

Vaccine Safety: The Benefit-Risk Ratio

by Steven L. Shafer, MD

THE SWINE FLU FIASCO

In January 1976, a group of young healthy servicemen fell ill with an unknown respiratory illness at Fort Dix, a US Army training center in New Jersey. Several were hospitalized. One recruit, refusing hospitalization, died. The cause proved to be H1N1, the influenza strain responsible for the 1918 pandemic. It was considered the most dangerous form of influenza, but since 1918 it was mostly limited to those working with pigs. For the first time in 58 years, H1N1 was clearly spreading quickly through human to human contact. Out of 500 young men, 13 became sick over a few weeks, and 1 died.

It appeared to scientists at the Center for Disease Control (CDC) that an influenza



apocalypse was upon us. Armed with technology (vaccination) not available in 1918, or the smaller influenza epidemics of 1957 and 1968, the CDC pressed for mass vaccination. On March 24, 1976, President Gerald Ford,

flanked by Drs. Sabin and Salk of polio vaccine fame, announced:

“I have been advised that there is a very real possibility that unless we take effective counteractions, there could be an epidemic of this dangerous disease next fall and winter here in the United States. Let me state clearly at this time: no one knows exactly how serious this threat could be. Nevertheless, we cannot afford to take a chance with the health of our nation. Accordingly, I am today announcing the following actions. I am asking the Congress to appropriate \$135 million, prior to their April recess, for the production of sufficient vaccine to inoculate every man, woman, and child in the United States.”¹

See “Vaccine Safety,” Page 50

The APSF Revisits Its Top 10 Patient Safety Priorities

by Steven Greenberg, MD, FCCP, FCCM

In 2018 the APSF Board of Directors (BOD) voted on its top perioperative patient safety priorities. This list was generated from a combination of a review of the most current literature, submissions to the *APSF Newsletter*, and expert opinions from the multiprofessional representatives of the BOD. Since then, the APSF has devoted its resources to enhancing education, research, and awareness with regards to these priorities (<https://www.apsf.org/article/improving-perioperative-patient-safety-a-matter-of-priorities-collaboration-and-advocacy/>). The current BOD has felt the need to revisit the top patient safety priorities on an annual basis

to accurately represent the most current perioperative patient safety issues.

Current APSF Vice President Dan Cole, MD, led a task force to generate a survey that was distributed to all APSF BOD and committee members. The poll responses were then tallied by the task force generated from the BOD. From a list of the top 16 priorities, the BOD voted on selection of the Top 10 Patient Safety Priorities for 2021 (figure 1). Past, present, and future activities focusing on these patient safety priorities are also listed in figure 1. A culture of safety, inclusion, and diversity ranked number one, while teamwork, collegial communication, and multidisciplinary collaboration, and preventing, detecting, determining pathogenesis, and mitigating clinical deterioration in the perioperative period were ranked two and three, respectively.

New additions to the current patient safety priority list include (2) teamwork, collegial communication and multidisciplinary communication; (6) prevention, and mitigation of opioid-related harm in surgical patients; (8) emerging infectious diseases (including, but not limited to COVID-19), including patient management, guideline devel-

opment, equipment modification, and determination of operative risk; and (9) clinician safety, occupational health, and wellness.

The priority of creating a culture of safety was elevated to the top priority in 2021 and was modified to encompass the importance of inclusion and diversity in perioperative patient safety. All of these topics represent the current world we live in with respect to perioperative patient safety and are in line with the APSF’s vision “that no one shall be harmed by anesthesia care.”

Some topics that were ranked at the lower end of our priority list in 2018 did not remain on the top 10 priority list in 2021: (9) cost-effective protocols and monitoring that have a positive impact on safety; (10) integration of safety into process implementation and continuous improvement; (11) burnout; and (12) distractions in procedural areas. Some of these topics will be integrated into the new 2021 patient safety priorities and others did not gain traction for ranking when compared to the current ones.

See “Top 10 Priorities,” Page 53

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TABLE OF CONTENTS

ARTICLES:

Vaccine Safety: The Benefit-Risk RatioCover
 The APSF Revisits Its Top 10 Patient Safety PrioritiesCover
 Postpartum Peripheral Nerve Injuries—What is Anesthesia’s Role?Page 54
 APSF Statement on Pulse Oximetry and Skin Tone: Pulse Oximeters are Important for Keeping all Patients Safe.....Page 57
 Establishing a Difficult Airway Response Team for a Regional Hospital: A Case Study in the Adoption and Diffusion of InnovationsPage 58
 Important Medication Errors and Hazards Reported to the ISMP National Medication Errors Reporting Program During 2020Page 61
 Practice Considerations for the Anesthesia Professional for Methamphetamine Substance Use Disorder PatientsPage 67
 CULTURE OF SAFETY: The Multidisciplinary Anesthesia Professional RelationshipPage 74
 Lessons Learned from Calls to the MHAUS Malignant Hyperthermia HotlinePage 78
 One Year After PRODIGY—Do We Know More About Opioid-Induced Respiratory Depression?Page 80
 The Evolution and Role of Simulation in Medical EducationPage 82
 Management of Massive Intraoperative HemorrhagePage 85

RAPID RESPONSE:

Rapid Response: Inadvertent Unplugging of Rapid Infuser Causing a Large Volume of Cold Fluid to Be Infused With Subsequent Cardiac ArrestPage 64
Rapid Response: Laryngoscope Hook Poses Safety Issue.....Page 72
Rapid Response: Cardiopulmonary Arrest Precipitated by Supraglottic Kinking of Polyvinyl Endotracheal Tube.....Page 76

APSF ANNOUNCEMENTS:

Guide for AuthorsPage 49
 APSF Newsletter Podcast: *Now Available Online @ APSF.org/podcast*.....Page 56
 A Tribute to Ron Litman, DO, MLPage 63
 APSF 2021 Stoelting Conference: Clinician Safety: To Care is Human.....Page 66
 Anesthesia Quality and Patient Safety MeetingPage 70
 APSF Donor Page.....Page 71
 CrowdfundingPage 87
 Legacy MembersPage 88
 2020 Board Members and Committee Members:<https://www.apsf.org/about-apsf/board-committees/>

Guide for Authors

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

The APSF Newsletter is the official journal of the Anesthesia Patient Safety Foundation. It is widely distributed to a variety of anesthesia professionals, perioperative providers, key industry representatives, and risk managers. Therefore, we strongly encourage publication of those articles that emphasize and include the multidisciplinary, multiprofessional approach to patient safety. It is published three times a year (February, June, and October). **Deadlines for each issue are as follows: 1) February Issue: November 15th, 2) June Issue: March 15th, 3) October Issue: July 15th.** The content of the newsletter typically focuses on anesthesia-related perioperative patient safety. Decisions regarding content and acceptance of submissions for publication are the responsibility of the editors.

- All submissions should be submitted via Editorial Manager on the APSF website: <https://www.editorialmanager.com/apsf>
- Please include a title page which includes the submission’s title, authors’ full name, affiliations, conflicts of interest statement for each author, and 3–5 keywords suitable for indexing. Please include word count on the title page (not including references).
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Types of articles include (1) Invited review articles, Pro/Con Debates and Editorials, (2) Q and As, (3) Letters to the Editor, (4) Rapid Response, and (5) Conference reports.

- Review articles, invited Pro/Con debates, and Editorials are original manuscripts. They should focus on patient safety issues and have appropriate referencing. The articles should be limited to 2,000 words with no more than 25 references. Figures and/or tables are strongly encouraged.
- Q&A articles are submitted by readers regarding anesthesia patient safety questions to knowledgeable experts or designated consultants to provide a response. The articles should be limited to 750 words.
- Letters to the editor are welcome and should be limited to 500 words. Please include references when appropriate.
- Rapid Response** (to questions from readers), formerly known as, "Dear SIRS," which was the "Safety Information Response System," is a column that allows for expeditious communication of technology-related safety concerns raised by our readers, with input and response from manufacturers and industry representatives. Jeffrey Feldman, MD, current chair of the Committee on Technology, oversees the column and coordinates the readers’ inquiries and the response from industry.

Commercial products are not advertised or endorsed by the APSF Newsletter; however, upon exclusive consideration from the editors, articles about certain novel and important safety-related technological advances may be published. The authors should have no commercial ties to, or financial interest in, the technology or commercial product.

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SARS-CoV-2 Vaccine Safety and Efficacy

From “Vaccine Safety,” Page 48

Field trials for a vaccine began in April. Mass immunization began on October 1st, 1976. Eleven days later, three elderly patients in Pittsburgh died almost immediately after vaccination. The Allegheny County Health Department suspended the vaccination program. In Minnesota, health authorities noticed several cases of Guillain-Barré. This was followed by a rising incidence of unexplained deaths and Guillain-Barré (a complication of both influenza itself and other influenza vaccines).² When no cases of H1N1 appeared in the winter, the perceived risk/benefit ratio shifted to all risk, and the vaccination program was stopped in December.

New programs were set up following this “Swine Flu Fiasco” of 1976. A considerable irony is those vaccinated in 1976 may have been protected as older adults during the 2009 H1N1 pandemic.³ The 1976 Swine Flu vaccination program also presaged many of the challenges of communicating vaccine benefits vs. vaccine safety that we see with vaccination programs today.

OPERATION WARP SPEED

Unlike the 1976 swine flu fiasco, when no subsequent cases of H1N1 were seen after the initial outbreak at Fort Dix, as of April 5, 2021, there have been over 130 million cases and 2.8 million deaths worldwide (figure 1) secondary to SARS-CoV-2. In the United States, 1 in 11 have been infected by SARS-CoV-2, and 1 in roughly 600 Americans have died from COVID-19 (more than 540,000 as of March, 2021).

The COVID epidemic has focused the world’s scientific firepower as never before. In the United States, “Operation Warp Speed” was a public/private partnership to provide nearly unlimited government support to companies pursuing vaccines and other therapies to address COVID-19. Similar programs were established in Europe, India, and China, with unprecedented success.

According to the World Health Organization, there are currently 82 vaccines in clinical development (table 1).⁴ Of these, 13 are presently approved in at least 1 country.⁵ All of the vaccines have demonstrated efficacy. The only serious safety concern that has emerged is the exceedingly small possibility of thrombosis with the AstraZeneca vaccine. I will repeat that for emphasis: the **only** serious safety concerns that has emerged is the very low possibility of thrombosis with the AstraZeneca vaccine.

Vaccines stimulate the immune system. Very obviously, that is the entire point! You know what this feels like: fatigue, headache, myalgias, lethargy, and generalized “flu-like” symptoms. These responses aren’t caused by the virus *per se*. This is simply what it feels like when your



Left panel: 1918 influenza pandemic, National Museum of Health and Medicine, Armed Forces Institute of Pathology, Washington, DC, United States; Right upper panel: Army Cpt. Dr. Isaiah Horton receives COVID-19 vaccine, US Secretary of Defense; Right lower panel: US President Gerald Ford receiving swine flu vaccine, Gerald R. Ford Presidential Library;

immune system gets activated. Since the vaccines activate the immune system, any of the vaccines can make you feel ill for a couple of hours to perhaps a day or two. Just as you should expect the shot to hurt a little, because they are sticking a needle in your arm, you should expect to feel somewhat viral, because the shot activates your immune system.

The safety question is: what other unwellcome effects might the vaccine have, other than making you feel like you have a virus?

VACCINE SAFETY AND EFFICACY

1. **BNT162b2** is an mRNA vaccine developed by Pfizer and BioNTech. It is the first vaccine approved via an Emergency Use Authorization (EUA)* in the United States. In a study of 43,548 subjects, the vaccine demonstrated an outstanding 95% efficacy and nearly 100% efficacy against severe disease.⁶ This is similar to the efficacy of the MMRV vaccine.⁷ Only 1 patient who received the vaccine (out of > 20,000) developed severe COVID-19. Common adverse events were limited to injection site pain and flu-like symptoms. The safety and efficacy demonstrated in the Phase 3 study was subsequently reproduced when the vaccine was deployed on a large scale in Israel.⁸

Shortly after the BNT162b2 vaccination program was launched several cases of anaphylaxis were observed.⁹ The most recent assessment is that the risk of anaphylaxis is approximately 1 in 100,000.¹⁰ The mRNA vaccines incorporate a lipid nanoparticle to facilitate mRNA entry into the cell. It is currently thought that the lipid nanoparticle is responsible for the rare allergic reactions.¹¹ The risk

Table 1: Vaccine Platforms in Development.³³

Platform	Candidate Vaccines
Protein subunit	28
Viral Vector (non-replicating)	12
DNA	10
Inactivated Virus	11
RNA	11
Viral Vector (replicating)	4
Virus Like Particle	4
Live Attenuated Virus	2
Replicating Viral Vector + Antigen Presenting Cell	2
Non-replicating Viral Vector + Antigen Presenting Cell	1

of anaphylaxis was mitigated through introduction of immediate postvaccination monitoring of individuals for up to 30 minutes, reducing the risk of injury from anaphylaxis to nearly 0. **The CDC estimates that there have no deaths associated with the BNT162b2 vaccine.**¹²

2. **mRNA-1273** is an mRNA vaccine developed by Moderna. It is the second vaccine with EUA approval in the United States. In the phase 3 study of 30,420 individuals, the mRNA-1273 vaccine also demonstrated outstanding efficacy of 94%. To place this into perspective, the FDA set a bar of 50% efficacy for vaccine approval.¹³

*Emergency Use Authorization, an authorization granted by the FDA to permit the use of a drug without full FDA approval to treat a public health emergency.

The Risk of Anaphylaxis to the SARS-CoV-2 Vaccine is Rare

From “Vaccine Safety,” Preceding Page

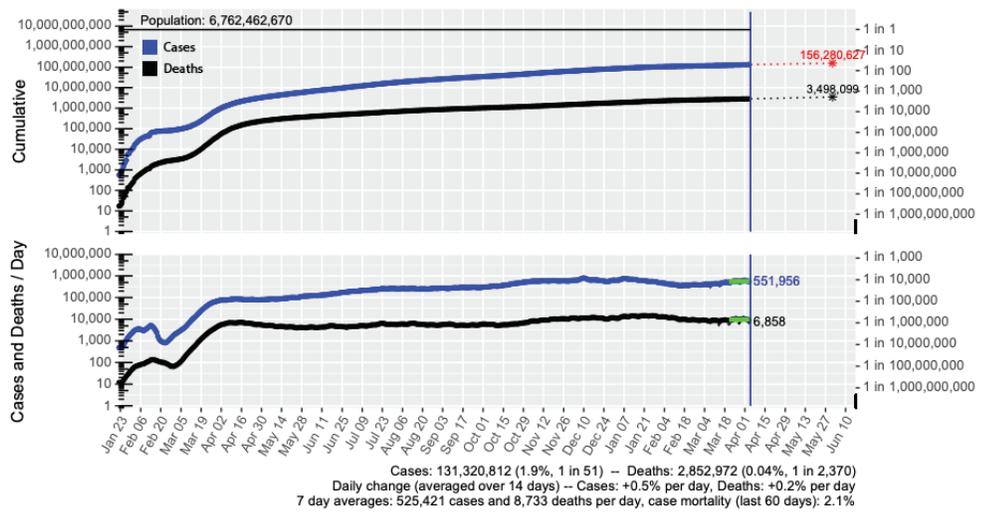
The risks of the Moderna mRNA-1273 are identical to that of the Pfizer/BioNTech.¹⁴ This is expected, because both vaccines use the same lipid nanoparticles to facilitate entry into the cell.¹⁵ The risk of anaphylaxis is about 1 in 200,000. There have been no deaths or serious injuries. Otherwise, recipients of mRNA-1273 should expect to feel mildly ill while their immune system ramps up.

3. **AD26.COV2.S** is not an mRNA type vaccine but rather a non-replicating viral vector vaccine developed by Johnson & Johnson. It is the third vaccine with EUA approval in the United States. The phase 3 trial of 44,325 adults found an efficacy of 72% in the United States, 66% in Latin American countries, and 57% in South Africa.¹⁶ No vaccinated patients died of COVID-19. The safety data has not appeared in the peer-reviewed literature. However, the safety profile is well described in the FDA briefing document¹⁷: “Safety analysis through the January 22, 2021 data cutoff included 43,783 randomized (1:1) participants ≥18 years of age with 2-month median follow-up. The analysis supported a favorable safety profile with no specific safety concerns identified that would preclude issuance of an EUA.” There were no instances of anaphylaxis in the study, but one individual had a hypersensitive reaction two days after vaccination that was not classified as anaphylaxis.*

4. **AZD1222**, also known as ChAdOx1 nCoV-19, is an adenovirus vectored vaccine developed by a partnership between Oxford University and AstraZeneca. It is approved throughout Europe, Asia, and South America. AstraZeneca recently completed a phase 3 trial in the United States and has announced plans to seek EUA approval in the US.

AZD1222 would seem to have been cursed since the outset. In the pivotal phase 3 trial, there was a dosing error resulting in a sub-population of patients having a lower dose than intended. Amazingly, these patients had a better immune response, but it is unclear exactly why that was the case! In an interim analysis, the vaccine was 62% effective in patients who received the higher dose as specified in the protocol, and 90% effective in patients who received the lower dose.¹⁸ In the final analysis, vaccine efficacy was 76% after a single standard dose.¹⁹ No patients in the vaccinated group required hospitalization after 21 days, and there were no COVID deaths in the vaccinated group.

Worldwide Projection as of April 5, 2021



Source: Daily COVID-19 update, used with permission from author.

Figure 1: Worldwide projection as of April 5, 2021.³²

The safety analysis identified two concerning adverse events: one case of transverse myelitis, and one instance of a fever following vaccination of 40°C without explanation. Both cases resolved. One subsequent case of transverse myelitis was reported, but subsequently was determined by the site investigator to be unrelated.

A paper from South Africa published in the *New England Journal of Medicine* after approval of AZD1222 showed that it didn't work against the B.1.351 variant that has become the predominant strain in South Africa.²⁰

In March 2021, three patients in Norway suffered thrombotic events after receiving the AZD1222 vaccine, and one patient died. Norway suspended use of the vaccine pending investigation. Several additional thrombotic events were reported in Europe, including 22 in the UK.²¹ A case has also been reported in Australia.²² What is unusual about these cases is that they are associated with low platelet counts, suggesting a mechanistic link to heparin-induced thrombocytopenia.²³ In response, Denmark, Norway, Iceland, Bulgaria, Ireland, the Netherlands, Germany, Italy, France, Spain, Portugal, Sweden, Luxembourg, Cyprus, and Latvia all suspended use of the vaccine. Subsequently the European Medicines Agency, the World Health Organization,²⁴ and AstraZeneca²⁵ determined that the cases of thrombosis were not related to the vaccine, and recommended continued use.

On March 22, 2021, AstraZeneca announced the results of the 32,449-subject phase 3 US trial.²⁶ The vaccine was 79% effective, and 100% effective at preventing severe disease. The data safety monitoring board reviewed thrombotic events, including cerebral venous sinus thrombosis, and found no evidence of increased risk. No cases of cerebral venous sinus thrombosis occurred in the trial. The following day, the Data and Safety Monitoring Board (DSMB) issued through the National Institute of Allergy and Infectious Disease, a statement disputing the AstraZeneca press announcement, stating that the DSMB expressed concern that AstraZeneca may have included outdated information from that trial, which may have provided an incomplete view of the efficacy data.²⁷

As mentioned, AZD1222 seems to have been cursed, starting with a dosing error in the clinical trial. Controversy continued with the findings of lower doses producing greater efficacy, concerns over very rare transverse myelitis cases, thrombosis, and now with concerns over the cherry picking of data. There is an excellent review of the odd twists and turns of AZD1222 in *Nature News*.²⁸ The Medicines and Healthcare products Regulatory Agency in the United Kingdom has published guidelines for diagnosing and treating thrombosis and cytopenia following vaccination.²⁹

*Since this article entered production, the Johnson & Johnson vaccine appears to be associated with the syndrome of thrombosis and low platelets (see <https://www.cdc.gov/coronavirus/2019-ncov/vaccines/safety/JJUpdate.html>). The incidence appears to be approximately 1 case per million vaccine doses. The CDC had recommended pausing administration while the association was studied and risk factors were identified. On April 23, 2021, the CDC and FDA lifted the pause for administration of the Johnson & Johnson vaccine, citing that its potential benefits outweigh its risks.

SARS-CoV-2 Vaccine Risk Benefit Ratio: Asymptotically 1:0!

From “Vaccine Safety,” Preceding Page

Would I get the AZD1222 vaccine? Absolutely! The vaccine has been given to more than 17 million people. There have been about 50 embolic events, a rate of about 3 per million. Case mortality for COVID-19 is currently running about 2.4%, and more than 20% of all patients who get COVID-19 have some level of persistent symptoms. Some simple math: 17 million \times 75% herd immunity threshold \times 2% case rate mortality \times 90% efficacy in preventing death = \sim 230,000 lives saved already through vaccination with AZC1222.

5. **Sputnik V** is a combination of two adenovirus vectored vaccines, developed by Gamaleya Research Institute in Russia and currently approved in Russia and multiple countries in Asia, Africa, The Middle East, and South America. The phase 3 trial of 21,977 subjects found an efficacy of 92%.³⁰ The vaccine was 100% effective against serious disease and death after 21 days. No serious adverse events have been reported related to vaccination.

6. **Coronavac** is an inactivated SARS-CoV-2 vaccine developed by Sinovac, and currently approved in China and multiple countries in Asia and South America. The data from large phase 3 trials is currently only available in press releases, but these suggest “the efficacy rate against diseases caused by COVID-19 was 51% for all cases, 84% for cases requiring medical treatment, and 100% for hospitalized, severe, and fatal cases.”³¹

7. **BBIBP-CorV** is an inactivated SARS-CoV-2 vaccine developed by Sinopharm, and currently approved in China and multiple countries in Asia, South America, and the Middle East. There seems to be even less safety and efficacy data than for CoronaVac. A summary in Wikipedia suggested 86% efficacy in a study in Bahrain, with 100% efficacy in preventing severe disease. These data have not been published.

In summary, the currently approved vaccines appear to be highly effective at preventing infection and almost 100% effective in preventing severe disease and death. There are some exceptionally rare events, such as anaphylaxis with the mRNA vaccines, and possibly very rare cases of thrombosis from the AstraZeneca AZD1222 vaccine. Given this profile, and the profound health, social, and economic costs of an unmitigated pandemic, the ratio of benefit to risk is asymptotically 1:0.

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The author has no conflicts of interest.

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Refining APSF's 2021 Patient Safety Priorities and Activities

From "Top 10 Priorities," Page 48

The APSF is creating advisory groups whose goals are to develop recommendations on how to best allocate APSF resources to the 2021 Top 10 Patient Safety Priorities. These groups will also act as experts on the specific priorities so that the APSF can provide the most novel

approaches to improving patient safety on these important issues to its worldwide constituency. Please join the APSF in making the necessary changes in your own practices as it relates to patient safety priorities and beyond.

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Figure 1: APSF's 2021 Perioperative Patient Safety Priorities and Ongoing Activities

The following list contains our top 10 priorities and notes the activities for each that we have done in the past 5 years. The summary of activities is not exhaustive.

1. Culture of safety, inclusion, and diversity

- APSF addressed this issue in its 2017 ASA Annual Meeting workshop, as well as in *APSF Newsletter* articles and presentations
- The 2019 Pierce Lecture by Jeff Cooper, PhD, highlighted this issue; his remarks were published in February 2020 *APSF Newsletter*
- APSF has supported 1 research grant on this issue in the past 5 years

2. Teamwork, collegial communication, and multidisciplinary collaboration

- APSF serves as the collaborating organization and supporter of the Multicenter Handoff Collaborative (<https://www.apsf.org/article/multicenter-handoff-collaborative/>)
- This was the topic of the 2017 APSF Stoelting Conference and several *APSF Newsletter* articles
- APSF provides financial and infrastructure support to the Multicenter Handoff Collaborative

3. Preventing, detecting, determining pathogenesis, and mitigating clinical deterioration in the perioperative period

- Early warning systems in all perioperative patients
 - Monitoring for patient deterioration
 - Postoperative continuous monitoring on the hospital floor
 - Opioid-induced ventilatory impairment and monitoring
 - Early sepsis
 - Early recognition and response to decompensating patient
- The 2019 Stoelting Conference was dedicated to this topic
 - This topic has been highlighted in 2020 *APSF Newsletter* issues and APSF-sponsored panels and presentations
 - APSF is collaborating with American Society of Anesthesiologists (ASA) and other subspecialty organizations to address specific issues related to this topic
 - APSF will support prototype development for several models that may reduce failure-to-rescue
 - APSF has supported 2 research grants on this issue in the past 5 years

4. Safety in non-operating room locations such as endoscopy, cardiac catheterization, and interventional radiology suites

- APSF has addressed aspects of this issue recently in *APSF Newsletter* articles (e.g., June 2020)
- APSF has supported 3 research grants on this issue in the past 5 years

5. Perioperative delirium, cognitive dysfunction, and brain health

- The APSF supports this ASA-American Association of Retired Persons initiative.
- This issue is addressed in the October 2020 *APSF Newsletter*.
- APSF has supported 3 research grants on this issue in the past 5 years

6. Prevention and mitigation of opioid-related harm in surgical patients

- This issue has been addressed in 11 articles in the *APSF Newsletter* since 2016
- APSF has supported 1 research grant on this issue in the past 5 years
- APSF supports ongoing efforts in the U.S. Congress, Joint Commission, and regulatory agencies to promote postoperative monitoring of patients who have received opioids

7. Medication safety

- Drug effects
 - Labeling issues
 - Shortages
 - Technology issues (e.g., barcoding, RFID)
 - Processes for avoiding and detecting errors
- The 2018 Stoelting Conferences was dedicated to this topic
 - APSF presented panels at the 2019 ASA and New York State Society of Anesthesiologists' annual meetings
 - Multiple *APSF Newsletter* articles have been published on this issue in 2020
 - APSF will co-host a summit in 2021 with the Institute for Safe Medication Practices

8. Emerging infectious diseases (including but not limited to COVID-19), including patient management, guideline development, equipment modification, and determination of operative risk

- APSF helped develop the 2018 Society for Healthcare Epidemiology of America (SHEA) consensus guidelines on intraoperative infection-prevention (<https://www.cambridge.org/core/journals/infection-control-and-hospital-epidemiology/article/infection-prevention-in-the-operating-room-anesthesia-work-area/66EB7214F4F80E461C6A9AC00922EFC9>)
- APSF sponsored the 2017 NYSSA and ASA panels on this topic
- APSF made significant contributions to the development and sharing of information related to COVID in 2020 and assisted with development of pertinent shared statements, practice guidelines, and frequently asked questions
- APSF has supported 2 research grants on this topic in the past 5 years

9. Clinician safety: Occupational health and wellness

- This will be the topic of the 2021 APSF Stoelting Conference
- Five articles on this issue have been published in the *APSF Newsletter*
- APSF has supported 1 research grant on this issue since 2016

10. Airway management difficulties, skills, and equipment

- Several *APSF* articles have addressed this issue in recent *APSF Newsletter* articles
- APSF has supported 3 research grants on this issue in the past 5 years

Postpartum Peripheral Nerve Injuries—What is Anesthesia’s Role?

by Emery H. McCrory, MD; Jennifer M. Banayan, MD; and Paloma Toledo, MD, MPH

Postpartum peripheral nerve injuries occur in approximately 0.3–2% of all deliveries. The majority of nerve injuries are attributed to intrinsic obstetric palsies secondary to compression or stretch of the nerve during delivery; however, the possibility that neuraxial anesthesia/analgesia contributes to the injury exists. It is important that anesthesia professionals create systems to identify women who have experienced postpartum lower extremity nerve injuries and connect patients with resources.

Childbirth is the most common reason for admission to the hospital within the United States.¹ While neurologic complications during pregnancy and delivery are still fortunately a relatively rare event, when they do occur, they can have a significant impact. Nerve injuries during childbirth are traditionally attributed to intrinsic obstetric palsies, either due to compression or stretch of the nerve. Although this is still true in a majority of cases, neuraxial procedures may contribute to a small proportion of these injuries. Given the rarity of these injuries, there are not accurate risk-prediction models. Therefore, anesthesia professionals should work with obstetricians and nurses to develop systems to identify women who do develop postpartum lower extremity nerve injuries and also provide these women with resources regarding symptomatology and mobility safety, especially if there is a motor component to the injury.

COMMON PERIPHERAL NERVE INJURIES

The incidence of postpartum peripheral nerve injuries varies in the literature from 0.3 to 2% of all deliveries.²⁻⁴ In a study of over 6,000 parturients, the most common peripheral nerve injuries found postpartum were to the lateral femoral cutaneous nerve and the femoral nerve. Less common nerves affected include common peroneal, lumbosacral plexus, sciatic, obturator, and radicular nerves (table 1).⁴

Lateral femoral cutaneous nerve injury occurs in approximately four out of 1000 parturients.⁴ The nerve, which supplies sensation to the anterolateral thigh, courses under the inguinal ligament, which makes it susceptible to compression while in lithotomy position. This purely sensory dysfunction, also known as meralgia paresthetica, is typically self-limited with a short recovery period, and can often be treated with nonsteroidal anti-inflammatory drugs or lidocaine patches.⁵

Femoral nerve injury is slightly less common, but involvement causes weakness in thigh flexion, knee extension, loss of patellar reflex, and sensory loss to the medial thigh and calf. The femoral nerve also courses under the inguinal ligament (figure 1) and compression at this point is traditionally believed to be the mechanism of injury.

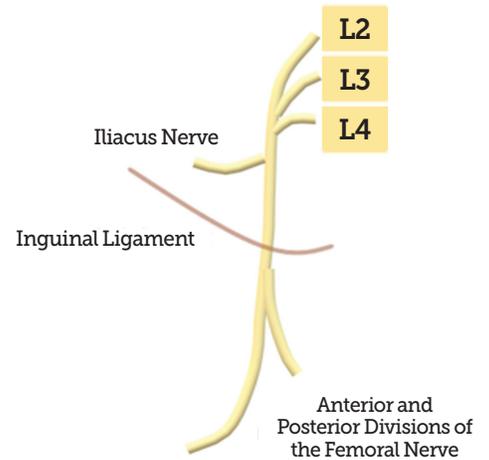


Figure 1. Illustration of the femoral nerve coursing underneath the inguinal ligament, and the iliacus nerve branching off more proximal to the inguinal ligament.

RISK FACTORS

A variety of risk factors have been identified that contribute to peripheral nerve injuries. Some of these risk factors, such as duration of labor and mode of delivery are not modifiable. The attributable risk of any individual risk factor to the development of nerve injuries is not known. In this section, we will discuss several of the known risk factors.

Parturients who suffer a nerve injury are more likely to be nulliparous and spend longer time in the second stage of labor while in the lithotomy position than those without injury.⁴ Patients who have an assisted vaginal delivery (either with forceps or a vacuum device) are also more likely to have a postpartum peripheral nerve injury.⁴ Patients with neuraxial catheters are typically less mobile and maintain the same position for longer periods of time, which may make compression injury more likely. Anatomical variations in the epidural space could cause a high concentration of local anesthetic surrounding individual nerve roots (detected as an unequal distribution of a block) which could be neurotoxic at a high enough dose.⁶ In addition, a low concentration of local anesthetic through the epidural catheter should be considered. Although this has not been explicitly studied, it is reasonable to assume that patients with a dense analgesic block may be more likely to have compressive nerve injuries, as the local anesthetic may inhibit nociceptive warning signs of neuropathic pain.

See “Nerve Injury,” Next Page

Table 1. Common Postpartum Peripheral Nerve Injuries and Proposed Mechanisms of Injury

Nerve	Observed deficit	Proposed mechanism and location of injury and risk factors
Lateral femoral cutaneous nerve	Sensory: decreased on anterolateral thigh, “meralgia paresthetica”	Compression under the inguinal ligament with prolonged hip flexion, obesity (secondary to increased pressure at the inguinal ligament)
Femoral nerve	Sensory: decreased on anterior thigh and medial calf Motor: weak thigh flexion (if involvement of the iliacus nerve), weak knee extension	Compression under the inguinal ligament secondary to prolonged hip flexion, abduction, and external rotation; retraction during cesarean delivery; possibly decreased perineural flow to the iliacus nerve
Lumbosacral plexus and sciatic nerve	Sensory: decreased on posterior thigh Motor: weak quadriceps, weak hip adduction, foot drop, involves multiple levels	Compression due to fetal position, compression against pelvic rim, forceps assisted vaginal delivery
Obturator nerve	Sensory: decreased on medial thigh Motor: weak hip adduction, wide gait	Compression due to fetal position, improper positioning, forceps assisted vaginal delivery
Common peroneal nerve	Sensory: decreased on lateral calf Motor: foot drop	Lower extremity positioning, compression at fibular head either by hand or stirrups while anesthetized, compression while pushing

Nerve Injury Prognosis During Labor Is Favorable

From “Nerve Injury,” Preceding Page

A large retrospective study evaluating 20,000 laboring parturients who received neuraxial anesthesia identified a nerve injury incidence of 0.96%, with a higher incidence of lumbosacral plexus injuries.⁷ Risk factors identified included a forceps assisted vaginal deliveries, newborn birth weight >3.5 kg, late gestational age (≥41 weeks), and late initiation of the neuraxial procedure.⁷ They did not find any significant difference when looking at time of day of neuraxial placement or provider level of training. Out of the 19 injuries identified, four were attributed to direct trauma from either the Touhy needle or catheter to the nerve root, based on either electromyography, magnetic resonance imaging, or a computerized tomography scan within 48 hours of delivery. Of those four injuries, three of the patients experienced a paresthesia during placement at the same level.⁷ In addition, in three of the four patients, the neuraxial procedure was performed with a cervical dilation greater than five centimeters, and all four of the patients had a documented difficult neuraxial placement with either severe pain or several attempts.⁷ Given this significance, it is especially important to include nerve injury in anesthetic consent for neuraxial procedures, and appropriately counsel patients if a traumatic placement occurs. Further evaluation needs to be conducted regarding appropriate troubleshooting when a paresthesia occurs during neuraxial placement, as this limited study indicated that these patients may be at higher risk of postpartum neuralgia. Our institutional practice is as follows: If a patient complains of a transient paresthesia with either the spinal or epidural needle, and it resolves without further intervention, injection may proceed. If the patient has a persistent paresthesia, the needle is moved away from the direction of the paresthesia. If the paresthesia occurs with spinal injection of local anesthetic, the injection is aborted and the intrathecal space is re-identified prior to injecting local. Finally, if the patient experiences a persistent paresthesia when the epidural catheter is threaded, the catheter is typically removed. At this point saline can be infused prior to re-attempting to thread the catheter to help expand the epidural space or the Touhy needle can be directed away from the direction of the paresthesia and the epidural space located again.

In a prospective observational study of new-onset postpartum lower-extremity nerve injuries, there were some injuries which did not fit the classic mechanism of nerve compression or stretch.⁴ Twenty-four patients had lateral femoral cutaneous nerve injuries, which are believed to



be due to compression under the inguinal ligament in lithotomy position; however, four of these patients had a scheduled cesarean section. In addition, all 22 of the femoral nerve injuries had iliopsoas weakness, which is anatomically more cranial than the inguinal ligament, and also supporting the theory that nerve hypoperfusion may contribute to postpartum nerve injuries.^{4,8} Further work is needed to elucidate the role of blood pressure management on nerve injuries, and understand if treatment of blood pressure can prevent or mitigate certain nerve injuries. Our group is currently investigating risk factors for new onset postpartum lower-extremity nerve injuries in an Agency for Healthcare Research and Quality (AHRQ)-funded study. The study will evaluate the contribution of patient-related, as well as obstetric, neonatal, and anesthetic risk factors. We hope to further our understanding of these nerve injuries and identify potentially-modifiable factors.

OUR ROLE AS ANESTHESIA PROFESSIONALS

Anesthesia professionals in collaboration with obstetrics play an important role in the identification of nerve injuries and connecting patients to resources for management of these injuries. An important consideration after a nerve injury is that patients are at a significant fall risk. If there is significant motor dysfunction, as seen with femoral neuropathies and lumbosacral plexus injuries, patients should be thoroughly assessed and counseled prior to discharge. Thankfully, prognosis on nerve injury during labor is favorable as recovery typically occurs on the order of weeks.² In one study, the median duration of symptoms was two months.⁴ In another prospective study, the median time to recover from nerve injury was 18 days, but three women continued to have a neurologic deficit after a year.⁹

Anesthesia professionals should work with the obstetricians and nurses at their institution to ensure that all patients are evaluated after delivery and asked about symptoms consistent with postpartum lower extremity nerve injuries. If the post-anesthetic evaluation occurs immediately after delivery, the residual effects of the neuraxial block may mask any new-onset lower extremity nerve injuries. Ideally, on postpartum day one, either anesthesia professionals, obstetricians, or postpartum nurses should ask patients, are you having any difficulty walking or do you have any new numbness or weakness in your legs? If the patient endorses a new sensory deficit or weakness, these patients should have a more thorough evaluation by the anesthesia team (if the patient had a neuraxial anesthetic), or by a physiatrist or physical therapist if the patient did not have an anesthetic for delivery. If the pattern of injury is unclear, a neurology consult may be indicated as electromyography could assist in revealing individual nerve and muscle dysfunction.¹⁰ It is critically important for patients with any weakness to be evaluated for safe ambulating because there is the potential that the new mother could injure herself, or her infant, if she is unable to bear weight due to the nerve injury. A physical therapy evaluation will identify if any assistive devices such as a knee brace, orthotic shoe, or walker are needed prior to leaving the hospital. While typically no medical treatment is needed for new onset lower extremity nerve injuries, gabapentin could be considered if the patient complains of neuropathic pain. Studies in this patient population have been small, but gabapentin has not been shown to have an effect on the neonate through breast milk exposure.¹¹ The more significant risk is that gabapentin has a wide side-effect profile, including increased fatigue, which may be undesirable. Lastly, emotional support is crucial, as a debilitating injury could further exacerbate any postpartum

See “Nerve Injury,” Next Page

Anesthesia Professionals Can Help Assess Postpartum Patients For New Onset Nerve Injuries

From "Nerve Injury," Preceding Page

depression or anxiety; therefore, close follow-up with their obstetrician after delivery is vital. Typically, follow-up with a neurologist or physical medicine and rehabilitation is not needed, as long as symptoms continue to resolve and are not worsening in nature.

SUMMARY

Postpartum nerve injuries are very rare, but can be very worrisome to both the patient and the anesthesia professional. The majority of nerve injuries are attributed to intrinsic obstetric palsies secondary to compression or stretch of the nerve during delivery. However, it is important to be aware of our role as it relates to hypoperfusion of nerves, traumatic neuraxial placement, and decreased motor function during labor secondary to dense local anesthetic. Further research is needed to help understand which factors place patients at increased risk for these injuries. Anesthesia professionals can directly impact safety by educating other perinatal providers and ensuring that all patients, regardless of whether or not they had a neuraxial procedure, are assessed by a provider for new-onset postpartum nerve injuries. If a nerve injury is detected, the nerve(s) affected should be identified, and the injury

described in the medical record (motor, sensory, or mixed). The patient should also be evaluated by physical therapy or psychiatry to ensure that the patient is safe to ambulate with her infant prior to discharge from the hospital.

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Allison Bechtel, MD
APSF Podcast Director

APSF Statement on Pulse Oximetry and Skin Tone

Pulse Oximeters are Important for Keeping all Patients Safe

by Jeffrey Feldman, MD, and Meghan Lane-Fall, MD, MSHP

On December 17, 2020, Sjoding *et al.* published a retrospective analysis of pulse oximetry (SpO₂) data from two patient cohorts indicating that in some patients, occult hypoxemia was not detected when compared to paired oxyhemoglobin saturation measured by laboratory co-oximetry (SaO₂).¹ Occult hypoxemia was defined as an SaO₂ of < 90% when the paired SpO₂ measurements were 92% or greater. The authors compared sub-groups from the cohorts self-identifying as Black and White, and found that the incidence of occult hypoxemia was three times greater in Black patients (11.7%) compared with White patients (3.6%). As the authors noted, these findings, if correct, have important patient safety implications since patient triage based upon pulse oximeter measurements could fail to lead to appropriate escalation of care. As a retrospective, uncontrolled study without objective measurements of skin tone, the analysis performed by Sjoding *et al.* has important limitations. Nevertheless, it is important to verify these findings to understand if there is the potential for pulse oximeter measurements to mislead clinicians, especially in patients with dark skin tones.

WHAT IS THE EVIDENCE?

The impact of skin tone on pulse oximeter measurements has been documented in the scientific literature since at least 2005. The putative source of bias in measurement is overlapping absorption of light in the red region (660 nm) for both oxyhemoglobin and the skin pigment melanin. Laboratory studies into the impact of skin tone on pulse oximeter measurements have documented a bias, although not of the magnitude identified in the Sjoding data. Bickler *et al.* found that SpO₂ measurements overestimated SaO₂ measurements to a greater degree in patients with dark skin tones. The bias increased as saturation decreased and varied with the type of oximeter. They found a maximum bias of $3.56 \pm 2.45\%$ for test subjects with dark skin in the 60–70% saturation range but no more than $0.93 \pm 1.64\%$ for saturations above 80%.² The same group studied additional pulse oximeters in test subjects with dark and light skin tones and concluded that several factors were predictive of errors in pulse oximeter measurements including skin tone, probe type, saturation level, and sex. They also stated that bias would be important for patients with a saturation less than 80%.³ Of note, Jubran and Tobin prospectively studied a cohort of ICU patients to determine if SpO₂



measurements could be used to titrate oxygen to maintain a PaO₂ > 60. Those authors identified a greater bias in SpO₂ measurements in patients with dark skin tones and recommended that a threshold of 95% be used for oxygen titration versus 92% for White patients.⁴ No known studies to date investigate the impact of sex and skin tone together, which could potentially lead to greater measurement bias in female patients with dark skin tones.

The measurement bias demonstrated in the Bickler *et al.* and Jubran and Tobin publications was apparently not well known by medical professionals, as gauged by a lack of description of this phenomenon in major textbooks of medicine, surgery, and emergency medicine. The phenomenon is described in textbooks of anesthesiology, though the degree to which this is considered in current clinical practice is unclear. The Sjoding *et al.* publication, if replicated, is concerning because measurement bias was demonstrated at SpO₂ levels thought to be consistent with normoxemia. Since the Sjoding publication, there has been significant work by pulse oximeter manufacturers, the United States Food and Drug Administration (FDA) and independent testing laboratories to further investigate the potential for bias due to skin tone (Personal communications). The results of this work will be forthcoming, but are not yet ready for publication.

REGULATORY RESPONSE TO DATE

The FDA began to investigate the Sjoding *et al.* findings shortly after they were published and that work is ongoing. On January 25, 2021, United States Senators Warren, Wyden, and Booker requested that the FDA “conduct a review of the accuracy of pulse oximeters across racially diverse patients and consumers.”⁵ On

February 19, 2021, the FDA issued a safety communication entitled: “Pulse Oximeter Accuracy and Limitations.” That communication emphasizes the known accuracy limitations of pulse oximeters including patients with dark skin tones stating that “if an FDA-cleared pulse oximeter reads 90%, then the true oxygen saturation in the blood is generally between 86 and 94%.⁶ It is important to note that FDA clearance of a pulse oximeter requires that 15% of test subjects with dark pigmentation, or two subjects (whichever is greater) be included in the participant pool.⁷ The FDA safety communication addresses the Sjoding publication, identifying the limitations of that retrospective analysis and recognizing the “need to further evaluate and understand the association between skin pigmentation and oximeter accuracy.”

CONCLUSIONS

The preponderance of evidence supports the conclusion that there is a measurement bias in pulse oximeter measurements due to skin tone such that pulse oximeter measurements may overestimate the actual oxyhemoglobin saturation in patients with dark skin tones. Laboratory data obtained under controlled conditions does not indicate that the magnitude of the bias is significant enough to influence clinical decision making until the saturation is less than 80%. Clinical performance is likely to be different from that obtained in the laboratory, and it is clear that many factors will influence the accuracy of pulse oximetry in addition to skin tone. Therefore, clinicians should not make patient care decisions such as hospital or intensive care unit discharge on the basis of a single SpO₂ value.

See “Pulse Ox and Skin Tone,” Next Page

The APSF Supports Renewed Attention to the Accuracy of the Pulse Oximeter Reading

From “Pulse Ox and Skin Tone,” Preceding Page

Despite the known limitations of the pulse oximeter, APSF believes that patients are safer with continued use of pulse oximetry to estimate arterial oxygenation. It is potentially more harmful if the known bias in measurement related to skin tone resulted in a lack of confidence in pulse oximetry as a monitoring tool for patients with dark skin tones.

The findings by Sjoding et al. require verification but present at least two opportunities to improve clinical care and outcomes. First, there is an opportunity for manufacturers, regulators, and clinicians to work together to ensure that technology is developed and tested to document clinical performance in demographically and clinically diverse populations. The FDA's requirement for inclusion of “darkly pigmented subjects” in device development warrants reconsideration. Requirements for objective measurement of skin tone should be specified. More importantly, including 15% darkly pigmented subjects in the study group may reduce the average measurement bias in that population, but not necessarily result in ideal performance for the individual patient. Closer scrutiny to minimizing measurement bias in subjects with dark skin tones is warranted, including reconsideration of the 15% threshold. Second, this is an opportunity to examine more closely

how pulse oximetry is used in the clinical setting and to heighten awareness of the factors that can lead to inaccurate measurements. Like any monitoring device, the measurements obtained by a pulse oximeter are estimates of the actual physiologic condition and can be erroneous. Factors other than skin tone known to affect the accuracy of pulse oximetry include perfusion, dyshemoglobinemias, anemia, brand of oximeter, and motion. Sound clinical decision making depends upon a complete assessment of the patient, not a reliance on a single monitored parameter.

APSF supports the renewed attention to the accuracy of the pulse oximeter, which has rightly revolutionized medical care and augmented patient safety. We call on clinicians, manufacturers, and regulators to work together to ensure that this device offers equitable benefits to all the patients we serve.

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The authors have no conflicts of interest.

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Establishing a Difficult Airway Response Team for a Regional Hospital: A Case Study in the Adoption and Diffusion of Innovations

by Sarah K. Pierce, CRNA, and Gary E. Machlis, PhD

INTRODUCTION

Difficult airway adverse events are the fourth most common event in the American Society of Anesthesiologist Closed Claims Database, with detrimental or devastating consequences to patients, their families, health care providers, and hospitals.¹ In response, Johns Hopkins Hospital conducted a two-year evaluation of actual and near-miss events related to emergency difficult airway management in non-OR areas. The comprehensive review revealed a set of critical challenges: inconsistent communication processes (including paging issues and delays), lack of knowledge among providers in non-OR areas on when and how to activate airway support, limited accessibility and availability of surgical emergency equipment, lack of defined roles during difficult airway events, and lack of

familiarity with specialized airway techniques. The hospital created a Difficult Airway Response Team (DART) program to prevent related morbidity and mortality. Their system-based approach resulted in a reduction in adverse events.²

Difficult airway adverse events are not limited to large institutions and occur at hospitals of all sizes. Adapting a DART program established at a major metropolitan research hospital for use in a small regional hospital is both a significant challenge and an important opportunity. Regional hospitals have limited financial resources, no residents or fellows, and fewer in-house medical staff. Yet scaling a successful large-hospital program to meet small regional hospital needs can result in improved patient safety, provider efficiencies, and institutional quality.

THE ADOPTION AND DIFFUSION OF INNOVATIONS

One strategy for developing such scaled programs is to consider the challenge as an “adoption and diffusion of innovations” problem. In the social sciences, significant research literature provides theory and evidence as to how innovations are initially adopted and then, over time, diffused throughout a social system. Everett Rogers' *Diffusion of Innovations* (now in its fifth edition) provides a general introduction and a wide set of examples, beginning with the 18th century adoption of oranges and lemons prescribed as part of a sailor's diet by a British Navy physician to prevent scurvy.³

See “Airway Team,” Next Page

Developing DART in A Regional Rural Setting

From “Airway Team,” Preceding Page

Rogers identifies several key elements of a successful adoption including: 1) characteristics of the innovation itself, 2) characteristics of the organization considering the innovation, 3) the role of change agents in encouraging adoption, and 4) characteristics of the individual adopters. For example, innovations that are perceived to be of relative advantage to the adopter, not complex to execute, culturally appropriate within the organization, and observable (i.e., adopted from existing use elsewhere) are more likely to be successful. Adapting a metropolitan hospital DART program to a regional hospital is an adoption and diffusion challenge, and this general strategic approach guided the program developed by Anesthesia Associates of Coeur d’Alene (AACDA) for Kootenai Health Hospital in Coeur d’Alene, Idaho.

KOOTENAI HEALTH HOSPITAL AND AACDA

Kootenai Health is a 331-bed community-owned hospital located in Coeur d’Alene, Idaho, 105 miles south of the Canadian border. The region has experienced significant population growth and the city of Coeur d’Alene has approximately 50,000 residents. Kootenai Health services a large radius of rural communities for trauma and has made rapid expansions to its service lines over the past decade to accommodate the increasing population and health needs (<https://www.kh.org/>).

Anesthesia Associates of Coeur d’Alene (AACDA) is a private practice under contract with Kootenai Health. AACDA is a 41-provider anesthesia practice comprised of both independently practicing anesthesiologists and certified registered nurse anesthetists (<https://www.aacda.com/>). The development of the Kootenai Health DART program was led by Sarah Pierce of AACDA and involved several steps, each focused on adapting the Johns Hopkins DART program and having the innovation adopted by Kootenai Health.

MAKING THE ARGUMENT FOR A DART PROGRAM

The need for a DART program was motivated by a difficult airway event. A local surgeon subsequently learned about the Johns Hopkins DART program and approached AACDA about working to implement a similar program for Kootenai Health. Significant modifications were needed in order to make the Johns Hopkins DART program compatible for the smaller facility. A multidisciplinary task force was established, composed of important stakeholders and leaders in airway management, including the medical director of the Intensive Care Units, the medical director of the Emergency Department, an Ear Nose and Throat surgeon, and an anesthesia professional. Over the following year, we developed

a plan that would be feasible for the facility and worked to gain momentum and recognition from key hospital administrators. This included presenting the plan to the Surgery Committee, at quarterly Medical Staff meetings, to joint operating committees, and ultimately to the Board of Trustees for submission as a “Pillar of Safety” for the institution. After an in-depth presentation of how this program could be adapted and implemented for our regional hospital with a staged approach and modifications, we received unanimous approval and a starting budget of \$500,000 for equipment and training (see table 1).

ASSEMBLING THE EQUIPMENT

It was imperative that we provide the most up-to-date equipment for providers. We had a blended group of medical staff (including emergency medicine [EM] physicians, anesthesia providers, and intensivists) that would be managing airways; so it was imperative that the equipment would be easy to use for all specialties and agreed upon by all. After much research and several trial evaluations of equipment, we selected a disposable video laryngoscopy and bronchoscopy system with dual view capability. This allowed for two providers to work together on establishing an airway.

Table 1: Key Components for Developing a DART Program at Regional and Rural Hospitals.

• Treat development of the program as the adoption and diffusion of an innovation
• Identify a provider or physician leader to champion program development
• Build a multidisciplinary team
• Gain support of key stakeholders (including leaders in airway management) early in program planning
• Conduct a comprehensive assessment of available resources and equipment
• Create a feasible plan scaled to the facility that can be implemented in stages
• Secure administrator’s support via educational presentations and briefings
• Select equipment designed for multidisciplinary teams and agreed upon by all users
• Conduct multidisciplinary team-based training that replicates real-life scenarios
• Build an airway management culture that encourages collaboration across provider disciplines
• Encourage early intervention in difficult airway management and proactive use of DART teams
• Continue education, training, evaluation, and program improvement

We began the adoption process by building a fleet of “ideal” difficult airway carts. Each cart contained standard and advanced airway equipment as well as video laryngoscopes and bronchoscopes.⁴ Our goal was to provide uniform, standardized airway equipment throughout the hospital so that no matter where a response to a difficult airway or intubation was needed, the same equipment was always available. We created identical DART carts to be located in our three Intensive Care Units (ICU), Obstetrics (OB), Emergency Department (ED), Operating Room (OR), as well as a travel cart and one for exchange in Central Supply.

These carts remain locked until use (similar to a code cart) and restocked after every use by the hospital’s central supply utilizing a standardized checklist and two-person verification. Each DART cart has a video laryngoscope with every size of intubating handle and pediatric and adult bronchoscopes. Roll out of the equipment required significant communication and educational support to increase awareness and familiarity with the equipment for the nursing staff, rapid response team, medical staff, anesthesia professionals, and respiratory therapy staff. Demand for the new DART carts was high and, therefore, the response within the hospital resulted in the purchasing of a second exchange cart for Central Supply as well as an additional cart for our COVID-19 ICU. Prior to this program, each unit had their own airway cart that was often lacking equipment, disorganized, and not routinely re-stocked; the new standardized carts were rapidly recognized as providing a distinct advantage and extremely well received.

TRAINING FOR THE PROGRAM

Training for the program was a key element of the adoption and diffusion strategy. An annual multidisciplinary Difficult Airway Workshop was established; so far three have been conducted. Each workshop focused on core difficulty airway topics, tools and procedures including awake fiber-optic intubation, the “can’t intubate/can’t ventilate” algorithm, the difficult airway cart, emergency cricothyrotomy and tracheostomy, and difficult airway scenarios. The workshop has had an exceedingly positive response within the institution. Ear, Nose, and Throat (ENT) surgeons from two separate surgical groups participated and helped to teach the cricothyrotomy and tracheostomy portion of the course. Attendees were placed in multidisciplinary groups (EM physician, anesthesia professional, intensivist, paramedic, rapid response nurse, respiratory therapist, and ENT surgeon) to perform cricothyrotomy on pig tracheas and practice simulated airway emergencies. The workshop provided pig tracheas for all participants to practice the surgical airway procedures, and therefore better understand the process.

See “Airway Team,” Next Page

DART Program Enhanced Culture of Collaboration

From “Airway Team,” Preceding Page

Participants included individuals that would not be performing the surgical airway procedure, because this helps them better collaborate and assist with actual difficult airway events. Over 50 intubating providers of different specialties attended. At the end of the workshop, the ENT surgeons discussed different difficult airway cases encountered throughout the year in a roundtable format.

The results have been dramatic. In 10 months of operation, the DART carts have been used 167 times. Based on anecdotal evidence and written comments by medical staff, there has been a profound improvement in our collaborative culture and in patient safety. Intensivists and EM physicians are more likely to reach out to anesthesia professionals with a potentially difficult airway situation, do so early, and use a team approach for securing the airway. Communication between disciplines and in emergencies has significantly improved. Surgeons of other specialties are reaching out to participate in our annual Difficult Airway Workshop, and we anticipate continued multidisciplinary growth. After a full year of operation, a quality improvement survey that covers such topics as program barriers and limitations, improvements in patient safety, and reduction of adverse airway events will be administered to all intubating providers and support staff.

LABELING OF PATIENTS

Another key element of our DART program has been improved identification of high-risk patients. This has been a particular challenge with significant staffing shortages and scarce resources related to COVID-19 cases and has required improvisation for success. Patients who meet established criteria for “difficult airway” (such as BMI >50, sleep apnea, or recent neck surgery) have a blue sign placed above the head of their bed that reads “Please call anesthesia for any imminent, or emergent airway concerns” with a phone number that goes to a designated in-house anesthesia professional 24/7. We have encouraged our Rapid Response and ICU nurses to call anesthesia for respiratory- or airway-related concerns and for any patients that meet the criteria for “difficult airway.” From this point forward, all patients admitted to the hospital will be screened for “difficult airway” and those meeting criteria will have an indicator placed by the provider in the electronic medical record (much like an allergy). This will also help establish a data collection process for clinical evaluation of the efficacy of the DART program over time.

BUILDING THE CULTURE

Adoption of new innovations is never easy or straightforward, and the DART program was no exception. The COVID-19 pandemic led to significant supply chain issues for airway supplies and the need to increase ICU capacity to care

for critically ill COVID-19 patients. Higher than anticipated demand for DART equipment meant frequent exchange of carts. The transition from physicians working independently to manage all airways toward a team approach and pre-emptive requests for assistance was a significant change in operational style.

While the DART program has been the initial focus in the adoption process, the development of a culture that emphasizes collaboration between specialties with an emphasis on patient safety is the ultimate goal. The development of a collaborative culture in small regional hospitals extends beyond managing difficult airways and can and will be instrumental in many medical emergencies.

In order to develop a multidisciplinary team capable of functioning well under extreme pressure, we needed to be able to train together, recognize each other’s strengths and limitations, understand how to perform as a collective team, know when to ask for help, and communicate effectively. The innovative DART program has helped establish these practices within our institutional culture. As new providers join the medical practices at Kootenai Health, and are brought into the program alongside early adopters, patient safety and a multidisciplinary, collegial culture will be built and sustained.

CONCLUSION: CALL TO ACTION

The DART program at Kootenai Health, a small regional hospital in Idaho, was adapted from a successful program at Johns Hopkins, a major metropolitan research hospital. It required a strategic effort to propose a plan suitable for the institution, assemble the necessary equipment in usable form, invest in team-based training, improvise with patient labeling, and build a culture of patient safety and cross-disciplinary collaboration. Kootenai Health can now manage difficult airway situations more effectively and safely. Next steps include 1) conduct a survey of participants and a retrospective study of adverse airway events, DART usage, and mortality, 2) use the results to improve the DART program effectiveness, 3)

expand training to include additional workshops and advanced simulations, 4) provide additional training for regional Emergency Medical System (EMS) and pre-hospital providers, and 5) respond to assistance requests from other regional and small rural hospitals interested in developing their own DART program.

But beyond difficult airways scenarios, the adoption and diffusion of programs and practices from large research hospitals to small regional facilities—and even smaller rural hospitals and clinics—has significant potential to improve health care throughout the smaller cities and rural communities of America. It is both a challenge and opportunity.

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Sarah K. Pierce, CRNA, initiated into a contract as an independent contractor for Verathon (the makers of GlideScope) as of December 2020. As a Verathon independent contractor focused on providing education, the contractor is not considered an agent, representative or employee of the company.

Gary E. Machlis, PhD, has no conflicts of interest.

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Important Medication Errors and Hazards Reported to the ISMP National Medication Errors Reporting Program During 2020

by Ronald S. Litman, DO, ML, Medical Director, ISMP

The Institute for Safe Medication Practices (ISMP.org) receives thousands of medication error reports through their voluntary practitioner online reporting system. By this mechanism, ISMP compiled a list of important medication errors and hazards during 2020, most of which are of interest to perioperative, intensive care, or pain management practices. They include

PRESCRIBING, DISPENSING, AND ADMINISTERING EXTENDED-RELEASE (ER) OPIOIDS TO OPIOID-NAÏVE PATIENTS.

Inappropriate prescribing of ER opioids to opioid-naïve patients has resulted in serious harm and death. ISMP, as well as the US Food and Drug Administration (FDA), have warned practitioners about this well-known problem for decades. However, inappropriate opioid prescribing continues to occur, often due to a knowledge deficit about the dangers associated with prescribing ER opioids to opioid-naïve patients and/or not understanding the difference between opioid-naïve and opioid-tolerant. For example, in 2020, ISMP published several new reports related to prescribing fentaNYL patches to opioid-naïve, elderly patients, sometimes to treat acute pain or due to a codeine “allergy” that was a minor drug intolerance.¹ FentaNYL patches should only be prescribed to opioid-tolerant patients for the management of pain severe enough to require daily, around-the-clock, long-term opioid treatment. This is so critical to safety that, in 2018, ISMP called for the elimination of prescribing fentaNYL patches to opioid-naïve patients and/or patients with acute pain in our *Targeted Medication Safety Best Practices for Hospitals*. In 2020, this Best Practice was incorporated into a new Best Practice to verify and document the patient’s opioid status (naïve vs. tolerant) and type of pain (acute vs. chronic) before prescribing and dispensing ER opioids.²

To do this, ISMP first recommends establishing definitions for opioid-naïve and opioid-tolerant patients (for example, following the fentaNYL package insert definitions), and then developing and implementing a standard process for gathering and documenting each patient’s opioid status and type of pain (if pain is present). Order entry systems should default to the lowest initial starting dose and frequency when initiating orders for ER opioids, and interactive alerts should be built to confirm opioid tolerance when prescribing and dispensing ER opioids. Distinguish between true allergies and

drug intolerances when collecting allergy information. Eliminate the storage of fentaNYL patches in automated dispensing cabinets (ADCs) or as unit stock in clinical locations where primarily acute pain is treated (e.g., in the emergency department [ED], operating room, post-anesthesia care unit, procedural areas). Our 2020 survey showed low compliance with many of these recommendations.³

NOT USING SMART INFUSION PUMPS WITH DOSE ERROR-REDUCTION SYSTEMS (DERS) IN PERIOPERATIVE SETTINGS

Our updated (2020) *Guidelines for Optimizing Safe Implementation and Use of Smart Infusion Pumps* recommend the use of smart pumps with DERS throughout the organization, including in perioperative settings, for all infusions (including hydrating solutions) and bolus/loading doses. However, use of smart pumps with DERS by anesthesia providers in perioperative settings is limited due to barriers and unique challenges. One common barrier to optimal use of smart pumps with DERS in perioperative settings is that there may not be a clear expectation from leadership for anesthesia professionals to use smart pumps with DERS. Many anesthesia professionals do not understand the capabilities of smart pumps, including loading/bolus dose capabilities. Anesthesia professionals may also feel that the soft and hard dose/infusion limits set in the pump are unacceptable, often because they have not been included when building the anesthesia/perioperative drug library. In many organizations, smart pumps are used in the operating room with an “anesthesia mode” setting. However, the organization may fail to understand that, in some pumps, “anesthesia mode” settings reduce all hard stops to soft stops, (soft stops can be overridden, while hard stops cannot), thereby allowing easy overrides of dosing/concentration limits that should never be bypassed.

Leadership should clearly establish that the use of smart pumps with an engaged DERS is expected in perioperative settings for all infusions and loading/bolus doses (except when the hydrating solution rate is greater than the pump allows). Anesthesia professionals involvement with building the smart pump library is paramount. When possible, implement upper and lower hard limits for medication doses, concentrations, infusion rates, and loading/bolus doses, and restrict the use of



Figure 1: (Left) Depicts oxytocin vials with green caps that look similar to the ondansetron vials.

Figure 2: (Right) Depicts an ondansetron vial with a green cap that looks similar to some oxytocin vials.

pumps in “anesthesia mode” if it affects individualization of infusion limits. Anesthesia professionals should use the bolus feature (if available) with hard limits for catastrophic doses, and not allow the delivery of bolus doses by increasing the rate of the infusion. Hands-on education about how to use smart pumps with DERS, including the bolus dose feature, along with competency assessments should be implemented for all anesthesia professionals. Organizations are encouraged to analyze pump data to understand any barriers to the effective use of smart pumps with DERS in the perioperative setting.

ERRORS WITH OXYTOCIN

In 2020, ISMP conducted an analysis of oxytocin errors, many of which caused hyperstimulation of the uterus, which can result in fetal distress, uterine rupture, or an emergency cesarean section. Sadly, a few maternal, fetal, and neonatal deaths have been reported. More than one-third of the reported errors were associated with look-alike vials and label confusion.⁴ For example, generic oxytocin and brand PITO-CIN vials look similar to ondansetron vials from various manufacturers, which all have green caps (see figures 1 and 2). Several recent 10-fold dosing errors were caused by label confusion with 1, 10, and 30 mL oxytocin vials (Fresenius Kabi, Homburg, Germany). The labels prominently display “10 USP units/mL,” with the total volume in the vial at the bottom of the label, causing staff to think there were only 10 units total in each vial. A few prescribing errors were caused by selection of the wrong drug on order entry screens when searching using only the first few letters of a drug name (e.g., “OXY10” for

See “Medication Errors,” Next Page

Medication Errors (Cont'd)

From “Medication Errors,” Preceding Page

oxytocin vs. oxy**CODONE**; “PIT” for Pitocin vs. **PITRESSIN** [discontinued brand of vasopressin]). Occasionally, verbal orders for “Pitressin” were misheard as Pitocin and dispensed, or vice versa. Administration errors were often related to incomplete or omitted labels on nurse-prepared oxytocin solutions, which often led to infusion bag swaps. Numerous errors were reported in which an oxytocin bag was mixed up with either a hydrating fluid or magnesium infusion.

To help prevent oxytocin errors, hospital systems may require prescribers to use at least five letters of a drug name when searching electronic systems. Avoid nurse-prepared oxytocin infusions and instead have pharmacy dispense oxytocin in ready-to-administer, labeled bags in standardized concentrations. Ensure oxytocin vial (and premixed infusion) labels are clear regarding the amount of drug per total volume. Employ barcode scanning technology when stocking automatic dispensing cabinets and when preparing and administering infusions. Infuse oxytocin solutions through a smart infusion pump with an engaged DERS. Immediately discard discontinued oxytocin infusion bags.⁴

HAZARDS ASSOCIATED WITH POSITIONING INFUSION PUMPS OUTSIDE COVID-19 PATIENTS’ ROOMS

During the COVID-19 pandemic, some hospitals have [positioned infusion pumps outside COVID-19 patients’ rooms](#) to conserve personal

protective equipment (PPE), reduce staff exposure, and enhance the ability to hear and respond to pump alarms in a timely manner. This has been accomplished, in part, through the use of extension sets. The length and inner diameter of the long extension tubing can impact the volume of fluid needed for priming, flow rates, and the time medications and solutions take to reach a patient. Inadvertent bolus doses of medication remaining in the extension set might be administered to a patient when flushing the long tubing. Occlusion alarms may be delayed at low flow rates or become excessive at high flow rates. The long extension tubing (and electrical cords) may pose a tripping hazard and become tangled and disconnected. Barcode scanning of the patient and drug may be more challenging, and certain components of an independent double check may become difficult or impossible in some situations.

While recognizing that this is not ideal, hospitals must weigh the risk vs. benefit of positioning infusion pumps outside COVID-19 patients’ rooms. If a decision has been made to locate pumps outside of rooms, health care professionals should periodically assess the process. A [special report from ECRI](#) can help guide the selection and use of long extension sets for this purpose and includes other factors (e.g., fluid viscosity) that should be considered.⁵ ECRI recommends the following:

- The nurse should conduct periodic infusion pump rounds in the hallway to verify the accuracy of the fluids and medications infus-

ing as well as the pump settings;

- Check that the tubing is not disconnected or a tripping hazard;
- Develop a temporary process that allows some components of barcode scanning and/or independent double checks to occur prior to medication administration. For example, because nurses cannot scan the barcode on the patient’s identification band, some hospitals affix the patient’s name, birthdate, and a barcode to the pump or intravenous (IV) pole located outside the room.
- At the end of the pandemic or when pumps are no longer located in hallways, discontinue temporary identification measures and have staff return to the verification processes in place prior to the pandemic.

COMBINING OR MANIPULATING COMMERCIALLY AVAILABLE STERILE PRODUCTS OUTSIDE THE PHARMACY

Our recent [2020 survey on admixture outside the pharmacy](#) showed that this error-prone practice happens often during emergency situations, mostly without formal training, and that there are significant procedural deviations and challenges associated with the practice that contribute to risk.⁶ Survey respondents told us that IV push medications, IV intermittent infusions, IM injections, and IV continuous infusions were the most frequent sterile injectables prepared outside the pharmacy, primarily by nurses, anesthesia professionals, and physicians. Nearly half of the respondents told us they have not been formally trained for this complex task. The biggest concerns expressed by respondents were lack of space, rushing through the preparation process, labeling issues, mixing by memory instead of following written instructions, interruptions and distractions, and concerns about sterility and accuracy. Nearly one-third of the respondents were aware of associated errors in the past year, particularly preparation errors.⁶

The results of this survey can be used to prompt internal discussions about the need to limit the preparation of admixtures outside the pharmacy as much as possible and how to increase the use of pharmacy- and manufacturer-prepared, ready-to-use products. If your organization did not participate in this survey, you can download it by [clicking here](#), conduct it internally, and review the results to pinpoint your vulnerabilities and establish a plan for improvement. The goal for 2021 should be to significantly reduce the need and frequency of admixture outside the pharmacy.

See “Medication Errors,” Next Page

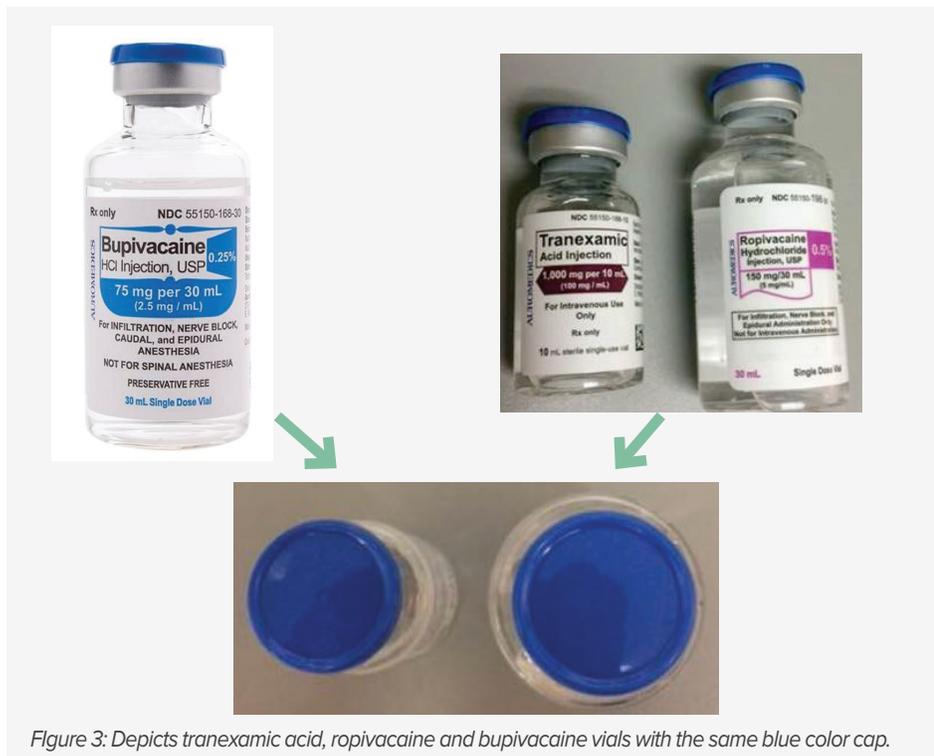


Figure 3: Depicts tranexamic acid, ropivacaine and bupivacaine vials with the same blue color cap.

Wrong Route Medication Errors Can Be Fatal

From “Medication Errors,” Preceding Page

WRONG ROUTE (INTRASPINAL INJECTION) ERRORS WITH TRANEXAMIC ACID

ISMP continues to receive reports involving the accidental intraspinal injection of tranexamic acid instead of a local anesthetic intended for epidural or spinal anesthesia. Bupivacaine, ropivacaine, and tranexamic acid are sometimes packaged in vials with the same blue color cap (see figure 3). When the vials are standing upright in storage, practitioners have picked up a vial based on cap color and not noticed it was the wrong vial. Wrong route errors with tranexamic acid are the only error type repeated from our 2019 list of *Top 10 Medication Errors and Hazards*, and they are the only danger that rose to the level of activating the *National Alert Network* during 2020. Last month, the [FDA announced](#) that it will be revising the tranexamic acid labeling to highlight the IV route of administration and strengthen the warnings to include the risk of wrong route errors. Accidental intraspinal injection of tranexamic acid can result in severe patient harm, with a mortality rate of 50%.⁷

We urge practitioners to purchase these products from different manufacturers to help

differentiate their appearance and/or consider alternate preparations (e.g., premixed bag, pharmacy-prepared syringes or infusions). Providers should avoid upright storage of the vials so the labels are always visible. Pharmacies should store tranexamic acid vials away from other look-alike vials and add an auxiliary label to vials to highlight the IV route of administration. When possible, employ barcode scanning prior to dispensing and administration. Some manufacturers provide a premixed bag of 1 g/100 mL of tranexamic acid, which should be used when appropriate, or have the pharmacy prepare minibags to reduce the risk of mix-ups. Providers should also consider transitioning to NRFit syringes and connectors for local anesthetics to prevent misconnections with drugs intended for IV use.

In summary, ISMP has compiled some of the most common medication errors reported from perioperative care areas in 2020, and they are reported here.

This article was adapted from the ISMP Top Ten List of Medication Errors and Hazards,⁸ with permission.

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The author has no further conflicts of interest.

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A Tribute to Ron Litman, DO, ML



In this issue of the *Newsletter*, there are two articles by Ron Litman, DO, a frequent contributor to APSF. As the *Newsletter* was being finalized for publication, Ron passed away after a battle with leukemia. The articles in this issue provide a glimpse into the breadth of his career. As an MH consultant for many years, he took calls at all hours of the day and night, advising colleagues faced with patient care decisions to recognize and treat malignant hyperthermia. He was not only a world expert on MH, but an important voice for MHAUS (Malignant Hyperthermia Association of the US), serving as the medical director from 2013 to 2019. Of note, his article on lessons learned from the MH hotline was authored with a medical student,

one of countless students and residents he mentored with the goal of inspiring them to a career of inquiry and contribution. Ron also had a longstanding interest in medication safety and served as medical director for ISMP (the Institute for Safe Medical Practices) and as former Chair of the FDA Anesthetic and Analgesic Drug Products Advisory Committee. Ron was a leading voice in pediatric anesthesia, contributing to our understanding of the pediatric airway, and inspiring many to contribute to the field. He had a thirst for knowledge and found time to earn a Masters of Law degree in recent years. He did it all with humor and a very human touch. Ron’s passing is a great loss, not only to his family and friends, but to our specialty and the patients we serve.

Jeffrey M. Feldman, MD, MSE
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RAPID Response

to questions from readers

Inadvertent Unplugging of Rapid Infuser Causing a Large Volume of Cold Fluid to be Infused with Subsequent Cardiac Arrest

Dear Rapid Response:

The ThermoCor® 1200 Rapid Infusion (Smisson-Carlledge Biomedical, Macon, GA) is a rapid heated fluid infuser, which utilizes dry, conduction temperature-controlled heating when plugged into an AC input voltage source.¹ When unplugged, the device makes a single beep, and the lit indicator on the infusion system that states “HEAT ON” is replaced by a flashing “HEAT OFF” message (figures 1 and 2). The nominal fluid outlet temperature with the heater on is 37°C when running at 1000mL/min. However, when the infuser is unplugged from an AC power source, the heater also turns off.¹ Despite the heater turning off, the device will continue to infuse at the same rapid rate using a lithium-ion battery pack.¹ Similarly, the Belmont® Rapid Infuser, FMS2000 (Belmont Instrument Corporation, Billerica, MA) will continue infusing up to 50mL/min without heat when unplugged.²

We experienced an incident during a trauma surgery, which required rapid transfusion of

fluids and blood products, where the ThermoCor® 1200 was inadvertently unplugged. In the middle of this high acuity surgery, the beep to indicate that the infuser was unplugged was too quiet to be noticed by the anesthesiology team. This incident occurred at the height of the COVID pandemic and the patient’s SARS-CoV-2 status was unknown at the time of arrival to the operating room (OR). The OR policies to reduce viral transmission were followed throughout the case, including donning surgical hoods and face shields that might have impeded the providers’ ability to visualize the “HEAT OFF” signal.

As a result of the unnoticed “HEAT OFF” alert, a large volume of unheated blood was transfused into the patient. The patient developed sinus bradycardia which progressed to cardiac arrest. Osborn waves were apparent upon review of the EKG. Heated rapid infusers are used to prevent the known risks of acute hypothermia such as coagulopathy and cardiac arrhythmias.³ Fortunately, the patient was resuscitated and survived. Given this event we



Figure 1: Device plugged in, “HEAT ON.” (Note: Photo obtained after the actual clinical event.)

believe there should be protective measures in place to prevent rapid infusion of cold fluids. While there may be clinical scenarios where an unplugged rapid infuser is required, such as during emergency transport of a patient, there should be a requirement for acknowledgment of the unplugging by the provider. It is not uncommon while resuscitating a patient to not look at the screen of a rapid infuser for several minutes or enough time for the patient to receive a significant volume of cold fluid. Therefore, the flashing “HEAT OFF” indication may not be a useful notification. To prevent future similar adverse events, we would recommend a louder, more persistent beeping to alert the provider that the infuser has been unplugged, as well as an acknowledgment screen that prompts the provider to respond to the unplugged device prior to continuation. Education of the end user would also help to prevent a similar outcome.

Cynthia Wong is an anesthesiology resident at Westchester Medical Center/New York Medical College, Valhalla, NY.

See “Response to Inadvertent Unplugging,”
Next Page

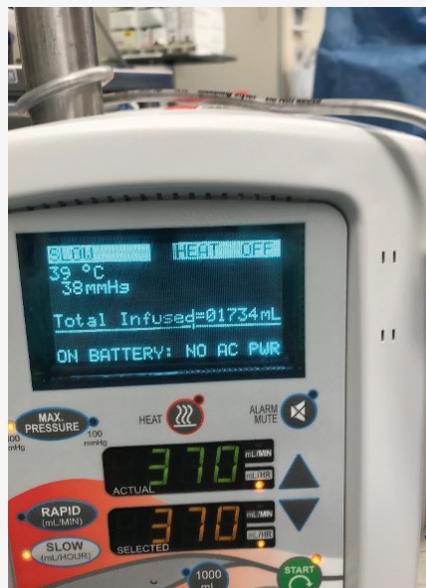


Figure 2: After the rapid infuser is unplugged, the display screen no longer states “HEAT ON” and instead clarifies “ON BATTERY: NO AC PWR,” and flashes “HEAT OFF.” (Note: Photos obtained after the actual clinical event.)

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RAPID Response

to questions from readers

In Response to Inadvertent Unplugging of Rapid Infuser Causing a Large Volume of Cold Fluid to be Infused with Subsequent Cardiac Arrest

From “Inadvertent Unplugging,” Preceding Page

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The authors have no conflicts of interest.

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In Response:

While Smisson-Cartledge Biomedical (SCB) understands the potential issue raised in the letter, please know that the ThermaCor® 1200 Rapid Thermal Infuser was designed with patient safety as the highest priority, and we are very pleased to hear that there was no permanent injury to the patient. While not preferable that unwarmed fluids were delivered, if no fluids had been delivered the outcome might have been worse. In the scenario presented, there are four items to consider: 1) the unit inadvertently became unplugged, 2) the heating was turned off after it was inadvertently unplugged, 3) the user notification and alarm regarding heat and AC Power properly activated after the unit became unplugged and 4) the training and experience of the operator.

As to the unit becoming inadvertently unplugged, the ThermaCor® 1200 Rapid Infuser was specifically designed to prevent this type of occurrence, with a heavy duty three (3) prong grounded plug held in place by a safety latch (figure 1) that must be manually released in order for the power cord to become unplugged from the unit. This safety latch is in place to prevent the power cord from being accidentally unplugged (e.g., someone tripping on the power cord), and it requires that a user intention-



Figure 1: Depicts a three-prong grounded plug held in place by a safety latch to prevent the accidental unplugging of the power cord.

ally lift and release the safety latch in order for the power cord to be separated from the unit. SCB has never received any reports of units being inadvertently unplugged until this letter. It is not possible for the company to prevent inadvertent unplugging where the plug is connected to the power source.

It would certainly be SCB’s preference that all capabilities—including heating—be available while the unit is on battery power, and we continue to make development efforts in this regard. However, the current limitations in battery technology will not permit any rapid infuser to both infuse and heat while on battery power. Therefore, the ThermaCor® 1200 Rapid Infuser, like all rapid infusers on the market, prioritizes functions while on battery power. The design challenge becomes whether to stop the device at the loss of AC Power or continue to infuse life-saving blood or fluids without heat. After much input from the user community (e.g., emergency medicine physicians, surgeons, anesthesia professionals, nurses, etc.), it was highly recommended to continue infusing because stopping blood or fluid delivery to a critically ill patient was deemed unacceptable

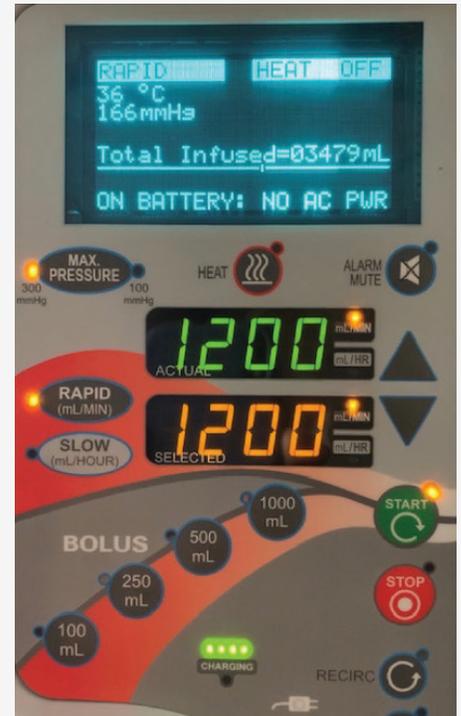


Figure 2: Shows the rapid infuser’s display on the battery supply. See bottom display line “ON BATTERY: NO AC PWR”. Also, notice that in the top right hand corner, it states “HEAT OFF” that continuously flashes on/off.

and, in many cases, could result in immediate patient injury or death. As a result, SCB designed the ThermaCor® Rapid Infuser to have full infusion capabilities including discrete bolus delivery even when running on battery backup while notifying the user that AC power is no longer available and heating has stopped. We continue to search for solutions that would make the heating function available as well. It should also be noted that, even when the ThermaCor® Rapid Infuser switches to battery and active heating is disabled, blood or fluids passing through the device continue to be “passively warmed” for a period of time. That is, the heat exchanger continues to retain significant heat and transfers it to the blood and fluids coming in contact with it, so there is not an abrupt change to infusing cold fluids.

See “Inadvertent Unplugging,” Next Page

RAPID Response
to questions from readers

Response to Inadvertent Unplugging of Rapid Infuser Causing a Large Volume of Cold Fluid to be Infused with Subsequent Cardiac Arrest (Cont'd)

From “Inadvertent Unplugging,” Preceding Page

This brings us to the third point. How should the device properly notify the user when the AC power is disconnected? The ThermoCor® 1200 Infuser accomplishes this in multiple ways. First, the device has a single audible alarm that sounds the instant the device becomes unplugged or AC Power fails. In the early design, consideration was given to having a continuous alarm, but since the device could be on battery for two hours or more, having a device continuously alarming was deemed unacceptable and distracting to clinicians. In addition, there are concerns expressed by the health care industry about “alarm fatigue” and a push to have fewer “distractions” in the operating room.

Beyond the instant audible alarm, on the Information Display (figure 2) in the top right, text which normally displays “HEAT ON,” immediately changes to “HEAT OFF” with loss of AC Power, and continuously flashes on and off at more than one time per second to catch the user’s attention. Next, on the Information Display, on the bottom line where only Alarm Information is displayed, in all capital letters is “ON BATTERY: NO AC PWR,” informing the user of the changed state of the device. SCB developed this “plain text” format to make it as easy as possible for the user to understand the power status of the unit and alarms, instead of codes utilized by other rapid infusers. In addition, the LED, located next to the Heat button at the top center of the panel, turns off, signifying that heat is off, and an LED in the Power Cord Icon, located on the bottom of the panel, turns off, further signifying that there is no AC Power. As always, the temperature of the outflow fluid is displayed on the top left of the display. Once AC Power is restored, a single audible alarm sounds and the heat automatically turns back on and all displays will return to normal.

Finally, and probably most importantly, all facilities utilizing the ThermoCor® Rapid Thermal Infuser receive intensive training on the use of the device, with specific emphasis on the device’s capabilities while on battery power. When an operator is infusing fluids at high flow rates, it is always important to moni-

tor the device to ensure that it is programmed and functioning as expected. All the points that we have stated above are reviewed and emphasized during our training and should be reviewed and reinforced with any new user. Understanding the operation, capabilities, and limitations of any technology that is critical to a patient’s health and safety is vitally important.

We always appreciate hearing from different users on their experience with the ThermoCor® Rapid Thermal Infuser. SCB launched the ThermoCor® Rapid Thermal Infuser in 2006, and we have hundreds of units currently in the field used for tens of thousands of clinical cases. To date, the user experience has been extremely positive. In response to the letter, SCB conducted a thorough review of the history of the ThermoCor® Rapid Thermal Infuser and deter-

mined that there have been no previous complaints or reports of inadvertent unplugging putting a patient at risk. SCB, however, is dedicated to continuously improve the ThermoCor® Rapid Thermal Infuser and provide a better and safer technology for saving lives. In this ongoing effort, we will review the recommendations of both Cynthia M. Wong, BMBS, and Saman Yaghoubian, DO, for inclusion in future ThermoCor® Rapid Thermal Infusers.

Sincerely,

Hugh Smisson III, MD
Medical Director
Smisson-Cartledge Biomedical, LLC
Macon, Georgia

ThermoCor® is a registered trademark of Smisson-Cartledge Biomedical, LLC

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Practice Considerations for the Anesthesia Professional for Methamphetamine Substance Use Disorder Patients

by Jennifer Krogh, MSN, CRNA; Jennifer Lanzillotta-Rangeley, PhD, CRNA; Elizabeth Paratz, MD; Lynn Reede, DNP, CRNA; Linda Stone, DNP, CRNA; Joseph Szokol, MD; Laura Andrews, PhD; Joan Kearney, PhD, APRN, FAAN

Substance Use Disorders (SUD) are a topic of increasing concern in the United States and continue to impact families and communities. Of the reported 329.9 million population of the United States in 2014, 21.5 million people were diagnosed with SUD.¹ Methamphetamine accounts for approximately 1.6 million of the 21.5 million individuals who misuse substances in this country. According to the National Institute on Drug Abuse, 0.6 percent of the population reported using methamphetamines.² That number is likely drastically under-reported due to the criminal nature and stigma related to diseases associated with drug use. A survey of 5,000 participants found that approximately 81% of patients provide false information to their providers regarding substance abuse.³ The most common reason given in the study was that patients did not want to be “judged.”³ Therefore, it would be prudent for an anesthesia professional to be aware that patients presenting for elective cases to the operating room may conceal the truth with regard to their illicit substance use.

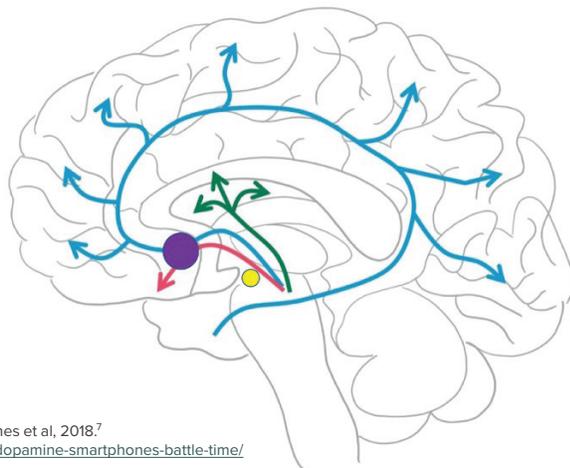
The COVID-19 pandemic also has the potential to increase the likelihood of encountering a patient with a SUD. Many patients who had previously maintained sobriety are now experiencing relapse due to increased stress, social isolation, and economic strain.⁴ It is important to remember that SUD still exist as an epidemic even during the pandemic. The use of substances, like methamphetamine, has not gone away or decreased, but rather increased in fre-

quency.⁴ It is important for each anesthesia professional to be aware of the potential lethal effects of methamphetamine use in the preoperative setting, the consequences of which may include hypertensive crisis, cardiovascular collapse from hypotension, and death.⁵ Adhering to practice from the most up to date literature may abate the potential morbidity and mortality and ensure the most appropriate care of patients with this particular SUD.

PHARMACOLOGY OF METHAMPHETAMINES

The International Union of Pure and Applied Chemistry (IUPAC) name for methamphetamine is (2S)-N-methyl-1-phenylpropan-2-amine.⁶ Though the mechanism of action is not fully understood, methamphetamine causes a release of the endogenous monoamines dopamine, norepinephrine, and serotonin (figure 1).

Once released, the monoamines bind to their appropriate postsynaptic receptors to affect a response. The release of dopamine into the nucleus accumbens follows the same pathway for natural rewards like social interaction, sex, eating, and exercise, but the stimulation from methamphetamine causes 2 to 10 times more dopamine to be released from endogenous stores than the natural rewards resulting in a dopamine release above 1000% basal levels.⁷⁻¹⁰ Methamphetamine also interacts with the endogenous opioid system further increasing endorphins in the nucleus accumbens which mediates reward centers.¹¹



Source: Adapted from SITNBoston. Haynes et al, 2018.⁷ <https://sitn.hms.harvard.edu/flash/2018/dopamine-smartphones-battle-time/> Accessed April 16, 2021.

Figure 1. Release of Dopamine. Dopamine activates the mesolimbic, mesocortical tract, and nigrostriatal pathways. This pathway extends from ventral tegmental areas to the nucleus accumbens which is responsible for the euphoric feeling after using methamphetamine.⁷

Table 1. Signs and Symptoms of Methamphetamine Intoxication.^{11,13,14}

Signs of Methamphetamine Intoxication According to Category	
Central Nervous System	
Agitation	
Restlessness	
Mydriasis	
Seizures	
Hyperthermia	
Anxiety	
Increased alertness	
Hallucinations	
Psychosis	
Cardiothoracic	
Hypertension	
Tachycardia	
Dysrhythmia	
Malignant arrhythmia	
Myocardial infarction	
Coronary vasospasm	
Aortic dissection	
Bronchodilation	
Acute Respiratory Distress Syndrome	
Pulmonary arterial hypertension	
Right heart failure	
Sudden cardiac arrest	
Death	
Diaphoresis	
Musculoskeletal	
Rhabdomyolysis	
Severe muscle spasms	
Other	
Ischemic colitis	
Metabolic acidosis	
Placental abruption -> fetal death	

Lastly, the scarcity of dopamine caused by the body’s inability to recover from the massive release of monoamines from storage vesicles causes feelings of depression and withdrawal which can further induce drug-seeking behaviors.¹² These physiologic changes combined create an almost manic-depressive state in patients which can create a vicious cycle of misuse.

The peripheral action of monoamines culminates in a diffuse and complex chain of systemic events.¹¹ Those intoxicated with methamphetamines experience a variety of signs and symptoms (table 1).

See “Methamphetamines,” Next Page

Anesthesia Care for Patients with Methamphetamine Use

From “Methamphetamines,” Preceding Page

Hyperthermia is a common symptom experienced in these patients, which seems to be related to muscular activity, and therefore antipyretics will have no impact in decreasing body temperature.¹³ An alarming medical concern with methamphetamines is abrupt cardiac arrest following a physical altercation. Isovolumetric muscle contractions can lead to severe acidosis, rhabdomyolysis, hyperkalemia, and sudden asystolic cardiac arrest.^{13,15}

PHARMACOKINETICS OF METHAMPHETAMINES

Pharmacokinetics and metabolism of methamphetamine are highly dependent on the route of administration and the dose, or repeated doses. Methamphetamine elimination occurs via cytochrome CYP2D6 in the hepatic pathway and several renal pathways. Excretion occurs in the first 20 hours but is highly dependent on urine pH. For alkaline urine, excretion can be as low as 2% whereas with acidic urine this can be as high as 76%.^{16,17} The duration of action of methamphetamine is usually around 24 hours. However, elimination and clinical effect vary highly from person to person with some withdrawal symptoms persisting for up to 10 days.^{13,16,18}

Detection of methamphetamine in the clinical setting is via serum or urinalysis. If a patient is using methamphetamine, they may test positive for either methamphetamine or the metabolized drug of amphetamine.^{16,17} At this time, there are no quantitative toxicology screenings that could equate to clinical intoxication or severity of physiologic responses under anesthesia. Consequently, it is difficult to determine the associated risks under anesthesia for any patient who tests positive for methamphetamine use.

GUIDELINES AND PRECAUTIONS

Anesthesia care of the patient under the influence of methamphetamine is centered around a few core concepts. If the patient is acutely intoxicated and requiring emergent surgery, providers should avoid physically restraining these patients because any intervention that leads to intense muscle contractions could cause cardiovascular collapse.^{13,15} Instead, chemical restraint via sedation with benzodiazepines is the primary therapy. The literature recommends administering midazolam 2mg intravenously every 8 to 10 minutes until the patient is no longer aggressive. Some patients may require up to 20mg.¹³ If benzodiazepines are not effective in treating psychosis, secondary agents such as haloperidol may be given. Benzodiazepines and haloperidol mitigate the

Table 2. Medications and Considerations for Treatment of Methamphetamine-associated Hypertension.^{13,14,19,20-22}

MEDICATION	CONSIDERATIONS
1. MIDAZOLAM	Repeated dosing required for sedation, high doses of midazolam may cause respiratory compromise
2. HALOPERIDOL	Risk of QT prolongation, risk of Neuroleptic Malignant Syndrome, may trigger extrapyramidal symptoms
3. DEXMEDETOMIDINE	Few studies for safety in obstetric patients
4. NITROGLYCERINE	Decreases blood pressure, may cause slight reflex tachycardia
5. NITROPRUSSIDE	Decreases blood pressure with reflex tachycardia, may cause cyanide toxicity
6. PHENTOLAMINE	Anesthesia professional may not have phentolamine available for use
7. NICARDIPINE (DIHYDROPYRIDINE CCB)	Decreases blood pressure with reflex tachycardia
8. VERAPAMIL (NON-DIHYDROPYRIDINE CCB)	Less vasodilatory effect with slight reflex tachycardia or may cause severe bradycardia.
9. LABETALOL	May cause coronary spasm. Can cause hypertension related to unopposed alpha stimulation.

CCB = Calcium Channel Blocker

reciprocal effect of methamphetamine by antagonizing the activity of dopamine in the central nervous system.¹⁹

Hypertensive patients will most likely see a return to baseline after administration of sedating agents; however, anesthesia professionals may note refractory hypertension in some patients. In these cases, a variety of medications may be used to treat hypertension (table 2).

The concept of “unopposed alpha stimulation” with the use of beta-blocking agents is becoming increasingly controversial. Some authors have published systemic reviews with scant adverse outcomes and have observed no untoward outcomes when using nonselective beta-blocking agents such as labetalol.²² Furthermore, beta-blockers have been used to treat other hyperadrenergic conditions such as thyrotoxicosis.²² However, the American College of Cardiology Foundation with the American Heart Association have stated in their most recent executive summary from 2014 that patients demonstrating acute signs of intoxication should not be given beta-blockers due to the possibility of potentiating coronary spasm.²³ Therefore, suppressing the catecholamine surge with benzodiazepines is still the primary treatment for methamphetamine hypertension.¹³

Methamphetamine SUD patients who require immediate surgical intervention should be monitored closely for hypotension related to catecholamine depletion. Insertion of an arterial line may be prudent. If hypotension is encountered, treatment with direct-acting vasopressors such as norepinephrine, epinephrine, dopamine, or phenylephrine may be

considered.^{13,24} Although spinal or epidural anesthesia is not contraindicated, many anesthesia professionals choose to avoid neuraxial anesthesia during the anesthetic due to persistent hypotension caused by the sympathectomy despite treatment with vasopressors.

Methamphetamine SUD patients have an increased risk of developing rhabdomyolysis. This multifactorial problem is likely due to a decrease in fluid intake while intoxicated, vasoconstriction from decreased perfusion, and a direct toxic effect on skeletal muscle.²⁵ Succinylcholine may potentiate rhabdomyolysis and is considered a relative contraindication for airway management. Therefore, rocuronium or vecuronium is the paralytic of choice and even more favorable if sugammadex is available to the clinical provider.¹³ If the patient does develop rhabdomyolysis, administering fluid boluses as indicated is appropriate.¹³ In addition, clinicians should adjust the ventilator settings to avoid metabolic acidosis.¹³ Failure to treat any patient aggressively could lead to an irreversible progression of symptoms and may lead to patient death.¹³

Beyond acute intoxication, some patients may be taking chronic amphetamines as treatment modalities for diagnosis such as attention deficit hyperactivity disorder. Researchers indicate that there is no increased risk of labile blood pressure under anesthesia for this patient subset. Therefore, patients who are taking amphetamines as part of their treatment regimen may continue their medication perioperatively without pause.^{26,27}

See “Methamphetamines,” Next Page

Methamphetamines Can Cause Serotonin Toxicity

From “Methamphetamines,” Preceding Page

CONSIDERATIONS FOR THE PARTURIENT

Pregnant women who use methamphetamine may present with hypertension, premature rupture of membranes, hemorrhage, or placental abruption.²⁸ If the patient is acutely agitated, benzodiazepines are the best treatment option, especially compared to physical restraint prior to induction. Previous case reports from the 1960s listed benzodiazepines as a significant contributing factor of congenital malformations related explicitly to cleft palate and heart defects. Despite flaws in previous research suggesting a link between benzodiazepines and congenital malformations, a deep aversion to expose pregnant women resulted in a lack of further research.^{29,30} Recently, more robust data has emerged and several studies have indicated there are no correlations between most benzodiazepines and congenital malformations taken either immediately before surgery or to control anxiety symptoms during the pregnancy.^{29,31-33} It is unwise for clinicians to withhold benzodiazepines for agitated methamphetamine parturient since the mother is still at risk of cardiovascular collapse with struggle, which could be fatal to both patients. However, the anesthesia professional may prefer to give haloperidol to patients in their first trimester.³⁴ Ketamine is not generally used due to possible catecholamine surge and subsequent hypertension.²²

Anesthesia professionals concerned about drug trapping in the newborn may also be hesitant to administer benzodiazepines. Researchers have shown that the increased bio-availability may cause newborns to have three to four times the levels of benzodiazepines in their system when compared to their mothers.³⁵ However, at low doses (0.02–0.025mg/kg) of midazolam, there are no differences in Apgar scores in the newborn following pre-cesarean administration.^{28,30} The parturient is also at risk of cardiovascular collapse from intense muscle contraction from physical restraint. Since this could be fatal to both mother and newborn, it may still be prudent to sedate agitated pregnant patients via chemical restraint and tend to the respiratory status of the newborn after delivery.

SEROTONIN TOXICITY

Serotonin toxicity, also referred to as serotonin syndrome, is an increase in serotonergic activity in the central nervous system that has the potential to be fatal.³⁶ Serotonin toxicity is a predictable consequence of excess serotonergic activity in the central nervous system and peripheral receptors leading to a variety of



symptoms caused by the release of excess serotonin such as agitation, hypertension, tachycardia, and diaphoresis. There have been cases of serotonin toxicity from a single ingestion of methamphetamine.³⁷ Serotonin toxicity may also be precipitated by tramadol, meperidine, opioids (e.g., fentanyl), and methylene blue.^{36,38,39} Fentanyl is of particular importance to the anesthesia professional since it is one of the more common opioid medications used in the operating room.

If anesthesia professionals encounter a methamphetamine SUD patient who is experiencing serotonin toxicity, benzodiazepines are recommended as the first line of treatment for both. However, unlike methamphetamine intoxication, serotonin toxicity may also be treated with non-selective serotonin antagonists such as cyproheptadine and risperidone. Serotonin toxicity may also be treated with a postsynaptic dopamine blocking agent such as chlorpromazine.⁴⁰

SUMMARY

Methamphetamine SUD is on the rise, even more so with the COVID-19 pandemic increasing stress, social isolation, and economic strain. Patients who present with this particular SUD present with challenges for the anesthesia provider. As a reminder, chemical restraint should be used as opposed to physical restraints to limit muscle contractions, which can lead to cardiovascular collapse. Direct-acting vasopressors are often needed as profound hypotension is likely, but, if the patient is hypertensive, beta-blockers are to be used with caution. Finally, methamphetamine SUD patients may present

with rhabdomyolysis or serotonin toxicity; providers should avoid administering associated triggering medications.

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See “Methamphetamines,” Next Page

Methamphetamine Abuse Is On Rise

From “Methamphetamines,” Preceding Page

The authors have no conflicts of interest.

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RAPID Response **Laryngoscope Hook Poses Safety Issue**

to questions from readers

Dear Rapid Response:

I would like to present a case of lower lip injury in a patient during intubation associated with the design of a Macintosh laryngoscope blade (BritePro Solo™, Flexicare Inc., Irvine, CA). The patient was a 75-year-old male who was scheduled for a urologic procedure. He was intubated smoothly with a 7.5 endotracheal tube (ETT) using a disposable Macintosh 3 laryngoscope. The Cormack-Lehane view was

Grade 2b on laryngoscopy. While the nurse anesthetist was securing the ETT, I picked up the disposable laryngoscope to discard it and noticed blood on the blade and handle (figure 1).

On examination of the patient’s face, we noticed a laceration on the lower lip with fresh bleeding (figure 2). We applied pressure, antibiotic ointment, and sterile gauze on the wound after which the bleeding stopped. By the end of the procedure, the laceration had sealed off with no significant injury or consequences. The

patient was on a daily low dose of aspirin and was not worried about the incident.

DISCUSSION

Soft tissue injuries during laryngoscopy and tracheal intubation are common especially in a difficult airway. However, we had no problem intubating this gentleman. Tongue injuries were found to have the highest incidence in a study on the electrophysiology population in a large academic center.¹ In another review study, soft tissue trauma was observed in 52% of patients after direct laryngoscopy with Mac 3 or 4 blade with maximum injuries to the tongue (36.3%), followed by lower lip injuries (22.3%).² Old age was not found to be a significant risk factor in that study except in injuries to the oral mucosa. However, injuries with significant bleeding are possible in patients on anticoagulation.

The reason for presenting this incident is to bring to your attention the design of this particular laryngoscope blade, BritePro Solo™ from Flexicare, Inc. The blade has an overhang or hook at the fulcrum where it attaches and engages at the handle (figure 3).

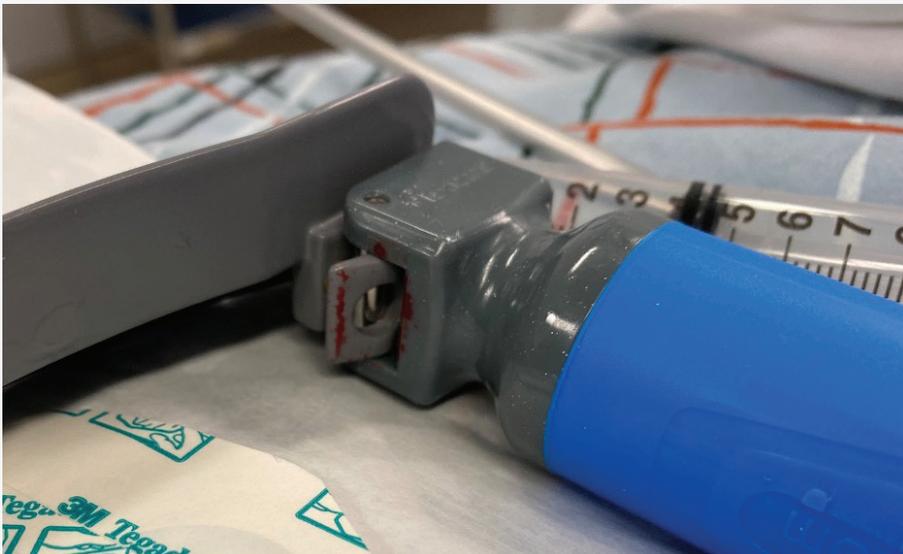


Figure 1: Blood noticed on the blade and handle of the disposable laryngoscope.



Figure 2: The injury to the lower lip from the hook of laryngoscope blade.



Figure 3: The blue arrow points to the hook on the laryngoscope blade (BritePro Solo from Flexicare, Inc.).

See “Hook Problem” Next Page

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RAPID Response

to questions from readers

Laryngoscope Hook Poses Safety Issue

From “Hook Problem,” Preceding Page

This hook helps in securing the blade to the handle, but has the potential to dig into the soft tissue of the lower lip area. This is a patient safety issue that warrants attention. There are other Macintosh blades available that do not have this design.

Thank you for your attention to this matter.

Tazeen Beg, MD
Assistant Professor of Anesthesiology
Division Chief, Non-Operating Room
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The authors have no conflicts of interest.

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In Response:

SAFETY OF MACINTOSH BLADE DESIGN

Thank you for sharing this report with us and the opportunity to provide the rationale for different Macintosh blade designs. Flexicare regards patient safety and clinician feedback as the highest priorities for the organization. As an industry leader in the disposable laryngoscope market, and with roughly 15 million laryngoscopes sold in the United States over the past decade, we could not have succeeded without direct input from clinicians such as yourself and value your feedback.

We pride ourselves as an innovator in this space and the design of BriteBlade™ Pro/ BritePro™ Solo was created with the clinician’s input and patient safety in mind. This particular product is designed to offer a disposable blade, but a reusable handle. More specifically, the design is intended to address the concerns around cross contamination amongst reusable laryngoscope handles. Studies have shown that decontamination using impregnated ger-

micidal wipes is ineffective—between 75%–86% of “patient ready” reusable handles tested positive for bacterial contamination remained positive for bacterial contamination.^{1,2} The “hook”, as noted in the attached report, was created not only as a mechanism to attach the blade to the handle, but more importantly designed to help prevent the laryngoscope blade from touching the handle when collapsed after use, therefore, reducing the risk for cross contamination. Although Flexicare is highlighted as the product in use in the attached report, we are not the only disposable laryngoscope manufacturer with this design.^{3,4} This has become a standard design for other manufacturers in this market as it provides superior performance if used properly.

The adverse event in the attached report is the first of its kind reported to Flexicare with over 15 million laryngoscopes of this blade/handle design sold in the past decade. We have investigated the event to the best of our ability with the information provided thus far and escalated it to the highest levels of the organization. This includes not only input from our engineering, technical, and quality teams, but also our consulting anesthesiologist.

As stated in the report, although the patient may have been “intubated smoothly,” an airway with a Cormack Lehane score of 2b may require a significant amount of force to elevate the soft tissue and expose the vocal cords for endotracheal tube placement during direct laryngoscopy. It is apparent, as depicted in the pictures of the report, the incident occurred with the patient’s lip coming into direct contact with the “hook” of the blade. While it is impossible to determine based on the information provided, we want to reassert that proper blade size selection is extremely important. As noted in the attached report, a Mac 3 blade was selected for this 75-year-old male patient and may not have provided a sufficient amount of clearance between the blade and the soft tissue of the lower lip. The Mac 4 size was created specifically to address anesthesiologists concerns that a Mac 3 is too small for many male patients. “The standard adult Macintosh blade (equivalent to today’s size 3) proved too short for many patients, simply because Macintosh had tested his prototypes on women presenting for gynecological surgery.” (Sir R.R. Macintosh, letter to Sir A. Jephcott, May 9, 1983). Following requests from anesthesiologists, a larger adult blade (the size

4) was added to the Longworth range in 1951.⁴ By 1952, Foregger was also producing 4 sizes of Macintosh blade.”⁵

In summary, the product used in this report is specifically designed to reduce handle contamination and shares that design with other products on the market. The patient injury is not a product safety issue as much as it is an issue with blade size selection and direct laryngoscopy technique.

Ian Ross
Product Manager, Anesthesia
Flexicare Inc.

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CULTURE OF SAFETY: The Multidisciplinary Anesthesia Professional Relationship

by Katherine A. Meese, PhD, and D. Matthew Sherrer, MD, FASA

INTRODUCTION

A recent article in APSF by Jeffrey Cooper, PhD, highlighted the importance of considering the relationship between certain dyads in the operating room, specifically between anesthesia professionals and surgeons.¹ The article discussed implications for patient safety, and the potential for patient harm due to relational degradation in this dyad. However, we suggest that an equally important dyad to consider is that between anesthesia professionals. External pressures have the potential to bleed into our operating rooms, and influence our experiences at the point of care. Therefore, it is most important to create a satisfying work environment for all team members so that collaborative care can translate into improved patient safety.

OPTIMIZING OUR TEAMS

There is a growing body of research that give us insights on how we can promote better team performance which can lead to enhanced patient care.

Collective Intelligence and Teaming

The performance of teams is only moderately connected to the individual intelligence of its members.² Woolley et al. found empirical support for a collective intelligence factor (c-factor) that explains a group performance. Specifically, this c-factor is “not strongly correlated with the average or maximum individual intelligence of group members, but is correlated with the average social sensitivity of group members, the equality in distribution of conversational turn-

taking, and the proportion of females in the group” (which is likely also related to social sensitivity).³ Teams with members who can be socially sensitive, encourage all members to participate in the conversation, and value input from all team members may function better as a team.

The nature of the operating room setting requires unique modes of team interaction. Much of the research on teams assumes stable membership among team members, which allows them to practice and hone their team performance over time. However, in the perioperative context, each case may represent a unique combination of clinicians who have worked together with varying degrees of frequency. While some teams enjoy stable membership, others have a frequently changing mix of anesthesia professionals, surgeons, and trainees. Researchers have referred to this concept as “teaming” which requires relative strangers to come together quickly to perform challenging tasks with little or no time to practice. Edmonson describes teaming as “teamwork on the fly,” which is apropos for the situations in the perioperative space.⁴ A critical component of teaming is psychological safety, which is the belief that the team is a safe place for interpersonal risk-taking, and describes an environment of trust and mutual respect. In the perioperative context, this risk-taking may include speaking up when a team member has a concern about patient safety or disagrees with a care decision. Successful teaming also requires situational humility, which acknowl-

edges the difficulty of the task ahead, and understands that it cannot be solved alone.⁴ Situational humility leaves room for all members of the team to make a contribution to the end goal. In the face of uncertainty and ambiguity—both central features in the current health care environment—situational humility fosters an environment that encourages teams to engage in more learning behavior. However, if one member within the team retains an authoritarian or dictatorial leadership style, they risk not only suppressing valuable input that might increase patient safety, but also devalue other members of the care team.

The Role of Stereotyping

When a person is dealing with another person who is unknown to them, they often look to cues and stereotypes to try to anticipate how that person will behave. Stereotyping is a mechanism for reducing perceived uncertainty. For example, if an anesthesia professional is working with a surgeon that they do not know, they may rely on stereotypes about surgeons or specific specialties to try to navigate this new relationship during the case. If these stereotypes or assumptions are incorrect, they can lead to communication errors and threats to patient safety. Nurses, physicians, and other members of the care team who are familiar with one another within the hospital setting may have built trusting working relationships. However, when the people in those roles are unknown to each other personally (which is common in large organizations) inaccurate stereotypes can be increasingly detrimental. External pressures, intra-organizational power struggles, and professional clashes have the potential to saddle members of the care team with negative stereotypes regardless of the characteristics of the individual. This stereotyping can create a mistrusting and threatening environment before the case begins. When a threat to safety is perceived, then self-preservation, not collaboration, can become the norm.

Role Ambiguity

As the roles of health care providers evolve and change, they also bring new questions about exactly what functions each team member should fill.

The lack of clarity about how each team member can best contribute or what functions each team member should serve can lead to role ambiguity.



See “Culture of Safety,” Next Page

Role Ambiguity Can Cause Occupational Stress

From “Culture of Safety,” Preceding Page

Role ambiguity is “the extent to which one’s work responsibilities and degree of authority are unclear.”⁵ Role ambiguity is a determinant of occupational stress, and is associated with anxiety, burnout, depression, job dissatisfaction, dissatisfaction with supervision, and dissatisfaction with co-workers among other negative outcomes.⁵ High levels of burnout and stress have been reported among both physicians⁶ and advance practice providers (APPs).⁷ Therefore, it is imperative that we work to reduce sources of distress such as role ambiguity, and identify the strengths that each type of practitioner can bring to the team and to the bedside. By understanding which team configurations produce the best outcomes, we are better positioned to help each member see the unique value and contribution of the others, thus reducing role ambiguity, and creating an environment of appreciation, mutual respect, and psychological safety. Efforts should be made to clearly identify what functions each clinical professional should serve, in order to reduce friction in areas of possible overlap and maximize team performance. A clear plan that is developed mutually can help the physician, APP, nurses, and technicians understand how their efforts support the team.

THE PATH FORWARD

The COVID-19 pandemic has provided incomparable pressure to the perioperative team and has laid bare the underlying nature of the relationships among members of the care team. Under stress, one’s ability to disguise and bury relational damage can become more difficult. Teams that were cohesive and trusting beforehand may pull together more, while those that were not, may have a tendency to fracture under the pressure. What shall we do, both in the near-term and as we re-emerge from this pandemic?

First, we need to routinize the concept of micro-empathy with teammates into our daily interactions. The concept of micro-aggressions in the workplace has been a subject of recent focus. Originating in studies of racial discrimination, the concept of micro-aggression has been more broadly applied in the health care setting.⁸ The premise is that small acts of disrespect, insults, aggression, or hostility can occur frequently and have the ability to degrade and demoralize employees. We propose the need to institutionalize the practice of micro-empathy, or small and deliberate acts of consideration, concern, and respect. We suggest that micro-empathy can occur through small acts of listening and concern which have an important



cumulative effect over time, building relational capital among team members. Just as we have implemented surgical safety checklists, we need to implement micro-empathy into our routine operations. While showing empathy when a team member experiences an obvious hardship is critical, we need to initiate frequent conversations that allow us to show empathy for the stresses of the day or week before they take a cumulative toll. The Circle Up model⁹ suggests that this routinization can occur during daily huddles, by asking questions such as:

- “Reactions to today?”
- “What helped your team work well together?”
- “How could our work be 1% better?”
- “How did the shift affect you personally?”

This is likely to be most effective when the team has prioritized building trusting and open relationships.

Additionally, we need to ensure team building early on in professional careers. We should train together. Across the nation, trainees from different disciplines oftentimes do not train together. Health care could be better served by intentional collaborative education, not only on the art and science of care itself, but on the foundations of highly reliable teamwork.

In conclusion, many anesthesia professionals report collegial and rewarding work environments, with mutual respect toward one another. A patient deserves the very best care, and we suggest that this occurs when all members of the care team work together in harmony using their diverse skill sets and training, pooling their collective intelligence to create smart teams that result in the highest quality delivered care. While we unite against the common and formidable enemy of disease, we must take care of each other. It is only then that we will achieve APSF’s vision, “*That no one shall be harmed by anesthesia care.*”

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The authors have no conflicts of interest.

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RAPID Response

to questions from readers

Cardiopulmonary Arrest Precipitated by Supraglottic Kinking of Polyvinyl Endotracheal Tube

Dear Rapid Response:

A 55-year-old male with a history of pre-existing bifascicular heart block was orally intubated uneventfully with a 7.5 millimeter Shiley polyvinyl endotracheal tube (ETT) (Covidien LLC, Mansfield, MA) for elective endoscopic sinus surgery. The ETT was secured in a neutral position with a cloth tube tie and supported with an endotracheal tube holder. Anesthetic maintenance was accomplished with a combination of inhaled sevoflurane 0.9 percent augmented with a continuous propofol infusion at 100 microgram per kilogram per minute and remifentanyl 0.15 microgram per kilogram per minute. The patient was ventilated using an Aisys CS² Anesthesia Delivery System (GE Healthcare, Chicago, IL) with volume control mode settings of 450 milliliter of tidal volume, positive end expiratory pressure of 5 centimeters of water (cm H₂O), respiratory rate of 12, and an inspiratory to expiratory ratio of 1:2 with pressure limit set to 40 cm H₂O. After 120 minutes following surgical start, the patient developed an acute sustained elevation in peak airway pressure (PIP) from 33 cm H₂O to 62 cm H₂O. This pressure rise immediately preceded the development of a third-degree atrioventricular (AV) block, which progressed to cardiac arrest. Cardiopulmonary resuscitation was performed, and the patient ultimately stabilized with an epinephrine infusion. Post arrest respiratory compliance remained poor necessitating an increase in the pressure limit to allow for PIP persistently greater than 40 cm H₂O, despite reduction in tidal volume to 4 milliliter per kilogram, muscle relaxation, and prolongation of inspiratory time. A bronchoscope was unable to be advanced through the ETT due to near complete luminal occlusion secondary to ETT distortion (Panel A) with subsequent video assisted laryngoscopy confirming a kink in the ETT at the 19-centimeter marking (Panel B). After failure to advance a 14 French airway exchange catheter (Cook Medical, Bloomington, IN) due to ETT luminal occlusion, extubation was performed followed by emergent reintubation with immediate normalization of ventilation mechanics.

Initial post-arrest diagnostic workup was significant for an elevated arterial partial pressure of carbon dioxide of 64 torr, which normalized rapidly after endotracheal tube exchange. Electrocardiogram documented sinus rhythm with bifascicular block while transesophageal echo-

cardiography identified generalized left ventricular hypokinesis with an estimated ejection fraction of 40% and mild-moderately reduced right ventricular systolic function. Chest x-ray was negative for acute findings. Serial cardiac troponins were below the institutional cutoff for myocardial ischemia. Electrolytes were within normal limits with the exception of ionized calcium that was low at 3.75 milligrams per deciliter.

DISCUSSION

An acute increase in intrathoracic pressure can produce increased vagal activity which in turn results in decreased conductance through the AV node.^{1,2} This process is similar physiologically to the use of a Valsalva maneuver to terminate supraventricular tachycardia.² The postulated mechanism in this patient is the generation of vagally mediated bradycardia precipitated by the acute increase in intrathoracic pressure causing progression of this patient's bifascicular block to a third-degree AV block. Although it is plausible that air trapping secondary to acute expiratory flow obstruction was causative, the absence of an inspiratory pause to confirm the presence of elevated intrathoracic pressure precludes diagnostic certainty. Consequently, the ultimate etiology of the cardiac arrest remains impossible to ascertain given the multitude of other potentially contributing factors including loss of cardiac output, hypercarbia, hypocalcemia, surgical stress, coronary ischemia, arrhythmia, and concurrent volatile anesthetic agent administration.

ETT kinking is relatively uncommon with the majority of kinks occurring external to the oropharynx such that they are easily identified.³ ETTs are resistant to kinking at room temperature. However, once heated to body temperature, kinking may occur at markedly reduced acute angles.⁴ The cuff air inflation line has been noted as a point of potential weakness, with others reporting kinking at this location with Mallinckrodt (Tyco Healthcare)⁴ and Rusch (Teleflex)⁵ ETTs. Kinking occurs more frequently with bending in the direction of the convexity of the tube.⁵ The first sign of an endotracheal tube kink may be changes in peak airway pressures or the capnography waveform that may precede the development of hypercarbia and/or hypoxia. Difficulty passing a flexible suction catheter may raise suspicion for an occlusion. In our case, the kink was readily identified via bronchoscopy. After assessing the difficulty of

reintubation and obtaining backup airway equipment including supplies for surgical airway, it is recommended to emergently replace the kinked endotracheal tube. Preventative strategies include ensuring the non-traumatic insertion and securing of the ETT while protecting against physical displacement during patient positioning or oropharyngeal surgery. Approaches to mitigate clinically significant physiologic perturbations involve the rapid identification of ETT occlusion to facilitate prompt airway exchange in a controlled setting prior to onset of respiratory and/or cardiovascular collapse. Should the surgical scenario require the exit of the ETT at an acute angle, consideration should be given to replacement with a Ring-Adair-Elwyn (RAE) or wire spiral ETT, although the latter carries the potential risk of permanent occlusion should kinking occur due to the reinforced nature of its design. Additionally, should concern for or confirmed kinked ETT occur, established institutional incident reporting mechanisms should be utilized and, if necessary, manufacturer review/correspondence be initiated.

Troy Seelhammer, MD, is an assistant professor of Anesthesiology at the Mayo Clinic, Rochester, MN.

Robert White, MD, is a resident physician in the Department of Anesthesiology at the Mayo Clinic, Rochester, MN.

Roger Hofer, MD, is an assistant professor of Anesthesiology at the Mayo Clinic, Rochester, MN.

The authors have no conflicts of interest.

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See “Kinking Tube,” Next Page

RAPID Response
to questions from readers

Cardiopulmonary Arrest Precipitated by Supraglottic Kinking of Polyvinyl Endotracheal Tube (Cont'd)

From “Kinking Tube,” Preceding Page

In Response:

Thank you for reaching out to request the Medtronic response to the report by Drs. Seelhammer, White and Hofer entitled “Cardiopulmonary Arrest Precipitated by Supraglottic Kinking of Polyvinyl Endotracheal Tube”, submitted for publication in the *APSF Newsletter*.

In assessing the issue raised in the report, senior members of the Medtronic Respiratory Interventions Design, Safety, Post-Market Vigilance (PMV) and Marketing teams, along with the company representative and me, met with the authors. Our aim was to address the concerns raised by the authors, gain deeper understanding of the event, and establish whether this event occurred due to a product design defect. This letter serves as a summary of our discussion with the authors, respectfully submitted to you and the authors in response.

BACKGROUND INFORMATION

The authors describe a case of bronchoscopically confirmed emergent endotracheal tube (ETT) occlusion with subsequent cardiac arrest, during anesthesia. The authors also refer to previous reported cases where kinking occurred at the entry point of the cuff inflation line (which is not where the kinking occurred in the subject case), and raise the question whether efforts to prevent recurrence of this event may require ETT design mitigation. The ETT was not returned to Medtronic for examination, so a picture record of the ETT was supplied to us (and also submitted to you). These photographs show that the kink occurred below (proximal to) and at a point opposite to

the inflation line at its entry point into the tube (this is visible in the photo). The authors did not offer an explanation as to how they determined the kinking was due to a design defect, nor did they discuss how they eliminated other possible causes. This event was also submitted via formal complaint to Medtronic, and this discussion will form part of the response to same.

REPORTED INCIDENTS

Our PMV team have confirmed that between November 2018 and October 2020, Medtronic sold roughly 11.2 million Shiley™ endotracheal tubes. The complaint rate is 0.7 complaints per million ETTs sold during that time period.

DESIGN DISCUSSION

This correspondence arose in response to authors raising the potential of the cuff inflation line being a site of possible kinking. All Shiley™ endotracheal tubes are designed and tested to comply with the requirements of international standard ISO-5361, which provides requirements and guidance to ensure products are designed to be state of the art and meet safety and performance expectations. The standard includes specific requirements regarding tube dimensions and features, as well as specific functional test methods that include a ball/curve test to measure each tube’s resistance to kinking or collapse.

OUTCOME AND SUMMARY

We had a fruitful discussion with Troy Seelhammer, MD, regarding details around this complaint, specifically around the condition of the tube pre-insertion, surgical positioning, and other possible intraoperative events that may have resulted in the kink. Based on this discus-

sion, the pictorial evidence provided, and the documented complaint submitted by the authors, we are confident that the kink did not occur due to a design flaw, and that no design mitigation is necessary.

The Medtronic Mission guides us to *strive without reserve for the greatest possible reliability and quality in our products*. In order to achieve that outcome, we rely heavily on physicians such as the authors of this paper, and organizations such as the APSF, to ensure that we remain true to this statement. May we therefore take this opportunity to request that, should adverse events occur with any Medtronic product, and where not prohibited by COVID-19 or other guidelines, the actual product (or product of the same lot) be returned to us. This would help immensely in the investigation of reported complaints.

Please feel free to reach out should you have any further questions or concerns.

Respectfully,

Karen A. Phillips, MD, FCA, MBA
Chief Medical Officer, Respiratory Interventions
Consultant Anesthesiologist and Intensivist

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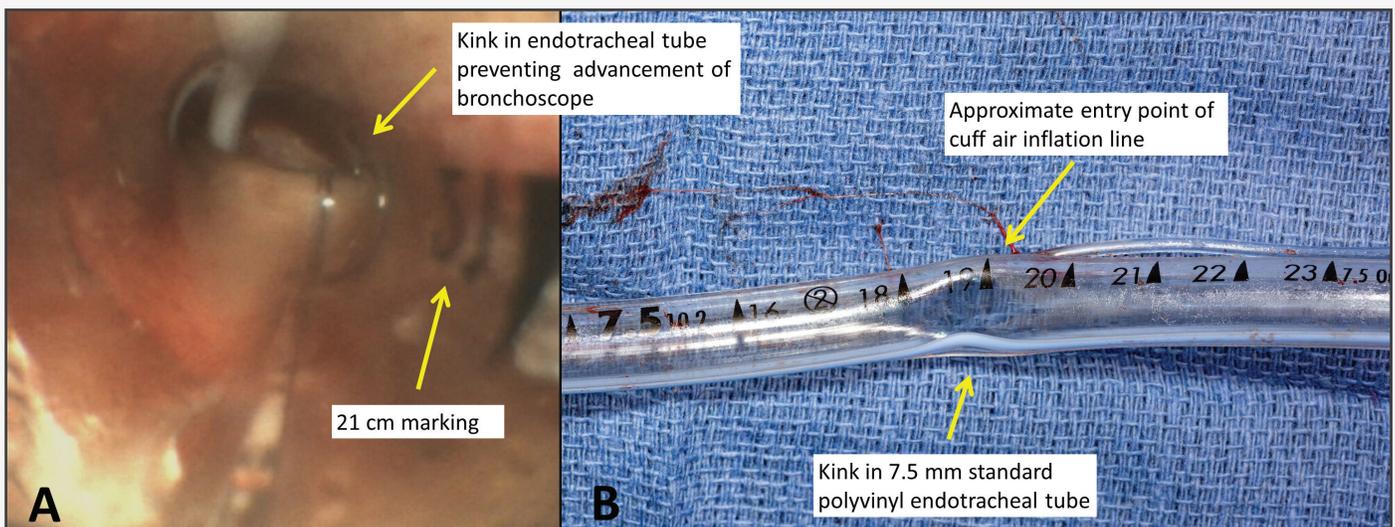


Figure A: Bronchoscopic evaluation demonstrating supraglottic obstruction of the polyvinyl endotracheal tube near the 19-centimeter marking.

Figure B: Photograph of the patient’s 7.5 centimeter polyvinyl endotracheal tube following extubation with an acute angle luminal narrowing evident at the 19-centimeter marking.

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Lessons Learned from Calls to the MHAUS Malignant Hyperthermia Hotline

by F. Jay Garcia, MS4; Ronald S. Litman, DO, ML; and Teeda Pinyavat, MD

The Malignant Hyperthermia Hotline (MHH) (800-MH-HYPER) is a service provided by the Malignant Hyperthermia Association of the United States (MHAUS), a non-profit patient advocacy organization. The telephone hotline service provides real-time, 24/7 access to a physician with substantial expertise in MH. During a call, the hotline consultant (HLC) speaks directly with the caller who is either actively managing a suspected MH crisis or has an inquiry about MH susceptibility and medical management. During an active case, the HLC guides the caller, asking diagnostic questions as necessary, gives their impression of likelihood of MH, and makes recommendations for further management. Since 2001, the MHAUS hotline has fielded over 13,000 calls (personal communication with MHAUS hotline coordinator).

In late 2013, MHAUS began systematically logging and saving the details of these calls (including the audio file) into a database. In 2020, we accessed that database to characterize those calls over an approximate 6-year period. Our intention was to inform anesthesia professionals about the characteristics of likely MH patients, and those that were unlikely to have MH. When possible, depending on the nature of the call and the opinion of the HLC, we categorized each call with the likelihood of MH diagnosis as “Unlikely,” “Likely,” or “Indeterminate” when there was not enough information for the consultant to decide. This categorization was based on a database “diagnosis” field, which was completed by a scribe at the time of the call. In general, the diagnosis was gleaned from verbal cues from the hotline consultant, and in most cases the consultant told the caller their beliefs before completing the call.

Our analysis revealed 3,003 calls over five-and-a-half-years, about 1.8 calls per day. There were 88 calls from outside the U.S., originating from eight countries across five continents, with the majority (76) from Canada. Caller specialty was recorded in 1,877 calls. Most (57%) calls were initiated by anesthesia professionals (e.g., anesthesiologists and nurse anesthetists), followed by allied professionals (22%) (e.g., nurses, pharmacists, etc.), and other types of physicians (21%) (e.g., emergency medicine or intensive care).

Patient location at the start of the episode was reported in 859 calls. The most common location was an operating room (OR), with 349 cases. The next most common locations were a post-anesthesia care unit (PACU) and intensive care unit (ICU), with 206 and 304 reported cases, respectively. When referenced to the

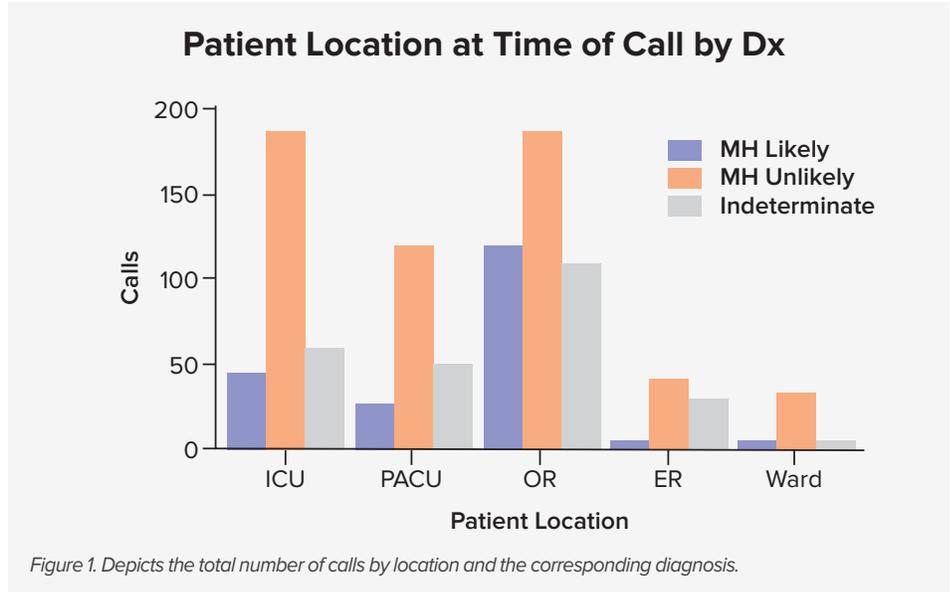


Figure 1. Depicts the total number of calls by location and the corresponding diagnosis.

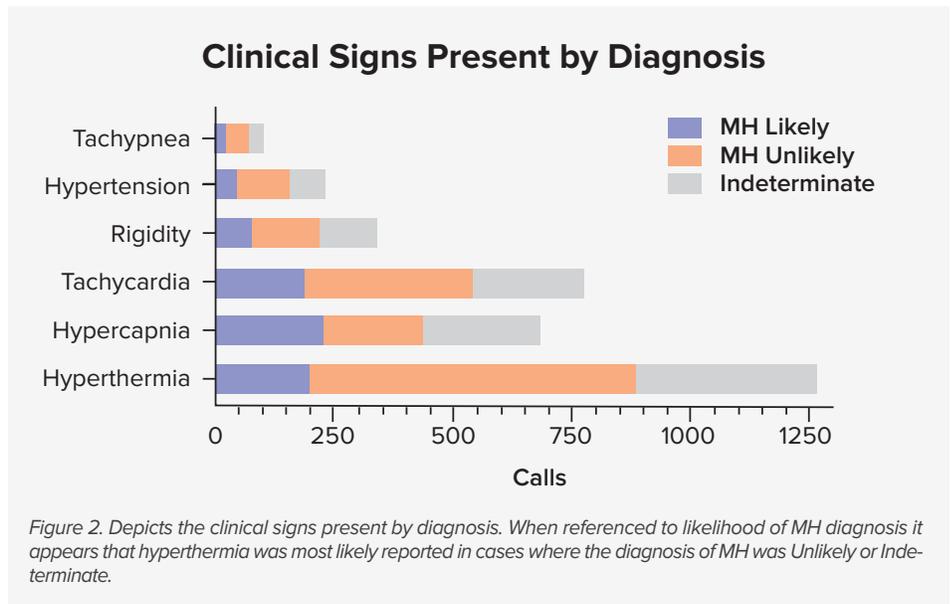


Figure 2. Depicts the clinical signs present by diagnosis. When referenced to likelihood of MH diagnosis it appears that hyperthermia was most likely reported in cases where the diagnosis of MH was Unlikely or Indeterminate.

likelihood of MH, calls from the ICU had the greatest number of “Unlikely MH” cases, and calls from the OR had the greatest number of “Likely MH” cases (figure 1).

Clinical signs were reported in 1,787 calls (figure 2). Hyperthermia, hypercapnia, and tachycardia were the most common signs, reported in 1,266, 684, and 777 calls respectively. Rigidity was reported in 342 calls. Maximum EtCO₂ and maximum temperature were reported in 811 and 1395 calls, respectively.

MH DIAGNOSIS

Overall, the calls consisted of 298 “MH Likely,” 924 “MH Unlikely,” and 806 “Indeterminate” cases recorded.

HLC RECOMMENDATIONS

HLC recommendations were recorded for 1,336 calls. The most common recommended laboratory studies were an arterial blood gas (806), urine myoglobin (352), and coagulation studies (88) (see figure 3).

See “MHAUS Lessons,” Next Page

Hotline Lessons Learned

From “MHAUS Lessons,” Preceding Page

The therapies most commonly recommended were dantrolene (560), external cooling (119), bicarbonate (39), and internal cooling (34). Dantrolene was recommended in 27.6% (560/2028) of all calls. An interesting observation is the number of times the HLC recommended dantrolene therapy (191/924, 20.7%) when the diagnosis of MH was unlikely in comparison with the number of recommendations for dantrolene (205/298, 68.8%) when MH was considered to be likely. Genetic testing was discussed in 171 cases, while a contracture test was recommended in 112 cases.

INQUIRIES

In addition to consults about suspected active cases, there were 950 inquiries about MH. The most common perioperative questions were for a “2nd opinion” (380), safe (trigger-free) technique (e.g., machine preparation) (175), and safe medication (e.g., trigger-free anesthetics) (157). There were 73 inquiries on diseases associated with MH, 41 inquiries on postoperative testing, and 21 on dantrolene pretreatment.

LESSONS LEARNED

The characteristics of the calls and the recommendations of the HLCs provide a useful way for anesthesia professionals to decide on the likelihood of MH and subsequent therapy:

- Hyperthermia was the most frequent sign reported by callers. The name “malignant hyperthermia” leads to many calls reporting extremely high temperatures (>104° F) regardless of the underlying cause. A vast majority of these calls reported isolated hyperthermia and were judged by HLCs as unlikely MH.
- When hypercapnia was reported, almost 1/3 cases were judged as likely MH—indicating that hypercarbia could be a more sensitive sign for MH than temperature elevation and other signs in this particular subset analyzed.
- Rigidity was not one of the more common signs of MH reported by callers. Rigidity represents the skeletal muscle contractures that occur when unregulated calcium floods the inside of the muscle cell. Rigidity should be considered an important sign of MH (although it is also seen with neuroleptic malignant syndrome and serotonin syndrome), but its absence in no way implies the absence of MH.
- MH was deemed unlikely in the majority of calls originating from the ICU and PACU. From the ICU, 57 callers described a patient with respiratory failure who received succinylcholine to assist with tracheal intubation, and who then developed hyperthermia several hours afterward. Many callers from the PACU report unexpected elevated temperatures following

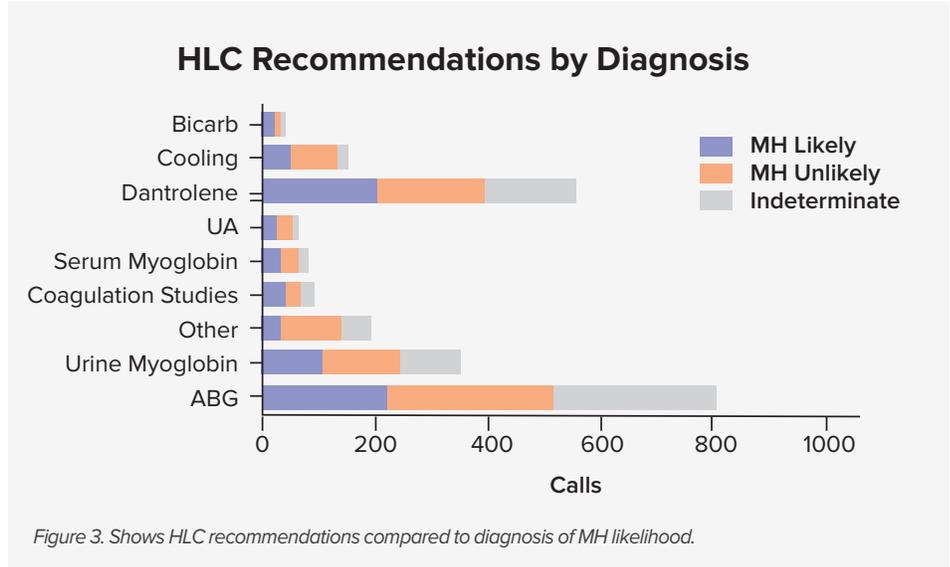


Figure 3. Shows HLC recommendations compared to diagnosis of MH likelihood.

elective surgery. Calls from both locations are most likely to involve hyperthermia without other concomitant hypermetabolic signs of MH (as mentioned above). We are not aware of any cases of MH that presented with hyperthermia in the ICU without other signs of hypermetabolism.

- The most common intervention recommended by the HLC was arterial blood gas (ABG) analysis. MH is unlikely without the presence of a metabolic acidosis, although possible in early suspected cases. Therefore, an ABG or venous blood gas provides a critical piece of diagnostic information. It may be necessary for HLCs to recommend ABGs more often than other interventions because they are commonly overlooked or difficult to obtain in some centers.
- Dantrolene was recommended in many cases when MH was deemed unlikely. Because it acts as a nonspecific antipyretic, dantrolene can sometimes be recommended as a last resort when active cooling measures are ineffective, and the patient's temperature is dangerously high. However, dantrolene is not without side effects, such as muscle weakness and thromboembolism at the site of administration. Therefore, the benefits and risks of administering dantrolene need to be evaluated on a case-by-case basis.
- The most important limitation to deciphering this data is to remember that there exists no rapid bedside test for MH. Experts in MH are using their best judgement based on years of experience managing these cases, but the only way to diagnose MH positively is by contracture biopsy or genetic confirmation of an MH-causative pathogenic variant, usually at the RYR1 gene. By contrast, the only way to rule out MH susceptibility is a negative muscle biopsy contracture test. A very small number of cases reported to the MHAUS hotline have

this information entered into the database at a time distant from the original call.

In summary, the MH Hotline provides an important service to the medical community in aiding in diagnosing MH and providing real time clinical recommendations. An in-depth analysis of over 3,000 calls from 2013 to 2020 to the MH Hotline revealed that 1) Isolated post-operative or post-intubation hyperthermia, while commonly leading to a suspicion of MH by callers, is a poor predictor of a “likely MH” diagnosis by an expert consultant; 2) Episodes arising in an OR and those including hypercarbia as a clinical sign more often lead to a “likely MH” consultant impression; 3) Blood gas analysis is the most commonly recommended diagnostic test during a call; and 4) Dantrolene is commonly recommended by consultants, even when they are unsure of an MH diagnosis.

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The authors have no conflicts of interest.

One Year After PRODIGY—Do We Know More About Opioid-Induced Respiratory Depression?

by Ashish K Khanna, MD, FCCP, FCCM, FASA; Richard D. Urman MD, MBA, FASA; and Toby N. Weingarten MD

Editor's Note: The Prodigy trial was funded by Medtronic. However, the following information is applicable across a broad spectrum of equipment types.

The results of the “*PRediction of Opioid-induced respiratory Depression In patients monitored by capnoGraphY*” (PRODIGY) clinical trial were published last year.¹ This was a prospective, observational trial of blinded continuous capnography and oximetry, conducted at 16 sites in the United States, Europe, and Asia. A total of 1,335 patients receiving parenteral opioids were continuously monitored with provider-blinded capnography and oximetry on general care floors. Vital signs were intermittently monitored per standard of care and hospital protocol. The study’s pre-defined respiratory depression episodes included any of the following: respiratory rate ≤ 5 bpm, oxygen saturation $\leq 85\%$, or end-tidal carbon dioxide ≤ 15 or ≥ 60 mmHg for ≥ 3 minutes; apnea episode lasting >30 seconds; or any respiratory opioid-related adverse event. The primary aim of PRODIGY was to define the incidence of opioid-induced respiratory depression (OIRD) and to create a multivariable risk prediction tool (i.e., PRODIGY score) to predict respiratory depression (RD) in hospitalized patients.¹ One or more respiratory depression episodes were detected in 614 (46%) of 1,335 general care floor patients (43% male, mean age 58 \pm 14 years) who were continuously monitored for a median of 24 hrs (IQR 17–26). Five independent variables that included age ≥ 60 (in decades), sex, opioid naivety, sleep disordered breathing, and chronic heart failure were part of a multivariable respiratory depression prediction model with an area under the curve (AUC) of 0.76 (table 1). For PRODIGY, capnography and pulse oximetry tracings were obtained on standard hospital wards and reviewed to determine if patients had an episode of RD. During the study, we noticed that many patients who had an RD episode often had multiple episodes. Recently, we conducted a secondary analysis of 250 patients from two participating centers to better understand these multiple episodes.² We confirmed our impression that RD episodes were rarely isolated. One hundred and fifty-five patients had an RD episode, and of these 136 (88%) had multiple episodes. Also, the number of RD episodes per patient increased with higher PRODIGY scores. For example, 100 patients had a low PRODIGY score and of these 47 had RD with a median [interquartile range] 0 [0, 4] number of RD episodes per patient, while 70 patients had a high PRODIGY score and of these 59 had RD with 5 [IQR 1-16] RD episodes

Multivariable Model Predictors				
Clinical Characteristic	Estimate	OR (95% CI)	Pr > [t]	Points if Clinical Characteristic = 'Yes'
Age (≥ 60 – <70)	0.8077	2.243	<0.0001	8
Age (≥ 70 – <80)	1.2323	3.429	<0.0001	12
Sex (M)	0.7550	2.128	<0.0001	16
Opioid Naïve	0.2912	1.388	0.0782	3
Sleep Disorders	.04755	1.609	0.0175	5
Chronic Heart Failure	0.7494	2.116	0.0668	7
				Sum = PRODIGY Score

PRODIGY Score Distribution				
	Low-Risk	Intermediate Risk	High-Risk	p value
PRODIGY Score	<8 points	≥ 8 & <15 points	≥ 15 points	
% Pts with RD in Risk Category	24%	42%	65%	<0.0001
Sensitivity	—	0.86	0.52	
Specificity	—	0.39	0.77	
OR (p value)	OR _{IL} = 2.35; p<0.001 OR _{HL} = 6.07; p<0.001	OR _{HI} = 2.6; p<0.001		

Reproduced and modified with permission. Khanna AK, Bergese SD, Jungquist CR, et al. Prediction of opioid-induced respiratory depression on inpatient wards using continuous capnography and oximetry: an international prospective, observational trial. *Anesth Analg*. 2020;131:1012–1024.

Pr > [t] = Probability of observing any value equal to or larger than t; OR = Odds Ratio; IL = Intermediate versus low risk; HI = High versus intermediate risk; HL = High versus low risk; RD = Respiratory Depression; Pts = Patients.

Table 1: The PRODIGY risk score and distribution across risk categories. Cells highlighted in green depict an example patient with a high risk of 15 points.

per patient, P<0.001. The time from end of surgery to RD episode was also analyzed. The time to the first RD episode was 8.8 hrs [IQR 5.1, 18.0] postoperatively with a peak occurrence of first RD episodes between 14:00–20:00 the day of surgery (figure 1a). Many subsequent episodes also occurred during this time, but there was a statistically significant peak of RD occurrences the next morning from 02:00–06:00 (All episodes within the first 24 postoperative hours, figure 1b). These results suggest that the PRODIGY score not only calculates risk for a patient having an RD episode, but that these patients have more episodes. Also, the time distribution of RD episodes has implications for postoperative continuous monitoring—specifically, such monitors should be applied upon dismissal from the recovery area.

In another recent post hoc analysis we used existing PRODIGY data to get a better understanding of geographic differences that may drive inpatient parenteral opioid administration. This was a unique opportunity given that the

original data were collected from the United States, Europe and Asia, and included a total of 16 general care medical and surgical wards. In addition, we wanted to know if the type and route of opioid administered is associated with a reduction of OIRD. There are some interesting findings in this post-hoc analysis that have important social and clinical implications. For example, we found that at Asian study sites, hospitalized patients received 7.2 Morphine Milligram Equivalent (MME) (OR 1.7–18.7) on average, whereas opioid use in the United States (31.5 MME, OR 12.5–76.7) and Europe (31.0 MME, OR 62–99.0) was significantly higher. These differences in analgesic practices are intriguing and should be the subject of future studies. OIRD episodes differed by opioid type, where 54% of patients who received only short-acting opioids (e.g., fentanyl) experienced ≥ 1 OIRD episode, whereas 45% who only received long-acting opioids (duration of action ≥ 3 hours) experienced OIRD. Another interesting finding

See “PRODIGY,” Next Page

OIRD is Common on Hospital Wards and Continuous Pulse Oximetry and Capnography Detects This Impairment

From “PRODIGY,” Preceding Page

was that tramadol and epidural opioids were associated with a significant decrease in OIRD. The results of our analysis validate previous studies, suggesting that the type of opioid used may impact postoperative outcomes, including the risk of OIRD.³

The health economics of OIRD are currently being investigated. We collected cost data for 420 United States patients enrolled in the PRODIGY trial. Using the PRODIGY risk prediction tool, patients who were at high risk for OIRD and who had ≥ 1 respiratory depression episode detected by continuous capnography and oximetry had higher hospital costs compared to high-risk patients without respiratory depression ($\$21,948 \pm \$9,128$ vs $\$18,474 \pm \$9,767$, $p=0.0495$). Propensity weighted analysis identified 17% higher costs for patients with ≥ 1 respiratory depression episode ($p=0.007$).

Total hospital cost increased exponentially for patients with ≥ 1 respiratory depression episode as length of stay increased.⁴ Similarly, the cost-effectiveness or the ‘break-even point’ for the cost of investment in continuous monitoring with the estimate of the probability of cost-saving with continuous monitoring for an estimated decrease in respiratory depression is being modelled into an easy-to-use health economics model.

PRODIGY has reinforced some lessons learned from the past. First, OIRD is indeed common, and continuous oximetry and capnography can detect this impairment. Second, OIRD occurs in clusters which are commonplace on the day of recovery from surgery and early the next morning. Third, there are distinct geographical variations in the use of opioid analgesia, and regional anesthesia techniques or tramadol may protect from OIRD. Fourth, there is a significant exponential increase in costs associated with length of hospital stay in high-risk patients who experience respiratory depression episodes. While the majority of respiratory depression episodes were not directly associated with immediate life-threatening adverse events, several patients did develop severe opioid-related complications which were treated with naloxone administration. While continuous, portable cardiorespiratory vital signs monitoring for every patient in the hospital may be the ultimate goal, we continue to develop better clinically relevant prediction models using granular characterization of the spread of OIRD events on the hospital ward. Using this continuously collected data to identify patients with pending serious adverse

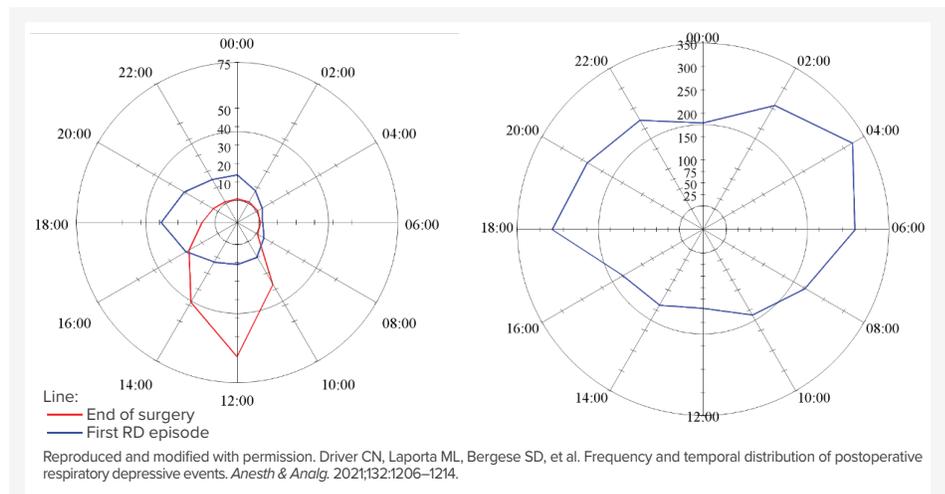


Figure 1a (Left): The time of day of the end of surgery and the initial postoperative respiratory depressive episodes. Radar plots representing time of day on a 24-hour clock. The magnitude of each spoke is the total number of episodes between the previous spoke time and the current spoke time. (e.g., the number of episodes that occurred between 00:00 and 2:00 is shown at 2:00). The scale of episodes is different between the two plots. The number of respiratory episodes for each time slot is shown as the blue line and the end of surgeries is shown in red.

Figure 1b (Right): The time of day for all postoperative respiratory depressive episodes within the first 24 postoperative hours.

events (e.g., respiratory arrest) so that timely mitigating interventions can be implemented is the ultimate goal. We also hope to continue developing cost-effectiveness models to better predict which patients will receive the most benefit and the amount of reduction in effect size for OIRD events. PRODIGY was not a prospective randomized interventional trial and is, therefore, limited by its nonrandomized study design; however, the signals seen in PRODIGY pave the way for an appropriately powered and designed trial that is able to establish or refute the connection between surveillance monitoring on the general care floor and in patient mortality.

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The Evolution and Role of Simulation in Medical Education

by Cameron R. Smith, MD, PhD, and Yong G. Peng, MD, PhD, FASE, FASA

INTRODUCTION

Preventable medical errors are believed to be one of the largest causes of death in the United States (US), resulting in approximately 400,000 deaths per year.¹ Likewise, iatrogenic injuries result in the disability of approximately 3.5 million patients per year in the US.¹ These numbers are alarming. It is more shocking to consider that despite an abundance of new pedagogical methodologies and technologies, medical education has changed little in nearly 100 years and remains firmly rooted in apprenticeship.²⁻⁴ There is not only room for improvement, but also room to embrace tools that are currently available, namely simulation. Simulation as part of training and education has been successfully integrated into the curricula in other industries where errors have high consequences, notably aviation, to which medicine is often compared. Effective use of high-fidelity simulation has become a main-

stay of commercial pilot education, so much so that when a commercial pilot flies an aircraft for the first time, it has a full load of passengers.⁴ Although simulation has been increasingly integrated into medical education, it has not occurred to the same extent as other industries such as aviation.

ORIGINS OF SIMULATION

With this in mind, it is surprising to learn that the application of simulation in medical education is not new. Ancient clay and stone models found across the globe were used to demonstrate clinical features of various diseases (figure 1).³ With the passage of time and advancement of technology, medical simulation has become more sophisticated. The first “modern” simulator, an interactive task trainer, was developed around 1700 by Gregoire and Gregoire, a father and son team in Paris, France,



Figure 2: Michael Gordon demonstrating the original Harvey® cardiology simulator. Reused with permission from Cooper JB, Taqueti, VR. A brief history of the development of mannequin simulators for clinical education and training. *Postgrad Med J.* 2008; 84: 563–570.

from a human pelvis and a dead baby.⁵ It was used primarily for teaching delivery methods to midwives and resulted in a demonstrable decrease in infant mortality.^{3,5} There is also ample documentation from the middle ages through modern times of the use of non-human animals in the development and teaching of surgical skills.⁶

DEVELOPMENT OF MODERN SIMULATION

The modern era of simulation in medical education began in the early 1960s after Dr. Peter Safar, working at Baltimore City Hospital, “rediscovered” and described “mouth-to-mouth” resuscitation.^{7,8} This work, and the prodding of a Norwegian anesthesiologist, Bjorn Lind, convinced Norwegian plastic doll and toy maker Asmund Laerdal to design and produce a realistic model of a human torso, allowing the application of Safar’s head tilt/chin lift to relieve airway obstruction and deliver mouth-to-mouth rescue breaths.⁹ Later, at Safar’s urging, a spring mechanism was added inside the chest of Resusci-Anne® to allow for chest compressions.^{6,9,10} This was the origin of one of the most widely used CPR mannequins of the 20th century.⁵

Another major leap in simulation technology occurred in 1968 when Michael Gordon, MD, PhD, of the University of Miami presented Harvey®, the cardiology patient simulator (figure 2).⁶ Harvey® is capable of simulating almost any cardiac disease by presenting varying auscultatory findings, blood pressures, and pulse findings. It remains in service today at many medical schools, helping to teach physical diagnosis in cardiology.^{3,6,10}

See “Simulations,” Next Page



Figure 1: Ancient clay models of human anatomy recovered from sites throughout the Middle East, North Africa, and Central Asia. Left, anatomical votive offerings (Credit: Altes Museum, CC BY 3.0 via Wikimedia Commons) Right, votive male torso, Roman, 200 BCE-200 CE. (Credit: Science Museum, London. Attribution 4.0 International (CC BY 4.0))

The Evolution of Simulation

From “Simulations,” Preceding Page

Resusci-Anne® and Harvey® are examples of the two major families of simulators in use today: *task trainers*, whose purpose is to teach a set of physical skills and *diagnostic trainers*, whose purpose is mainly to teach the interpretation of information. Task trainers have been developed for teaching everything from simple peripheral intravenous placement to laparoscopic surgical skills.^{5,6,10} Likewise, diagnostic trainers have been expanded to help medical trainees understand an array of patient information and presentations ranging from heart sounds to diagnostic imaging.^{5,6,10}

Diagnostic trainers have further evolved to facilitate learning of patient interaction skills. In the early 1960s, Dr. Howard Barrows, a neurology resident at the New York Neurological Institute, made the astute observation that some patients, after repeated examinations by medical students and residents, would modify the neurologic findings on their examinations in response to repeated examinations by medical students and residents.³ When he graduated from residency and moved on to his own academic practice, Barrows began to train healthy actors to mimic various conditions; thus, in 1964, the standardized patient came into being.^{11,12}

As computer hardware and software developed more rapidly throughout the 1980s and 1990s, the complexity and capabilities of simulators simultaneously evolved. The capability to simulate physiological states and responses to medications thereby providing real feedback to learners was developed. Anesthesiology simulation as a result began to take center stage. David Gaba and colleagues at Stanford University developed the Comprehensive Anesthesia Simulation Environment (CASE).® This tool advanced simulation beyond mere interaction with a mannequin to include a computerized waveform generator, which could produce all of the information typically found on patient monitors in the anesthesia environment.^{13,14}

This development gave rise to the idea of simulators as *environment trainers*. Unlike task trainers or diagnostic trainers, environment trainers are not focused on learning skills or information but on the application of skills and information that the learner already possesses under a pre-established set of circumstances or conditions. This type of simulation immediately lent itself to applications such as anesthesia crisis resource management training.^{14,15}

NEW TECHNOLOGIES IN SIMULATION

As the capabilities of computers have continued to evolve, new technologies such as virtual reality, augmented reality, and mixed reality have been incorporated into simulation as well. Below, we provide definitions and examples of these terms.

Virtual reality is a fully immersive experience that tricks the user’s senses into thinking they are in a different environment separate from the real physical world. Using a head-mounted display or headset, the user can experience a computer-generated world of imagery and sounds in which digital objects can be manipulated using haptic controllers tethered to a console or PC. While in a virtual reality environment, interaction with the real world is limited. The most developed of these virtual reality simulators is the SimX® platform (San Francisco, CA),¹⁶ which allows multiple users to participate in the same simulation simultaneously. SimX® is one example of a platform that reacts to participants’ natural behavior and allows multiple users to be engaged in the same scenario (i.e., interacting with the same virtual patient and each other). As an example of the use of natural behavior when using this platform, if a participant were to pick up a virtual stethoscope in a virtual reality environment and apply it to the patient, the user can hear what they typically would through the stethoscope. Fundamental Surgery (FundamentalVR, London, UK),¹⁷ is a virtual reality platform designed for surgical training, also allows multiple users to interact with the same simula-

tion and makes use of hand control devices, which mimic various surgical tools.

Augmented reality overlays digital information on real-world elements. Pokémon GO (Niantic, San Francisco, CA) is among the best-known examples. Augmented reality keeps the real world central in the simulation but enhances it with other digital details by the layering of new information that is not available without the computer additions thereby supplementing reality. Augmented reality allows for digital interaction with digital elements and physical interaction with real-world elements. One example is a platform made by GIGXR (Los Angeles, CA),¹⁸ which generates “holographic” patients in a real clinical environment. This system can be accessed using a head-mounted goggle system, which allows visualization of a virtual patient and displays his/her vital signs within the physical room where the user is located. The system can also be accessed using a smartphone or tablet, which uses the onboard camera to display the room and the virtual patient on the screen.

Mixed reality brings together real-world and digital elements. In mixed reality, the user interacts with and manipulates physical and virtual items and environments, using next-generation sensing and imaging technologies. Mixed reality allows the user to see and be immersed in the real world while physically interacting with both items in the real world as well as digital items. As a result, mixed reality breaks down barriers between real and imaginary. An example is the Heartworks® ultrasound simulation system¹⁹ by Intelligent Ultrasound (Cardiff, UK), which allows a user to place transthoracic and/or transesophageal ultrasound probes into a mannequin, manipulate the probe as would be performed at bedside, and explore how probe manipulation impacts the ultrasound image displayed on a computer monitor.

See “Simulations,” Next Page

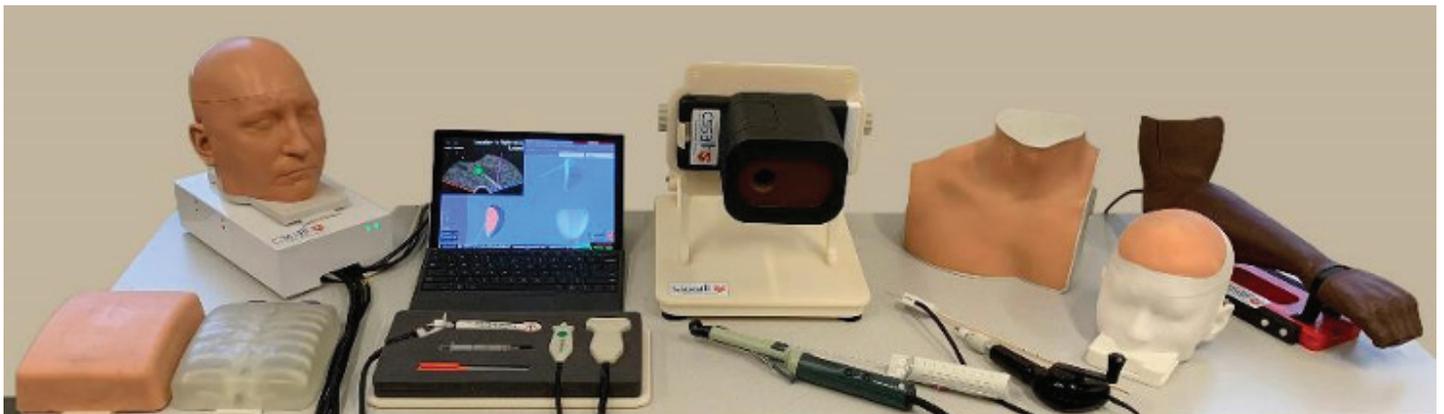


Figure 3: The current range of System of Modular Mixed and Augmented Reality Tracking Simulators (SMMARTS) simulator modules, including thoracic regional anesthesia, head and neck regional anesthesia, central venous access, peripheral venous access, ventriculostomy and prostate modules.

Simulation Continues to Evolve to Meet Educational Advancements

From “Simulations,” Preceding Page

This system facilitates the acquisition of ultrasound probe manipulation skills and the examination of various pathologies, functioning as a combined diagnostic trainer and task trainer. Another example of a mixed-reality simulation system is the System of Modular Mixed and Augmented Reality Tracking Simulators (SMMARTS),²⁰ which was developed at the University of Florida. SMMARTS is built around a core module that includes the tracking hardware and add-on modules that can be made to simulate essentially any desired anatomy.²¹ The physical module contains three dimensional-printed bony anatomy and a silicone gel or ballistics gel model of the surrounding soft tissue. The bony and soft tissue are modeled within the software environment. This allows the user to examine the tissue of interest and perform interventional procedures.²¹ Multiple modules have been developed for SMMARTS, including a spine for thoracic regional anesthetic procedures, a head for regional anesthetic procedures in the head and neck, a head for ventriculostomy procedures, a chest for internal jugular and subclavian central venous access, an arm for peripheral venous access, and a box for transrectal prostate examination and biopsy (figure 3).^{21,25}

All of these technologies have been employed in various formats for medical education, primarily in the surgical and interventional care domains. They allow for ultrarealistic simulation of procedural skills without the need for a patient to be involved, for facilitation of anatomic diagnoses based on patient imaging data, or for complex surgical planning. Mixed-reality simulators offer multiple advantages because they are capable of simultaneously acting as diagnostic trainers, task trainers, and environment trainers.

One point of contention has been whether simulation practice can help improve patient safety. Although simulation training is gradually being adopted into medical curriculum, it still has not been widely practiced in many disciplines beyond advanced cardiovascular life support training or limited clinical crisis scenario exercises.²⁶ Certain simple procedural tasks, such as central venous cannulation simulation, have indeed demonstrated a reduction of complications and improved patient outcomes.²⁷ However, there remains a need for large prospective cohort studies to provide data that simulation training not only enhances medical procedure efficiency, but also improves patients safety.

CONCLUSIONS

As health care becomes more complex and clinical practice becomes more specialized, simulation is likely to continue to evolve to meet

educational needs. We should expect virtual reality, augmented reality, and mixed-reality simulators to become increasingly more commonplace. Simulators are also likely to become more capable, integrating diagnostic, task, and environment trainers. Imagine a simulator mannequin that can generate waveforms and send them to anesthesia monitors, while simulating physical examination findings of a tension pneumothorax, allowing for bronchoscopic examination and endotracheal tube manipulation, central venous line placement, thoracocentesis, and chest tube placement, all using the same simulator tool. Not only would such tools be invaluable for medical education, but they would likely form the basis of a new paradigm for performance evaluation such as board certification, allowing for the examination of not only knowledge and judgement, but also physical skills. A broader adoption of simulation-based curricula into undergraduate and graduate medical education may have the potential to not only simplify evaluation, but also to improve the quality and safety of patient care.⁴

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Conflicts of interest: Cameron Smith, MD, PhD reports he is the inventor of the SMMARTS head and neck regional anesthesia simulator module but is not the patent-holder on the underlying technology. Yong G. Peng, MD, PhD, reports he has no conflicts of interest.

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Management of Massive Intraoperative Hemorrhage

by Taizoon Q. Dhoon, MD; Darren Raphael, MD; Govind RC Rajan, MBBS; Doug Vaughn, MD; Scott Engwall, MD, MBA; and Shermeen Vakharia, MD

Hemorrhage is the leading cause of death in the operating room,¹ with two thirds of hemorrhagic deaths occurring in the setting of emergent surgery. However, one third of hemorrhagic deaths occur during elective procedures due to unexpected organ or vessel injury.^{1,5} The response to unanticipated hemorrhage can mean the difference between life and death for these patients.

Crisis management is the process by which one deals with an emergent critical event in the operating room.⁶ When an unanticipated hemorrhage occurs, the anesthesia professional must mobilize resources, coordinate multidisciplinary care, and treat the patient within minutes. This process is often chaotic and is provider dependent, which can lead to compromised patient care. A recent elective surgical case at our institution was complicated by uncontrolled surgical bleeding and ultimately resulted in a surgical death. A 70-year-old female with hypertension and chronic pain was scheduled for a spinal fusion and artificial disc replacement via an anterior retroperitoneal exposure of the lumbar spine. A vascular surgeon provided surgical exposure to the spine, but the case was complicated by major venous injury when providing exposure. A root cause analysis was performed, which prompted reevaluation of our crisis management protocol. We describe here the development and implementation of a crisis response protocol for intraoperative bleeding called *Code Hemorrhage*.

Development of the protocol began with a working group of key stakeholders. Anesthesia professionals, surgeons, nursing staff, transfusion specialists, and hospital administrators reviewed existing guidelines, consensus statements, and current practices relating to intraoperative crisis resource management and surgical bleeding. Key factors linked to critical events were identified utilizing the Joint Commission's methodology and its extranet site *Joint Commission Connect™* to create a framework for the root cause analysis and action plan. Components of the root cause analysis and elements pertaining to anesthetic management are depicted in table 1. Using this information, the team developed a comprehensive crisis response protocol for intraoperative hemorrhage whereby an alert summons a multidisciplinary team including anesthesia professionals, a trauma surgeon, nursing staff, support staff, and the blood bank. This protocol was then refined by holding simulations with key personnel and stakeholders.^{4,6} *Code Hemorrhage*

Table 1: Key Factors Linked to Critical Events.

Depicts important elements linked to critical adverse events in the perioperative period.

KEY FACTORS
TYPE OF SURGERY
SURGICAL JUDGEMENT
SURGICAL TECHNICAL COMPLICATIONS
TIMING OF CALL FOR HELP
COMMUNICATION
BLOOD SUPPLY
ANESTHETIC MANAGEMENT
– MEDICATION
– EQUIPMENT
– TIMING OF ADDITIONAL ACCESS
– ROLE CLARITY
– FOLLOW-UP COMMUNICATION
– TIMING OF CALL FOR HELP
– AVAILABILITY OF ADDITIONAL MANPOWER

may be initiated by anesthesia professionals, surgeons, or operating room nurses in response to a bleeding event. A call to the operating room front desk triggers an overhead page of “*Code Hemorrhage* operating room number.”

THE ANESTHESIA TEAM'S ROLE

The anesthesia team leader mobilizes additional anesthesia professionals and assigns staff to specific roles (figure 1). The secondary anesthesia professionals include anesthesiology attendings, residents, nurse anesthetists, and an anesthesia technician. Assigned roles include medication and infusion management, venous and arterial access, administration of blood products, deployment of a rapid infuser, operation of point of care lab testing, and appropriate documentation. The anesthesia technologist is responsible for setting up the rapid infuser, obtaining a transesophageal echocardiogram (TEE) machine and assisting in placement of central venous or arterial access. The secondary anesthesia professional provides explicit and succinct instruction to the anesthesia team and ensures execution of tasks, permitting the primary anesthesia professional to focus on patient management and communication with the surgical team, which is critical for patient outcomes.⁵ Additionally, the

secondary anesthesia professional serves as a sounding board for the primary one, expediting diagnosis and treatment. Our institution has multiple anesthesia professionals in-house during nights and weekends. For institutions with less accessible resources, utilizing intensivists or the hospital's rapid response team as part of the operative crisis response team could be an option.

THE NURSES' ROLE

Code Hemorrhage triggers a nursing staff response as well. The OR charge nurse assigns an additional circulating nurse (a float/break nurse) to assist the primary OR circulating nurse, enhancing OR efficiency. The role of the additional nurse includes bringing a trauma surgical cart to the OR, so equipment is available to treat bleeding. The additional circulating nurse also facilitates communication with the blood bank and the anesthesia team and assists with the independent double check process of blood products in the OR. Our institution has nurses available for breaks, as well as a charge nurse to provide help. For other institutions who have more limited resources, employing post-operative care nurses as part of the operative crisis response team may be an option.

The OR charge nurse also alerts the blood bank that a massive transfusion protocol (MTP) could be imminent. The additional circulating nurse facilitates close communication with the blood bank throughout the case. The transfusion medicine team's role involves preparing for the massive transfusion protocol. The blood bank physician specialist routinely discusses management of transfusion, coagulation optimization, and blood bank resources with the anesthesia professional by calling into the operating room or an in person discussion.

THE TRAUMA SURGEON'S ROLE

Unique to *Code Hemorrhage* is the standardized involvement of an in-house trauma surgeon as a member of the crisis response team. A trauma surgeon offers a set of experienced hands that can address life-threatening injuries and rapidly stabilize the patient's condition. The most crucial step in a hemorrhagic crisis is to determine and control the source of the bleeding.² Publications on OR hemorrhage management espouse a multidisciplinary approach, massive transfusion protocols, and often focus on obstetric/peripartum bleeding.

See “Hemorrhage,” Next Page

Code Hemorrhage Includes Participation of a Trauma Surgeon

From “Hemorrhage,” Preceding Page

One publication discussed the benefits of a multidisciplinary protocol, involving early vascular surgeon involvement when managing patients with a suspected ruptured abdominal aortic aneurysm.⁷ Despite this concept having been described in high-risk surgical procedures, it is likely to be useful in many other causes of hemorrhagic shock. Though numerous massive transfusion protocols exist in the literature, *Code Hemorrhage* is distinctive in that it always includes participation of a trauma surgeon, who can expeditiously help secure the source of intraoperative hemorrhage and lend a trained hand to the primary surgeon.

When deciding whether or not to call for help in an operative crisis, the primary surgeon may feel a sense of trepidation in inconve-

niencing a colleague. The primary surgeon may be unduly influenced by ego when making this decision, as well. Therefore, the objective use of a trauma surgeon as compulsory member of the *Code Hemorrhage* may reduce the risk of delayed inappropriate treatment. Also unique to *Code Hemorrhage* is the availability of an emergency trauma cart with the instruments needed to perform emergency exploratory laparotomy and thoracic surgery. Finally, *Code Hemorrhage* is remarkable in its organized approach to resource deployment for all disciplines involved; enhancing communication, decision making, and patient care at our institution.

A trauma surgeon’s expertise offers expedited diagnosis and treatment which may include source control, application of direct pressure, temporary packing, clamping of the

aorta, resuscitative endovascular balloon occlusion of the aorta (REBOA), or damage control surgery.¹ Intraoperative emergencies are tremendously stressful, and a loss of situational awareness may lead to “tunnel vision” on the part of the primary surgical team. This is further compounded in the academic setting where cases may be more complex, and residents may lack the education and experience to assist in intraoperative crisis management.⁴ The trauma surgeon provides both perspective and expertise for the primary surgical team.

CONCLUSION

In creating *Code Hemorrhage*, our goal was to establish a shared mental model to facilitate an organized, systematic, and robust response when managing intraoperative crises.

See “Hemorrhage,” Next Page

Figure 1: Code Hemorrhage Personnel and Responsibilities.

Depicts the responsibilities of each team during a perioperative critical adverse event.

ANESTHESIA PROFESSIONAL		TRAUMA SURGEON	
<ul style="list-style-type: none"> • Assist primary anesthesia professional • Assign staff to specific roles: <ul style="list-style-type: none"> – Check blood products – Manage rapid infuser – Manage medication and infusions – Central venous & arterial access – Frequent lab draws – Documentation • Coordinate multidisciplinary response • Optimize communication with surgeon • Declare end of response in conjunction with primary anesthesia professional and surgeon 	<ul style="list-style-type: none"> • Assist primary surgeon • Address life-threatening injuries • Discuss: <ul style="list-style-type: none"> – Etiology of bleeding – Anticipated procedures – Length of procedure/repair – Temporary packing bimanual vessel compression – Damage control surgery • Confirm with anesthesia team that packing, vascular compression, and/or aortic cross clamp is maintained until adequate resuscitation has occurred • Optimize communication with anesthesia team 		
ANESTHESIA TECHNICIANS	OR CIRCULATING NURSE	BLOOD BANK	
<ul style="list-style-type: none"> • Setup equipment that is potentially used during hemorrhage: <ul style="list-style-type: none"> – Ultrasound – Rapid infuser – Transesophageal echocardiogram – Central venous and arterial catheter access • Assist anesthesia team as directed 	<ul style="list-style-type: none"> • Assist primary circulating nurse • Communicate with blood bank • Coordinate transport of blood to operating room • Expedite equipment and supply retrieval • Check blood products 	<ul style="list-style-type: none"> • Prepare for massive transfusion • Communicate with operating room staff regarding product availability • Provide consultation: Blood product utilization and coagulation optimization 	

Success of “Code Hemorrhage” is Predicated on the Multidisciplinary Approach

From “Hemorrhage,” Preceding Page

Implementation of this structured response strategy has enhanced communication, decision making, and patient care at our institution. Since *Code Hemorrhage* went live approximately one year ago it has been triggered eight times to manage intraoperative hemorrhagic crises that would have possibly resulted in intraoperative death prior to its application. The cases were comprised of four hepatobiliary, two obstetric, and two orthopedic procedures. In addition to hemorrhage, four cases involved suspected concomitant pulmonary embolism based on transesophageal echocardiography findings. All eight patients survived the intraoperative period. Five patients died following their operative course; notably, three patients suffered ischemic brain injury related to hypotension and hemorrhage. Remarkably, three

patients were successfully discharged home. Adoption of *Code Hemorrhage* at other institutions offers the potential to improve patient outcomes.

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