

## Perioperative Brain Health: A Patient Safety Priority All Anesthesia Professionals Must Address

by Natalie C. Moreland, MD, Lena Scotto, MD, Arnoley S Abcejo, MD, and Emily Methangkool, MD, MPH

It is not uncommon for patients to ask if and how anesthesia will affect their brain. Perioperative brain health is a particular concern for older patients, families, and caregivers. As such, brain health has been recognized as an APSF Patient Safety Priority. The number of Americans aged 65 and older is predicted to double to 95 million by 2060,<sup>1</sup> and nearly 40% of all surgical procedures are performed on patients over 65.<sup>2</sup> With age, comorbidities increase in frequency and complexity, challenging perioperative care and contributing to their risk of worse outcomes, including perioperative neurocognitive disorders (PND).<sup>1</sup> Optimizing brain health with interventions in the perioperative period is of paramount importance. Anesthesia professionals, as integral members of the perioperative team, are uniquely positioned to improve patient outcomes by identifying patients at risk of PND and ensuring specific steps are taken to reduce its occurrence.

Multiple societies and organizations have proposed recommendations, outlined frameworks, and published guidelines for perioperative brain health.<sup>3–8</sup> Following these recommendations, many health care institutions have established programs to prevent PND in surgical patients. These guidelines and programs all highlight the need for a multidisciplinary team-based

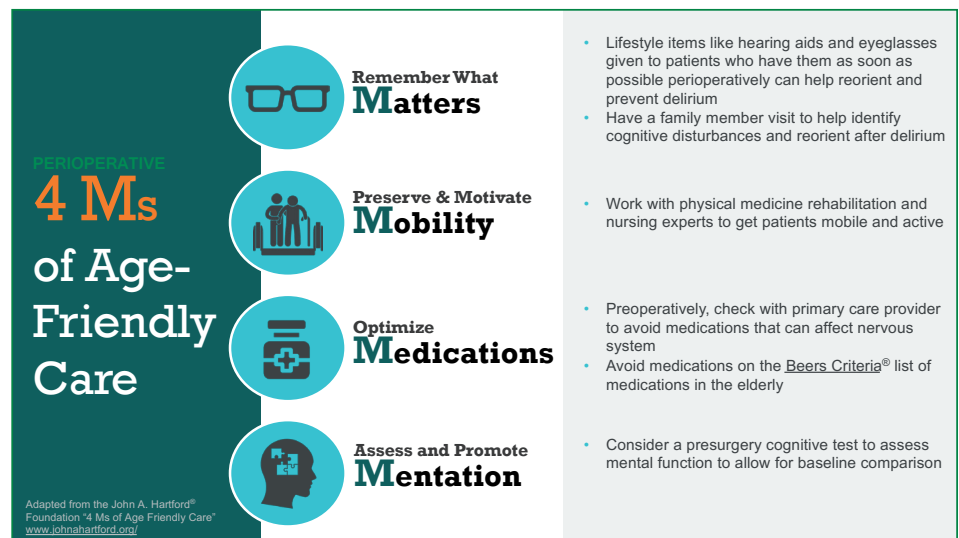


Figure 1: The Four Ms of Age-Friendly Care.<sup>10</sup>

approach with interventions in the preoperative, intraoperative, and postoperative periods.

The National Academy of Medicine has recognized the increasing population of elderly patients as a defining challenge of the 21st century.<sup>9</sup> As such, in 2017 The John A. Hartford Foundation and the Institute of Healthcare Improvement, in partnership with the American Hospital Association and

the Catholic Health Association of the United States, launched the "Age-Friendly Health System" to improve the health, productivity, and quality of life of older adults.

The "Age-Friendly Health System" uses the framework of the **4 Ms**: What Matters, Mobility, Medication, and Mentation (Figure 1).<sup>10</sup>

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## New Practice Guidelines for Neuromuscular Blockade

by Connie Chung, MD, Joseph W. Szokol, MD, JD, MBA, Wade A. Weigel, MD, and Stephan R. Thilen, MD, MS

The American Society of Anesthesiologists (ASA) Committee on Practice Parameters (CPP), chaired by Karen Domino, MD, MPH, created a task force to develop guidelines for neuromuscular blockade (NMB) to improve patient safety and satisfaction. The Anesthesia Patient Safety Foundation (APSF) and its leadership have long advocated for guidelines on the use of NMB, its monitoring, and reversal, given the patient

safety risk of residual muscle weakness. The task force, co-chaired by Stephan Thilen, MD, MS, and Wade Weigel, MD, developed the 2023 ASA Practice Guidelines for Monitoring and Antagonism of Neuromuscular Blockade, which were published in a January issue of *Anesthesiology*.<sup>1</sup> This article will provide an overview of the new guidelines.<sup>2</sup>

**Disclaimer:** ASA practice guidelines aim to improve patient care, safety, and outcomes by providing up-to-date information for patient care. Practice guidelines are subject to revision as warranted by the evolution of medical knowledge, technology, and practice. Practice guidelines are not intended as standards or absolute requirements to replace local institutional policies, and their use cannot guarantee any specific outcome.<sup>1</sup>

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# Delirium Can Be Associated with Longer-term Neurocognitive Decline

From “Brain Health,” Page 34

## IMPACT OF PERIOPERATIVE NEUROCOGNITIVE DISORDERS (PND)

Postoperative delirium, characterized by inattention and confusion occurring within seven days of surgery, is the most common adverse event after surgery in older adults with an incidence of up to 65%.<sup>3</sup> Health care costs increase with postoperative delirium, with an estimated toll of \$32.9 billion per year.<sup>11</sup> More is known about the factors contributing to postoperative delirium than the other perioperative neurocognitive disorders. When predisposing factors such as age >65, pre-existing cognitive decline, poor baseline functional status, visual or sensory impairment, and chronic illness are combined with precipitating factors such as duration and invasiveness of surgery, postoperative pain management, and use of certain medications, the risk for postoperative delirium is increased. In addition, postoperative delirium is associated with increased length of stay, higher morbidity and mortality, and severe distress to patients and their family members.<sup>4,12</sup> Patients with normal preoperative cognition who experience postoperative delirium are more likely to develop cognitive impairment later.<sup>13,14</sup> Delirium has also been shown to be associated with longer-term neurocognitive decline.<sup>3,15</sup> The Hospital Elder Life Program (HELP), an evidence-based approach targeted at risk factors for delirium showed that almost half of delirium cases could be prevented.<sup>16</sup> In a study of a modified HELP protocol in surgical patients (orienting communication, early mobilization, and oral and nutritional assistance), the incidence of delirium decreased by 56%. The authors of this study credited the program’s effectiveness to daily adherence to the protocol, facilitated by dedicated nurses. Several centers have now published their experiences and results with implementation of these guidelines, with evidence that delirium can be prevented.<sup>17</sup>

## WHAT CAN ANESTHESIA PROFESSIONALS DO?

Several professional societies have published best practice guidelines for maintaining perioperative brain health. The American Geriatrics Society (AGS),<sup>7</sup> the American College of Surgeons (ACS),<sup>18</sup> the American Society of Anesthesiologists’ *Brain Health Initiative* (ASA),<sup>4</sup> as well as the Sixth Perioperative Quality Initiative consensus conference (POQI-6) and the Fifth International Perioperative Neurotoxicity Working Group<sup>5</sup> have recommendations to guide health care professionals in identifying patients at risk of cognitive decline and preventing cognitive impairment after sur-

### PERIOPERATIVE MEDICATIONS TO POTENTIALLY AVOID IN PATIENTS WHO ARE 65 YEARS AND OLDER

Promethazine Diphenhydramine	Risk of cognitive impairment, anticholinergic effects
Benzodiazepines	Risk of cognitive impairment, delirium, and falls
Meperidine	Increased risk of neurotoxicity (e.g., delirium) compared to other opioids
Metoclopramide	Risk of extrapyramidal effects

#### DRUG-DRUG INTERACTIONS TO AVOID

OPIOIDS – GABAPENTANOIDS\*

OPIOIDS – BENZODIAZEPINES

ANTICHOLINERGIC – ANTICHOLINERGIC

\*Concomitant use of opioids and gabapentinoids has been correlated with increased risk of opioid-related death.

Adapted from the 2019 American Geriatrics Society Beers Criteria Update Expert Panel. American Geriatrics Society 2019 Updated AGS Beers Criteria for Potentially Inappropriate Medication Use in Older Adults. *J Am Geriatr Soc.* 2019;67(4):674–694.

Figure 2: Perioperative Drugs That Should Be Avoided When Possible in Patients 65 Years and Older.

gery. Preexisting cognitive impairment is a significant risk factor for postoperative delirium and other complications.<sup>19,6</sup> All of these guidelines recommend that cognitive screening and an assessment of risk factors for PND should be conducted for all patients over 65.<sup>4-8</sup> Several cognitive screening tools, such as the Mini-Cog, the Mini-Mental State Examination (MMSE), and the Montreal Cognitive Assessment (MoCA) are quick, easy to use, require no formal training, and could be applied in the preoperative clinic.<sup>16</sup> With the identification of an abnormal screening test, patients can receive further

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## Preoperative Cognitive Screening is Feasible Without Previous Experience

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evaluation and treatment for a potential cognitive deficit, be informed of the risk of PND prior to surgical intervention, and be referred to resources and interventions beneficial to high-risk patients.<sup>1,6</sup> Interventions for delirium include mobilization, orientation, sleep hygiene, returning personal items (glasses, hearing aids and dentures) after surgery, and education about delirium for health care professionals.<sup>4,8</sup>

There is also evidence supporting the avoidance of specific medications in patients at risk of PND (Figure 2). The American Geriatrics Society Beers Criteria recommends avoiding potentially inappropriate medications such as benzodiazepines, anticholinergics, antipsychotics, meperidine, and gabapentin in high-risk patients.<sup>20</sup> A multimodal regimen with limited opioids is recommended.<sup>21</sup> Strong evidence supporting the association between these medications and postoperative delirium makes these recommendations an important potential target for improving perioperative brain health.<sup>15</sup>

While there is agreement in the above recommendations, other areas remain uncertain. Data are conflicting regarding the use of processed electroencephalogram (EEG)-guided anesthetic dosing to decrease postoperative delirium and PND; however, some authors argue that there may be a subset of cognitively frail patients who could benefit from EEG-guided avoidance of anesthetic overdose resulting in brain activity suppression.<sup>1</sup> Similarly, there are conflicting data regarding the impact of intraoperative blood pressure management and choice of anesthetic technique on PND. The Best Practices for Perioperative Brain Health state that while further research is warranted in these areas, anesthesia professionals “should monitor age-adjusted end-tidal minimal alveolar concentration (MAC) fraction, strive to optimize cerebral perfusion, and perform EEG-based anesthetic management in older adults.”<sup>6</sup>

Comprehensive programs to identify patients at risk and address multiple factors contributing to perioperative brain health are necessary. Authors at the University of California, San Francisco have described their experience with implementing a “Perioperative Delirium Prevention and Treatment Pathway” for perioperative brain health.<sup>15,22</sup> First, they identified stakeholders and received their feedback. They then provided educational material through meetings and email. In their pathway, patients were screened with the Age, WORLD backwards, Orientation, iLLness severity, Surgery-specific

risk (AWOL-S) tool: Age > 80, failure to spell “World” backward, disorientation to place, ASA status, and a surgery-specific risk based on National Surgical Quality Improvement Program (NSQIP) data. Patients with a greater than 5% risk for delirium were flagged in the electronic medical record (EMR) with a banner. To ease implementation, the delirium screening questions were embedded into the existing questions asked by the preoperative nurses. The standard PACU order set, which includes several of the Beers Criteria Potentially Inappropriate Medications (PIMs), was modified to omit these medications. Delirium risk was also added to the standard PACU handoff tool. The authors emphasized that changes integrated into existing workflows and automated processes through the EMR were most successful in promoting changes in behavior.<sup>22</sup>

Implementing routine cognitive screening at the preoperative evaluation clinic at the University of Southern California revealed that preoperative cognitive screening with the Mini-Cog test was feasible without prior experience in cognitive screening. High-risk patients were flagged with alerts in the EMR and referred to a geriatrician and geriatric pharmacist before surgery. They found that 21% of their patients screened positive for cognitive impairment and that a significant proportion of patients would have been missed without a formal cognitive screen. These findings increased “buy-in” at their preoperative clinic and in their institution.<sup>23</sup>

As research continues to answer many remaining questions, how can we integrate the existing recommendations and published experience into our clinical practice? Despite recent recommendations on perioperative brain health and a call to action by the ASA’s *Brain Health Initiative*,<sup>4</sup> a recent survey reported that preoperative screening occurred in less than 10% of cases.<sup>24</sup> Several authors have emphasized the importance of engaging the many stakeholders including nurses, surgeons, patients, families, organizational and departmental leadership, and pharmacists.<sup>15,23</sup> Pre-existing Enhanced Recovery After Surgery (ERAS) protocols, which use a multidisciplinary team-based approach to improve various aspects of perioperative care with evidence-based interventions, could be used to help implement perioperative brain health recommendations.<sup>25</sup> Since its inception in 2005, ERAS has expanded worldwide and is now widely accepted within the field of perioperative medicine. Researchers have proposed a “Brain-ERAS” protocol that, rather than being a

separate protocol, is incorporated into existing ERAS protocols.<sup>25</sup>

Given the wide availability of information technology, more patients are taking steps to be informed and active participants in their health. Anesthesia professionals should take advantage of this movement and help patients, their caregivers, and their care teams optimize patient outcomes, including preventing PND in those at risk.

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## Quantitative Monitoring is Recommended by NMB Guidelines Over Qualitative Assessment to Reduce Residual Neuromuscular Blockade

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The practice guidelines present eight recommendations regarding the type of monitoring of neuromuscular blockade, location of monitoring, and medications used to achieve appropriate reversal of neuromuscular blockade. Six recommendations (1–6) were classified as strong recommendations with moderate strength of evidence. The two remaining recommendations (7–8) were classified as conditional recommendations with low and very low strength of evidence, respectively.

Neuromuscular blocking drugs are commonly used and have been shown in the literature to be associated with an incidence of residual blockade at the end of surgery and/or in the postanesthesia care unit (PACU) of up to 64%.<sup>2,3</sup> Residual blockade is associated with numerous complications, such as upper airway obstruction, reintubation, atelectasis, pneumonia, prolonged PACU stay, and decreased patient satisfaction.<sup>4,7</sup>

Quantitative assessment of neuromuscular blockade can be performed with peripheral nerve stimulators that deliver four brief electrical pulses. The amplitude of the fourth twitch divided by the amplitude of the first twitch results in a train-of-four (TOF) ratio. The baseline TOF ratio in the unparalyzed patient should be 1.0, indicating all four twitches have equal amplitude. The smaller the TOF ratio, the greater the degree of paralysis. There is a broad consensus that acceptable recovery of neuromuscular function is defined as a TOF ratio greater than or equal to 0.9.<sup>1</sup> However, despite multiple studies reporting significant benefits of quantitative monitoring of neuromuscular blockade, it has not been widely adopted among all anesthesia professionals.<sup>1</sup> A 2019 international survey identifies several factors that have contributed to the slow adoption of quantitative monitoring: anes-

thesia professionals' overconfidence in the assessment of neuromuscular blockade depth, an underappreciation of the frequency of residual neuromuscular blockade and its clinical consequences, and a lack of commercially available quantitative TOF monitors that are user-friendly and inexpensive.<sup>8</sup>

Qualitative assessment of neuromuscular blockade is more frequently used by anesthesia professionals.<sup>1</sup> Following peripheral nerve stimulation, one performs visual inspection or manual (tactile) evaluation for subjective assessment of thumb movement, resulting in a TOF count. However, studies have shown that clinically significant weakness cannot be identified with this technique, as fade cannot be reliably appreciated until the TOF ratio is less than approximately 0.4.<sup>9</sup> Another common approach is subjective assessment of sustained head lift or grip strength. However, studies have also shown that these maneuvers are not sensitive enough to detect residual neuromuscular blockade, as 80% of patients with a TOF ratio < 0.7 could perform a head lift maneuver.<sup>10</sup>

Moreover, the duration of action of neuromuscular blocking drugs has great interpatient variability, and it is not possible to use time intervals to predict when the block has regressed to a specific depth of block. The practice guidelines cite 11 studies that were pooled and analyzed, reporting lower incidences of residual neuromuscular blockade with quantitative monitoring compared with qualitative or clinical assessment (Supplemental Tables S8 and S9 (Note: [link downloads a Word doc](#)), <https://links.lww.com/ALN/C928>).<sup>1</sup> Therefore, when neuromuscular blocking drugs are administered, clinical assessment alone is not recommended to avoid residual neuromuscular blockade (Recommendation 1), and quantitative monitoring is recommended over qualitative assessment to

reduce the risk of residual neuromuscular blockade (Recommendation 2).<sup>1</sup>

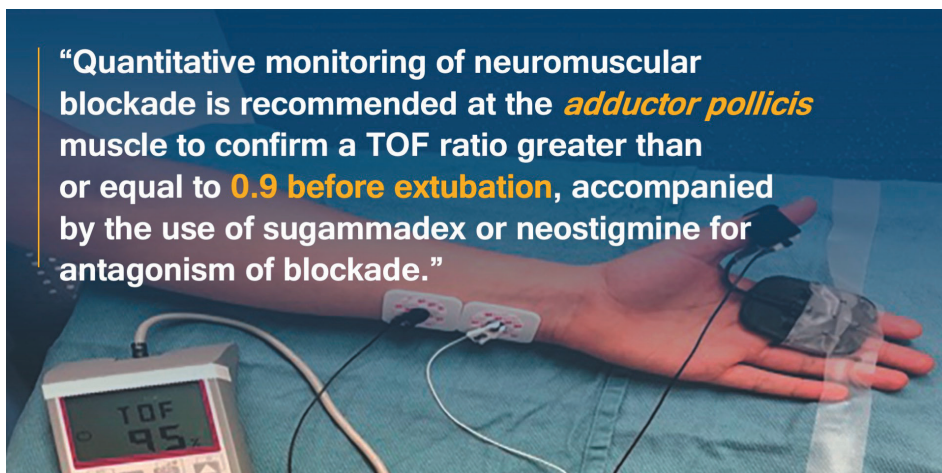
Residual neuromuscular blockade was initially defined as a TOF ratio less than 0.7, based on earlier work showing that vital capacity and inspiratory force had recovered to near normal at this ratio,<sup>11</sup> but numerous later studies have shown that patients have clinical symptoms of weakness with a train of four ratio less than 0.9.<sup>12</sup> As mentioned, the practice guidelines recommend using quantitative TOF monitoring, and the guidelines specifically recommend confirming a TOF ratio greater than or equal to 0.9 before extubation, as there is a lower incidence of residual neuromuscular blockade compared to when the TOF ratio was not confirmed to recover to this level (Recommendation 3).<sup>1</sup>

Of note, various types of quantitative TOF monitors exist, such as acceleromyography, electromyography, kinemyography, and mechanomyography. The guidelines present two supplemental tables that summarize the last 30 years of data regarding the agreement among technologies (bias) as TOF differences at a given TOF ratio (Supplemental Table 24 (Note: [link downloads a Word doc](#)), <https://links.lww.com/ALN/C928>) and as time to attain a given TOF ratio (Supplemental Table 26 (Note: [link downloads a Word doc](#)), <https://links.lww.com/ALN/C928>). These data indicate there are differences among technologies (a discussion of which is beyond the scope of this article), but the guidelines state there is no preferred type of quantitative neuromuscular monitor.<sup>1</sup>

The practice guidelines state that acceptable recovery of all muscles from neuromuscular blockade optimizes patient safety, and therefore, measurements “should be obtained at sites with longer times to recovery.”<sup>1</sup> Studies have shown that eye muscles (*corrugator supercilii* and *orbicularis oculi*) are relatively resistant to neuromuscular blocking drugs compared to the *adductor pollicis* muscle.<sup>1</sup> Therefore, the time to reach a TOF ratio greater than or equal to 0.9 at the *adductor pollicis* muscle was longer than the time to reach this threshold at the eye muscles (Supplemental Tables S15 and S16 (Note: [link downloads a Word doc](#)), <https://links.lww.com/ALN/C928>).<sup>1</sup> Therefore, it is recommended to use the *adductor pollicis* muscle for neuromuscular monitoring (Recommendation 4), and it is recommended to avoid using eye muscles for neuromuscular monitoring (Recommendation 5).<sup>1</sup> The guidelines also state that if intraoperative neuromuscular monitoring has been performed at the eye muscles because no other site was easily accessible

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“Quantitative monitoring of neuromuscular blockade is recommended at the *adductor pollicis* muscle to confirm a TOF ratio greater than or equal to 0.9 before extubation, accompanied by the use of sugammadex or neostigmine for antagonism of blockade.”



## Residual Neuromuscular Blockade Remains an Important Patient Safety Issue

From “NMB Practice Guidelines,” Preceding Page  
intraoperatively, then changing the site to the *adductor pollicis* muscle before antagonism is recommended.<sup>1</sup>

Efficacious pharmacologic antagonism of neuromuscular blockade depends on the depth of blockade. The practice guidelines use the same scheme for classification of different depths of block presented in the 2018 Consensus Statement on Perioperative Use of Neuromuscular Monitoring (Table 1).<sup>1,13</sup> Aminosteroid induced neuromuscular blockade can be antagonized in two ways. Anticholinesterases inhibit acetylcholinesterase and butyrylcholinesterase, prolonging the presence of acetylcholine at the neuromuscular junction. Neostigmine was the only anticholinesterase

**Table 1: Depths of Neuromuscular Blockade by Quantitative and Qualitative Measurement.**

Depth of Blockade	Peripheral Nerve Stimulator and Qualitative Assessment	Quantitative Monitor
Complete	Posttetanic count = 0	Posttetanic count = 0
Deep	Posttetanic count $\geq 1$ ; train-of-four count = 0	Posttetanic count $\geq 1$ ; train-of-four count = 0
Moderate	Train-of-four count = 1–3	Train-of-four ratio = 1–3
Shallow*	Train-of-four count = 4; train-of-four fade present	Train-of-four ratio $< 0.4$
Minimal*	Train-of-four count = 4; train-of-four fade absent	Train-of-four ratio = 0.4–0.9
Acceptable recovery	Cannot be determined	Train-of-four ratio $\geq 0.9$

\*The quantitative threshold of train-of-four ratio of 0.4 cannot reliably be subjectively determined by the presence or absence of fade in the train-of-four ratio response. The absence of subjectively appreciated fade has been reported with a train-of-four ratio of less than 0.3, and the presence of fade has been reported with train-of-four ratio of greater than 0.7.

Deep: post-tetanic count greater than or equal to 1 and train of four count 0; moderate: train of four count 1 to 3; shallow: train of four count 4 and train of four ratio less than 0.4; minimal: train of four ratio 0.4 to less than 0.9.

Table 5 from the 2023 ASA Practice Guidelines for Monitoring and Antagonism of Neuromuscular Blockade: A Report by the American Society of Anesthesiologists Task Force on Neuromuscular Blockade.<sup>1</sup> Reprinted and modified with permission from Wolters Kluwer Health, Inc.

### SUMMARY OF RECOMMENDATIONS<sup>1</sup>

1. When neuromuscular blocking drugs are administered, we recommend against clinical assessment alone to avoid residual neuromuscular blockade, due to the insensitivity of the assessment.<sup>1</sup>
2. We recommend quantitative monitoring over qualitative assessment to avoid residual neuromuscular blockade.
3. When using quantitative monitoring, we recommend confirming a train of four ratio greater than or equal to 0.9 before extubation.
4. We recommend using the *adductor pollicis* muscle for neuromuscular monitoring.
5. We recommend against using eye muscles for neuromuscular monitoring.
6. We recommend sugammadex over neostigmine at deep, moderate, and shallow depths of neuromuscular blockade induced by rocuronium or vecuronium, to avoid residual neuromuscular blockade.
7. We suggest neostigmine as a reasonable alternative to sugammadex at minimal depth of neuromuscular blockade.
8. To avoid residual neuromuscular blockade when atracurium or cisatracurium are administered and qualitative assessment is used, we suggest antagonism with neostigmine at minimal neuromuscular blockade depth. In the absence of quantitative monitoring, at least 10 minutes should elapse from antagonism to extubation. When quantitative monitoring is utilized, extubation can be done as soon as a train of four ratio greater than or equal to 0.9 is confirmed before extubation.

that was evaluated in the practice guidelines, as edrophonium is no longer available in the United States. Sugammadex is a selective relaxant binding agent, and it can antagonize any depth of block that is induced by rocuronium or vecuronium. It is more efficacious than neostigmine for antagonism of deep, moderate, and shallow levels of block and is recommended for antagonism of these depths of neuromuscular blockade (Recommendation 6).<sup>1</sup> The FDA-approved dose recommendations for antagonizing rocuronium or vecuronium with sugammadex are 2 mg/kg for TOF count = 2 to TOF ratio  $< 0.9$ , 4 mg/kg for posttetanic count = 1 to TOF count = 1, and 16 mg/kg for immediate antagonism after administration of a single dose of rocuronium 1.2mg/kg.<sup>14</sup>

Neostigmine is efficacious for antagonism of minimal block (TOF ratio  $\geq 0.4$  to  $< 0.9$ ), and it is recommended as a reasonable alternative to sugammadex for antagonism of minimal block (Recommendation 7).<sup>1</sup> If neostigmine is used for antagonism of a block that is deeper than minimal blockade, the degree of antagonism will vary between patients. If qualitative assessment is used, it is not possible to determine when recovery to a TOF ratio  $\geq 0.9$  is attained. The guidelines include a comment on this situation: “Depending on clinical judgment and in the context of quantitative monitoring, neostigmine may be considered for a depth of block deeper than minimal (TOF ratio of 0.4 to 0.9), with the understanding that deeper blocks will require more time to attain a TOF ratio greater than or equal to 0.9.”<sup>1</sup>

Studies examining the adverse effects of sugammadex and neostigmine (co-administered with glycopyrrolate) do not favor either drug. The practice guidelines cite more than 75 studies that did not detect a difference between sugammadex and neostigmine in the incidence of pulmonary complications, anaphylaxis, bradycardia, or tachycardia (when administered with glycopyrrolate), postoperative nausea alone, and postoperative vomiting.

Benzylisoquinolinium neuromuscular blocking drugs, such as atracurium and cisatracurium, can only be antagonized by acetylcholinesterase inhibitors. The antagonist effect of neostigmine, the most used acetylcholinesterase inhibitor, is maximal within 10 minutes.<sup>15</sup> Moreover, neostigmine’s efficacy is significantly improved when antagonizing minimal block compared to deeper levels of block. Therefore, Recommendation 8 states that to avoid residual neuromuscular blockade when qualitative assessment is used, antagonism of a cisatracurium- or atracurium-induced block should not be initiated before there is absence of subjectively assessed fade in the train of four response and at least 10 minutes should elapse from antagonism with neostigmine to extubation.<sup>1</sup> When quantitative monitoring is used, extubation can be done as soon as a train of four ratio greater than or equal to 0.9 is confirmed.

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# NMB Monitoring Practice Guidelines (cont'd.)

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**CONCLUSION**

Residual neuromuscular blockade is an important patient safety issue, and recently published practice guidelines present eight recommendations for the monitoring and antagonism of neuromuscular blockade in the United States that are supported in the literature. Quantitative monitoring of neuromuscular blockade is recommended at the *adductor pollicis* muscle to confirm a TOF ratio greater than or equal to 0.9 before extubation, accompanied by the use of sugammadex or neostigmine for antagonism of blockade. Recognizing that quantitative monitoring may not be available in all practice settings, qualitative monitoring of the TOF count can guide dosages and timing of reversal agents of neuromuscular blocking drugs.

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# Opioid Induced Respiratory Depression—Beyond Sleep Disordered Breathing

by Toby N. Weingarten, MD

More than a decade ago the APSF established a clear edict: “No patient should be harmed by opioid-induced respiratory depression in the postoperative period.”<sup>1</sup> Research studies established a strong association between obstructive sleep apnea (OSA) and adverse postoperative opioid-related outcomes. In response, medical societies issued perioperative guidelines calling for universal screening for OSA, continuation of OSA therapies in the postoperative period, and calls for the anesthesia team to appropriately modify the anesthetic and postoperative monitoring of patients.<sup>2,3</sup> Unfortunately, the published rates of severe postoperative opioid-related respiratory depression (OIRD) have remained relatively constant.<sup>4</sup>

More recent studies have expanded our understanding of which patients are at the highest risk for severe OIRD. These results suggest we need a more holistic approach of assessing patients beyond screening for OSA and begin to consider patient, surgical, anesthetic, and importantly anesthetic recovery characteristics. Also, these recent studies give us a better idea of *when* and *how* postoperative OIRD presents, allowing us to develop better postoperative monitoring strategies.

### PATIENT CHARACTERISTICS

The association between severe OIRD and OSA is well established. For example, Mayo Clinic researchers have studied the administration of naloxone on postoperative wards as a proxy measure for severe OIRD.<sup>5,6</sup> These studies found that patients with a history or positive screen for OSA have double the risk for developing severe postoperative OIRD compared to patients without OSA.<sup>5,6</sup>

These Mayo Clinic naloxone studies<sup>5,6</sup> and the PRediction of Opioid-induced respiratory Depression In patients monitored by capnoGraphY (PRODIGY) trial<sup>7</sup> have identified other important patient characteristics in addition to OSA, which also increase OIRD risk. The PRODIGY trial used bedside capnography and pulse oximetry on general care wards to identify episodes of OIRD (Figure 1). The PRODIGY researchers were then able to look at 46 potential patient risk factors to develop a risk score for OIRD (PRODIGY score, Table 1). While, as expected, OSA and other sleep breathing disorders were found to increase risk, so was older age, male sex, congestive heart failure, and opioid-naïveté; with age beyond 70 years being most important.<sup>7</sup>

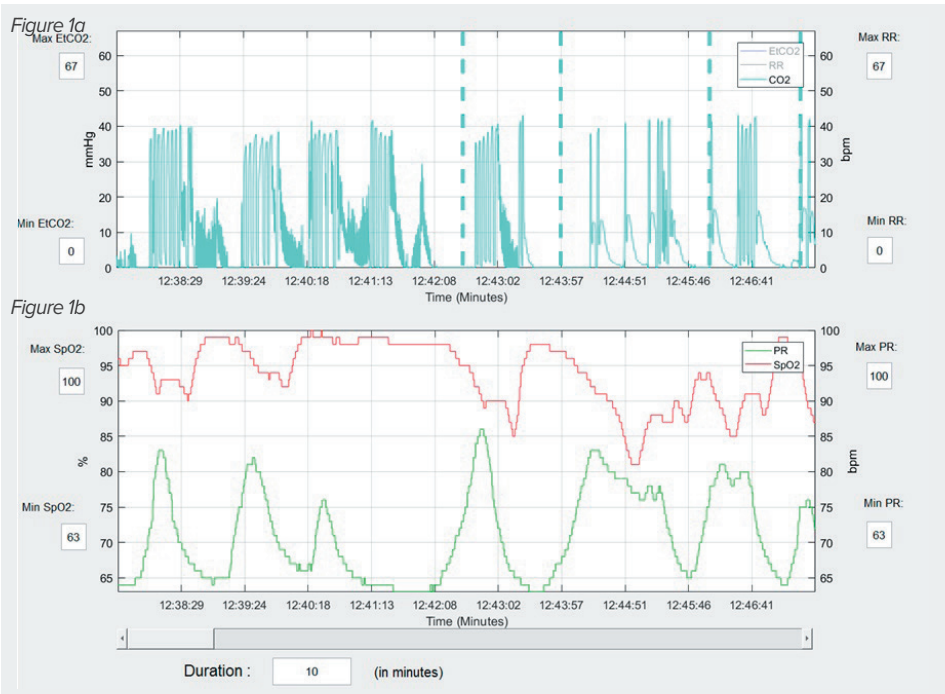


Figure 1: An actual capnography (1a) and pulse oximetry (1b) reading from PRODIGY, illustrates the typical OIRD breathing pattern.<sup>20</sup> This patient is having repetitive apnea and partial apnea episodes intersceded with normal breathing patterns. The periods of hypoxemia develop during the apnea episodes and the oxygen saturation normalizes when normal breathing resumes. Reprinted and modified with permission from Anesthesia & Analgesia and Wolters Kluwer Health, Inc.

**Table 1: PRODIGY Scoring System for Assessing Risk for OIRD Among Patients Hospitalized on General Care Wards Receiving Opioids**

Clinical characteristic		Points
Age		
≥ 60–70 years		8
≥ 70–80 years		12
≥ 80 years		16
Male sex		8
Opioid naïve		3
Sleep-disordered breathing*		5
Congestive heart failure		7
PRODIGY category	PRODIGY score†	RD risk
Low risk	< 8	REF
Intermediate risk	8–14	2-fold
High risk	≥ 15	6-fold

Abbreviations: PRODIGY, PRediction of Opioid-induced respiratory Depression in patients monitored by capnoGraphY; RD, respiratory depression; REF, reference range.

\*Sleep-disordered breathing can be determined from either patient history or positive screen for sleep apnea.

†To calculate the PRODIGY risk score, summate the assigned points per positive clinical characteristic. Patients are assigned low-, intermediate-, or high-risk category based on the number of points. Compared to low-risk scored patients, intermediate-risk patients have a 2-fold increase and high-risk patients a 6-fold increased risk for experiencing respiratory depressive episodes on the general care ward. (Adapted from Khanna et al.<sup>7</sup>)

## Perioperative Course Must Be Considered When Assessing OIRD Patient Risk

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One weakness of PRODIGY was that many of these 46 factors were specific diagnoses and some were too rare (amyotrophic lateral sclerosis) to adequately examine. Instead, the Mayo Clinic naloxone studies<sup>5,6</sup> used organ system disease to assess risk, and found cardiovascular disease, OSA, and debility more than doubled the OIRD risk, but that *central neurologic diseases quadrupled* OIRD risk. These studies suggest we should, in addition to OSA, also consider increasing age, disease burden, and debility as risk factors for OIRD.

### PERIOPERATIVE COURSE

We should not just focus on patient factors when assessing OIRD risk, but also consider the perioperative course. More extensive and invasive procedures increase the risk for respiratory failure, while regional anesthetics may decrease risk.<sup>8</sup> Different anesthetic drugs can increase or decrease the risk for OIRD while patients are admitted to the postanesthesia care unit (PACU). The Mayo Clinic has developed a unique protocol to manage patients in the PACU who are experiencing respiratory depression.<sup>9</sup> In that protocol, OSA risk is assessed preoperatively and postoperatively. PACU nurses continuously monitor patients for episodes of respiratory depression (apnea, bradypnea, oxyhemoglobin desaturation, or “pain-sedation” mismatch (defined as when a heavily sedated patient complains of severe pain)). Any patient who has one of these respiratory depressive episodes then undergoes monitoring for two additional 30-minute periods for additional episodes of respiratory depression. Those patients who have additional episodes of respiratory depression then undergo postoperative continuous monitoring with telemetry and are also considered for non-invasive positive pressure ventilation.<sup>9</sup>

Use of the soluble volatile anesthetic isoflurane, preoperative sustained release oxycodone administration, increasing doses of intraoperative opioids, and preoperative gabapentin were all found to increase PACU respiratory depression.<sup>10,11</sup> When one clinical area at the Mayo Clinic substituted desflurane for isoflurane and avoided routine use of midazolam, episodes of PACU respiratory depression decreased by 30%.<sup>12</sup>

Gabapentin and pregabalin continue to increase the risk for OIRD after PACU discharge. One study found that patients using gabapentin at home who then continued gabapentin postoperatively were at a 6-fold increase risk for naloxone administration.<sup>5</sup> Researchers using the Premier Healthcare Database found that the use of preoperative gabapentin and pregabalin (as part of an Enhanced Recovery After Surgery [ERAS] multimodal protocol) increased the risk of postoperative pulmonary complications following colorectal, gynecological, and joint arthroplasty surgeries.<sup>13-15</sup> The Federal Drug Administration has issued a black box warning that coadministration of gabapentin or pregabalin with other sedating medications increases the risk for severe respiratory complications.<sup>16</sup> Given that recent meta-analyses have found that gabapentin and pregabalin are only weak analgesics when used during surgery<sup>17</sup> and with evidence showing their potential to cause serious OIRD,<sup>5,10,11,13-15</sup> the continued use of these medicines in ERAS protocols should be questioned.

### ANESTHESIA RECOVERY

In many ways a patient's course through PACU recovery can provide the most important information regarding OIRD risk on the general care wards. Patients who have PACU respiratory depression have higher rates of postoperative pulmonary complications, and as many as one third of patients who have both a positive OSA screen and PACU respiratory depression

develop postoperative pulmonary complications.<sup>9</sup> Further, the Mayo naloxone studies found that patients who have PACU respiratory depression<sup>9</sup> have five-fold increased risk for naloxone administration.<sup>5,6</sup> Another study which examined the postoperative course of patients administered naloxone in the PACU who then were discharged to general care wards found that these patients had a three-fold increase risk of postoperative adverse events compared to patients who did not receive naloxone in the PACU.<sup>18</sup>

One possible explanation for the association between PACU respiratory depression and adverse respiratory events following discharge (even though PACU discharge criteria had been fulfilled) is that respiratory depression occurring during anesthesia recovery may persist on the ward. This was demonstrated in a study that used bioimpedance to continuously monitor minute ventilation of 119 patients admitted to the PACU and then for the first 12 postoperative hours on the general wards.<sup>19</sup> Those patients who had depressed minute ventilation in the PACU continued to do so for about 10 hours on the ward. In contrast, those patients who had normal minute ventilation in the PACU mostly continued to have normal minute volume on the wards.

### PRESENTATION OF OIRD

Postoperative OIRD often develops in ways which are surprising to most anesthesia professionals, both as to time of onset and presenting signs and symptoms. Understanding these concepts will help develop better postoperative monitoring plans.

A common belief is that critical OIRD events occur late at night when opioid analgesics, other sedating medications, and underlying OSA combine during sleep to create a lethal mix. A secondary analysis of PRODIGY found

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Moderator:

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Presented by:

John Eichhorn, MD

## The First Hours of Ward Admission May be Associated with Highest Frequency of OIRD

From “Respiratory Depression,” Preceding Page that the time relationship between OIRD, surgery, and time of day is more complex.<sup>20</sup> In that study, almost all patients who had postoperative OIRD began to have multiple episodes of OIRD in the late afternoon and early evening (16:00–22:00) shortly after arriving on the wards. The frequency of OIRD episodes surged during the early morning hours (02:00–06:00).<sup>20</sup> However, in the Mayo Clinic naloxone studies<sup>5,6</sup> naloxone was typically administered during the afternoon and evening.<sup>4</sup> These studies suggest it is the first few hours of admission to the ward that are most hazardous. Therefore, monitoring for OIRD should begin upon admission to the ward and not wait until bedtime.

Another common belief is that OIRD usually presents as bradypnea and/or hypoxemia. However, studies which examined nursing notes preceding severe episodes of OIRD have found that oftentimes normal respiratory rates and oxygen saturations are documented.<sup>21,22</sup> There are several potential explanations for these findings. One is that severe OIRD devel-

ops suddenly, and, thus, signs of respiratory depression are not present during preceding vital signs checks. Research does not support this possibility. Postoperative OIRD persists for hours following PACU discharge,<sup>19</sup> and PRODIGY showed that patients usually have multiple, repetitive OIRD events.<sup>20</sup> A more likely possibility as to why nursing notes are often falsely reassuring is that OIRD does not present as bradypnea or oxygen desaturation. The capnography and pulse oximetry used in PRODIGY paints a different picture of OIRD than is commonly assumed.<sup>7,20</sup> In PRODIGY, almost 100% of OIRD episodes consisted, in part, of an apnea or partial apnea event, and isolated bradypnea or oxygen desaturation were extremely rare (Figure 1).<sup>7,20</sup> Though not shown, patients who were on supplemental oxygen and had OIRD, oftentimes did not have periods of oxygen desaturation during apnea spells. In the setting of a repetitive apnea OIRD breathing pattern, it is plausible that when a nurse comes to make an assessment, the patient will awaken to the point that normal breathing resumes, thus masking signs of respiratory depression. It is

important to note that in many cases of severe OIRD, the nursing notes, while not recording signs of respiratory depression, will note that a patient is somnolent or sedated.<sup>21,22</sup> These observations suggest that nurses should be trained to quietly observe breathing patterns of sleeping patients to assess respiratory status before measuring other vital signs that may awaken the patient such as blood pressure measurement. The fact that many patients who developed critical OIRD events were noted to be somnolent or sedated beforehand also presents an opportunity to educate nursing staff that such sedated patients should be considered higher risk and more carefully monitored.

### A PROPOSED NEW APPROACH TO POSTOPERATIVE OIRD

Findings from these recent studies can allow the anesthesia professional to expand the assessment of OIRD risk beyond a preoperative OSA screen (Figure 2).<sup>8</sup> In addition to a mandatory preoperative screening of patients

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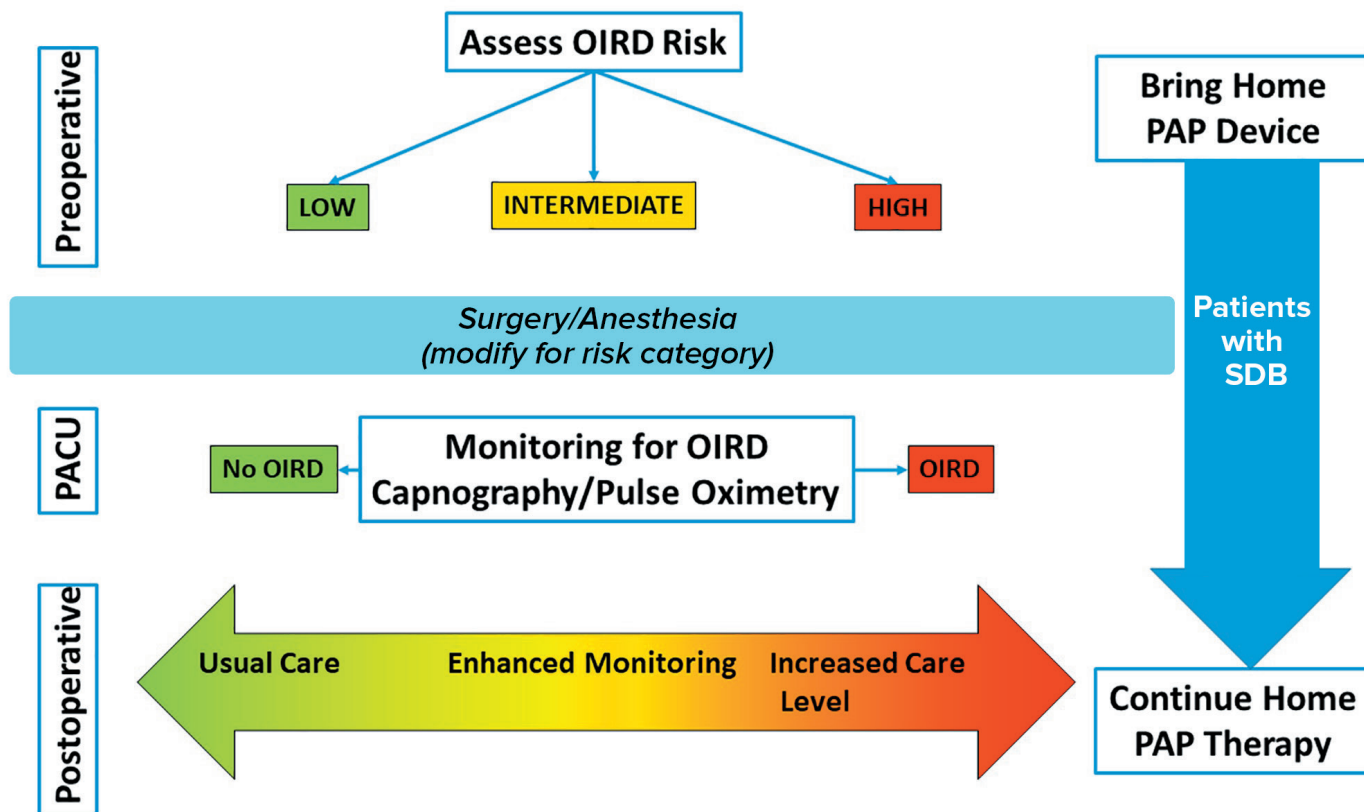


Figure 2: Proposed Clinical Pathway for Patients with Postoperative Opioid-Induced Respiratory Depression.

Clinical decisions on the postoperative level of care are complex and unique for each patient. Preoperatively, patients should have a risk assessment for respiratory depression. The surgical and anesthetic management should be tailored for this risk. During anesthesia recovery, patients' respiratory status should be monitored for various signs of respiratory depression. Postoperative management decisions regarding level of monitoring and care should be guided by preoperative status, intraoperative status, and the anesthesia recovery course. Home therapies for sleep-disordered breathing should be continued into the postoperative period. PACU indicates postanesthesia care unit; OIRD, opioid induced respiratory depression; SDB, sleep disordered breathing; PAP, positive airway pressure.

# Respiratory Depression (cont'd)

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for OSA,<sup>2,3</sup> risk for OIRD should consider advancing age and overall disease burden. Calculating the PRODIGY score for OIRD risk is easy, convenient, and can be incorporated into electronic health record platforms.<sup>7</sup> Patients with OSA should continue to use their continuous positive airway pressure or other devices in the postoperative period.<sup>2,3</sup> The anesthetic could be modified for higher risk patients utilizing regional blocks, shorter acting agents, and non-sedating analgesics (e.g., acetaminophen). Finally, during anesthesia recovery, patients should be monitored for episodes of respiratory depression.<sup>5,6,9</sup> Based on this information as well as the extent of the surgical procedure, the anesthesia professional could tailor the postoperative care plan based on level of risk in regards to postoperative disposition and level of monitoring where patients deemed higher risk for OIRD are specifically targets for escalation of postoperative care.

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*The author receives consulting and speaking fees from Medtronic and Merck.*

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## APSF Stoelting Conference 2023 Emerging Medical Technologies— A Patient Safety Perspective on Wearables, Big Data and Remote Care

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## LETTER TO THE EDITOR:

## Definition of Monitored Anesthesia Care

by Dinesh Ramaiah MBBS, and Gregory Rose MD, FASA

We appreciate the reprinting in the *APSF Newsletter* of the article from *Anesthesia & Analgesia*, (June 2022 • Volume 134 • Number 6, pages 1192–1200), entitled “Pro-Con Debate: Monitored Anesthesia Care Versus General Endotracheal Anesthesia for Endoscopic Retrograde Cholangiopancreatography” by Janik et al., and we hope that in reprinting it in the *APSF Newsletter*, there will be a larger and more diverse group of clinicians who will benefit from reading it.

However, the authors do not mention what they consider the definition of “MAC (monitored anesthesia care)” to be. We all know that with a propofol total intravenous anesthetic (TIVA) we can adjust the rate of infusion to go from light sedation to total general anesthesia. In fact, in our experience, when a proceduralist requests “MAC anesthesia,” they are virtually always requesting a propofol general anesthetic (GA) without an endotracheal intubation. Without knowing the authors’ definition of MAC, the debate is incomplete.

The fault with the nomenclature lies with us and the specialty. The introduction of propofol into clinical use greatly expanded the quality and the spectrum of MAC, but we have ended up victims of our own success. We are clinically able to almost always administer a “room air general anesthetic” when anyone asks for a MAC. And we have perpetuated the falsehood that a general anesthetic without intubation and inhalational agent use is MAC.

The pretense can be confusing to the patient as well as the proceduralist. The grossly inaccurate term “twilight sleep” is also a term which anesthesia professionals should avoid using, even though proceduralists use it a great deal in describing what the patient should expect.

We urge anesthetic professionals to put a stop to describing a TIVA general anesthetic without an endotracheal tube or supraglottic device as MAC, and to educate staff, patients, and families on the correct use of terminology to avoid confusion and potential lapses in safety that broadening the definition of MAC can cause.

*Dinesh Ramaiah, MBBS, is an associate professor of anesthesiology at the University of Kentucky College of Medicine in Lexington, Kentucky.*



*Gregory Rose, MD, is a professor of anesthesiology at the University of Kentucky College of Medicine in Lexington, Kentucky.*

*The authors have no conflicts of interest.*

## REPLY

by Jeffery S. Vender MD, MCCM, and Luke S. Janik, MD

We appreciate the interest of Ramaiah and Rose in our Pro-Con debate and understand their concern regarding the lack of clarity around the definition and application of the term “Monitored Anesthesia Care” (MAC). As authors of the “Con” section, we were asked to present why general endotracheal anesthesia (GEA) is preferred over MAC for endoscopic retrograde cholangiopancreatography (ERCP).

The American Society of Anesthesiologists (ASA) defined MAC in their 2018 Position on Monitored Anesthesia Care as “a specific anesthesia service performed by a qualified anesthesia provider, for a diagnostic or therapeutic procedure.”<sup>1</sup> This service includes pre-procedural assessment and optimization, administration of anesthetic agents, support of hemodynamic stability and airway management, and the diagnosis and treatment of clinical problems arising during the procedure.<sup>1</sup> The term MAC, in and of itself, does not describe the continuum of depth of sedation as defined in the ASA’s Continuum of Depth of Sedation: Definition of General Anesthesia and Levels of Sedation/Analgesia.<sup>2</sup>

The ASA recognizes that MAC “may include varying levels of sedation, awareness, analgesia, and anxiolysis as necessary,”<sup>1</sup> and acknowledges that deep sedation may transition to general anesthesia (with or without intention), thus requiring the skills of an anesthesia provider to manage the effects of general anesthesia on the patient and return the patient to a state of lesser sedation.<sup>3</sup>

We recognize your concern that MAC is often interpreted and/or employed as a general anesthetic without an endotracheal tube. That is not our definition of MAC. In addition, our position on MAC vs. GEA is influenced by the numerous concerns articulated in our paper, which contrasts the uniqueness of ERCP procedures with many other procedures that commonly employ MAC (e.g., prone/semi-prone position, shared airway, special procedure table, varying duration of procedure, etc.).

We share your concern that medical professionals, staff, patients, and families should understand the intent and provision of our anesthesia services.

*Jeffery Vender, MD, MCCM is a professor emeritus in the Department of Anesthesiology, Critical Care, & Pain Medicine at NorthShore University HealthSystem, Evanston IL.*

*Luke Janik, MD, is an assistant professor in the Department of Anesthesiology, Critical Care, & Pain Medicine at NorthShore University HealthSystem, Evanston IL.*

*Jeffery Vender, MD, MCCM, is a consultant for Fresenius Kabi, Medline Industries, and Medtronic. Luke Janik, MD, has no conflicts of interest.*

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# Medication Errors Related to Look-Alike, Sound-Alike Drugs—How Big is the Problem and What Progress is Being Made?

by Tricia A. Meyer, PharmD, MS, FASHP, and Russell K. McAllister, M.D, FASA

## BACKGROUND

Administering the wrong medication is one of the most feared complications in any field of medicine. Anesthesia professionals are some of the only providers who prescribe, prepare, and administer their own medications. Therefore, the perceived fear among anesthesia professionals is even greater due to this unique responsibility. Medication error may occur for a variety of reasons. One of the most common sources of medication error is related to look-alike and sound-alike (LASA) drugs as well as the often-similar appearances of the vials. LASA medications are typically thought of as medications that are similar in physical appearance related to packaging as well as medications whose names are similar in spelling or in the phonetic pronunciation. This is a difficult problem to quantify because it is a moving target due to ever-shifting manufacturer trade names, new medications on the market, changes in packaging between different manufacturers, and the ever-changing formulary at individual hospitals. Further complicating the issue is that pharmacies must pivot frequently by changing who they order medications from as they manage frequent drug shortages. The sudden change in appearance of a medication vial that the team has previously grown accustomed to can be disruptive and lead to increased risk of a medication error.

In a recently published article which reviewed the first 4000 incident reports in the webAIRS anesthetic incident reporting system from Australia and New Zealand anesthesia professionals, the authors found 462 incidents involved medication errors with incorrect dosing and substitution as the top-ranked error categories.<sup>1</sup> A primary contributing factor for the substitution category were look-alike drugs.<sup>1</sup> LASA-related mistakes are compounded when the involved medications are either high alert (e.g., opioids, insulin, anticoagulants, neuromuscular blocking agents, etc.) or hazardous (e.g., chemotherapy agents) or the route of administration is potentially dangerous (e.g., intrathecal). The issue is further compounded by the fact that each vial will have at least three names (chemical name, generic name [may vary by country], and often more than one brand or trade name). In addition, the medication vials can share many similarities in appearance such as color of the vial medication cap as well as similarities in the labels. (See Figures 1a, 1b, and 1c.)

## INCIDENCE

It is difficult to know how many LASA errors occur, but it has been estimated that LASA errors account for as much as 25% of medication errors.<sup>2</sup> Medication pairs that look-alike sound-alike may be one of the most common contributing factors to medication errors.<sup>3,4</sup> Attempts by regulatory agencies, hospitals, and practitioners to eliminate these LASA errors have thus far been unsuccessful, and there are numerous recent examples in the literature and news.

## CASES OF LASA ERRORS

There have been several very high-profile medication error cases in the recent past. The one that received the most attention recently occurred when a nurse intended to give a benzodiazepine (Midazolam [Versed]) to a patient to alleviate procedural anxiety. However, she entered the letters V-E into the automated medication dispensing cabinet (AMDC) and vecuronium was offered by the AMDC as the medication option to dispense and was chosen by the nurse. She bypassed several safety measures in order to withdraw and administer vecuronium to the patient, which led to the ultimate demise of the patient. The nurse was eventually tried and convicted of criminally negligent homicide. One of the primary issues was felt by many to be an unfamiliarity with the medications involved and the fact that multiple safety barriers were ignored in the process including warnings from the AMDC and on the medication vial's cap and label.<sup>5</sup>

There have also been recent inadvertent administrations of the wrong medications intrathecally. Most notably, tranexamic acid and digoxin have been mistakenly administered into the subarachnoid space during attempted spinal block (Figure 2). These examples are attributed to the similar appearance of the ampules or vials for these medications. The mistaken administration of tranexamic acid intrathecally resulted in seizures and ventricular arrhythmias in the described cases.<sup>6-8</sup>

Intrathecal administration of digoxin has been associated with paraplegia and encephalopathy (Figure 3).<sup>9,10</sup> A recent review of the literature found at least 8 incidences of accidental intrathecal injection of digoxin.<sup>10</sup> Additionally, the review found a total of 33 instances of cardiovascular drugs accidentally administered via the neuraxial route often associated with devastating outcomes.<sup>10</sup> In this review, incorrect visual inspection of look-alike



Figure 1a: Look-alike vials of epinephrine and ephedrine.



Figure 1b: Look-alike vials of ondansetron and phenylephrine.



Figure 1c: Look-alike vials of metoclopramide and ondansetron.

# Look-Alike Medication Errors Remain a Patient Safety Issue

From "Medication Errors," Preceding Page



Figure 2: Look-alike vials of tranexamic acid, ropivacaine, and bupivacaine. While label colors and vial sizes are different, the caps are blue and if stored upright, may lead to selecting a vial based on cap color. (Used with permission from ISMP).<sup>8</sup>

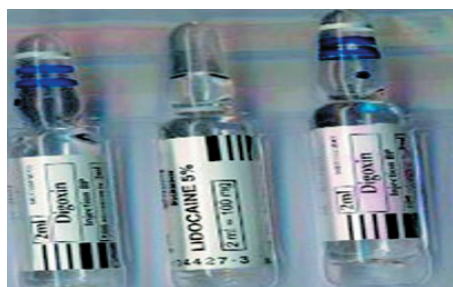


Figure 3: Look-alike vials of digoxin and lidocaine. (Used with permission from Anesthesia & Analgesia).<sup>9</sup>

ampules was found to be the most common factor in the mistaken administrations.

An additional two examples occurred in two separate instances when insulin was accidentally administered instead of an influenza vaccine in a group care facility and for an employee group. These incidents resulted in the hospitalization of multiple symptomatic individuals.<sup>11,12</sup> Both of these instances were attributed to the similar appearances of the two vials.

## PREVENTION TECHNIQUES

Regulatory agencies such as The Joint Commission (TJC) and the Food and Drug Administration (FDA) have identified these LASA errors as a focus in the past several years and have made efforts to eliminate them through education and tools to decrease the risk. The Joint Commission recommends that all hospitals have their own LASA list of medications. Instead of simply downloading one from the internet unchanged, they recommend that each site personalize the list to only include medications that are administered at the individual sites and utilize internal error reports associated with LASA drugs.<sup>13</sup> They also recommend that the lists

ce <b>FAZ</b> olin	dexame <b>THASONE</b>	<b>DOBUT</b> amine	Huma <b>LOG</b> *
cefo <b>TE</b> tan	desmede <b>TOM</b> idine	<b>DOP</b> amine	Humu <b>LIN</b> *
cefo <b>OX</b> itin	diphenhydr <b>AMINE</b>	e <b>PHED</b> rine	hydr <b>ALAZINE</b>
cef <b>TAZ</b> idime	diaze <b>PAM</b>	<b>EPINEPH</b> rine	<b>HYDRO</b> morphone
cef <b>TRIA</b> Xone	dil <b>TI</b> Azem	fenta <b>NYL</b>	hydro <b>OX</b> Yzine
chlorpro <b>MAZINE</b>	<b>LOR</b> azepam	<b>SUF</b> entanil	Solu- <b>CORTEF</b> *
clo <b>NID</b> ine	ni <b>CAR</b> dipine	<b>PENT</b> obarbital	<b>SOLU</b> -Medrol*
qui <b>NID</b> ine	ni <b>FED</b> ipine	<b>PHEN</b> obarbital	

\*Brand names, which always start with a capital letter.

Figure 4: Tall Man Lettering of some drugs used in the perioperative setting. (<https://www.asahq.org/standards-and-guidelines/statement-on-labeling-of-pharmaceuticals-for-use-in-anesthesiology>) (Reprinted with permission of the American Society of Anesthesiologists, 1061 American Lane, Schaumburg, Illinois 60173-4973).

should be reviewed and updated at least annually.

In addition, the FDA has incorporated the "tall man lettering" (TML) system for drug names that may be confused due to similarities in appearance or sound.<sup>14</sup> The TML system is a technique that utilizes uppercase lettering in a portion of the drug labeling where confusion may occur. For example, the written appearance of dexmedetomidine and dexamethasone are similar and could lead to confusion. Using TML, they would appear as dexmede**TO**-Midine and dexameth**ASONE**, drawing attention to the portions of the name which are dissimilar. Medications that receive this labeling modification are typically chosen because of similarities that occur in the spelling of the medication name, especially if these similarities have previously resulted in a reported drug error. The FDA also developed a computer analysis tool that measures the phonetic and orthographic similarities of the planned brand name of the medication against datasets from different sources including preexisting drug brand and generic names. The FDA's intention is to assist in developing proprietary names for drugs that are less likely to cause errors.<sup>15</sup> The American Society of Anesthesiologists adopted a statement on the labeling of pharmaceuticals for use in anesthesiology in 2004 and it was most recently updated in 2020.<sup>16</sup> This document addresses the hazards of LASA drugs and includes a list of medications frequently used in anesthesiology which have been identified as high risk for LASA and the medication names are formatted using the TML system (Figure 4).

Since 2008, the Institute for Safe Medication Practices (ISMP) has maintained a list of often confused drug names related to look-alike and sound-alike characteristics.<sup>17</sup> However, due to lack of standardization in the packaging of medications, an additional list of medication

that are similar in appearance in the packaging is difficult to compile.

Understanding that LASA medication errors can occur at every stage of the medication use process, ISMP and other groups have developed counter measures for each phase (procuring, prescribing/ordering, verifying, dispensing, administering, and stocking/storing).<sup>18</sup> The administration phase may be the most vulnerable stage, as it is the least likely stage to catch an error.<sup>19,20</sup> The following is a partial list with abbreviated strategies for problematic LASA medications from the Institute of Safe Medication Practices.<sup>18</sup>

## PURCHASING

- Avoid stocking/purchasing medications in which the manufacturer's trademark symbol/logo is larger than name of product.
- Ensure that names are evaluated by practitioners who use them before adding to formulary/inventory.
- Ask pharmacy to identify LASA concerns for medications that are new or shortage substitutes

## ORDERING/PRESCRIBING

- Avoid abbreviations (e.g., MgSO<sub>4</sub>, TXA), stemmed, or stems (e.g., "caines"), or shortened names (e.g., "dex"). Communicate the full generic name and/or brand name.
- Brand and generic name should be displayed for problematic look-alike names in the medication description field, on product selection menus, and for search choices
- Build order sets with the indications for problematic names (e.g., hydroXYzine for pruritus, hydrALAZINE for hypertension).

See "Medication Errors," Next Page

# Medication Errors (cont'd)

From "Medication Errors," Preceding Page

## ADMINISTRATION

- Before administering a medication, read the container and/or pharmacy label when obtaining from unit stock or AMDC. Never rely solely on a partially turned label, the color of a label/cap, the auxiliary warning, or company graphics to identify a product.

## STOCKING/STORING

- In anesthesia carts/trays, organize vials in a label-up instead of cap-up position, and avoid close proximity with LASA names (or look-alike packaging and labeling, particularly cap colors).

## NOMENCLATURE

- For problematic look-alike medication names, use tall man lettering on electronic prescribing drug selection screens, order sets, AMDC screens, smart infusion pump screens, medication administration records, and any other drug communication tools.
- If short names are permitted to search for products or populate fields without entering the full medication name, require practitioners to enter at least 5 letters during a drug name search to reduce the number of medications, including those with LASA names, that appear together on a screen. (<https://www.ismp.org/resources/adopt-strategies-manage-look-alike-and-or-sound-alike-medication-name-mix-ups>)

## CONCLUSION:

LASA medication errors have been described as a preventable threat to a patient safety. The oversight of the LASA drug dilemma is not just the responsibility of the frontline health care professional. There have been numerous strategies recommended, but there are multiple strategies for each of the stages of the medication use process and many are challenging to implement, particularly in a busy, fast-paced preoperative, intraoperative, and postoperative setting. Currently, there is little that can be done about existing drug names with LASA implications other than the suggested strategies. Health care professionals, safety groups, and professional organizations should continue to work with manufacturers, regulators, and naming entities to explore opportunities to minimize the LASA risks for drugs that are either new to the market or in the pre-marketing stage.<sup>15</sup>

For more information, please visit the APSF website "Look-Alike Drug Vial: Latest Stories & Gallery" at: <https://www.apsf.org/look-alike-drugs/#gallery>

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Russell K. McAllister has no conflict of interest. Tricia A. Meyer is a speaker/consultant for Acacia Pharma; Consultant for Heron.

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## Vision

The vision of the Anesthesia Patient Safety Foundation is to ensure that no one shall be harmed by anesthesia care.

## & Mission

The APSF's mission is to improve the safety of patients during anesthesia care by:

- Identifying safety initiatives and creating recommendations to implement directly and with partner organizations
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# A Review of Adverse Events Associated with Perioperative Intrahospital Transport of Pediatric Patients and Guidance on Improving Safety

by Anila B Elliott, MD, Anne Baetzel, MD, Jessica Kalata, MD, and Bishr Haydar, MD

Intrahospital transport is a common occurrence for many hospitalized patients. Critically ill children are an especially vulnerable population who experience preventable adverse events at least once a week, on average.<sup>1</sup> Transporting these patients throughout the hospital introduces additional hazards and increases the risk of adverse events.<sup>2</sup> The transport process can be decomposed into a series of steps, each incurring specific risk. These risks are numerous and few of these risks are specific to the transport process. There is a paucity of literature available on pediatric intrahospital transport and related adverse events. Therefore, we recently reviewed the Wake Up Safe database, a pediatric anesthesia quality improvement initiative across member institutions to disseminate information on best practices, for pediatric perioperative adverse events associated with anesthesia-directed transport. Below we present several examples of airway and respiratory events taken from the database and discuss the complexity of the transport process.

## AIRWAY AND VENTILATION MANAGEMENT CASE VIGNETTES

**Case #1:** 2-week-old, former 32-week premature infant underwent largely uneventful exploratory laparotomy in the operating room (OR) for presumed necrotizing enterocolitis. On arrival to the intensive care unit (ICU), the infant was transitioned to the ventilator with assis-

tance from the respiratory therapist. The ventilator tubing fell, dislodging the endotracheal tube (ETT). The patient rapidly deteriorated requiring chest compressions and reintubation. After several minutes of cardiopulmonary resuscitation (CPR), return of spontaneous circulation was achieved and the patient stabilized over the next several hours.

**Case #2:** 8-month-old infant with complex medical history including congenital hydrocephalus status post ventriculoperitoneal shunt placement, recurrent pneumonia, and current respiratory failure was scheduled for tracheostomy placement. Patient was transported to the operating room with an ETT *in situ*. Following transfer from patient stretcher to the OR table, the team also converted the patient from a state of spontaneous ventilation with a Jackson-Rees circuit to mechanical ventilation. Within one minute of this transition, the patient became difficult to ventilate, acutely hypoxemic, and subsequently asystolic. CPR was initiated and a repeat laryngoscopy was performed due to concern for ETT dislodgement. The ETT was replaced and shortly thereafter, there was restoration of normal sinus rhythm. The post-event review diagnosed bronchospasm and noted that a routine morning chest x-ray from that day showed the ETT positioned in the right bronchus. This was not reviewed by the anesthesia team prior to transport, in part due to task overload.

**Case #3:** Ventilatory changes after sedation and neuromuscular blockade: 11-month-old infant in the ICU, ETT *in situ*, who required reoperation for bleeding following Tetralogy of Fallot repair earlier in the day. In preparation for transport to the operating room, the team administered midazolam and rocuronium. Shortly after medication administration, the patient became difficult to hand ventilate. The patient quickly became hypoxic, followed by pulseless electrical activity. CPR was initiated and during resuscitation, a large mucus plug was suctioned from the ETT. Afterwards ventilation improved significantly and return of spontaneous circulation was achieved. The remainder of the procedure and the perioperative transport was without further incident.

## AIRWAY AND VENTILATION MANAGEMENT RISKS

The majority of complications in the transport of critically-ill and anesthetized pediatric patients are respiratory in nature.<sup>3</sup> From the Wake Up Safe data, approximately 40% of transport-related events occurred in patients less than or equal to 6 months of age, and a large majority occurred in patients with American Society of Anesthesiologists (ASA) 3 status or greater.<sup>3</sup> Of the 15 unplanned extubations reported, 14 occurred in patients less than or equal to 6 months of age and 11 of 15 occurred in patients less than 4 kg. One reason for the higher rate of unintended extubation is the practice of positioning the ETT between the first and second thoracic vertebrae in the neonatal ICU, which reduces nonuniform lung aeration, localized pulmonary interstitial emphysema, and pneumothorax.<sup>4</sup> However, this position may increase risk for inadvertent extubation if there is extension of the head/neck that may lead to cephalad movement of the ETT.<sup>5,6</sup> On the contrary, ETTs that are positioned close to the carina can lead to mainstem intubation with inadvertent caudal movement, leading to hypoxemia, hypercarbia, pneumothorax, and mucosal injury.<sup>4,7</sup> Therefore, we recommend review of the most recent chest x-ray and positioning the ETT in the mid-thoracic trachea for transportation to mitigate this risk. Auscultation of bilateral breath sounds and utilization of continuous capnography can also mitigate these risks. A pillow can be used to help stabilize the head and care taken to avoid any tension on the ETT during transport. During transportation, the removal of these ventilator circuit holders that off-load tension while in the ICU can lead to ETT obstruction from kinking of smaller ETTs (Figure 1a and Figure 1b). Caution should be taken to ensure the ETT and circuit

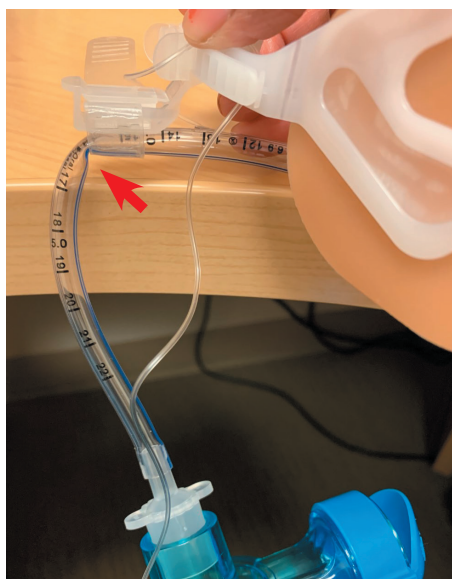


Figure 1a: Endotracheal tubes secured with Hollister (Hollister Inc., Libertyville, IL) endotracheal tube fastener, with kink when attached to Ambu bag (Ambu Inc., Columbia, MD) without offloading the weight of the circuit/ventilation system.

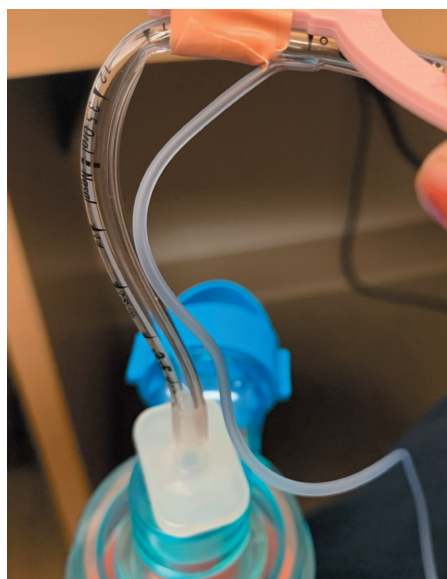


Figure 1b: Endotracheal tubes secured with NeoBar ET tube (NeoTech Products LLC, Valencia, CA) with kink when attached to ambu bag (Ambu Inc., Columbia, MD) without offloading the weight of the circuit/ventilation system.

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## Effective Teamwork and Communication is Integral in Reducing Risk During Transport of Intubated Pediatric Patients

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are positioned in a way to prevent kinking by off-loading the weight of breathing circuits used during transportation. A transport ventilator provides more consistent minute ventilation and will avoid hypo- or hypercarbia in high-risk patients.<sup>8,9</sup> However, it will not prevent the risks associated with inappropriate ETT positioning, kinking, or obstruction. The specific devices that secure ETT to the face can vary from unit and institution, but typically securing devices that minimize skin breakdown are preferred in pediatric patients in the ICU. Furthermore, the seemingly simple act of moving an intubated patient can be quite stimulating, which can result in sympathetic activation, leading to tachycardia, agitation, and coughing, which may lead to bronchospasm from airway irritability. Movement may result in altered pulmonary compliance and the ability to provide adequate oxygenation and ventilation.

Invasive ventilation is a risk factor for mucus plugging given impaired mucociliary clearance<sup>10</sup>; add to that sedative or neuromuscular blocking agents and the intrinsic ability to cough and expel mucus is further impaired. During transportation, patients are typically transported without heat and humidification of airway gases which can perpetuate mucus plug formation. Many clinicians elect to administer neuromuscular blockade along with sedation medication to intubated patients. The benefits of giving neuromuscular blockade for transport include eliminating ventilator dyssynchrony, which can be obviated by using a modern portable ventilator. Neuromuscular blockade can reduce the risk of unplanned line or tube removal in agitated patients and also reduce transport team workload. There are also potential unintended consequences when using neuromuscular blockade for transportation of intubated pediatric patients. It has been associated with worsened mucus plugging of the endotracheal tube leading to two cardiac arrests in two children through unclear mechanisms.<sup>3,11</sup> It eliminates patient respiratory effort, which may require changes in ventilator settings and can worsen an existing endotracheal tube leak. Additionally, sedative medications may reduce sympathetic tone creating the potential for hypotension, and neuromuscular blockade may reduce basal metabolism which may lead to hypocarbia. The decision to use neuromuscular blocking agents and sedatives during the transportation of pediatric patients should be predicated on the aforementioned advantages and disadvantages.

### Teamwork and Communication Strategies to Reduce Risk During Transport of Pediatric Intubated Patients

40% of transport-related events occurred in patients <6 months, from Wake Up Safe data.

#### Understanding Airway and Ventilation Management Risks



#### Effective Communication and Teamwork

Checklists may help prevent task overload during emergencies and transportation.

~75% of respiratory complications occur in the postoperative period.

#### Identifying and Mitigating Risk



#### Culture of Safety

A positive safety climate and effective team processes are associated with fewer adverse events during transport of critically ill patients.

### IDENTIFYING AND MITIGATING RISK

Before any transport of a critically ill child is undertaken, the risks, benefits, and alternatives should be carefully considered. Potential for harm includes line dislodgement, derangements in hemodynamics, unplanned extubation, hypoxemia, hypo- and hypercarbia, hemorrhage, pneumothorax, elevation of ICP in at-risk patients, hypothermia, and increased risk for hospital-acquired infections.<sup>3,12-15</sup> If a patient is on an advanced mode of ventilation, such as high-frequency oscillatory or jet ventilation (HFOV/HFJV), or on an extra-corporeal device, such as extra-corporeal membrane oxygenation (ECMO), there should be a multidisciplinary discussion regarding the risk of transportation to the radiology, procedural, or operating room suites versus having their diagnostic or therapeutic procedure done at the bedside. Whenever feasible, bedside alternatives should be strongly considered for high-risk patients.

Postoperative transport appears to be a period associated with numerous potential complications. Almost 75% of respiratory complications and 70% of cardiac arrests occurred in the postoperative period.<sup>3</sup> For patients who received anesthetics, patients may emerge from anesthesia during transport. Many patients are extubated prior to postoperative transport,

during which it is often more difficult to detect or treat respiratory adverse events. This is due to the increased cognitive load of navigating hallways, availability of emergency equipment, and assistance. In fact, task overload was often noted as a secondary contributor in these events.<sup>3</sup>

### EFFECTIVE COMMUNICATION AND TEAMWORK

We recommend the use of standardized handover tools, appropriate training of providers directly involved in transportation, and close communication with ordering clinicians regarding the possible risks associated with transporting patients throughout the hospital. Freely available and validated tools are available here: <https://www.handoffs.org/patient-handoff-resources/>. Each team member involved in transportation should have a specific role, with a dedicated provider for airway management, medication administration and maneuvering the bed and other devices, as needed. It may be “just another imaging study” to facilitate a diagnosis or a simple procedure to progress care, but if not weighed carefully, it could lead to serious and catastrophic complications for patients, families, clinicians, ancillary staff, and even visitors.

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# A Positive Safety Climate May Reduce Adverse Events During Intrahospital Transport of the Critically Ill

## From “Transport and Safety,” Preceding Page

Whenever possible, consideration should be given to available bedside alternatives. Checklists to ensure that all pertinent information is transferred correctly as well as confirming necessary equipment and emergency medications are available, may help this sometimes overwhelming task seem more manageable and prevent information from being lost. Bedside nurse handover for direct patient care report noting frequency of interventions such as fluid/medication boluses or infusion changes or ETT suction frequency may provide context for changes in patient status.

Critical events are best managed by a team with a clear leader, effective communication, and clear roles for team members.<sup>16</sup> These principles have been applied to cardiac arrest, life support, trauma, and during complex resuscitations in the operating room. These principles can also be applied to the transport of critically ill and anesthetized children. A team leader should be clearly identified, and for unstable or complex patients, they should have no other tasks other than leading the team. Ensuring there are the appropriate number of skilled team members dedicated to every task during transportation is important. The bed may be pushed by ancillary staff so the medical and nursing teams can focus on the care of the patient. Patients who rely on physiologic support such as a ventilator, vasoactive infusion, or mechanical circulatory support require dedicated and appropriately skilled staff for each task. Patients who require frequent sedative, vasopressor, or hypertonic saline boluses may require a provider be dedicated solely to these tasks during transport.

## CULTURE OF SAFETY

Creation of local standardized processes for transport and team training should improve the culture of safety around transport. There is no national or international standard of care for the intrahospital transportation of patients, and there are limited data to validate a specific transport team at this time. As described above, careful risk assessment is essential. Patients with reliance on lifesaving technologies such as mechanical ventilation, vasoactive medications or a tracheostomy will require a transport team knowledgeable, skilled, and experienced at using those technologies, with appropriate backup equipment and medications. Two studies identified junior trainee physicians to have

experienced higher rates of adverse events than senior trainees/faculty.<sup>17,18</sup> When possible, a senior member of the team should transport with critically ill patients and help train junior clinicians. A recent multicenter study showed that a positive safety climate and effective team processes were associated with fewer adverse events during intrahospital transport of critically ill adults.<sup>19</sup> Team experience and mandatory training also reduced adverse events.<sup>19</sup>

## CONCLUSIONS

Intrahospital transport represents the intersection of numerous patient safety concerns—airway management, early recognition of clinical deterioration, communication, and teamwork.<sup>20</sup> In our recent review of pediatric intrahospital transport events in the Wake Up Safe database, the populations most at risk were those less than or equal to 6 months of age and children with more severe medical comorbidities. Despite the relatively short time that intrahospital transport requires, this phase of care may represent up to 5% of all pediatric anesthesia adverse events.<sup>3</sup> Standardized risk assessment and resource allocation and structured handovers are an essential way to begin to improve our care during this potentially tumultuous period.

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# Medical Alarms: Critical, Yet Challenging

by Kendall J. Burdick, MD; Nathan Taber, MD; Kimberly Albanowski, MA; Christopher P. Bonafide, MD, MSCE; and Joseph J. Schlesinger, MD, FCCM

## INTRODUCTION

Ensuring patient safety during surgical procedures remains at the forefront of quality improvement initiatives, as supported by APSF. In addition to administering and monitoring anesthesia, clinicians manage patient vital signs and overall well-being throughout the surgery, often in a very distracting environment.<sup>1</sup> This is only made possible with the crucial help of medical alarms. These alarms are designed to alert the clinician and other medical staff to changes in patient vital signs, such as a drop in blood pressure or a decrease in oxygen saturation. However, clinicians often need to filter out the extraneous stimuli of the operating room to recognize and respond to these alarms. There are many disturbances that can draw the clinician's attention away from the patient, including equipment delays, personal conversations, and pager/electronic device use.<sup>1</sup> Furthermore, without the added confirmation of the patient's subjective experience, clinicians must rely strictly on the data presented by the monitor, highlighting the importance of accurate and clinically actionable alarms. Medical alarms are an essential component of the clinician's toolkit and help to ensure the safety of patients undergoing surgical procedures.

Alarm fatigue occurs when a user becomes desensitized to alarms due to excessive, non-actionable or invalid alarms, ultimately resulting in a delayed or no response.<sup>2,3</sup> Alarm fatigue contributes to missed alarms and medical errors resulting in death, increased clinical workload and burnout, and interference with patient recovery—making it a safety issue that spans clinician to patient.<sup>4</sup> The multifaceted approach to alarm fatigue should include consistent equipment, delaying alarm activation, and reducing alarm volume.<sup>2</sup> In this article, we highlight the continued need for patient safety, and recent clinical and engineering advances in mitigating alarm fatigue.

Alarms are made to alert staff to a significant clinical change or a required action, though many can be nonactionable or invalid. Nonactionable alarms are alarms that require no action by the clinical care team and have been measured to comprise up to 85% of clinical alarms.<sup>5</sup> In addition to nonactionable alarms, alarm fatigue can result from frequent invalid alarms.<sup>6</sup> Invalid alarms occur due to device artifact or error, such as an electrocardiogram reporting ventricular tachycardia when the patient is actually in sinus rhythm and has a loose electrocardiogram lead. Invalid alarm rates have been measured to range from 85%



to 99.4% of all clinical alarms.<sup>7</sup> When alarms are consistently nonactionable or invalid, the priority for a user to respond may be lost or replaced with exasperation, accumulating in desensitization and dissatisfaction among health care staff.<sup>8</sup> While individual personality traits and workload are not easily modifiable, alarm tones and thresholds are, making alarm research and innovation the key to decreasing alarm fatigue and desensitization.

These various factors converge to exacerbate alarm fatigue and subsequent effects of nonoptimal medical alarms. Fortunately, there are efforts underway from safety organizations, clinical workflow, and engineering innovations to prevent and combat these workplace and patient risks.

## PATIENT SAFETY

The APSF recommends the use of medical alarms to help improve patient safety and reduce the risk of adverse events during the administration of anesthesia and perioperative period.<sup>9</sup> Similarly, the American Society of Anesthesiologists Equipment and Facilities Committee (of which author, Joseph Schlesinger, is a member) prioritizes workplace safety and plans to release an "Alarm Position Statement" in late 2023. Additionally, addressing alarm fatigue and alarm impact on patients has been a focus for safety regulatory bodies. Alarm fatigue has been named a Top 10 safety priority for The Joint Commission every year since 2013.<sup>10</sup> ECRI (originally founded as the Emergency Care Research Institute) has named missed alarms and alarm overload as a "Top 10 Health Technology Hazard" every year from

2012 to 2020.<sup>11</sup> In 2011, the Association for the Advancement of Medical Instrumentation (AAMI) held a Medical Device Alarms Summit focused on alarm challenges, patient safety, and alarm research. Since then, AAMI has provided a variety of webinars and research grants to support the investigation and innovation of alarm fatigue prevention.

These patient safety-focused organizations remain dedicated to the improvement of the clinical environment, with a primary focus on innovating medical alarms. As a result of their dedicated safety initiatives and through the efforts of researchers around the globe, numerous advancements in medical practice and alarm design have been accomplished and are still underway.

## CHANGES TO WHEN ALARMS SOUND

An effective adjustment to clinical alarms has consisted of individualizing alarm parameters<sup>2</sup> to increase precision. Individualizing parameters consists of modifying the threshold of an alarm to reflect an individual patient's physiologic status as compared to an unmodified default clinical alarm setting. Adjustments include alarm threshold tightening, adding delay periods between detection and alarm, disabling nonactionable alarms, and adjusting volume based on priority. These adjustments have been shown to reduce alarm rates (specifically nonactionable)<sup>12</sup> and perceived workload.<sup>13</sup> Evidence-based software has been developed to assist in safe and effective personalized thresholds. For example, Halley

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# Multisensory Alarms Provide Alerts Using Different Senses, Such as Sound, Light, and Vibration,

From “Medical Alarms,” Preceding Page

Ruppel, PhD, RN, and colleagues utilized and evaluated the impact of an alarm parameter customization software in an ICU.<sup>14</sup> They found that the alarm parameter customization software significantly reduced the number of alarms by up to 16%, and the duration of alarms by up to 13%. This key study has shown that alarm parameter customization can have a profound impact on the alarm atmosphere and function in a hospital, especially for clinicians who frequently respond to alarms.



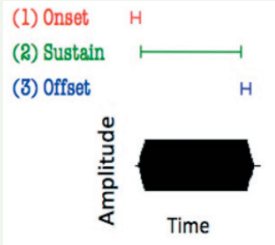
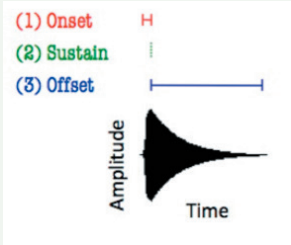

### CHANGES TO HOW ALARMS SOUND

In addition to adjusting when an alarm sounds, innovating how an alarm sounds is an opportunity to make them more learnable, communicative, and tolerable. For anesthesia professionals, alarms are frequently concurrent and occur during procedures that require visual attention, making the need to have clear and communicative alarms critical.

In 2006, the International electrotechnical commission (IEC) established an international standard for medical alarms 60601-1-8.<sup>15</sup> However, alarms that abided by the IEC 60601-1-8 were difficult to learn and distinguish from concurrent alarms, as they used the same melodic structure, offering little individualizing detail between simultaneous alarms.<sup>16,17</sup> As a result, a group of researchers created auditory icons as an alternative to the standard auditory alarms. Auditory icons mimic and/or represent the parameter that they are monitoring. For example, instead of the monotone beeping of a standard heart rate monitor, an auditory icon sounds like the “lub-dub” of a heartbeat (Table 1, [additional IEC icons available for listening](#)). These auditory icons were found to be easier to learn and more localizable than the traditional alarms tested.<sup>18</sup> During clinical simulations, participants performed better when using auditory icons, including the ability to discriminate between simultaneous alarms and to identify alarm type.<sup>19</sup> As a result of this strong supporting evidence, the IEC updated the 60601-1-8 in 2020 to include auditory icons as a supported medical auditory alarm.<sup>20</sup> By incorporating auditory icons, alarm systems can optimize their notification designs in an evidence-based manner.

In addition to alarms being difficult to discriminate, annoyance with the alarm sound itself has also been documented as a contributor to alarm fatigue in clinicians.<sup>21</sup> Amplitude envelope describes the “structure” of a sound—where a flat envelope (that of a typical alarm) would have a quick onset and offset, a decaying envelope (such as the noise of clinking wine glasses) has a quick onset, followed by a

Table 1: Comparison of Traditional vs Novel Alarm Design.

Category	Traditional alarm	Novel alarm
Auditory Icons	Tonal Alarm: Simple melodic structure 	Auditory Icon: Mimics physiologic structure 
Amplitude Envelope	Flat Envelope <sup>28</sup> : Quick onset, quick offset 	Decaying Envelope <sup>28</sup> : Quick onset, gradual offset 
Multisensory alarm	Tonal Alarm (as above)	Visual display of multisensory Apple Watch, with vibration and auditory alarm <sup>25</sup> 

gradual alarm decline (Table 1). The literature has shown that using a decaying amplitude envelope significantly reduces alarm annoyance without interfering with learning or performance—while also preserving an alarm’s melodic and rhythmic structure.<sup>22,23</sup>

Even simpler than re-engineering the auditory alarm structure, decreasing the volume at which an alarm is delivered has shown great benefits. At baseline, hospitals are noted to regularly exceed the World Health Organization’s recommendations for the clinical environment volume; however, alarms delivered at lower volumes may still elicit similar accuracy of alarm identification. One study found that participant performance in interpreting and responding to patient crises had a minimal difference when an alarm was delivered at a volume 11 dB below the background noise, compared with the typical 4 dB above background noise.<sup>24</sup> Furthermore, devices, such as the Dynamic Alarm Systems for Hospitals, or D.A.S.H., have been developed

and patented to regulate alarm volume based on the surrounding noise level.<sup>25,26</sup> These systems provide important benefits to improve the auditory environment’s saturation with unnecessarily loud alarms.

Traditionally, medical alarms have relied primarily on the auditory sense, with partial notification through visual stimuli, such as a monitor. Multisensory alarms provide alerts using different senses, such as sound, light, and vibration, making them more noticeable in a busy operating room environment. Using multiple senses allows clinicians to respond to changes in a patient’s condition more rapidly and take appropriate action, improving patient safety and outcomes. Multisensory alarms also provide the opportunity to use wearable notification systems, such as an ankle band or smart watch (Table 1). When combining tactile (similar to vibration), visual and auditory stimuli into a wearable smart watch, undergraduate participants showed better accuracy, reaction time, and

See “Medical Alarms,” Next Page

# Integration of Multisensory Alarm Devices Is Feasible and May Improve Patient Safety

From “Medical Alarms,” Preceding Page

decreased mental workload in feasibility studies.<sup>27</sup> Studies are currently underway with clinical end-users to confirm the workflow and performance benefit. Based on these and more studies, integration of multisensory alarm devices is feasible and may relieve the auditory burden of the medical environment and increase the overall quality of care and patient safety.

Research and engineering teams dedicated to the modernization and innovation of medical alarms through auditory icons, adjustments to alarm character, and use of multisensory devices are crucial contributors to the prevention of alarm fatigue.

## CONCLUSION

Anesthesia professionals play a critical role in monitoring a patient's vital signs and adjusting the anesthetic care as needed to ensure the patient remains in a safe and stable condition. They are also trained to respond quickly to medical emergencies that may arise during a procedure. Both roles require medical alarms to be safe and effective. This constant vigilance is essential to ensuring the best possible outcomes for patients undergoing medical procedures, making alarm design and optimization critical.

Patients in all medical settings rely on clinicians to care for and react to all their medical needs. Currently, the demanding workplace environment challenges staff with suboptimal alarm technology, contributing to alarm fatigue and burnout. By focusing on patient and provider safety, clinical workflow, and alarm technology, researchers, and policy makers can transform the medical alarm realm into one that is evidence-based and personnel-focused.

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*The authors have no conflicts of interest.*

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## RAPID Response

to questions from readers

## Visual Illusion Results in Malfunction of Anesthesia Machine Sensors

by Steven Simon, Bryan Gaeta, CRNA, Enrique Pantin, MD, and Antonio Chiricolo, MD

A 57-year-old male underwent a robotic assisted ventral hernia repair under general endotracheal anesthesia. This was the first case of the day and the Avance CS<sup>2</sup> (GE Healthcare, Chicago, IL) machine passed the automated check. There was no reported malfunction of the anesthesia machine prior to this event, and induction of the patient was uneventful. Approximately one hour into the case, we noticed that the inspiratory concentration of carbon dioxide had increased and ranged between 4 and 6 mmHg. The absorbent was inspected, and although not fully spent, the absorber canister was replaced. At this time, the condenser reservoir appeared empty as shown in Figure 1, Exhibit A. Replacement of the absorber had no effect on the reported levels of carbon dioxide, and we proceeded to change the airway module D-fend water trap connected to the gas sampling line and subsequently the GE CARESCAPE Respiratory Module (GE Healthcare, Chicago, IL) without any change in the inspiratory CO<sub>2</sub> concentration. At this point, we also noticed that the end-tidal concentration of volatile anesthetic was not consistent with the concentration being delivered. The sevoflurane



Figure 1A

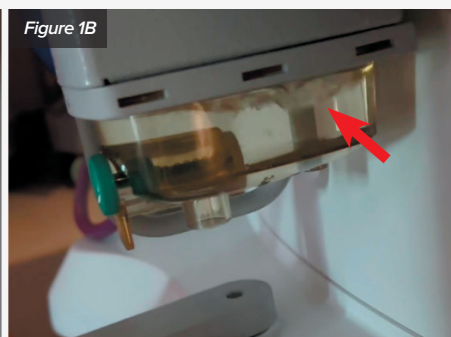


Figure 1B

Figure 1: Exhibit A and B demonstrating the full condenser reservoir undisturbed (A) and the same condenser reservoir when shaken (B).

vaporizer was set to 4%, yet the inspiratory concentration was significantly lower than expected at 1.6%. Intravenous anesthetic was initiated to maintain adequate minimum alveolar concentration while we continued to troubleshoot. Further inspection revealed that the fraction of inspired oxygen was reported at 21% while the anesthesia machine was set to deliver 50%. Moreover, the patient's oxygen saturation remained within normal ranges throughout the entire procedure. Up to this moment, the fresh gas flow was set at 2 liters per minute with 50% oxygen, and we then raised the flow to 4 liters per minute at 50% oxygen with no change in measured oxygen, CO<sub>2</sub>, and agent concentrations. At this point, we contacted our biomedical team with a suspicion that the one-way valves within the circuit may have been faulty. This too was ruled out, and the valves and flow sensor were confirmed to be functioning properly. Upon consultation with another colleague, we decided to inspect the condenser reservoir more closely for water accumulation. The anesthesia machine was jostled revealing that the water line in the condenser reservoir had risen above the transparent plastic, and what visually appeared to be an empty reservoir was in fact completely filled with water as demonstrated by the air-fluid level that appeared in Figure 1, Exhibit B. The condenser reservoir was drained, and the reported measurements gradually returned to the expected values. This finding led us to conclude that the excess moisture in the circuit caused the airway module sensor to malfunction. Of note, the condenser reservoir filled completely before the end of the case and was drained a second time. We suspect that the

delay in the return of accurate measurements and the speed at which the reservoir filled for a second time was due to significant moisture buildup within the circuit after the capacity of the reservoir was exceeded.

### DISCUSSION:

We would first like to recognize that proper maintenance according to the user's reference guide published by GE Healthcare recommends that operators visually inspect the condenser reservoir daily and drain it if needed. The condenser reservoir is located adjacent to the CO<sub>2</sub> absorbent canister and collects water from the breathing circuit. Drainage is accomplished by pressing the green drain button on the side of the condenser and allowing the water to drain from the opening underneath.<sup>1</sup> Appropriate maintenance is essential for the proper functioning of anesthesia equipment, and this incident further demonstrates that point. However, the aforementioned event raises several concerns regarding the location and the design of the condenser reservoir. The reservoir on the Avance CS<sup>2</sup> is located behind the absorber canister and is only a few inches above the base of the left lateral side of the machine as seen in Figure 2. Direct access to the left side of the anesthesia machine in the operating room is often blocked by various equipment and is typically in close proximity to the sterile surgical field. Even when approached from the front of the machine, the low and posterior location of the condenser



Figure 2: Location of the condenser reservoir on the Avance CS<sup>2</sup>.

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## RAPID Response

to questions from readers

# Visual Illusion Results in Malfunction of Anesthesia Machine Sensors (cont'd)

### From "Visual Illusion," Preceding Page

reservoir makes viewing and draining cumbersome and easily overlooked.

A further concern regarding the condenser reservoir is related to the design of the reservoir itself. With proper maintenance, water levels should never exceed the height of the transparent plastic that the reservoir is comprised of. However, as we have demonstrated, if the water level exceeds the level of the transparent plastic, the condenser reservoir may appear empty. We suggest that a consideration be made for modification of the reservoir with a means to easily determine if the reservoir contains any water. Possible modifications may include a float, the use of translucent plastic on the condenser walls, or the use of an electronic sensor that notifies the user if there is excess water accumulation in the reservoir.

Finally, our report of this incident is intended to inform the reader and create awareness amongst other users of the Avance CS<sup>2</sup> so that issues with condenser reservoirs can be ruled out early in the troubleshooting of sensor abnormalities. We have been in contact with our local company representatives and welcome their response as well as an explanation as to how moisture affects sensor integrity.

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Bryan Gaeta is a certified registered nurse anesthetist at Robert Wood Johnson University Medical School, New Brunswick, NJ.

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The authors have no conflicts of interest.

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## GE HealthCare Response: Visual Illusion Results in Malfunction of Anesthesia Machine Sensors

March 15, 2023

### Dear APSF Rapid Response,

GE HealthCare would like to thank the team from Rutgers University/Robert Wood Johnson Medical School for submitting their experience with water accumulation and gas sampling in the Avance CS<sup>2</sup> to the Rapid Response column. In response to this report, GE HealthCare performed extensive testing to replicate the experience described. Unfortunately, the observations could not be reproduced. Nevertheless, this report provides an opportunity to review the design features of the Avance CS<sup>2</sup> intended to mitigate the impact of humidity in the anesthesia breathing system, and the recommended procedures for managing the challenge of water accumulation.

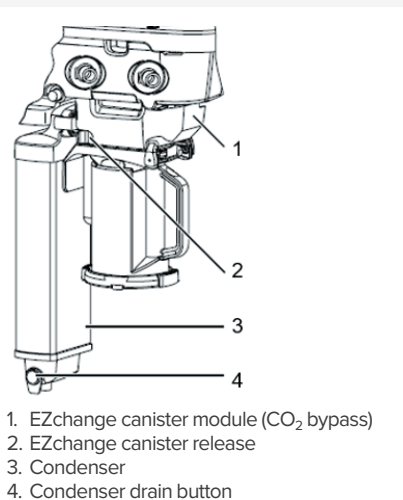


Figure 3: Condenser Location.

Useful practices to minimize the impact of water on gas sampling include:

- A. Heat and moisture exchanger with filter (HMEF) between the patient and the breathing circuit to prevent exhaled water vapor from the patient reaching the breathing system. Even though this is considered optional as noted in the figure, it is useful for controlling water intrusion into the circuit.
- B. Ensure correct size and fit of accessories according to patient type and application.
- C. Ensure airway gas measurement setup is correct. See Figure 5.

See "Visual Illusion," Next Page

Managing humidity and water accumulation in the breathing system is necessary for all anesthesia systems. There are recommended strategies for minimizing water in the breathing system, as well as procedures that can be followed to eliminate the impact of water on the performance of flow and gas concentration sensors. With that goal in mind, the Avance CS<sup>2</sup> anesthesia system includes a condenser designed into the inspiratory flow channel to control water accumulation. See Figure 3.

Adhering to the prescribed user care and maintenance instructions would minimize liquid water buildup in the condenser as observed at the Robert Wood Johnson Medical Center. When the condenser is in use and not full, condensation is visible on the walls of the condenser reservoir which serves as an indicator the reservoir is not full. See Figure 4. When condensation is not present during use, the reservoir drain should be opened to drain any accumulated water. While the condenser drain is located where it is not easily visible from a standing position, it is easily accessed from the front of the machine to visually check the water levels and drain the condenser daily.



Figure 4: Reservoir Condensation.

## Visual Illusion Results in Malfunction of Anesthesia Machine Sensors (cont'd)

### From "Visual Illusion," Preceding Page

The drain is also located within close proximity to the CO<sub>2</sub> absorber, which also is recommended to be visually examined prior to anesthetizing a patient.

Consideration has been given to the additional detection methods suggested in the report by Simon et al. to improve the identification of a full reservoir, but those methods may reduce the overall reliability and simplicity of the design. If the reservoir is full, the inspiratory flow from the ventilator will simply push through the water column or bypass the reservoir completely due to bypass flow paths designed into the condenser top housing. This feature ensures that ventilation continues regardless of the water level in the reservoir. The condenser wall is designed using aluminum, as it serves as both a structural element and a heat shield to prevent the CO<sub>2</sub> absorber heat from warming the condenser tubes.

Returning to the original report, even though it seemed that emptying the condenser reservoir corrected the gas concentration measurements, we could not simulate nor explain how the water accumulation could cause a combination of increased FICO<sub>2</sub>, and low FiAA, and low FiO<sub>2</sub> compared with the set values. Measuring gas and anesthetic concentrations lower than the set values typically results from either low fresh gas flow or leaks in the gas sampling setup. When fresh gas flows are low enough to cause significant rebreathing, patient uptake of anesthetic and oxygen will result in low measured exhaled agent and O<sub>2</sub> concentrations compared with the set values. Leaks in the gas sampling setup cause dilution of sampled gas which is possible in this case since FiO<sub>2</sub> readings of 21% are identical to room air. Increased FICO<sub>2</sub> is typically caused by either high apparatus dead space or waning effectiveness of CO<sub>2</sub> absorbent.

Despite extensive testing, GE Healthcare cannot provide a verified explanation of the reported observations. Following recommended procedures for managing humidity

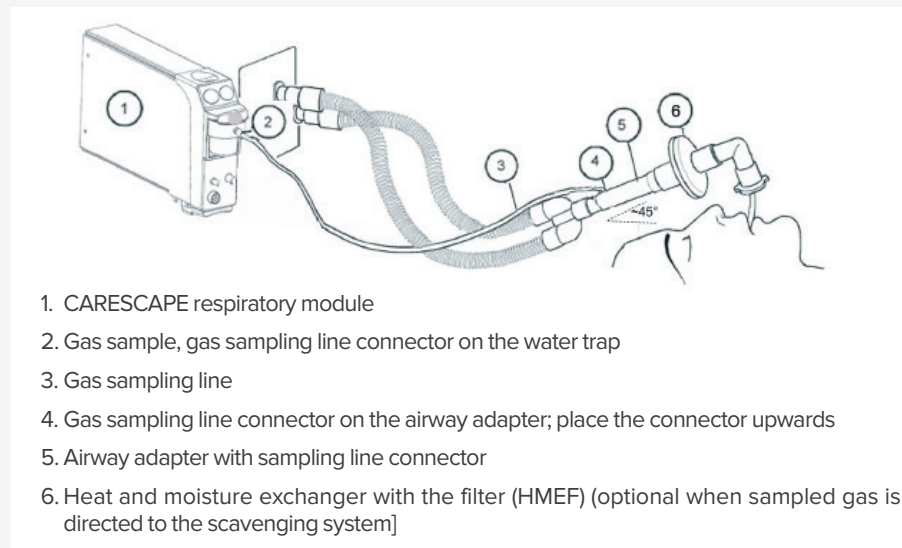


Figure 5: Gas Measurement Setup.

- D. If using a D-lite/D-lite+ flow sensor, place all D-lite ports upwards with a 20° to 45° tilt to prevent condensed water from entering the sensor interior and tubing
- E. Use a D-lite+ flow sensor for high humidity conditions
- F. When using a mask and sampling patient gas, ensure the configuration allows water to drain away from the gas sample port. See Figure 6

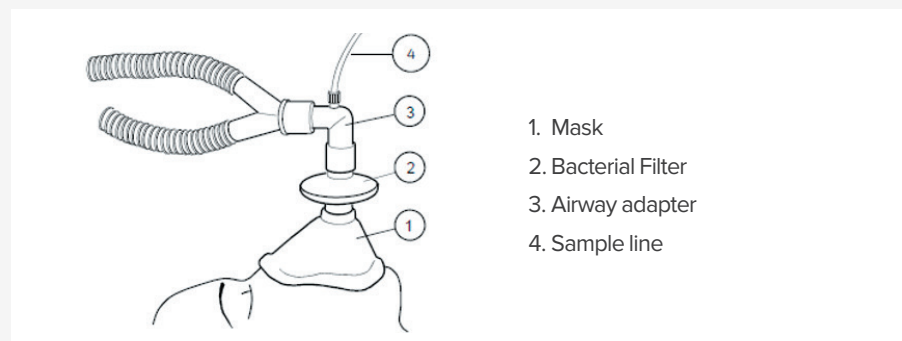


Figure 6 – Gas Measurement Setup during mask ventilation.

- G. Visually check the condenser daily and drain the reservoir daily (See Figure 3)

and accumulated water in the breathing system should minimize any related problems. The recommendations summarized in this report should be a useful guide and users can always refer to the instructions for use or contact GE Healthcare directly with questions: [www.gehealthcare.com/about/contact-us](http://www.gehealthcare.com/about/contact-us)

Sincerely,

Tim McCormick

Chief Engineer—Anesthesia & Respiratory Care, GE HealthCare

# Updates from the Multi-center Handoff Collaborative

by Aalok V. Agarwala, MD, MBA, and Philip E. Greilich, MD, MSc

The transition of responsibility and accountability for patient care from one clinical team to another is a routine part of modern health care delivery. Whether between physical locations (e.g., from the emergency department to an inpatient floor), or between teams in a static location (e.g., from a day team of trainees to a night float team), effective handoffs are crucial to safe, high-quality care.<sup>1</sup> With over 300 million surgical procedures performed worldwide, a number that is poised only to increase as the population ages and low and middle income countries gain access to surgical care,<sup>2,3</sup> perioperative handoffs between anesthesia clinicians, postanesthesia care unit (PACU) nurses, and intensive care unit (ICU) teams will only increase in frequency.

Yet, despite the fact that handoffs occur so frequently, they continue to be a critical point in patient care that can result in patient harm. The Joint Commission reports that its sentinel event database contains reports of wrong-site surgery, delays in treatment, falls, and medication errors as a result of inadequate communication at handoff,<sup>4</sup> and has maintained handoffs as an area of patient safety concern since they were first included in their National Patient Safety Goals in 2006.<sup>5</sup> Perioperative handoffs are especially risky, often occurring in noisy, com-

plex care environments. While the published literature is evolving, there have been numerous studies supporting the association of intraoperative handoffs with increased morbidity and mortality.<sup>6-10</sup>

Aware of the challenges related to perioperative handoffs, and each leading improvement efforts in their own institutions, a small group of academic anesthesiologists from around the United States assembled at the annual meeting of the American Society of Anesthesiologists (ASA) in 2015 to brainstorm how we could learn from one another. As we shared ideas about how to expand interest in the topic of handoffs as a perioperative patient safety issue, our group collaborated with the APSF to plan and conduct the first Stoelting Consensus Conference on Perioperative Handoffs in 2017. The interprofessional conference of patient safety experts led to over 50 consensus recommendations across a number of domains, including process elements, behaviors, metrics and measurement, education and training, implementation, and research.<sup>11</sup>

The Stoelting Conference recommendations created the foundation for what is now the Perioperative Multi-center Handoff Collaborative (MHC) under the leadership of Philip Greilich,

MD, MSc, as its founding chair. With a steering committee and initial working groups on communication, education, implementation, and research, the group began to expand its work. In 2019 the MHC's collaborative relationship with APSF was formalized as it became a sponsored special interest group focused on perioperative transitions of care, enabling the group to access resources that have helped energize and sustain the work of the MHC.

Since its formation, the members and working groups of the MHC have worked tirelessly to improve handoffs through multiple channels. Members of the MHC have participated as lecturers and panelists on the topic of handoffs at national meetings of the ASA, International Anesthesia Research Society, Society of Cardiovascular Anesthesiologists, and International Symposium of Human Factors Ergonomics in Healthcare and the World Federation of Societies of Anesthesiology. The communications workgroup successfully created and launched a website ([www.Handoffs.org](http://www.Handoffs.org)), with literature, resources and tools related to perioperative handoff improvement. The education and training group has created and curated a collection of handoff education and

See "Multicenter Handoff," Next Page

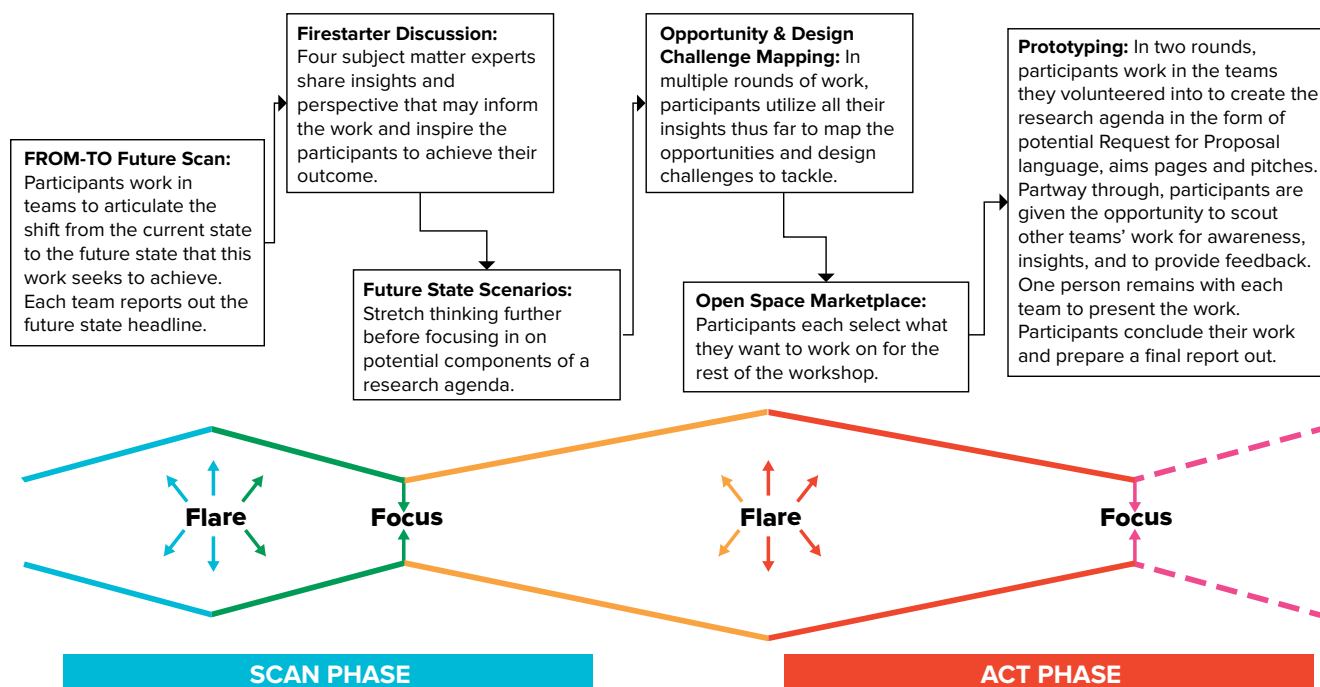


Figure 1: HERO Design Studio Process.

# Multicenter Handoff Collaborative

From “Multicenter Handoff,” Preceding Page

training tools, including a comprehensive list of mnemonics and checklists for all types of perioperative handoffs. The implementation/electronic medical record (EMR) workgroup successfully partnered with Epic Systems (Madison, WI) to create a standardized intraoperative handoff tool that is now included in the standard Epic build for hospitals and health systems across the United States.<sup>12</sup> Members of the research workgroup have worked independently and together to expand the evidence base for optimal handoffs, publishing multiple manuscripts in journals related to anesthesiology, quality and safety, human factors, and implementation science.<sup>10-26</sup>

Alongside and in addition to these accomplishments, the MHC has continued its push to further the conversation about perioperative handoffs. In 2019, the MHC held a workshop during the ASA Annual Meeting where we confirmed interest in setting a formal research agenda and began characterizing the questions that would benefit from a research conference to generate solutions. A proposal entitled “Handoff Effectiveness Research in periOperative environments (HERO) Collaborative Research Conference” was initially submitted in January 2020, funded by the Agency for Healthcare Research and Quality (AHRQ) in March 2021, and ultimately conducted in February 2022 after a number of COVID-related delays. The objective of this research development conference was to operationalize the existing literature base, create a research agenda, foster full stakeholder engagement, and build the research infrastructure necessary to address critical evidence gaps. The conference was designed to leverage MHC’s accomplishments and growth, harness the synergy of stronger relationships with diverse stakeholders required to advance and accelerate handoff research, and promote widespread adoption of this patient safety priority.

The HERO collaborative research conference was a two-day virtual design studio workshop cochaired by Philip Greilich, MD, MSc, and Dan France, PhD, and designed by members of the MHC.<sup>17</sup> The design workshop was facilitated by the Vanderbilt University Medical Center’s Strategy and Innovation office, taking advantage of their expertise in the design studio methodology and the mentorship of its senior advisor, Matt Weinger, MD, MSc. Design Studio is a Lean User Experience (UX) method that combines divergent and convergent thinking.<sup>27</sup> It allows a group of people to address a

**Table 1. Topics identified through the HERO conference for further exploration and development.\***

<b>National Recognition &amp; Integration</b>	
Universal guidelines for handoff communication and care coordination	
National requirements by federal agencies for core handoff processes and assessment	
Research network to identify key handoff issues and foster collaborative initiatives	
Harmonization of measurement system for key effectiveness-implementation outcomes	
<b>Teamwork and Safety Culture</b>	
Handoff toolkits supported by institutional guidance teams	
Teamwork competencies required for resilient interprofessional handoffs	
Combined top-down and bottom-up user-centered change culture	
<b>Process Identification &amp; Improvement</b>	
Workflow redesign to optimize handoff ergonomics	
Engineering sociotechnical systems that reduce distractions and promote resilience	
Platforms for accelerating organizational and/or institutional learning	
Integration of patient/caregiver needs into the handoff continuum	
<b>Tools, Technology &amp; Cognitive Aids</b>	
Augmented assistant to prompt and improve information transfer	
Interactive/adaptive cognitive aids to anticipate risks and promote anticipatory guidance	
<b>Education &amp; Training</b>	
Competency-based handoff education curriculum and assessment	
Longitudinal, interprofessional teamwork education and training strategy	

\*Sparling JL, France D, Abraham J, et al. Handoff Effectiveness Research in periOperative environments (HERO) Design Studio: A Conference Report. *Jt Comm J Qual Patient Saf*. Published online February 2023.doi:10.1016/j.jcjq.2023.02.004.

well-defined problem, generate many ideas, and then converge into shared solutions in a short amount of time (Figure 1).

The research conference was designed to 1) organize and engage key stakeholders through inclusion of interdisciplinary experts on the planning committee and outreach to interested researchers and stakeholders across the country; 2) facilitate maximal attendance by interprofessional teams from participating sites, representatives from relevant national organizations, and subject matter experts; 3) utilize a facilitated, creativity-enhancing, design studio process to energetically engage participants and complete clear and actionable deliverables at the conclusion of the conference, and 4) identify and prioritize the most promising scalable solutions.

We were intentional in inviting a diverse group of stakeholders and personas to achieve organizational alignment and identify user-friendly, technically feasible solutions that would create value. These solutions were intended to allow us

to integrate research gaps and applicable interventions across different perioperative environments and health systems. Special attention was given to leveraging current health care technologies (e.g., cognitive aids, integrated data aggregation/analytics) to prompt and assess handoff interventions in real-time.

One hundred and ten individuals representing 43 organizations from academia, industry, professional societies, regulatory agencies, patient safety organizations, and funding agencies attended the two-day HERO design workshop. This design workshop brought together the key stakeholders in this domain, including clinicians, hospital leaders, researchers, quality improvement specialists, human factors and implementation scientists, and representatives from medical and nursing societies, industries, patient safety organizations, regulatory bodies, and funding entities, to build partnerships and to create an agenda to close the gap in perioperative handoff safety.

# Multicenter Handoff Collaborative (cont'd)

## From "Multicenter Handoff," Preceding Page

Primary work products from the workshop included a paper on perioperative handoffs in the areas of intervention, design, measurement, and dissemination and implementation delivered to attendees prior to the studio event; the identification and prioritization of 18 product prototypes to advance perioperative handoff safety (Table 1); and publication of a Special Issue on Perioperative Handoff Quality and Safety in *The Joint Commission Journal on Quality and Patient Safety*.<sup>18</sup>

The growth and evolution of the MHC as a network hub for perioperative handoffs was positively impacted by the studio event by introducing 50 non-anesthesiologists to the MHC with half expressing an interest in becoming members. The transition of the HERO Planning Committee and the workshop solutions are driving transformational changes in the MHC to support the most promising individuals and ideas arise from this event. The workshop has already set into motion myriad activities to advance handoff research, develop academia-industry partnerships, and to train and develop future leaders in perioperative safety.

As we look forward to what is next for the MHC, we have begun strategic planning for "MHC 2.0" under the leadership of Aalok Agarwala, MD, MBA, as the new chair of the MHC. We have reorganized our workgroups to address the areas identified as most impactful in improving perioperative handoffs after taking into account the results of the HERO conference. Our communication workgroup will be focusing on increasing the visibility of the MHC and the work of its members through our website, social and traditional media, and collaborative relationships with partner organizations. Our education and training workgroup has begun work on creation of a comprehensive repository of the perioperative handoff literature and will be working to curate a repository for handoff education and training materials. Our EMR workgroup will continue its work with Epic (Madison, WI.) to expand OR-to-PACU handoff tools to mobile platforms and to create easy-to-use tools for OR-to-ICU handoff. And our newly formed implementation workgroup is in early stages of planning for a comprehensive implementation toolkit, designed to help individual champions improve perioperative handoffs in their own care environments. With dedicated individuals committed to continuous improvement, we are excited about the work that lies ahead.

*If you or someone you know is interested in working to improve perioperative teamwork, communication, and patient safety, we invite you to join us in our efforts to make handoffs safer. We would love to have your help!*

[www.handoffs.org](http://www.handoffs.org)

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*The authors have no conflicts of interest.*

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# APSF Recognizes the 25 Institutions that Submitted Letters of Intent for Research Projects

by Yan Xiao, PhD; Dru Riddle, PhD, DNP, CRNA; Rebecca L. Johnson, MD; and Stacey Maxwell

The APSF grant programs and the Foundation for Anesthesia Education and Research (FAER) received 35 Letters of Intent from 25 institutions across the United States and Canada during the 2023–2024 funding cycle (Table 1 and Figure 1). The Investigator Initiated Research (IIR) Grant program is designed to stimulate and fund studies that will improve patient safety and lead to prevention of morbidity and mortality resulting from perioperative care. The IIR program funds up to \$150,000 for each project. The Joint APSF-FAER Mentored Research Training Grant (MRTG) program is to develop the next generation of perioperative patient safety scientists. The APSF-FAER MRTG program funds up to \$300,000 for each project. In the 2022–2023 funding cycle, APSF awarded two projects in the IIR Grant program “*Nasotracheal Intubation with Videolaryngoscopy versus Direct Laryngoscopy in Infants (NasoVISI) Trial*,” led by Annerly Garcia-Marcinkiewicz, MD, MSCE at Children’s Hospital of Philadelphia, and “*Electromagnetic Interference with an Underbody Dispersive Electrode in Patients with Implantable Cardioverter Defibrillators Undergoing Surgery*,” led by Peter Schulman, MD, at Oregon Health & Science University). The deadlines for the 2024–2025 funding cycles may be found on the APSF website under “Grants & Awards” ([Grants & Awards—Anesthesia Patient Safety Foundation](#)), along with projects funded.

Yan Xiao, PhD, is professor of nursing and engineering at University of Texas at Arlington.

**Table 1: Institutions that submitted letters of intent (LOIs) during 2023–2024 funding cycle.**

Institutions	Number of LOIs Received	Institutions	Number of LOIs Received
Beth Israel Deaconess Medical Center	2	Sinai Health System	1
Cincinnati Children's Hospital Medical Center	1	University of Texas MD Anderson Cancer Center	1
Duke University	2	University Health Network, Toronto	1
George Washington University	1	University of California, San Francisco	4
Harvard Medical School	1	University of Chicago	2
Henry Ford Health System	1	University of Kansas Medical Center	1
Icahn School of Medicine at Mount Sinai	1	University of Miami	1
Johns Hopkins University	1	University of Nebraska	1
Massachusetts General Hospital	3	University of Texas Southwestern Medical Center	2
Medical University of South Carolina	1	University of Toronto	2
Memorial Sloan Kettering Cancer Center	1	University of Wisconsin-Madison	1
Montefiore Medical Center	1	Virginia Commonwealth University	1
Ohio State University	1		

Dru Riddle, PhD, DNP, CRNA, is associate professor of nursing at Texas Christian University.

Rebecca L. Johnson, MD, is associate professor of anesthesiology at Mayo Clinic College of Medicine.

Stacey Maxwell is administrator of Anesthesia Patient Safety Foundation.

The authors have no conflicts of interest.

## 2023–2024 APSF|IIR and APSF|FAER MRTG LOI Submissions

- University of Nebraska Medical Center
- University Health Network, Toronto; University of Toronto
- University of California, San Francisco; San Francisco Veterans Affairs Medical Center
- The University of Texas MD Anderson Cancer Center; University of Texas Southwestern Medical Center
- University of Wisconsin-Madison
- Henry Ford Health System
- NorthShore University HealthSystem; University of Chicago
- University of Miami Miller School of Medicine
- Medical University of South Carolina
- Duke University
- Virginia Commonwealth University Medical Center
- Johns Hopkins University School of Medicine
- George Washington University Medical Faculty Associates
- Memorial Sloan Kettering Cancer Center; Icahn School of Medicine at Mount Sinai; Montefiore Medical Center
- Ariadne Labs / Harvard T.H. Chan School of Public Health; Harvard Medical School; Beth Israel Deaconess Medical Center; Mass General Brigham/Harvard Medical School
- Cincinnati Children's Hospital Medical Center; Ohio State University
- University of Kansas Medical Center

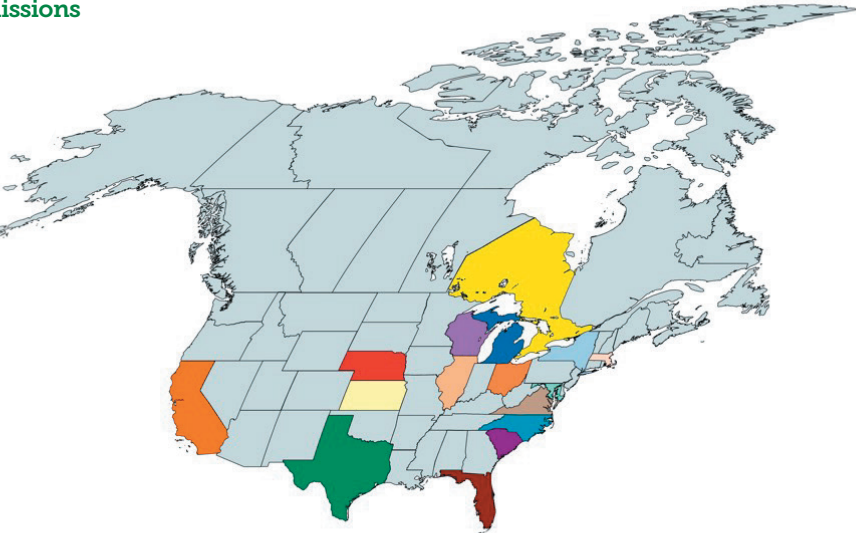


Figure 1: Map of the submitting institutions.

## SPOTLIGHT on Legacy Society Members

NEW MEMBERS



### Jeffrey and Deb Feldman

When Deb and I arrived at the University of Florida to begin my training in anesthesiology, we were both welcomed into the department and anesthesia community by Dr. JS (Nik) Gravenstein and his wife, Alix. Nik provided mentorship and a role model of an accomplished anesthesiologist, who was never satisfied with the status quo and was driven to enhance the safety of anesthesia practice. He was among a few visionaries who recognized the essential role of technology in patient care at a time when digital electronics were opening up possibilities for patient monitoring that had previously been impossible. Partnering with industry, he and others helped to shape the technology we use every day to keep patients safe. Nik was one of the founders of the APSF and, as a young trainee, I witnessed the birth of the organization, never dreaming that I might one day be able to contribute personally. What a privilege and joy it is to be a part of an incredible community of people who dedicate countless hours to promoting patient safety.

How does one decide where to spend their time and resources in life for the most impact? It is difficult to find organizations as impactful in our specialty on anesthesia care at the bedside as the APSF. This foundation embraces all anesthesia professionals to achieve the mission that "no one shall be harmed by anesthesia care." The *Newsletter* is translated into seven languages and read worldwide! Deb and I are pleased to be able to strengthen the APSF as members of the legacy society.

NEW MEMBERS



### Bill, Patty, and Curran Reilly

As a nurse and as a CRNA I have always been a patient advocate with a focus on safe care. I was lucky early on in my anesthesia career to meet Dr. Ellison Pierce who not only invited me to volunteer within the Foundation but also inspired me to want to make a difference in the safe practice of anesthesia.

I have been honored to be a part of the APSF for 35 years, contributing to the work being done, always feeling a sense of pride about what we do and how we do it, knowing in my heart we make such a difference and very proud as a CRNA that I am a part of that difference. I have watched the organization grow; we now have a global reach; our *Newsletter* is read by so many anesthesia clinicians in so many countries.

I have been privileged to collaborate with many great anesthesia leaders within the APSF, I can never thank them enough for their care of the patient and their work in moving safety forward. My special thanks to all the APSF family, for in some small way you have touched me, my practice, my husband, or my daughter, for which I am and will continually be grateful. I hope in a small way my contribution to the Legacy Society will continue to support the work of the 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 Sara Moser, APSF Director of Development at: [moser@apsf.org](mailto:moser@apsf.org).



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# 21

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