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Thinking Fast and Slow in Medicine: The Cognitive Basis of Errors and Tools for Prevention

by Joyce A. Wahr, MD, FAHA

When surveyed, nearly all (85%) of anesthesiologists acknowledge committing at least one medication error.[1] Clearly, the vast majority of these errors are of little consequence, but some, such as the recent spate of ampule swaps of tranexamic acid (TXA) for bupivacaine, can be deadly.[2] Often, the difference between "of little consequence" and "lethal" is pure luck—your syringe swap was vecuronium for neostigmine (a relatively common syringe swap) rather than vincristine for methotrexate or heparin 10,000 Units per mL for heparin flush.[3] When such a syringe swap occurs and a patient is harmed, reviewers and even the clinician involved are often perplexed as to how such an error could have been made. The intent of this article is to discuss some of the known cognitive processes that can lead to such an error.

SYSTEM 1 VS. SYSTEM 2 THINKING

The science of cognition—how we think—has been around for some time. The knowledge that humans think and act unconsciously

and consciously and that these modes of thinking are related to specific errors has been described previously by James Reason,[4] but a deeper understanding has come through the work of Amos Twersky and Daniel Kahneman over a collaboration of about 15 years beginning in 1970.[5] This work in what Kahneman calls "bounded rationality" earned him the 2002 Nobel Prize in Economics, an award he would have shared with Twersky had the latter not died at a young age.[6] In his summative book, *Thinking, Fast and Slow*, Kahneman delves deeply into what he terms System 1 and System 2 thinking.[5] System 1 is the incredibly fast, unconscious, effortless and automatic process by which humans perceive the ever-changing world around them, fit these perceptions into mental models and then, again, unconsciously and effortlessly, determine how to act. When driving home from work, for example, you are not conscious that your System 1 has recognized the gas station on the left and determined that a right turn is required to continue home.

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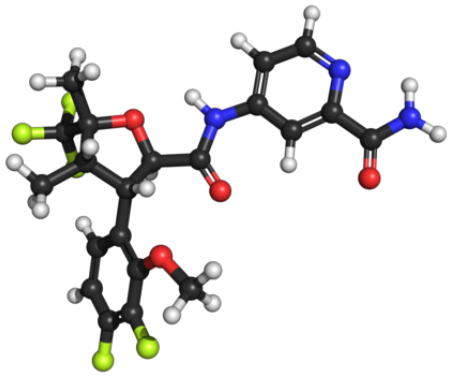
Suzetrigine: A Novel, Peripherally Acting Analgesic

by Paul Lee, MD; Michael Kim, DO; Joseph Szokol, MD; and Michael Bottros, MD

On January 30, 2025, the U.S. Food and Drug Administration (FDA) approved the drug Journavx™ (suzetrigine), a first-in-class nonopioid analgesic to treat moderate to severe pain in adult patients.[1] The Acting Director of the FDA's Center for Drug Evaluation and Research, Jacqueline Corrigan-Curay, MD, JD, called the approval "an important public health milestone in acute pain management…an opportunity to mitigate certain risks associated with using an opioid for pain and provides patients with another treatment option." Suzetrigine is the first drug to be approved in a new class of pain management medicines. Despite approval of numerous analgesic agents throughout the 20th century, greater than half of surgical patients still experience moderate to severe postoperative pain.[2]



Suzetrigine, a nonopioid, nonaddictive, selective pain signal inhibitor, holds the potential to be the first treatment for moderate-to-severe acute pain in a new pharmacologic class in over two decades. Suzetrigine inhibits NaV1.8 by binding to the protein's second voltage sensing domain (VSD2) to stabilize the closed state of the channel. This novel allosteric mechanism results in tonic inhibition of NaV1.8 and reduces pain signals in the primary human dorsal-root ganglion (DRG) sensory neuron. By blocking pain signals in nociceptive C-fibers, before they reach the brain, suzetrigine offers an alternative to opioids without addiction or organ toxicity.

Acute, neuropathic, or inflammatory pain is caused by excessive firing of dorsal-root DRG or trigeminal ganglion neurons. The identification of multiple sodium channel genes led to a search for "peripheral" sodium channels

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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.

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b. Articles preferentially will focus on our top 10 APSF safety initiatives see APSF Newsletter).
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Cognitive Errors Play a Role in Medication Safety Events

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System 1 quickly and effortlessly supplies the answer to 2 + 2 or 2 x 2 (a mental model exists), but System 1 cannot supply the answer to 27 x 14 (no prior mental model). For that calculation System 2 is required: an effortful, slow, deliberate, and conscious process that works throught principles of multiplication to achieve the answer. Humans flit between these two systems of thinking throughout the day, always preferring to have System 1 perceiving and acting, but pulling in System 2 when System 1 does not have a mental model that fits the current situation. We are endlessly creating new System 1 mental models—every time we pick up a new hobby or learn a new skill (e.g., placing an arterial line) we begin with a System 2 process that effortfully lays out the steps. With repetition, this skill moves into what James Reason calls a schema, a mental construct of the sequence of tasks to be done to reach a goal.

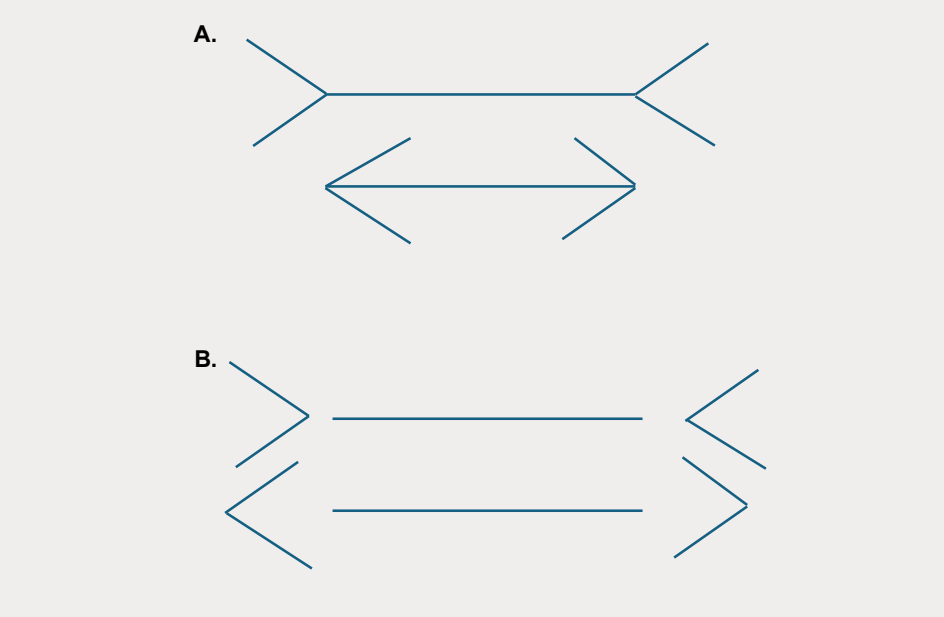

Figure 1A and B: Which horizontal line is longer? An example of System 1 overiding System 2 thinking.

HOW SYSTEM 1 THINKING LEADS TO ERROR

Humans strongly prefer to work in System 1—effortless, unconscious, automatic—and this preference leads to errors. Evaluating an unusual presentation with System 2 requires effort; as humans are averse to effort, the subconscious mental model that quickly comes to mind is chosen. Characteristics of the current situation that do not fit the chosen mental model may be discarded or discounted. System 1 can surreptitiously override System 2. It was recognition of the fact that humans make wrong choices even when the facts are known that initiated Kahneman and Twersky's work. One famous example is this simple problem:

- A ball and bat together cost $1.10
- The bat costs $1 more than the ball
- What does the ball cost?

The answer that instantly and effortlessly comes to mind is the ball costs 10 cents, even when a very simply calculation provides the answer that the ball must cost 5 cents. Even when System 2 can easily and consciously do the math, System 1 chooses the easiest and "most available" answer. Another example of System 1 overriding System 2 is shown in Figure 1a and 1b. If you cover 1a, it is clear that the two horizontal lines are of equal length—but when you cover 1b, System 1 simply cannot accept that the two are of equal length.

These two concepts are only the first two chapters of *Thinking Fast and Slow*; there are many other situations in which System 1 surreptitiously subverts our rational System 2. Cognitive biases abound in System 1 and mislead us frequently.[6] These two examples, however, provide enough evidence to explain many of our errors.

COGNITIVE ERRORS AND MEDICATION SAFETY

The *APSF Newsletter* has described in detail the recent series of ampule and vial swaps in cesarean deliveries, where an ampule of TXA is erroneously drawn up and injected into the cerebral spinal fluid.[7] Most of us would believe that we would not make such an error, but a quick glance at the "look alike" ampules and vials that were swapped should give us pause (Figure 2). The retina, optic nerve, and optical cortex may correctly read the ampule as tranexamic acid, but System 1 is running a mental schema of "spinal anesthesia," so the ampule MUST be bupivicaine; that is what System 1 reports and acts on. Just as in Figures 1a and 1b, System 1 cannot NOT see what it expects to see based on the mental model being enacted.

What can we possibly do to avoid errors, given that System 1 is unconscious? The answer is simple—create a fail-safe process that System 1 cannot subvert. Provide TXA to the anesthesia professional in an infusion bag, never in an ampule.[7] We do not have a mental model whereby we infuse infusion bags into the cerebrospinal fluid. A further step would be to have the pharmacy only supply bupivacaine

Figure 2: An example of look-alike vials, courtesy of the APSF look-alike vial gallery. https://www.apsf.org/look-alike-drugs/.

in prefilled NRFit syringes that can only couple with a NRFit needle. Other fail-safe interventions include barcode medication administration, which employs both visual and audible presentation of the medication; using two senses provides two chances to catch an error. A less expensive, but effective approach is that the circulating nurse is the only one authorized to pull TXA from the dispensing cabinet, and the process includes prohibition of supplying the TXA until after the spinal or epidural is completed.

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Interventions That Rely Solely on Human Efforts Are Ineffective

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Unfortunately, most forcing functions or fail-safe processes cost more and are much harder to implement than an exhortation to "try harder" (Figure 3). In addition, as anesthesia professionals, we often believe that we are each "better than average," that we do not need prefilled syringes, pharmacy-supplied medications, or barcoded medication administration systems in the OR. If we could truly "be careful," i.e., use System 2 to monitor our actions at every step of the subconscious scheme, perhaps we could be error free. But, System 2 is effortful. If one is on a hike and then asked to supply the answer to 27 x 14, one would simply stop hiking, as we have a limited reservoir of effort; physical, emotional, and mental efforts all pull from the same reserve. One simply cannot continually expend the mental effort to use System 2 for every task. Fortunately, most fail-safe or forcing functions to reduce medication errors, while costing something, are not prohibitively expensive. Human factors engineers and medication safety experts have told us for many years that interventions that rely solely on human effort are ineffective.

We as a profession must accept that we are not infallible, that System 1 is the elephant and System 2 is the rider—mere effort will not keep the elephant on the right path. We need to demand that our hospitals provide us tools that go well beyond "try harder."

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Joyce Wahr, MD, receives royalties from publication of her book, Medication Safety in Anesthesia and the Perioperative Period.

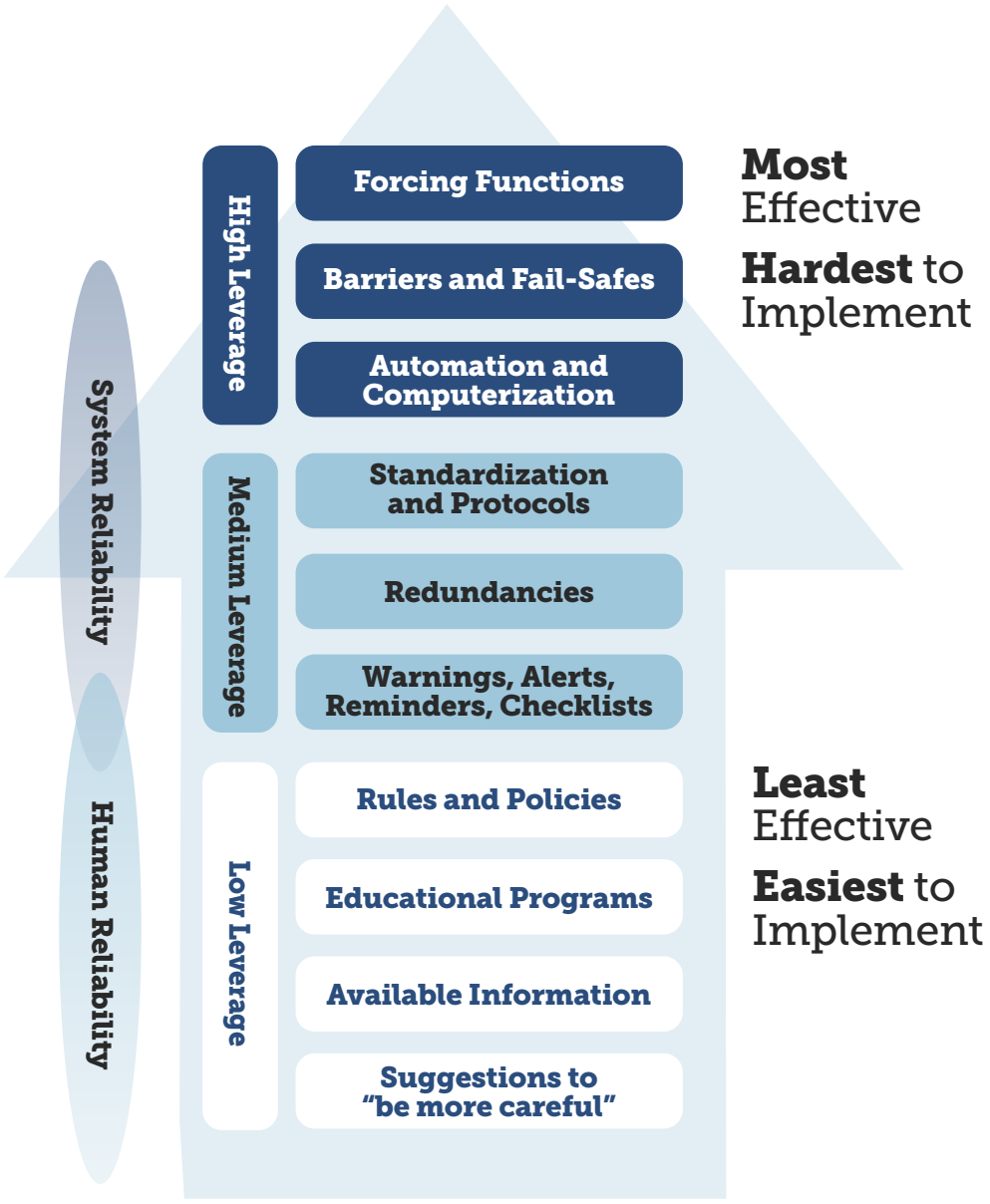

Figure 3: Strength of Interventions.

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NaV1.8 Inhibitors Reduce Pain with Few Central Nervous System or Cardiac Side Effects

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essential for DRG neuron firing but not involved in the brain or heart. Three such channels—NaV1.7, NaV1.8, and NaV1.9—regulate peripheral pain-signaling in nociceptive C-fibers. Of these three channels, NaV1.8 produces more than 70% of the current, allowing propagation of the action potential. Suzetrigine inhibits depolarization in peripheral pain-signaling neurons without an effect on the brain or heart, thereby reducing pain with few central nervous system (CNS) or cardiac side effects. *In vitro* studies show suzetrigine has a >31,000-fold selectivity for Nav 1.8 channels, unlike nonselective sodium channel blockers.[3] Suzetrigine specifically and solely targets the NaV1.8 receptors, avoiding unpleasant side effects (Figure 1).[4] Future NaV1.8 molecules may offer even greater analgesic potential pending clinical trials (Figure 2, next page).

To test drug safety and efficacy, Vertex Pharmaceuticals (Boston, MA), conducted two large randomized clinical trials: an abdominoplasty trial that enrolled 1,118 patients and a bunionectomy study with 1,073 patients. Patients were randomly assigned to one of three groups: a placebo, a combination of acetaminophen and hydrocodone, or suzetrigine. The recommended loading dose of suzetrigine is 100 mg orally, followed by 50 mg every 12 hours.[1] In addition to receiving the randomized treatment, all participants in the trials who experienced breakthrough pain were permitted to use ibuprofen as needed for "rescue" analgesia. Both trials demonstrated a statistically significant superior reduction in pain with suzetrigine compared to placebo. Superiority versus the combination of hydrocodone 5 mg/acetaminophen 325 mg was not demonstrated. However, a responder's analyses at various timepoints (12h, 24h, and 48h) showed similar 30/50/70% reductions in Numeric Pain Rating Scale of suzetrigine versus hydrocodone 5 mg/acetaminophen 325 mg. Side effects of suzetrigine reported by patients were similar to those taking the placebo. There may be an increased risk of adverse reactions with the concomitant use of moderate to strong CYP3A inhibitors. There may also be a risk of drug interactions with certain hormonal contraceptives, and patients taking suzetrigine should use nonhormonal contraceptives (such as condoms) or use alternative contraceptives containing levonorgestrel and norethindrone.

Patients with moderate to severe hepatic impairment may have higher systemic exposure of suzetrigine and its active metabolites. Suzetrigine should be avoided in patients with renal impairment of eGFR < 15 mL/min.

The most common adverse reactions in study participants who received suzetrigine were itching, muscle spasms, increased blood level of creatine phosphokinase, and rash. Suzetrigine was generally safe and well tolerated with a lower incidence of adverse events than placebo and the acetaminophen/hydrocodone combination. Additionally, patients should avoid food or drink containing grapefruit when taking suzetrigine.

Sodium channel inhibitors might be able to fill the unmet need in perioperative pain management with current nonopioid analgesics. Postoperative pain control is a vital component to proper recovery for surgical patients. One major component of successful programs such as Enhanced Recovery After Surgery (ERAS)

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Voltage-Gated Sodium Channels are Crucial for Generation and Propagation of Pain Signals as Action Potentials

- There are nine voltage-gated sodium channel subtypes (NaV1.1—NaV1.9), each with a unique cell type specific expression pattern and function[2]
- NaV1.7, NaV1.8, and NaV1.9 are highly expressed in peripheral sensory neurons[2]
- These channels are essential for the initiation and propagation of pain signals in peripheral nociceptive neurons

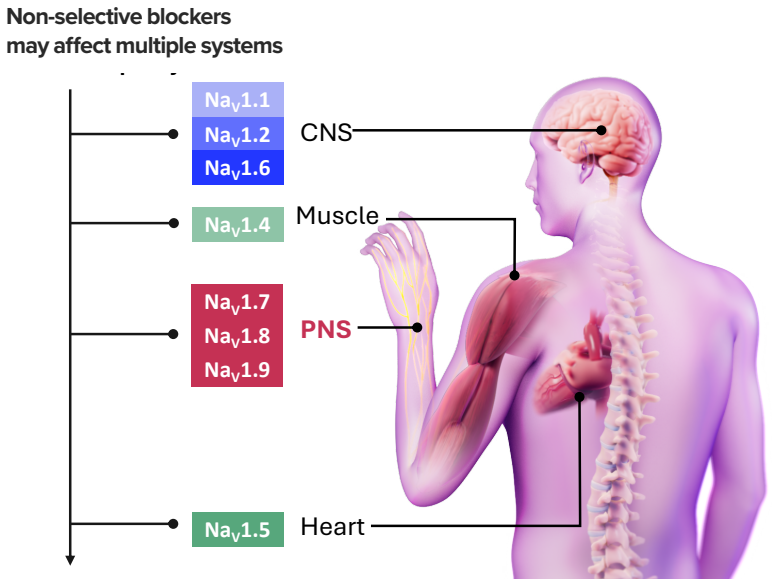

Figure 1: Voltage-gated sodium channels associated with the propagation of pain signals. Used with permission from Vertex Pharmaceuticals.

Suzetrigine Has No Abuse Potential and No Known Organ Toxicity

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protocols is optimizing pain control throughout the entire perioperative period. This starts with preoperative loading of acetaminophen and ibuprofen, which acts synergistically with other analgesics. Intraoperatively, postoperative pain is minimized with regional anesthesia blocks and catheters. Suzetrigine appears to be an effective, safe, and nonaddictive medication that can provide new options for patients at high-risk of opioid-related adverse events or where nonsteroidal anti-inflammatory drugs (NSAIDS) are contraindicated, offering a meaningful alternative to opiates with ERAS protocols.

The FDA approved suzetrigine on January 30, 2025, for the oral treatment of moderate to severe pain. Suzetrigine is a selective sodium channel blocker and is the first sodium channel blocker to be approved in the United States for this indication and is the first nonopioid drug to be approved for the treatment of pain in over 25 years. Suzetrigine is a selective blocker of the voltage-gated sodium channel NaV1.8 which is expressed in peripheral dorsal root ganglion neurons. Suzetrigine has no abuse potential and no known organ toxicity; therefore, it is a reasonable alternative to opiates or NSAIDs.

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The authors have no conflicts of interests.

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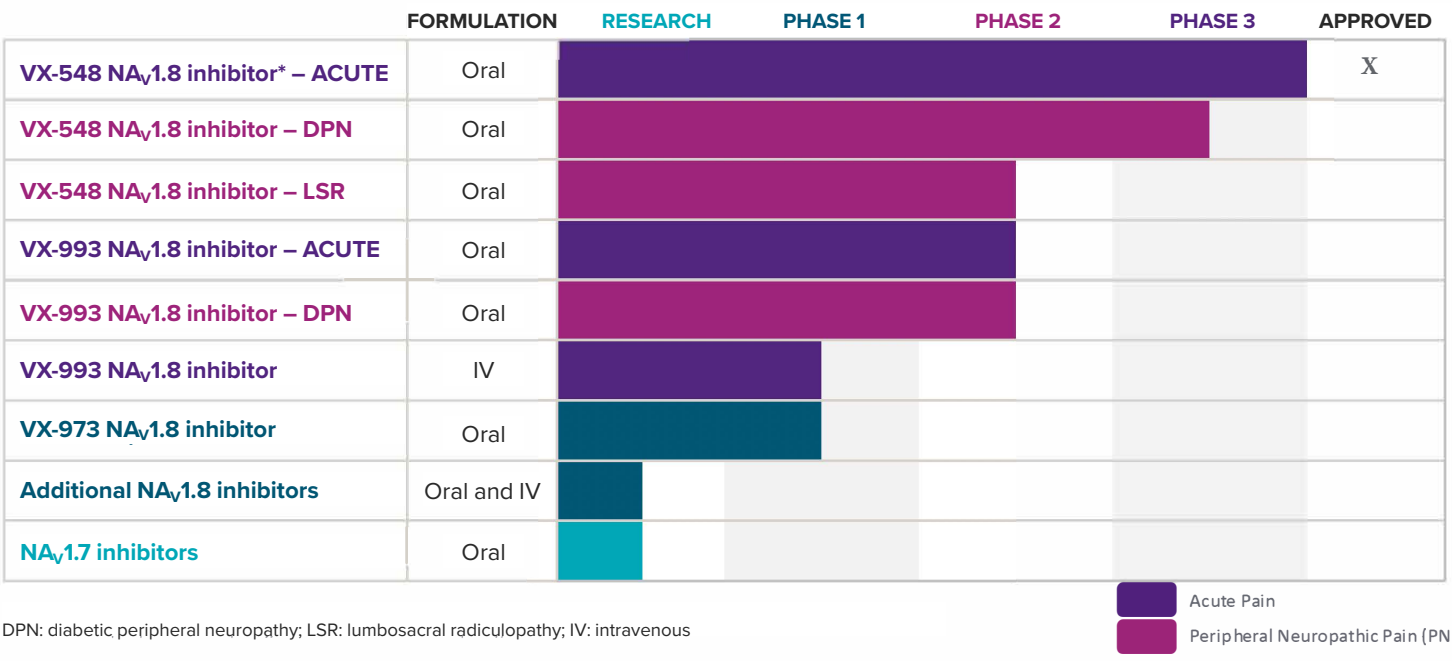
Pipeline of Future Na_V 1.8 molecules



DPN: diabetic peripheral neuropathy; LSR: lumbosacral radiculopathy; IV: intravenous

Figure 2: Pipeline of future Nav1.8 molecules. Used with permission from Vertex Pharmaceuticals.

Perioperative Opioid Analgesia: Finding the Right Balance

by Mychaela Mathews, Paul Guillod, MD, and Steven Greenberg, MD, FCCP, FCCM

Opioids have served a primary role in surgical pain control since the isolation of morphine in the 19th century through the development of synthetic agonists used in modern anesthesia. While opioids offer potent analgesia, there are considerable downsides for patients perioperatively and long-term. The broader adverse impacts of opioids as well as scrutiny around their appropriate use intraoperatively has intensified. Advances in multimodal analgesia have reduced reliance on opioids, allowing for opioid-sparing and even opioid-free anesthesia. This effort has further expanded to providing effective pain control while minimizing opioids as part of enhanced recovery after surgery (ERAS). This article will explore differences and outcomes of these approaches and discuss the positive outcomes of culture change with implementation of ERAS protocols.

Over 50 million surgeries are performed annually in the United States with around 60–80% of opioid-naïve patients prescribed opioids postoperatively.[1,2] Patients who already take opioids prior to surgery face poorer outcomes, worse pain control measures, and higher costs.[3] For many surgical patients, perioperative opioid exposure can lead to continued use, with rates of new persistent opioid use 90 days after surgery around 6%,[4] despite the consensus that extended opioid use for chronic, noncancer pain has marginal benefit and considerable risk.[5] The opioid epidemic varies by country with many lower income populations facing considerable inadequate access to opioid medication.[6] Anesthesia professionals are in a unique position to intervene at this juncture, using expertise in pain management to investigate alternative options to achieve optimal analgesia in the perioperative period that are affordable and accessible worldwide.

Opioid-based anesthesia refers to the standard treatment of pain through opioid receptor agonists, such as morphine or fentanyl, or an agonist-antagonist, like buprenorphine. Opioids are historically prioritized perioperatively due to their quick onset, high efficacy in relieving somatic pain, predictability, and widespread availability. However, opioids also contribute to postoperative nausea and vomiting (PONV), respiratory depression, bowel hypomotility or ileus, delirium, tolerance, and even increased pain through opioid-induced hyperalgesia.[7] Opioids, particularly in high doses, may also increase postoperative complications, extend hospital stays, and lead to readmissions.[7] While complete elimination of opioid-based analgesia appears to be a solution, simply reducing intraoperative opioid administration can result in worse postoperative pain and increased opioid consumption.[8] This can be detrimental for patients as uncontrolled pain after surgery itself contributes to postoperative complications and increases the risk of chronic postsurgical pain, suggesting effective and timely pain control is paramount to successful recovery.[9]

Clinicians leverage multimodal analgesia to minimize opioids, a combinatorial approach to pain control by acting on multiple pathways pharmacologically in addition to incorporating regional anesthesia. Regional techniques include single-shot injections (e.g., upper and lower extremity nerve blocks, paravertebral blocks, and field blocks), continuous nerve catheters, and neuraxial anesthesia. Medications include nonsteroidal anti-inflammatory drugs (NSAIDs), acetaminophen, ketamine, dexmedetomidine, gabapentinoids, and local anesthetics.[10] Each has advantages and risks. Ketamine, an NMDA receptor antagonist, has direct analgesic effects and reduces central sensitization, but higher doses cause dissociation and hallucinations. NSAIDs decrease inflammation and pain through COX inhibition, while higher doses can lead to gastrointestinal bleeding or renal injury. Dexmedetomidine, an α_2-agonist, enhances inhibitory pain pathways and blunts the sympathetic response to pain; however, higher doses contribute to excess sedation, bradycardia, and hypotension. The recently FDA-approved medication suzetrigine is part of a promising new nonopioid class that acts through voltage-gated sodium channel 1.8 (NaV1.8) inhibition, stopping nociceptive signals in peripheral neurons.[11] The combination of multiple analgesics may reduce the effective dose of each individual medication and their associated side effects.

Opioid-free anesthesia (OFA) is a strategy that avoids intraoperative opioid administration. High quality, robust research in the effectiveness of OFA is limited, although there are some noteworthy studies. One randomized controlled trial of women undergoing gynecologic laparoscopic surgery compared intraoperative ketamine and dexmedetomidine vs. sufentanil and found no significant differences in PONV, pain scores, or opioid consumption, while the OFA group had a delayed discharge effect from excess sedation.[12] Another study on patients undergoing laparoscopic hiatal hernia repair showed no difference in postoperative pain requirements in the OFA group, though they were significantly more likely to be discharged the same day (the primary endpoint).[13] A study on patients undergoing video-assisted thoracoscopic surgery compared OFA with a paravertebral block to opioid-based anesthesia without a block and demonstrated significantly decreased pain scores and 24-hour opioid consumption in the OFA group.[14] When broadening our scope to meta-analyses, OFA cohorts have demonstrated advantages with decreased PONV and time to normal bowel function, but

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Studies Have Not Demonstrated Convincing Evidence to Support Broad Use of Opioid-Free Anesthesia

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increased chance of bradycardia and overall similar postoperative pain scores and opioid consumption.[15,16] In other words, there is not clear evidence to broadly espouse OFA outside of specific considerations, and therefore more research is warranted.

Opioid-sparing anesthesia, on the other hand, minimizes, while not eliminating, the use of intraoperative opioids, seeking a balanced approach. There are numerous studies on individual adjuvant medications and regional techniques, which demonstrate reduced opioid requirements and improvements in recovery by incorporating an opioid-sparing strategy. One small randomized controlled trial compared dexmedetomidine infusion to placebo during laparoscopic cholecystectomy, with the treatment group showing decreased postoperative morphine use, decreased incidence of severe pain, and longer time to first rescue analgesic.[17] In cardiac surgery patients, an opioid-sparing regimen incorporating a parasternal block and intravenous ketamine for the first 24-hours postoperatively in the ICU demonstrated similar visual analog scales (VAS) pain scores, but significantly lower opioid consumption as well as reduction in rates of ileus, delirium, mechanical ventilation time, and bronchopneumonia.[18]

These studies provide evidence for strategies to be incorporated into formalized ERAS protocols, which can vary by surgery type and institution, but which focus on opioid-sparing comprehensive patient recovery and pain control strategies. The implementation of ERAS protocols may address opioid overuse through a multidisciplinary cultural shift in approaches to perioperative care. At our institution (a multihospital, community-based health system), ERAS protocols were implemented across seven surgical specialties, each with a unique set of interventions to enhance patient education and recovery.[19] Following the establishment of these ERAS protocols, the length of hospital stay decreased by approximately one day, patients were more likely to be discharged in fewer than three days, in-hospital opioid consumption decreased by 50%, and pain scores were more commonly mild compared to the moderate/severe pain scores observed prior.[19] We are also performing a double-blinded randomized controlled trial (ClinicalTrials.gov number NCT05953428) building upon the prior mentioned study on laparoscopic hernia repair,[13] investigating the potential benefits of an opioid sparing anesthesia regimen in this population of patients with respect to reducing discharge opioid consumption, pain scores, PONV incidence, and hospital length of stay. Implementing these changes requires a cultural shift in how perioperative clinicians approach patient education and treatment at each phase of care, which includes provider education, stakeholder buy-in, and resource availability.

Opioid-sparing anesthesia strategies emphasizing multimodal analgesia have been shown to improve outcomes and mitigate risks associated with perioperative opioid use. Implementing this framework through evidence-based ERAS protocols can have institutional and logistical barriers, but ultimately enhances care on a hospital system level to improve patient safety, recovery, and satisfaction. Studies have not demonstrated convincing evidence to support broad use of OFA, although particular patients and types of surgeries may certainly benefit. It remains to be demonstrated whether opioid-reducing strategies decrease the risk of chronic postsurgical pain or new persistent opioid use, as many of the patients receiving OFA were still prescribed opioids at discharge. The anesthesia professional plays an integral role in helping further bridge the gap and avert adverse events from inadequate or inappropriate analgesic practices in the perioperative period.

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Treatment and Complications of IV Infiltration of Neuromuscular Blocking Agents

by Govind Rangrass, MD, FASA; Karolina Brook, MD, FASA, CPPS; Rachel C. Wolfe, PharmD, MHA, BCCCP, FCCP; Fenghua Li, MD, FASA; and Andrea Vannucci, MD, FASA, CPPS

INTRODUCTION

Over 150 million peripheral intravenous catheter (PIVC) insertions occur in the United States annually, making it the most common invasive procedure performed in hospitals.[1] Complications associated with PIVCs include nerve injury, vascular injury, and infiltration. Infiltration of a PIVC is the unintended administration of any medications or fluids into tissue surrounding the catheter.[2,3] Infiltration occurs in approximately 13.7% of PIVC insertions and can have significant perioperative patient safety consequences.[4,5] Risk factors for PIVC infiltration include both equipment and care-related factors.[5-8] While most PIVC infiltration events can be managed conservatively, severe cases can result in tissue injury requiring surgical intervention, specialized wound care, persistent pain, or loss of limb function.

In the acute perioperative setting, PIVC infiltration can introduce a unique set of complications leading to patient harm, including intraoperative awareness, failed resuscitation, or compartment syndrome. Infiltration events involving neuromuscular blocking agents (NMBAs) may occur in the inpatient or outpatient surgery setting, complicate patient care significantly, and warrant additional considerations beyond tissue injury prevention and wound care. Specifically, the infiltration of a nondepolarizing NMBA risks subsequent reabsorption and recurarization, potentially resulting in muscle weakness, respiratory insufficiency, and postoperative pulmonary complications. Patients with compromised hepatic and renal function may be at higher risk of complications from NMBA infiltration. Unfortunately, few resources from anesthesiology societies or guidelines inform the management of this complication, whether it requires escalation of care, or if more conservative treatments can be prescribed. Anesthesiology professionals may be faced with a dilemma on how to proceed while prioritizing patient safety, especially when considering discharging same day surgery patients with higher risk comorbidities.

INFILTRATION OF NEUROMUSCULAR BLOCKING AGENTS

Relatively few studies and reports describe the clinical effects of infiltrated NMBAs. Thirty years ago, Korean researchers studied the clinical effects of subcutaneously administered succinylcholine.[9] They found that patients receiving equal doses of subcutaneous succinylcholine had incomplete maximum depressed twitch height and prolonged paralysis onset time, but shorter paralysis recovery time compared to intravenous (IV) administration. In contrast, inadvertent subcutaneous administration of a nondepolarizing NMBA can prolong the onset and duration of neuromuscular blockade (NMB) with significant variability, making it difficult to predict neuromuscular recovery and complicating subsequent management.[10-13] The prolonged onset and duration of NMB is due to the unpredictable shifting of NMBAs from subcutaneous tissues to the central circulation. While recurarization of intravenously administered rocuronium is possible after administration of NMB reversal agents, recurarization risk is increased when rocuronium has infiltrated into the subcutaneous tissue, even in patients with normal hepatic and renal function.[14,15] In published cases, this "secondary recurarization" occurred most commonly when patients were administered additional "intubating doses" of rocuronium (0.6–1.2 mg/kg of ideal body weight [IBW]) after an initial infiltrated administration (subcutaneous injection), along with suboptimal dosing of NMB reversal agents.[16,17]

In cases involving infiltrated rocuronium, sugammadex has been successfully utilized to reverse NMB in patients with and without renal and hepatic dysfunction.[18-21] Despite these case reports, the short two-hour half-life of sugammadex and its molar 1:1 binding ratio may not always result in a reliable and sustained reversal of recurarization from infiltrated rocuronium.[19] In the context of renal impairment, where the half-life of sugammadex is prolonged up to 4 hours in mild renal insufficiency and 19 hours in severe renal insufficiency, sugammadex may confer a theoretical benefit in the management of infiltrated aminosteroidal NMBAs when its binding capacity is not saturated.

MANAGEMENT OF NEUROMUSCULAR BLOCKING AGENT INFILTRATION

While no guidelines for the management of infiltrated paralytic exist, several strategies may help reduce patient harm from this complication (Figure 1, next page). Even if its effectiveness is

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Local Circulation Can Significantly Alter the Predictability of Onset and Duration of Infiltrated Neuromuscular Blocking Agents

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limited, the PIVC should be left in place and medication aspiration should be attempted. If the infiltration is recognized after anesthesia induction drugs have been administered and a non-depolarizing NMBA was used, the subsequent induction attempt through the new PIVC should consider using a reduced dose of a non-depolarizing NMBA, avoiding redosing non-depolarizing NMBA altogether, or switching to succinylcholine. Intraoperatively, the anesthesia team should elevate the extremity with the infiltration, apply warm compresses (dry heat) to facilitate systemic uptake of drugs, demarcate the area of infiltration, and consider administration of hyaluronidase through the infiltrated PIVC and intradermally around the leading edge of infiltration site.[22] Serial exams should be conducted along with surgical consultation if there remains concern for tissue injury or compartment syndrome.

Local circulation can significantly alter the predictability of onset and duration of infiltrated rocuronium.[20] Techniques to improve the systemic absorption of NMBAs may facilitate optimal NMB reversal in the immediate intraoperative period. Hyaluronidase and nitroglycerine paste have been utilized to accelerate the systemic absorption of many infiltrated medications and vesicants.[23] Hyaluronidase is an enzyme that hydrolyzes hyaluronic acid to aid in the absorption and dispersal of injected agents. It is commonly used for the treatment of severe infiltration events involving pH-related and hyperosmolar vesicants. Hyaluronidase is commonly available in a 1 mL vial containing 150 units, and can be administered using a tuberculin syringe and 25-gauge (or smaller) needle. One recommended administration method is to dilute hyaluronidase to 15 units/mL and perform five 0.2 mL injections (1 mL total) around the leading edge of the infiltration site.[22] Prior to the removal of the infiltrated PIVC, 15 units may be administered through the catheter and repeated every 30–60 minutes until the infiltration site resolves.[22,24] The administration of hyaluronidase should occur optimally within 1 hour of the infiltration event; improvements in swelling may be observed within 15–30 minutes of enzyme delivery along the tissue plane.[25] Similarly, the vasodilating effects of nitroglycerin 2% paste can improve systemic drug absorption when applied to one square inch areas of infiltration, avoiding any areas of skin breakdown.[25,26]

NMB reversal needs to be carefully considered. Studies on the pharmacokinetics and pharmacodynamics of subcutaneously administered steroidal NMBAs to support evidence-based NMB reversal treatments are sparse and have not included benzylisoquinoline alkaloids. Only twelve case reports/case series and one prospective study address the pharmacokinetics and pharmacodynamics of subcutaneously administered steroidal NMBAs.[10-19,21,27-29] The cohort of cases reviewed included 30 patients and the NMBAs involved were pancuronium, vecuronium, and rocuronium. It is possible that the spontaneous degradation of benzylisoquinoline alkaloids at tissue pH may protect against severe complications from their reabsorption, hence the lack of infiltration reports involving this class of NMBAs. Due to the paucity of data, approaches to NMB reversal recommended in the literature are based on the availability of qualitative and quantitative monitors of NMB depth and on general pharmacokinetic and pharmacodynamic considerations, including the hepatic and renal function of patients.

After initiating treatment for infiltrated NMBA, every attempt should be made to reverse NMB, with sugammadex being the preferred agent for rocuronium and vecuronium.[30] Intraoperatively, should the patient continue to have deep levels of NMB or if sugammadex is unavailable, the anesthesia professional may also elect to keep the patient intubated postoperatively. If only qualitative twitch monitoring is available or the concern for residual NMBA at the infiltration site remains, and NMB depth is mild-moderate,

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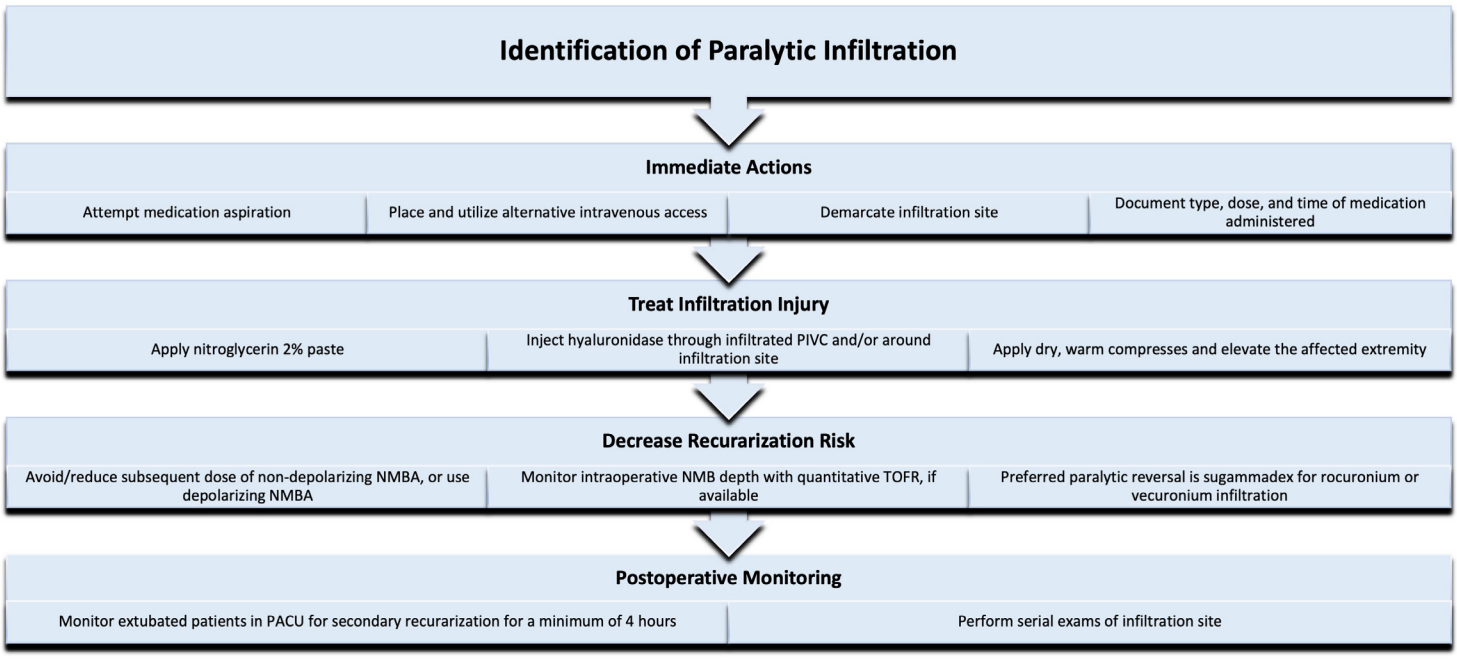

Figure 1: Authors' proposed algorithm to manage paralytic extravasation.

Neuromuscular blocking agent (NMBA); Neuromuscular blockade (NMB); Post-anesthesia care unit (PACU); Train-of-four ratio (TOFR).

Quantitative Train-of-Four Ratio Monitoring Should Be Used to Assess Residual Paralysis

From "NMB Infiltration," Preceding Page

the anesthesia professional should use standard reversal doses and monitor the patient closely for clinical signs of recurarization in the postanesthesia care unit (PACU). If quantitative train-of-four ratio (TOFR) monitoring capabilities are available and the infiltration site looks visibly better at the end of the operation, patients may still be monitored clinically but with the added benefit of quantitative TOFR data to guide reversal redosing. Previous studies have used stimulation currents of 50 milliamperes to detect residual paralysis in patients in the PACU, but reducing the stimulation current amplitude to below 40 milliamperes using a newer commercially available electromyography-based quantitative TOFR monitor can significantly reduce discomfort in non-sedated patients without compromising TOFR accuracy.[31] Due to the lack of predictability of subcutaneously injected paralytic absorption, extubated patients without hepatic or renal dysfunction should be monitored for at least four hours in the PACU.[12,13,19,20] Both the patient and nursing teams should receive counseling on the signs and symptoms of residual NMB with parameters to guide care escalation.

CONCLUSION

Infiltration events can cause significant patient harm and complicate patient care in the perioperative period. Should NMBA infiltration occur, the anesthesia professional is presented with the challenge of not only managing potential patient injuries but also preventing secondary recurarization from the unpredictable reabsorption of NMBA from the subcutaneous depot. Anesthesiology professionals should remain aware of management options to reduce adverse sequelae from this complication.

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EDITORIAL:

Cardiac Arrest in the Operating Room: Reevaluating Advanced Cardiovascular Life Support

by Zachary Smith, DNP, CRNA, CHSE

The Advanced Cardiovascular Life Support (ACLS) guidelines have long stood as the global standard for resuscitation efforts, with a particular focus on sudden cardiac arrest and emergency interventions. Yet, as we shift our focus to the operating room, where an intricate and high-stakes ecosystem unfolds, the limitations of ACLS become evident. There are inherent shortfalls of ACLS when applied to the intraoperative environment, which highlights why specialized guidelines, such as the American Society of Anesthesiologists' (ASA) Perioperative Resuscitation and Life Support (PeRLS) certification, may offer a more contextually appropriate approach.

The origins of ACLS lie in managing out-of-hospital cardiac arrest and in-hospital emergencies where standard protocols can be universally applied. This standardized approach has provided a foundational framework that emphasizes early recognition of cardiac arrest, high-quality chest compressions, airway management, and the use of defibrillation and pharmacologic support.[1] However, its applicability begins to diminish when brought into the operating room, where the variables are more complex, and the interventions required are highly specific to the intraoperative context.

Intraoperative cardiac events often stem from unique etiologies distinct from those encountered in out-of-hospital or emergency department scenarios. While cardiac arrests outside the operating room may result from sudden arrhythmic events, arrests during surgery can be precipitated by catastrophic hemorrhage, embolic phenomena, or pharmacologic reactions such as malignant hyperthermia (MH) or local anesthetic systemic toxicity (LAST).[2] These perioperative emergencies necessitate immediate and precise interventions that go beyond the standard ACLS algorithm, which may be inadequate or even inappropriate for such situations.[2] For instance, while ACLS emphasizes early administration of epinephrine, in cases of LAST the dose is much smaller (≤ 1 mcg/kg) than typical doses for ACLS and must be accompanied by the administration of lipid emulsion therapy, an essential step absent from ACLS guidelines.[3] Repeated epinephrine boluses have been shown to reduce the effectiveness of lipid emulsion, potentially worsening patient outcomes.[4] Additionally, certain medications commonly used in resuscitation, such as calcium-channel blockers, beta blockers, and lidocaine, are contraindicated in this scenario, underscoring the critical importance of tailoring interventions specifically to the etiology of cardiac arrest in LAST.[5]

In addition to these medical challenges, intraoperative resuscitation is further complicated by the physical environment itself. The positioning of the patient, whether prone, lateral, or in steep Trendelenburg, can significantly affect the efficacy of chest compressions and defibrillation efforts.[6] Prone positioning, for example, can render traditional chest compressions impossible, and transitioning a patient to supine may be impractical or delay life-saving interventions.[7] Emerging research has shown that prone Cardiopulmonary Resuscitation (CPR) can be effective, but it requires modifications to technique and training that ACLS does not provide.[8] Additionally, repositioning these patients could result in fatal outcomes if surgical hemostasis is compromised, as repositioning would obstruct necessary surgical access needed to control bleeding.[7,9]

Moreover, ACLS guidelines do not take advantage of the advanced monitoring capabilities available in the operating room. Anesthesia providers depend on continuous monitoring and frequently have access to invasive measures, such as arterial blood pressure, central venous pressure, and echocardiography, to guide their resuscitation efforts in real-time.[10] The ability to leverage such data is crucial for tailoring interventions and understanding the immediate response to treatment. ACLS, with its reliance on simplified measures like pulse checks and waveform capnography, fails to encompass the depth of data that anesthesia providers routinely utilize to make informed decisions during crises. These protocols are often designed with unwitnessed cardiac arrests in mind, which does not reflect the circumstances typically encountered in the perioperative environment.

The shortcomings of ACLS in these scenarios highlight the need for an approach tailored specifically to the intraoperative environment. The ASA's Perioperative Resuscitation and Life Support (PeRLS) certificate is a prime example of this needed shift. PeRLS was created to address perioperative emergencies by integrating ACLS principles with knowledge specific to anesthesia and surgical care. This program teaches practitioners to recognize and treat life-threatening conditions that can arise under anesthesia, using tools and strategies that are more applicable to the complexities of the operating room.[11] By emphasizing rapid identification of the underlying causes of cardiac instability, PeRLS training prepares clinicians for scenarios where ACLS is insufficient or where adherence to it without adaptation could lead to suboptimal outcomes.

Similar to how neonatal resuscitation or trauma life support protocols adapt standard resuscitative measures to the specific needs of

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Specialized Protocols Are Necessary to Address Perioperative Emergencies

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those populations, perioperative care requires a guideline that can adapt to the intricacies of surgical and anesthetic practice.[12-14] For instance, the Neonatal Resuscitation Program modifies traditional CPR techniques to account for the unique physiology of neonates.[13] Likewise, the European Resuscitation Council and other international bodies have tailored their guidelines to fit special circumstances like traumatic cardiac arrest and drowning, recognizing the limitations of applying one-size-fits-all protocols.[15]

The necessity for specialized training becomes evident when considering the stakes involved. Perioperative cardiac arrest, although rare, carries significant morbidity and mortality risks.[2] Rapid, precise management that integrates the nuances of anesthetic pharmacology, surgical factors, and patient positioning is essential for improving outcomes. PeRLS provides an answer to this challenge by offering a comprehensive approach that equips perioperative teams to respond swiftly with contextually relevant interventions.

The need for specialized guidelines is not an indictment of ACLS; rather, it acknowledges the inherent limitations of applying a generalized protocol in a highly specialized environment. Resuscitative efforts in the operating room should draw from ACLS where applicable but must go beyond its confines to incorporate anesthesiology's distinct needs and capabilities. This approach underscores the importance of training that prepares perioperative teams not only to recognize cardiac arrest but to do so within the context of surgical, pharmacologic, and positional realities that define their practice.

In conclusion, the ACLS guidelines serve as a fundamental template for cardiac arrest management, but their limitations in the intraoperative environment are evident. Emergencies such as MH, LAST, and significant surgical complications necessitate a flexible, informed approach that ACLS alone cannot provide. Programs like ASA's PeRLS exemplify the shift needed in the perioperative environment—one that builds on the foundation of ACLS while tailoring it to the high-stakes, variable environment of the operating room. Adapting resuscitative protocols to specific patient populations and scenarios will ultimately bridge the gap between standardized emergency care and the specialized needs of perioperative patients, ensuring that practitioners are equipped not just to respond, but to do so with precision and efficacy.

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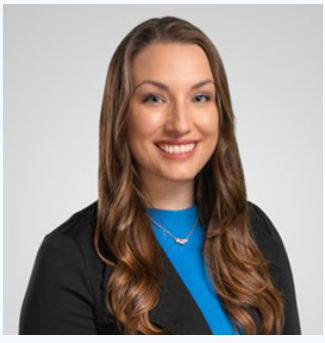

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Postoperative Apnea and Former Preterm Infant: Evolving Evidence for Management

by Ying Eva Lu-Boettcher, MD; Rahul Koka, MD, MPH; Priti G. Dalal, MD; Charles J. Coté, MD; Members of Wake Up Safe/Society of Pediatric Anesthesia Quality & Safety

Infants born at gestational age < 37 weeks are categorized as premature or preterm.[1] Apnea of prematurity is defined as a respiratory pause for more than 15–20 seconds, or shorter respiratory pauses accompanied by oxygen desaturation or bradycardia (heart rate<100 beats per minute) in premature or preterm infants.[1-3] The incidence of apnea is inversely correlated with gestational age. In one study, almost all infants born at ≤ 28 weeks gestation were diagnosed with recurrent apnea; this incidence decreased to 85% for infants born at 30 weeks and 20% for infants at 34 weeks gestation.[4]

Preterm and former preterm infants are known to be at increased risk for postoperative apnea following emergence from anesthesia.[2-3] Inconsistent definitions of apnea, desaturation, and bradycardia in previous studies make it difficult to identify the true incidence of postoperative apnea, which has resulted in differences in monitoring protocols across institutions.

POSTOPERATIVE APNEA IN THE PRETERM POPULATION

Apnea of prematurity reflects an immature development of respiratory control centers. Premature infants have underdeveloped respiratory and chemoreceptor function and are less likely to adjust to postnatal environment changes.[5] Premature infants experience hypoxic ventilatory depression in which the initial increase in respiratory rate and volume in the setting of hypoxia transitions to a decline in spontaneous breathing that is sustained. In response to hypercapnia, premature infants increase ventilation by prolonging the period of expiration, but do not increase breath frequency or overall tidal volume, leading to less minute ventilation than that seen in term infants.[1,6]

Apnea of prematurity and postoperative apnea have a similar combination of central and obstructive pathophysiology. Studies have shown that obstructive apnea episodes often begin with upper airway obstruction that occur with the central component of mixed apnea. Premature infants are more likely to respond to airway obstruction with apnea and periodic breathing, which decreases with increasing post menstrual age (gestational age plus postnatal age).[2-4] Furthermore, general anesthesia decreases upper airway tone and increases airway obstruction, contributing to the development of apnea after anesthesia. This occurs even in infants without a history of apnea.[1-4] The risk factors for postoperative apnea include cardiac shunts, anemia, decreasing gestational age, hypothermia, glucose and electrolyte disturbances, and a patent ductus arteriosus.[1]

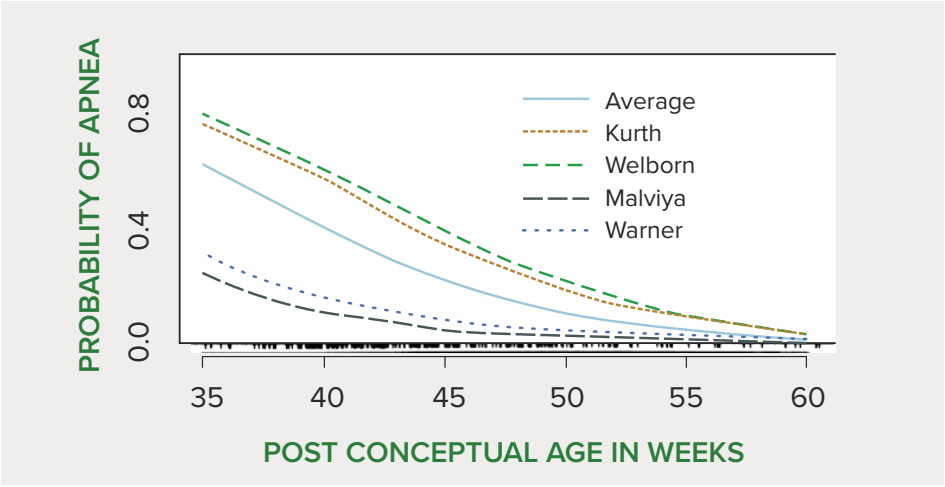

Figure 1: Predicted probability of apnea in recovery room and post-recovery room by weeks postconceptual age for all patients for each investigator. Bottom marks indicate the number of data points versus postconceptual age. The curves for the Kurth et al. and Welborn et al. studies are nearly identical in the upper range, and for the Malviya et al. and Warner et al. studies, in the lower range. There was significant institution-to-institution variability. The reasons for this are unclear but may represent differences in monitoring technology as well as patient populations, because the studies with the highest rate of apnea were also those that used continuous recording devices.

Figure from Postoperative apnea in the former preterm infants after inguinal herniorrhaphy. A combined analysis. Anesthesiology. *1995;82(4):809-822. PMID: 7717551.*

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Premature infants are at significantly higher risk than term infants for cardiopulmonary complications in the immediate postoperative period. Most anesthesiology studies use the term postconceptual age (PCA).[5] Early prospective studies in the 1990s showed that postoperative apnea can affect as many as 20–32% of otherwise healthy former-preterm infants under 60 weeks PCA receiving general anesthesia.[7-10] In 1995, Coté et al. compiled data from eight studies of former preterm infants undergoing inguinal hernia repair to better characterize the incidence and risk of postoperative apnea. The authors reported a combined apnea rate of ~25%.[11] Rates from contributing studies varied from 5% to 49% depending on the technique of apnea detection. Most apneas were pneumogram-diagnosed, occurring in infants <44 weeks PCA, and anemia was shown to be an independent risk factor. Similar to apnea of prematurity, the incidence of postoperative apnea in the preterm population was inversely related to the infant's gestational age and PCA at the time of anesthesia (Figure 1). Postoperative apnea probability decreased to less than 1% at 54 weeks PCA in infants whose gestational age was 35 weeks and at 56 weeks PCA in infants whose gestational age was 32 weeks.[11]

These findings align with other reports, which showed that infants less than 45 weeks PCA were more likely to develop postoperative apnea, while in older infants with PCA between 46 and 60 weeks, comorbidities influenced their predisposition to apnea. The reported comorbidities included necrotizing enterocolitis, bronchopulmonary dysplasia, former apnea episodes, anemia, and lower birth weight.[12] These findings led to a study that suggested infants between 46 and 60 weeks PCA be monitored for 12 hours postoperatively, and respiratory monitoring is recommended if the patient's history reveals episodes of apnea, chronic lung disease, neurological disease, or anemia.[13] In addition, a greater incidence of apnea within 30 minutes of surgery requiring significant interventions (maneuvers greater than tactile stimulation) was identified in infants who received general anesthesia, but no difference in the incidence of late apnea in infants who received regional versus general anesthesia.[14]

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Postoperative Monitoring Is Necessary for Infants at Risk for Apnea

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TIMING OF POSTOPERATIVE APNEA

Previous studies found that in the majority of infants who experienced postoperative apnea, the first event occurred within 2 hours of surgery. Yet, some authors have reported the first apneic event to occur as late as 12 hours after surgery.[15-18] In a study that monitored children for 24 hours postoperatively for apnea, none of the 91 infants examined had their first apnea event after 12 hours.[19] Thus, they recommended cardiorespiratory (respiratory impedance and electrocardiography) monitoring for former preterm infants for at least 12 hours after surgery. Rarely, infants have been reported to experience recurrent apneas up to 72 hours postoperatively, suggesting that even longer periods of postoperative monitoring may be required in certain cases.[12,20]

Most pediatric surgery centers have policies regarding postoperative admission and observation criteria for former preterm and term infants. Due to the variability in available data on gestational age, PCA, incidence, and timing of apnea events, there are nuanced differences in these policies (Table 1).[6,12-14,24]

The current available literature suggests that while there is variability across studies, a 12-hour apnea-free period currently appears to be a reasonably safe option in determining discharge in former preterm infants at risk for apnea after any anesthetic. However, a detailed analysis from a larger data set is warranted. Importantly, spinal or caudal anesthesia offers reduction in occurrence of early, but not late apnea. This is likely due to residual depressent effects of the general anesthetics.

Although most pediatric surgical centers have established policies regarding admission criteria after any anesthetic for young term and former preterm infants, policies vary from one institution to another. This variability can be partly attributed to small sample sizes and variable incidences of postoperative apnea among early studies. Data are currently being compiled and the results from a meta-analysis and micro-analysis are underway. We hope that new recommendations in the postoperative management of this vulnerable cohort will be forthcoming.

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Table 1: Postoperative Admission and Observation Recommendations[6,13-15,24]

General Recommendations based on current available literature:

Patients who are term or preterm/former preterm under 60 weeks PCA should be considered for postoperative monitoring and an observation period.[13-15]

Monitoring: Apnea and bradycardia monitoring, nursing observation, continuous pulse oximetry, and a respiratory monitor are recommended.

Preterm Recommendations:	Term Recommendations:
• Former preterm infants < 55 weeks PCA should be admitted postoperatively.[6]	• Term infants < 44 weeks PCA should be admitted postoperatively and must remain apnea-free for 12 hours prior to discharge.[24]
• Former preterm infants < 60 weeks PCA with risk factors for postoperative apnea should be admitted and observed for a minimum of 12 hours.[15]	• Any term infant should be monitored for a minimum of 2 hours post-anesthetic and be discharged only with uneventful postop course.
• Former preterm infants who are > 55 and < 60 weeks PCA without anemia, apnea, or other risk factors can be observed postoperatively for 6 hours and then later discharged if no events occur.[6]	• All patients < 6 months who receive opioids should be monitored for a minimum of 2 hours and may require admission depending on complexity and duration of the procedure.
• All infants should have been apnea-free for 12 hours prior to discharge.	• Term infants with a history of bradycardia and apneas, or those with a sibling with Sudden Infant Death Syndrome, should be considered for admission.[6]
• Postoperative apnea in former preterm infants > 60 weeks PCA has not been reported—the most conservative approach would be to admit any premature infant under 60 weeks PCA.[6]	• Term infants > 30 days but less than 6 months old can be discharged based on attending anesthesiologist discretion if without comorbidities or postoperative complications.

Preterm Infants Need to Be Apnea-Free for 12 Hours Prior to Discharge

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Keeping Patients Safe During Emergency Tracheostomy Management

by Jack Buckley, MD

INTRODUCTION

A tracheostomy is a common procedure done for patients who need prolonged mechanical ventilation, are unable to protect their airway, or have pathologies of the oropharynx leading to the potential for upper airway obstruction. While a tracheostomy is relatively safe, complications are common, and it is essential to understand the management steps to ensure that the patient's tracheostomy functions as intended.[1]

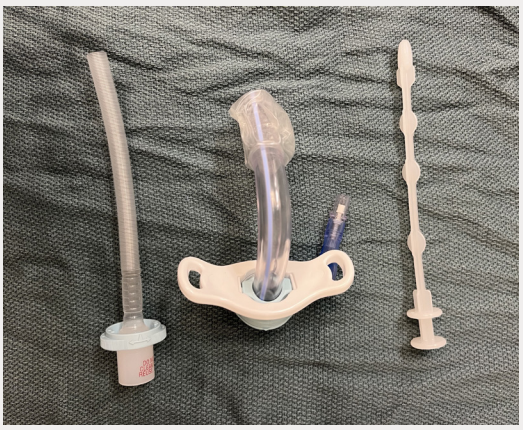
In a single center study of 100 patients undergoing tracheostomy, the complication rate was 47% during the initial hospitalization. The most common complications included obstruction of the tracheostomy (19%), bleeding (16%), infection (14%), and accidental decannulation (13%).[2] While these complications are common, if managed appropriately, mortality directly related to the tracheostomy has a very low incidence.[3,4]

MANAGEMENT STEPS OF A POTENTIALLY MALFUNCTIONING TRACHEOSTOMY

In the setting of an occluded or accidentally decannulated tracheostomy, one would expect high airway pressures or loss of tidal volumes if the patient is being mechanically ventilated, and potentially a loss of end-tidal carbon dioxide. If there is concern for either of these complications, the following interventions should be taken to determine the cause of the potential malfunctioning of the tracheostomy tube.

First, the anesthesia professional should deflate the tracheostomy cuff to allow spontaneous breathing, if possible. At the same time, it is important to gain more information about the tracheostomy, including how long ago was it placed, the indication for placement, and the type of tracheostomy (surgical vs. percutaneous). One also needs to determine whether the patient has a patent upper airway allowing for mask ventilation and intubation and the potential for difficult oral intubation, if necessary. If the patient is breathing spontaneously around the deflated cuff, the anesthesia professional should place an oxygen mask on the patient's mouth and tracheostomy stoma since the patient could potentially be breathing through either location. If available, waveform capnography should be used to assist in determining which site, if any, the patient is able to breathe through.[5]

To exclude the possibility of an occluded tracheostomy tube, the anesthesia professional should remove the inner cannula (if present) (Figure 1). The inner cannula is designed to be easily removable to allow cleaning of mucous and other material which can occlude the tracheostomy tube. If ventilation still remains inadequate, the anesthesia professional can then advance a suction catheter through the tracheostomy tube into the distal trachea. If the suction catheter does not advance beyond the end of the tracheostomy, the tip of the tracheostomy may be pressed up against the tracheal wall or occluded by an overinflated cuff.



< *Figure 1: Middle—cuffed tracheostomy, left—obturator to assist with insertion of tracheostomy, right—removable inner cannula.*

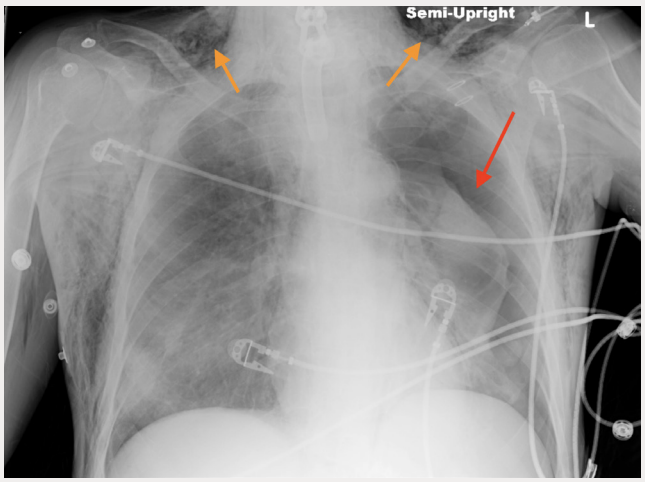


Figure 2: Chest x-ray from a patient with a malpositioned tracheostomy tube who received positive pressure ventilation, leading to a left-sided pneumothorax (red arrow) and subcutaneous emphysema (orange arrows) in the neck. >

If the suction catheter does not advance beyond the tip of the tracheostomy, the tracheostomy may have become displaced from the trachea and positioned in the subcutaneous tissue in the neck.[6] To determine the cause of the inadequate ventilation, the anesthesia professional can attempt to gently provide positive pressure ventilation via a bag-valve-mask. If end-tidal CO_2 is not present and/or high airway pressures are experienced, attempts to provide positive pressure ventilation must immediately be stopped and it should be assumed that the tracheostomy tube is no longer in the trachea. If available, a bronchoscopy scope can be advanced down the tracheostomy tube to confirm that it is no longer in the trachea.[7] Attempts to provide positive pressure ventilation with a dislodged tracheostomy that is located in the subcutaneous tissue can lead to complications including subcutaneous emphysema, pneumothoraces, and pneumomediastinum. In addition, the pressurized air can track into the subcutaneous tissues of the upper airway making intubation difficult. (Figure 2).

If there is concern that the tracheostomy is in the subcutaneous tissue and the patient is not ventilating adequately, the tracheostomy must be removed. Once the tracheostomy tube has been removed, assess the patient's ventilation both orally and through the tracheostomy stoma; if adequate, wait for additional help to arrive. If ventilation remains inadequate and the patient is desaturating, the anesthesia professional should attempt to mask ventilate the patient either orally while occluding the stoma or via the tracheostomy stoma itself.[8] A pediatric mask may be helpful in ventilating via the stoma.

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Patients With a Total Laryngectomy Require Special Considerations When Managing Respiratory Distress

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If mask ventilation is inadequate, the patient will need to be urgently intubated orally or via the tracheostoma stoma. The decision of oral vs. via stoma will be influenced by the presence of a patent upper airway, the expected difficulty of oral intubation, experience of the providers present, and the age of the tracheostomy. Factors that would support attempting oral intubation include providers inexperienced in replacing tracheostomies, history of easy oral intubation, no oropharyngeal pathology present, or if it is a "new" tracheostomy (surgical tracheostomy <4 days, percutaneous tracheostomy <7–10 days).[9] With a "fresh" tracheostomy stoma there is a risk of inadvertently advancing the tube into the subcutaneous tissue. A surgical tracheostomy is considered "mature" earlier because the surgical tracheostomy typically has a portion of the trachea that is sutured to the skin which decreases the risk of advancing a tube into the subcutaneous tissue. Factors that would support intubating the tracheostomy stoma as opposed to intubation orally include the provider's comfort in replacing a tracheostomy, a history of difficult intubation or known oropharyngeal pathology that will make oral intubation difficult, or a "mature" tracheostomy with a well-healed stoma.[6]

If the stoma is "mature" with a moderate sized opening and a clear path to the trachea, a tracheostomy tube can simply be advanced back into the trachea. If the stoma is small or difficulty is expected, an endotracheal tube is recommended since it may be less likely to advance into a false passage.[5] An intubation bougie can be placed into the stoma first and used to feel for the tracheal rings in a fashion similar to oral intubation. Alternatively, a bronchoscopy scope can be advanced into the stoma first while attempting to identify the trachea. Then a bougie or bronchoscopy scope can be used to facilitate advancing the endotracheal tube into the trachea.[10]

To improve the safety for patients with a tracheostomy, it is recommended to have bedside signs and algorithm sheets readily available for reference to facilitate the management of these patients (Figures 3 and 4).[11]

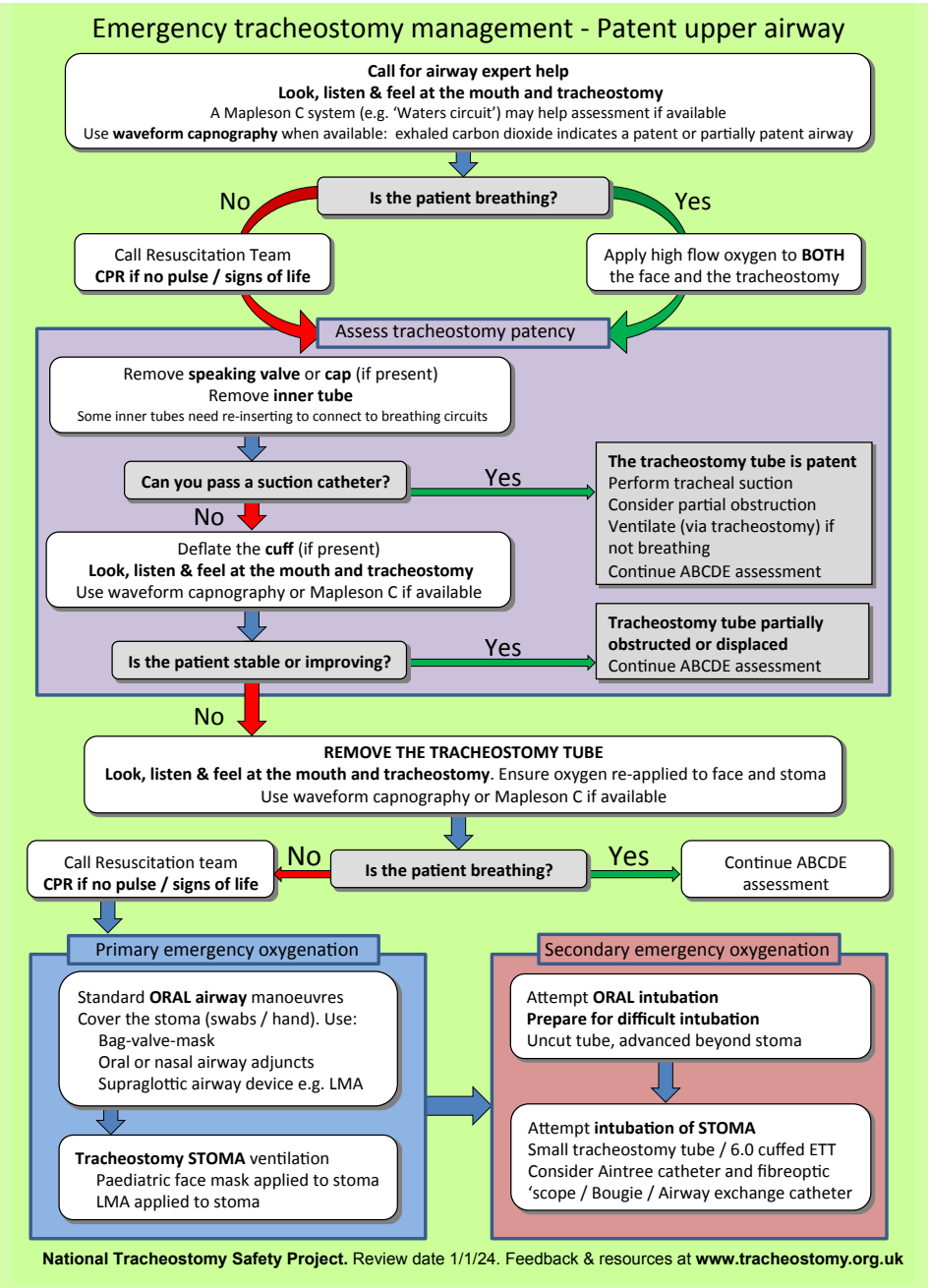

Figure 3: Emergency tracheostomy management algorithm. Used with permission from Brendan McGrath and the National Tracheostomy Safety Project.

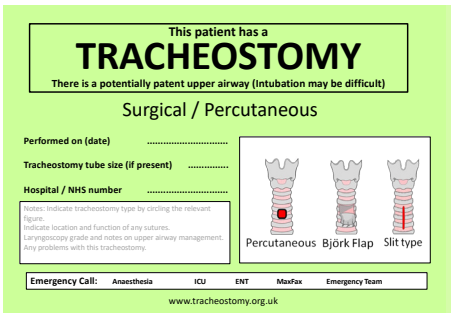

Figure 4: Tracheostomy bedside sign. Used with permission from Brendan McGrath and the National Tracheostomy Safety Project.

PATIENTS PRESENTING TO THE OPERATING ROOM WITH A TRACHEOSTOMY IN PLACE

For the patient presenting to the operating room with an existing tracheostomy, there are multiple considerations for management.[12] The first priority is obtaining a "tracheostomy history" (including whether there is a patent upper airway, maturity of trach, etc). Next assessment of the ventilation needs during the procedure is required. The simplest situation is a cuffed tracheostomy that will not be in the surgical field, which can be used without any modifications. If the tracheostomy is uncuffed, it could potentially be used if the patient will be spontaneously breathing and positive pressure ventilation is not indicated. The decision is determined by the need for positive pressure ventilation during the procedure. If the tracheostomy tube will be in the surgical field, it may need to be replaced with an endotracheal tube

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Bedside Signs Are a Helpful Tool to Manage Patients With Tracheostomies and Laryngectomies

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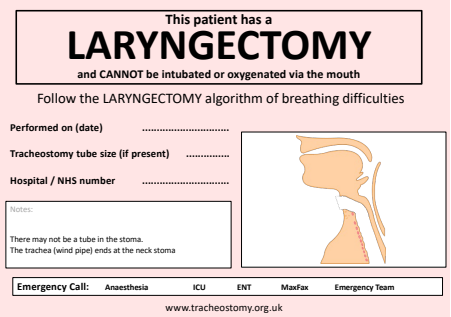

Figure 5: Laryngectomy bedside sign. Used with permission from Brendan McGrath and the National Tracheostomy Safety Project.

that is placed either orally or via the tracheostomy stoma.

If the tracheostomy tube needs to be exchanged, the factors described previously in this article can be used to influence the decision as to whether to intubate the patient orally or use the stoma in the neck. For oral intubation, the cuff of the endotracheal tube should be placed just beyond the stoma site to allow a seal to be created with the trachea. If the stoma site is to be used, a wire-reinforced endotracheal tube may be selected to minimize the risk of kinking. The tracheal stoma site is typically placed between the 2nd–4th tracheal ring. The distance from the stoma to the carina is approximately 6.5 cm so caution must be used to ensure that the endotracheal tube does not enter the mainstem bronchus.[13] Ausculation of bilateral breath sounds after endotracheal tube insertion confirms proper position and facilitates adjustment if needed

If there is a concern for difficult placement of the endotracheal tube into the stoma such as with a fresh stoma, an airway exchange catheter can be used to facilitate the exchange of a tracheostomy tube.[14] The exchange catheter can minimize the risk of placing the endotracheal tube into a false passage in the subcutaneous tissue. Some brands of tube exchangers have an open channel which allows the insufflation of oxygen during the exchange to minimize desaturation.

SPECIAL CONSIDERATIONS: LARYNGECTOMY PATIENTS

Patients with a total laryngectomy or "neck breathers" require special considerations. In these patients, the larynx is surgically removed, and the trachea is sutured to the skin of the anterior neck. The end result is the trachea no longer communicates with the oropharynx so the patients cannot be orally intubated or mask ventilated. This is a significant safety risk for these patients if respiratory distress occurs. A survey of otolaryngologists demonstrated that over half of these clinicians had experienced a situation where health care providers attempted to orally intubate or mask ventilate patients with a total laryngectomy. When this occurred, the reported mortality rate was 26%.[15]

To minimize the risk of harm for patients with laryngectomies, they must be distinguished from patients with a patent upper airway. One method to do this is with a bedside sign specific for laryngectomy patients (Figure 5) and placing an alert in the patient's chart.[16] If a patient with a total laryngectomy experiences respiratory distress, an oxygen mask should be applied to the stoma site. If mask ventilation is indicated, a pediatric mask can be placed over the stoma and ventilation provided. Most patients with a total laryngectomy do not have a cuffed tracheostomy tube in place. If the patient needs positive pressure ventilation, a cuffed tracheostomy tube can be exchanged for the uncuffed tracheostomy tube or an appropriately sized endotracheal tube can be inserted into the stoma in the neck. The tube should advance easily into the trachea since these patients typically have a reasonably sized stoma. It should be noted that during laryngectomy the trachea is sutured to the skin, so it is more difficult for a clinician to advance the endotracheal tube into a false passage even after the sutures have been

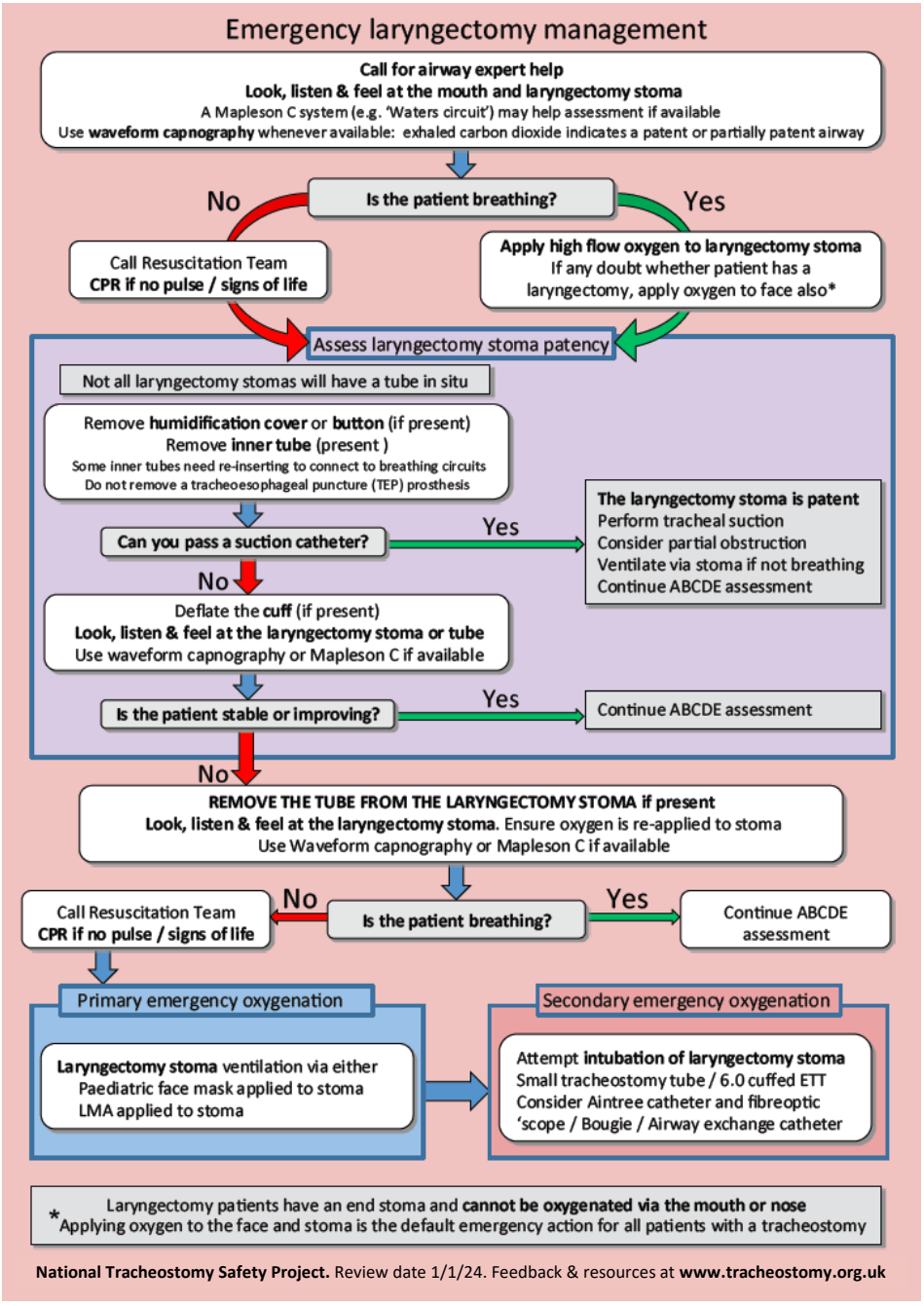

Figure 6: Laryngectomy management algorithm. Used with permission from Brendan McGrath and the National Tracheostomy Safety Project.

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Anesthesia Professionals Should Learn to Manage Tracheostomy Complications

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removed.[17] It can be helpful to have algorithms for laryngectomy management at the bedside in a fashion similar to patient's with tracheostomies for easy reference (Figure 6).[16]

CONCLUSION

Patients with a tracheostomy are commonly encountered in clinical practice, and complications can occur. By understanding the recommended management steps, these complications can usually be managed to ensure that patients do not suffer harm related related to their artificial airway. Bedside signs can be an effective method provide pertinent information related to the airway and to assist providers with the recommended steps if the surgical airway is not functioning properly.

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Advanced Respiratory Monitoring Therapies in the Operating Room: A New Frontier for Obese Patients

by Cristina Mietto, MD; Roberta Santiago, RRT, MD, PhD; and Lorenzo Berra, MD

Pulmonary complications following major surgery are the most frequent type of postoperative complications.[1] Preoperative identification of patients at higher risk for postoperative pulmonary complications is critical for minimizing risks and implementing monitoring techniques to ensure protective ventilation. The incidence of postoperative pulmonary complications has been reported to exceed 20% in patients with class III obesity (BMI ≥ 40 kg/m^2) undergoing major abdominal surgery, and no standardized approach has proven effective in reducing their occurrence.[2] The underlying pathophysiology of this susceptibility is linked to increased abdominal fat, which causes cephalic displacement of the diaphragm and a reduction in lung volumes, particularly functional residual capacity and expiratory reserve volume. The reduction in lung volumes is primarily responsible for the decreased respiratory system compliance observed in obesity. Moreover, supine position is associated with increased airway resistance in obese patients, likely due to breathing at low volumes, leading to flow limitation in the expiratory phase and, in some cases, intrinsic positive end expiratory pressure (PEEPi).[3]

According to the World Health Organization, the global prevalence of obesity is rising, with more than 40% of the U.S. population now affected.[4] Mechanical ventilation for patients with obesity presents unique challenges that have become increasingly common in clinical practice. However, current ventilation strategies (Table 1) often fail to account for the specific respiratory physiology of these patients, who are frequently excluded from major randomized controlled trials.[3] Obesity is associated with higher pleural pressure, reduced lung volumes, atelectasis, and increased risk of airway occlusion.[5] Current intraoperative monitoring standards remain limited to basic ventilator settings (pressure, volume, and flow), which may not be sufficient in defining the best ventilation settings for these patients. These concerns become even more critical during laparoscopic and robotic-assisted procedures.

RESPIRATORY SYSTEM MECHANICS AND LAPAROSCOPIC SURGERY

The rising use of robotic-assisted surgeries—requiring pneumoperitoneum and, often, steep Trendelenburg position—complicates the physiologic characteristics associated with obesity. A pneumoperitoneum increases chest wall elastance, which reduces respiratory lung compliance, resulting in formation of atelectasis. Counterbalancing the increase in pleural pressure by providing positive end expiratory pressure (PEEP) is essential to avoid negative transpulmonary pressure and lung collapse.[6] Loss of lung volumes leads to ventilation-perfusion mismatch and hypoxemia. The use of carbon dioxide as an insufflation agent increases the required minute ventilation. This hyperventilation in the presence of reduced lung volumes and increased chest wall rigidity can lead to heterogenous ventilation and higher driving pressure, increasing the complexity of intraoperative ventilation management.

Table 1: Suggested Settings for Mechanically Ventilated Obese Patients[3].

Ventilation Mode	Volume control preferable during pneumoperitoneum and Trendelenburg Pressure control requires close monitoring of tidal volume
Tidal Volume	Tidal volume 6 ml/kg IBW Inspiratory time 0.6–1 s
Ventilation Pressures	Plateau pressure ≤ 30 cm H_2O Driving pressure ≤ 15 cm H_2O Higher PEEP or titrate PEEP on advanced respiratory techniques If hypoxemia consider recruitment maneuver
Postoperative Phase	Consider noninvasive ventilation in the postoperative period
Positioning	Intubate and extubate with head elevated

IBW: Ideal body weight. PEEP: Positive end-expiratory pressure. Driving Pressure = Plateau Pressure - PEEP

Patients with obesity frequently experience increased driving pressures during robotic-assisted procedures, often exceeding physiological accepted values (<15 cm H_2O).[6] However, no advanced monitoring tools are routinely used to guide adjustments in ventilatory support. This clinical gap needs to be addressed to improve patient safety and reduce respiratory intraoperative and postoperative complications.

ADVANCED RESPIRATORY MONITORING TECHNIQUES

Esophageal manometry (Pes) and electrical impedance tomography (EIT) are advanced respiratory monitoring techniques that can be used to guide safely personalized intraoperative ventilatory support. Studies utilizing postoperative computed tomography (CT) scans have demonstrated a reduction in lung atelectasis in patients treated with intraoperative individualized PEEP.[7,8] However, further research is needed to evaluate the impact of these various techniques on postoperative pulmonary complications.

ESOPHAGEAL PRESSURE MANOMETRY

The respiratory system consists of two anatomical parts: the lung and the chest wall. Airway pressure can be considered as the sum of pleural pressure and transpulmonary pressure, where transpulmonary pressure represents the true distending force on the lungs. Negative transpulmonary pressure indicates a force pushing against the alveoli, resulting in lung collapse and reduced lung volumes.

Esophageal pressure is a user-friendly surrogate of continuous pleural pressure monitoring. This technique consists of a standard naso/orogastric tube equipped with a small plastic balloon at the end. The catheter is inserted to position the balloon in the lower third of the esophagus, which is in close proximity to the lungs, allowing for the measurement of the pleural pressure (Figure 1). Studies have shown that Pes reliably estimates pleural pressure in

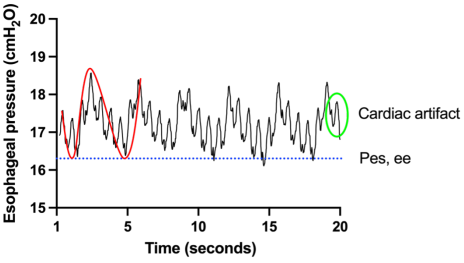

Figure 1: Esophageal pressure waveform recorded in a mechanically ventilated patient with a BMI of 67 kg/m^2. The red line represents the esophageal pressure trace, while the blue dotted line marks the end-expiratory esophageal pressure (Pes,ee). The green circle highlights cardiac artifacts. (Used with permission of the authors.)

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Esophageal Manometry and Electrical Impedance Tomography Are Advanced Respiratory Monitoring for Obese Patients

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adjacent lung regions, though it may overestimate pleural pressure in more ventral lung regions.[9] Pes monitoring can trace the whole respiratory phase and compute real-time continuous transpulmonary pressure. This technique has been proposed to set individualized PEEP equal to Pes measured at end-expiration.[10,11] Because negative transpulmonary pressure values are associated with lung collapse, Pes can guide PEEP settings by maintaining a transpulmonary pressure equal to zero at the end of expiration, thus preventing atelectasis (Figure 2).

Individuals with class III obesity and healthy lungs have been shown to have higher pleural pressure.[5] Under general anesthesia, with sedation and paralysis and in absence of PEEP and lung recruitment, this tendency towards lower lung volumes and airway collapse is further exacerbated, leading to atelectasis and ventilation/perfusion mismatch if not prevented by adequate PEEP.[12]

Esophageal pressure monitoring has been used for decades in intensive care units (ICU) with studies demonstrating improvement in oxygenation in acute respiratory failure.[13] A recent observational trial found that a transpulmonary pressure >0 was associated with a lower 60 days mortality in patients with BMI > 30kg/m^2.[14] Additionally, our group studied the implementation of a dedicated team consisting of experts in advanced respiratory techniques (Lung Rescue Team) at the Massachusetts General Hospital to individualize ventilation settings in patients with obesity admitted to the ICU. This study showed that individualized ventilation in patients with obesity was associated with better oxygenation, respiratory mechanics, and improved survival at 28 days, 3 months, and 1 year.[15]

ELECTRIC IMPEDANCE TOMOGRAPHY

Electrical impedance tomography (EIT) is an FDA-approved, radiation-free, noninvasive lung imaging technique that provides real-time visualization of regional ventilation, lung volumes, and perfusion. It measures the electrical impedance of tissues, which changes as the lungs fill with air. Electrodes positioned on a belt around the chest produce low electrical currents, and the resulting voltage differences are analyzed to be visualized in a color-coded image of air distribution across different lung regions during each breath (Figure 3).[16] An important feature is the ability to evaluate regional (right versus left, anterior versus posterior) ventilation, and determine regional differences in compliance.[17] EIT can also guide PEEP adjustments based on the amount of lung collapse and overdistension at different pressures, optimizing lung recruitment while minimizing the risk of overinflation and atelectasis (Figure 4). This technique has been validated in ICU patients during a decremental PEEP trial, in which EIT displays impedance changes associated with each PEEP step.[18] The best PEEP is identified as the crossing point between minimum overdistension and collapse and correlates to a positive transpulmonary pressure. The use of EIT for individualized ventilation has been proposed across the entire spectrum of severity of respiratory failure, from noninvasive ventilation to intubated patients and during extracorporeal membrane oxygenation.[19] The use of EIT for PEEP titration during abdominal surgery (laparoscopic or open) has been shown to reduce postoperative atelectasis, as assessed by computer tomography after extubation.[8] Moreover, individualized PEEP was associated with better oxygenation and lower

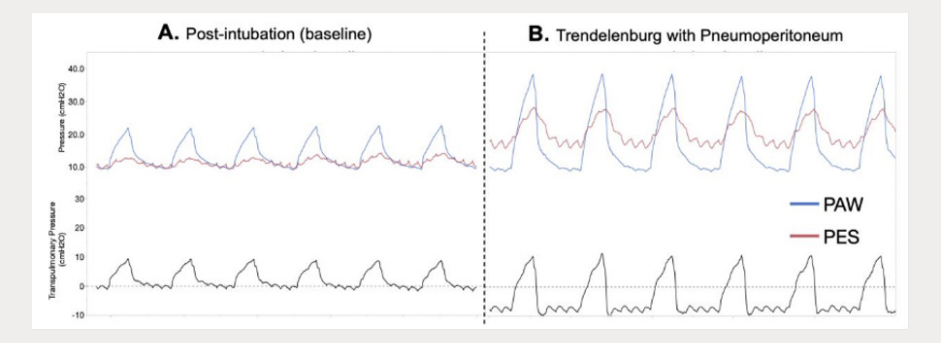

Figure 2: Esophageal pressure manometry curves recorded in a mechanically ventilated patient during a laparoscopic procedure. Panel A shows the traces for airway pressure (Paw, blue line), esophageal pressure (Pes, red line), and transpulmonary pressure (PL, grey line) after intubation in the supine position at PEEP 10 cmH_2O. Panel B shows the traces for Paw (blue line), Pes (red line), and PL (grey line) for the same patient after pneumoperitoneum and Trendelenburg positioning at PEEP 10 cmH_2O. In Panel A, Paw and Pes are similar at end-expiration, and PL equals zero at end-expiration (dotted line). After insufflation and Trendelenburg positioning, Pes exceeds Paw at end-expiration, resulting in a negative PL during expiration (dotted line), a condition associated with lung collapse. (Used with permission of the authors.)

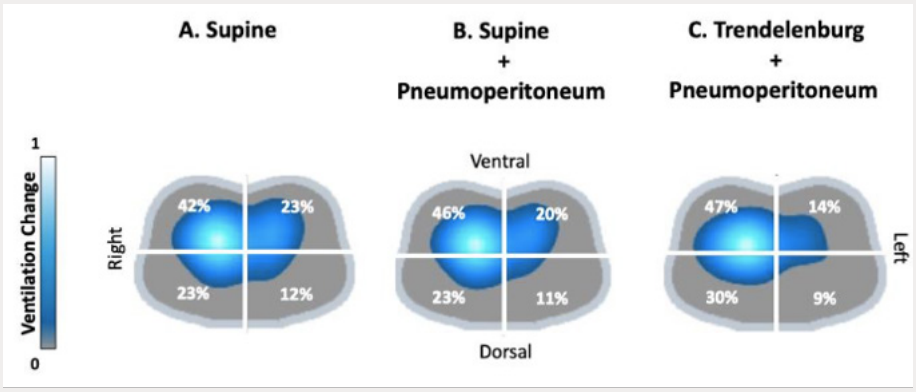

Figure 3: EIT images of ventilation distribution in the four quadrants during a robotic-assisted procedure. Panels show the changes in ventilation at the same PEEP level during three different phases of the procedure; Panel A: after intubation in supine position, Panel B during pneumoperitoneum in supine position; Panel C: during pneumoperitoneum and Trendelenburg position. (Used with permission of the authors.)

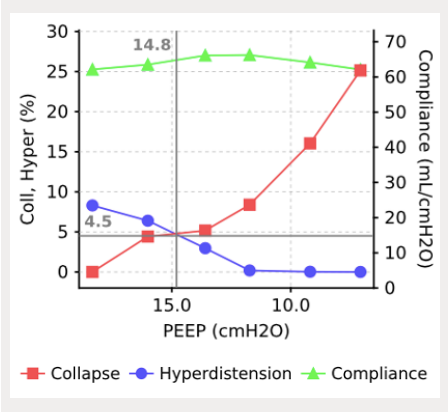

Figure 4: EIT analysis of consolidation versus overdistention curves during a decremental PEEP trial. The crossing point of the red (collapse) and blue (overdistension) lines defines the PEEP level with the lowest percentage of lung collapse and overdistension.[18] (Used with permission of the authors.)

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Minimizing Lung Injury and Improving Respiratory Outcomes in Obese Patients Is Essential

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driving pressure during surgery, without hemodynamic complications.[8]

Additionally, EIT can provide dynamic lung perfusion images by detecting changes in impedance related to blood flow in the chest. This offers the potential to monitor both ventilation and perfusion in real time at the bedside, enabling a more comprehensive assessment of lung function and helping clinicians optimize ventilation/perfusion matching.

CLINICAL IMPLEMENTATION

Raising awareness of the importance of ventilator optimization and advanced respiratory monitoring during mechanical ventilation in the operating room is critical to minimize lung injury and improve respiratory outcomes in patients with obesity. Clinical, educational, and technological gaps prevent clinicians from providing safe and personalized ventilation for complex patients. A number of barriers have been identified in the process of clinical implementation of advanced respiratory techniques.[20] Common barriers are lack of device availability, limited clinician education, and organizational challenges. To overcome these barriers, our Lung Rescue Team at Massachusetts General Hospital is available in the operating room.[21] This multidisciplinary team with expertise in Pes and EIT can be consulted for those complex patients in whom advanced respiratory monitoring may be beneficial. The project is accompanied by the development of an educational curriculum to teach residents and clinicians in providing such techniques.

CONCLUSIONS

Providing mechanical ventilation for obese patients undergoing operating room procedures is often challenging. Advanced monitoring techniques such as Pes and EIT can provide important data to individualize the mechanical ventilation support, minimizing lung injury, and prevent postoperative atelectasis. Consequently, the traditional "one-size-fits-all" approach should be replaced by strategies tailored to adapt respiratory management for individual differences, which can improve patient outcomes. Addressing the clinical and educational gaps surrounding personalized ventilation is critical to reduce respiratory complications in this vulnerable population. By overcoming implementation barriers, we can promote the widespread adoption of advanced respiratory therapies in anesthesia practice.

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The authors have no conflicts of interest

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RAPID Response
to questions from readers

Beware of Semiquantitative Mainstream Carbon Dioxide Sensors in the Operating Room

by Amrutha Bindu Nagella, MD; Sripriya Ramalingam, DNB, IDRA, MANMS; Prabha Parthasarathy, DA, MD; and Ravishankar Murugesan, DA, MD, FRCP

Dear Rapid Response:

Nihon Kohden provides miniaturized carbon dioxide (CO_2) sensors for mainstream CO_2 analysis in both intubated and nonintubated patients. They offer two distinct models for this purpose: the cap-ONE TG 980-P (quantitative) and the cap-ONE TG 920-P (semiquantitative), both of which feature a waveform display that is compatible with all of their monitoring systems. These sensors have been primarily designed for monitoring respiration in non-operating room settings.[1]

In this report, we present two clinical cases in which our ill-informed use of the semi-quantitative CO_2 sensor (cap-ONE TG 920-P) during general anesthesia resulted in significant unrecognized CO_2 rebreathing and subsequent respiratory acidosis. These cases highlight the importance of understanding the nuanced limitations of any monitor one uses and the need for anesthesia providers to stay informed about innovative technologies in the operating room setting.

Case 1: A 34-year-old ASA 1 patient was scheduled for an anterior cervical discectomy under general anesthesia. The Datex Ohmeda 9100c NXT workstation and a Nihon Kohden Life Scope 3562 monitor, with a cap-ONE TG920P CO_2 analyzer, were used. After an ueventful intravenous induction and intubation, 5% desflurane was administered in oxygen: air mixture (1:1) with a total fresh gas flow (FGF) of 4 L/min for the first 15 minutes. Subsequently, the FGF was lowered to 0.8 L/min. The displayed CO_2 level on the monitor was 34 mmHg. An hour later, the displayed CO_2 value during expiration had fallen to 8 mmHg. Hemodynamic parameters remained stable. The ventilator parameters, airway pressure, and lung compliance were also normal. Upon increasing the FGF to approximately 8 L/min, the displayed CO_2 value on the monitor immediately increased to approximately 33 mmHg. The displayed expired CO_2 seemed to vary with the FGF, increasing with higher FGF and decreasing with low FGF (Figure 1). An arterial blood gas analysis revealed respiratory acidosis (pH 7.18; $PaCO_2$ 60 mmHg). While troubleshooting the cause of the arterial blood gas identified hypercapnia, we found that the CO_2 absorbent appeared exhausted and replaced it. This normalized the displayed CO_2 values and eliminated the FGF related fluctuations with alteration in FGF (Figure 2). The reason for this was not immediately evident.

Case 2: A 26-year-old ASA 1 patient was scheduled for septoplasty in the same operating room with the same workstation and monitor as Case 1. As with the preceding case, on initiation of low flows, the displayed expired CO_2 value decreased and then on increasing the FGF, the reported $ETCO_2$ value rose. Given our experience with the previous case, replacing the exhausted CO_2 absorbent corrected

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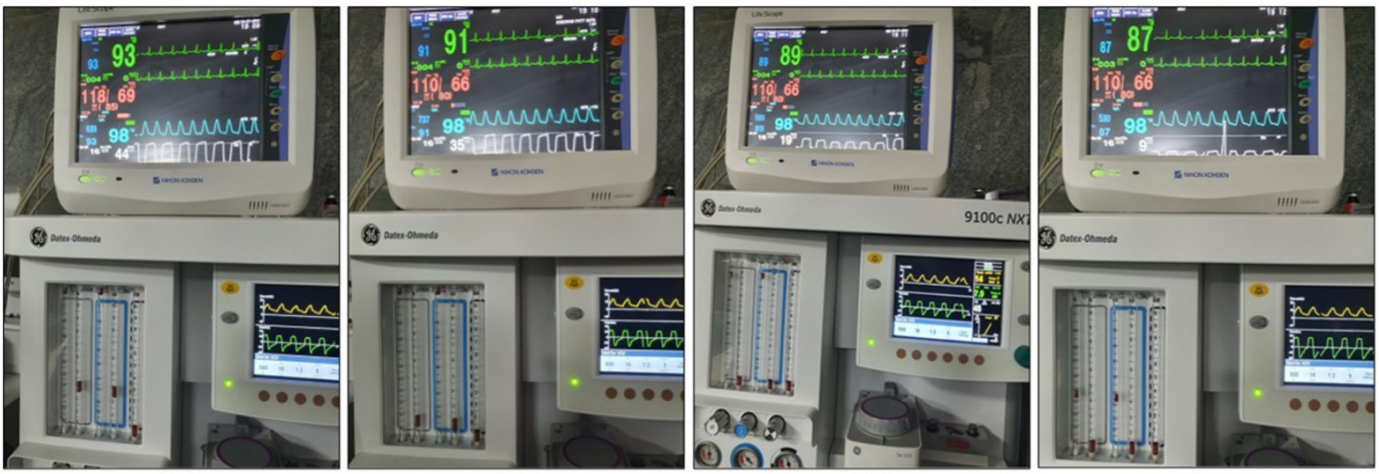

Figures 1(a) and (b) show higher expired CO_2 (44 mHg and 35 mmHg) with higher fresh gas flows (8 L/min and 4 L/min, respectively). Figures 1(c) and (d) show low expired CO_2 (19 mmHg and 8 mmHg) with reduced flows (1.8 L/min and 0.8 L/min, respectively).

RAPID Response
to questions from readers

Carbon Dioxide Sensors, Cont'd

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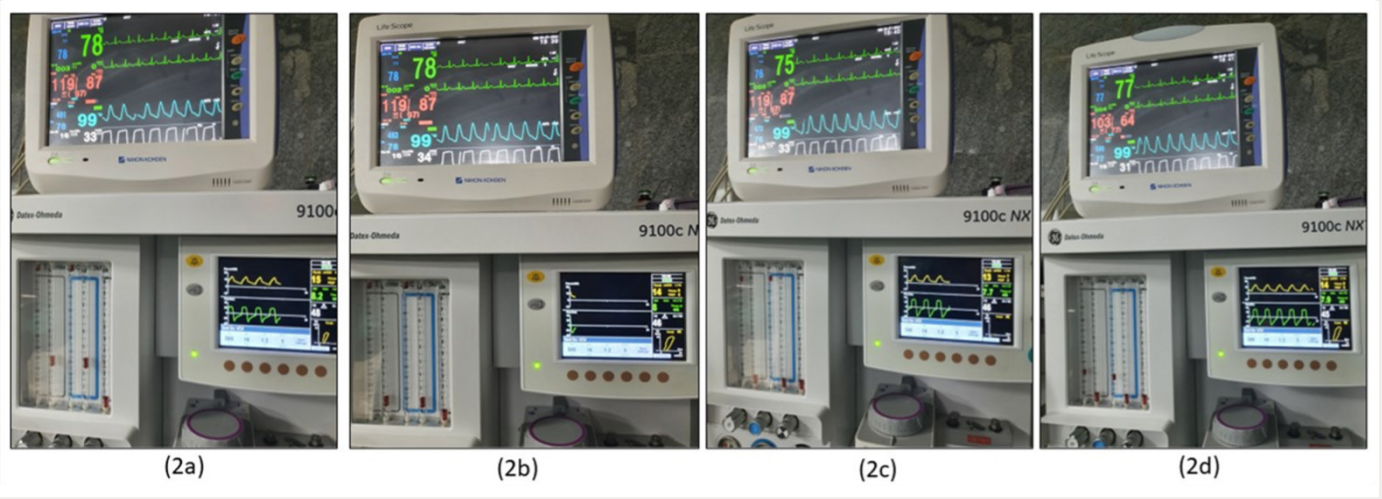

Figure 2: Figures 2(a) to 2(d) show that the variations, however, did not occur after changing the exhausted CO_2 absorbent and correcting rebreathing. The images have been taken while using the same fresh gas flows as in Figure 1a.

this FGF related variation in the reported end tidal CO_2.

Analysis of the preceding cases led us to consider the possibility of improper calibration of the CO_2 analyzer, but the logic of increasing FGF increasing $ETCO_2$ did not make sense. On further exploration, we learned that the cap-ONE Mainstream sensor (TG-920p) is fundamentally a semi-quantitative CO_2 analyzer with no calibration chamber provided. It has a single CO_2 sensor. It assumes that inspired air has no CO_2, and irrespective of the CO_2 in the inspired air, self-calibrates the inspired CO_2 value to zero (Figure 1).[2] These devices are designed for the intensive care unit and recovery room environments where there is no rebreathing through a semi-closed circle system as in an operating room (OR). It is also not intended for use in the setting of general anesthesia with a CO_2 absorber where iCO_2 monitoring is mandatory to detect rebreathing from either valve malfunction or absorbent depletion.

An institution may have several models of monitoring systems installed at various locations, and monitors may get shifted from one setting to another. Root cause analysis revealed that in our institute, the implicated CO_2 sensor had been shifted from the ICU to the OR. This underscores the importance of anesthesia professional being involved in decisions regarding the suitability of monitors for each hospital location.

We encourage the manufacturer to ensure that these monitors are provided with safety tags, e.g., "Not suitable for use with rebreathing systems in the operating room during anesthesia." Further, all safety tags supplied by the manufacturers should be tagged to the monitor. The admonition currently provided with the sensor—"With the TG-920P CO_2 sensor kit (cap-ONE), measurements are based on the assumption of no CO_2 gas being present on inspiration and uses zero mmHG during the calibration process. Therefore, when monitoring CO_2 on a patient with an oxygen mask, CO_2 gas may be present on inspiration and may result in the acquired data being lower than the actual value. It is therefore not recommended to use the cap-ONE on patients receiving oxygen by mask"[3]—does not make it obvious that it is not intended for use with anesthesia breathing circuits. This is aggravated by the fact that the waveform displays on a moving graph with an adjacent numerical value leading the observer to potentially mistakenly infer that the inspired CO_2 value is zero.

Amrutha Bindu Nagella, MD, was an associate professor in anesthesiology, Sapthagiri Institute of Medical Sciences, Bangalore, India, when these cases were encountered. She works as a research scientist at the University at Buffalo at present.

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The authors have no conflicts of interest.

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RAPID Response
to questions from readers

Carbon Dioxide Sensors, Cont'd

NIHON KOHDEN's Response to RAPID Response Case Report on Semi-Quantitative Mainstream Carbon Dioxide Sensors in the Operating Room

Dear Rapid Response:

Thank you for bringing your concern to our attention regarding the misuse of our TG-920P series product due to incorrect product selection in the operating room clinical setting.

Nihon Kohden's CO_2 sensor lineup includes the TG-920P, which was the subject of this report, and the TG-980P, which uses a different measurement method.

We would like to focus on the differences between the two sensors' measurement methods, their intended uses, and the points to note.

The TG-920P series (which was the subject of this report) is a product that uses a semi-quantitative method. This does not require calibration so that in an emergent treatment and other situations, CO_2 measurement can begin immediately. The measurement method is based on the premise that there is no CO_2 in the inhaled air.

As there is no need for calibration, it is quick and easy to use, but, as has been reported, in cases where there is CO_2 in the inhaled air, it will not be possible to measure the exact CO_2 concentration. To be more specific, in respiratory circuits, like an anesthesia circuit with depleted CO_2 absorption capability, or a facemask with insufficient fresh gas flow, where the inspired gas contains CO_2, the displayed value will be lower than the actual CO_2 concentration. A cautionary note and example of CO_2 waveform with inspired CO_2 is provided in the Operator's Manual.

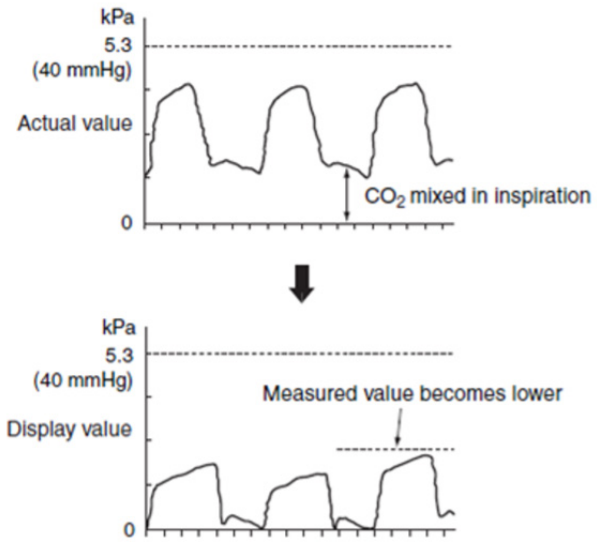
In contrast, the TG-980P series uses the quantitative measurement method for CO_2 sensors. It can be used in settings where the inspired air may contain CO_2 gas. It is designed for use in respiratory management during anesthesia, mechanical ventilation management in ICUs, and noninvasive (non-intubation) respiratory management. This measurement method uses a sensor that accurately measures CO_2, including environments where inhaled air contains more CO_2 gas than normally found in the atmosphere. Before use, it is necessary to perform a zero calibration of the CO_2 measurement manually on the patient monitor interface. Five to six seconds is required for the calibration process before measurement can begin.

Each sensor series uses a different method to measure CO_2 values. By using the most appropriate one for the situation and purpose of use in each clinical setting, one can get the most out of the performance of each product.

In addition to providing the optimal measurement method for each use situation, Nihon Kohden CO_2 sensors incorporate unique technology that allows them to cope with condensation without a heater (condensation is a major factor of difficult CO_2 measurement). Thus, they are also significantly smaller, lighter, and more robust than conventional mainstream sensors.

Following is a summary of use for each product series.

When CO_2 is Mixed in Inspiration



The CO_2 sensor kit performs measurement based on the assumption of no CO_2 gas in the inspired air. The acquired CO_2 data may be lower than the actual value when CO_2 is present in the inspired air. When inspired air contains 0.13 kPa (1 mmHg) of CO_2 gas, the measured value will be 10% lower than the actual value.

Figure 1: Note in the TG-920P Operator's Manual: Description of the impact of CO_2 gas mixing in inspired air.

TG-920P SERIES

- **Measurement:** Employs the mainstream capnography using **semi**-quantitative method.
- **Operation:** Measures the CO_2 partial pressure of expired air based on the assumption that the **inspired air does not contain CO_2.**
- **Advantage:** This design eliminates the need for manual calibration, allowing for a prompt start in emergency treatment scenarios.
- **Limitation:** In respiratory circuits, like an anesthesia circuit with depleted CO_2 absorption capability, or a facemask with insufficient fresh gas flow, where the inspired gas contains CO_2, the displayed value will be lower than the actual CO_2 concentrations. A cautionary note and an example of CO_2 waveform are provided in the Operator's Manual, as shown in Figure 1 above.

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RAPID Response
to questions from readers

Carbon Dioxide Sensors, Cont'd

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- **Clinical conditions:** Do not use the device when inspired air contains or may contain CO_2 gas. Any inspired CO_2 that might be present is not measured or reported. The device is applicable only for the inspired gas without CO_2 gas.

Regarding the TG-920P, the reported issue is listed as a caution in the Operator's Manual as outlined in Figure 2.

TG-980P SERIES

- **Recommended use:** Ideal for situations where the inspired air may contain CO_2.
- **Measurement:** Employs the mainstream capnography using quantitative method with a single wave spectroscopic method, which requires manual zero calibration before use.
- **Advantage:** Provides a measurement of any CO_2 partial pressure in the inspired air unlike the TG-920P series.
- **Clinical condition:** Can be used in settings where the inspired air may contain CO_2 gas. The device is applicable for both inspired air with and without CO_2 gas.

Nihon Kohden is dedicated to improving the labeling of our devices to more clearly indicate the appropriate product in the presence of inspired air containing CO_2. As a medical device manufacturer, we will continue not only to improve our product technology on a day-to-day basis but also place a renewed emphasis on patient safety by working with anesthesia professionals on this matter in the future. Thank you for this valuable opportunity.

Sincerely,

Masao Togawa is senior manager, Safety Management Department, Quality Management System Division, Corporate Quality Management Operations, Nihon Kohden Corporation.

Maki Suezawa is senior manager, Product Quality Management Division, Corporate Quality Management Operations, Nihon Kohden Corporation.

Isao Matsubara is senior manager, Vital Sign SensorTechnology Department Division, Technology Development Operations, Nihon Kohden Corporation.

CAUTION

Supply adequate oxygen when measuring CO_2 partial pressure of a patient connected to a Jackson Rees, Mapleson D or any other respiration circuit where CO_2 gas may be present during inspiration. The semi-quantitative method measures CO_2 partial pressure based on the assumption of no CO_2 gas in the inspired air; it measures the CO_2 partial pressure of the expiration of every respiration. If the inspired air contains CO_2 gas, the measured CO_2 value may be lower than the actual value.

Figure 2: Caution in the TG-920P Operator's Manual: Impact of CO_2 gas mixing in inspired air to the measured CO_2 value.

Perioperative Stroke Prevention: A Review of Recent Guidelines for Noncardiac and Nonneurologic Surgery

by Robert Pranaat, MD, and Jacob W. Nadler, MD, PhD

INTRODUCTION

Perioperative stroke is defined as a brain infarction of ischemic or hemorrhagic etiology that occurs during surgery or within 30 days after surgery.[1] Fortunately, perioperative stroke is uncommon. According to data from the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP), between 0.1–0.7% of patients undergoing noncardiac surgery suffer from stroke.[2] Additionally, the greatest risk factors for postoperative stroke were history of stroke, including transient ischemic attack, advanced age, anemia (hematocrit <27%), and renal dysfunction. Most perioperative strokes occur on postoperative days 2–9.[3,4] Surgeries that are at particularly high risk include emergency surgery, vascular surgery (such as carotid endarterectomy and thoracic endovascular aortic repair), and brain surgery.[2] Since most perioperative strokes in noncardiac, nonneurological surgery are ischemic in nature, they are typically attributed to hypotension and/or low-flow states, previously undisclosed large-artery stenosis, anemia-associated tissue hypoxia, embolism (thrombus, fat, or foreign material), enhanced coagulability or thrombosis in the setting of systemic inflammation, and/or recent discontinuation of antithrombotic medications.[1]

Questions surrounding diagnosis and management of perioperative stroke continue to be a major issue for patients and health care providers, and the risks facing patients undergoing surgery appear to be underrecognized. A Canadian study assessing anesthesiologists' perception of strokes found that less than 50% of those surveyed correctly identified the overall incidence of stroke in the perioperative time period, while only 25% of those surveyed knew that thrombosis was the most common etiology.[5] Furthermore, most respondents (64% of those surveyed) believed that the overall risk of dying from a perioperative stroke is rare when the actual stroke-associated mortality rate is 25–87%. Despite these knowledge gaps, the majority of respondents reported they were confident in delivering care to high-risk patients.[5]

TIMING OF ELECTIVE SURGERY

Patients who have had a stroke in the past are at increased risk of complications with surgery, but this risk decreases with time. The consensus opinion regarding the optimal timing of elective surgery for patients who have had a prior stroke has changed in the last several years. In 2011, a retrospective study of a Danish national health database found that for patients undergoing elective surgery the greatest risk for ischemic stroke and cardiovascular death was within the first three months of the initial event.[6] Additionally, they found that the risk for cerebrovascular and cardiovascular complications appeared to plateau at about nine months. Based on this study, the American Stroke Association/American Heart Association (ASA/AHA) published guidelines in 2021 which recommended delaying elective surgery following stroke for nine months, but suggested that surgery could be considered after six months if the benefits outweighed the risks of waiting.[4] In contrast to the Danish study a recent cohort study of 5.8 million patients found that the risk of stroke and death leveled off when more than 90 days elapsed between a previous stroke and elective surgery, suggesting that the initial ASA/AHA guidelines may be too conservative.[7] In 2024, a joint guideline by the AHA, ASA, and other international societies for perioperative cardiovascular management of patients undergoing noncardiac surgery was published suggesting that patients wait at least three months after stroke before undergoing elective surgery to decrease risk of recurrent stroke and/or major adverse cardiovascular events.[8]

PREOPERATIVE RECOMMENDATIONS

Comprehensive guidelines for the prevention of perioperative stroke were published by the ASA/AHA in 2021 and the Society of Neuroscience in Anesthesiology and Critical Care (SNACC) in 2020.[1,4] Together these guidelines emphasize the need for multidisciplinary approaches to preoperative testing and optimization, continuation of medications like beta-blockers,[9] and appropriate management of anticoagulation (Table 1). Notably, these guidelines differ on several points. For instance, SNACC advises caution with the use of intraoperative metoprolol as it has been associated with perioperative stroke and suggests that alternative beta-blockers may be more appropriate, while ASA/AHA guidelines recommend continuing beta-blockers.[1,4] The ASA/AHA guidelines raise particular concern for a higher perioperative stroke risk among patients with patent foramen ovale, advocate for the use of the web-based American College of Surgeons Surgical Risk Calculator (ACS-SRC), and recommend carotid artery revascularization in patients with symptomatic carotid artery stenosis (>70%) before elective surgery. Recommendations also

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Table 1: Summary of Preoperative Considerations.

Preoperative Evaluation	• All patients should be assessed for their perioperative stroke risk—specifically increased age, renal disease, history of transient ischemic attack/stroke, and patent foramen ovale.[1,4] • Patients at higher risk of perioperative stroke should be discussed by a multidisciplinary team. • Consider using web-based ACS-SRC to assess risk • Delay noncardiac surgery for ≥3 months following cerebrovascular event[1,1]
Optimization	• Perform carotid artery revascularization in patient with symptomatic carotid artery stenosis (>70%) before elective surgery.[5]
Medication Management	• **Beta blockers:** Continue prescribed beta blockers, but do not initiate beta blocker therapy.[1,4] • **Aspirin:** Do not routinely continue aspirin solely for stroke risk reduction. Consider continuing aspirin in patients at high risk for a major adverse cardiac events (e.g., patients on aspirin for secondary prevention) if benefits outweigh risk of bleeding. Aspirin should be continued if there is a history of percutaneous coronary intervention.[1,4] • **Warfarin:** Hold for 5–6 days before surgery. Restart 12–24 hours after surgery. Consider heparin or low molecular weight heparin (LMWH) bridging for high thromboembolic risk only. For intermediate risk, bridging is at the clinician's discretion; not recommended for low risk.[1,4] • **Direct Oral Anticoagulants (DOACs):** For high bleeding risk surgeries hold 3 days prior and restart 2–3 days after surgery. For low bleeding risk surgeries hold 2 days prior and restart 24 hours after surgery. Bridging is based on clinical judgment regardless of bleeding risk.[1,4] • Timing of resuming anticoagulants should be discussed by the multidisciplinary team.[1,4]

Patient Should Wait at Least 3 Months After Stroke Before Elective Surgery

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differ slightly with regard to management of patients receiving vitamin K antagonists, although both guidelines recommend bridging with either therapeutic dosing of low molecular weight heparin (LMWH) or intravenous heparin in patients at high risk for thromboembolic complications (i.e., atrial fibrillation with high CHA_2DS_2-VASc score or recent thromboembolic disease). The SNACC guidelines recommend against the use of heparin whereas ASA/AHA guidelines suggest its use. Specific recommendations are also given regarding management of anticoagulation. Both guidelines agree that aspirin, warfarin, and DOACs should be held before elective surgery depending on bleeding risk and restarted shortly after surgery, with heparin bridging only for high thromboembolic risk cases.[4] Aspirin should be continued if there is a history of percutaneous coronary intervention.[1,4] Given the complexity of opposing risks and benefits of antiplatelet and anticoagulant medications, these decisions should be discussed by a multidisciplinary team of surgeons, anesthesiologists, neurologists, and other medical professionals involved in the patient's care. Lastly, perioperative statin administration may not reduce stroke risk, though it may improve other outcomes.[10]

INTRAOPERATIVE RECOMMENDATIONS

Intraoperative recommendations are largely supportive in nature focusing on ensuring adequate cerebral and end-organ perfusion, maintaining appropriate acid-base status and end-tidal carbon dioxide levels, and transfusing blood products when appropriate (Table 2). It is important to avoid large fluctuations in blood pressure given the risks of both hemorrhagic and ischemic stroke. Specific blood pressure targets to avoid hypotension are not well described across all patient populations and for all circumstances, although the ASA/AHA guidelines recommend MAP goals > 70 mmHg. In contrast the SNACC guidelines recommend careful attention to the blood pressure gradient or height difference between the blood pressure measuring device (noninvasive blood pressure cuff or invasive blood pressure transducer), and the brain.[1] An appropriate blood pressure on the arm when lower than the head, for instance, could potentially result in cerebral hypoperfusion.

There is some controversy regarding blood transfusion targets. Both guidelines recommend more liberal hemoglobin transfusion targets. Specifically, ASA/AHA guidelines recommend a hemoglobin transfusion target of 8 g/dL for patients with a history of recent stroke or cerebrovascular disease, or 8–9 g/dL in patients with an acute perioperative stroke, ongoing bleeding, hemodynamic instability, or known cerebrovascular insufficiency attributable to stenosis or occlusion.[4] The SNACC guidelines recommend a higher transfusion target of 9 g/dL or greater in patients taking beta blockers to reduce perioperative stroke risk.[1]

Anesthetic technique such as the choice of regional versus general anesthesia,[11] propofol versus volatile inhaled agents,[12] or the use of nitrous oxide[13] probably has little impact on stroke risk. There may be an exception for joint arthroplasty, where researchers found a benefit of regional anesthesia, likely attributable to differences in blood loss and risk of thromboembolism.[14]

Table 2: Intraoperative Considerations to Minimize Risk of Stroke.

• Maintain mean arterial pressures > 70 mmHg, especially in patients with moderate to high perioperative stroke risk.[1,4]
• Careful attention to blood pressure gradients between the brain and wherever the blood pressure is being measured in order to avoid hypotension.[1,4]
• Transfuse to Hgb > 8 g/dl in patients with recent stroke or cerebrovascular disease and maintain Hgb 8–9 g/dl if there is a history of recent stroke, ongoing bleeding, or hemodynamic instability in presence of known cerebrovascular insufficiency due to occlusion or stenosis. Consider transfusion to Hgb > 9 g/dl if patient is taking a beta blocker.[1,4]
• No specific recommendations for or against use of regional versus general anesthesia, and no recommendations against use of nitrous oxide or volatile anesthetics versus total intravenous anesthesia.[1,4]
• Maintain normocarbia.[1,4]
• Maintain serum blood glucose 130–180 mg/dL.[1,4]

Table 3: Postoperative Considerations to Minimize Risk of Stroke.

• If concern for perioperative stroke, obtain emergent brain imaging.[1,4]
• If high suspicion for perioperative stroke on brain imaging, a multidisciplinary group discussion is warranted to recommend either intravenous thrombolytics and/or the use of mechanical thrombectomy.[1,4]
• If the patient is given recombinant tissue plasminogen activator (rtPA), maintain SBP < 180 mmHg and DBP < 105 mmHg.[1,4]
• Additional testing should include an EKG, troponins, and cardiac telemetry for at least the first 24 hours.[1,4]
• Avoid hypotension. Aim for MAP targets > 70mm Hg in patients at moderate to high risk of stroke.[1,4]
• Initiate aspirin therapy in the first 24–48 hours after ischemic stroke onset but this can be delayed until after 24 hours in patients who have received rtPA.[1,4]
• Maintain serum blood glucose 140–180 mg/dL.[1,4]

POSTOPERATIVE RECOMMENDATIONS

Both the ASA/AHA and SNACC guidelines recommend that institutions have standardized approaches for the emergency evaluation of patients suspected to have perioperative stroke (Table 3). Since the greatest risk for stroke is within the first 72 hours following surgery, diagnostic challenge exists due to the residual effects of the procedure itself and effects from anesthesia.[4] Multidisciplinary communication and collaboration are essential given the acuity of perioperative stroke and the need for ongoing care to occur efficiently and safely. The anesthesia professional is well equipped to help direct hemodynamic monitoring and management, ventilator support, and patient transportation to brain imaging, procedural rooms, and hospital floors or intensive care units.

CONCLUSION

Perioperative stroke is often an underrecognized complication by anesthesia professionals. Current recommendations suggest delay of

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Perioperative Stroke Is an Underrecognized Complication

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elective surgery for at least three months after stroke. While controversy over specific perioperative interventions remain, a multidisciplinary approach to perioperative optimization and planning is important to caring for these higher risk patients. Patients with symptoms suggestive of perioperative stroke should undergo emergent evaluation with early engagement of a multidisciplinary team.

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Jacob W. Nadler, MD, PhD, FASA, is an associate professor of perioperative medicine and anesthesiology and division chief of neuroanesthesiology, medical director of the Anesthesiology Clinical Research Center, and medical director of the Post-Anesthesia Care Unit at Strong Memorial Hospital at the University of Rochester School of Medicine and Dentistry in Rochester, NY.

The authors have no conflicts of interest

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Free Online Anesthesia CME and MOCA QI with New APSF TEI Course on Manual External Defibrillation, Cardioversion, and Pacing

by Michael Kazior, MD; Christopher Samouce, PhD; Daniel Rosenkrans, MD; David Lizdas, BSME; Cole Dooley, MD; Nikolaus Gravenstein, MD; Jeffrey Feldman MD; and Samsun Lampotang, PhD

A 54-year-old male is undergoing an emergent exploratory laparotomy under general anesthesia. Shortly after the surgeon opens the abdomen, the heart rhythm changes to ventricular fibrillation and there is no longer a palpable pulse. The team is notified, there is a call for help, and chest compressions are started. The operating room nurse brings in the crash cart with the manual external defibrillator. Defibrillation is indicated, and time is of the essence to prevent a poor outcome. However, the anesthesia professional does not remember where to place the pads, which setting should be selected, and what to do if the first shock is unsuccessful in establishing a sinus rhythm.

The manual external defibrillator (MED) is a complex medical device used in emergency settings to provide defibrillation, synchronized cardioversion, or transcutaneous pacing. However, gaps in clinician knowledge and proficiency can compromise patient safety during use. Therefore, the APSF launched Technology Education Initiative (TEI) 3, Manual External Defibrillation, Cardioversion, and Pacing in February 2025. The content aligns with Advanced Cardiac Life Support (ACLS) guidelines and encompasses eight topics with guided simulations where users receive instructions while navigating scenarios, detailed below.

Topic 1 serves as an introduction to the course. In topic 2, the technical aspects of defibrillators, including physics principles, are discussed. Sliders to adjust current and transthoracic resistance are connected to animated delivery of electricity in a simulated patient. In topic 3, monophasic and biphasic defibrillator waveforms are demonstrated and summarized. For topic 4, interactive placement of defibrillator pads in both anterior/lateral and anterior/posterior configurations is accompanied by real-time feedback to facilitate proper pad placement (Figure 1). Topics 5, 6 and 7 cover the three main functions of the MED: defibrillation, synchronized cardioversion, and transcutaneous pacing. In these topics, the user operates a generic MED user interface to apply the indicated therapy (Figure 2). The final module, topic 8, evaluates users on applying the MED to Advanced Cardiac Life Support (ACLS) scenarios, including identification of arrhythmias, palpation for pulse, establishment of patient clinical status, and decisions on MED therapy (if any) to be delivered.

The free MEDCP course is available on the ASA Learning Management System and is accessed from the APSF TEI web portal at https://apsf.org/tei. The course is free and offers three (3) hours of AMA Category 1 Credits towards continuing medical education (CME). This activity also contributes to patient safety CME and the Quality Improvement (QI) component of Maintenance of Certification in Anesthesiology (MOCA). Although this education was designed for anesthesia providers, it is applicable to all health care professionals who use the MED. Anyone can take the course free of charge by creating an account on the ASA website, then use the course links provided above through the APSF TEI web portal to enroll in the course. Providers can apply the CME offered by

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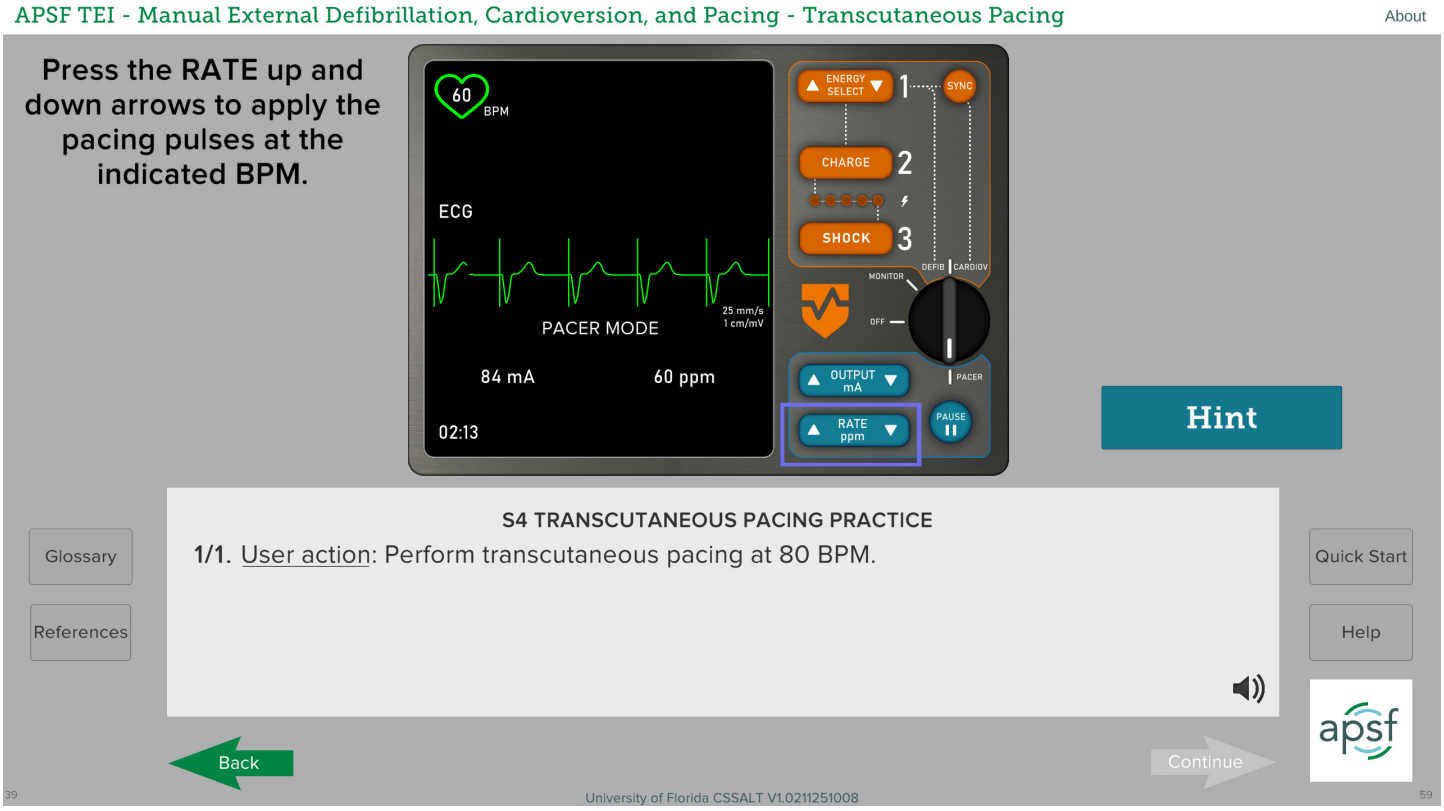

Figure 1: Defibrillator pad placement practice in the MEDCP simulation.

New APSF TEI Course, Cont'd

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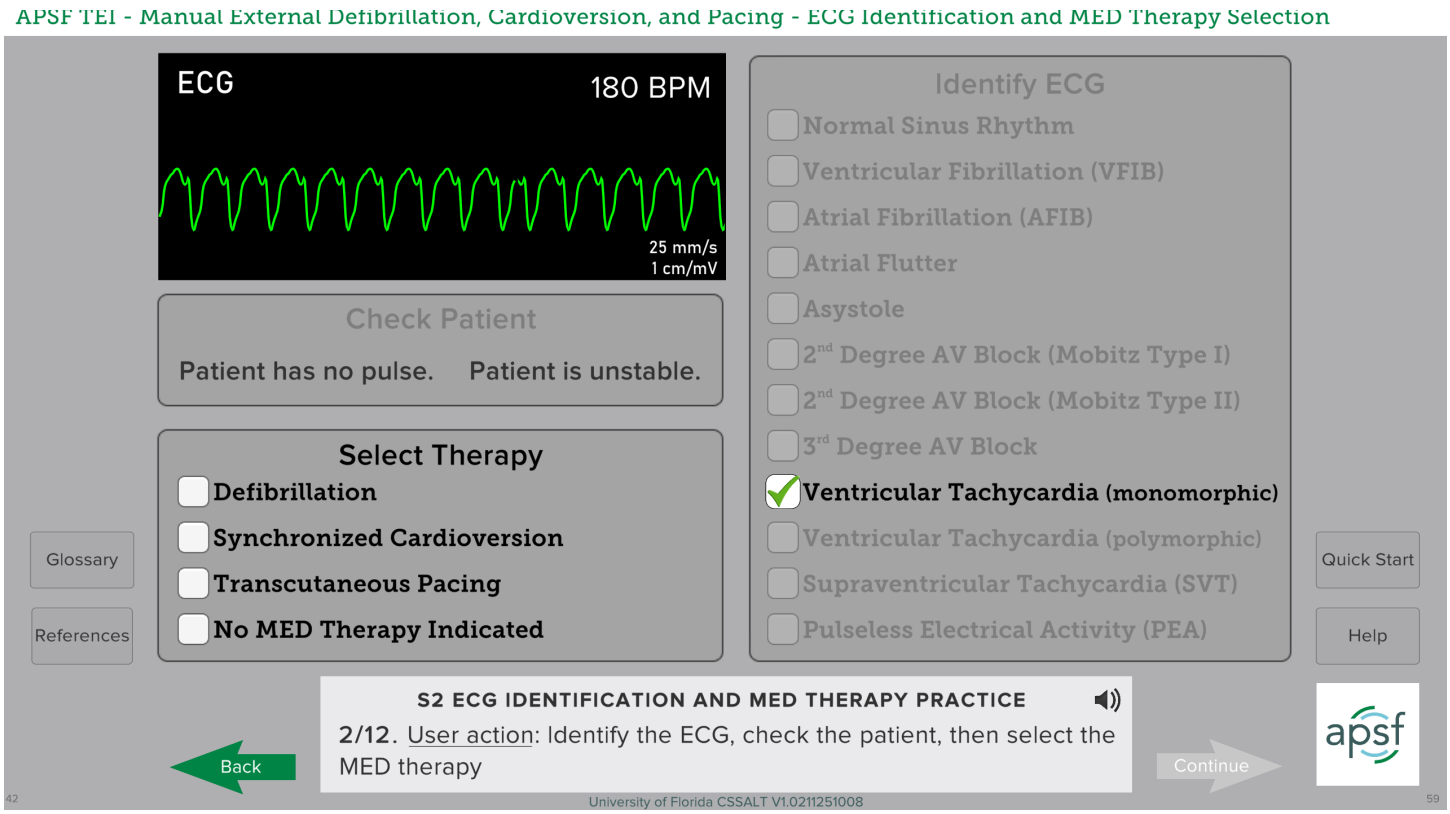

Figure 2. Performing cardioversion using the generic manual external defibrillator user interface in the MEDCP simulation.

this course towards their own recertification requirements.

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The APSF continues to accept and appreciate contributions.

Please donate online at www.apsf.org/donate/ or make checks payable to the APSF and mail donations to
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A Tribute to Jannicke Mellin-Olsen (1957-2025)

by Daniela Filipescu, MD, PhD, DESA, FESAIC

Norwegian anesthesiologist and global health leader, Jannicke Mellin-Olsen, MD, DPH, FESAIC, passed away suddenly on February 7, 2025 at her home outside Oslo. With her death, the world lost a giant in patient safety and patient-centered care.

Jannicke Mellin-Olsen, MD, DPH, FESAIC

Dr. Mellin-Olsen completed her medical education and residency at the University of Trondheim, Norway, and became the first female military doctor in Norway. She later served with both the United Nations (UN) and Red Cross. She was recognized globally for her immense commitment to her patients and to the safety of anesthesiology all over the world and was the recipient of honorary membership from medical societies across Europe and beyond.

With more than 40 years of leadership at the local, national, regional, and global level, Dr. Mellin-Olsen was instrumental in many of the leading innovations within anesthesia safety and health care quality, including

- Being one of the authors of the seminal 2010 Helsinki Declaration on Patient Safety in Anaesthesiology, which has been endorsed by anesthesia and critical/intensive care organizations worldwide;
- Implementing simple, yet highly effective bedside changes to improve patient safety through improved communication between health care professionals and those receiving care, such as "the orange chair" project, which encourages Norwegian health care professionals to sit down by their patients' beds to encourage better two-way communication;
- Being one of the originators of The National Commission of Inquiry into Health & Care Services in Norway which reviews patient safety incidents nationally; and
- Being the first non-American member of the Board of the Patient Safety Movement Foundation.

In her many leadership positions, Dr. Mellin-Olsen committed to eliminating preventable deaths in hospitals and was recognised as a champion of nonpunitive approaches to medical errors. She was particularly committed to human factors solutions, and always promoted communication, open disclosure, and cooperation between all stakeholders, from politicians to patients and relatives, clinical staff, industry partners and hospital managers, all with the aim of improved patient safety. She was regarded as a highly experienced interlocutor between anesthesia professionals and other medical specialties and always sought consensus as a means of attaining objectives and achieving progress.

Dr. Mellin-Olsen's inspirational career was celebrated at the 18th World Congress of Anaesthesiologists in Singapore in March 2024, where she was one of two Harold Griffith lecturers, delivering the only named plenary lecture of the World Congress to a standing ovation by the 1,700+ strong in-person audience. Gracious as always, she generously agreed for the lecture to be made publicly available.

Dr. Jannicke Mellin-Olsen carried out these activities and roles on a voluntary basis while working as a consultant anesthesiologist at Baerum Hospital, demonstrating her selfless work in the service of humanity.

Please join us honoring her legacy by continuing to strive for safer anesthesia care.

Daniela Filipescu, MD, PHD, DESA, FESAIC, is professor of anaesthesiology and intensive care medicine at Carol Davila University of Medicine and Pharmacy, Bucharest, and current president of the World Federation of Societies of Anaesthesiologists.

The author has no conflicts of interest.

In recognition of the wide-reaching impact she had on patient safety in Norwegian health care and beyond, Dr. Mellin-Olsen was awarded the highest civilian honor in Norway (Knight 1st Class of The Royal Order of St. Olav). She also received the Distinguished Service Award from the World Federation of Societies of Anaesthesiologists (WFSA), where she served as President between 2018–2020.

Upon her untimely passing, tributes were paid across social media with comments such as:

> *"With your inspiring leadership and kind support in our training programmes, you and I have witnessed the number of anesthesia providers grow from 18 to 2,700 in the 40 years in both Ethiopia and Eritrea."*

> *"With your proactive inspiring support, the untimely death of mothers and children from preventable obstetric and pediatric emergencies has decreased from grave level to WHO commendable levels."*

> *"I was saddened to hear about the recent passing of Jannicke Mellin-Olsen, whose dedication to patient safety touched so many lives. Her commitment and compassion will always be remembered. I had the privilege of hearing her speak at the Ellison C. Pierce, Jr, MD, Memorial Lecture in Philadelphia and was moved by her story and passion."*

> *"Her contributions to the WFSA and the field of anesthesiology have left a lasting impact, inspiring generations of professionals worldwide. Her legacy will endure through the countless lives she touched and the advancements she championed."*

Centers for Medicare and Medicaid Services (CMS) Patient Safety Structural Measure: An Overview for Anesthesia Professionals

by Patricia A McGaffigan, MS, RN, CPPS, and Jonathan B. Cohen, MD, MS, FASA, CPPS

THE PATIENT SAFETY STRUCTURE MEASURE

Patient harm continues to occur in hospitalized patients, with at least one adverse event occurring in almost 24% of admissions.[1] Recognizing this, the Centers for Medicare & Medicaid Services (CMS) announced the Patient Safety Structural Measure (PSSM) for acute care hospitals.[1-3] Beginning in Spring 2026, acute care hospitals participating in the Hospital Inpatient Quality Reporting (IQR) and Prospective Payment System Exempt Cancer Hospital Quality Reporting (PCHQR) programs will self-attest to their performance on structural and cultural safety practices for the 2025 calendar year. Hospital scores will be public on the CMS Care Compare website in October 2026 and the reporting incentive will be reflected in hospitals' fiscal year 2027 payment determinations from CMS. Hospitals will face a decrease in their annual Medicare reimbursement if they fail to report on the PSSM.

The PSSM requires applicable hospitals to attest to their engagement in specific, evidence-based practices for five domains that are deemed essential for system safety, including leadership commitment to eliminating preventable harm, strategic planning and organizational policy, culture of safety and learning health system, accountability and transparency, and patient and family engagement. Attestation to each of the practices within a domain is required for the hospital to receive a point for the domain.[3] We discuss the evidence-based practices in each of the domains, as well as the role of anesthesia professionals in assisting hospitals with the achievement of these practices.

WHY IS A PATIENT SAFETY STRUCTURAL MEASURE NECESSARY?

While outcome measures reflect the results of care, the domains and elements of the PSSM reflect the most salient, evidence-based, structural and cultural elements of safety, and assess the features of a hospital relevant to its ability to provide safe care, such as leadership practices and operational policies and processes that support patient safety. This attestation-based measure requires applicable hospitals to assess and report the degree to which they meet elements across each of the domains. A summary of key elements in each domain can be found in Table 1. The domains and elements of the PSSM are aligned with the Safer Together: A National Action Plan to Advance

Table 1. Sample of key elements that hospitals must attest to in each of the Patient Safety and Structural Measure (PSSM) Domains.

PSSM Domain	Key Elements That Hospitals Must Attest to in Domain
1. Leadership Commitment to Eliminating Preventable Harm	
The hospital leadership and governance board must establish the organization's commitment to patient safety.	Safety must be prioritized as a core value and hospital leadership is held accountable for patient safety by ensuring adequate resources are available to support safety programs. Safety events and initiatives must be discussed regularly at board meetings, and serious safety events must be discussed by the board within three days of their occurrence.
2. Strategic Planning and Organizational Policy	
This domain addresses the importance of an organization's commitment to a goal of zero preventable harm, to foster the mindset that preventable harm is unacceptable.	Hospitals must have a public strategic plan that shares their commitment to patient safety and utilizes metrics to identify and address disparities in safety outcomes. A patient safety curriculum and competencies must be developed for all clinical and nonclinical staff, and an action plan to address safety, including activities which cultivate a just culture, will be developed.
3. Culture of Safety and Learning Health Systems	
A culture of learning and a proactive approach to achieving safety is essential to reducing harm.	Hospitals must conduct regular culture of safety surveys and have a dedicated team that conducts event analysis using an evidence-based approach. Hospitals must use a safety metrics dashboard with external benchmarks to monitor performance, must participate in a large-scale learning network, and must implement high reliability practices.
4. Accountability and Transparency	
Accountability to patients and the workforce is critical and requires transparency around adverse events and performance.	Hospitals will use a confidential safety reporting system and work with a Patient Safety Organization listed by the Agency for Healthcare Research and Quality to carry out patient safety activities. Patient safety metrics will be tracked and made publicly visible on hospital units. An evidence-based communication and resolution program (CRP) that is implemented after harm events will be established, and the performance of the program will be presented regularly to the hospital board.
5. Patient and Family Engagement	
This domain addresses the importance of meaningfully embedding patients, families, and caregivers in co-producing safety for themselves and for the organization.	Hospitals must have a diverse patient and family advisory council (PFAC) that is representative of the patient population and provides input on safety-related activities. Patients will have comprehensive access to their medical records, and the presence of persons designated by the patients as essential members of their care team must be supported by the hospital.

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Anesthesia Professionals Play a Leading Role in Patient Safety

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Patient Safety, the CMS National Quality Strategy and Health Equity Structural Measure, the Health and Human Services National Action Alliance for Patient and Workforce Safety, and much of the focus of the World Health Organization Global Patient Safety Action Plan. Additional information on the PSSM, including an Attestation Guide, may be found on the CMS website (https://qualitynet.cms.gov/inpatient/iqr/measures#tab2).

ANESTHESIA PROFESSIONALS' ROLE IN WORKING WITH HOSPITALS TO ACHIEVE THE PSSM DOMAINS

Safety is an important component of education in the training of anesthesia professionals.[4] Given the historic and ongoing role that anesthesia professionals play in leading patient safety initiatives and serving in patient safety leadership roles, we are well-suited to teach essential components of patient safety within a health system.[5] Frameworks for educating clinicians and nonclinicians in patient safety can be adapted from several sources. The American Society of Anesthesiologists' Fundamentals of Patient Safety Educational program is revised regularly with updated content and addresses the epidemiology of safety, culture, communication, analysis and prevention of adverse events, and strategies for implementing and continuously improving reliable systems. The Institute for Healthcare Improvement's Certified Professional in Patient Safety (CPPS) Review Course covers key domains based upon a job analysis of practicing patient safety professionals, which currently include the following: culture; systems thinking, human factors engineering, and design; safety risks and responses; and performance measurement, analysis, improvement, and monitoring.[6] While the content and emphasis of the CPPS domains in the Patient Safety Structural Measure's required education of all clinical and nonclinical staff must be adapted for various audiences, these domains represent core content areas of safety science and practice, with availability of continuing medical education credit. The use of the CPPS domains as a framework could benefit interested and eligible candidates who wish to seek certification.

With increasing focus on perioperative outcomes and recognition of anesthesiology as a bridge between medical and surgical specialties, anesthesia professionals are well-suited to advise hospital boards on safety assessment and initiatives as well as identify resources necessary to bring these initiatives to fruition.[7,8] While improvement projects for safety often address clinical variation, whole system safety

requires balanced attention to strategic and operational variation which has been a key target of anesthesia professionals and is the current focus of the Patient Safety Structural Measure.[9] For example, anesthesia professionals can reference the work of the American Society of Anesthesiologists Statement on Safety Culture (https://www.asahq.org/standards-and-practice-parameters/statement-on-safety-culture) and the work of the Anesthesia Patient Safety Foundation's Patient Safety Priorities Advisory Groups (https://www.apsf.org/patient-safety-priorities/) when advising their hospital leadership on best practices to improve patient safety. In addition to these resources, the National Steering Committee for Patient Safety has developed an action plan for organizations, as well as a self-assessment tool and implementation resource guide, which can be accessed from the Institute for Healthcare Improvement website. (https://www.ihi.org/national-action-plan-advance-patient-safety)

CONCLUSION

Transformational progress is necessary to improve safety for our patients and the workforce. It will not be achieved by treating safety as a clinical improvement project focusing on a narrow safety challenge, nor will it be achieved by treating safety as a priority, as priorities are subject to change. Patient safety will be achieved by targeting the system and treating it as a purpose, a nonnegotiable true north among other organizational priorities.[10] Due to their broad education and training in safety, anesthesia professionals are invaluable assets for a health care organization as it executes systems-oriented actions to advance safety and attests to the PSSM practices. Most of the elements within the PSSM domains are routine practices used by anesthesia professionals and are ubiquitous for safety in all settings. By working with the hospital leaders, anesthesia professionals can demonstrate that their value extends well beyond the operating rooms, procedural areas, and ICUs and can benefit the entire organization.

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Patient Engagement: The Cornerstone of Patient Safety

by Maria van Pelt, PhD, CRNA, CNE, CPPS, FAAN, FAANA; Salvador Gullo Neto, MD, PhD; Katherine Megan; Steven J. Barker, PhD, MD; and Della M. Lin, MD, MS, FASA

In 2022, the Anesthesia Patient Safety Foundation (APSF) Board of Directors embraced "patient engagement" as an active strategic focus to further advance the foundation's vision that "no one shall be harmed by anesthesia care." This commitment led to the formation of a dedicated Patient Engagement Workgroup that welcomed patients as member partners in the committee and featured co-design as a key guiding principle. This collaborative approach represented a significant evolution in how the APSF approached patient safety initiatives.

Prior to this initiative, APSF had not historically developed online patient education content. To identify critical gaps that APSF might fill in this arena, the workgroup employed a multifaceted approach combining user-design principles, web analytics, and traditional review methodologies. This comprehensive analysis revealed significant opportunities to enhance patient education and engagement in anesthesia and surgical care.

UNDERSTANDING PATIENT CONCERNS

Through careful research and direct solicitation of feedback from patients, the workgroup discovered that patients consistently sought answers to fundamental questions about anesthesia and surgery, including:

- Do I need to have surgery?
- What if I have trouble waking up from anesthesia?
- How many times is it safe to go under anesthesia?
- Are there long-term side effects of anesthesia?

Notably, available online content to adequately address these concerns was scarce or incomplete. Search engine keyword research, coupled with analysis of high-ranking websites, revealed a significant opportunity to provide dedicated patient-centered resources. Meanwhile, medical journal articles, while highly detailed and up-to-date, were not patient-centered and frequently employed technical language beyond the comprehension of most patients. This clearly identified a distinct opportunity for APSF to bridge this information gap by providing content that patients truly valued—content that would enable them to take ownership of their care and effectively participate in shared decision-making with their health care providers.

Table 1: Patient Guide to Anesthesia: Content Overview.

Category	Questions
Understanding Anesthesia	• How safe is anesthesia? Common fears & concerns • What are the types of anesthesia? • What drugs are used in anesthesia?
Presurgery Considerations	• Is surgery necessary? • How do I pay for surgery? • How do I prepare for surgery?
Risk Assessment	• What are risk factors for surgery?
Postsurgery Pain	• Will I feel pain after surgery? • How do I speed up healing after surgery?
Pain Management	• What are the types of pain? • What should I know about pain management? • How can I manage pain without medications? • What nonopioid medications are used in pain management? • What opioids are used in pain management? • What are the risks of using opioid medications?
Important Questions	• Questions to ask your anesthesia professional • Questions to ask your surgeon

THE BIRTH OF THE PATIENT GUIDE TO ANESTHESIA AND SURGERY

As a direct result of these findings, the "Patient Guide to Anesthesia and Surgery" was founded in 2022, marking APSF's first patient-focused initiative. Developed by the APSF's Patient Engagement Workgroup, this resource brought together patient advocates and anesthesia and surgical professionals to answer the most commonly asked questions patients have before surgery (Table 1).

The mission of this initiative extends beyond merely providing information—it aims to encourage patients to actively participate in their health care journey and gain a better understanding of how they can minimize perioperative risks and complications. The ultimate goal is patient empowerment, helping individuals become more involved in their care decisions and learn practical ways to mitigate their own risks.

INNOVATIVE METHODOLOGY FOR CONTENT DEVELOPMENT

The workgroup determined that the initial step in building content for the Patient Guide should embrace user-design methodology to genuinely "listen to the patients." The primary objective was to understand their fears, concerns, and informational needs in their own terms. This approach represented a deliberate departure from typical medical articles developed for patients, which often carry a technical bias based on health care professionals' perceptions of what information is necessary.

For the first version of the Patient Guide, the workgroup conducted comprehensive online patient surveys and in-depth interviews. The team designed survey questionnaires specifically to help understand the main fears and concerns patients harbor regarding anesthesia. Making a conscious effort to gather diverse perspectives, the surveys included participants from different age, social, and ethnic groups by utilizing the Amazon MTURK platform, an online marketplace that provides access to a demographically diverse participant pool beyond researchers' immediate networks, thus reducing potential selection bias.

To complement the survey data, through snowball sampling, the team conducted in-person interviews to explore patients' and their families' concerns more deeply. These interviews employed the Empathy Map, a

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APSF Created a Guide to Anesthesia and Surgery for Patients to Utilize

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methodological tool used to understand user behavior, developed by Dave Gray and XPLANE[1] (Figure 1). This tool allowed us to record in different quadrants what patients see, feel, think, and do in relation to anesthesia and surgical care. It also directly explored their perceived losses and gains related to surgical procedures and anesthesia. Both the surveys and interviews provided the workgroup with a valuable list of priority topics that served as the foundation for creating the initial content for the website.

RIGOROUS QUALITY ASSURANCE PROCESS

With the priority topics clearly defined, the workgroup designed a systematic process for content development to ensure both accuracy and accessibility. Each article followed a three-step review process:

1. Initial drafting by a workgroup member with professional expertise in anesthesia who used readability assessment tools to create content at an 11th grade reading level or lower.
2. The first review was conducted by another workgroup member without professional expertise in anesthesia to ensure readability and relevance.
3. The final review was carried out by a professional writer to standardize the texts and ensure the quality, clarity, and consistency of the information.

This multilayered approach ensured that the content maintained scientific accuracy while remaining accessible and relevant to patient needs.

MEASURING SUCCESS THROUGH ANALYTICS

Since its launch in October 2023, the Patient Guide microsite has been viewed over 82,000 times by more than 60,000 visitors, now attracting over 10,000 visits per month (Figure 2, next page). With its broad patient audience, the Patient Guide has quickly become one of the most-visited resources on the APSF website, accounting for five of the ten most-viewed pages for the past six months.

FUTURE DIRECTIONS

Looking ahead, the Patient Engagement Workgroup has established both short-term goals and long-term strategic objectives. In the immediate future, the Workgroup plans to expand content based on analytics and user feedback, addressing additional high-priority questions identified through ongoing research.

The long-term vision focuses on more deeply integrating patient perspectives, lived experiences, and feedback into all of APSF's initiatives. This approach recognizes that genuine patient engagement must extend beyond educational content to influence the foundation's broader safety work, research priorities, and policy recommendations.

Opportunities for expansion include developing strategic partnerships with other patient-focused organizations and foundations to amplify reach and impact. The workgroup is also exploring multimedia formats, interactive tools, and expanded language offerings to make the content more accessible to diverse populations.

As the Patient Guide to Anesthesia and Surgery continues to evolve, APSF invites health care professionals, patients, and families to become familiar with these resources (https://www.apsf.org/patient-guide/). The "must-have" priority remains keeping patients as the cornerstone of all safety initiatives and educational materials. By maintaining this unwavering commitment to patient-centered approaches and shared decision-making as essential components rather than optional features, APSF aims to significantly advance its core vision that no one shall be harmed by anesthesia care.

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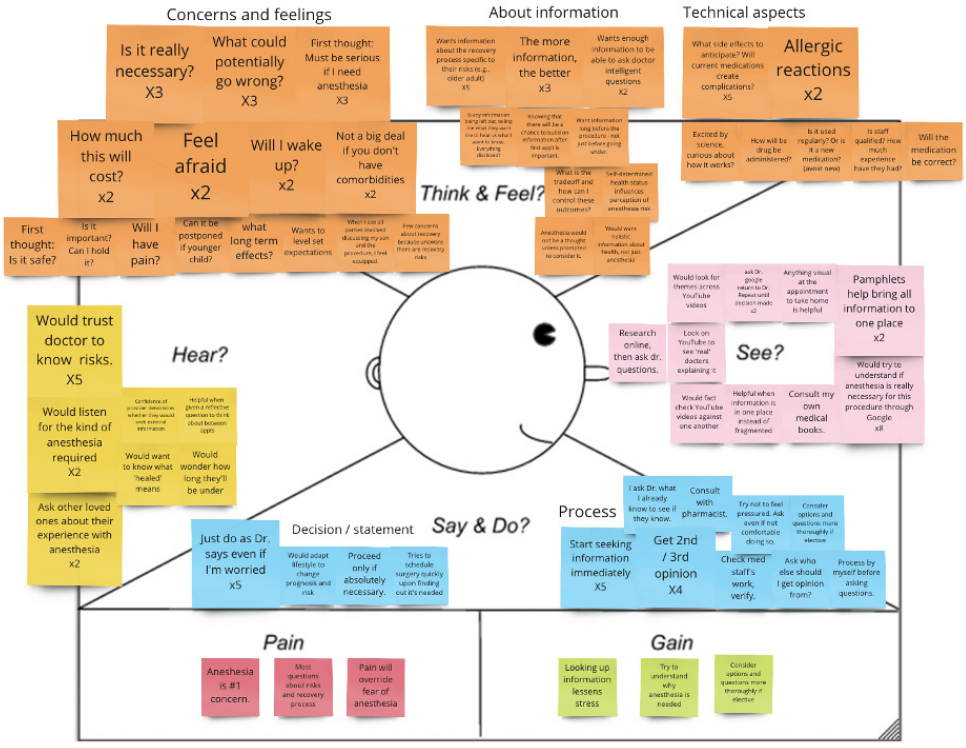

Figure 1: Empathy Map.[1] Used with permission from xplane.com.

See "Patient Engagement," Next Page

APSF Created a Guide to Anesthesia and Surgery for Patients to Utilize

From "Patient Engagement," Preceding Page

APSF Patient Engagement Workgroup for their valuable contributions to this initiative:

Arnoley S. Abcejo, MD; Vonda Vaden Bates; Richard P. Dutton, MD, MBA; Mike Edens; Bernadette Henrichs, PhD, CRNA, CCRN, CHSE, FAANA; Olivia Lounsbury, MS; Jay Mesrobian, MD, MBA, FASA, FACHE.

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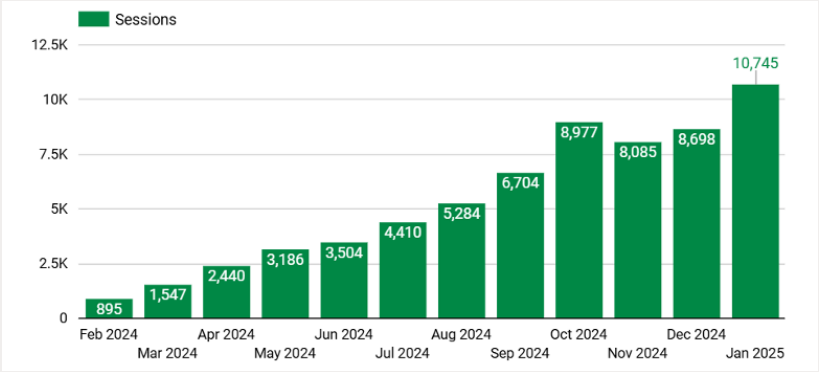


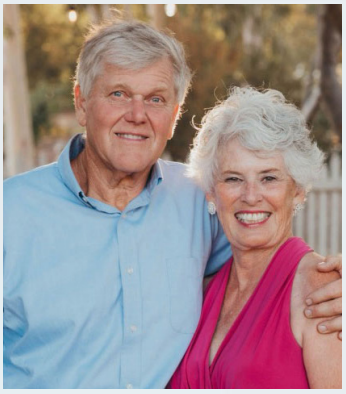
Figure 2: Patient Guide to Anesthesia and Surgery Website Sessions.

SPOTLIGHT on Legacy Society Members

Dan and Cristine Cole

We went into medicine to make the world a better place. How professionally and personally gratifying it is to be an anesthesiologist and have a role in the miracles of medicine. But how tragic it is whenever I hear of an instance where the medical system that was intended to help a human being ends up harming them. The Anesthesia Patient Safety Foundation (APSF) has a mission that we can all connect to and it is an honor to work with the many selfless professionals at APSF who volunteer their time to eradicate preventable harm. It is a mission that Cristine and I are privileged to support.

Tim and Linda Vanderveen



In the 4th year of my undergraduate Pharmacy program I experienced a potentially fatal medication error. The allergy nurse at the student clinic administered to me two doses of another student's allergy extract. This error, and numerous others I observed in my early clinical pharmacy practice, focused my career on improving medication safety, and especially intravenous drug administration. It was Dr. Stoelting who first got me involved with APSF, and I have had the opportunity to participate in the Committee on Technology, serve three terms on the APSF Board, co-chair a Stoelting Conference on medication safety, and publish several articles in the *APSF Newsletter*. It is an honor to be invited to join the APSF Legacy Society, and Linda and I are happy to help ensure the continued success of APSF.

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.

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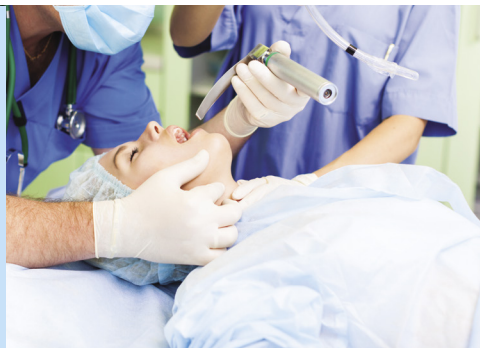

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