Current and Emerging Anesthesia Technology in 2016

Jorge A. Gálvez, MD
2016 Annual Meeting Program Co-Chair
Society for Technology in Anesthesia
Assistant Professor of Anesthesiology and Critical Care
Perelman School of Medicine at the University of Pennsylvania
The Children’s Hospital of Philadelphia
Philadelphia, Pennsylvania

Patrick J. McCormick, MD
2016 Annual Meeting Program Co-Chair
Society for Technology in Anesthesia
Assistant Professor of Anesthesiology
Icahn School of Medicine at Mount Sinai
New York, New York

Allan F. Simpao, MD
Assistant Professor of Anesthesiology and Critical Care
Perelman School of Medicine at the University of Pennsylvania
The Children’s Hospital of Philadelphia
Philadelphia, Pennsylvania

The authors reported no relevant financial disclosures.

This review focuses on emerging technological developments in anesthesiology that are available in the United States and around the world. Much of this review comes from content presented at the 2016 annual meeting of the Society for Technology in Anesthesia (STA), which can be accessed online at www.stahq.org.

Anesthesiologists work in an increasingly complex technological environment inside and outside of the operating room. Every day, they rely on sophisticated devices to provide safe care to patients. Those devices include anesthesia machines, drug delivery systems, physiologic monitors, diagnostic imaging equipment, and electronic health records (EHRs). Device manufacturers and technology startups are continuously introducing devices to improve patient care.

Closed-Loop Systems

Important news in the world of anesthesia technology focuses on the withdrawal of a new device rather than the introduction of one. The Sedasys System from Johnson & Johnson was quietly retired in early 2016. Despite substantial press coverage and promises to reduce the cost of providing propofol sedation for colonoscopies, sales did not grow as expected. Sedasys was a device that only covered propofol sedation in...
specific care scenarios. Automated medication delivery systems, known as target-controlled infusions (TCIs), deliver medications that are based on user input to achieve a specific, predicted drug concentration, and are employed in clinical care across the world. For example, based on a pharmacokinetic mathematical model for propofol, an anesthesiologist can set a target concentration, and the TCI-enabled infusion pump will adjust the infusion rate over time to achieve the set concentration.

The FDA held a workshop in October 2015 to discuss the broader category of physiologic closed-loop controlled devices. The FDA and vendors hope to usher more closed-loop technology through the FDA approval process, but it is not clear when these products will actually arrive in the US market.

Variations of the closed-loop systems include “human-in-the-loop” systems. In these systems, the device notifies the person that an event is occurring and accepts the user’s input to proceed. For example, Edwards Lifesciences is developing perioperative goal-directed therapy algorithms for fluid management based on key physiologic parameters, including hemoglobin, heart rate, oxygen saturation, stroke volume, and oxygen delivery index. A perioperative goal-directed therapy system is designed to notify the anesthesiologist whether the patient is becoming “dry” or “wet” and recommend an intervention for IV fluid administration.

Quality Measurement and Health Information Exchange

Federal quality programs continue to require more data from anesthesiologists. The Anesthesia Quality Institute’s National Anesthesia Clinical Outcomes Registry (AQI NACOR) has collected over 22 million cases since its inception in 2010. Practices that report to NACOR also can submit quality measures. While only 3 of the federal Physician Quality Reporting System measures apply to anesthesiologists in 2016, AQI has authored 22 additional quality measures specific to anesthesiology. AQI is a Qualified Clinical Data Registry and can submit these measures to the federal government for an anesthesiology practice.

Technology to assist with collection and reporting on outcomes data is improving, but the nature of quality measurement means that there is no “silver bullet” program or device to immediately measure the outcomes of an anesthesiology group. The perioperative consult service at Vanderbilt University, in Nashville, Tennessee, used the existing perioperative data warehouse and EHRs to collect outcomes data that showed how a restructuring of perioperative care for colorectal surgery patients improved hospital length of stay and lowered hospital costs.

The Mount Sinai Hospital, in New York City, was able to reduce mortality from sepsis by implementing a custom dashboard in the Epic EHR to alert a designated “sepsis team” when vital signs fell within sepsis parameters. Both of these projects created designated teams to use existing health care records technology to measure and improve outcomes.

Hospitals throughout the country continue to install and improve EHR systems to maintain compliance with the federal Meaningful Use program. One of the main goals of the program is to improve the ability for hospitals to share patient information with each other to facilitate patient care. The Meaningful Use program

Figure 1. Aisys CS (GE Healthcare)
Photo courtesy of GE Healthcare.

Figure 2. Apollo (Dräger)
Photo © Drägerwerk AG & Co. KGaA er.
requires that hospitals and participating providers demonstrate implementation and use of EHRs over 6 years in 3 gradual incremental stages. The final rule for Meaningful Use Stage 3 was published in 2015. Participation in health information exchanges, the regional systems that enable interhospital data sharing, is one of the expectations to demonstrate compliance with Meaningful Use. As such, anesthesiologists can expect to see a change in their daily practice. At press time, the authors have noted an increasing number of patients in our practice who have clinical documents from other institutions that are accessible within the EHR’s pre-anesthesia evaluation system.

Anesthesia Machines

Anesthesia machine manufacturers continue to introduce technological advances in their newest machine models. New technology focuses on patient safety as well as optimizing the efficiency of anesthetic delivery and minimizing anesthetic gas waste. Target-controlled low-flow anesthesia systems automate the fresh gas flow rate and vaporizer settings to achieve a specific end-tidal percentage that is set by the anesthesiologist. The GE Healthcare Aisys CS, the Dräger Apollo, and the Maquet FLOW-i models all have implementations of target-controlled low-flow anesthesia (Figures 1-3).

Each manufacturer continues to explore opportunities to integrate anesthesia machines with hospital information systems, including data sharing with anesthesia information management systems (AIMS) for automatic documentation. Improved connectivity and integration will offer new opportunities to enhance workflow efficiency and patient safety.

Carbon Dioxide Absorber

A novel, lithium-based carbon dioxide (CO₂) absorber offers potential advantages over conventional absorbers. The lithium-based absorber by SpiraLith (Figure 4) is reusable and can be recycled by the manufacturer. This technology offers certain advantages, including no desiccation and no generation of dust or workplace contaminants. However, this absorbent requires some practice adjustments, as it does not visibly change color as it nears the end of its life span. Anesthesiologists must remain attentive to continuous capnography when using SpiraLith to identify expired SpiraLith canisters when inspired CO₂ is greater than zero.

Physiologic Monitors

Accelerometers, magnetometers, and gyroscopes in consumer devices such as smartphones and activity trackers allow for monitoring various aspects of individuals’ daily lives, from exercise to sleep. Medical device manufacturers are exploring the role of wearable devices integrated in physiologic monitors. Research groups such as ORCATECH are integrating wearable devices and motion sensors in patients’ homes to detect cognitive impairment in vulnerable populations, such as older adults.

Wearable devices such as the Medtronic ZephyrLIFE system allow for remote monitoring of ambulatory activity, respiratory rate, heart rate, blood glucose, blood pressure, temperature, weight, and oxygen saturation when incorporated with appropriate monitors. BioStamp Research Connect System by MC10 is a small device approximately the size of 2 electrocardiographic (ECG) leads that records complex physiologic data for up to 36 hours (Figure 5). The device can monitor
patient activity, respiratory rate, single-lead ECG, and surface electromyography. There is potential for growth in this sector, particularly to maximize patient safety on both an inpatient and ambulatory basis. However, the benefits of monitoring physiologic data remotely on an outpatient basis require scrutiny, particularly if such monitoring requires significant time and resources for implementation.

Patients may develop pressure-related injuries during or after surgical procedures. Anesthesiologist-led Leaf Healthcare, Inc aims to reduce the incidence of pressure ulcers by notifying nurses of each patient’s movement activity and which patients are due for repositioning. The company provides a device that measures a patient’s activity in bed and identifies patients at risk for pressure-related injuries if inactivity is detected; clinical staff is notified to assist patients on a scheduled basis.

**Capnographic Analysis**

Continuous respiratory monitoring is one of the most essential components of anesthesiologists’ vigilance. Minimally invasive monitoring of ventilation is appealing, particularly for settings outside of the operating room. Noninvasive monitors range from oxygen delivery systems with integrated capnography masks to transcutaneous measuring devices. Anesthesiologists often administer 100% inspired oxygen to minimize the risk for hypoxemia during periods of apnea, such as during laryngoscopy.

Masimo has introduced a parameter called the Oxygen Reserve Index (ORI) that quantifies the level of hyperoxygenation by estimating the partial pressure of oxygen when it is in the range of 100 to 200 mm Hg. The ORI has the potential to serve as an early-warning system for impending hypoxemia.

Continuous end-tidal CO₂ measurements can be challenging to obtain when a patient is spontaneously breathing with a natural airway. The nasal cannula with integrated sampling lines for capnography may become dislodged or clogged depending on their positioning. Monitor Mask Inc introduced the CapnoVue face masks to address capnography monitoring by incorporating CO₂ sampling ports into an oxygen delivery mask (Figure 6). The CapnoVue M1 masks are available in various configurations for use in adult and pediatric patients, and are designed for trans-oral procedures.

**Surgical Blood Loss Monitoring**

Monitoring surgical blood loss is fraught with imperfections. Suction canisters may contain blood and other body or irrigation fluids. Visual estimation based on number of sponges and saturation of sponges also is inaccurate. Weighing sponges is time-consuming and may be inaccurate, particularly if there are other body fluids intermixed with the blood. In March 2015, the FDA gave 510(k) clearance to the Gauss Surgical Triton, an iPad app that quantifies the blood volume in sponges and suction canisters using the inbuilt iPad camera (Figure 7). The app scans images of sponges and suction canisters and quantifies the volume of blood.

**Anesthesia Information Management and Clinical Decision Support Systems**

AIMS were primarily designed to assist anesthesiologists in documenting the anesthesia record in electronic form. Many current AIMS not only record data...
from the anesthesia machine, but also integrate with hospital EHRs to facilitate the flow of information into and out of the perioperative environment.

Clinical decision support systems (CDSS) have been integrated into AIMS to improve multiple aspects of patient care, including medication administration reminders, hemodynamic monitoring alerts, and completion of required documentation. A recent review of CDSS research within anesthesiology found multiple studies concluding that CDSS improves compliance with quality measures and documentation. However, demonstrating improved clinical outcomes as a result of CDSS interventions remains a challenge. A recent study of clinical decision support to alert anesthesiologists to “critically low systolic blood pressure” based on consecutive low blood pressure measurements found no change in the observed rate of hypotension or on hospital length of stay.

Commercial perioperative decision support with FDA 510(k) clearance is available from vendors such as AlertWatch, a University of Michigan Health System spin-off. AlertWatch functions as a secondary alert system that integrates physiologic data from existing monitors and displays animated alerts that are based on specific organ systems. Additional CDSS abstracts of note this year at STA include a mathematical model for detection of endotracheal intubation (abstract 24) and data visualization for respiratory status assessments (abstract 11).

Simulation

Medical simulation continues to play an integral role in education in the operating room. In 2016, consumer devices for consumption of virtual reality content are entering the market (Figure 8). Generating content is also increasingly easy with consumer cameras. Medical simulation and education may benefit from this increased accessibility. Virtual reality headsets range from the cardboard box frames that house a smartphone to sophisticated devices, such as the Oculus VR Rift.

At the STA meeting, Shoeb Mohiuddin, MD, from the University of Illinois College of Medicine at Chicago, presented a regional anesthesia immersive training simulator experience designed for the do-it-yourself cardboard virtual reality headset (abstract 35). Examples of freely available virtual reality videos are on YouTube, GoPro VR, and even in The New York Times. The virtual reality industry is just beginning to find applications in the consumer and health care markets.

Consumer and medical device electronics continue to develop at a rapid pace. Will patients take home wearable monitors after discharge from the post-anesthesia care unit? Will anesthesiologists rely on physiologic data recordings during the preoperative period for perioperative counseling and risk stratification? Will immersive virtual reality revolutionize medical simulation and training? As anesthesiologists, we have a front-row seat to continue to investigate and implement technological solutions to improve perioperative medicine.

Acknowledgments

The authors thank their colleagues and fellow members of the Society for Technology in Anesthesia, many of whom have published works that are cited as references in this review, and Mohamed A. Rehman, MD, for his mentorship and guidance during the writing of this article.
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