40 YEARS 1985–2025 ANNIVERSARY

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The Future of Anesthesia: Embracing Innovation for Safer, Personalized Perioperative Care

by Daniel J. Cole, MD, FASA; Maxime P. Cannesson, MD, PhD; and Mark A. Warner, MD, FASA

> "If I had asked people what they wanted, they would have said faster horses."
> — *Henry Ford*

Henry Ford's quote underscores the importance of transcending legacy systems and embracing innovative models of health care that align with the needs of our patients. The vision of APSF—that no one shall be harmed by anesthesia care—is a mandate shaped by the needs, values, and voices of our patients. Achieving this vision requires reimagining care—driven by emerging technologies that not only elevate outcomes but also embed safety into every moment of the patient journey.

AI-generated photo of a futuristic operating arena.

We stand at the threshold of a perioperative renaissance, and we must rise above cognitive, implementation, and financial barriers to deliver truly predictive, personalized, and safer care. We should demand care that delivers improved outcomes for patients and impacts our workforce with an experience that sustains purpose and attracts the brightest minds to our field. The future will belong to those who embrace innovation as the foundation of safer care.

See "Future," Page 74

APSF's Forty-Year Commitment to Medication Safety in Anesthesia

by Aubrey Samost-Williams, MD, MS; Jeffrey Cooper, PhD; Arney Abcejo, MD; and Elizabeth Rebello, MD, FASA, FACHE

As anesthesia professionals, improving patient safety can easily feel like running on a treadmill—each day we jump on, sprint forward, and as tired as we may get, it can seem that we are making no forward progress. However, as we celebrate **40 years of the Anesthesia Patient Safety Foundation (APSF)**, we hope to show you that we should also celebrate 40 years of steady progress towards the goal of zero preventable harm to patients from medication administration.

40 years

of steady progress towards the goal of zero preventable harm to patients from medication administration

Since its founding in 1985, the APSF has consistently prioritized medication safety in anesthesia practice. The APSF identified medication errors as a significant patient safety concern early in its history. In 1987, the *APSF Newsletter* addressed issues related to look-alike medication errors.[1,2] Over the years since, the *APSF Newsletter* has published over 140 articles on medication safety, emphasizing the importance of standardizing drug concentrations and equipment to reduce confusion and errors.[3] Through the *APSF Newsletter*, the organization

See "Medication Safety," Page 76

TABLE OF CONTENTS, NEXT PAGE

TABLE OF CONTENTS

ARTICLES:

The Future of Anesthesia: Embracing Innovation for Safer, Personalized Perioperative Care ..... Page 72
APSF's Forty-Year Commitment to Medication Safety in Anesthesia ..... Page 72
APSF 2000–2025: Transitioning to Perioperative Patient Safety and Reaching Worldwide ..... Page 79
40 Years of the Anesthesia Patient Safety Foundation: Past Progress and Continued Promise ..... Page 82
Airway Safety in the OR and Beyond: Balancing Innovation, Safety, and Core Skills ..... Page 84
ICU Patient Safety Frontiers: Reducing Harm Through Better Handoffs and Infection Prevention ..... Page 88
Perioperative Brain Health and Postoperative Delirium Prevention: Recommendations from the APSF Brain Health Patient Safety Priority Group ..... Page 90
40 Years of Progress in Obstetric Anesthesia Safety Advisory: Milestones, Challenges, and Future Directions ..... Page 94
40 Years of Progress and Future Directions in Chronic Pain Management and Patient Safety ..... Page 97
Pediatric Anesthesia Safety: Yesterday, Today, and Tomorrow ..... Page 100
Enhancing Safety in Cardiac Anesthesiology: Current Practices and Emerging Perspectives ..... Page 104
The Evolution of Patient Safety in Regional Anesthesia: A Journey of Progress ..... Page 108

APSF ANNOUNCEMENTS:

Guide for Authors ..... Page 73
Annual Meeting of the American Society of Anesthesiologists ..... Page 75
Announcing the Procedure for Submitting APSF Grant Applications ..... Page 80
APSF Newsletter Podcast ..... Page 80
Announcing 2026 Co-Sponsored APSF-FAER Mentored Research Training Grant ..... Page 81
Get Social With Us! ..... Page 86
APSF Donor Page ..... Page 87
Donate to APSF ..... Page 93
SPOTLIGHT on Legacy Society Members ..... Page 110
The *APSF Newsletter* Reaches the World ..... Page 111
2025 Board Members and Committee Members: ..... https://www.apsf.org/about-apsf/board-committees/

Guide for Authors

A more detailed Guide to Authors with specific requirements for submissions can be found online at https://www.apsf.org/authorguide

The *APSF Newsletter* is the official journal of the Anesthesia Patient Safety Foundation. It is widely distributed to a variety of anesthesia professionals, perioperative providers, key industry representatives, and risk managers, and is available free of charge in digital format to other interested persons, including members of the public. The content of the *Newsletter* typically focuses on anesthesia related perioperative patient safety issues.

The *Newsletter* is published three times a year (February, June, and October). Deadlines for each issue are as follows:

November 1 for the February issue

March 1 for the June issue, and

July 1 for the October issue

However, authors should feel free to submit manuscript at any time for review.

Decisions regarding content and acceptance of submissions for publication are the responsibility of the editors. Some submissions may be published in future issues, even if the deadline is met. At the discretion of the editors, submissions may be considered for publication on our APSF website and social media pages earlier than the deadlines above. Articles (case reports, editorials, letters) that are intended to provide our authorship/readership with more rapid information will be posted on our online website section under "Articles between issues." These articles could be considered for *APSF Newsletter* publication at the discretion of the Editor Group and based on their importance and current relevance to perioperative patient safety.

Types of Articles

1. Review article (invited or unsolicited)

a. All submissions should focus on perioperative patient safety issues.
b. Articles should be limited to 2,000 words.
c. Figures and/or tables are strongly encouraged.
d. References should be limited to 25..

2. Case Reports

a. Case reports should focus on novel perioperative patient safety cases.
b. A case report should be limited to 750 words.
c. References should be limited to 10.
d. Authors should follow the CARE guidelines and the CARE checklist should be provided as an additional file.

3. Letters to the Editor

a. A letter to the editor can either comment on a past article or a current perioperative patient safety issue.
b. A letter to the editor should be limited to 750 words.
c. References should be limited to 5.

4. Rapid Response

a. The purpose of this column is to allow expeditious communication of technology-related safety concerns raised by our readers, with input and response from manufacturers and industry representatives.
b. Please limit the word count to fewer than 1,000 words.
c. References should be limited to 15.

5. Editorials

a. All submissions should focus on perioperative patient safety issues, preferably a recently published article.
b. The editorial should be limited to 1,500 words.
c. Figures and/or tables are welcomed.
d. References should be limited to 20.

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Technology May Help Make Perioperative Care Safer

From "Future," Page 72

TECHNOLOGY AS THE FUTURE OF SAFER CARE

Consider Alex, a 75-year-old retiree, who underwent surgery for colon cancer. Prior to his surgery, Alex had a history of hypertension and diabetes, but was independent with no cognitive impairment. During the procedure, multiple episodes of modest hypotension occurred. On the night after surgery, Alex exhibited signs of postoperative delirium and fell while getting out of bed. The delirium worsened, prolonging the hospital stay. Alex never returned to independent living and was discharged to long-term care.

This story highlights the consequences of a reactive care model—where early signs of deterioration are often missed. With emerging technology, we can predict risk, intervene proactively, and change outcomes.

ARTIFICIAL INTELLIGENCE (AI)

The modern age of AI dates to the growth of digital health records and computational power which provide the foundation for machine learning, personalized medicine, and predictive analytics. Machine learning—a key branch of AI—develops learning algorithms which detect patterns that predict complications, identify appropriate therapies, and enable earlier intervention.

The perioperative environment is data-rich, relying heavily on the electronic medical record, physiological waveforms, and outputs from infusion and monitoring devices. The advancement of AI in perioperative medicine will likely focus on real-time signal processing, integration of multimodal physiologic data, and closed-loop interoperability between monitoring platforms and delivery systems. These technologies employ real-time decision support to drive earlier interventions and adapt signal processing to personalize therapy. Moreover, AI-enabled alarm management may reduce alarm fatigue by suppressing nonactionable alerts, enhancing safety, and mitigating the burden on a strained workforce.

Responsible AI should be viewed as a powerful complement to the human connection—enhancing complex decision-making and amplifying situational awareness. In the words of Karim Lakhani, "AI won't replace humans—but humans with AI will replace humans without AI."[1]

WEARABLES

Consumer-grade wearables have become widely adopted for personal health. In contrast, health care systems have been slow to integrate medical-grade wearables into clinical workflows due to performance requirements, regulatory thresholds, cost, and concern about the impact on strained caregivers.

Unfortunately, in the perioperative setting there are striking "monitoring deserts" where personalized, continuous data could greatly enhance personalized care. Examples include the preoperative period, where data could inform prehabilitation strategies; the postoperative floor, where monitoring is typically limited to intermittent checks; and the home, where monitoring is usually absent.

A unique challenge is the need to integrate wearable technologies with AI systems capable of transforming continuous streams of raw physiologic data into meaningful, actionable insights. One promising solution is the development of a **digital twin**—a real-time, data-driven virtual model of a patient's biologic and physiologic status. Informed by wearable sensors and linked to AI, this dynamic model could enable earlier and more precise interventions, shifting health care from a reactive, one-size-fits-all approach to one that is proactive, personalized, and predictive. For example, a postsurgical patient equipped with a biosensor might transmit multiple physiologic parameters to a centralized AI-supported monitoring platform. The AI system could identify early signs of respiratory depression and trigger an alert, guiding timely clinical intervention before a critical event occurs.

CLOSED LOOP SYSTEMS

Workstations of the future will employ closed-loop systems that will be extenders of care by automating simple, repetitive tasks. A closed-loop system uses data from an input (e.g., the electroencephalogram), which is fed to a controller (computer algorithm), which adjusts the output (e.g., propofol dose) to maintain the patient within an optimal zone, thus, reducing variation. In theory, spending more time in the optimal zone should reduce the risk of complications and offload repetitive tasks from the clinician and allow them to spend more time on situational awareness and total patient care. The ideal system would integrate several closed-loop systems into a master controller as opposed to three independent systems (i.e., hypnosis, fluid therapy, and hemodynamic management).

THE CRITICAL IMPORTANCE OF SAFETY CULTURE

Safety culture reflects "the sum of what an organization is and does in the pursuit of safety."[2] This definition acknowledges that safety cultures differ across organizations. Maya Angelou famously said, "People may forget what you said, but they will never forget how you made them feel." This powerful reminder underscores the essential role of culture, high-functioning teams, and the healing power of the human connection. At its core, the human touch fosters trust, improves outcomes, and reaffirms the purpose of our work.

Health care systems face a challenging environment, and efforts to strengthen safety culture are too often subservient to immediate operational needs. While this may seem pragmatic, the long-term costs are substantial. When we fail to embed safety into every moment of care, we compromise the mission of health care and erode public trust. It is therefore imperative to advocate for investment in systems, training, and technologies that embed safety as foundational.

Consumer-grade wearables have become widely adopted for personal health.

See "Future," Next Page

The Future of Patient Safety Relies on Personalized Care

From "Future," Preceding Page

CONCLUSION

The future of perioperative safety must transcend the boundaries of today's systems. Grounded in our enduring vision, we have an opportunity to reshape the arc of patient outcomes. Artificial intelligence, decision support, wearable technologies, and closed-loop systems are catalysts for a new model of care and high-value solutions to promote safety culture. They change health care from a reactive system to a predictive, personalized, and proactive system. Importantly, they reduce cognitive burden, enhance professional fulfillment, and attract the brightest minds to our specialty. The next era of perioperative safety is within reach. And if we choose to lead with vision, courage, and purpose, we can rewrite the story of Alex.

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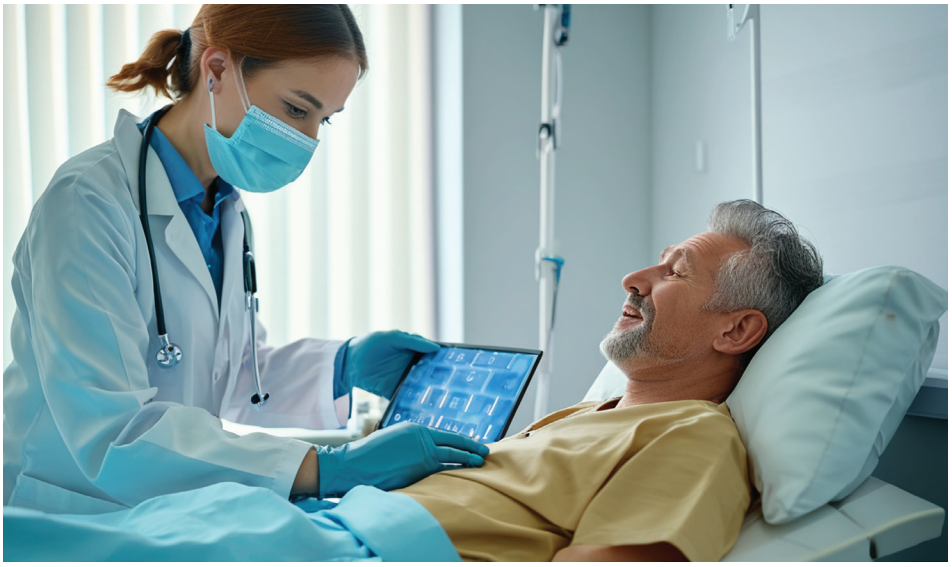

AI-generated image of doctor consulting AI with patient.

Maxime Cannesson is a consultant for Edwards Lifesciences/BD and Masimo. He is co-founder and co-owner of Sironis and Perceptive Medical. He receives royalties from Edwards Lifesciences/BD and Sironis.

Mark Warner and Daniel Cole have no conflicts of interest.

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ANESTHESIOLOGY 2025 OCTOBER 10–14, 2025

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Room 225CD, Meeting Level
https://www.asahq.org/annualmeeting

ASA/APSF Ellison C. Pierce Jr., MD, Patient Safety Memorial Lecture

Tools for Enhancing Patient Safety

Saturday, October 11, 2025

1:30 p.m.–2:30 p.m. CDT

Presented by: ***Adrian W. Gelb, MBChB, FRCPC***

Anesthesia Patient Safety Foundation Panel

Transforming Maternal Care: innovations and Collaborations to Reduce Morbidity and Mortality

Saturday, October 11, 2025

2:45 p.m.–3:45 CDT

Moderator: ***May Pian-Smith, MD, MS***

Medication Errors Are a Significant Patient Safety Concern

From "Medication Safety," Page 72

has disseminated research findings, best practices, and expert recommendations to mitigate medication errors in the perioperative setting.

Medication administration in the operating room is a unique and challenging process (Figure 1). Nowhere else in the hospital does the same person (1) select the medication and dose, (2) prepare the medication, and (3) administer the medication. Elsewhere, these three functions are done by (1) the physician, physician assistant, or nurse practitioner, (2) the pharmacist or pharmacy technician, and (3) the bedside nurse. These independent team members provide monitoring and double-checking throughout the process. In the operating room, these same three tasks are done by a single anesthesia professional and are typically done quickly, as seconds count in acute life-saving situations.

Early medication safety efforts focused on the behavior of the anesthesia professional, with efforts to improve safety typically through educational programs encouraging close reading of labels and design work to make those labels more readable. As safety science matured, the emphasis on attentiveness was recognized as inadequate for prevention of medication errors. Rather, emphasis was refocused on forcing functions and creating feedback mechanisms and constraints. This need to shift the paradigm in thinking of medication errors led to the 2010 APSF Stoelting Conference focused on medication safety.

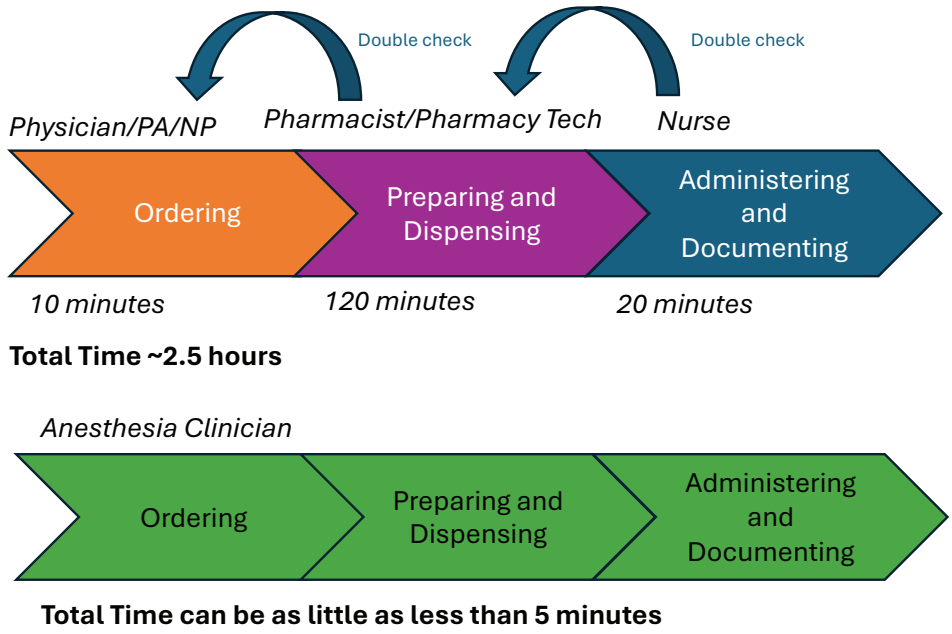

Figure 1: Comparison of the inpatient medication administration process and the OR medication administration process. Timing estimated from Bhansali and colleagues,[7] Yen and colleagues,[8] and internal pharmacy data.

2010 APSF STOELTING CONFERENCE ON MEDICATION SAFETY

This conference focused on creating an expert consensus-based framework for moving medication safety beyond admonishing clinicians to pay more attention, instead creating the Standardization, Technology, Pharmacy/Prefilled/Premixed, and Culture (STPC) framework (Table 1).[4]

See "Medication Safety" Next Page

Table 1: 2010 Recommendations and STPC Framework.

Standardization	Technology	Pharmacy/ Prefilled/ Premixed	Culture
• High-alert medications should be provided in **standardized concentrations**. • Infusions should be administered using **electronically controlled smart devices.** • **Machine-readable labels** should be mandatory. • Standardized **placement of drugs within anesthesia workstations** and protocols for **infusion libraries** should be implemented. • **No concentrated versions** of potentially lethal agents should be present in the OR.	• **Every anesthetizing location should have a mechanism to identify medications** before drawing up or administering them. • Systems should provide **feedback, decision support, and documentation**. • **Mandatory safety checklists** and improved user interfaces on infusion pumps should be required. • **Training and certification** for users of technology should be established.	• Routine **provider-prepared medications should be discontinued.** • Clinical pharmacists should be **integrated into the perioperative team.** • **Standardized, pre-prepared medication kits** tailored to case types should be used. • **Automated dispensing machines** should be deployed in the operating room suite.	• Establish a **"just culture"** for reporting medication errors (including near-misses) and learning from them. • Implement **mandatory education** on medication safety. • Promote **cooperation across institutions, professional organizations, and accreditation agencies.**

STPC: Standardization, Technology, Pharmacy/Prefilled/Premixed, and Culture

Top Standardization Strategies for Medication Safety Should Include Syringe Label Design

From "Medication Safety," Preceding Page

2018 APSF STOELTING CONFERENCE ON MEDICATION SAFETY

In 2018 the APSF annual conference again focused on medication safety. This conference continued some of the same themes from 2010, such as an emphasis on standardization and human factors, but expanded to further consider new challenges in medication safety, including drug safety profiles and drug shortages (Table 2).[5]

ACTIVITIES BETWEEN MEETINGS

While the Stoelting Conferences on medication safety have provided large pushes and paradigm shifts in our collective work on promoting safer use of medications, it would be remiss to ignore the hard work that has come in between. Here are a few recent efforts and wins to highlight:

- In 2018, following the Stoelting Conference, APSF began hosting the Look-Alike Drug Vials Gallery (Figure 2). The stark visualizations of the risks to our patients has helped us form industry partnerships to begin to tackle these challenges.

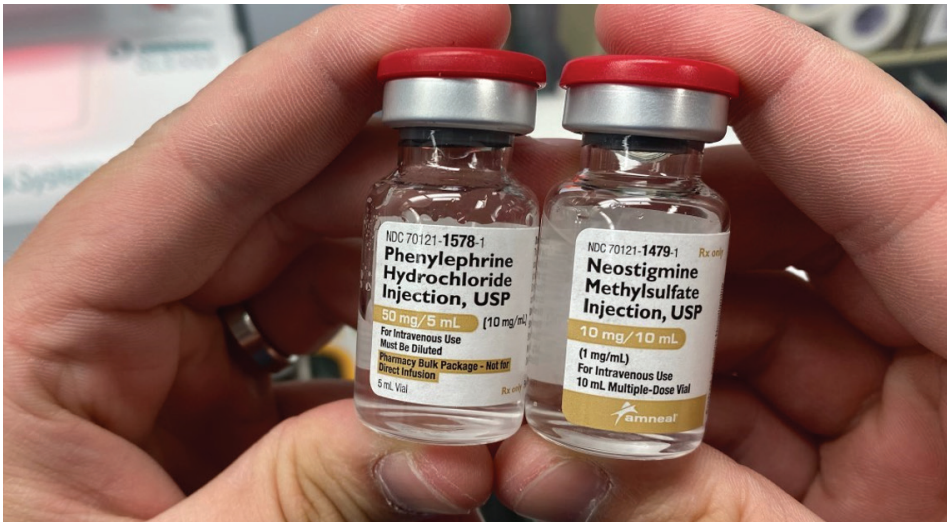

Figure 2. Look-Alike Medication Vials (Photo courtesy of Christopher Seiter, DO)

- In 2021, APSF formed Patient Safety Priority Advisory Groups, one of which focused on medication safety. This group included a diverse membership of key stakeholders, including anesthesiologists, certified registered nurse anesthetists, anesthesiologist assistants, anesthesiology residents, pharmacists, perioperative nurses, a lawyer specializing in medical malpractice, and industry partners representing pharmaceutical and device companies. Currently, the group is working on implementing the recommendations arising from the recent 2024 Stoelting Conference.

See "Medication Safety," Next Page

Table 2: 2018 Stoelting Conference Medication Safety Recommendations.

Drug Safety *Identify and promote potentially safer anesthetics*	Drug Shortages *Share information, simplify ordering, and establish contingency plans*	Reducing Drug Administration Errors *Standardize procedures and doses, carefully document administration, and simplify preparation*	Standardization and Innovation *Collaborate across specialties and establish consensus for refined standards*
• Encourage research on nitrous oxide • Endorse the routine use of multimodal approaches for postoperative pain • Endorse continuous monitoring of ventilation for perioperative patients • Collaborate with the FDA and convene a work group to identify novel and potentially safer anesthetics	• Provide up-to-date drug shortage information on the APSF website • Encourage efforts to standardize concentrations of commonly used drugs • Encourage the FDA to develop a manufacturer/supplier quality report card • Collaborate to encourage contracting processes that lead to shared risks for drug shortages and quality issues • Encourage the FDA to require manufacturers to have contingency plans to reduce the risks of drug shortages	• Encourage and endorse the use of prefilled syringes and standardized carts • Encourage identifying and documenting drugs before administering them • Encourage the development of technologies that can identify and document administered drugs • Encourage efforts that promote perioperative work environments in which collaboration is encouraged and all individuals are encouraged to identify opportunities to improve patient safety	• Promote consensus on standardization of drug concentrations and labeling of drugs • Collaborate to encourage health systems to standardize the delivery processes of high-risk drugs • Develop a grant for the development of standardized labeling of vials and syringes

New Technology May Help Improve Medication Safety

From "Medication Safety," Preceding Page

- APSF reported on a series of medication errors involving intrathecal administration of tranexamic acid (TXA).[6] Through advocacy and industry partnership, they were able to promote the availability of TXA in infusion bags and the reduction of the use of TXA vials in the perioperative environment.
- Additionally in 2024, APSF partnered with the Institute for Safe Medication Practices (ISMP) to investigate increased reports of coring of vial tops when preparing medications for administration and released an alert to anesthesia professionals nationwide in the US.
- In 2023–25, APSF helped advocate for the reinstatement of American Society for Testing and Materials (ASTM) standard D4774, which standardizes the color-coding used on labels for different medication classes. While this sounds esoteric, APSF's lobbying for these industry-wide standards ensures that the concerns of practicing anesthesiology professionals are incorporated into the equipment that we work with every day in the OR.

2024 APSF STOELTING CONFERENCE: TRANSFORMING ANESTHETIC CARE: A DEEP DIVE INTO MEDICATION ERRORS AND OPIOID SAFETY

Finally, in 2024 the APSF Stoelting Conference again focused on medication safety. As in 2018, the unique context and challenges of the moment brought a different perspective on the problem of medication safety.

The intervening six years since the prior Stoelting Conference focused on medication safety brought about significant advances in our understanding of the harms of opiates, not just in the immediate postoperative period, but even beyond, as we have witnessed communities ravaged by the epidemic of opiate addiction. With the rise of Enhanced Recovery After Surgery (ERAS) protocols with their multimodal pain management approach and a debate over the proper role for and dosing of perioperative opiates, there was a robust discussion about how to use opiates wisely.

Additionally, we are witnessing the rise of artificial intelligence to a level not imaginable just six years ago. We now have the ability to move past simple electronic double-checks of medications, where we might scan the label and have the software confirm that the patient is not allergic to it. Now we can imagine clinical decision support tools that can help determine whether the medication to be administered is a good choice given the patient's current physiological state. This type of technology opens new avenues for promoting safety, while also raising new challenges and new safety risks.

Despite these new technologies and new challenges, this meeting also recognized that many of the challenges being faced in medication safety have been present since the founding of APSF 40 years ago. We continue to face challenges with basic syringe swaps and medication dosing errors due to differing concentrations. The prior two conferences approached these challenges with calls for work grounded in human factors and system safety principles. Despite recognizing the importance of improving these processes and identifying best practices for medication safety, there exists a significant implementation gap.

In a preconference poll prior to the 2024 APSF Stoelting Conference, attendees, a group self-selected for interest and leadership in medication safety (n=69), reported that fewer than half of their institutions had fully implemented practices such as standardized drug labeling, prefilled syringes for at least three unique medications, or standardized medication drawers for automated dispensing cabinets or medication trays. Respondents reported top standardization strategies for medication safety should include syringe label design, color-coded syringe labels, standardized concentrations, prefilled syringes, and standardized medication storage locations during surgery. In addition, preoperative assessments, postoperative monitoring, and research into nonopioid alternatives are measures that should be prioritized to prevent opioid-related harm.

Therefore, pivoting the focus on the relatively new field of implementation science may better identify the barriers to implementing these medication safety best practices. Recommendations this year will continue to encourage the practices highlighted in prior years, but the work products will aim to help institutions successfully implement measures that we know can save lives.

CONCLUSION

Forty years is a long time. Our medication administration has evolved from copper kettles to variable bypass vaporizers, and from relatively few medication options to an entire automated medication dispensing cabinet. But just as our care has evolved, our medication safety practices have evolved from education and policy interventions to strategies incorporating human factors, cutting-edge technology, systems engineering, and implementation science. There has been an increased focus given to systems issues and less blame on an individual. Through work in this field, we can safeguard our communities and patients by developing into perioperative clinicians with a lens that broadens beyond the operating room and PACU. Much of this progress has been made collaborating as a team with pharmacists, nurses, institutional leadership, industry, safety organizations, standard-setting organizations, and federal agencies. It has been an exciting journey over the past 40 years, and we look forward to seeing what the next 40 years will bring.

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APSF 2000–2025: Transitioning to Perioperative Patient Safety and Reaching Worldwide

by Mark A. Warner, MD, and Daniel J. Cole, MD

The unprecedented improvement in anesthesia-specific patient safety from the start of the anesthesia patient safety movement in America until the turn of the century stands as one of the most significant achievements in medicine. The exponential reduction in patient harm from the 1980s through 2000 was remarkable, but unsustainable in high-income countries that had and used their resources to adopt new standards in anesthesia care, advanced technologies, and safer medications. The rate of improvement of anesthesia-specific perioperative morbidities and mortality subsequently slowed.

This represented a transition period in anesthesia patient safety, and the APSF responded by pursuing two distinct new approaches: (1) expansion of efforts to reduce perioperative patient harm, and (2), a focus on improving both anesthesia-specific and perioperative patient safety in lower-income, often under-resourced countries around the world.

TRANSITIONING TO PERIOPERATIVE PATIENT SAFETY

APSF's first president and co-founder, Ellison (Jeep) Pierce, was well-aware by 1995 that unique collaboration between anesthesia leaders, their societies, and industry in the foundation's first decade was crucial to the anesthesia patient safety movement's amazing initial success in reducing anesthesia-specific patient harm, and that the coming years would be unlikely to experience such rapid improvements. In his 1996 Rovenstine Lecture at the ASA annual meeting, he summarized his insights about the need to transition anesthesia-specific patient safety to perioperative safety and to relentlessly pursue the potentially less exciting but necessary incremental improvements that would be needed into the future:[1]

> *Patient safety is not a fad. It is not a preoccupation of the past. It is not an objective that has been fulfilled or a reflection of a problem that has been solved. Patient safety is an ongoing necessity. It must be sustained by research, training, and daily application in the workplace.*
>
> *—Ellison C. (Jeep) Pierce, MD*

In response, since 2001 the APSF has sponsored annual consensus conferences to address specific issues that potentially impact patient safety.[2] Conferences from 2001 through 2014 focused primarily on anesthesia-specific issues. During this period, studies accumulated and pointed to perioperative issues as the most significant problems leading to surgical morbidity and mortality. Daniel Sessler, one of the world's most prolific and insightful clinician investigators in perioperative safety, implored anesthesia professionals everywhere to put their efforts into improving perioperative morbidity and mortality during his 2023 Rovenstine Lecture:[3]

> *One thing we can and should do is to establish intense postoperative management as a fourth branch of anesthesia. A radical change, yes, but necessary if anesthesia is to remain strong, and we need it now because the window of opportunity is brief. Carpe diem. Seize the day. Today.*
>
> *—Daniel I. Sessler, MD*

Since 2015, the APSF's conference topics and many of the foundation's communication efforts have shifted towards more expansive perioperative issues such as how to better communicate during handoffs of care, detect clinical deterioration earlier in the postoperative period, and involve family members in decision-making processes. The APSF has also recognized its invaluable industry partners and their many ongoing efforts in perioperative care. During the past decade, many of APSF's research grants have focused on perioperative issues. This transition towards reducing perioperative patient harm will continue into the future.

ANESTHESIA AND PERIOPERATIVE PATIENT SAFETY IN LOWER RESOURCED COUNTRIES

Numerous reports on perioperative morbidity and mortality around the world have found very significant anesthesia patient safety issues associated with an absence or maldistribution of human, technology, and medication resources; few patient safety-related educational opportunities; and limited financial and institutional support for anesthesia and perioperative care.[4] A number of national anesthesia and surgical organizations, the World Federation of Societies of Anaesthesiologists, the World Health Organization, the International Federation of Nurse Anesthetists, charitable organizations such as Lifebox, and other groups have increasingly focused their efforts on perioperative patient safety in lower income countries.

The APSF expanded its patient safety education efforts from its U.S. focus to include lower resourced countries around the globe in 2017. This change started with the introduction of translations of the *APSF Newsletter*. This effort has been very successful. In 2025, the newsletter is published in 8 languages. These languages are estimated by the World Health Organization to be readily understood by more than 90% of the world's anesthesia professionals. The APSF also produces podcasts, videos, and other materials that are accessible to any anesthesia professional globally with cell or internet connections. A number of these are translated into languages other than English.

Daniel J. Cole, MD

Mark A. Warner, MD

CONCLUSION

After an initial exponential reduction of anesthesia-specific harm to patients, the anesthesia patient safety movement in general, and the APSF specifically, have transitioned focus to comprehensive perioperative issues that cause harm to patients undergoing surgical and diagnostic procedures. Importantly, the APSF has joined with other leading organizations to promote efforts to improve anesthesia patient safety worldwide.

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The authors report no conflicts of interest

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THE APSF INVESTIGATOR-INITIATED RESEARCH (IIR) GRANT APPLICATIONS

FEBRUARY 15, 2026, IS THE DEADLINE TO SUBMIT LETTERS OF INTENT (LOIs) FOR AN APSF IIR GRANT TO BEGIN JANUARY 1, 2027

We are pleased to announce the opening of our next funding cycle for our APSF Investigator-Initiated Research grants.

KEY DETAILS:

- Application Period: Letters of Intent (LOIs) will be accepted electronically beginning January 1, 2026.
- Award Amount: Up to $200,000 maximum.
- Grant Duration: Maximum of two years.
- Grant Start Date: January 1, 2027.
- Selection Process: Following review by the APSF's Scientific Evaluation Committee, a limited number of applicants will be invited to submit full proposals

READY TO APPLY?

Complete instructions for submitting a Letter of Intent are available at:

https://www.apsf.org/grants-and-awards/investigator-initiated-research-iir-grants/

We encourage qualified researchers to review the application requirements and prepare their submissions for the upcoming deadline.

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APSF Podcast

Now Available Online @ APSF.org/podcast

The APSF now offers you the opportunity to learn about anesthesia patient safety on the go with the Anesthesia Patient Safety Podcast. The weekly APSF podcast is intended for anyone with an interest in perioperative patient safety. Tune in to learn more about recent *APSF Newsletter* articles with exclusive contributions from the authors and episodes focused on answering questions from our readers related to patient safety concerns, medical devices, and technology. The mission of the APSF includes being a leading voice for anesthesia patient safety around the world. You can find additional information in the show notes that accompany each episode at apsf.org. If you have suggestions for future episodes, please email us at podcast@APSF.org. You can also find the Anesthesia Patient Safety Podcast on Apple Podcasts or Spotify or anywhere that you listen to podcasts. Visit us at APSF.org/podcast and at @APSForg on X, Facebook, and Instagram.

Allison Bechtel, MD
APSF Podcast Director

Announcing 2026 Co-Sponsored APSF-FAER Mentored Research Training Grant

The Anesthesia Patient Safety Foundation (APSF) and Foundation for Anesthesia Education and Research (FAER), related foundations of the American Society of Anesthesiologists (ASA), are pleased to announce the next offering of the co-sponsored APSF-FAER Mentored Research Training Grant (APSF-FAER MRTG) as part of FAER's Spring 2026 Grant Cycle.

The APSF-FAER MRTG provides **$300,000 over a two-year period** to fund patient safety research directly related to the perioperative care of patients, as well as chronic pain and critical care medicine. Patient safety is defined as the avoidance, prevention and improvement of adverse outcomes or injuries stemming from health care processes.

Those interested in applying for the 2026 APSF-FAER MRTG will need to submit a Letter of Intent (LOI) prior to submitting a full application. The submission window for LOIs for this grant will be open from **December 1, 2025, through January 1, 2026**. Information on the APSF-FAER MRTG can be found on FAER's website at FAER.org/APSF.

Since the grant's first offering in 2019, the APSF and FAER have awarded a total of $1.5 million to the following researchers:

- **Alexander Arriaga, MD, MPH, ScD**
  2019 APSF-FAER MRTG Recipient
  Brigham and Women's Hospital (Boston, Massachusetts)
  Increasing the Frequency of Debriefing After Perioperative Crises: Altering Trajectories that Impact Provider Burnout and Wellness

- **Timothy Gaulton, MD, MSc**
  2020 APSF-FAER MRTG Recipient
  University of Pennsylvania (Philadelphia, Pennsylvania)
  Mapping the Epidemiology of Perioperative Driving Safety and Behavior

- **Jonathan M. Tan, MD, MPH, MBI, CMQ**
  2021 APSF-FAER MRTG Recipient
  Children's Hospital Los Angeles (Los Angeles, California)
  The Impact of Air Pollution and Neighborhood-Level Risk Factors on Pediatric Perioperative Respiratory Adverse Events

- **Meghan Michael, MD**
  2023 APSF-FAER MRTG Recipient
  University of Texas Southwestern Medical Center (Dallas, Texas)
  A Structured Communication and Team Training Program to Improve Perioperative Patient Safety

- **Caoimhe Duffy, MD, MSc**
  2024 APSF-FAER MRTG Recipient
  University of Pennsylvania (Philadelphia, Pennsylvania)
  Resilience Training to Prevent Intubation Harm: The One Safe Act-Airway Study

THE ANESTHESIA PATIENT SAFETY FOUNDATION (APSF)

Founded in 1985, APSF promotes research of perioperative patient safety issues, supports the development of careers in patient safety, provides patient safety educational materials and communications to all anesthesia professionals, and advocates for changes in clinical practices that improve patient safety. The APSF's goal is that no one shall be harmed by anesthesia care.

APSF provides support for research and education in perioperative patient safety. Its past initiatives have resulted in significant contributions to the field of anesthesia patient safety. APSF has distributed over $15 million in funding for anesthesia patient safety research projects over its 30+ year history. For more information on APSF or to donate, please visit www.apsf.org.

THE FOUNDATION FOR ANESTHESIA EDUCATION AND RESEARCH (FAER)

FAER is a related foundation of the ASA. For over 35 years, FAER has been dedicated to developing the next generation of physician-investigators in anesthesiology. Charitable contributions and support to FAER help fuel the future of anesthesiology through scientific discovery. Funding priorities include: Research, Education, and Training. At the time of this article's publication, FAER has awarded more than $59 million in research grants and programs since 1986. To donate to FAER, visit FAER.org/donate.

40 Years of the Anesthesia Patient Safety Foundation: Past Progress and Continued Promise

by John H. Eichhorn, MD

When the Anesthesia Patient Safety Foundation was created in the Fall of 1985, with the admirable mission "that no patient shall be harmed by anesthesia care," an agenda of communication, education, advocacy, debate, and research support was begun that continues enthusiastically in force to this day.

The first issue of the *APSF Newsletter*, in March 1986, immediately embraced the current issues of that era: essential intraoperative monitoring, risks of hypercarbia vs hypoxemia, verification of correct endotracheal tube placement, lessons from closed claims, and grant support for much-needed high-quality patient safety research. Some of the early questions and concepts have been resolved or significantly transformed over time—others, not so much. Review of every issue of the *Newsletter*, in order since its creation, reveals that many concerns recur over the decades.

Previously published histories have detailed the antecedents, driving forces, and organizational efforts to launch the APSF, as well as its role in establishing, naming, and defining the discipline of patient safety, and as the first formal patient safety organization.[1-3] Note that the APSF was prominently cited as the prototypical example of a formal organization helping to improve patient safety in the landmark (and controversial) comprehensive 1999 "To Err Is Human," report from the Institute of Medicine,[4,5] which resulted in an APSF response from then APSF President Robert K. Stoelting, MD, (successor to inspirational founding APSF President, the late Ellison C. ["Jeep"] Pierce, Jr., MD) highlighting the significant recognition of APSF, but objecting to the report's emphasis on identifying and eliminating "unsafe providers," as opposed to preferred objectively proven system-based protocols and efforts.[6]

Within the initial year of the APSF, the American Society of Anesthesiologists (ASA) adopted the first ever formal mandatory standards for intraoperative monitoring,[7] with the strongest possible backing of the APSF, especially through the involvement and efforts of Dr. Pierce (past ASA president, who initiated its standards committee) and John H. Eichhorn, MD, (then *APSF Newsletter* editor, secretary of that new ASA standards committee, and chair of group that created the original Harvard monitoring standards).[8] Over its first few years, the APSF supported, endorsed, and publicized both the updating of the ASA standards and the creation and adoption of intraoperative monitoring standards by numerous anesthesia societies and governments from all around the world.

ANESTHESIA PATIENT SAFETY FOUNDATION
NEWSLETTER
Volume 1, No. 1, pp 1-8 March, 1986

Safety Foundation Organized

Statement of Purpose

This is the first Newsletter of the Anesthesia Patient Safety Foundation, which was incorporated on September 30, 1985. The mission of the APSF is clear and simple—to encourage activities that will prevent patients from being harmed by the effects of anesthesia. Why such a boundaries? What activities shall it promote to fulfill its mission? What resources will support those activities? What can you do to help?

It is generally agreed that anesthesia is safer than it has ever been, but that it still isn't safe enough. In the United States, annually some several thousand patients die or are seriously injured at least in part by their anesthetic experience. There is strong evidence that more than half of these adverse outcomes are preventable by applying known precepts of anesthesia management. Yet, the causes of preventable deaths and injuries are diverse and complicated. There is no one evil and no simple cure.

The first step toward improvement is creating awareness that a problem exists. Education, training, application of current and developing technologies and acquiring new knowledge about the causes and prevention of mishaps are components of a judicious matrix.

Anesthesia mortality is everybody's problem. Most people will be exposed to the risk several times in their life. When a bad outcome occurs, it affects not only the patient, but has a lasting impact on the family, the anesthetist, and the anesthetist's colleagues as well. It is also a problem for many other constituencies—the manufacturer and designer of equipment that is involved or implicated in an accident and the hospital administrator in whose operating room an accident occurred. For the companies that provide liability insurance, there is the clear and present danger that the malpractice crisis, caused at least in part by preventable injuries, may severely damage or cripple the viability of their organizations. That this crisis puts the entire health care system in jeopardy makes this a problem for the federal government also.

Because there has been no place that these constituencies can join forces to promote change, the Anesthesia Patient Safety Foundation was formed. Its goals are:

"To foster investigations that will provide a better understanding of preventable anesthetic injuries.

"To encourage programs that will reduce the number of anesthetic injuries, and

"To promote national and international communication of information and ideas about the causes and prevention of anesthetic injuries.

During the first year, the Foundation's aims are to start a communication vehicle (this newsletter) and to establish a research fund, awarding several grants. Committees have been created to implement these activities.

Who is the APSF? Its 50-member Board of Directors includes representatives from anesthesiology, nurse anesthesia, device and pharmaceutical manufacturing, the insurance industry, hospitals, biomedical engineering, and the FDA (see page 2 of this newsletter for a complete list of the Board and committees). Membership in the APSF is open to any individual contributing at least $25 and any corporation contributing at least $500. Contributions will go toward funding the cost of producing and distributing this newsletter to the approximately 45,000 people who have a stake in preventing anesthesia injuries and toward the support of safety-related research activities.

You won't have to be a member of the APSF to benefit from its efforts but, yes, you will receive a certificate of membership if you join. The real reason to contribute $25 or more is because you want to make anesthesia safer. Because it can be. Because it should be. We think that some improvements, through increasing awareness and through implementing some new technologies, can be had in the short term—a few years. But, the ultimate goal of near-absolutely injury-free anesthesia will take longer because the impact of training, of education, and of innovative ideas derived from research take time to percolate through a culture. But, it can be done. We need your help.

Jeffery B. Cooper, Ph.D.
Elison C. Pierce, M.D.
For the Executive Committee

Grant Applications Sought—Pg. 3

THE APSF EXECUTIVE COMMITTEE recently met in Atlanta, GA. Left to right: Dr. J.S. Gravenstein, Dr. J.D. Cooper, Dr. L.S. Satin (Secretary), Nr. J.F. Fraites, Dr. E.C. Pierce (President), Mr. B.A. Dale (Treasurer), and Mr. W.D. Bourdon (Vice President).

Front page of the first issue of the APSF Newsletter, *Vol. 1, No. 1, March 1986, with a photo of the first APSF Executive Committee members.*

Multiple areas of patient safety interest have received intense APSF efforts over the decades. Good examples include safety issues related to non-OR anesthetizing locations (MRI, cath lab, etc.) and office-based anesthesia. Anesthesia automated electronic information systems and their electronic anesthesia records (with debate and mixed opinions about safety implications) have been often considered. Patient-injury fires during monitored anesthesia care with open supplemental oxygen being administered to the sedated patient generated major safety recommendations and is the subject of one of the APSF Executive Summary videos (intended for both professionals and patients) available on the APSF main webpage. Patient vision loss after prolonged prone spine surgery was a critical issue that APSF fixated on more than 15 years ago and publicized widely, encouraging preventive protocols. A related concern is hypotension and adverse events in patients anesthetized in the beach chair position, often for shoulder surgery. This issue surfaced in 2007,[9] was the subject of a 2009 APSF Workshop,[10] provoked the creation of an APSF registry of injury cases in 2010, and led to several preventive practice recommendations. Safety implications of distractions in the OR, yielded a series of recommendations for practice and provided another example of the recurring nature of safety issues in anesthesia.[11] The topics of distraction (especially "reading" in the OR, which produced for years a torrent of Letters to the Editor in the *Newsletter*), practitioner fatigue, and, later, OR production pressure (usually with institutional financial motives) have intermittently permeated throughout APSF efforts for decades. Monitoring neuromuscular blockade by muscle relaxants during, at the end of, and even after general endotracheal anesthesia has been (and continues to be) an intense and heavily debated issue for the APSF. These discussions have highlighted quantitative neuromuscular monitoring technology[12] and contributed to the eventual adoption by the ASA of specific practice guidelines to enhance patient safety.[13] Surgical infections were another topic that received significant attention.[14,15] The implications and challenges of the COVID-19 pandemic were addressed by the APSF, especially the use of anesthesia machine ventilators in make-shift emergency ICUs set up in operating rooms.

Closely related to human factors in anesthesia patient safety are the topics of crisis management, emergency manuals, cognitive aids for use in clinical practice (both emergency and routine), checklists, and hand-off communications. The APSF has awarded research grants on technical and nontechnical decision support tools for perioperative pediatric crises, sponsored Pierce Memorial lectures on the importance of cognitive aids, and organized conferences on the implementation of cognitive aids and checklist in the perioperative setting.[16-18] Checklists as a tool to enhance anesthesia safety (and the classic analogy comparing administering anesthesia to piloting a commercial jumbo jet) appeared very early in APSF discussions;[19] anesthesia machines and equipment were the first checklist targets.[20] The APSF administered a profession-wide survey to help formulate a template for a preanesthetic checklist.[21] More recently, proposals for implementation of checklists have focused on handoffs between caregivers. Formed in 2015, the Perioperative Multi-Center Handoff Collaborative is supported by the Anesthesia Patient Safety Foundation.[22] The inaugural APSF Stoelting Conference yielded recommendations for handoff procedures to enhance patient safety.[23]

See "Past and Future," Next Page

Fundamental Questions in Anesthesia Patient Safety Remain

From "Past and Future," Preceding Page

The APSF has periodically conducted surveys of anesthesia practitioners to help determine the relative priorities in order of importance from a list of more than 50 specific patient safety ideas: in 1999[24] (difficult airway management was number 1); in 2018[25] (perioperative clinical deterioration and responses topped the list); and in 2021[26] ("culture of safety, inclusion, and diversity" was the first priority). The ordering of the priorities ranked in the surveys has changed some and progressed over the years, but, as noted, reviewing those lists, most of the fundamental questions persist, thus providing stimulus, inspiration, and direction for APSF engagement in both the present and the future.

John Eichhorn, MD, was the founding editor and publisher of the APSF Newsletter. *He lives in San Jose, CA, as a retired professor of Anesthesiology, and continues to serve on the APSF Editorial Board.*

John H. Eichhorn, MD

The author has no conflicts of interest.


Anesthesia Patient Safety Foundation
NEWSLETTER
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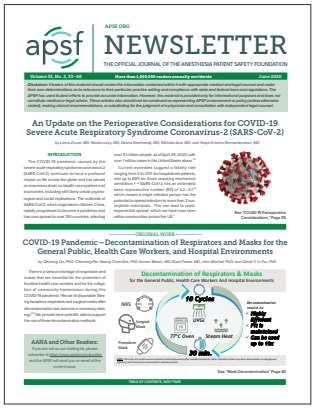
Patient Safety A Key ASA Meeting Theme
Closed Claims Project Shows Safety Evolution
Inside:
Medical Error Studies ..... Pg 40
Novel Staring Hybrid ..... Pg 41
ICU Patient Safety ..... Pg 42
"Wrong Organ Removed" ..... Pg 43
Sedation Policy & Anesthesia ..... Pg 44
ICARO Standards ..... Pg 46
See "ASA Preview," Next Page
See "Closed Claims," Next Page


apsf NEWSLETTER
www.apsf.org
The Official Journal of the Anesthesia Patient Safety Foundation
Volume 30, No 2, 17-44 Circulation 10,102 October 2015
Leading the Anesthesia Patient Safety Foundation (APSF) into the Future: Seeking Candidates for the Next APSF President
Position Summary
Search Announcement
ASA/APSF Ellison C. Pierce, Jr., MD, Patient Safety Memorial Lecture
Expanding Our Influence: How the Perioperative Surgical Home Will Improve Patient Safety
Annual Meeting of the American Society of Anesthesiologists
Saturday, October 24, 2015, 10:45 AM-11:45 AM
Upper Ballroom 20D
San Diego Convention Center, San Diego, CA
TABLE OF CONTENTS, PAGE 15


apsf NEWSLETTER
THE OFFICIAL JOURNAL OF THE ANESTHESIA PATIENT SAFETY FOUNDATION
An Update on the Perioperative Considerations for COVID-19 Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2)
COVID-19 Pandemic—Decontamination of Respirators and Masks for the General Public, Health Care Workers, and Hospital Environments
Decontamination of Respirators & Masks
for the General Public, Health Care Workers And Hospital Environments
10 Cycles
72°C Oven
30 min.
AANA and Other Readers:
See "Mask Decontamination" Page 60
TABLE OF CONTENTS, NEXT PAGE

The APSF Newsletter *through the years, starting with the original design under John Eichhorn; changes to the logo and format under Bob Morell; and our latest edition with the new branding under Steven Greenberg.*

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Airway Safety in the OR and Beyond: Balancing Innovation, Safety, and Core Skills

by Avery Tung, MD, FCCM, and P. Allan Klock, Jr., MD

INTRODUCTION

Over the past three decades, few aspects of anesthesia practice have evolved as much as airway management. Amidst an explosion of new devices, medications, and techniques, an anesthesia professional practicing in 1990 would have considerable difficulty recognizing airway management as it is currently practiced in 2025. Among the innovations likely to amaze the clinician of yesteryear would be the use of the Supraglottic Airway (SGA) as a rescue device or intubating tool,[1] and that video laryngoscopy (VL) is now commonly used for even routine airway management.[2] They would be surprised that airway management guidelines now recognize the physiologically difficult airway and the value of limiting the number of intubating attempts,[3] astonished that nondepolarizing muscle relaxants can be quickly and completely reversed,[4] and impressed that extracorporeal membrane oxygenation (ECMO) is increasingly used for extremely high-risk airways.[5]

After their initial surprise, our anesthesia professional of yesteryear would realize that high-success approaches are now available for many airways previously considered difficult and wonder whether the difficult airway is mostly solved or whether safety issues still remain for today's practitioner. They might then be intrigued to learn that while the number of publications per year with the keyword "difficult airway" has increased from 79 in 1990 to over 450 per year in 2024, the number of closed claims for difficult tracheal intubation as the damaging event has not decreased over time and, in fact, more recent claims generally involved sicker patients and nonoperative locations.[6]

This review will identify existing safety considerations, discuss current approaches to improving and maintaining safety, and suggest future strategies for addressing ongoing issues in modern airway management.

EPIDEMIOLOGY

The characteristics of adverse events during difficult airway management (DAM) are tough to describe because such events occur infrequently. Nevertheless, a 2019 review of closed malpractice claims due to airway management suggests a shift in the clinical features of such adverse events.[6] When compared to claims from 1993–1999, those from 2000–2012 more often involved sicker patients undergoing emergency procedures in nonoperating room (OR) locations. A 2017 review of Norwegian malpractice claims for injuries related to airway management noted that 37% of claims occurred during emergency procedures and that more than half of cases resulting in death were due to failed intubation or a misplaced endotracheal tube.[7] The 2015 United Kingdom National Audit Program 4 collected reports of airway management complications from 2008 to 2009 and similarly found that of the 33 events resulting in death, 16 occurred in the intensive care unit (ICU) and 3 in the Emergency Department.[8] Together, these observations suggest that today, airway events that lead to severe injury occur less often in elective OR situations and have shifted to occur more often during emergencies and in the ICU or other non-OR locations.

"...while the number of publications per year with the keyword 'difficult airway' has increased from 79 in 1990 to over 450 per year in 2024, the number of closed claims for difficult tracheal intubation as the damaging event has not decreased over time and, in fact, more recent claims generally involved sicker patients and nonoperative locations."

CURRENT SAFETY IMPLICATIONS

This shift in the types of clinical encounters likely to lead to severe complications of DAM has two implications for improving safety. Because airway encounters associated with severe outcomes are more likely to be emergent and occur outside the OR, a focus of safe airway management should be to verify that equipment needed to handle likely DAM scenarios is readily accessible to airway managers outside the OR. In addition, the emergent nature of many DAM situations introduces time pressure, which increases stress and the risk for cognitive errors.

Whether originating in a call for urgent or emergent airway management in ICU or during a sequence of failed airway attempts in the OR, cognitive training is an increasingly important element of DAM. Evidence is increasing that "judgment errors" play a large role in adverse airway management events. Such errors include a lack of backup plans for airway management, failure to call for help early, failure to use a SGA as a bridge to oxygenation, and failure (or reluctance) to awaken the patient or progress to a surgical airway when it is clear that all available noninvasive options have failed.

Addressing the cause of "judgment" or decisional errors during DAM likely requires a multipronged approach. In the 2019 American Society of Anesthesiologists (ASA) closed claims study, judgment errors were more common during elective than urgent airway management. This observation suggests that prior to airway management, airway managers may have failed to recognize predictors of DAM during screening evaluations, or that screening exams may not always predict airway difficulty.[6] Both possibilities identify potential avenues for improvement. During airway management, several "cognitive traps" have been described including failure to promptly move to a surgical airway when indicated, repeatedly attempting intubation when previous efforts have failed, a reluctance to admit defeat, or not clearly declaring failure of conventional airway management techniques. These "human factor" issues may be amenable to metacognitive reflection[9] or simulation training.[10] Debriefing after events occur and participating in focused case conferences may also "move the needle" with respect to improving performance.[11]

Cognitive errors can meaningfully affect the course of airway management. Considerable data now suggest that repeated airway instrumentation both decrease the likelihood of subsequent success[12] and worsen eventual outcomes.[13] The 2022 ASA guidelines advise limiting intubation or supraglottic airway attempts to 3 or fewer if possible.[3] Repeatedly attempting to intubate or an unwillingness to admit failure can thus not only delay successful intubation but lead to adverse events.

Existing data show that airway managers must also make difficult decisions in the context of cardiorespiratory instability. The 2024 INTUBE study reviewed 2964 patients requiring intubation in the ICU and found that 45% experienced either cardiovascular instability, severe hypoxemia, or cardiac arrest during emergency intubation.[14] Even during elective anticipated DAM, the incidence of cardiorespiratory destabilization can be high, as observed

See "Airway Management," Next Page

Cognitive Errors Can Contribute to Adverse Events in Airway Management

From "Airway Management," Preceding Page

in a 2025 descriptive study of 1295 episodes of elective DAM.[15] Although no cases from that series were cancelled for failure to intubate, the incidence of hypoxemia was 50%, the frequency of cardiovascular destabilization was 20%, and 30% of patients required 3 or more intubation attempts.[15]

Taken together, these large studies of airway management and clinician behavior suggest that airway managers should expect DAM to be both cognitively and technically difficult. Increasingly in 2025, important elements of safe airway management include developing an airway strategy with sequences of backup plans and training to avoid cognitive pitfalls such as perseveration, failure to call for help, losing track of time during a crisis, and reluctance to proceed to surgical airway access.

FUTURE CONSIDERATIONS

With the introduction of VL, SGA, other advanced airway tools, rapidly reversible neuromuscular blockers, and recognition of cognitive pitfalls in DAM, modern airway management is considerably safer than in the 1990s. However, the expanded "menu" of airway options and strategies available today introduces other potential safety challenges.

Among these challenges is the relative role of different intubating devices. Although not introduced into wide clinical practice until 2001, VL has overcome cost and learning curve challenges and supplanted direct laryngoscopy for many DAM applications. A 2023 multicenter randomized trial of intubation in critically ill patients found a higher first pass success rate with video than with direct laryngoscopy[16], leading many to propose that VL should become the standard for intubation. However, it is easy to see that preferential VL use can create a self-reinforcing loop where a "first attempt VL" preference leads to gradual deskilling in the use of direct laryngoscopy, which then tilts comparative trial outcomes towards VL—further reinforcing a "first attempt VL preference." It is likely that future use of direct laryngoscopy will diminish rapidly unless steps are taken to preserve it.

Similarly, because VL and SGA are effective in a wide variety of difficult airways, the role of awake flexible bronchoscopic intubation (AFB) is increasingly unclear. Because AFB requires considerable skill and practice, a preference for alternative techniques can lead to the same "deskilling" cascade as with direct laryngoscopy. Ultimately, further work is needed to determine whether AFB can/should continue to play a role in difficult airway management.

The more rapid learning curve for VL than for direct laryngoscopy or AFB also raises an organizational question as to how best to deploy airway management expertise.[17,18] Because fewer repetitions are needed with VL to achieve basic airway expertise, Emergency Room and Medical ICU clinicians can now provide a wide range of airway management services, freeing up anesthesiology clinicians currently in high demand for OR anesthesiology coverage. However, deciding when and how to bring anesthesiology and surgical expertise to an airway management event initiated by a nonanesthesia clinician remains an unanswered question. Although a first attempt by nonanesthesia airway managers is likely more efficient, potential pitfalls include a failure to recognize the difficult airway, the likelihood of airway damage or worsening conditions with repeated attempts. Multidisciplinary difficult airway response teams have had some success but still need to be called in a timely fashion by the initiating service.[19] How best to collaborate among services with respect to DAM will clearly be a safety challenge going forward.

Another unresolved issue is to determine the optimal approach to airway management in patients at increased risk for aspiration of gastric contents. Although current data suggest that asleep intubation with cricoid pressure does not reduce aspiration risk in high-risk patients and may worsen laryngoscopic views,[20] it is unclear whether an awake, topicalized, or AFB approach is better. No prospective randomized trial comparing the two techniques has been performed, and although a 1989 prospective observational trial found no explicit aspiration in 123 high-risk patients intubated via AFB, 10 patients developed laryngospasm, and severe coughing was present in 32.[21] From a safety perspective, strategies to preserve AFB skills among practitioners and identifying the optimal approach in patients at high risk for aspiration are both relevant future safety questions.

Another potential safety issue is the operational use of ECMO services for extremely difficult airways such as in patients with severe substernal goiter. In addition to being anatomically challenging, a large goiter can often make surgical airway access difficult and such patients may have tracheal compression below the vocal cords potentially impeding passage of an endotracheal tube. By restoring adequate gas exchange and potentially providing hemodynamic support in patients with mediastinal masses, venovenous or venoarterial ECMO can reduce the risk of oxygen desaturation or hypercarbia during airway management.[22]

Providing ECMO support to airway management is complex and requires strong teamwork between the ECMO clinician (usually cardiology or cardiac surgery) and the airway management team.[22] Issues include whether to implement ECMO in the awake patient prior to airway management, provide standby support with sheaths pre-inserted into the femoral vessels, or be ready to cannulate if airway management fails and emergent rescue is needed. If ECMO is needed for urgent rescue, training becomes an important element of successful time-dependent execution. Although ECMO services are currently limited mostly to major academic or urban medical centers, accessibility may improve as ECMO technology becomes increasingly widespread. Better understanding how to deploy it effectively for DAM and how to train participants for rescue cannulation will be relevant future safety concerns.

See "Airway Management," Next Page

Higher First Pass Success Rate With Video Laryngoscopy Than With Direct Laryngoscopy

From "Airway Management," Preceding Page

SUMMARY

Although modern airway management is safer than ever, challenges still remain and the task of maintaining safe airway practice has grown increasingly complex. Many previously difficult airways are now easily managed with VL, and use of SGA as rescue devices and intubating tools is now widely recognized. However, the proliferation of intubating devices and techniques raises new safety questions. Among these is how best to preserve direct laryngoscopy skills when VL is increasingly the first choice for routine airways, how best to mitigate aspiration in high-risk patients, developing and teaching behavioral strategies to avoid cognitive traps, and integrating ECMO support into preemptive, standby, or rescue scenarios in patients with particularly high-risk airways. The solutions to these questions are likely to make airway management even safer in the future.

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ICU Patient Safety Frontiers: Reducing Harm Through Better Handoffs and Infection Prevention

by Jonathan Charnin, MD, and Randy Loftus, MD

Intensive care units (ICU) emerged in the 1950s to localize the knowledge and resources needed to treat patients with respiratory failure. This care concept was effective, and ICUs have become ubiquitous in hospitals throughout the world. There has always been a close relationship between anesthesia professionals and the specialized field of critical care which has developed alongside the evolution of ICUs. Many hospitals have more than one ICU, which allows for sub-specialization in critical care. Outside of operating rooms and emergency departments, ICUs are the locations for treating our sickest patients, especially those suffering from shock, respiratory failure, and other life- or limb- threatening illnesses.

While not all anesthesia professionals practice intensive care, some do. The frequent movement of patients back and forth between operating rooms, procedural areas, and the ICUs makes critical care practice relevant to anesthesia professionals. As an example, adult respiratory distress syndrome (ARDS) is an all-too-common cause of respiratory failure in the ICU with a high associated mortality. The Acute Respiratory Management in ARDS (ARMA) trial, published in the year 2000, changed the paradigm of respiratory care to emphasis the protective effects of low tidal volume ventilation.[1] Since the adoption of low tidal volume ventilation, the incidence and mortality of ARDS have both been declining.[2] Low tidal volume ventilation prevents ventilator-induced lung injury by "dosing" tidal volumes using a formula based on the patient's ideal body weight. Higher tidal volumes have been found to increase inflammation even in uninjured lungs.[3] The practice of low tidal volume ventilation has transferred, although slowly, from the ICU to the operating rooms. Lung injury from large tidal volume ventilation is preventable. The story of lung protective ventilation shows that we can embrace practice changes to reduce preventable harm.

The Anesthesia Patient Safety Foundation (APSF) has been inspiring anesthesia professionals to eliminate preventable patient harm since 1985. As we mark the 40th anniversary of the APSF, let's extend its vision to eliminating patient harm in ICUs as well. Two patient safety frontiers for ICU patients are highlighted here: information sharing during handoffs and preventing the transmission of pathogens (Figure 1). These are complex areas where our knowledge is still growing, but research exists prompting us to act in order to prevent patient harm.

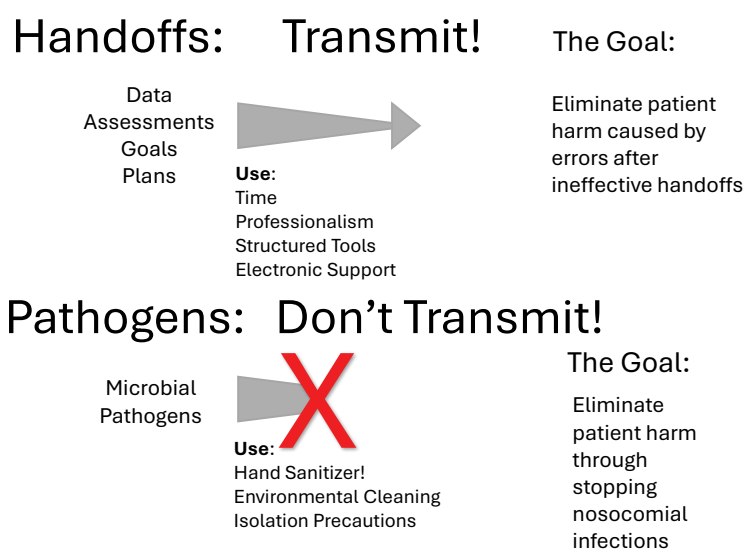

Figure 1: Reducing Patient Harm by Transmissing More and Transmitting Less.

HANDOFFS

Handoffs between ICU professionals occur regularly. Shorter duty periods in the ICU have reduced sleep deprivation but increased the number of handoffs between team members working in the ICU. Additionally, ICU patients often transition to the care of non-ICU teams for surgery, procedures, and diagnostic tests. This creates additional handoffs both when a patient leaves and returns to the ICU. Managing the flow of information during these handoffs is an ongoing challenge. Hemodynamic monitoring, imaging procedures, pharmacologically relevant genetic testing, medication administration history, and the patient's own wishes and requests can result in a mountain of information. Transmitting even a portion of this information to providers is challenging and this communication gap can lead to errors. Adverse events in the ICU are common, and more than half of them may be preventable.[4] A recent multicenter trial that compared the impact of extended duration duty shifts of 24 hours or more with shift work of among trainees in the ICU found that there were more medical errors in the shorter duration duty periods and more errors unit wide, hypothesizing that the increased number of handoffs is a contributing factor.[5]

Optimizing handoffs both during anesthesia care and for ICU patients remains an area of research. Synthesizing the relevant information to effectively support a transition of care can be difficult and time-consuming. In the ICU, structured handoff approaches such as using the I-PASS tool suggested by the Agency for Healthcare Research and Quality may be helpful.[6] Successful handoffs between anesthesia professionals and ICU teams require time and attention and may benefit from the use of structured handoff tools. Electronic tools have been developed to facilitate information transfer during transitions of care.[7,8] Perhaps more important than the format of the handoff is the culture of excellent attention to detail that should be displayed during each handoff. The Multicenter Handoff Collaborative (MHC) is supported by the APSF as a special interest group to research, educate, and promote safe handoffs and has resources for the implementation of perioperative handoff initiatives.

The frontier for patient safety in handoffs of care in the ICU involves clinicians both recognizing the importance of excellent communication and utilizing the appropriate tools to ensure that a successful transition is completed. Even with advancements in computer technology providing new tools to process and present patient information, anesthesia and ICU team members are essential to successful patient handoffs.

PREVENTING PATHOGEN TRANSMISSION

While the ICU concept localizes critically ill patients to optimize patient care from specialized teams, it also creates an environment for potential pathogen transmission. While many patients come to the ICU to receive treatment for life-threatening infections, others develop nosocomial infections in the ICU that become life-threatening. Most of these nosocomial infections are preventable. Understanding the serious infectious risks for ICU patients and tools that are available to prevent nosocomial

See "ICU," Next Page

Handoffs and Pathogen Transmission Are Major Areas of Patient Safety Concern in the ICU

From "ICU," Preceding Page

infections are the responsibility of all professionals who provide care to critically ill patients inside and outside of the ICU.

The challenges of pathogen transmission in the ICU mirror those in the operating room. Multidrug resistant pathogens are of particular concern in the ICU environment. In addition to usual modes of transmission, bacteria with antibiotic resistance may develop other characteristics, like biofilm creation, which allow them to survive on environmental surfaces longer than expected. A threshold of contamination of 100 colony forming units of any bacteria recovered from highly contacted surfaces in the ICU environment has been associated with the detection of major bacterial pathogens on that surface.[9] Once these bacteria establish a reservoir in an area that is touched frequently, like the bed-rail in the ICU or the adjustable pressure-limiting valve in the operating room, these bacteria will continue to spread to both providers and patients until effective decontamination occurs.

Many of the same interventions that generate life-saving care in the ICU also produce opportunities for pathogens to create new infections. Vascular access catheters, including central lines and mechanical circulatory support access points, urinary drainage catheters, endotracheal tubes, and surgical or traumatic wounds are all susceptible to nosocomial infections. Often, it is the hands of the health care providers that directly cause the transmission of these pathogens.

Basic bacterial identification can reveal which pathogens are causing a particular infection, but they do not suggest a pattern of movement or transmission. After all, everyone has some bacteria on their skin. Research using bacterial genome analysis of bacterial populations contaminating anesthesia work environments and the hands of anesthesia professionals has shown that transmission of pathogens does occur in the operating room.[10] Similar research in the ICU has shown that poor hand hygiene plays a crucial role in the transmission of pathogens, leading to health-care-associated infections (HAIs).[11]

Methods for preventing the spread of pathogens are well defined in the medical literature and enabled by tools already at our disposal. Such methods for anesthesia and ICU professionals include frequent utilization of alcohol-based hand sanitizers, and attention to isolation requirements.[12] The APSF Patient Safety Priorities Advisory Group for Infectious Diseases has recommended the use of alcohol-based hand sanitizer at least 4 times per hour while caring for patients in the ICU and at least 8 times per hour while providing care in the operating room..[13]

Since the introduction of ICUs more than 70 years ago, there have been dramatic improvements in the life-saving interventions that can be provided. There have been consistent improvements in mortality associated with the treatment of respiratory failure and shock. While improvements in these areas continue to be sought after, there is also an urgent need to make progress in the areas of handoffs, and prevention of transmission of nosocomial pathogens. If health care members are provided the necessary information during a handoff they can make the best decisions, and our patients will have better outcomes. When nosocomial infections are prevented, patient outcomes will also improve. Our goal should be to transmit optimal information during handoffs and not transmit pathogens during patient care.

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Perioperative Brain Health and Postoperative Delirium Prevention:

Recommendations from the APSF Brain Health Patient Safety Priority Advisory Group

by Ryan Field, MD; Lisa Bethea, MD; Arney Abcejo, MD; and Jeffrey Huang, MD

As we celebrate the 40th anniversary of the APSF, it is important to reflect on the growth and evolution of our specialty—specifically around the patient safety outcomes that matter most to our patients. Postoperative delirium (POD) is the most common adverse event following surgery in older adults, with an incidence as high as 65%. It is associated with prolonged hospital stay, increased morbidity and mortality, and significant distress for both patients and their families.[1,2] Recognizing the critical importance of brain health, the APSF has identified it as a Patient Safety Priority. Optimizing brain health through targeted perioperative interventions is of utmost importance. In 2023, the *APSF Newsletter* published an article titled "Perioperative Brain Health: A Patient Safety Priority All Anesthesia Professionals Must Address,"[3] which, along with the American Society of Anesthesiologists (ASA) Brain Health Initiative, has served as a foundational guide for developing brain health implementation protocols. Many hospitals have successfully created and implemented their own protocols, achieving positive outcomes.

Several evidence-based interventions have been shown to potentially reduce the risk of postoperative delirium. These include preoperative cognitive screening, early mobilization, maintaining orientation, promoting sleep hygiene, ensuring the timely return of personal items (such as glasses, hearing aids, and dentures) after surgery, intraoperative dexmedetomidine use, and providing delirium education for health care professionals.[4] However, the role of intraoperative anesthetic management remains a topic of ongoing debate and controversy. Numerous new studies have emerged, some with conflicting results that may create uncertainty among anesthesia professionals regarding best practices. Consequently, the APSF Perioperative Brain Health Patient Safety Priority Advisory Group (PSPAG) believes it is essential to present these new findings to anesthesia professionals, along with updated recommendations, to facilitate effective implementation and ultimately improve patient safety and outcomes.

INTRAOPERATIVE HYPOTENSION (IOH)

Intraoperative hypotension, defined by episodes of low blood pressure during anesthesia, has been proposed as a modifiable risk factor for postoperative delirium particularly in elderly or high-risk patients.[5] The brain normally maintains constant blood flow despite fluctuating systemic pressures (cerebral autoregulation), but this capacity is blunted in the elderly and those with vascular disease.[5] During intraoperative hypotension, cerebral perfusion pressure falls, especially if mean arterial pressure (MAP) drops below the lower autoregulatory limits (~50–60 mmHg).[5,6] Experimental and clinical evidence suggest that sustained cerebral hypoperfusion can trigger neuronal dysfunction, blood brain barrier breakdown, and neuroinflammation, all of which are implicated in delirium pathophysiology.[5,6] Thus, hypotension can lead to reduced cerebral blood flow and oxygen delivery, potentially causing brain tissue injury and contributing to the development of postoperative delirium.[5]

Table 1: Studies on the Relationship Between Intraoperative Hypotension and Postoperative Delirium.

Study Type	Authors / Source	Population	Key Findings	Conclusion
Retrospective Study	Wang et al.[5] (2025)	Elderly laryngectomy patients	Sustained ≥30% MAP drop for ≥30 min → OR ≈ 1.74 (95% CI 1.04–2.91); surgery duration amplified risk	IOH + prolonged surgery synergistically increases POD risk
Large Retrospective Cohort	Wachtendorf et al.[7] (2022)	316,717 patients (mean age >70)	MAP<55 mmHg: OR ≈ 1.22 (short) to 1.57 (prolonged); +6% POD risk per 10 min MAP<55	Duration- and dose-dependent effect; absolute MAP<55 is key risk factor
Meta-analysis (RCTs)	Feng et al.[8] (2019)	5 RCTs comparing high vs low MAP	No significant POD difference; RR ≈ 3.30 (CI 0.80–13.54), *P*=0.10	RCTs show non-significant trend toward harm; small sample sizes, few POD cases
Prospective Cohort	Hirsch et al.[9] (2015)	594 patients >65, major noncardiac	No POD association with MAP<50 or 20–40% drops; BP variability was predictive	BP instability, not absolute level, linked to POD
Retrospective Study	Yang et al.[10] (2025)	1,002 elderly hip fracture patients	MAP Coefficient of Variation >10% → OR ≈ 1.45 for POD	BP variability independently predicts POD
Retrospective Cohort	Zarour et al.[11] (2024)	2,352 elective elderly patients	No POD association with MAP <65 AUC after adjustment	Contradictory finding; may reflect differing IOH definitions or patient factors
Randomized controlled trial	Marcucci et al.[12] (2025)	2,603 patients with mean age, 70 years undergoing noncardiac surgery	Intraoperative MAP>80 vs MAP >60, no difference in Montreal Cognitive Assessment (MoCA) 1 year after surgery	No difference in neurocognitive outcomes between the hypotension-avoidance and hypertension-avoidance strategies

IOH: intraoperative hypotension; POD: postoperative delirium; RCT: randomized controlled trial; CI: confidence interval; MAP: mean arterial pressure; BP: blood pressure; AUC: area under curve.

Several retrospective studies[5,7] suggest an association between intraoperative hypotension and postoperative delirium, but in general evidence is mixed (Table 1). A prospective randomized trial,[9,12] a systematic review and meta-analysis,[8] and other retrospective studies[10,11] found no association between intraoperative hypotension and postoperative delirium. Overall, the evidence more strongly suggests that

See "Brain Health," Next Page

Maintaining Optimal Intraoperative Blood Pressure May Maintain Perioperative Brain Health

From "Brain Health," Preceding Page

intraoperative hypotension may not be a primary cause of postoperative delirium.

Variability in definitions (absolute vs relative hypotension) and patient populations make universal conclusions difficult. Given that intraoperative hypotension is modifiable, it remains a reasonable prevention target; guidelines now advocate vigilant blood pressure monitoring and management in older surgical patients.[7] The ASA Practice Advisory for Perioperative Care of Older Adults Scheduled for Inpatient Surgery suggests individualized hemodynamic goals and rapid correction of hypotension.[13] Future high-quality trials are needed to determine whether strict BP control or autoregulation-guided management reduces postoperative delirium.

Therefore, the APSF Brain Health PSPAG agrees that maintaining optimal intraoperative blood pressure, with proactive and individualized management strategies to minimize the occurrence, severity, and duration of hypotension and its associated complications in older adults is warranted.

PREOPERATIVE BENZODIAZEPINE USE

A Historical Lens on Benzodiazepines Use and Brain Health

The Beers Criteria were initially introduced to inform practitioners of medications to use with caution in nursing home residents, and these criteria were expanded to all older adults in 1997. In 2012, the American Geriatrics Society (AGS) assumed stewardship of the Criteria, introducing rigorous, evidence-based approaches to medications. These recommendations, updated in 2023, continue to place benzodiazepines on the "potentially inappropriate" list for adults over the age of 65. In the context of neuroanesthesia, brain health, and patient safety, where cognitive preservation is paramount, this caution seems well-founded. Currently, the pervasive culture around benzodiazepines in many institutions is to avoid them preoperatively.

However, it is important to recognize the limitations of the scope of the Beers Criteria. Much of the early evidence grouped benzodiazepines together: short- and long-acting agents, outpatient and inpatient medicine, one-time dose and chronic use.

Contemporary Practice Advisories and Evidence from Recent Trials

The ASA Practice Advisory for Perioperative Care of Older Adults Scheduled for Inpatient Surgery thoughtfully addressed the impact of perioperative medications with central nervous system effects on postoperative cognitive dysfunction and outcomes. The Advisory took a measured approach: "Consider the risks and benefits of medications with potential CNS effects in older adults, as these drugs may increase the risk of postoperative delirium."[13] Notably, the Advisory did not recommend avoiding short-acting benzodiazepines like midazolam or remimazolam, recognizing recent data have not demonstrated a consistent link between their use and cognitive dysfunction/delirium in older adults.

Recently, a prospective multicenter cohort study of >5,600 patients aged 65 years and older undergoing elective noncardiac procedures in China did not show an increased risk of postoperative delirium in those who received intraoperative midazolam versus those who did not (adjusted risk ratio 1.09 (95% CI, 0.91–1.22; *P*=0.35).[14] Subgroup analyses based on age, sex, ASA class, and comorbidities revealed no population in which midazolam incurred an increased delirium risk. However, patients who received midazolam had significantly lower rates of postoperative anxiety (5.7% versus 13.4%).[14]

A multiperiod, double-blinded, cluster-randomized crossover trial to assess the impact of perioperative benzodiazepine use on delirium was conducted at 20 North American cardiac surgical centers (n=19,768; mean age, 65 years).[15] The patients underwent cardiac surgery during either restricted (n=9,827) or liberal (n=9,941) benzodiazepine use periods. Delirium occurred in 1,373 patients (14.0%) during restricted periods and 1,485 patients (14.9%) during liberal periods (adjusted odds ratio [aOR], 0.92; 95% CI, 0.84–1.01; *P*=0.07). The investigators concluded that restricting benzodiazepines during cardiac surgery did not reduce the incidence of delirium.[15]

Pragmatic Clinical Takeaways

Altogether—between the 2025 ASA Practice Advisory and recent multicenter studies—the evidence likely does not support a recommendation to avoid single-use of short-acting benzodiazepines like midazolam in the perioperative setting in older adults.

The APSF Brain Health PSPAG agrees that in older adults:

- Regular review of home medications and deprescribing when appropriate can reduce the risk of postoperative delirium.
- Preoperative doses of short- (midazolam) or ultra-short acting benzodiazepines (remimazolam) need not be proscriptively avoided if specifically trying to minimize postoperative delirium.
- Cognitive screening should still be considered to incorporate into preoperative workflows.

Table 2: Anesthesia Depth and Postoperative Delirium.

Study Type	Authors / Source	Population	Key Findings	Conclusion
Randomized clinical trial	Wildes T et al.[16] *JAMA* 2019	1232 patients (aged >60, undergoing major surgery and receiving general anesthesia)	Postoperative delirium occurred in 26.0% of the EEG-guided anesthetic group and 23.0% of the usual care group	The use of EEG-guided anesthetic administration did not prevent postoperative delirium
Multicenter randomized clinical trial	Deschamps A, et al.[17] *JAMA* 2024	1140 patients (aged >60, undergoing cardiac surgery with cardiopulmonary bypass)	Delirium during postoperative days 1 to 5 occurred in 18.15% in the EEG-guided group and 18.10% in the usual care group	EEG-guided anesthetic administration did not decrease the incidence of postoperative delirium
Multicenter randomized clinical trial Delirium subgroup was retrospectively registered. The subgroup study was conducted in China	Evered LA, et al.[18] *BJA* 2021	547 patients (aged >60, undergoing major surgery lasting 2 hr or more)	The incidence of postoperative delirium in the bispectral index (BIS) 50 group was 19% and in the BIS 35 group was 28% (*P*=0.010)	Targeting light anesthesia reduced the risk of postoperative delirium.

EEG: electroencephalography; BIS: bispectral index.

See "Brain Health," Next Page

Data on the Effects of Intraoperative EEG on Postoperative Delirium is Inconclusive

From "Brain Health," Preceding Page

ANESTHESIA DEPTH AND MONITORING

For many years, the impact of monitoring and maintaining anesthetic depth with electroencephalography (EEG) monitoring on postoperative cognitive decline has been debated. The results are mixed (Table 2). The ENGAGES trial (1232 patients) found no significant reduction in delirium with EEG-guided anesthesia (26.0% vs 23.0%, *P*=0.22).[16] In that trial, EEG guidance successfully reduced EEG burst suppression but failed to reduce the rate of delirium. Similarly, the ENGAGES-Canada trial (1140 patients) found delirium incidence of 18.15% vs 18.10% (EEG-guided vs usual care).[17] A sub-study of the BALANCED trial (515 patients) reported lower delirium with lighter anesthesia (BIS 50: 19% vs BIS 35: 28%, *P*=0.010),[18] but the full BALANCED trial (6644 patients) showed no overall benefit to targeting light vs deep anesthesia.[18] The lower delirium incidence with lighter anesthesia in the BALANCED subtrial may be driven by centers with high baseline delirium, including patients with high frailty and preoperative risk factors. Furthermore, the sub-study results were mostly reflective of Asian centers, potentially highlighting the need for a population-based approach to anesthetic delivery.[19]

However, the benefits of intraoperative EEG monitoring were demonstrated in a randomized clinical trial of 177 pediatric patients in which EEG-guided titration of anesthesia was compared with standard 1.0-MAC sevoflurane anesthesia. EEG-guided management of general anesthesia reduced the incidence of pediatric emergence delirium (35% vs 21%), while also resulting in faster emergence and shorter postanesthesia care unit stays.[20] While promising, these findings may not directly translate to adult populations given the differing pathophysiology and types of delirium.

The evidence from studies in adult patients suggests the use of EEG-guided anesthetic administration for the prevention of postoperative delirium did not decrease the incidence of postoperative delirium or yield significantly superior outcomes in patients receiving volatile-agent-based general anesthesia. Burst suppression can be visually identified in raw EEG recordings, yet its association with postoperative delirium remains unclear. Most studies rely on commercial monitoring technologies that estimate burst suppression using processed EEG values, which typically underestimate its extent. Some experts suggest that raw EEG-guided intraoperative drug titration may offer a more accurate and effective approach to detect and prevent burst suppression.[21] Future clinical trials are needed.

Table 3: Summary of APSF Brain Health PSPAG Recommendations.

Clinical Category	APSF Brain Health PSPAG Recommendations
Preoperative Benzodiazepine Use	Preoperative doses of short- (midazolam) or ultra-short acting benzodiazepines (remimazolam) need not be proscriptively avoided if specifically trying to minimize postoperative delirium in older adults.
Intraoperative Hypotension	Maintaining optimal intraoperative blood pressure is recommended, with proactive and individualized management strategies to minimize the occurrence, duration, and severity of hypotension and its associated complications in older adults.
Anesthesia Depth and Monitoring	Currently, the data on intraoperative EEG monitoring and the prevention of postoperative delirium in older adults is inconclusive.
Anesthesia Techniques	Selection of anesthesia techniques (GA or RA) does not significantly affect the incidence of postoperative delirium in older adults.

EEG: electroencephalography; GA: general anesthesia; RA: regional anesthesia.

The APSF Brain Health PSPAG agrees that in older adults:

1. Intraoperative EEG monitoring is a useful adjunct to tailor anesthetic depth and support precision anesthesia by individualizing care, where it may help minimize drug exposure.
2. The evidence on intraoperative EEG monitoring and prevention of postoperative delirium is inconclusive.

ANESTHESIA TECHNIQUES

Alongside depth, the choice of anesthetic (general vs regional) has been debated. A recent meta-analysis (21 trials, >1.7 million patients)[22] found that delirium was not significantly different between general anesthesia and regional anesthesia groups once confounders were controlled.[22] The RAGA trial (950 patients) found similar delirium rates with regional anesthesia without sedation (6.2%) vs general anesthesia (5.1%), a nonsignificant difference.[23] Using regional techniques alone did not reduce postoperative delirium. A recent meta-analysis encompassing 10 randomized controlled trials with a total of 3,968 elderly patients undergoing hip fracture surgery found no significant difference in the incidence of postoperative delirium between neuraxial anesthesia and general anesthesia.[24] The authors concluded choice of anesthesia technique alone does not significantly influence postoperative delirium risk in this patient population. Interestingly, a small study (n=114) of elderly patients undergoing hip fracture surgery under spinal anesthesia, reported that light propofol sedation (BIS ≥80) halved delirium incidence compared to deep sedation (19% vs 40%, *P*=0.02).[25] Avoiding excessive sedation may be a key strategy. Future work is needed to identify subgroups and confounding variables that explain conflicting results and help us learn how to selectively apply these interventions.

Current evidence indicates that there are no significant differences in the incidence of postoperative delirium or other delirium-related outcomes between the regional anesthesia and general anesthesia groups.

The APSF Brain Health PSPAG agrees that in older adults (Table 3):

1. Selection of anesthesia techniques does not significantly affect the incidence of postoperative delirium.

CONCLUSION

Current evidence suggests that intraoperative hypotension is unlikely to be a primary driver of postoperative delirium. However, maintaining optimal intraoperative blood pressure remains important to minimize related complications, particularly in older adults. The use of short-acting (e.g., midazolam) or ultra-short-acting benzodiazepines (e.g., remimazolam) in the preoperative period does not need to be categorically avoided solely to reduce the risk of postoperative delirium. The data on intraoperative EEG monitoring and delirium prevention is inconclusive. Furthermore, the choice of anesthetic technique—whether general or regional anesthesia—does not appear to significantly impact the incidence of postoperative delirium. As brain health research continues to evolve globally, it is essential to regularly update clinical guidelines based on emerging evidence, and all recommendations should be interpreted in the context of ongoing developments.

See "Brain Health," Next Page

Selection of Anesthetic Technique (GA vs RA) Does Not Affect Postoperative Delirium in Older Adults

From "Brain Health," Preceding Page

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40 Years of Progress in Obstetric Anesthesia Safety: Milestones, Challenges, and Future Directions

by Lauren Crosby Zawierucha, MD, MSc; Emily Naoum, MD; and May C. M. Pian-Smith, MD, MS

INTRODUCTION

Anesthesiology has emerged as a leader in patient safety through innovations in monitoring, education, and simulation, and a willingness to look introspectively at human factors in critical events. This is evident in obstetric anesthesiology, where the latter half of the last century saw a significant reduction in anesthesia-related maternal mortality and anesthesia-related complications.[1] Publication of guidelines for best practice and standards of excellence in obstetric anesthesiology continue to advance the specialty with respect to patient safety.[2] However, maternal mortality remains a leading cause of death in women aged 20–44 years, and although the rising rate of maternal mortality in the United States has leveled in recent years, it continues to rank the worst of any high resource country on this metric.[3] Anesthesia-related complications are now the least common cause of maternal mortality according to the Pregnancy Mortality Surveillance System, but emerging issues such as patient complexity and workforce demands, and persistent challenges including racial and socioeconomic disparities, still pose a threat to maternal safety.[4] There continue to be opportunities for anesthesia professionals to leverage expertise in acute care medicine, maternal physiology, and principles of patient safety to help address other causes of maternal morbidity and mortality. To mark the *APSF Newsletter's* 40th anniversary, this article provides a retrospective on four decades of progress in obstetric anesthesiology, explores ongoing challenges, and looks ahead to future directions in patient safety.

MILESTONES

Anesthesia-related maternal mortality decreased significantly with the shift away from general anesthesia and toward neuraxial analgesia and anesthesia over the last 40 years.[1] Much of the improvement in anesthesia outcomes can be attributed to advances in neuraxial anesthesia safety. Modern labor analgesia has moved toward lower-dose local anesthetic concentrations and lower total local anesthetic consumption, reducing the risk of high neuraxial block, local anesthetic toxicity, and operative vaginal delivery.[5,6] The introduction of noncutting needles allowed for the widespread use of subarachnoid block for surgical anesthesia, while reducing the likelihood of postdural puncture headache, failed regional anesthesia, and local anesthetic exposure.[2] Research into the optimal vasopressor to mitigate spinal-induced hypotension and utilizing the lowest effective opioid dose to enhance postpartum analgesia have minimized the adverse effects of neuraxial anesthesia for mother and baby.[7,8] Use of neuraxial anesthesia in patients has been shown to reduce severe maternal morbidity.[2,9] Subspecialty training in obstetric anesthesiology has been shown to reduce the use of general anesthesia for cesarean delivery, which may further reduce maternal morbidity.[10] That said, neuraxial anesthesia is not without risk. High neuraxial block and bradyarrhythmia associated with spinal anesthesia are leading causes of maternal cardiac arrest, and the increased presence of tranexamic acid on labor and delivery floors following the Woman Maternal Antifibrinolytic Trial (WOMAN), has led to rare but catastrophic medication errors.[11,12]

Once a leading cause of anesthesia-related maternal mortality, fatalities from aspiration and failed airway management have declined to very low levels. Expanded access to videolaryngoscopy, use of aspiration prophylaxis, publication of difficult airway algorithms, and incorporation of obstetric-specific recommendations in airway guidelines have improved the safety of general anesthesia for pregnant patients.[13] Taken together, these changes to neuraxial and general anesthesia have resulted in remarkably safe anesthesia and analgesia for childbirth.[14]

Obstetric anesthesiology as a specialty has also had a key role in addressing nonanesthetic causes of maternal morbidity and mortality. Anesthesia professionals are instrumental to the implementation of maternal early warning systems and the recognition and management of the main contributors to maternal morbidity and mortality, including hemorrhage, hypertensive crisis, sepsis, venous thromboembolism, and heart failure.[15] Care bundles to address these complications have been developed by multiple groups, including the Alliance for Innovation on Maternal Health and the California Maternal Quality Care Collaborative, and have been shown to be cost-effective in reducing severe maternal morbidity.[16] Even in low resource settings, protocolized care for postpartum hemorrhage has repeatedly been associated with improved outcomes.[17] Specifically for hemorrhage and hypertensive disorders, the care bundles identify anesthesia professionals as active participants in the multidisciplinary protocolized care of these patients to improve outcomes.[3]

Interdisciplinary communication and coordination are features of high-reliability organizations, and preoperative and pre-procedural checklists and huddles have been found to facilitate effective teaming on labor and delivery units.[18] Debriefings following critical events and reporting and reviewing patient safety

See "Obstetric Anesthesia," Next Page

Advances in Neuraxial Anesthesia Safety Have Improved Obstetric Anesthesia Outcomes

From "Obstetric Anesthesia," Preceding Page

concerns through peer-protected Quality Assurance committees allow for mutual learning and the opportunity to address system-level safety challenges, and provide support to the potential "second victims" of critical events.[19] Increased use of simulation as a means to practice recognizing and managing peripartum emergencies has also helped bolster a culture of safety and has been shown to improve multidisciplinary team performance.[20]

CHALLENGES

Emerging and persistent challenges to maternal safety include increasing patient complexity, maternal mental health conditions, racial disparities in outcomes, and geographic and socioeconomic barriers to care. The risk profile of the birthing population is changing, with an increasing prevalence of chronic diseases. There is a dose-dependent relationship between the number of maternal comorbidities and risk of severe morbidity.[21] A useful tool in risk stratification is the Obstetric Comorbidity Index (OB-CMI), a validated, numerical scoring system that uses maternal comorbidities to assess and predict the risk of severe maternal morbidity and mortality. Such targeted surveillance, ensuring risk-appropriate levels of maternal care, and the expanded role of the anesthesia professional as a perinatal consultant are tactics for improved maternal outcomes.[3] Antenatal planning and optimization is a core component of obstetric anesthesiology, but over half of pregnancy-related deaths occur between 7 and 365 days postpartum.[22] Experience in perioperative medicine means that the anesthesia professional is also well positioned to recognize patients at high risk for postpartum decompensation and escalate their care to the appropriate level with respect to scope and acuity. Team-based care should not end at delivery, and anesthesia professionals can meaningfully contribute to postpartum disposition planning.

Maternal mental health conditions, including suicide, and overdose or poisoning related to substance use disorder, are now leading causes of maternal mortality, along with hemorrhage, cardiac and coronary conditions, infection, thrombotic embolism, and cardiomyopathy.[22]

Recognizing at-risk patients, implementing trauma-informed care, and addressing pain are important ways that anesthesia professionals can impact morbidity and mortality related to maternal mental health.[23]

Maternal mortality remains unacceptably high among racial and ethnic minority groups, and this trend persists even in countries where maternity care is covered.[24] Black women in the United States experience a substantially higher rate of severe maternal morbidity and are overrepresented among maternal deaths.[25] Black women are more likely to die from cardiac and coronary conditions, are less likely to receive care escalation for postpartum hemorrhage, and are less likely to receive an epidural blood patch for postdural puncture headaches.[22,26,27]

Social determinants of health play an ongoing role in maternal morbidity and mortality. Geographic and socioeconomic barriers to care result in low- and middle-income countries experiencing higher rates of preventable maternal deaths.[28] Even within high-income countries, there are barriers to accessing safe and comprehensive reproductive health care. These include legislative barriers in the form of bans or restrictions on abortion care, which disproportionately affect women who may already have difficulty accessing appropriate care due to socioeconomic circumstances.[29] Advocacy, workforce planning, and anesthesia training can help address these inequities in global health care settings.

FUTURE DIRECTIONS

Modernization of anesthesia care, increasing patient complexity, and ongoing challenges in health care inequity highlight the need for new tools in the safety toolkit of the peripartum clinician and a renewed focus on maintaining the standards of care set out by professional associations. Point of care ultrasound is an example

See "Obstetric Anesthesia," Next Page

Point-of-Care Ultrasound May Reduce Procedural Complications

From "Obstetric Anesthesia," Preceding Page

of such a tool, which can reduce procedural complications related to neuraxial anesthesia, objectively assess aspiration risk, and aid in the diagnosis and management of cardiopulmonary complications in the unstable patient.[30] Risk predictive tools driven by artificial intelligence (AI), big data models, and biologic markers may offer novel solutions to personalizing risk stratification, coordinating early intervention, and managing scarce resources. Wearable technology represents a new paradigm in postoperative care and at-home monitoring may provide an avenue for addressing a component of postpartum morbidity and mortality.[31] Implementation of consensus-based standardized care, such as enhanced recovery after cesarean delivery (ERAC) protocols, may help to address racial disparities and continue to advance the specialty from the perspective of patient safety and quality care.[32]

CONCLUSION

The majority of pregnancy-related deaths continues to be preventable, indicating ongoing barriers to care and safety concerns in obstetric anesthesia. For every maternal death, there are 70 to 80 cases of severe morbidity at the time of hospitalization, and this definition does not include morbidity in the prenatal or postpartum periods.[33] Reflecting on the last 40 years in obstetric anesthesia highlights the progress that has been made in anesthesia-related patient outcomes, but also underscores how far we have yet to go in advancing maternal care for all women. Anesthesia professionals can play an important role in addressing the impact of hemorrhage, hypertensive disorders, and other threats to maternal well-being by utilizing clinical expertise and evidence-based protocols to provide timely care, at an appropriate level of acuity, and with safe interventions. We can continue to encourage the use of neuraxial anesthesia where possible, and have a more nuanced approach to patient selection and safety for general anesthesia. Adhering to standards of best practice, leveraging new technologies in obstetrics and anesthesia, and continuing to foster a culture of safety can help to ensure continued forward progress.

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40 Years of Progress and Future Directions in Chronic Pain Management and Patient Safety

by Steven P. Cohen, MD; Leena Mathew, MD; Stephanie G. Vanterpool, MD, MBA; and Amy C.S. Pearson, MD

Although pain has been a primary reason to seek medical treatment for centuries,[1] pain management has only been a medically recognized multidisciplinary subspecialty since 1992.[2] Since then, pain specialists have expanded, refined, and innovated their practices to meet the growing needs of their patient populations, with considerable improvements in patient safety.

GLOBAL PREVALENCE OF PAIN

Pain is the leading cause of disability, and its prevalence is increasing worldwide.[3] Low back pain, the number two cause of Disability-Adjusted Life Years worldwide, affects over 619 million people, approximately 10% of the 2020 world's population.[4,5] The prevalence of unspecified persistent pain in low to middle-income countries is estimated to be 34%.[6] In 2022, the World Health Survey was used to model the prevalence of pain across over 52 countries, identifying an average prevalence of 27.5%, ranging from 9.9% in China to 50.3% in Morocco.[7]

The global prevalence of pain is influenced by several factors. At the individual level, female gender, older age, and rural versus urban living environments are associated with higher pain prevalence.[7] At the country level, factors associated with increased pain prevalence include population density, life expectancy, gender inequality, and income inequality.[7] The reported prevalence of pain is also intimately related to the frequency of surveillance, and surveillance for pain is often ignored in lower income countries. According to the 2021 Global Burden of Disease study, the most dramatic growth in prevalence of low back pain is expected in Asia and Africa, where many of these country-level inequalities may be more pronounced.[5]

SOCIOECONOMIC IMPACT OF PAIN

Aside from disability, chronic pain also exacts a major socioeconomic toll on individuals and societies. The National Health Service in the UK spends nearly £5 billion annually on general practitioner evaluations of low back pain.[5] In the USA, the health care expenditures for low back and neck pain in 2016 was an astonishing $134 billion.[5] In addition to direct health expenditure, there are the additional socioeconomic costs of absenteeism, presenteeism, and productivity losses, which far exceed direct costs. The effect of low back pain on the ability to work is even more profound in low to middle-income countries, where known risk factors for chronic pain may be accentuated.

MEDICAL MANAGEMENT OF CHRONIC PAIN

The medical management of chronic pain has long been fraught with complexity and has historically centered on pharmacologic solutions—particularly opioids. In the late 20th century, pain was reframed as the "fifth vital sign," prompting a dramatic increase in opioid prescribing, often with insufficient evidence and an underestimation of the risks of dependence, tolerance, and hyperalgesia.[8,9] A focus on symptom management and ignoring the individuality of pain perception gave rise to a widespread overreliance on chronic opioid therapy. The fallout of this approach has been well-documented as the global opioid crisis.[10] Even without opioids, chronic pain management often relies on "synergistic" polypharmacy despite side effects like somnolence, mood and memory impairment, fatigue, and organ dysfunction. These treatments are associated with adverse reactions, cognitive decline, falls, and hospitalizations, particularly in elderly and complex patients.[11]

ADVANCEMENTS IN THE UNDERSTANDING OF PAIN

Research in the mechanisms of chronic pain has increased substantially in the last 40 years, leading to new understandings in pain signaling. Early research identified neurologic pathways and differentiated the types of nerve fibers involved in pain transmission.[2] Further studies elucidated more mechanisms for pain such as the descending inhibitory system, the endogenous opioid system, and the contribution of the autonomic nervous system. Newer research, especially utilizing functional MRI and other biomarkers, further explores the brain's dual role in the processing of chronic pain. Specifically this has identified not only the sensory-discriminative (e.g., location and intensity) components, but also the under-appreciated yet equally important affective-motivational and cognitive-evaluative (e.g., emotional and attentional) components.[12] Recently, two new classes of medications have been developed: selective NAV1.8 receptor inhibitors intended for acute pain management and CGRP (calcitonin gene-related peptide) inhibitors intended for migraine treatment.[13]

John Bonica, a pioneering anesthesiologist and former wrestler who suffered from chronic pain himself, seemingly anticipated these findings when he started the first multidisciplinary pain program in 1961.[2] Multidisciplinary pain clinics address the medical needs of patients using a biopsychosocial model. The biopsychosocial model of pain acknowledges the multidimensionality of pain as unique physical, psychological, and social factors shape it.[14] The limitations of pharmacotherapy and interventions targeting pain as a symptom are now the catalyst for a shift towards a more integrated, patient-centric care framework. Such an approach incorporates psychological support and lifestyle interventions into the treatment algorithm. Patients supported with lifestyle changes often report reduced pain alongside mood, energy, and quality of life improvements.[15-17] These approaches seek to address some of the underlying causes of inflammation, metabolic dysfunction, and stress and are especially valuable for those

See "Chronic Pain" Next Page

Multidisciplinary Pain Clinics May Improve Outcomes

From "Chronic Pain," Preceding Page

seeking noninvasive, self-directed care.[18] Multidisciplinary pain clinics that address the biopsychosocial model reduce emergency room visits, medication costs, and overall health care utilization. Further, patients of multidisciplinary clinics report less pain, have higher pain-related health literacy, and experience less pain-related limitations on their activities.[19]

ADVANCEMENTS IN INTERVENTIONAL PAIN MEDICINE

Interventional management of pain has also seen major advancements in patient safety. Perhaps the most important safety development has been the use of image guidance which allows for precision needle placement, surveillance of injectate spread, and detection of vascular uptake. Well into the early 2000s, high-impact general medical and specialty journals published clinical studies and case reports evaluating the effectiveness of commonly performed procedures such as epidural steroid injections (ESI), and high-risk procedures such as stellate ganglion block and celiac plexus neurolysis, done blindly without image guidance, sometimes with catastrophic consequences.[20-22] The use of imaging, which now includes real-time injection under fluoroscopy and ultrasound guidance, and in some cases computed tomography, has significantly improved outcomes and reduced complications.

SAFETY RESEARCH IN INTERVENTIONAL PAIN

A second advancement in safety has paradoxically been payor requirements for clinical studies to support various procedures, including high-risk ones, that previously were being widely performed based on anecdotal evidence and often biased by conflicts of interest. Previously commonly performed procedures that have been debunked by high-quality studies are intradiscal procedures (e.g., intradiscal electrothermal therapy and methylene blue injection). These can result in a subsequent increased risk of disc herniation, accelerated degeneration, and clinical deterioration. A second area in which payor pushback has resulted in improved safety is the use of sedation for routine procedures such as ESI, facet blocks, and sacroiliac joint injections. According to some studies, sedation was used through the 2010s in around half of all lumbar ESI. When used indiscriminately, deep sedation not only dramatically increases the cost of procedures, but has also been shown to increase the risk of complications and false-positive diagnostic blocks, leading to unnecessary procedures such as radiofrequency ablation and celiac plexus neurolysis, and overall poorer treatment outcomes.[23,24]

Identifying the prevalence and risk factors for rare but catastrophic complications is often impossible based on clinical studies, but relative risks can be ascertained by large database reviews, such as what U.S. Food and Drug Administration (FDA) investigators did for epidural steroid injections. The evidence for epidural depo-steroid injections is stronger than for injections performed with non-depo-steroids, so determining whether depo-steroids are associated with greater risks during lumbar transforaminal injections for sciatica is important for proper evaluation of risk vs benefit.[6] In the aforementioned FDA study, the authors could not find a difference in complication rates between particulate (depo) and nonparticulate steroids for transforaminal injections in over 1 million Medicare patients.[25]

LIFESTYLE MEDICINE

Prescriptive lifestyle approaches are invaluable in pain management for sustainable analgesia, decreased pain perception, and functional improvement, which may be more sustainable and safer than pharmacotherapy.[26,27] Mindfulness-based stress reduction, breathwork, and cognitive behavioral therapy help with coping, distraction, anxiety mitigation, and stress management, increasing agency and resilience while decreasing pain perception.[27] Quality sleep is also essential to pain modulation as circadian disruption and sleep dysregulation correlate with heightened pain sensitivity, anxiety, and reduced pain tolerance. Several integrative practices such as acupuncture, yoga, virtual reality, massage, and tai chi offer excellent low-risk alternatives. Physical activity decreases neuroinflammation and modulates pain signaling while also enhancing resilience, strength, circulation, and mobility.[28] In addition, it can also improve sleep and mood, thereby creating a virtuous cycle. Anti-inflammatory diets help modulate pain and improve mitochondrial and glial function.[29] Diets rich in omega-3s, antioxidants, and sirtuins reduce systemic inflammation while low-FODMAP (Fermentable Oligo-, Di-, Mono-saccharides And Polyols) diets modulate serotonin. Addressing chronic inflammation, supporting gut health, and promoting neuroprotection with such diets may additionally impact disease progression.[30,31] Improved sleep with behavioral techniques, relaxation, regular sleep-wake cycles, light exposure, melatonin, and cognitive behavioral therapy for insomnia—are linked to reduced pain and improved health biomarkers.[32]

THE FUTURE: POLICY CHANGES AND GLOBAL HEALTH

Addressing pain on a global scale requires appropriate public health and health policy measures. This is especially important given that many low- and middle-income country governments do not prioritize pain management services, instead focusing on the treatment of communicable diseases. Raising awareness of the individual-level and country-level impact of untreated chronic pain is a logical starting point. A comprehensive health policy and public health approach will likely involve a combination of awareness of the impact of chronic pain, and education on how to prevent and treat chronic pain. Advocating for access to appropriate, cost-effective treatment options within a country's resource limitations is also key.

An example of where this approach has been successfully implemented is in Southeast Asia through the Association of Southeast Asian Pain Societies (ASEAPS). Over a 20-year period, the ASEAPS has systematically and collaboratively worked to improve awareness and access to multidisciplinary pain care. Through a coordinated approach that involves multilevel education and training of clinicians, the ASEAPS, in conjunction with the International Association for the Study of PAIN (IASP), has successfully increased access to multidisciplinary pain centers in the region.[33]

Ultimately, in a world where the prevalence and impact of chronic pain continues to rise, it is in our best interest to intentionally develop public health policy and education campaigns designed to both raise awareness and encourage appropriate action to increase access to effective pain management care.

THE FUTURE: INTERVENTIONAL PAIN

As medicine in general shifts to a more personalized treatment paradigm, this will inevitably improve both the risk to benefit and the cost to effectiveness ratios, paving the way for more

See "Chronic Pain," Next Page

Digital Tools May Help Improve Outcomes for Chronic Pain Patients

From "Chronic Pain," Preceding Page

efficient resource allocation and better outcomes. For example, ESI and riskier, more costly procedures such as spinal cord stimulation where the data on effectiveness shows tremendous variability, are purported to provide benefit to approximately half the patients who receive the treatment. Yet with phenotyping, or identifying unique characteristics associated with treatment outcome, we will someday be able to accurately predict which patients will improve and which patients will not. For some comorbidities such as obesity, diabetes, and central sensitization, studies evaluating multiple procedures have even shown complication rates to be higher.

THE FUTURE: PERSONALIZED PAIN MEDICINE

The implementation of lifestyle models of care aligns with broader health care goals of harm reduction and minimizing health care disparities harm by treating patients as partners rather than passive recipients of prescriptions and invasive interventions. It is safe, scalable, and easily adaptable across communities and cultures. The shift to integrate lifestyle medicine supports improved adherence, reduced hospitalizations, and improved outcomes across domains beyond pain, including metabolic, cardiovascular, and mental health.

Emerging digital tools, remote monitoring, telemedicine, and artificial intelligence-driven risk stratification may improve safety and personalize care.[34] Harnessing these technologies may be of great value in identifying complications, nonadherence, or noncompliance without delay. They may also aid in improving self-efficacy and engagement. Such approaches to care may be transformative within populations with barriers to accessing specialty care or navigating fragmented health care systems. For individuals who may experience adverse outcomes from overmedicalization, or risks associated with polypharmacy and invasive interventions, lifestyle strategies are safe, sustainable, and offer a culturally adaptable path to acceptable health outcomes.

A paradigm shift will require considering such an approach not as a soft alternative to conventional care, but as a necessary evolution. As health care systems worldwide strive to become equitable, safer, and person-centered, lifestyle-based and root-cause approaches must be at the forefront—not only for their clinical efficacy—but also for their capacity to uplift, engage, and sustain the well-being of populations.

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Pediatric Anesthesia Safety: Yesterday, Today, and Tomorrow

by Elizabeth B. Malinzak, MD; Megha K. Kanjia, MD; and C. Dean Kurth, MD

Shortly after the introduction of anesthesia for dental and surgical procedures in the 1840s, the death of a 15-year-old girl during chloroform anesthesia precipitated a focus on safety in pediatric anesthesia.[1] Pediatrics was quickly recognized as a distinct discipline in anesthesiology by John Snow, anesthesiologist, epidemiologist, and author of the earliest anesthesia textbooks.[2,3] The diversity of the pediatric population in terms of age, weight, anatomy, and psychosocial disposition could present many safety challenges; children were not simply "little adults." From history to present day, there is ample evidence for safety as a principal concern in pediatric anesthesia.

HISTORICAL INNOVATIONS IN PEDIATRIC ANESTHESIA

The historical safety innovations in pediatric anesthesiology over 30-year periods are summarized in Table 1.[4-7] Innovations can be grouped by technology (e.g., hardware, software, drug), people (e.g., education, technique), or organization (e.g., professional society, operating procedure). Many innovations seen in pediatric anesthesiology were modified and customized from adult practice, since the earliest pediatric anesthesia practitioners were dentists, surgeons, and general anesthesiologists. More recent pediatric innovations resulted from the evolving field of safety science. "Wake-Up Safe," the patient safety organization of the Society for Pediatric Anesthesia (SPA), has collaborated with the Children's Hospital Association's "Solutions for Patient Safety," the Institute for Healthcare Improvement, and the United Stated Navy, as one such example.

Table 1. Pediatric Anesthesia Safety Innovations by Period.

Period	Technology	People	Organization
1860-1890	Ether, chloroform, PR, RR	Dentistry, surgery	Operating room
1890-1920	Nitrous oxide, vaporizer, thiopental	Anesthesia textbook	London Society
	Hypodermic needle, oral airway	Anesthesia journal	
	Mask, circuit, anesthesia machine	Pediatric textbook	
1920-1950	Laryngoscopes, endotracheal tubes	Anesthesia residencies	
	Pediatric circuit, ventilator, ECG, BP	Safety conferences	ASA
	IV fluid, warming blanket, curare		
1950-1980	Halothane, ketamine	ABA, ASA practice standards	NICU, PICU
	MAC, blood gases	Pediatric fellowships	SPA, APSF
1980-2010	Propofol, sevoflurane		ASA standards
	$etCO_2$, SpO_2, etGAS		Safety Departments
	Laryngeal mask airway		Wake-Up Safe
	Electronic health record	Simulation, PBLD	Safety-1
2010-2040	Dexmedetomidine	ABA Pediatric Certification	Pediatric standards
	Video laryngoscopy, pEEG		
	Image-analysis ultrasound, Artificial Intelligence		

PR, Pulse rate; RR, respiratory rate; MAC, median alveolar concentration; ECG, electrocardiogram; ASA, American Society Anesthesiologists; SpO_2, pulse oximetry; BP, blood pressure; $etCO_2$, expired carbon dioxide; etGAS, expired anesthetic agent; SPA, Society for Pediatric Anesthesia; APSF, Anesthesia Patient Safety Foundation; ABA, American Board of Anesthesiology; NICU, PICU, neonatal, pediatric intensive care units; pEEG, processed electroencephalography; Italics, early adoption. Bold italics, pre-adoption.

At the beginning of pediatric anesthesia practice, inhalation of ether or chloroform through a face cloth or inhaler was used to induce children and adolescents until unconsciousness and immobility ensued. Neonates and infants did not receive anesthesia. The monitoring of respiratory and heart rate in the operating room (OR) was a notable innovation in safety at this time. During the early 1900s, anesthesia machines containing bag, circuits, mask, oxygen, nitrous oxide, and vaporizers were invented, which undoubtably improved pediatric anesthesia safety. The earliest anesthesia professional emerged as a separate medical specialty from surgeons and dentists during this period.

The years between 1920–1950 witnessed many innovations. The first pediatric anesthesia textbook, *Anesthesia in Children*, was published in 1923.[8] Although hypodermic needles, thiopental, blood pressure cuffs, and electrocardiogram (ECG) monitors were available, they were rarely used in pediatrics until the 1930s, when Dr. William Ladd at Boston Children's Hospital founded the subspecialty of pediatric surgery, and infant anesthesia was first attempted for major procedures like correction of intestinal malrotation and tracheoesophageal fistula.[9] The addition of ventilators and curare during the 1940s fostered invention of pediatric-sized laryngoscopes, endotracheal tubes, intravenous fluids, and warming blankets for pediatric anesthesia. Most neonatal and infant anesthetics in the 1940s and 1950s were performed with mask anesthesia or using custom made tracheal tubes, because the cuffed rubber endotracheal tubes used in children and adults could not be manufactured for the small size of neonates and infants. Hemodynamics were assessed by ECG, pulse, and precordial sounds. Educational and organizational innovations included anesthesiology residencies with specialty rotations in pediatric care, mortality conferences, and the founding of the American Society of Anesthe-

See "Pediatric Anesthesia," Next Page

Pediatric Patients Have Specialized Safety Considerations

From "Pediatric Anesthesia," Preceding Page

siologists (ASA) to educate best clinical practices. Pediatric perioperative and anesthesia-related mortality from 1947–1956 declined, from 49 to 29 cases per 100,000.[1,5]

Innovations in pediatric anesthesia safety from 1950 to 1980 enabled surgery on younger and sicker patients. Halothane, a nonflammable vapor, permitted electrocautery, which allowed for a broader range of surgical procedures to be performed, such as cardiovascular, thoracic, and major abdominal surgery. Determination of minimum alveolar concentration and greater precision in vaporizer delivery improved dosing of volatile anesthetics in children. Creation of neonatal and pediatric intensive care units (NICU and PICU) in the 1950s and 1960s, respectively, allowed for improved postoperative monitoring and care for neonates and infants. In the 1960s, neonatal and infant plastic endotracheal tubes became commercially available, and in the 1970s, mechanical ventilators and arterial transducers were developed for use in the NICU. These advances, along with use of ketamine as an alternate anesthetic to halothane, enabled more surgery on neonates, infants, and sicker patients. In response to rising acuity, the ASA developed the physical status score for risk stratification, pediatric anesthesiology fellowships were developed, and hospitals began to require privileges for the practice of pediatric anesthesia. Pediatric anesthesia-related mortality decreased by two-fold from the prior 30 years to 8 per 100,000 cases during this period.[5]

Between 1980–2000, patient acuity and surgical complexity increased even further. Sevoflurane and propofol, possessing less cardiovascular depression and airway reactivity, replaced halothane and thiopental in the 1990s. Pulse oximetry, capnography, and expired sevoflurane monitors permitted real-time assessment of anesthetic drug level, oxygenation, and ventilation to better detect hypoxia, hypoventilation, and anesthetic overdose. Anesthesia machine ventilators for neonates also became available in the 1990s. Automated blood pressure devices entered the market, allowing for frequent blood pressure monitoring, and replacing manual blood pressure measurements and reliance on precordial stethoscopes. Laryngeal mask airways became available to mitigate difficult airway events and pediatric anesthesiologists began using cuffed endotracheal tubes as concerns regarding tracheal cuff pressure injuring the subglottic area were diminished. ASA practice standards, the Society for Pediatric Anesthesia (SPA), and the Anesthesia Patient Safety Foundation were created, which educated and influenced pediatric anesthesia professionals to follow the safest practices. Collectively, these innovations were associated with decreases in pediatric perioperative and anesthesia-related mortality to 24 per 100,000 cases and 4 per 100,000 cases, respectively, 2–5-fold less than the previous era.[5]

Since 2000, many safety innovations have involved education and organization, rather than technology. The Institute of Medicine's Report "To Err is Human—Building a Safer Health System" pushed hospitals and professional organizations to adopt safety science and specifically utilizing the Safety-1 framework, consisting of education, creation of pediatric standards and safety departments, and implementation of electronic health records (EHR).[4,10] The use of EHR enabled the development of databases, analytics, metrics, look-up tables, checklists, and critical notifications as tools to promote perioperative patient safety. Important pediatric anesthesia innovations in this safety domain include the SPA's "Wake up Safe," a federally sanctioned patient safety organization composed of 75 pediatric anesthesia departments, which offers education in tools such as safety analytics and quality improvement.[1] Additionally, in collaboration with the American College of Surgeons, the SPA established quality standards for pediatric perioperative care during this period.[11,12] The American Board of Anesthesiology also approved a special certification for pediatric anesthesia. By 2015–2019, pediatric perioperative and anesthesia related mortality decreased to 11 per 100,000 cases and 0.5 per 100,000 cases, respectively, 2–5-fold less than the previous era.[7,11]

PEDIATRIC ANESTHESIA SAFETY: WHAT'S NEXT

Looking forward to the next 10 years, the workload for pediatric anesthesia professionals will continue to grow due to higher-acuity patients and more complicated procedures.[13] Further, half of current pediatric anesthesiology fellowships remain unfilled, leading to concerns about a shortage of trained anesthesia professionals to care safely for these complex patients. To counter the potential for an increase in adverse events, additional innovations will be needed. Future innovations should be directed toward prevention of nonfatal adverse events, such as airway and cardiopulmonary events, which occur more often (0.1–5.2%) in neonates, infants, ASA physical status 3–4 patients, and in patients undergoing major surgery.[7,10]

Video Laryngoscopy (VL)

VL can help improve the reliability of first attempt intubation in neonates, infants, and children with difficult airways, as repeated attempts are common causes of hypoxia and cardiac arrest in this population. VL improves reliability of intubation due to a brighter, larger view of the larynx, and a video screen that allows other clinicians to assess the anatomy

See "Pediatric Anesthesia," Next Page

No Significant Difference in Gastric Volume or pH Between Children Who Fast for One Versus Two Hours From Clear Liquids

From "Pediatric Anesthesia," Preceding Page

and verify intubation. VL also enables a learner to practice intubation with an educator to teach airway anatomy and intubation skill better than direct laryngoscopy (DL). Neonatal airways pose a challenge for learners, as well as experienced clinicians, due to the limited space of the oropharynx to place the laryngoscope blade, view the anatomy, and insert the endotracheal tube before desaturation. The use of VL in neonates and infants has been shown to increase successful first-attempt intubation rates, along with fewer desaturation and cardiovascular events.[14] In pediatric anesthesiology, VL is standard practice in a few departments, clinician-dependent in most departments, and not available in other departments.

Intensive Care and Emergency Units have more rapidly adopted VL than pediatric anesthesiology, and it has become common for teaching in these specialties.[15] Successful first-pass DL intubation rates are often lower in these specialties than in pediatric anesthesiology, and failed intubation in critically ill children more often results in adverse events than in healthy children undergoing elective surgery. The main barriers to adoption of VL in pediatric anesthesiology are change in practice and training from DL, cost of VL in all anesthetizing locations, and sustainability, as VL often utilizes disposable blades.

Image Analysis Ultrasound

Ultrasound can help improve the diagnosis of causes of hypotension, low cardiac output, and poor ventilation in the OR, and facilitate vascular access. Computer-generated image analysis of ultrasound is currently used in radiology; ultrasound machines can deploy image analysis using artificial intelligence (AI), which can assist with structure identification and needle placement, while providing real-time feedback for the clinician and trainee.[16,17] Such AI-assisted technology may be especially helpful for anesthesia professionals inexperienced and unpracticed in ultrasound.

The continued improvement of ultrasound technology, with higher resolution and reduced image artifacts, is enhancing anesthesia professionals' skills in vascular access, regional anesthesia, Point of Care Ultrasound (POCUS), and cardiovascular assessment. Yet in neonatal and pediatric patients, these technical procedures remain challenging due to small size of structures, variable anatomy, infrequent use of the technology, and challenges with scalability of AI-assistance. This results in multiple attempts, failed diagnoses, and potential complications. Further, many anesthesia professionals trained prior to widespread adoption of ultrasound, and efforts for national and institutional education should be increased.

Barriers to adoption of image analysis ultrasound in pediatric anesthesiology include the lack of education and exposure to the technology, high cost (including purchasing and maintenance), as well as the large size of the machines in small ORs. While many portable ultrasound probes have been developed for adult patients, scalability may present a challenge.

Gastric Ultrasound and Fasting

The debate surrounding preoperative fasting has gained renewed attention with the rise of Glucagon-Like Peptide-1 (GLP-1) agonists for childhood obesity and the push in many children's hospitals to adopt a one-hour fasting interval for clear liquids, contrary to the ASA's recommendation of two hours. Pulmonary aspiration is a rare complication in children. The APRICOT study, a large, prospective multicenter cohort study of fasted and unfasted children undergoing elective or urgent surgery across 33 European countries in 2017, reported an aspiration incidence of 9.3/10,000, and no cases resulting in severe complications.[18]

Despite established guidelines, actual preoperative fasting durations in children often exceed recommendations, contributing to increased irritability, nausea, vomiting, dehydration, hypotension, and anxiety.[19] Importantly, studies show no significant difference in gastric volume or pH between children who fast for one versus two hours from clear liquids.[19] These findings have led several European pediatric anesthesiology societies to endorse a one-hour fasting interval for clear liquids. However, the ASA has maintained its two-hour recommendation, citing insufficient evidence to warrant a change.[20]

However, fasting guidelines, whether from ASA or international anesthesiology societies, are not absolute standards that can guarantee any outcomes, but solely suggestions to minimize aspiration risk in healthy patients undergoing elective procedures.[21] All societies emphasize that the judgement of the anesthesia professional is paramount. Given the limited availability of high-quality, peer-reviewed studies with definitive clinical outcomes on aspiration risk, expert consensus and knowledge of gastric physiology are often the basis for these guidelines.

Considering the low incidence of aspiration with serious outcomes, the difficulty in generating conclusive evidence, and the desire to mitigate the adverse effects of prolonged fasting, gastric ultrasound (especially when paired with image analysis) holds promise as a tool to assess preoperative gastric volume and aspiration risk in children. This approach could support more tailored fasting intervals and facilitate data collection to refine future guidelines, potentially enabling individualized fasting protocols based on real-time assessment.

Processed Electroencephalogram (EEG)

Processed EEG can help improve the precision of anesthetic dosing, as inadvertent overdose is a root cause of many cardiovascular events in unhealthy children, neonates, and infants.[22] Moreover, there has been a concern about anesthetics causing neurodevelopmental delay in children, as anesthetics can induce a dose-dependent neuronal degeneration in infant animals. While clinical studies of neurodevelopment in children following anesthesia for surgery have been equivocal, using processed EEG to minimize anesthetic dosing, and overdose in particular, might lessen this concern. Processed EEG in pediatric anesthesiology remains in early adoption due to lack of devices in many departments, and insufficient research, education, and clinical training with the technology. However, EEG-guided anesthesia education is increasing during residency, fellowships, and society meetings worldwide, and evidence is building.[23]

Sevoflurane and propofol dosages are based on population studies in healthy children of different ages, which in clinical practice are adjusted to the individual patient based on heart rate, arterial pressure, movement, and for sevoflurane, the expired gas concentration. Thus, current pediatric anesthetic dosages are not based on the brain (hypnosis) or pharmacology studies in unhealthy children.

Until 2018, EEG devices to assess hypnosis emphasized an index number that proved unreliable in young children and those with neurological conditions.[23] To have a reliable EEG monitor for hypnosis, the device must display several channels of raw waveform, density spectral array, and index numbers, which are now commercially available.

Pediatric anesthesia professionals using the new EEGs are learning that current dosing practices recommend more sevoflurane and propofol than necessary in all patients, that

See "Pediatric Anesthesia," Next Page

EEG-guided Anesthesia May Assist in Patient Precision Dosing

From "Pediatric Anesthesia," Preceding Page

unhealthy patients often require less dose for the same EEG features as healthy patients, and that inadvertent overdosing is associated with untoward outcomes and safety events.[16-18] EEG-guided anesthesia has the potential to transform pediatric anesthesiology practice from "population-based" dosing to "patient-precision" dosing for the brain in all patients.[23]

Artificial Intelligence (AI)

AI can alert clinicians to high-risk situations before they occur. In pediatric anesthesiology, AI is pre-adoption, and could be added into processed EEG and video laryngoscopy, like image analysis ultrasound. Pediatric anesthesia professionals rely on an EHR that is cumbersome for finding key information, particularly in patients who have complex co-morbidities and who are seen by numerous specialists around the country. AI-integrated EHR could aid in preoperative risk stratification that traditionally has been challenging to predict in children (e.g., airway assessment, blood pressure management, optimization of co-morbidities, transfusion likelihood, and postoperative outcomes and locations). Intraoperatively, AI-assisted monitoring could alert to the potential for adverse events that are critical in the pediatric patient, as well as adjust ventilation settings and medication dosing based on real-time vital signs, weight, and height.[17]

AI-integrated EHR is also beneficial for pediatric OR management. Workflows and resource allocation can be streamlined, essential for efficiently scheduling the numerous same-day add-on cases more common in pediatrics and the increasing pediatric non-OR case volume.[17,24] These technologies can adjust case durations by critical time points in the specific procedure, which would be beneficial for pediatric patients who can have multiple procedures with different specialists under general anesthesia. This will help to reduce cancellations, optimize efficiency, and assist in reduction of costs.[17]

While AI offers much potential for the workload, it requires large, high-quality datasets, which may not be available for pediatric patients. Barriers include ethical issues when using patient data, especially for vulnerable and small populations, and algorithms are subject to bias and response latency. The high cost, lack of regulations, liability, and implementation requirements can also be barriers in smaller pediatric hospitals.[17] Further, there are broad contextual factors considered in clinical judgements by pediatric anesthesia professionals, which may be missed by AI models.

CONCLUSION

Pediatric anesthesiology has evolved dramatically over the past century through successive waves of technological, educational, and organizational innovations that have markedly improved patient safety. As we look to the future, the demands on pediatric anesthesia professionals will intensify with increasing patient complexity and procedural acuity, as the workforce faces shortages. To meet this challenge, the specialty must shift toward proactive system design, resilience, and real-time adaptation of tools to enhance precision and efficiency. Successful adoption will require overcoming barriers related to education, cost, scalability, and trust. By investing in tools within safety science frameworks, pediatric anesthesia professionals can continue to lead in advancing safe, equitable, and high-quality care for the most vulnerable and complex patients.

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Enhancing Safety in Cardiac Anesthesiology: Current Practices and Emerging Perspectives

by Lida Shaygan, DO; Amanda J. Rhee, MD; Bruce A. Bollen, MD; and Miklos D. Kertai, MD, MMHC, PhD

INTRODUCTION

With evolving technologies and multidisciplinary care models, cardiac anesthesiology is uniquely positioned to lead patient safety initiatives in the perioperative setting. This article highlights advancements in patient safety in the field of cardiac anesthesiology, focusing on innovations and future directions that are reshaping the field. Key areas of advancement include cardiopulmonary bypass (CPB) management, transesophageal echocardiography (TEE), anticoagulation strategies, viscoelastic testing, blood transfusion protocols, and the growing impact of enhanced recovery protocols (Table 1).

Table 1: Systems and Strategies Enhancing Patient Safety in Cardiac Anesthesiology.

Focus Area	Key Innovations	Patient Safety Impact
Cardiopulmonary Bypass	Biocompatible circuit coatings; improved oxygenators and centrifugal pumps goal-directed perfusion	Reduced inflammatory response, embolic risk, and acute kidney injury
Transesophageal Echocardiography	Real-time intraoperative decisions support, improved detections of valve pathology	Reduced re-operative rates, enhanced surgical decision making, better patient outcomes
Anticoagulaton Management	Direct thrombin inhibitors, direct oral anticoagulant reversal, individualized protocols	Safer anticoagulation in high-risk patients, fewer bleeding and thrombotic complications
Viscoelastic Testing	TEG/ROTEM for coagulopathy assessment	Reduced blood product use, improved coagulation management, precision guided transfusion
Blood Management	Cell salvage, PCC, fibrinogen concentrate, restrictive transfusion strategies	Lower transfusion rates, fewer complications, improved hemostasis
Renal Safety	AKI risk models, renal oximetry, indexed oxygen delivery targets	Early detection and prevention of acute kidney injury
Atrial Fibrillation Prevention	Preoperative risk scoring, beta blockers, surgical techniques	Lower stroke rates, shorter hospital stay
Enhanced Recovery	Multimodal analgesia, early extubation, early mobilization	Faster recovery, lower complication rates, reduced ICU time

TEG: thomboelastography; ROTEM: rotational thromboelastometry; PCC: prothrombin complex concentrates; AKI: acute kidney injury; ICU: intensive care unit.

THE EVOLUTION OF PATIENT SAFETY IN CARDIAC ANESTHESIOLOGY

Over the past four decades, cardiac anesthesiology has evolved into a dynamic, safety-driven specialty central to modern cardiac surgery. In the early days of CPB, limited understanding of physiological responses to extracorporeal circulation, primitive oxygenator technology, and empirical transfusion practices contributed to high rates of perioperative complications. The introduction of invasive monitoring such as pulmonary artery catheters and arterial pressure lines in the 1980s provided critical insights into hemodynamic management. Nevertheless, clinical decision-making relied heavily on individual experience rather than standardized protocols.

The 1990s and 2000s marked a turning point with the widespread adoption of TEE, advancements in heparin monitoring, and simulation training. Anesthesia professionals began playing a more active role in surgical planning, intraoperative assessment, and postoperative management, solidifying their position as essential members of the cardiac surgical team. Alongside the rise of multidisciplinary collaboration came the development of goal directed perfusion strategies, enhanced anticoagulation algorithms, and restrictive transfusion protocols. The specialty's history reflects an ongoing commitment to learning from past complications, integrating evidence-based practices, and continually adapting to improve patient outcomes.

DEVELOPMENTS IMPROVING PATIENT SAFETY IN CARDIAC SURGERY

CPB and Perfusion: Safer Strategies

Modern CPB technology has evolved to minimize the systemic inflammatory response and reduce complications such as bleeding, organ dysfunction, and neurologic injury. Innovations include biocompatible circuit coatings that reduce platelet activation and complement cascade stimulation, minimizing coagulation disturbances.[1] Improved oxygenators and centrifugal pumps have enhanced hemodynamic stability, reducing hemolysis, and embolic risk. In addition, miniaturized and closed CPB circuit systems decrease prime volume and blood-air interface, which reduces hemodilution and inflammatory activation.[2] Furthermore, continuous monitoring of metabolic parameters (e.g., cerebral oximetry, lactate trends) allow for timely intervention, enhancing patient safety.

Looking to the future, the integration of artificial intelligence (AI) into perfusion, particularly CPB management, represents a rapidly evolving frontier in cardiac anesthesiology. Machine learning algorithms now support critical intraoperative decisions by modeling expert perfusionist responses when parameters such as oxygen delivery fall below 280 ml/min/m^2, helping to prevent organ injury such as acute kidney dysfunction.[3]

Artificial intelligence augmented perfusion systems are being developed to continuously analyze hemodynamic and metabolic data such as blood flow, pressure, oxygen saturation, and coagulation values to provide real-time decision support or institute automated adjustments aimed at maintaining optimal perfusion parameters.[4] These advancements allow for continuous analysis of vital signs and physiological data, enabling the rapid detection of abnormalities and generating real-time alerts for the surgical team. This proactive monitoring supports timely clinical interventions, reduces the risk of intraoperative complications, and enhances overall patient safety.[4]

However, as these systems mature, implementation challenges such as integrating data and achieving cross-platform standardization will require careful attention to ensure they enhance patient safety without introducing unintended risks or dependency on automated systems for safety.

Transesophageal Echocardiography (TEE)

Intraoperative TEE has undergone significant advancements and now plays a critical role in real-time monitoring and guiding intraoperative decisions during cardiac surgery. Several studies and registry analyses have found that intraoperative TEE is associated with improved

See "Cardiac Anesthesia," Next Page

Intraoperative TEE May Help Improve Patient Safety

From "Cardiac Anesthesia," Preceding Page

patient outcomes and enhanced safety in cardiac surgery.[5-7] More than 25 years ago, the first study showed that using intraoperative TEE to guide mitral valve repair improved long-term valve durability and decreased the need for future reoperations.[5] More recently, a large cohort study using data from Society of Thoracic Surgeons Adult Cardiac Surgery Database demonstrated that TEE use in valve and proximal aortic surgery was associated with significantly lower 30-day mortality (3.92% vs 5.27%), reduced stroke or composite mortality, and lower rates of reoperation or mortality.[6] The use of TEE during coronary artery bypass graft (CABG) cases is also associated with lower mortality, particularly in patients at elevated preoperative risk.[7] In addition, intraoperative TEE findings during planned isolated CABGs have led to the detection of previously unrecognized valve pathologies, contributing to improved surgical decision-making and potentially improved long-term safety and outcomes.[7]

Furthermore, intraoperative TEE plays a critical role in ensuring patient safety during left ventricular assist device (LVAD) implantation, heart transplantation, and lung transplantation by providing real time assessment of cardiac function, guiding surgical decision-making, and enabling early detection of life-threatening complications.

Retrospective analyses indicate that approximately 20% of patients undergoing orthotopic heart transplantation exhibit mild or greater tricuspid regurgitation on post-CPB TEE, a finding linked to right ventricular dysfunction and higher mortality rates.[8] During lung transplantation, intraoperative TEE plays an essential role by detecting clinically significant pulmonary vein obstruction (characterized by flow velocities exceeding 100 cm/s), which is reported in 1% to 24% of cases.[9] Intraoperative TEE also helps with early detection of worsening RV dysfunction which is common after LVAD implantation due to increased preload. Prompt detection of these complications during complex cardiac surgical procedures has led to improvements in patient safety and overall surgical outcomes.

Anticoagulation Management

Anticoagulation management in cardiac surgery presents a continuous challenge as providers must navigate a fine line between preventing thrombosis and avoiding excessive bleeding. Recent innovations have focused on more precise and individualized anticoagulation protocols, which have led to safer anticoagulation management. In patients with heparin-induced thrombocytopenia, where heparin is contraindicated, the innovation of direct thrombin inhibitors (e.g., bivalirudin or argatroban) has improved intraoperative patient safety during CPB cases. Bivalirudin in particular is increasingly used during CPB in heparin-induced thrombocytopenia positive patients as a safe and effective anticoagulant.[10]

The rise in direct oral anticoagulant use has also presented new perioperative challenges and hence the innovation of patient-safety-centered preoperative planning and medication reversal solutions prior to cardiac surgery. Preoperative planning includes appropriate timing of direct oral anticoagulant discontinuation, reversal strategies when needed, and re-initiation protocols postoperatively. Guidelines now emphasize timely preoperative risk assessment and interruption protocols based on the specific agent, renal function, and bleeding risk of the procedure. Rapid reversal agents (such as idarucizumab for dabigatran and andexanet alfa for factor Xa inhibitors) are becoming increasingly available in high-risk surgical centers, reducing the risk of major bleeding or surgical delays.[11]

Multidisciplinary collaboration between anesthesia professionals, perfusionists, surgeons, and hematologists, along with the use of viscoelastic testing to assess clotting function beyond standard coagulation assays, has further advanced anticoagulation safety, especially in reoperations and redo sternotomies.

Viscoelastic Testing

Traditional coagulation tests (e.g., PT, aPTT) provide limited real-time insight into coagulation status during surgery. Viscoelastic tests like TEG and ROTEM offer dynamic, bedside evaluation of clot formation, strength, and fibrinolysis.[12] This immediate feedback enables tailored management of coagulopathy, guiding precise administration of blood products or coagulation factors rather than empirical transfusion. Consequently, viscoelastic testing reduces unnecessary transfusions, limits exposure to transfusion-related complications such as transfusion-related acute lung injury, and improves hemostasis management, ultimately decreasing bleeding-related morbidity and mortality.[13]

Blood Transfusion Strategies

Several strategies are used to optimize blood management in cardiac surgery, reduce transfusion-related risks, and enhance patient safety (Table 2). Blood management has shifted toward patient blood management protocols incorporating cell salvage, acute normovolemic hemodilution, and therapeutic options to control coagulopathic bleeding.

Cell salvage involves collection and reinfusion of the patient's own blood loss intraoperatively, reducing allogeneic transfusion needs and associated risks. This process reduces reliance on allogeneic blood products and is associated with a more favorable inflammatory response,

See "Cardiac Anesthesia," Next Page

Table 2: Blood Transfusion Strategies in Cardiac Anesthesiology and Their Safety Impact.

Strategy	Description	Patient Safety Benefit
Preoperative Anemia Management	Iron supplementation and erythropoietin in anemic patients	Decreased transfusion requirement, improves oxygen delivery during surgery
Cell Salvage	Intraoperative collection and reinfusion of patient's own blood	Reduces need for allogenic transfusions, lowers infection and inflammatory risk
Acute Normovolemic Hemodilution	Preop removal with volume replacement, reinfused postop	Preserves red cells and clotting factors, though may not reduce transfusion rates
Prothrombin Complex Concentrates (PCC)	Concentrated vitamin K-dependent factors (II, VII, IX, X)	Enables rapid reversal of coagulopathy, lowers volume load and exposure to plasma
Fibrinogen Concentrate	Target fibrinogen replacement, often guided by viscoelastic testing	Improves clot strength, decreases bleeding and need for cryoprecipitate
Viscoelastic Testing	Real-time assessment of clot formation and function	Guides precise blood product use, reduces unnecessary tranfusions
Restrictive Transfusion Protocols	Use of evidence-based threshold to limit transfusion	Avoids over-transfusion, reduces risks such as transfusions associated acute lung injury or volume overload

Goal-Directed Perfusion May Decrease Acute Kidney Injury in Cardiac Surgery

From "Cardiac Anesthesia," Preceding Page

enhancing the overall benefits of using cell saver during CPB.[14] Acute normovolemic hemodilution involves removing and storing the patient's blood preoperatively while maintaining normovolemia, then reinfusing it after surgery, thereby preserving coagulation factors and red cell mass. It is important to note however, that while this strategy has been used to date, it has been recently shown that this method does not reduce blood transfusion rates.[15]

The use of prothrombin complex concentrates (PCC) and fibrinogen concentrate has further contributed to improved patient safety in cardiac anesthesiology, particularly in the management of bleeding and coagulopathy during and after cardiac surgery. PCC is a concentrated formulation of vitamin K-dependent clotting factors (II, VII, IX, and X) often used to reverse warfarin and manage coagulopathy. It allows rapid reversal of coagulopathy with smaller volume administration compared to fresh frozen plasma, reducing risk of fluid overload. PCC has improved patient safety in cardiac surgery by providing rapid reversal of anticoagulation during urgent or emergent cardiac procedures, reducing exposure to allogenic blood products (decreasing need for fresh frozen plasma and reducing risks of transfusion-related lung injury), and is now streamlined in many institutional massive transfusion and bleeding algorithms in cardiac surgery.[16]

The introduction of fibrinogen concentrate has also revolutionized patient safety in cardiac anesthesiology by enabling rapid, targeted correction of coagulopathy, reducing reliance on cryoprecipitate, reducing transfusion-related complications and minimizing bleeding-related complications, during and after cardiopulmonary bypass.[17] Moreover, goal-directed administration of fibrinogen concentrate based on viscoelastic testing leads to better clot formation and fewer complications.

Transfusions, while often necessary, carry risks of infection, immunologic reaction, and volume overload. Future blood management strategies in cardiac anesthesiology are shifting focus toward restrictive transfusion thresholds, intraoperative cell salvage, preoperative anemia correction (e.g., iron and erythropoietin supplementation), and autologous transfusion when feasible. Data-driven transfusion protocols combined with multimodal blood conservation techniques are significantly improving patient safety profiles in cardiac surgery.[18,19]

Advancements in Preventing Acute Kidney Injury (AKI)

Acute kidney injury (AKI) remains a prominent and serious complication following cardiopulmonary bypass, affecting up to 30% of adult cardiac surgery patients and worsening postoperative outcomes, including mortality and prolonged hospital stay. Recent patient safety innovations have focused on early risk identification and proactive intraoperative optimization. Predictive models such as the Cleveland Clinic Score and biomarkers (e.g., NGAL, cystatin C) provide early identification of high-risk patients, while intraoperative renal near-infrared spectroscopy offers continuous, noninvasive monitoring of renal tissue oxygenation. In adults, sustained low renal regional cerebral oxygenation values during and shortly after CPB have been strongly correlated with subsequent AKI, often preceding rises in serum creatinine and outperforming traditional biomarkers.[20-22]

Close monitoring and early identification of renal dysfunction (e.g., pre-existing CKD, decrease in glomerular filtration rate >10% on day of surgery, increase in serum creatinine, and oliguria) for at least 72 hours after cardiac surgery have also improved patient safety in cardiac surgical cases and allowed prompt implementation of renal protective strategies.[23]

Another key perioperative safety measure specific to AKI in cardiac surgery is goal-directed perfusion, which targets a minimum indexed oxygen delivery ≥280 mL/min/m^2. In a randomized controlled trial of adult patients undergoing CPB, maintaining indexed oxygen delivery above 300mL/min/m^2 significantly reduced AKI incidence.[24] Similar pilot studies and retrospective implementations have reported consistent reductions in AKI using the goal-directed perfusion approach.

IMPROVEMENTS IN ATRIAL FIBRILLATION MANAGEMENT

Postoperative atrial fibrillation complicates up to 30% of cardiac surgeries, increasing stroke risk and lengthening hospital stay. Recent advances include prophylactic strategies such as preoperative risk scoring (e.g., CHA_2DS_2-$VASC_c$ score), preoperative amiodarone, and optimized perioperative beta-blocker and amiodarone use.

Intraoperative interventions, including posterior pericardiectomy and avoidance of retained pericardial blood have also improved long-term rhythm control. Enhanced anticoagulation protocols and risk stratification tools help balance bleeding and thromboembolic risks. Improved atrial fibrillation management decreases stroke incidence, ICU time, and rehospitalization rates, enhancing overall patient safety.[25,26]

Enhanced Recovery Protocols

Enhanced recovery after cardiac surgery (ERACS) protocols in cardiac surgery integrate evidence-based perioperative strategies that reduce surgical stress, optimize organ function, and accelerate recovery. These practices can reduce morbidity, shorten length of stay, and improve patient satisfaction. Components include multimodal analgesia including chest

See "Cardiac Anesthesia," Next Page

Enhanced Recovery After Cardiac Surgery Reduces Morbidity

From "Cardiac Anesthesia," Preceding Page

wall regional blocks (e.g., parasternal intercostal fascial plan block) to minimize opioid use, early extubation protocols, goal-directed fluid therapy, and early mobilization. These measures decrease pulmonary complications, delirium, and cardiac ICU length of stay. ERACS also emphasizes preoperative optimization of nutrition and comorbidities, thereby enhancing patient resilience. Collectively, ERACS protocols have been shown to reduce morbidity, readmissions, and overall mortality, markedly improving patient safety.[25]

PERSISTENT AND EMERGING CHALLENGES IN PATIENT SAFETY

Despite major advances in cardiac anesthesiology, significant challenges remain. Advanced technologies, refined techniques, and enhanced coordination of care have led to significant improvements in cardiac surgical patient outcomes; however, there is little evidence that much progress has been achieved in reducing preventable errors.[27] Many safety threats today are not due to lack of knowledge or technology but rather reflect systemic or operational barriers that impede patient care.

Technological advancements in cardiac anesthesiology offer tremendous benefits but introduce new complexities. Real-time TEE, advanced hemodynamic monitoring, and point-of-care coagulation testing can enhance precise decision-making but also lead to alert fatigue, dependence on automated systems, or information overload. Poor integration between perfusion data, anesthetic records, and electronic health systems can further fragment situational awareness.

The increasing complexity of the cardiac surgical population presents persistent and evolving safety risks. Patients undergoing transcatheter aortic valve replacements, extracorporeal membrane oxygenation, or heart transplantation are often elderly, frail, and burdened with multiple comorbidities. Managing the delicate balance between anticoagulation and bleeding, addressing right ventricular dysfunction or pulmonary hypertension during lung transplantation, and ensuring organ protection during prolonged circulatory arrest in aortic dissection cases demand sophisticated team-based approaches. These cases often unfold in resource constrained environments and require rapid, high-consequence decision-making.

Meeting these challenges will require not only continuous technological and procedural innovation, but also cultural and structural shifts that prioritize standardization, communication, and resilience across the cardiac perioperative care arena. Sustained progress will depend on addressing both technical and human factors across cardiac procedures.

CONCLUSION

Patient safety in cardiac anesthesiology has evolved through technological innovation, data-driven practices, and an expanding culture of multidisciplinary collaboration. Continued advancement in cardiac anesthesiology depends not only on embracing technological and procedural innovations but also on recognizing and addressing persistent and emerging safety challenges.

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The Evolution of Patient Safety in Regional Anesthesia: A Journey of Progress

by Vikram Bansal, MD; Nicholas Statzer, MD; and Danial Shams, MD

INTRODUCTION

From its inception in the late 19th century to today, the field of regional anesthesia has undergone significant changes that have reduced risks and improved patient outcomes. This evolution has been shaped by innovations, clinical discoveries, and a culture of safety. We explore the milestones and advancements that have driven regional anesthesia to its current state, while also discussing ongoing challenges and potential future initiatives.

EARLY DAYS: THE BEGINNINGS OF REGIONAL ANESTHESIA

In 1884, Carl Koller discovered that cocaine was an effective local anesthetic for the eye, thus inaugurating the modern era of local anesthetics and the field of regional anesthesia.[1] While local anesthetics revolutionized surgery by enabling localized pain control, the practice of regional anesthesia was often complicated by unwanted side effects such as severe spinal headache, nerve injury, and local anesthetic toxicity.[2] The first regionalists were also surgeons, performing blocks and surgeries at the same time. Gaston Labat, a French surgeon, is credited as one of the founding fathers of regional anesthesia.[3] In the absence of modern imaging or monitoring, surgeons (and later, anesthesia professionals) relied on surface anatomy landmarks to guide needle placement. This "blind technique" was highly operator-dependent, with outcomes varying widely based on the practitioner's skill and experience. The potential for complications such as inadvertent vascular injections and excessive anesthetic dosing highlighted the need for a more precise and standardized approach.

THE ADVENT OF PROCEDURAL TIMEOUT AND SAFETY CHECKLISTS

Wrong-sided blocks are considered a "never event" but nonetheless still occur at a rate of 0.5–5.7 per 10,000 blocks performed.[4] Procedural timeouts have become a cornerstone of preventing wrong-sided blocks. In 2014, the American Society of Regional Anesthesia and Pain Medicine (ASRA) adopted a procedural timeout consisting of seven core components: patient identification, procedure and site verification, imaging and equipment preparation, local anesthetic verification, emergency preparedness, team communication and alignment, and documentation.[5]

While simple, this intervention dramatically reduced the incidence of wrong-sided blocks in regional anesthesia. One study showed the reported incidence of wrong-sided blocks dropped by as much as 42% in Pennsylvania since the 2000s.[4] With good communication and teamwork, the timeout ensures that all members of the care team are aligned and focused on patient safety.

FROM STIMMING TO SEEING: THE ADVANTAGES OF ULTRASOUND-GUIDANCE

Perhaps the most significant advancement in regional anesthesia has been the use of ultrasound. Introduced in the late 20th century and widely adopted in the 21st century, ultrasound has transformed the way anesthesia professionals approach nerve blocks.[6] By providing real-time images of anatomical structures, ultrasound allows practitioners to directly visualize nerves, blood vessels, and surrounding tissues, ensuring precise needle placement and reducing the risk of many complications.[6]

Ultrasound guidance has also allowed anesthesia professionals to use smaller volumes of local anesthetic, thereby decreasing the risk of systemic toxicity. This, combined with the development of local anesthetic dosing guides and local anesthetic systemic toxicity (LAST) treatment guidelines, has caused the incidence of LAST to fall from ~7.5–20 per 10,000 blocks to 0.8-8.7 per 10,000 blocks and the incidence of serious cardiac toxicity has fallen from 1 per 10,000 blocks to nearly zero over the last 30–40 years.[7-9]

Ultrasound guidance has also indirectly enhanced patient safety by increasing the efficacy of nerve blocks. The ability to confirm the spread of local anesthetic in real time has decreased the rate of block failure, compared to peripheral nerve stimulation, while also reducing the time to perform blocks and their onset.[10] Today, ultrasound is considered the gold standard for many regional anesthesia techniques and has become an essential tool for anesthesia professionals.

THE ROLE OF LIPID EMULSION IN LOCAL ANESTHETIC SYSTEMIC TOXICITY (LAST)

Local anesthetic systemic toxicity (LAST) is a rare but serious complication of regional anesthesia, often resulting from inadvertent intravascular injection of local anesthetics. Historically, treatment options for LAST were limited, and outcomes were poor. The discovery that lipid emulsion infusion is an effective treatment for LAST (and its incorporation into resuscitation protocols for LAST) has dramatically improved survival rates.[7,8]

SMARTPHONE APPS AND DIGITAL TOOLS

The digital age has brought an array of smartphone applications and online resources that enhance the safety and efficacy of regional anesthesia. These tools provide easy access to information on nerve block techniques, local anesthetic dosages, and anticoagulation guidelines. Many applications include ultrasound images, instructional videos, and even interactive decision-making algorithms, making them invaluable for both novice and experienced practitioners. Furthermore, these tools facilitate education, allowing anesthesia professionals to stay up to date on the guidelines and best practices. Examples include the ASRA Coags and Timeout applications.

WHAT REMAINS—AND WHY WE HAVEN'T SOLVED IT YET

Despite advances in technology, many complications in regional anesthesia remain. Wrong-sided blocks and failed blocks remain rare but significant concerns in regional anesthesia. While the procedural timeout has been instrumental in addressing wrong-sided blocks, these errors still occur. Multiple factors such as production pressure, poor communication, distractions, rushed/absent timeouts, absent site markings, and patient repositioning can contribute to the occurrence of this "never" event.[4,11] Failed blocks can occur secondary to a multitude of factors (including anatomical variations, communication barriers, obesity or other anatomic factors, surgical factors, and proceduralist experience) and are a risk of regional anesthesia that will likely never be fully eliminated.[12,13] However, advancements such as ultrasound-guidance have helped to decrease block failure rates by more than 50%, including decreasing the risk of conversion to general anesthesia.[10]

The risks of neurologic injury, while reduced, also continue to impact the field of regional anesthesia. While innovations in imaging and needle guidance have improved many outcomes, long-term neurological injury still occurs at a rate of 2 to 4 in 10,000 blocks.[9,14,15] Despite

See "Regional Anesthesia" Next Page

Wrong-sided Blocks and Failed Blocks Remain Rare but Significant Concerns in Regional Anesthesia

From "Regional Anesthesia," Preceding Page

the ability to visualize nerves and fascicles (and thus avoid direct contact) with ultrasound-guidance, nerve injury can still occur. This may be due to a host of elements (Table 1), many of which may never be fully eliminated. It is plausible that the mere injection of local anesthetic (itself a neurotoxic substance) near nerves in patients who are susceptible to nerve injury may lead to long-term neurological dysfunction. However, utilizing short-beveled needles, appropriately dosing local anesthetics, visualizing nerves directly with ultrasound, injection pressure monitoring, and appropriate patient counseling can help to further reduce the incidence of an already-rare event.

Table 1: Components of Nerve Injury.[9,10,14,16]

Host Factors	Causative Agents	Environmental Factors
Pre-existing Neuropathy: diabetic neuropathy, peripheral vascular disease, chemotherapy-induced neuropathy, neurologic diseases (multiple sclerosis, lupus, etc.)	Needle Trauma: presence of paresthesia during procedure; bevel shape (short vs long)	Ultrasound versus Nerve Stimulation: no difference in neurologic complications, but improved efficacy and decreased failure rates seen with ultrasound use
Surgical Elements: trauma surgery, prolonged tourniquet time, high levels of neural stretch, and surgical type	Pressure Injury: higher injection pressures may indicate intraneural needle	Injection Pressure Monitoring: measuring pressure may decrease risk of intrafascicular injection

EMERGING TECHNOLOGIES

3D and 4D Imaging

The future of regional anesthesia lies in cutting-edge imaging technologies such as 3D and 4D ultrasound. While traditional 2D ultrasound provides a flat, cross-sectional view, 3D imaging reconstructs anatomical structures in three dimensions, offering a more comprehensive view of the target area. 4D imaging adds the dimension of time, enabling real-time visualization of moving structures such as blood vessels and nerves.[16-19]

Advanced imaging may further enhance the precision and safety of regional anesthesia by providing increasing anatomical detail. As these technologies become more widely available, they are likely to set new standards and potentially reduce the learning curve for complex nerve blocks and other regional anesthesia procedures.

Needle Guidance Technology and Pressure Injection Monitoring

Needle guidance systems integrated with ultrasound machines could provide real-time feedback on needle trajectory. These systems use electromagnetic or optical tracking to ensure that the needle remains on course, reducing the risk of inadvertent puncture or misplacement. By enhancing control and accuracy, needle guidance technology has the potential to make regional anesthesia safer and more accessible.[20]

Pressure injection monitoring is another innovation designed to improve safety. This technology monitors the pressure exerted during the injection of local anesthetic, providing an early warning if the needle tip is in an incorrect location (e.g., intraneural or intravascular). High injection pressures are associated with an increased risk of nerve injury, and pressure monitoring allows practitioners to adjust their technique in real time to avoid complications.[21]

Additional avenues of research

The future of patient safety in regional anesthesia is bright, with ongoing research and innovation aimed at further reducing risks and improving outcomes. Further promising areas of development include the following:

- Artificial Intelligence (AI): AI algorithms are being developed to assist with ultrasound interpretation, needle trajectory planning, and complication prediction. By analyzing vast datasets, AI could provide personalized recommendations for each patient, optimizing safety and efficacy.[22]
- Wearable Sensors: Devices that monitor patient physiology in real time could provide early warnings of complications such as LAST or nerve injury, allowing for prompt intervention.[23]
- Simulation Training: High-fidelity simulation technology enhances the training of anesthesia professionals, allowing them to practice complex blocks in a risk-free environment. Simulation-based education is likely to play an important role in ensuring competency and minimizing errors.[25]

CONCLUSION

The evolution of patient safety in regional anesthesia has been nothing short of remarkable. From the early days of blind techniques and rudimentary safety measures to the modern era of real-time ultrasound-guidance, intralipid therapy, and advanced imaging, the field has made tremendous strides. Each innovation has brought us closer to the ideal of a safe, effective, and patient-centered practice.

As we look to the future, the integration of emerging technologies such as 3D/4D imaging, AI, and needle guidance systems promises to further enhance safety and precision. By continuing to prioritize patient safety and embracing innovation, regional anesthesia will continue to remain an important subset of the field of anesthesiology.

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See "Regional Anesthesia," Next Page

SPOTLIGHT on Legacy Society Members

Robert K. Stoelting, MD

The Anesthesia Patient Safety Foundation (APSF) was established in 1985 with the vision "that no patient shall be harmed by anesthesia." A foundation dedicated solely to advocate for anesthesia patient safety was the goal of APSF's founding president, Ellison C. Pierce, Jr., MD. Today, APSF and anesthesiology are recognized world wide as pioneers in advocating for patient safety.

I had the privilege of following Dr. Pierce as the second president of APSF (1997-2016), and it was on the "shoulders of those early pioneers in APSF's history" that during my presidency APSF was able to both continue and expand its role in pursuing its mission that "no patient shall be harmed by anesthesia."

Dr. John H. and Mrs. Marsha L. Eichhorn

Having been intensely involved with the APSF since its creation in 1985, of course we are supporting its long-term survival and success, including through a contingent legacy grant as part of our estate plan.

Mark and Mary Ellen Warner

We believe that foundations such as the Anesthesia Patient Safety Foundation are fundamental to the future development of anesthesiology. The APSF is especially important to us as improving perioperative patient safety is such a noble cause and has been a major goal for us during our careers. We are proud to have the opportunity to help APSF fulfill its vision that "no one shall be harmed by anesthesia care."

Drs. Mary Ellen and Mark Warner are anesthesiologists at the Mayo Clinic in Rochester, Minnesota. Mary Ellen has served as president of the American Society of Anesthesiologists' Wood Library Museum and is vice-president of the Anesthesia Foundation. Mark has served as president of the American Society of Anesthesiologists, been a director of the Foundation for Anesthesia Education & Research, and president of the APSF. Two of their sons and two of their daughters-in-law also are anesthesiologists at the Mayo Clinic.

An abiding belief in safeguarding the future of anesthesiology.

Established in 2019, the ***APSF Legacy Society*** honors those who make a gift to the foundation through their estates, wills, or trusts, thus ensuring that patient safety research and education will continue on behalf of the profession about which we are so deeply passionate.

APSF recognizes and thanks these inaugural members who have generously supported APSF through an estate or legacy gift.

For more information about planned giving, please contact Jill Maksimovich, APSF Director of Development at maksimovich@apsf.org.

Join us! **https://www.apsf.org/donate/legacy-society/**

From "Regional Anesthesia," Preceding Page

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