CURRENT OPINION

Beyond crisis resource management: new frontiers in human factors training for acute care medicine

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Purpose of review
Error is ubiquitous in medicine, particularly during critical events and resuscitation. A significant proportion of adverse events can be attributed to inadequate team-based skills such as communication, leadership, situation awareness and resource utilization. Aviation-based crisis resource management (CRM) training using high-fidelity simulation has been proposed as a strategy to improve team behaviours. This review will address key considerations in CRM training and outline recommendations for the future of human factors education in healthcare.

Recent findings
A critical examination of the current literature yields several important considerations to guide the development and implementation of effective simulation-based CRM training. These include defining *a priori* domain-specific objectives, creating an immersive environment that encourages deliberate practice and transfer-appropriate processing, and the importance of effective team debriefing. Building on research from high-risk industry, we suggest that traditional CRM training may be augmented with new training techniques that promote the development of shared mental models for team and task processes, address the effect of acute stress on team performance, and integrate strategies to improve clinical reasoning and the detection of cognitive errors.

Summary
The evolution of CRM training involves a 'Triple Threat' approach that integrates mental model theory for team and task processes, training for stressful situations and metacognition and error theory towards a more comprehensive training paradigm, with roots in high-risk industry and cognitive psychology. Further research is required to evaluate the impact of this approach on patient-oriented outcomes.

Keywords
crisis resource management, simulation, team training

INTRODUCTION

A medical error is defined as 'the failure of a planned action to be completed as intended (i.e. error of execution) or the use of a wrong plan to achieve an aim (i.e. error of planning)' [1]. In 1999, the Institute of Medicine (IOM) reported that medical error was responsible for an estimated 44 000–98 000 in-hospital deaths annually [2]. The majority of consequential errors identified were related to human or system factors, including ineffective team leadership, nonstandardized team communication, a lack of global situation awareness, poor use of resources and inappropriate triage and prioritization [2,3].

To combat error, the aviation industry has developed and implemented standardized crew resource management training. This robust inter-professional training strategy utilizes full scale, high-fidelity simulation to train flight teams in 'nontechnical' skills, such as effective communication closed-loop communication, cross-checking and cross-monitoring, leadership, resource utilization and situational awareness. Crew resource management is a mandatory component of flight-crew training and is credited in part for the decline of in-flight catastrophes over the past four decades [4].

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KEY POINTS

- Medical error is ubiquitous and inevitable, and nontechnical skills instruction should address the limitations of human ability while teaching practical error management strategies.
- High-fidelity simulation is an effective tool for eliciting participant 'buy in' and focusing instruction on complex team-based behaviours.
- In-situ simulation, mental practice and hybrid simulation are promising new tools to enhance the efficacy of team-training instruction.
- Promoting shared mental models of team and task processes can be accomplished by simulation-based cross-training and inter-professional education.
- Stress inoculation training and cognitive forcing strategies may address instructional 'blind spots' in contemporary team training paradigms.

Like aviation, healthcare can be classified as a high-hazard industry. Ambient noise, crowding and diagnostic ambiguity during complex, rapidly evolving scenarios can negatively impact cohesive team behaviours and pose a direct threat to patient safety. Acute stress further erodes decision-making and team performance, promoting a loss of situational awareness and encouraging errors in reasoning and heuristic-based decision-making [5]. Although effective medical team performance requires individual task work, this alone is insufficient during dynamic crisis situations; teamwork skills are also required [6–8] (Table 1). Anesthesia pioneered human factors theory for resuscitation training, incorporating elements of aviation team training toward the development of anesthesia crisis resource management (CRM) [9–11]. This team-based approach uses high-fidelity patient simulation to teach nontechnical skills required during operating room crises.

Helmreich *et al.* [4] contend that for CRM training to be effective, instruction must explicitly address the link between human factors training and error management, such that the creation of high-performance medical teams is regarded as a series of patient safety countermeasures with three lines of defense: the avoidance, capture and mitigation of consequential error. In this framework, error is regarded as ubiquitous and inevitable, and instruction is refocused on the natural limitations of human ability and error management strategies.

Table 1. Effective teams behaviours: forming the foundation for crisis resource management and team training

Team knowledge, skills and attitudes	Behaviour
Team leadership	Has a clear common purpose
	Ensures that team members believe the leaders care about them
	Distributes and assigns work thoughtfully
	Compensates for each member
Backup behaviour	Effective conflict and error management
	Regularly provides feedback/debriefing to each member (either within-team or instructor-led)
	Manages poor performers effectively
	Incorporates self-correcting techniques
	Effective interactions with stakeholders outside the team
Mutual performance monitoring	Ensures that members understand each others' roles[a]
	Periodically diagnoses team effectiveness, including its results
Communication	Communicates often enough
Adaptability	Reallocates resources appropriately
	Recognizes and adjusts strategies under stress[a]
	Consciously integrates new team members
Shared mental models	Coordinates without the need for explicit communication[a]
	Members predict rather than discuss the needs of each other[a]
Mutual trust	Trusts other team members' 'intentions'
Team orientation	Selects team members who value teamwork
	Strongly believes in the team's collective ability to succeed

[a]Behaviours that warrant further focus in human factors and team training. Adapted with permission from [7].

UPDATES ON SIMULATION-BASED MEDICAL EDUCATION FOR CRISIS RESOURCE MANAGEMENT TRAINING

The use of simulation-based medical education (SBME) for training health professionals has been described as an ethical imperative [12]. This section summarizes key theoretical concepts and novel training tools germane to the development of effective simulation-based team training programs.

General considerations

SBME offers a unique opportunity to practice and learn in a nonpunitive environment without posing a threat to patient safety [13,14]. Full-scale, high-fidelity human patient simulation involving a computer-controlled mannequin in a realistic clinical environment is likely required to achieve the necessary participant 'buy in', such that team behaviours can take precedence. The importance of adequate fidelity is based on the theory of transfer-appropriate processing – to enhance transfer to the clinical domain, the cues available to the learner at the time of encoding and memorization are the same cues that will be available at the time of recall [15].

Deliberate practice, defined as 'a regiment of effortful activities designed to optimize improvement' [16] has been shown superior to didactic learning and translates to improved acquisition and performance of CRM skills [17,18]. Theories on deliberate practice emphasize both practice and repeated exposure in the acquisition and maintenance of expert-level skill. Effective nontechnical SBME can enhance the development of expert-level team performance by varying both the range of clinical presentation and the level of difficulty to practice scenarios. Such an approach facilitates the implementation of multiple CRM principles across a spectrum of clinical situations [19–21].

Chiniara [22▪] proposed two key characteristics that should guide the use of simulation as a training modality: acuity (the potential severity of the event and the patient impact) and opportunity (the frequency in which the team is required to manage the event) (Fig. 1). Using this matrix, simulation training is ideally suited for infrequent and high-risk situations that are tightly coupled with the potential for significant patient harm.

Although team members may be content experts in their area, a team of experts does not necessarily constitute an expert team [6,23]. SBME presents an opportunity for team members from various disciplines, backgrounds and experience to train and debrief as a team. A recent systematic review reported that inter-professional team training is a key intervention to improve team effectiveness [24], and translates to improvements in collaboration, communication and enhanced team-based behaviours [25].

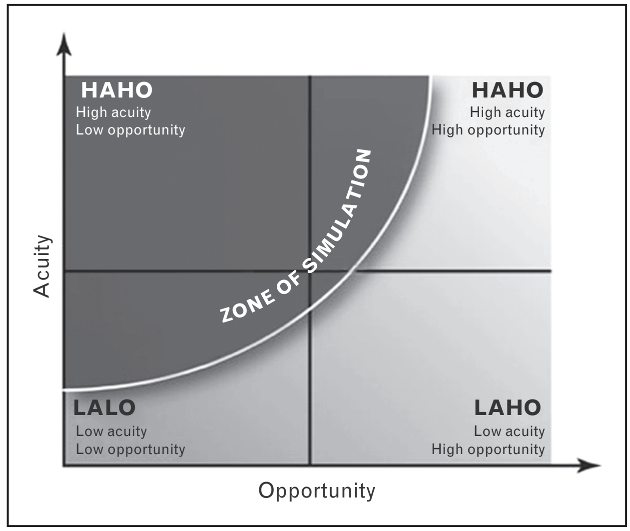

FIGURE 1. Zone of simulation matrix. Simulation may be ideally suited for clinical situations that fall within the zone of simulation, which includes high acuity, low-opportunity scenarios. Notably low acuity, high-opportunity scenarios may be best suited for an alternative training medium. Adapted with permission from [22▪].

Domain specificity

Effective team training is not a one-size-fits-all intervention – core CRM principles should be tailored to suit local and domain-specific needs in which the team is likely to operate [23]. To establish the necessary knowledge, skills and attitudes (KSA) needed for effective team performance and to guide the development of training curricula, an *a priori* team task analysis is required. Team task analysis addresses two essential aspects of any team: task work skills, including those focused on individual performance; and teamwork skills, which include the cognitive, behavourial and attitudinal approach of the team [23]. For example, a team task analysis as part of the development of a novel CRM curriculum for emergency medicine trainees highlighted domain-specific issues such as multiple patients and departmental management that were subsequently factored into the systematic design of an emergency medicine-focused CRM training program [26].

Debriefing

The provision of focused feedback through structured postscenario team debriefing is critical to implementing effective CRM training [27,28]. Team debriefing should be process-focused (such as processes like communication used by a team) rather than outcome-focused (such as overall outcome of team efforts) [29]. Feedback should be targeted toward the entire team, particularly for CRM topics, including situation assessment, leadership and team communication [29].

An expert instructor with content expertise in technical and nontechnical skills relevant to the training objectives typically leads a team through focused debriefing sessions. Within-team debriefing may be an effective alternative, whereby the reflective process is led by the team itself [30▪]. A recent study of simulated crisis scenarios that compared team performance of CRM skills reported that within-team debriefing was equally effective as instructor-led debriefing [30▪]. The introduction of within-team debriefing may offer a new option that promotes inter-professional communication while minimizing the resource challenges of instructor-led debriefing.

Assessment

Integrating nontechnical skills and CRM training into the patient safety culture has been limited in part by the lack of effective methods for evaluating the impact of instruction on team behaviours and patient-centred outcomes. This requires systematic, multilevel evaluation to verify that training objectives have been met. The Kirkpatrick typology, a popular framework for guiding program evaluation, examines the impact of training on four hierarchical levels: participant reaction, learning, behaviours (extent of performance change) and results (impact on organizational effectiveness) [31]. Salas *et al.* [32] have argued that effective CRM training should demonstrate a positive influence on multiple levels of the Kirkpatrick typology, with a particular emphasis on improved team behaviours and organizational effectiveness. Behavioural rating scales, used to quantify individual or team-based nontechnical skill performance, can be used as research tools to evaluate training programs or to facilitate feedback and debriefing [33–37].

Augmented simulation based medical education

Augmented SBME (a-SBME) involves education strategies designed to enhance the efficacy of simulation training. Three techniques have been studied within the context of team training and CRM skills: in-situ simulation, mental practice and hybrid simulation.

In-situ simulation is physically integrated into the learner's clinical environment [38]. This technique generates fidelity by promoting deliberate practice and repeated exposure for medical teams in a setting in which they will likely have to respond to actual critical events, while eliminating the cost and logistical challenges of utilizing a simulation centre. In-situ training has shown promise as a technique to augment simulation-based training by improving teamwork and patient-oriented outcomes compared with standard methods of instruction [39▪,40].

Mental practice is the mental rehearsal of an action in the absence of overt physical movement. SBME augmented by mental practice involves guiding participants through a period of focused mental rehearsal prior to simulation training. Although studied more extensively for technical skill acquisition [41–43], mental practice has recently been evaluated in team training [44]. Early data suggests that mental practice may enhance team performance when used to augment simulation-based trauma team training, compared with standard simulation training alone (S. Ahmed, G. Lorello, C. Hicks, D. Chandra, N. Ahmed, M. Hayter, unpublished data). Mental practice may be a quick and inexpensive method for improving the efficacy of simulation-based CRM training [45].

With hybrid simulation, participants have the opportunity to interact with a patient–actor while performing procedural skills on a mannequin [46]. Recent evidence supports this a-SBME technique as a method to improve communication during complex and emotionally sensitive situations and may prove to be a valuable technique for training CRM skills, such as communication and mutual support [47].

WHAT'S MISSING? AN AGENDA FOR THE FUTURE OF HUMAN FACTORS EDUCATION IN HEALTH CARE

A recent consensus statement by Eppich *et al.* [48▪▪] explored the evidence for simulation-based team training in healthcare, including high yield areas for future research. Based on guidance from high-risk industry and cognitive psychology, we propose a 'Triple Threat' framework of three key areas to be explored when developing next generation of highly effective team training (Fig. 2):

(1) Promote the creation of shared mental models for resuscitation teams;
(2) Formally investigate the impact of stress on team performance; and
(3) Refocus CRM training as a strategy to combat error and improve decision-making.

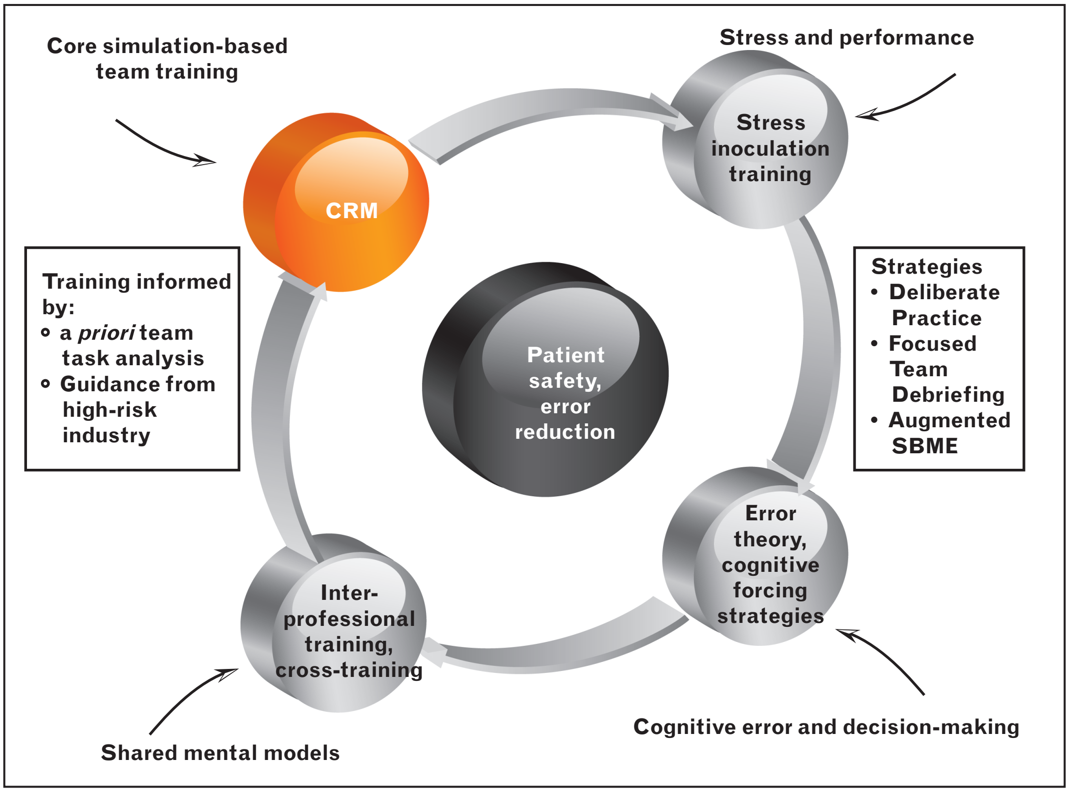

FIGURE 2. A Triple Threat' model for simulation-based human factors training in healthcare. This proposed model for simulation-based team training combines existing CRM paradigms with stress inoculation training, cognitive forcing strategies for mitigation of human error and interprofessional training to develop shared mental models. Training should be guided by an *a priori* team task analysis. Suggested methods for integration within human factors training include deliberate practice, focused team debriefing and augmented simulation-based medical education (a-SBME). Source Details: Original.

PROMOTE THE CREATION OF SHARED MENTAL MODELS FOR RESUSCITATION TEAMS

A mental model is a cognitive construct that allows a person to 'predict and explain the behaviour of the world around them among others and to construct expectations for what is likely to occur next' [49]. Shared mental model (SMM) theory was developed by combat aviation researchers to help explain how teams dealt with and communicate during complex, high stakes operations. SMM theory suggests that team behaviour is optimized when team members can predict rather than discuss each others needs [49]. This concept of 'implicit coordination' is facilitated by the extent to which team members share common mental models of team and task processes [49,50]. The extent to which mental models of team and task processes are 'shared' has, in turn, been shown to have a positive effect on team performance [49,50].

Research on SMMs in combat aviation suggests that team training strategies should include instruction on how to alter both the type and amount of communication needed to perform a task during stressful situations, shifting from explicit to implicit modes of communication [51]. Current CRM paradigms typically focus on the three Cs of communication: clarity (of the message), cite names and closing the loop; implicit coordination vis-à-vis the development of SMMs has not been formally explored in the medical team training literature. Cross-training – during which team members assume one another's positions to better understand various team member roles – is one proposed method for enhancing mental models, with evidence to suggest that cross-trained teams outperform teams that did not receive such training [51,52]. Interdisciplinary team training may also enhance SMMs as training resuscitation team members to develop a shared understanding of team and task processes along with the skills of other team members promotes team cohesion. Challenges persist in defining methods to promote SMMs for *ad hoc* hospital teams found in the emergency department, trauma room or critical care outreach.

FORMALLY INVESTIGATE THE IMPACT OF STRESS ON TEAM PERFORMANCE AND STRESS TRAINING

Complex, rapidly evolving, or unfamiliar resuscitations can be extremely stressful events for team members. In a recent study of simulated trauma resuscitations, elevated subjective and physiologic stress negatively impacted clinical performance [53▪▪]. Acute stress has also been shown to impair team performance and degrade SMMs among team members [5]. When stressed, individuals may default to heuristic-based reasoning and become less receptive to input from others [5], compromising situational awareness and promoting suboptimal problem solving and decision-making.

Stress inoculation training (SIT) is a three-phase cognitive behavioural training approach to limit the impact of acute stress on performance [54]. SIT has been used to decrease the perception and influence of stress – or promote 'stress resistance' – across a variety of domains, from public speaking to combat aviation. Stress training involves three sequential steps designed to desensitize individuals to the physiologic and behavioural effects of acute stress: identifying and understanding acute stress; skill acquisition and rehearsal; and skill application. SIT for military flight teams has been shown to improve team performance and mission success [55]. Importantly, SIT can be successfully implemented without an inordinate number of training sessions, and training appears to generalize to novel settings, [46] suggesting broad applicability for critical event training. [51]

REFOCUS CRISIS RESOURCE MANAGEMENT TRAINING AS A STRATEGY TO COMBAT COGNITIVE ERROR AND IMPROVE DECISION-MAKING

During a medical crisis, time pressures and the demand for rapid, high-stakes decisions promote errors in diagnostic reasoning. Team leaders often fall back on heuristics in an attempt to simplify and manage a complex or potentially uncontrollable circumstance. As a consequence, individuals may form conclusions using irrelevant information or ignoring key modifiers that would otherwise alert them to atypical presentations [56▪▪]. These 'cognitive errors' are both ubiquitous and difficult to detect, particularly during a crisis situation [57,58]. In a study of simulated anesthetic emergencies, cognitive errors were identified in more than 50% of cases [59▪▪]. Error, heuristics and decision-making receive some attention in traditional CRM instruction through the 'avoid fixation' heuristic, yet team members are often not equipped with the relevant countermeasures for faulty decision-making.

Cognitive-forcing strategies are a set of cognitive de-biasing tools that can be used by clinicians to detect and side-step common heuristics and biases [60]. Croskerry has outlined five steps for applying a cognitive forcing strategy to a clinical situation (Fig. 3). This approach requires an understanding of metacognition, or thinking about and reflecting upon one's thought process. The clinician then applies appropriate de-biasing techniques such as ruling out the worst-case diagnosis or searching for another fracture on radiography after the most obvious one is identified.

Cognitive de-biasing is not the exclusive domain of the team leader. The CRM framework promotes input from team members towards the management plan. Armed with effective forcing strategies and error theory, coupled with a team structure that encourages input from all sources, team members can assert their concerns when a safety threat arises, rather than falling victim to authority gradients [61,62].

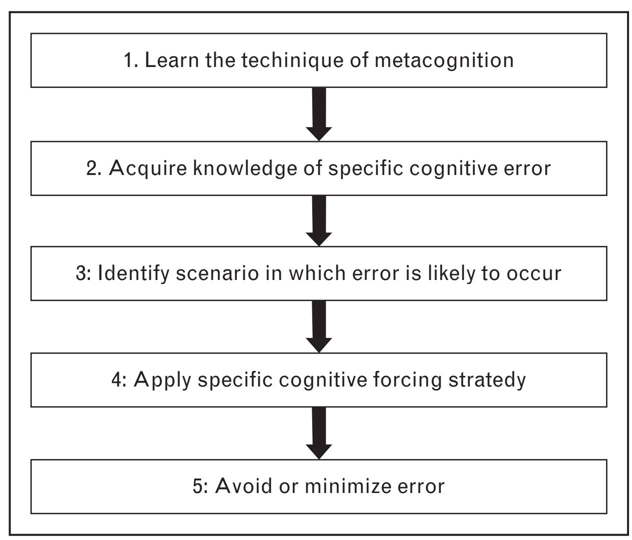

FIGURE 3. Steps in using a cognitive forcing strategy. Consider a trauma patient who suddenly develops hypoxia immediately after intubation – right mainstem intubation is thought to be the cause. Step 1: Step back to consider one's thought process. Step 2: In this case, failure to consider alternative diagnoses may lead to error. Step 3: Loud noise and competing issues during a trauma resuscitation may impair adequate consideration of alternative diagnoses. Step 4: Deliberate consideration of alternative diagnoses, such as oxygen disconnection or pneumothorax. Step 5: After appropriate consideration, the patient is diagnosed with a pneumothorax that is decompressed thus error is avoided. Adapted with permission from [60].

CONCLUSION

'Triple Threat' team training involves integrating SMM theory, stress inoculation training and cognitive forcing and error mitigation strategies toward the development of a more robust CRM paradigm with its roots in research from high-hazard industry and cognitive psychology. These elements are not outside of, but rather expand upon established CRM principles such as situation awareness, leadership, communication and problem solving. To be truly effective, team-based instruction must be accompanied by changes in hospital organizational and safety culture that reflect the inevitability of human error and the adoption of systemic approaches to error management. Evidence of organizational change and patient-focused outcomes remains an elusive 'gold standard' for human factors training.

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Conflicts of interest

There are no conflicts of interest.

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