Perspectives

Illuminating the Black Box of Surgery

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Everyday, surgeons are reminded about the potential impact of their actions, both positive and negative, on a person's life. In the operating room, the difference between a successful and debilitating outcome is often not more than the result of a single wayward movement of the hand. Despite the high stakes, many surgeons are permitted to carry on for the length of their careers without any recertification or even observation of their intraoperative performance. While all surgery will forever carry a certain adverse risk for reasons that are often outside of the surgeon's control, this should not quell our desire to constantly improve our outcomes for the benefit of our patients. Through analyzing and understanding the events and circumstances that lead to adverse patient outcomes, we can systematically target and improve deficiencies of skill and ability. This quality improvement (QI) mind-state is certainly not unique to medicine or surgery, and many of the initiatives described here draw their inspiration from non-medical sources.

Understanding human error and the role of 'human factors' in adverse events has been a central principle in aviation for over 4 decades.[1] The concept of the 'black box' was borne from this industry, specifically from the idea that all safety incidents deserve scrutiny to prevent repetition. The primary role of these devices is to amalgamate and record data from multiple inputs including navigation equipment, barometer and other sensor information, and communications between pilots and ground crew.[1] Analysis of airline black box data revealed that human factors were responsible for over 70% of adverse cases.[1] This and other impactful analyses of aviation data led to the development of the Crew Resource Management (CRM) concept. CRM compels users to utilize both human and technological sources of information during a flight to ensure 'safe operations'.[2] In essence, CRM speaks to the need to combine technical and non-technical skill (communication, leadership, decision making, etc.) in order to optimize outcomes. Furthermore, the CRM-style approaches to individual and system safety has been successfully implemented in other high-stakes industries, such as the nuclear energy sector.[2] Consequently, the success of the CRM-style led to the creation of the OR BlackBox© as a means to collect and analyze diverse forms of data in the surgical environment.

On the back of evidence showing that more than half of medical error occurs during surgery,[3] the Institute of Medicine released a report in 2000, entitled *To Err is Human*.[4] The purpose of this document was to spur the creation of strategies to prevent adverse outcomes across the healthcare spectrum. There has been some success in adopting these strategies in surgery, namely the operative safety checklist, which uses a pre-operative briefing style similar to the preflight check used in aviation.[5] Additional methods to uncover the frequency of, and circumstances around, surgical adverse events have been explored, including chart/operative note reviews, surveys, and mortality and morbidity rounds.[4] While this work has further revealed that surgical adverse events are prevalent and often preventable,[6,7] these methods are all retrospective and are prone to bias. Additionally, these methods only demonstrate correlation rather than causation. As a result, this prevents a *root-cause analysis* approach to be taken, which focuses on the chain of events leading up to an adverse event.[8]

The evidence for human involvement in adverse outcomes during surgery is growing. In a seminal study in the New England Journal of Medicine,[9] investigators were able to demonstrate that patient outcomes in bariatric surgery could be predicted by analyzing the objective technical performance of a surgeon. These findings have been replicated in pancreatic surgery, and early evidence from our group shows that global rating of technical performance, and error analysis in gastrectomy and radical prostatectomy is predictive of perioperative and patient-centered outcomes. However, human impact on patient safety goes beyond technical skill, with multiple studies showing a link between operative team communication and leadership measurements and outcomes.[10,11] It is this evidence that necessitates the use of audiovisual capture in the operating room, as only through direct observation of performance can we hope to identify deficiencies in both technical and non-technical skill.[13]

In order to better recognize and examine intraoperative adverse events, the OR BlackBox© was created. This innovation is a comprehensive data collection system that includes both human and environmental operating room factors in a number of analytical processes. Audiovisual inputs include

laparoscopic or endoscopic video, as well as wall-mounted video cameras. These views allow us to analyze both the technical skill of the operating surgeon, as well as the non-technical skills of the operating room team, including nurses and anesthesiologists. Environmental factors are captured through multiple sensors and include decibel level, room temperature, time of day etc. Physiological inputs from the patient are also captured, as recorded by the anesthesia equipment. Future iterations of this technology will include capture of surgeon physiological parameters, to better understand the stress experienced by surgeons around adverse intraoperative events. This holistic data capture approach to surgery closely resembles the aviation black box, and will allow our analysts to perform complex statistical modeling to predict, and subsequently prevent, intraoperative adverse events. The routine capture of intraoperative data will lead to increased individual and organizational awareness of the impact of adverse events in surgery, and will drive further QI initiatives surrounding patient safety. Furthering our understanding of the factors that lead up to and trigger intraoperative errors will allow for a targeted approach to improving patient safety in the perioperative environment.

The few challenges around collecting this data are centered on research ethics, and include consenting patients and the surgical team, and the transfer/protection of patient data. However, working closely with hospital administration and ethicists ensures that patient privacy remains of paramount importance in this data collection and analysis process. In addition, routine collection and analysis of this data has medicolegal implications, as it is feasible that litigators could point to intraoperative video to verify either negligence or competence on the part of the surgeon.

Ultimately, the collection of this data can be used in a multitude of ways. The utility of this technology is really measured by its ability to bring about change, and improve the safety and functional outcomes of our patients. The OR BlackBox© serves as an unparalleled educational source for surgical trainees and surgeons alike. Systematic analysis of surgical procedures allows us to identify which steps of a case are more prone to errors, as well as the stages of a procedure wherein an error will most likely cause an adverse event. This 'error-mapping' gives educators the ability to target specific aspects of a procedure or domains of skill that require additional focus in training and recertification.[13] Improvements in these areas can be addressed systematically as well, through a process termed 'deliberate practice',[14] which utilizes specific goal-setting and task repetition. In addition, the routine capture of both technical and non-technical performance allows for accreditors to base assessments on all aspects of intraoper-

ative ability, rather than clinical knowledge or technical skill in isolation. Finally, an exciting area of surgical quality improvement that is gaining traction is 'peer coaching,' which incorporates concepts from high-level athletics to improve surgeon performance.[15,16] There is already evidence for the effectiveness of coaching using operative video, and the OR BlackBox© represents an unrivaled means of facilitating this type of intervention in training and beyond.

The operating room culture is changing, and with public scrutiny of surgeons continuing to increase,[17] there is a demand from stakeholders to improve the way we understand the role of the surgeon and the operating room team in determining patient outcomes. We have adopted the philosophies and practices of other high-stakes industries, in order to create a systemic culture of safety that minimizes the iatrogenic perioperative morbidity and maximizes patient safety and other important outcome metrics. It is our responsibility as clinicians to continuously strive to improve our performance and our environment to afford the greatest possible benefit to those we care for.

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