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Threat and error management for anesthesiologists: a predictive risk taxonomy

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Abstract

Purpose of review—Patient care in the operating room is a dynamic interaction that requires cooperation among team members and reliance upon sophisticated technology. Most human factors research in medicine has been focused on analyzing errors and implementing system-wide changes to prevent them from recurring. We describe a set of techniques that has been used successfully by the aviation industry to analyze errors and adverse events and explain how these techniques can be applied to patient care.

Recent findings—Threat and error management (TEM) describes adverse events in terms of risks or challenges that are present in an operational environment (threats) and the actions of specific personnel that potentiate or exacerbate those threats (errors). TEM is a technique widely used in aviation, and can be adapted for the use in a medical setting to predict high-risk situations and prevent errors in the perioperative period. A threat taxonomy is a novel way of classifying and predicting the hazards that can occur in the operating room. TEM can be used to identify error-producing situations, analyze adverse events, and design training scenarios.

Summary—TEM offers a multifaceted strategy for identifying hazards, reducing errors, and training physicians. A threat taxonomy may improve analysis of critical events with subsequent development of specific interventions, and may also serve as a framework for training programs in risk mitigation.

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Keywords

error management; medical education; patient safety; risk management; simulation

Introduction

Patient care in the operating room is a dynamic interaction that requires cooperation among team members and reliance upon sophisticated technology. The operating room itself is a complex environment that is intolerant of errors. In many cases, adverse events are caused by multiple, small errors, which on their own may have no impact, but can combine to become life-threatening. During any given procedure, patients with unique comorbidities are exposed to a wide range of physiologic stresses and surgical insults, cared for by ad-hoc interprofessional teams with varying levels of training. As part of an ongoing effort to improve patient safety, numerous techniques have been adopted from the aviation industry in order to decrease the frequency and severity of critical events caused by human error [1,2].

Reducing the Risk of Errors

Most human factors research in medicine has been focused on analyzing errors and implementing system-wide changes to prevent them from recurring. Addressing these problems should decrease the probability that the same event, or events with similar cause, will occur in the future. For example, Orser *et al.* [3&] propose that medication errors remain a leading cause of adverse events in anesthesia. This group identifies anesthesiology as an ‘ODAM’ specialty because anesthesiologists order, dispense, administer, and monitor the effects of potentially dangerous drugs while working in a complex, dynamic environment. Orser then discusses how steps such as color-coding, labeling, medication reconciliation, automated identification through bar coding, and reporting adverse incidents can reduce the risk of medication errors. Many institutions have focused on implementation of checklists and root cause analysis of adverse events. Pronovost and others have recommended the institution of checklists before beginning high-risk medical procedures, and this strategy can help to reduce the risk of an adverse event [4&&]. In one study, Low *et al.* [5] identified departure from induction room, arrival in the operating room, departure from operating room, and arrival in the post-anesthesia care unit as being critical junctures in patient care. ‘Flow checklists’ were developed for each of these high-risk points, and a challenge and response system was used during their execution. The group was able to prevent the omission of 24 critical tasks.

Root cause analysis of an adverse event ideally results in a list of systemic problems, but despite its nearly universal use in healthcare, root cause analysis has significant drawbacks. The use of root cause analysis is not standardized, nor is its use consistent between organizations. In many cases, hospitals use root cause analysis in order to determine who made a mistake instead of determining the factors that ultimately caused the error. Too often, the causes identified by root cause analysis are nonspecific, and therefore cannot be used to develop a realistic correction plan. Lastly, there is no standardized nomenclature that would permit analysis of errors that recur across the organization [6&&].

Threat and Error Management

Over the past decade, the aviation industry has adopted a new paradigm, called threat and error management (TEM) [7]. TEM focuses not only upon error prevention, but also upon mitigating the likelihood of patient harm resulting from an error that has occurred. TEM is an overarching safety concept that describes adverse events in terms of risks or challenges that are present in an operational environment (threats) and the actions of specific personnel that potentiate or exacerbate those threats (errors). Most adverse events can be described in those terms. A threat is an event that is outside the control of the operator, which can decrease the margin of safety and requires action in order to prevent further incident. Errors are physician or treatment team actions that deviate from intentions in a way that increases risk. An error can, in turn, lead to an undesired state, in which options are limited and an immediate response is necessary in order to prevent an adverse event. This technique evolved from Line Operations Safety Audits (LOSA), initially developed by University of Texas and Delta Airlines in 1994. The LOSA program was initially designed to evaluate crew resource management behavior on the flight deck, but was expanded to address the other types of errors, and how these were managed. This technique enabled the observers to determine the cause of an error, the response to the error, who detected the error, and the ultimate outcome.

The goal of safe practice is to identify likely threats in the operating environment, and the associated unique set of actions. The next step is to then mitigate those threats, as well as to trap and correct any erroneous actions by the team members. TEM focuses on predicting risk conditions that facilitate or provoke errors. This may allow proactive management of latent errors or error-producing situations, in contrast to root cause analysis, which responds to an adverse event that has already occurred. The utility of TEM has been demonstrated for analyzing accidents, incidents, and safety reports [8,9]. It also has been adapted for developing training programs that teach pilots, dispatchers, and mechanics to identify and mitigate threats before a hazardous situation can occur. A critical component of TEM is the assumption that threats and errors cannot always be prevented; threats and operator errors are a routine occurrence that must be detected and mitigated. In this sense, aviation and medicine are similar in that operator errors are endemic and an expected result of human activity.

Helmreich, [10] who originally developed the ideas behind TEM, suggested in a review article that it might be applied to medical practice, explaining how TEM could be used to identify latent factors that could lead to an error. This review also offered an example of how TEM could be used to analyze a catastrophic event and stressed the importance of using an adverse event reporting system to gather information about conditions that produce errors. Helmreich further suggested that TEM could be used as a template for analyzing critical events in medicine and improving patient safety, and demonstrated its use in the analysis of an anesthetic mishap. This analysis revealed nine discrete errors that led to the death of an 8-year-old boy. Analyzing two representative errors revealed technical limitations of patient care equipment and multiple failures to act on previous reports of unsafe and unprofessional behavior.

The advent of several national adverse event reporting systems [e.g., the Anesthesia Quality Institute's Anesthesia Incident Reporting System (AIRS) – www.aqiairs.org] makes it possible to develop a threat taxonomy and to apply TEM to anesthetic practice. The anesthesiology threat taxonomy that this group is currently developing uses TEM to identify and proactively manage high-risk situations. Used in this context, TEM identifies potential threats so that risk can be mitigated by anticipating errors before the margin of safety is reduced [11]. For example, an equipment anomaly may lead the anesthesiologist to make a clinical decision based upon an erroneous physiologic parameter. Unfamiliarity with the operating mode of an infusion pump (listed under ‘Equipment Mode Confusion’) might lead to a patient receiving an incorrect dose of a drug. A catalog of such error-producing situations can potentially be used to detect and mitigate errors and as a method of classifying adverse events.

Applying Threat and Error Management to Anesthesia Practice

We hypothesize that TEM can be used as a multifaceted strategy that will allow healthcare providers to recognize potential threats to patient safety and proactively manage hazards before an operator error causes an injury. The first step toward predicting the points at which errors and violations can occur is the creation of a systematic description of anesthetic practice. Phipps *et al.* [12] have developed a hierarchical task analysis, after which they applied a human error taxonomy to each step, creating descriptions of the errors that could take place. The study used two specific frameworks to determine the type of information that an anesthesiologist would need in order to complete a task, and to analyze the cognitive activity that takes place during the planning and delivery of an anesthetic. This information can then be used to predict situations in which errors could potentially occur. The authors hypothesize changes in training, work-flow, or process resulting from the application of these frameworks could potentially reduce errors.

Oken *et al.* developed a technique for collection of nonroutine events, which are defined as any aspect of clinical care that is perceived by the clinicians or observers as a deviation from optimal care based on the context of the clinical situation. Their tool has a high rate of compliance, facilitates discovery of latent conditions, and provides information that can be used to develop strategies for intervention. On the basis of the work of Phipps and Oken, we have developed a novel ‘threat list’ for each phase of an anesthetic and surgical procedure. An abbreviated version of this threat list is displayed in Table 1.

After reviewing the list of threats that had been developed for the Aviation Safety Information Analysis and Sharing System (ASIAS) and other anesthesia taxonomies, our group developed a task list for a typical anesthetic and surgical procedure that takes place in an operating room. This list included preoperative and postoperative phases of care as well as events that would take place in the operating room. Any factor that could produce an undesirable patient state or that could create an error-producing situation was defined as a threat for the purposes of this study. Three experienced anesthesiologists (K.J.R, M.P.S and V.K) then constructed a list of threats for each segment of surgical anesthesia. Some threats may occur at any time during the procedure, and these were placed in a separate category. Others (e.g., surgical bleeding) could occur at any point after a given segment, and these were also identified. The threats listed in this taxonomy can be considered as error-producing situations that must be managed in order to prevent a decrease in the margin of safety. This taxonomy may improve analysis of critical events with subsequent development of specific interventions. It may also serve as a framework for training physicians in risk management.

After identification with TEM, specific threats and associated errors can be used to guide the content of educational programs or other quality improvement initiatives at individual institutions and throughout the profession. The airlines have successfully used this technique to improve safety: TEM-based line oriented safety audits, often accompanied by analyses of incident reporting and flight data monitoring, identify the most frequent threats and the most common errors for each phase of flight. Pilot training is then adapted to these events, and information is typically shared among airlines using the Federal Aviation Administration's ASIAS program. Physicians may be able to use a similar process to determine the incidence of threats and errors specific to their practice, after which new training programs and other interventions can be implemented. For example, a training program may offer a course on alternative airway management devices in response to an increasing number of patients with an unexpected difficult airway. Although the airline LOSA program makes use of a cadre of observers or auditors situated in the cockpit and trained to a common standard, this task may also be accomplished by the healthcare provider managing the patient, who can note threats and errors as these occur (time permitting) or at the end of the workday. That is, self-reports or records generated by patient care processes can document threats and errors. Training programs can use a TEM-structured review as a framework for evaluating the performance of and providing feedback to resident physicians. Error-producing conditions identified by TEM, and strategies to mitigate them, could ultimately be adopted as a core component of medical education.

TEM allows trainees to learn about latent conditions that can, under the right circumstances, ultimately lead to an adverse event [13]. It can be used to teach trainees how to spot these conditions and to act proactively to prevent an error from occurring. One interesting study used survey that was administered to pilots who were discussing adverse events that occurred while flying. The authors conclude that narrative stories can be collected and used as a source of information for TEM training, and that these experiences can be used to supplement operational experience [14&&]. Simulation can be used as a vehicle for identifying risk conditions and developing preventive strategies before real patients are harmed. Identified threats can be introduced into simulations of routine care, physician reactions examined, procedural solutions experimentally introduced, and the effectiveness of these interventions measured.

TEM has yet to be validated in a clinical or simulation setting, and has only been applied in a retrospective analysis of reported adverse outcome cases. Expert consensus is that the majority of potential and relevant error-producing situations have been included, and that the majority of events can be classified within the framework. Future studies should include incremental changes in the threat taxonomy by additional anesthesiologists, replication of the technique to other medical settings, and application to analysis of incidents and near misses. The AIRS may adopt this threat taxonomy, and changes to it will be guided by the events that are entered into the system.

The taxonomy described here has several limitations: it was developed primarily for anesthetics that are given in the operating room for patients who are undergoing a surgical procedure. It was developed as a generic model by a group of experts, and is not a comprehensive predictor of every error-producing situation that might occur at every institution. However, standardization of categories better allows for consistency in data analysis, evaluation, and comparative studies. Further, anesthesiologists' workflow is usually procedural in nature and bears many similarities to the aviation environment for which TEM was designed. Additional study is, therefore, required to determine whether TEM is broadly applicable to the practice of medicine. Lastly, this approach is predicated on the reliable use of event reporting systems so that emerging threats and error trends can be identified.

Conclusion

Anesthesiologists can adopt practices suggested by TEM to supplement physician education and improve patient safety. The anesthesiology threat list described here is a novel way of classifying and predicting the hazards that can occur in the operating room, and offers a paradigm for further research, training, and education. A preliminary validation suggests that this threat list has value for early identification of error-producing situations and as a method of classifying adverse events. It is hoped that adopting TEM will reduce the number of critical events in the operating room and improve patient safety.

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Papers of particular interest, published within the annual period of review, have been highlighted as:

◆ of special interest

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Key Points

- TEM is a safety concept that describes adverse events in terms of risks that are present in an operational environment and personnel actions that potentiate or exacerbate those threats.
- TEM may allow healthcare providers to recognize and manage threats to patient safety before an operator error causes injury.
- In addition to risk identification and stratification, TEM can be used to develop training programs and for resident feedback.

Table 1

Preliminary threat taxonomy for a routine general anesthetic

Phase of anesthesia	Threat	
All phases	Airway	Obstruction
		Dislodged airway device
		Airway device anomaly
		Laryngospasm (unprotected airway)
	Allergy/anaphylaxis/drug reaction	
	Anesthesia gas machine anomaly	Electronics failure
		Stuck valve
		Airway circuit anomaly
		Ventilator anomaly
	Blood transfusion	Incorrect units brought to the bedside
		Mislabled blood products
		Transfusion reaction
	Cardiovascular	Tachycardia
		Bradycardia
		Asystole
		Failure
		Ischemia
		Hypertension
		Hypotension
	Communication failure	
	Drugs	Unavailable
		Misfilled syringe/misprepared drug/incorrect location; infusion pump malfunction; infusion pump drug library error
	Equipment mode confusion	Anomaly
	Inadequate training	Distraction
	Information technology	Unavailable
	Inadequate training	Overdose
	Local anesthetic toxicity	Intravascular injection
		Catheter migration
	Medical gases	Pipeline/equipment malfunction
		Standby medical gas insufficient quantity
	Production pressure	
	Pulmonary	Desaturation (unknown cause)
		Edema
		Bronchospasm
		Pneumothorax
Notification	Room design	

Phase of anesthesia	**Threat**	
	Sepsis	
	Staff unavailable	
	Incorrect surgical procedure or procedure change	
	Medical record unavailable	
	No notification/incorrect personnel	
Day of surgery	Drugs not available*	
	Equipment not available*	
	Equipment missing or anomaly*	
	Rushed or delayed preparation	
	Schedule change/personnel change*	
	Support staff unavailable*	
Patient in holding area	Additional information needed/missing	
	Missing, incomplete, unreliable patient information; patient arrives late	
	Patient uncooperative	
	Unable to communicate with patient	
Patient in operating room	Patient ID problem	Missing name band
		Similar patient name/medical record number
	Unavailable personnel*	Anesthesiologist
		Surgeon
		Other staff
Induction	Monitoring equipment anomaly*	Incorrect default BP measurement interval
	Monitoring equipment unavailable*	Missing or incorrect blood pressure cuff
		Missing or incorrect ECG electrodes; missing incorrect pulse oximeter probe
	Laryngospasm	
	Patient characteristic*	Allergy
		Coronary artery disease
		Critical aortic stenosis
		Full stomach
		Hypovolemia
		Malignant hyperthermia
		Medication reaction
		Other comorbidity
Airway management	Difficult airway	Airway injury
		Airway tumor
		Patient anatomy
	Equipment unavailable or anomaly; inadequate training	
Vascular access	Catheter malfunction	

Phase of anesthesia	Threat	
	Equipment unavailable or anomaly	
	Inaccessible site	
	Missing or inadequate supplies	
	Patient factors	Dehydration
		Difficult access
		Multiple prior attempts
		Restricted limbs
		Scars or missing limbs
Invasive monitors	Equipment anomaly	
	Equipment unavailable or anomaly	
	Inadequate training	
	Missing or inadequate supplies	
	Patient factors	Dehydration
		Hypotension
		Multiple prior attempts
		Peripheral vascular disease
		Restricted limbs
		Scars or missing limbs
Time-out	Nonparticipating staff	
	Prospective memory	
Surgical procedure	Blood loss*	Expected
		Unexpected
	Iatrogenic injury	Organ injury
		Patient position
	Light anesthesia*	Hypertension
		Laryngospasm
		Patient movement
Wound closure/surgery ends	Attending surgeon unavailable	
	Occult bleeding*	
	Residual neuromuscular blockade	
	Respiratory depression	
Emergence	Difficult emergence	Coughing
		Bronchospasm
		Hypertension
		Combativeness
	Failed extubation*	Respiratory depression
		Stridor
		Bleeding
		Obstruction

Phase of anesthesia	Threat	
	Nausea and vomiting*	
	Altered mental status*	
Transport	Monitoring	Equipment unavailable
		Anomaly
		Inadequate
	Oxygen delivery failure	Empty tank
		Misfilled tank
		Breathing bag anomaly
		Ventilator anomaly
	Stuck elevator	
	Inadequate staffing	
	Patient care area inaccessible	

*Threats that may be present at any time after a specific phase.