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Cognitive Support to Promote Shared Mental Models during Safety-Critical Situations in Cardiac Surgery (Late Breaking Report)

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Abstract

To address the, currently unmet, need for intraoperative safety-critical cognitive support in cardiac surgery, we have developed, validated, and implemented a series of customized checklists to address intra-operative emergencies, using a simulated operative setting. These crisis checklists are designed to provide cognitive and communication support to the operative team to reduce the likelihood of adverse events and improve adherence to best-practice guidelines. We recruited a number of content specialists including members of the hospital safety network and intraoperative cardiac surgery team members, and utilized a Delphi consensus method to develop procedure-specific guidelines for select intraoperative crises. Cardiac surgery team members were subsequently trained on utilizing the developed checklists, performed operative simulations, and were surveyed to determine checklist facility and effectiveness. We developed and validated five checklists for the following cardiac surgery crisis scenarios: (a) Cardiopulmonary Bypass Failure; (b) Systemic Air Embolism; (c) Venous Air Lock; (d) Protamine Reaction; Heparin Resistance. Upon initiation of the crisis management, a crew resource management approach was triggered. A member of the operative team was designated as the “reader” for each scenario to guide the team through the process. After training, 89% of operative team members surveyed indicated that they would like the crisis checklist to be used if they had one of these events occurring to them.

Crisis management challenges members of the cardiac surgery team in reasoning accurately and according to best practice during periods of high cognitive workload and psychological stress. These crisis checklists were developed, validated, and simulated with the goal of supporting human performance and shared mental models in the clinical setting.

Keywords

shared mental models; cardiac surgery; patient safety; cognitive support

I. Introduction

The cardiac surgery operating room (COR) is among the most complex medical environments, requiring effective coordination of and communication between several medical professionals. As these procedures are high risk, cardiac surgery adverse events are highly consequential, and the high-stress, high workload intraoperative environment creates a setting particularly vulnerable to human error.

Several quality improvement initiatives have been introduced to reduce surgical adverse events, including surgical safety checklists, initially described by Gawande and colleagues [1]. They have since been incorporated into patient safety protocols in many hospitals, and have reduced postoperative patient morbidity and mortality by improving teamwork and coordination of care [2]. However, despite the widespread implementation of preoperative safety checklists, there is an unmet need for intraoperative crisis management checklists to improve safety behaviors and clinical outcomes in time-critical scenarios. Previous investigation by *Gurses* and colleagues reported that communication-related hazards present in the COR are drivers of reduced patient safety, especially during psychologically stressful situations, and often drive noncompliance with best-care practices [3].

A number of situations susceptible to error occur regularly in the COR, which include manipulation of the cardiopulmonary bypass circuit and patient systemic anticoagulation. In order to avoid error, these situations require careful interaction between surgical team members and between team members and surgical equipment. Inevitably, though, communication breakdowns and surgical flow disruptions occur at rates between 11 and 17 per hour during cardiac surgery [4, 5], and a regimented error protocol to support cognitive workload may help reduce adverse events that result from surgical error.

We have developed, validated, and implemented, in a simulated setting, a series of customized checklists to provide cognitive support to the Cardiac Surgery Team (CST) during operating room emergencies, with the goal of decreasing the likelihood of serious harm and improving adherence to accepted safety processes.

II. Approach

The Delphi consensus method has previously been utilized in a number of clinical investigations to develop synoptic operative reports and describe prescription protocols [6,

7]. We utilized a similar approach to develop our crisis checklists. This project was reviewed and approved by the Institutional Review Board.

We gathered a team of interdisciplinary content specialists from Cardiac Surgery, Cardiac Anesthesia, Perfusion, Pharmacy, Human Factor Engineering, Operating Room Operations, and Hospital Patient Safety. Using a three-iterative modified Delphi consensus method, these content specialists developed guidelines for what should be addressed by the crisis checklists, accompanied by appropriate evidence and rationale, and determined the procedure-specific process measures to be incorporated. In the first round, cardiac surgery content experts (3 board certified surgeons, one cardiac surgery resident) developed 5 emergency checklists for critical intra-operative scenarios. Once developed, a second round, incorporating the remainder of the aforementioned healthcare professionals, was utilized to address protocol accuracy, simplicity of communication, and protocol facility. After revision of the protocols following the second meeting, a third meeting was held to rate and evaluate the generated checklists using a 9-point Likert scale, with consensus defined as 70%.

Following creation of the checklists, members of the COR team received crisis checklist training. Team members were oriented to the format of the checklists, outlining the location of key troubleshooting information, and were instructed on how to initiate the protocol. Following training, team members were subject to 5 simulated scenarios, each reflecting one of the checklists. An anonymous survey was administered to the members of the CST following completion of the simulation, utilizing a 5-point Likert scale.

III. RESULTS

We developed and validated five checklists for the following cardiac surgery emergency crisis scenarios: (a) Cardiopulmonary Bypass Failure; (b) Systemic Air Embolism (Figure 1); (c) Venous Air Lock; (d) Protamine Reaction; (e) Heparin Resistance. These checklists reflect high stress, high cognitive workload situations, with which most surgeons have limited experience. All team members were trained on how to initiate the crisis checklist. During the simulations, upon initiation of one of the checklists, a crew resource management approach is triggered. This resulted in a broadcast message to the entire CST using our hospital voice-activated paging system (Vocera). This would alert additional perfusion, nursing, and anesthesia staff to assist with complex scenarios.

The professional characteristics of the simulation participants are given in Table 1, and 89% of participants had > 6 years of cardiac surgery experience. Upon checklist initiation, a member of the CST was designated as the “reader” for each scenario, responsible for guiding the CST through the process.

After training and simulation, 89% of CST members surveyed indicated that they would like the crisis checklist to be used if they had one of these events occurring to them. All (100%) of participants felt the checklist “would help provide safer patient care” (Table 2).

IV. Conclusions

There has been a recent paradigm shift towards human factors approach in determining means to reduce adverse events in the operating environment [8–10]. This can be attributed to other professions, such as the aviation industry, where effective communication and teamwork enhancement are critical components of safety. In this investigation, we developed, validated, and simulated 5 emergency crisis scenario checklists to address the currently unmet need for intraoperative cardiac surgery protocols to facilitate cognitive workload management in high-stress situations.

Several investigations have demonstrated that preventable errors are typically not related to the technical aspects of surgery; rather, they are a result of cognitive, system, or teamwork failures [3]. For example, *El-Bardissi* and colleagues demonstrated that team members who were familiar working together demonstrated significantly reduced teamwork failures, and that there was a strong correlation between teamwork failure and subsequent technical error [9]. To date, a number of error reduction strategies have been designed to improve teamwork, and have demonstrated efficacy in reducing mortality across a number of surgical specialties [10, 11]. Team-based training protocols, surgical checklists, site-verification processes, preoperative time-outs, and surgical briefings are examples of these cognitive tools [11]. However, dedicated intraoperative tools remain unavailable, though are critical in the COR. These emergency checklists challenge members of the CST to reason accurately by recognizing and acknowledging the crisis situation at hand, and act according to best practice guidelines during periods of high cognitive workload. Checklists were developed using the literature available one each topic. As these scenarios are fairly uncommon, literature review was mainly limited to case reports. However, the infrequent nature of these complications makes them unfamiliar for CST members, and a regimented protocol may help facilitate positive outcomes and reduce adverse events.

These crisis checklists were developed, validated, and simulated with the goal of supporting human performance and optimal team mental models. Though our investigation is limited to select faculty at a single center, further investigation into evaluating their usefulness and practicality in the clinical setting is warranted, and will likely require simulation-based training.

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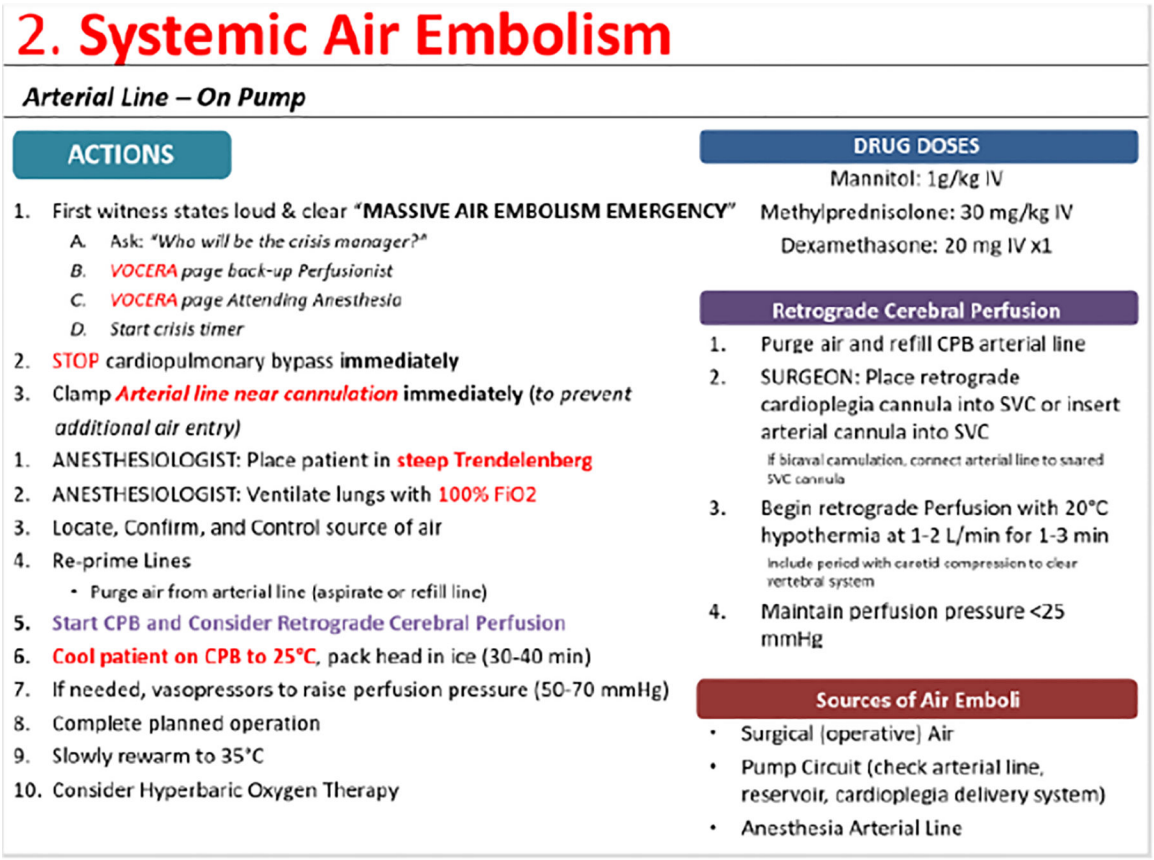

Fig. 1.

Crisis checklist developed for systemic air embolism while on cardiopulmonary bypass. Troubleshooting directives are on the right, crisis protocol is on the left.

TABLE I.

Professional Characteristics of Participants

Position	Participants (n = 9)	Years of Experience in Cardiac Surgery (%)				
	n (%)	>1	1 to 5	6 to 10	>10 to <15	>15
Surgical Attending	1 (11.2)	0	0	0	100	0
Anesthesia Attending	0	0	0	0	0	0
Operating Room Nurse	4 (44.1)	0	0	25	0	75
Perfusionist	4 (44.1)	25	0	0	25	50

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TABLE II.

Participants' perception of crisis checklists, with responses across all checklist scenarios

Survey Statement	Response, mean [SD]
The crisis checklists are clear and easy to read	4.9 [0.3]
The font on the crisis checklists are clear and easy to read	5.0 [0.0]
The crisis checklists are realistic	4.6 [0.7]
The crisis checklists do not disrupt the clinical flow of the operative emergency	4.9 [0.3]
The crisis checklists help me feel better prepared during emergencies	4.7 [0.7]
I will use these checklists if presented with this operative emergency in real life	4.9 [0.3]
If I were having an operation that had one of these emergencies, I would want a checklist to be use in my case	4.8 [0.7]
The crisis checklists will help me provide safer patient care	5.0 [0.0]
I learned new information during this in-service that I would not have learned otherwise	4.4 [0.7]
The knowledge gained from this in-service will be helpful to me in my practice	4.0 [0.3]

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