structure that is adaptive to task and environment, and distribute and manage workload effectively.[25,26] Research on team performance in dynamic environments highlights the importance of shared mental models to facilitate teamwork and taskwork.[27,28] Individual team members develop a psychological map—a mental model—to "predict and explain the behavior of the world … to recognize and remember relationships among components of the environment, and to construct expectations for what is likely to occur next."[27] The extent to which mental models are shared between team members influences their ability to execute a plan.[27,29] Mental models facilitate transactive memory—an individual's ability to draw from domain-specific knowledge and training and bring it to bear in a team setting.[30] Developing accurate shared mental models poses a specific challenge for ad hoc teams, where members are often unfamiliar with one another's baseline skills and needs. Strategies to establish flexible methods of communication, set expectations and assign roles, and provide options for team structure that are responsive to patient needs can facilitate performance by developing accurate and shared mental models.

Specific techniques

Maintain a common language The interplay between language and behavior is complex, and a full discussion is beyond the scope of this article. Several communication skills bear specific mention, because they are particularly effective tools to establish common language across a diverse group of team members.

1. Avoid mitigating language. As a subconscious nod to social hierarchies and authority gradients, team members often choose language that downplays or minimizes the meaning of what is being said.[31] This includes phrases like, "Would you be okay with intubating the patient?" or "Could someone draw up some analgesia?" which are better rephrased as the commands they are intended to be: "Please intubate." and "Mark, draw up 100 mg of ketamine." Concise and direct is not synonymous with impolite or offensive.
2. Define a resuscitation lexicon. Yamada and colleagues[32] have proposed the development of a lexicon of short words or phrases that succinctly communicate commands and requests, similar to what is used by cockpit crews. Examples include confirm ("Confirm prehospital systolic blood pressure was 70 mm Hg"), I say again ("I say again: carotid pulse is absent"), request ("Request update on volume status"), and read back ("Read back of blood products given thus far").
3. Practice closed-loop communication. Closed-loop communication has 3 steps—directing an order or request to a specific individual and having that request verbally acknowledged as both received and completed successfully. The third step is often the most challenging to implement, because *complete* is not synonymous with *completed correctly*. To ensure this requires cross-monitoring and mutual support among team members and the ability to recognize when an action or intervention does not achieve the predicted result.
4. Use graded assertiveness. The 2-challenge rule Concerned-Uncomfortable-Safety issue (C-U-S) is used to counteract authority gradients and provide a structured way to express concern about a course of action in a graded fashion.[33] The C-U-S framework begins with directly stating a concern ("I am concerned about using paralytics for this difficult airway"), which can be up-scaled to acknowledging being uncomfortable ("I am uncomfortable paralyzing this patient given the presence of severe airway trauma") if the desired response is not obtained. Finally, a safety issue is declared if the plan moves forward without adequate modification or retraction.

Set common expectations: prebriefing A significant amount of preparation—both cognitive and logistical—can occur in a short period of time using a limited amount of information prior to patient arrival. The provision of preparatory information has been shown to decrease stress and anxiety and improve performance.[34] In addition to mental preparation and planning, teams should verbalize anticipated findings and early priorities and focus preparation accordingly. This prebriefing is typically coordinated by the team leader but should be a 2-way process whereby all team members have an opportunity to provide input and propose solutions.[35] The authors use a 4-step structured prebriefing process addressing the following questions:

1. What do we know: a quick verbal summary of information available, even if rudimentary (87-year-old male driver, single vehicle collision on the driver's side, hypotensive on scene)
2. What do we expect (plan A): anticipated injuries and how to prepare for them (left-sided chest and abdomen injuries, lateral compression pelvic fracture, need for blood products, possible medical cause for collision)
3. What will we change (plan B): a defined secondary approach if the predicted initial impression is inaccurate or needs to be modified, including specific triggers for deciding when to deviate from the primary approach (hypotension that persists after pelvic binder and blood products prompts consideration for an obstructive cause for shock)
4. Roles: having identified anticipated early needs and priorities, assign specific personnel to each task in alignment with plan A (airway team, chest tube insertion, pelvic binder application, vascular access)

The European Trauma Course has published workflows for trauma resuscitation that include a structured prebriefing with early role allocation, and verbal discussion of primary (plan A) as well as secondary (plans B and C) strategies prior to patient arrival.[36] Regardless of the approach, an organized and succinct prebriefing can facilitate preparation and establish mental models prior to patient arrival. The goal should be to maintain a sense of near-field situation awareness—preparation for the first 5 minutes to 10 minutes of resuscitation, followed by a deliberate pause and reassess to update status and determine the need to move to a secondary plan of action.

Modify team structure to reflect dynamic patient needs A traditional trauma team is set up using a functional team structure—a team leader coordinating the actions of individual team members. During periods of high coordination overhead and task load, it may be beneficial for teams to move from a functional to a divisional team structure—the latter typified by the creation subteams whose responsibility is constrained to a specific task or series of interventions (**Fig. 2**).[37] In this model, the situation awareness of subteam members is deliberately restricted: they are empowered to operate semiautonomously toward a prespecified objective, such as airway management or central line insertion. This in turn offloads the team leader, freeing up cognitive resources to maintain global oversight (or far-field situation awareness), planning, and resource management. The use of subteams may also help to mitigate the impact of acute stress on performance by managing complexity: breaking down a multipronged resuscitation into smaller, more manageable components. Although subteams can function semiautonomously for short periods of time, the team periodically needs to be pulled together to maintain a shared sense of overall priorities, by way of command huddles and situation reports.

Adaptive coordination Adaptive coordination refers to a team's ability to predict and modify their behavior in response to dynamic clinical and environmental cues—in other words, this is how mental models are operationalized. In a 1999 study, Entin and Serfaty[38] examined the performance and communication strategies of 5-member naval officer teams during anti–air warfare exercises under several experimental training conditions. Teams whose leader periodically provided situation-assessment updates (Situation Reports) to summarize priorities and current situation assessment

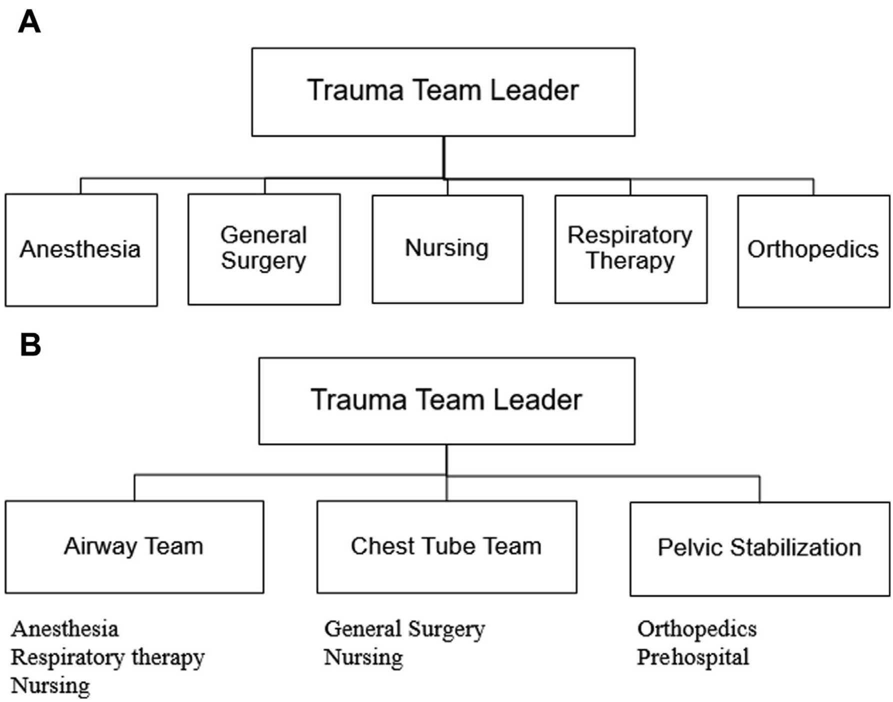

Fig. 2. Functional (*A*) versus divisional (*B*) trauma team structures. In a divisional structure, group members are organized into semiautonomous subteams based on clinical tasks.

demonstrated better teamwork and task completion and were more resilient to the effects of stress and task load. Furthermore, teams using sit-reps shifted from explicit to implicit modes of communication—that is, team members shared information with team members more frequently and directly, without having been asked to do so.[38] This observation is consistent with the ability to anticipate the needs of fellow team members—a key feature of shared mental models (clinicians recognize this as the "quiet code"). Translated to clinical practice, adaptive team behaviors are facilitated by team leaders who periodically pause and reassess to openly share information, summarize data, and voice specific findings, in addition to seeking team input and feedback.[39]

Environment: Optimizing Clinical Logistics and Resuscitation Ergonomics

The resuscitation environment is one of the most understudied aspects of clinical care. Poorly designed spaces lead to sequential failures—a lack of space around the head of the bed might prompt a physician to abandon the use of point-of-care ultrasound for central line placement or skip proper positioning to make up for lost time, which can in turn complicate procedures and pose risks to patients. Latent safety risks related to physical workspace are considerable: Patterson and colleagues[40] found 26 of 73 latent safety threats (LSTs) in an emergency department setting were equipment related. Participants did not identify the clinical environment as posing potential safety threats, suggesting there is a lack of awareness and understanding of clinical logistics to facilitate resuscitation goals. It may be unrealistic to expect clinical teams to invest time and energy during a dynamic resuscitation to thoughtfully organize their environment and optimize logistics—some element of environmental optimization should precede the clinical encounter.

Specific techniques

The authors propose a 3-pronged approach to optimizing the resuscitation environment that involves preparation and adjustments well before, immediately before, and in real time.

Well before Optimizing clinical logistics involves an iterative process of design, testing, and refinement. This is applicable to the clinical environment (in particular, space around the patient), equipment (location, bundling, and labeling), and processes (operationalizing a massive transfusion protocol). The authors have described a protocol to identify LSTs in trauma using in situ simulation exercises based on themes identified by a hospital's mortality and morbidity process.[41] The output from this work has been small adjustments or marginal gains that have summed to noticeable improvements in process and design.[42] This includes reorganizing the key real estate around a patient's head, neck, and thorax, adjusting the in-hospital routes used by nonclinical personnel to hasten blood product delivery, and streamlining equipment bundles by reorganizing and removing redundant tools (**Fig. 3**).

Immediately before Skilled providers should be focused on performance and execution, not fetching equipment. The authors' LST analysis has identified that nurses and physicians spend an inordinate amount of time and traverse a surprising distance to collect relevant clinical equipment (**Fig. 4**). This has a compounding effect on efficiency by delaying both the task at hand and encumbering or delaying subsequent tasks. The authors believe that lack of familiarity with the clinical environment and failure to assign roles contribute to this inefficiency. Cliff Reid argues that resuscitation should begin with a "zero point survey," whereby the team surveys and optimizes their clinical environment and assigns roles prior to engaging in the primary survey (Cliff Reid, Unpublished data , 2017). The authors believe this is an important step to include in the prebriefing element of preparation, prior to engaging in clinical care. Specifically, team members should be made aware of the location of and anticipate the need for key equipment and planned pathways for patient and team member movement. Nonclinical personnel should be assigned specific roles to support clinical logistics, including equipment gathering, layout, and patient positioning.

In real time Adjustments to the clinical environment invariably are required in response to patient needs. When possible, the authors recommend assigning a logistics and safety officer (LSO), who is responsible for optimizing the safe and efficient execution of clinical tasks. The LSO should be someone other than the trauma team leader, who remains responsible for establishing clinical priorities. The LSO role is perhaps best suited for a senior nurse working in step with the trauma team leader. The role includes crowd and noise control, patient positioning, layout and availability of equipment for procedures, safe movement of clinical personnel within the resuscitation environment, and planning for patient egress for the next phase of care. It is also the LSO's responsibility to oversee reviews of safety checklists prior to undertaking high-risk tasks like airway management or transitions in care.

System: Resilience Engineering and Safety-II

Systems capable of resilient performance are able to "adjust … functioning prior to, during, or following events (changes, disturbances, and opportunities), and thereby sustain required operations under both expected and unexpected conditions."[43] Hollnagel has defined the 4 pillars of resilient systems as

1. Ability to respond to variance, irregularities, and opportunities during both routine and nonroutine operations

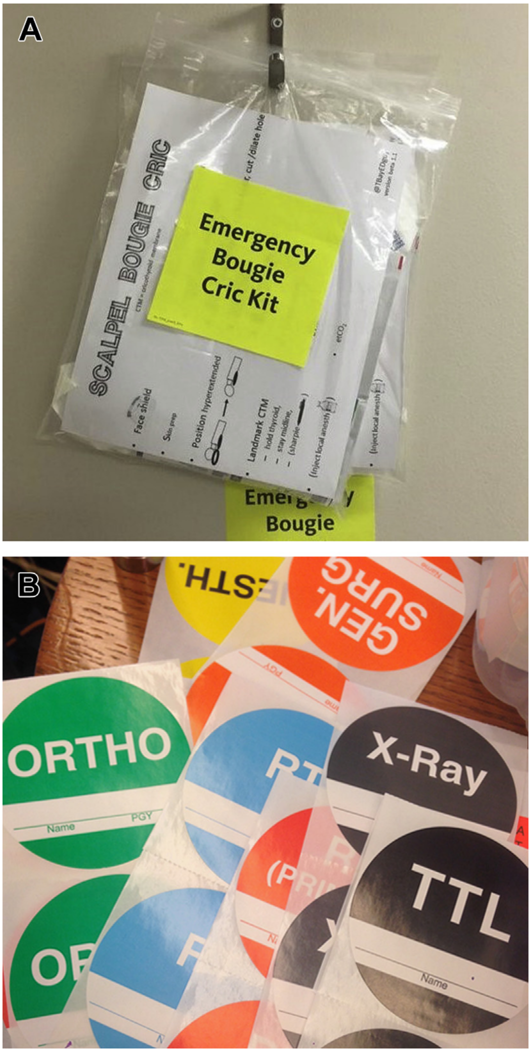

Fig. 3. Two simple trauma design hacks. (*A*) An abbreviated bougie-assisted cricothyroidotomy kit was pilot tested and refined using in situ simulation and is wall mounted in the trauma bay for quick and visible access. (*B*) Mandatory color-coded stickers (names and roles) for all team members. (*Data from* Surgical airway reference card developed by Dr Yen Chow. Available at: https://airwaynautics.com/category/surgical-airway/. Accessed March 1, 2017.)

2. Ability to monitor environmental and system-based cues, to detect safety threats
3. Ability to learn from adverse events, near misses, and successes
4. Ability to anticipate future demands, disruptions, or challenges to system function

In contemporary safety frameworks, resilience engineering is central to the notion of Safety-II—that is, a shift away from viewing safety as the absence of error and toward a model where the system's ability to succeed under varying circumstances is also analyzed.[44] The 4 pillars form the practical basis by which resilience engineering principles can be implemented to improve the performance of complex systems. By

A

B

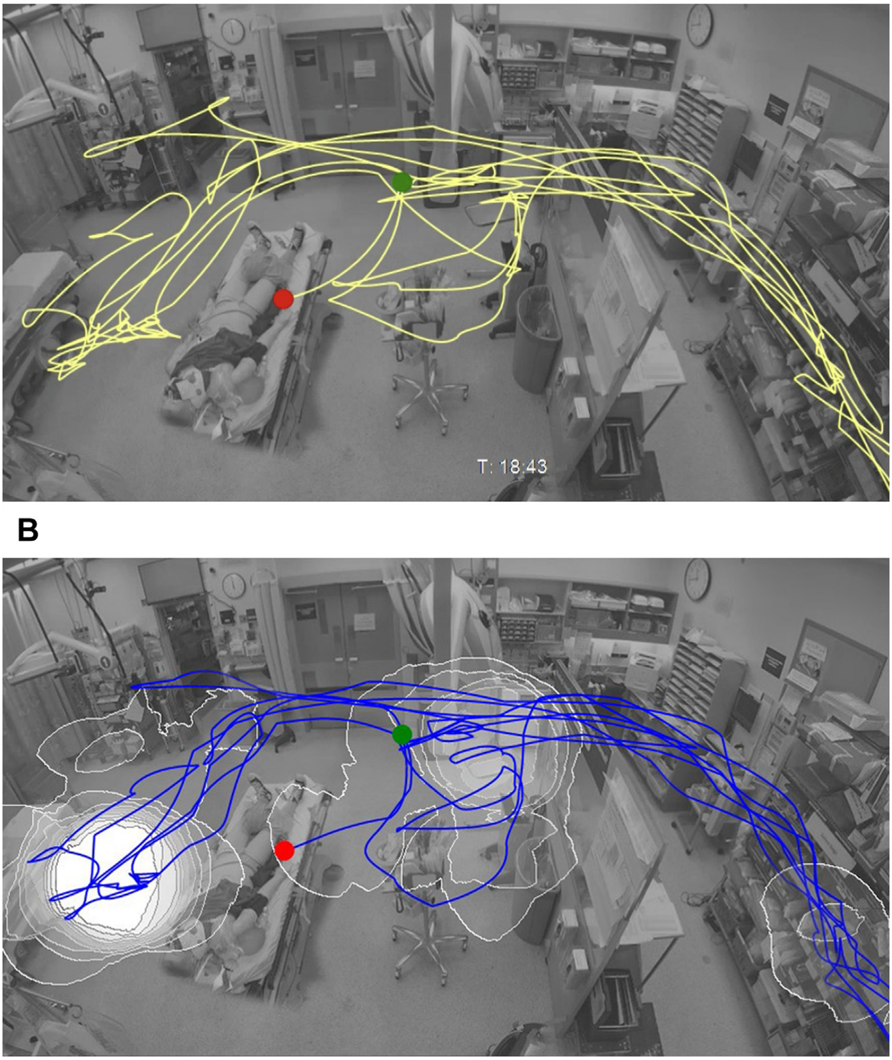

Fig. 4. Data from Trauma Resuscitation Using In-Situ Simulation Team Training (TRUST, in press) depicting clinician (*A*) and nurse (*B*) movement (*lines*) and hot zones (*spheres*) over a 12-minute period during a simulated surgical airway scenario. (*Data from* Almeida R, Pozzobon LD, Hicks C, et al. Tracking workflow during high-stakes resuscitation: the application of a novel human tracing tool during in-situ trauma simulation. In press.)

examining what goes well in addition to what went wrong, systems can identify elements of resilience and adaptation that can be applied proactively to prevent error.

Specific techniques

Ability to monitor: checklists and transitions in care Checklists can help integrate safety behaviors into both standard and nonstandard operations in situations where omissions are otherwise common, high-stakes, or both.[45] The thoughtful use of a checklist can force-function elements of care that might otherwise be bypassed. The World Health Organization has developed a trauma care checklist that the authors have modified according to identified local needs.[46–48] The authors use the modified the World Health Organization checklist as a predeparture review before egressing from the trauma bay to summarize key tasks, seek input from team members, and ensure adequate preparations have been made to facilitate patient movement.

Transitions in care (patient handoffs or sign-overs) are high-risk periods in patient care.[49] Standardized sign-over protocols can improve data transfer and ensure a smooth transition between care teams. Key behaviors to emphasize include a hands-off, eyes-on approach, whereby team members refrain from engaging with the patient while sign-over takes place and the use of sign-over checklists to ensure data are communicated quickly and concisely.

Ability to respond: clinical care pathways for complex events Locally developed clinical care pathways to coordinate care across multiple hospital resources and teams can facilitate decision-making for complex injuries.[50] Improvised solutions can be time consuming and ineffective; decision pathways that simplify decision making can minimize the potential for conflict or competing interests to encumber clinical care. For example, a patient in hemorrhagic shock with an open book pelvic fracture and suspicion of intra-abdominal injuries requires the ordered provision of emergency department, surgical, interventional radiology, and orthopedic care in a highly time-dependent manner. An institutional protocol specifying under what circumstances a patient is transported to an operating room versus an angiography suite can assist in the efficient gathering of resources and personnel.[51] True to the concept of resilience engineering, clinical care pathways must be specific about the triggers that prompt a preferred action and flexible enough to accommodate for a range of severity and complexity.

Ability to learn and anticipate: in situ simulation and debriefing In situ simulation—simulation-based training that occurs in a team's clinical environment—incorporates elements of clinical logistics that are difficult to reproduce in a simulation laboratory.[49] At the authors' institution, trauma team members engage in regular, team-based skills development, both in a simulation laboratory and by way of in situ training in a trauma room.[41,52,53] In situ exercises paired with team-based debriefings are designed as "living morbidity and mortality rounds," whereby challenging cases identified by a hospital's safety and error tracking processes are translated into simulation scripts that form the basis for in situ training.[52] In the authors' experience, the value of regular, structured simulation-based training to improve team and environmental familiarity and identify LSTs cannot be overstated. Practical steps for developing effective in situ simulation training for emergency medicine are described in detail elsewhere.[49,54]

Debriefing is not limited to simulation—real-life trauma resuscitations provide a rich substrate for identifying LSTs and improving team performance. Debriefing after live events poses additional challenges related case complexity, unpredictability, and the physical, emotional, and cognitive availabilities of team members, requiring modifications to simulation-based approaches.[55] From a systems perspective, documentation and follow-up of issues identified during debriefings are necessary to ensure safety concerns are addressed.[55]

SUMMARY: THE FUTURE STATE OF TEAMS

Resilience is built, not born, and there is no single strategy that reliably manufactures resilient performance in all circumstances. Optimizing team performance in dynamic environments involves the complex interplay of strategies that target individual preparation, team interaction, environmental optimization, and systems-level resilience engineering. To accomplish this, health care can draw influence from human factors research to inform tangible, practical, and measurable improvements in performance and outcomes, modified to suit local and domain-specific needs.[35] Viewed with this lens, and based on the recommendations presented in this article, the future state of elite trauma teams should include

1. Equipping team members with a suite of psychological skills to manage stress, attention, and arousal
2. Emphasizing specific team-based behaviors that facilitate the creation of accurate and flexible mental models, implicit communication, and adaptive coordination
3. Improving awareness of environmental and equipment issues to close the gap between strategy and logistics
4. Implementing systems-based initiatives aligned with Safety-II to improve system resilience in the absence of error, based on what went right

Arul and colleagues[56] have described the integration of human factors and system design strategies for damage control resuscitation and surgery at the Camp Bastion combat hospital in Helmand Province, Afghanistan. They concluded that the addition of command huddles/briefings, sit-reps, trauma care checklists, and standardized sign-overs in step with improvements with environmental design and clinical care “enhanced the communication in an already good team.”[56] Although improved teamwork is encouraging, future work should focus on patient-oriented quality-of-care outcomes to evaluate performance-oriented interventions.

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