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Operating Room Crisis Checklists and Emergency Manuals

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THERE is a growing movement toward the effective use of checklists, emergency manuals, and other cognitive aids in the operating room, both for routine and crisis situations. Crisis checklists are one type of cognitive aid that help a team remember critical steps during a crisis. A collection of cognitive aids for emergency use is referred to as an emergency manual. This article describes the history of operating room crisis resource management and its influence on the development of operating room crisis checklists and emergency manuals. We also explore current and future directions for work in crisis checklists and emergency manuals, including efforts to spread and improve clinical implementation. Understanding the history and interrelationship of these important emerging topics in anesthesiology will be essential for the successful development and implementation of processes to improve perioperative patient safety.

Part I: History of Operating Room Crisis Resource Management

To set the stage for the field of anesthesiology, we first examine how crew/crisis resource management evolved in aviation and the military.[1] In aviation, there was a recognition in the 1970s that a large proportion of incidents where planes were damaged beyond economic repair (often associated with fatalities) was due to failures of human performance.[2] For a majority of these accidents, the primary cause was "flight crew" action or inaction rather than mechanical failure. Similar to findings publicized in healthcare decades later in the 1999 Institute of Medicine report,[3] "flight crew" actions included critical lapses in communication, teamwork, and key details being missed at time-sensitive moments. In the Supplemental Digital Content (http://links.lww.com/ALN/B472), we provide aviation examples of these types of failures.

In 1979, the National Aeronautics and Space Administration convened experts from commercial and noncommercial aviation entities in a workshop called *Resource Management on the Flightdeck*.[4,5] They created the term "cockpit resource management," aimed at reducing pilot/human error by better utilizing the human resources that were available. Three fundamental areas were identified: interpersonal communication, leadership, and decision making. As a result of this work, routine simulation training of flight crews in these fundamental skills, as well as the use of checklists for standard workflow and emergency situations, became the norm in aviation.

The principles of crew resource management (CRM) were not universally accepted in the aviation industry or in the practice of anesthesia when they were first suggested.[2] It took years of promotion of the principles within the aviation industry and guidelines by the Federal Aviation Administration for this to happen.[4,6] Furthermore, the Federal Aviation Administration was intentionally broad in their guidelines for developing and implementing CRM, stating that their guideline "presents one way, but not necessarily the only way, that CRM training may be assessed."[6] It also takes continuous reinforcement to address late adopters and those who resist. In 2014, seven people were killed in a plane crash when the pilots did not conduct the preflight check and subsequently failed to disengage a mechanism before takeoff.[7] Further, an investigation from the National Transportation Safety Board

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found that these pilots habitually failed to conduct preflight checks, which leads one to believe that perhaps they did not think that routine safety checklists were inherently valuable.[8] In their recommendations, the National Transportation Safety Board called to amend standards to promote "compliance with best practices for checklist execution," including accepted aviation practices for proper communication. As we transition to the field of anesthesiology, we are reminded of the words of Dr. Ellison Pierce during the Emery Rovenstine 34th lecture: "Patient safety is not a fashion nor a preoccupation of the past. . . . It is not a problem that has been solved, but rather an ongoing requirement."[9]

In parallel to the efforts in aviation, there was a realization that these notions pertained also to anesthesiology. In 1978, an investigation entitled *Preventable Anesthesia Mishaps* by Cooper *et al.*[10] introduced the idea that human factors contribute to adverse patient outcomes. Elements such as fatigue, poor communication, and faulty equipment design were identified as promoting provider performance failures. This application of rigorous qualitative methods to anesthesiology unmasked mishaps that were previously underappreciated. In the study, Cooper *et al.* noted, "The syringe swap was a frequently reported incident despite the fact that such occurrences are rarely described in the literature or mentioned in case discussion conferences in this particular institution." Inspired by the work on critical incidents, Gaba *et al.*[11] published a report in 1987 revealing that much could be learned from other industries about how accidents evolve in healthcare. That report introduced the idea of using cognitive aids for operating room crises to "catalog and disseminate effective protocols for rapidly propagating incidents, as has already been done for malignant hyperthermia and basic and advanced cardiac life support." In 1990, the cognitive psychologist James Reason's book *Human Error*[12] gave deep insight into the mechanisms of human failure, particularly with more complex systems. It can be helpful to see an example of such errors in a context relevant to an anesthesiologist. In 1992, Reason presented a case report where a confused 72-yr-old patient booked for a cystoscopy died of a massive aspiration during induction of general anesthesia. The anesthesiologist (asked to do the case as a last-minute preoperative change in plan from "local only") did not have access to nor was he told about the nursing note indicating that the patient had recently been vomiting.[13] Gaba *et al.* applied the work of Reason to develop ways to reduce anesthesia errors related to human factors. They adapted aviation CRM to training individuals and teams in anesthesia. In 1994, Gaba's group published the book *Crisis Management in Anesthesiology*,[14] defining "resource management," including teamwork and dynamic decision-making skills, as: "the ability . . . to command and control *all* the resources at hand to execute the anesthesia as planned and to respond to problems that arise."

Howard *et al.*[15] introduced the idea of using simulation to train individuals in operating room crisis management and to study human performance. In 1995, Holzman *et al.*[16] published on their experience in using mannequin-based simulation to train anesthesia crisis resource management skills. The use of simulation training in crisis resource management has become an important tool to improve patient safety and to study and train for medical crises, both inside and outside of the operating room.[17–22]

Part II: Role of Checklists, Emergency Manuals, and Other Cognitive Aids in Operating Room Crisis Management

Checklists and other cognitive aids have long been used by high-risk industries, such as aviation, as tools to aid in crisis management.[2,23–25] The call for cognitive aids in healthcare has a long history. In 1924, the surgeon W. Wayne Babcock described the importance of well-functioning teams and cognitive aids when operating room emergencies occur.[26] However, for many decades, these prescient ideas were not embraced, nor were tools widely available.

Crisis Management in Anesthesiology contains the first large set of cognitive aids for operating room crises, along with descriptions of synergistic crisis resource management behaviors for improving teamwork and dynamic decision making, including appropriate use of cognitive aids.[14] There are also numerous other cognitive aids that have been developed, including Advanced Cardiac Life Support (ACLS) algorithms and anesthesia adaptations of these algorithms for the perioperative setting,[27,28] Malignant Hyperthermia Association of the United States (MHAUS) protocols,[29] a checklist on the treatment of local anesthetic systemic toxicity (LAST),[30] algorithms developed by the Australian incident monitoring study,[31] as well as other resources.[32]

Why would these cognitive aids be effective? There is evidence to suggest that failure of adherence to best practices during emergencies is common.[33,34] In studies of scenarios related to ACLS, there is a significant decay in clinicians' knowledge retention in the months to years after such certifications.[35] A recent study demonstrated that adherence to ACLS protocols was associated with increased patient survival after a cardiac arrest; doing the wrong things and omissions of indicated steps were associated with decreased survival.[36]

Renewed interest in the effect of checklists to reduce adverse events in healthcare began in the early 2000s. Pronovost's group[37] reported a significant reduction in catheter-related bloodstream infections in the intensive care unit using a comprehensive safety program including team training and a cognitive aid. The emphasis on implementation strategies, in addition to the central line checklist, was critical to this success. In 2006, the World Health Organization developed a "Safe Surgery Saves Lives" campaign. Gawande and Berry[38] led the World Health Organization effort that resulted in the Surgical Safety Checklist, which consists of a series of checks and prompts to be performed verbally at specific times during a surgical procedure. Use of this checklist has been shown to decrease surgical morbidity and mortality. Other articles have since been published on the value of surgical safety checklists used during routine operative care.[39–43] There are now numerous supportive systematic reviews on the topic of surgical safety checklists.[44–50] One notable study in Ontario, Canada, has called into question the value of surgical safety checklists.[51] As suggested in the accompanying editorial, the lack of impact on mortality rates is not surprising when considering the implementation gaps at the majority of involved hospitals.[52] To quote Dr. Lucian Leape, an internationally renowned figure in patient safety: "The likely reason for the failure of the surgical checklist in Ontario is that it was not actually used."[52] There is evidence to support that the positive effect of a surgical safety checklist relies on systematic implementation.[53]

The work described above set the stage for further development, evaluation, and implementation of checklists for use during crises in perioperative care. One trial of crisis checklists presented operating room teams with a set of simulated operating room emergencies in a high-realism simulation facility.[54] A set of crisis checklists were developed (at the Brigham and Women's Hospital and Harvard School of Public Health) based on information from the literature, as well as a multidisciplinary group of operating room experts, specialists in medical simulation and surgical education, and a lead checklist developer from the Boeing Company.[55] The use of surgical crisis checklists was associated with a nearly 75% reduction in failure to adhere to critical steps in management. The participants in this simulation study judged the checklists to be highly useful; 97% of participants reported that if they were a patient having an operation and one of these emergencies took place, they would want the checklists to be used. The current version is publicly available for free download.[56]

A group at Stanford has been developing real-time cognitive aids for decades. This work has drawn upon literature review, iterative revisions based upon observations during thousands of simulated crises, and multidisciplinary input from both clinical and aviation human factors experts. Beginning in 1990, Gaba and Howard developed a syllabus for a new simulation-based course for anesthesiologists called Anesthesia Crisis Resource Management.[21] This syllabus included 83 separate "crisis events" and a standard approach to diagnosis and treatment (event definition, etiology, typical situations, prevention, manifestations, similar events, and management). This syllabus evolved into the textbook noted earlier,[14] which was recently expanded to include 99 crisis events.[57] Their work was instrumental in the Veterans Health Administration's (VHA) development of a set of bound, laminated sheets comprising the VHA Cognitive Aid for Anesthesiology. This set of cognitive aids was placed in VHA operating rooms nationally, and its initial clinical use was studied.[58]

Over the last decade of research and user-centered design and testing, the Stanford team developed several types and generations of cognitive aids for anesthesiology and critical care. In 2012, the Stanford Anesthesia Cognitive Aid Group released version 1 of an emergency manual for perioperative critical events, featuring optimized design and content to facilitate effective clinical use under stress. The current version is publicly available for free download,[59] and a published framework of four vital elements for implementation of such tools was proposed.[60] Figures 1 and 2 include examples of designs from Harvard and Stanford, with additional figures available in the Supplemental Digital Content (http://links.lww.com/ALN/B472).

There have already been at least two published case reports in the peer-reviewed literature of successful real-time use of these tools during clinical crises: air embolism from Harvard crisis checklists[61] and malignant hyperthermia from Stanford perioperative emergency manual for critical events.[62] Recent publications suggest that conditions are ripe for implementation and effective use of emergency manuals in operating rooms, although clinical use is not yet widespread.[60,63]

With these tools available publicly for only a few years now, the first studies of clinical implementation and use are just now appearing in the literature. In a study of Stanford residents, 19 respondents (45%) reported using an emergency manual during a clinical crisis at least once in the 15-month study period, and the vast majority of them (78.9%) agreed or strongly agreed that it "helped the team deliver better care to the patient," with the rest neutral.[64] These results are significant given that many clinicians may not even see an operating room crisis in this time period though notably are in the setting of previously described widespread institutional trainings and local implementation efforts.[60,63] This study reinforces the point that the simulation of crisis events and the use of emergency manuals need to be incorporated into the education of all clinicians who work in the operating room.

In both aviation and anesthesiology, some emergencies may develop abruptly, whereas others may evolve over time. In aviation, there is already notation of checklist usage that can vary between styles of "read–do" (checklist items are read and actions are completed) and "do–confirm" (key steps are done immediately, and a checklist used to confirm nothing was missed).[25,65] This is an example of how training staff on the optimal ways to use crisis checklists/emergency manuals is essential to successful implementation.

Major anesthesia societies have adopted the use of checklists. The American Society of Regional Anesthesia and Pain Medicine published a practice advisory on local anesthetic systemic toxicity in 2010, which included a checklist on the treatment of LAST.[66] The American Society of Regional Anesthesia and Pain Medicine recommends keeping the LAST checklist available in any area where high doses of local anesthetics are used. A study using high-fidelity simulations of medical management tasks demonstrated

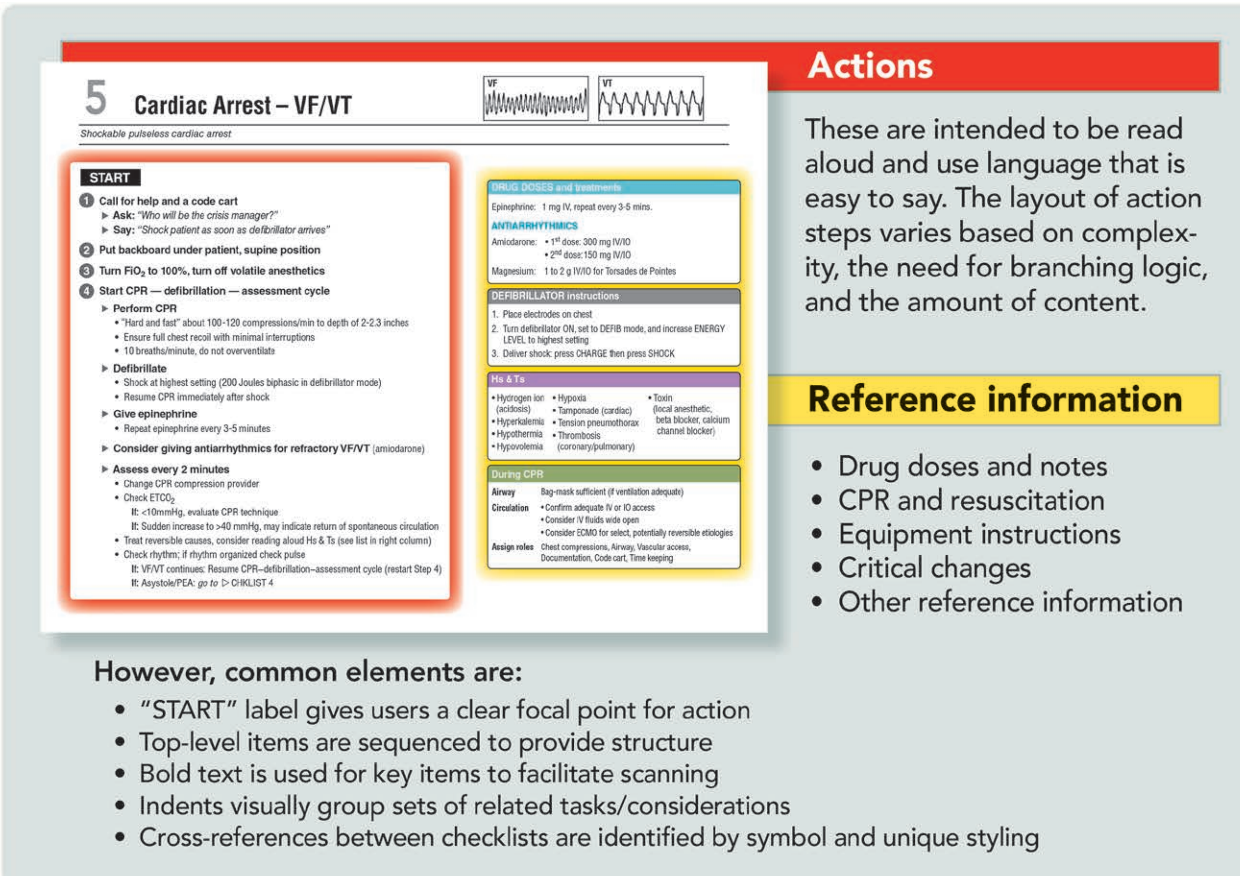

Fig. 1. Illustrative notes on the graphic design and recommended use of operating room crisis checklists from Brigham and Women's Hospital, Harvard Medical School, and Ariadne Labs.

that when the LAST checklist was utilized, there was better treatment, including proper ACLS protocol and more appropriate use of intralipid.[67] This is an example of how a modification of ACLS protocols allows for more specific, etiology-based resuscitation. Interestingly, there was higher knowledge retention 2 months later in the checklist group. This checklist has since been revised, illustrating that checklists are dynamic tools that require modification based both on local institutional differences and on temporal changes in clinical evidence.[30] The editorial accompanying this article emphasized the importance of using checklists and simulation for training.[68]

The Society for Pediatric Anesthesia (SPA) developed a cognitive aid for pediatric critical events that consists of 27 checklists.[69] A recent simulation-based evaluation compared the use of a paper to an electronic version of the SPA checklists by anesthesia trainees.[70] Interestingly, even though trainees had already been somewhat exposed to the checklists and had favorable opinion of their content and relevance in clinical practice, close to a third assigned to use cognitive aids did not use them. Lack of familiarity with the format led to frustration with use. Anesthesia trainees preferred paper over an electronic version, because of concern regarding technology barriers. The authors concluded that more simulation-based training with the use of cognitive aids is needed to make them more usable, as suggested by the conceptual framework for emergency manuals implementation.[60,63]

The Society for Obstetric Anesthesia and Perinatology developed a consensus statement on the management of cardiac arrest in pregnancy, which recommends that a checklist emphasizing key tasks be immediately available.[71] It also recommends that the code leader assigns a "reader" to read aloud the key steps from the checklist. In a simulation-based study of malignant hyperthermia and maternal cardiac arrest scenarios, the use of a checklist reader was more likely to lead to completion of all critical steps during an emergency than when no reader was utilized.[72] The 2015 guidelines for ACLS include a scientific statement from the American Heart Association about cardiac arrest in pregnancy.[73] The American Heart Association encourages institutions to create point-of-care checklists to be used during obstetric crises including maternal cardiac arrest. Globally, there are many anesthesia organizations supporting the use of emergency manuals or crisis checklists and linking to relevant resources: for example, the Anesthesia Patient Safety Foundation,[74] the American Society of Anesthesiologists (Chapter 6 of the *Manual for Anesthesia Department Organization and Management* describes resources and provides links),[75] the European Society of Anesthesiology

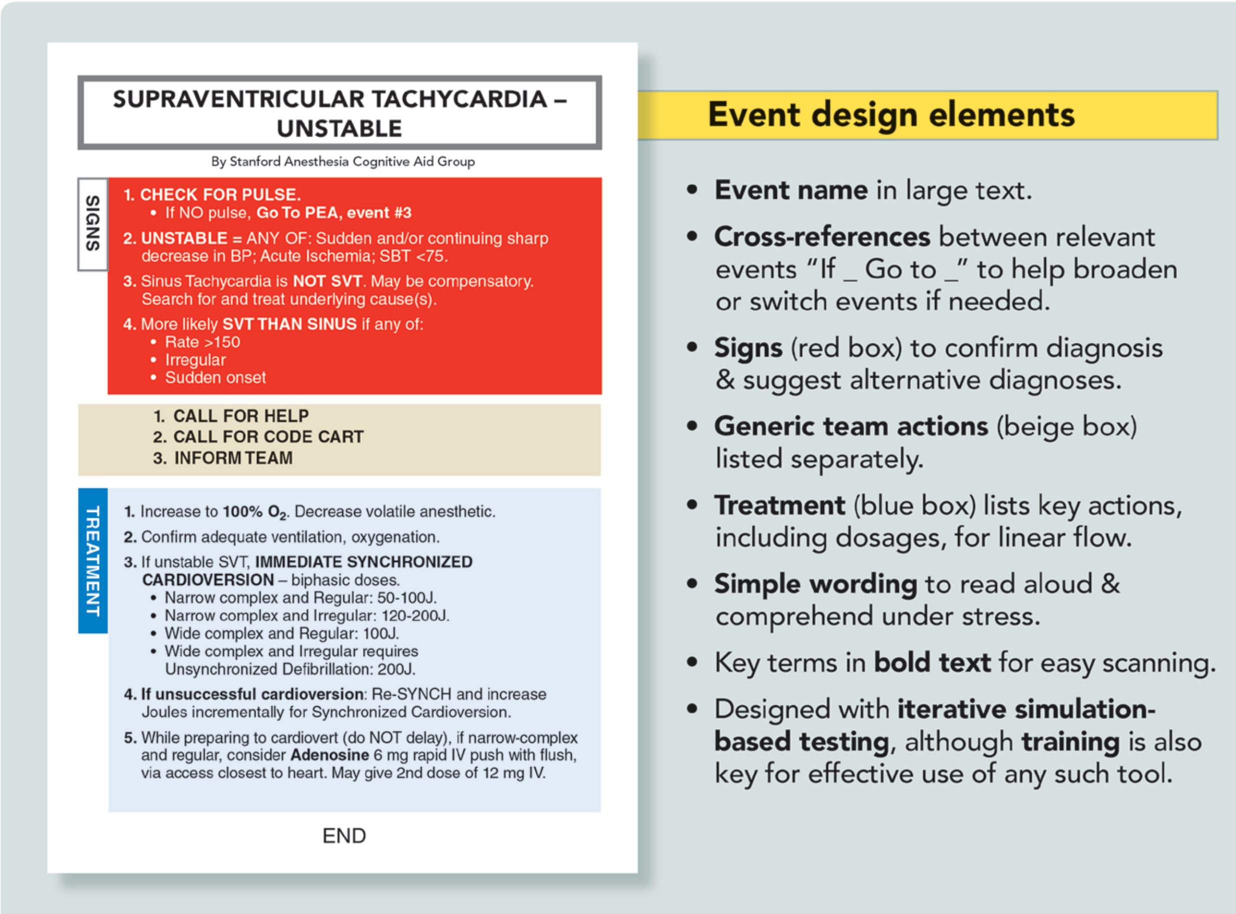

Fig. 2. Graphic design of an event from the Stanford Emergency Manual: Cognitive Aids for Perioperative Critical Events.

(Emergency Quick Reference Guide),[76] the Colombian Society of Anesthesiology and Resuscitation,[77] and both major Chinese anesthesia societies.[78] More institutions and organizations have adapted available tools or created their own.

Part III: Future Directions, Unanswered Questions, and Current Efforts for Clinical Implementation

There has been little work investigating the best methods to incorporate crisis checklists and emergency manuals into everyday practice; many questions remain unanswered: (1) What is the optimal format for organizing them? (2) Where should they be located? (3) When and by whom should they be introduced during a crisis? (4) Who should read and inquire about the items during an emergency? (5) What kind of training is needed to ensure that they are used effectively and how often is refresher training needed? (6) What can be understood about the resistance of some practitioners to utilizing crisis checklists? (7) What are effective processes for implementation in various perioperative settings?

From simulation-based trials, we believe that there is sufficient collective evidence to conclude that using a well-designed cognitive aid will lead to substantially fewer missed critical steps than would working from memory alone in crisis situations. Nonetheless, preparing for crises still requires training to attain competence in managing the event and effectively using a cognitive aid. The first several steps in responding to an emergency may need to be done immediately, without the use of a cognitive aid. By doing so, we are "buying time" to retrieve the checklist and then use it to help the team provide coordinated, evidence-based care during rare crises. The next priorities are understanding effective checklist implementation and how best to use them in clinical practice.

Like many healthcare innovations, these tools will not implement themselves, nor jump off the walls during crises. Changing human behavior, particularly of entire groups and systems, is challenging. Four factors have been suggested as being important for successful implementation of emergency manuals: create (or modify an existing tool), familiarize, use, and integrate.[60] Drawing upon the broader implementation literature in healthcare will help in guiding clinical implementation efforts toward success, with several recent publications presenting this extensive literature for clinical implementers of innovations and quality improvement leaders.[79–81] The first two[79,80] developed chronologic implementation guides, dividing the implementation process into discrete broad phases and important components within each. In contrast, the Expert Recommendations for Implementing Change group developed a detailed compilation of 73 specific implementation strategies, actively vetted in multiple rounds by an expert group of clinician implementers and implementation researchers.[81]

Among the many lessons we have collectively found particularly relevant for implementing this innovation are the importance of local leadership support; interprofessional implementation teams; achieving buy-in from diverse clinical opinion leaders and understanding any concerns; local customization; and training clinicians in the tools' existence, rationale, and use. Specific tips for each of these are contained in the references above[60, 79-81] and in the Supplemental Digital Content (http://links.lww.com/ALN/B472).

Emergency Manuals Implementation Collaborative

The implementation sciences promote the role of leadership buy-in.[82,83] The 1986 JAMA article promoting standards for patient monitoring during anesthesia was written by leaders in anesthesiology,[84] and the first sentence of their article stated: "Physicians traditionally have resisted standards of practice that prescribe specific details of their day-to-day conduct of medical care." Despite the growing evidence in favor of crisis checklists and emergency manuals, there is no guideline for crisis checklists or emergency manuals of any kind to be universally available or used in medical care.[54]

Leaders of multiple efforts to develop and implement cognitive aids formed the Emergency Manuals Implementation Collaborative (EMIC) to publicly share resources and further research on effectiveness and how best to implement and use emergency manuals. EMIC fosters the dissemination and effective use of emergency manuals to enhance patient safety with a primary focus on perioperative crises through shared principles throughout healthcare fields. The primary goals of EMIC are to encourage the use of emergency manuals in clinical practice and to build a community to share tools, overcome barriers, and facilitate implementation of emergency manuals. Although there is no clear evidence at this point that one design is better than another, operating room providers should consider use of cognitive aids for emergencies in their clinical practice in preference to not using any tool. The results of local use should be monitored and be subject to a process of continuous improvement. Published resources for training include curricula and videos on why and how to use emergency manuals.[85,86] More resources, including links to many of the above referenced tools, are available on the EMIC website (http://www.emergencymanuals.org).

Conclusions

Cognitive aids have been demonstrated to work to counter the effects of stress, ineffective teamwork, and inability to recall all evidence-based actions required for the optimal response in rare events. Our hope is that effective training and implementation strategies will lead to a perioperative culture that trains for and encourages appropriately using cognitive aids in conjunction with good teamwork and judgment and thus further reduces preventable perioperative adverse events. Despite the widespread dissemination of tools (more than 200,000 downloads of Stanford, Ariadne, and SPA tools combined) and multiple early-adopter implementing institutions, more research is needed to further assess the impact of implementation strategies and clinical use of emergency manuals.

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