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Perioperative Hypotension

by Daniel I. Sessler, MD

When patients reach the postanesthesia care unit after undergoing major noncardiac surgery, families assume they have naturally survived the most dangerous part of the perioperative experience. Their assumption is wrong. Mortality in the 30 days after surgery is more than 100 times higher than intraoperative mortality.[1,2] In fact, if the month after surgery were considered a disease, it would be the third leading cause of death in the United States.[3]

Three-quarters of postoperative mortality occurs during the initial hospitalization, that is, under direct medical care in our highest-level facilities.[4] The two most common and comparable causes of 30-day mortality after noncardiac surgery are major bleeding and myocardial injury.[5,6]

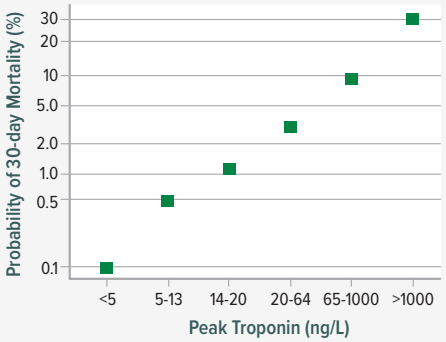
MYOCARDIAL INJURY

Myocardial infarction (MI), per 4th Universal Definition, is defined by troponin elevation *and* either symptoms or signs of myocardial ischemia.[7] Myocardial injury after non-cardiac surgery (MINS) is defined by troponin elevation of presumably ischemic origin, and is highly associated with 30-day[8] and one-year[9] mortality. MINS includes myocardial infarction *and* other ischemic myocardial injuries not fulfilling the definition of myocardial infarction.

Perioperative myocardial injury is generally a Type-2 event, resulting largely from supply-demand mismatch. MINS and perioperative myocardial infactions thus differ from nonoperative infarctions, which usually result from plaque rupture. Soberingly, mortality from perioperative myocardial events is higher than for nonoperative infarctions—and thus deserves considerable attention.[10,11]

TROPONIN SCREENING

More than 90% of MINS and MI occurs within the initial two postoperative days, and more than 90% are asymptomatic.[12] While it is tempting to dismiss asymptomatic troponin elevations as "troponitis," mortality is nearly as high without symptoms as with symptoms (Figure 1). MINS should thus be taken as seriously as classical symptomatic infarctions.



Data from Writing Committee for the Vision Study Investigators: Association of postoperative high-sensitivity troponin levels with myocardial injury and 30-day mortality among patients undergoing noncardiac surgery.[12]
This figure is adapted from data presented in reference 12.

Figure 1: 30-day mortality as a function of postoperative peak high-sensitivity troponin T. Mortality increases markedly from 0.1% at a troponin T concentration <5 ng/L to 30% mortality when troponin T exceeds 1,000 ng/L.

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Pulse Oximeters: The Invention That Changed the Paradigm of Patient Safety Around the World—A Japanese Perspective

by Katsuyuki Miyasaka, MD, PhD

OXIMETRY: PRINCIPLE, BUT NO THEORY

I am from a generation that experienced anesthesiology before the development of pulse oximeters. I was studying abroad in North America from 1973–1977, when Takuo Aoyagi, PhD, envisioned the principle of pulse oximetry. This was just about the time when Minolta began selling a finger-type device, and I knew nothing of Aoyagi's existence or the idea of pulse oximeters. At that time, it was hard to get up-to-date information. International telephone calls cost 8,000 yen for three minutes (the equivalent of 50,000 yen or US $500 now). Japan was just starting to shed the image of Made in Japan = cheap and poorly made. The Hewlett Packard 8-wavelength ear oximeter was already in use at a research laboratory. Although it appeared accurate, it seemed to be cumbersome for clinical use.

It wasn't until six years after returning to Japan that I met Aoyagi at a Japanese Subcommittee of the International Organization for Standardization. We attempted, unsuccessfully, to establish a standardized calibration method. In the 36 years since, I have had the privilege of learning from him, and having lived through the same generation as a clinician and a developer, I feel a responsibility to report how his great invention was born and how it grew. Therefore, I hope to use this occasion to enable people worldwide to learn how pulse oximetry, conceived in Japan, has developed and the issues left to still be resolved.

Pulse oximeters can be used on all people no matter their color, race, age, body shape, place of measurement, or type of device. By merely turning on a switch, a clear number from 0-100% is displayed and in healthy people a number that "seems right" shows up. However, according to Takuo Aoyagi, the basis for the numbers displayed just happens to make them look right. It is important to not overlook the precision and reliability of the measurement parameters, and also to understand the physiological and medical issues involved in order to correctly interpret the number displayed.

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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

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Postoperative Hypotension Is Associated With Myocardial Infarction

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In the absence of routine troponin screening, most myocardial injury is missed. A reasonable strategy is to measure troponin preoperatively and for the first three postoperative days. The thresholds for MINS differ depending on the assay generation and type:

1. non-high-sensitivity (fourth-generation) troponin T ≥0.03 ng/ml[4];
2. high-sensitivity troponin T ≥65 ng/L; or high-sensitivity troponin T=20–64 ng/L and an increase ≥5 ng/L from baseline[12];
3. high-sensitivity troponin I (Abbott assay [Abbott Park, IL]) ≥60 ng/L[13];
4. high-sensitivity troponin I (Siemens assay [Munich, Germany]) ≥75 ng/L (Borges, unpublished);
5. troponin I (other assays) is at least twice local 99th percentiles;
6. an increase of at least 20% in patients who have *preoperative* high-sensitivity troponin concentrations that exceed 80% of the relevant thresholds in items 2–5.

HYPOTENSION

Both MINS and MI are strongly associated with many *unmodifiable* baseline characteristics including age, diabetes, and cardiovascular history. Large randomized trials (n=7,000–10,000) have shown that MI cannot be safely prevented by beta blockers,[14] avoiding nitrous oxide,[15] by clonidine,[16] or aspirin.[17] In a recent large trial, one patient in seven who had MINS had a major vascular event (mostly re-infarctions) within 17 postoperative months.[11]

Intraoperative hypotension is associated with MINS and MI, with the harm threshold being a mean arterial pressure (MAP) ≈65 mmHg (Figure 2).[18,19] Postoperative hypotension is also associated with myocardial infarction, *independent of intraoperative hypotension* (Figure 3).[20,21]

Results from the VISION cohort show that postoperative hypotension is common (Figure 4) and strongly associated with major vascular events. Postoperative hypotension is more strongly associated with myocardial infarction and/or death than intraoperative hypotension (Figure 5).[22] Perioperative hypotension is also associated with stroke,[14,22-25] although inconsistently.[26]

OTHER FACTORS

Two recent studies identified remarkably strong associations between postoperative anemia and myocardial injury[27] and infarction,[28] even after adjusting for baseline patient characteristics and preoperative anemia.

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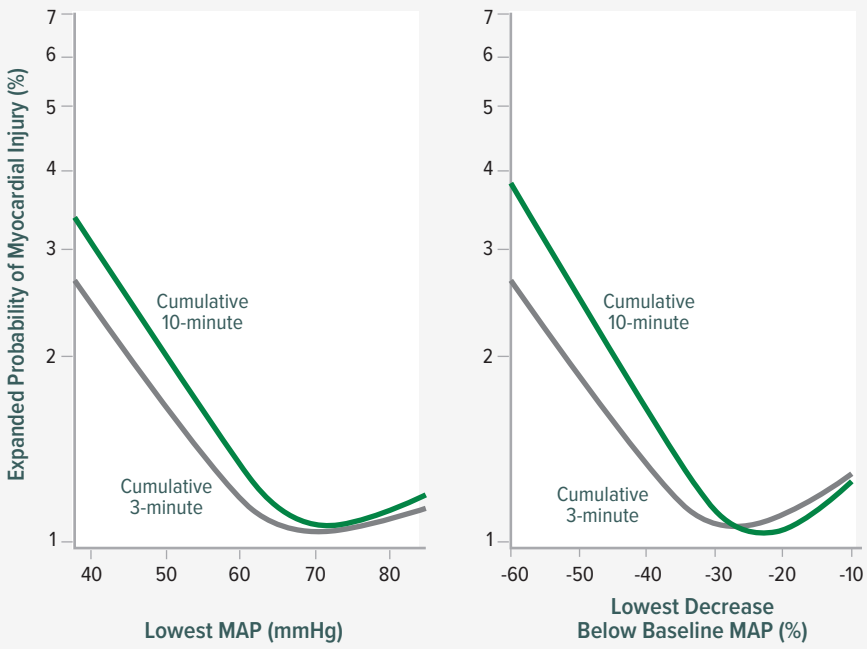

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Figure 2: Lowest mean arterial pressure (MAP) thresholds for myocardial injury after noncardiac surgery. The left graph shows the relationship between the lowest cumulative absolute mean arterial pressure maintained for 3 and 10 minutes and myocardial injury. The right graph shows the relationship between the lowest cumulative relative mean arterial pressure maintained for 3 and 10 minutes and myocardial injury. Both graphs are multivariable logistic regressions adjusted for baseline characteristics.[18]

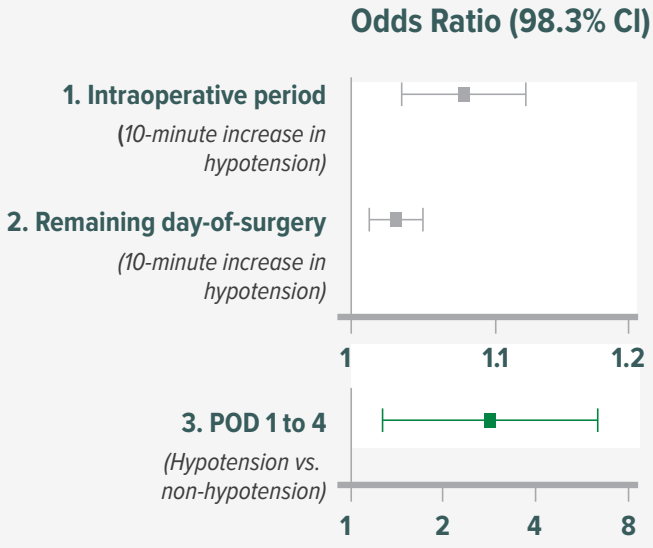

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Figure 3: Odds ratios of average relative effect on the primary composite of 30-day myocardial infarction and mortality for three perioperative periods: intraoperative, remaining day of surgery, and the initial four PODs of hospitalization. CIs for multiple comparisons were adjusted by Bonferroni correction. Correspondingly, P<0.017 (0.05/3) was considered to be significant for the average relative effect. The squares present the odds ratios, and the bars present the CIs. POD = postoperative day.[20]

Hypotensive Harm Threshold for Acute Kidney Injury Is Similar or Slightly Higher Than That For Myocardial Injury

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In contrast, a heart rate up to 100 beats/min and systolic hypertension up to 200 mmHg are not important risk factors for postoperative myocardial injury.[29] General hospital floor hypoxemia is common, profound, and prolonged[30]; however, it remains unknown whether hypoxemia contributes to myocardial injury. Fortunately, simultaneous hospital floor hypotension and hypoxemia—which might especially provoke supply-demand injury—is rare.

ACUTE KIDNEY INJURY

New-onset acute kidney injury (AKI) is common after noncardiac surgery, with stages 2–3 occurring in up to 1% of patients,[31] and in up to 7.4% of patients when stage 1 AKI is included.[32] There is currently no reliable way to predict AKI.[33] The hypotensive harm threshold for AKI is similar or slightly higher than that for myocardial injury, presumably because the metabolic rate of the kidney is high.[18,32,34]

Notably, at a more stringent MAP cut-off of <55 mmHg, <5 minutes below this pressure is associated with an 18% increase in risk for AKI.[34] Other analyses report similar associations.[35] Taken together, these studies confirm a robust association of both degree and duration of perioperative hypotension and AKI, and hence the importance of considering both duration and excursion when quantifying hypotension.

The implications of perioperative AKI extend past the index hospitalization. In a 1,869-patient observational cohort examining the association of perioperative AKI with 1-year mortality, AKI was associated with an adjusted hazard ratio for death of 3.[36] Lastly, we note that even milder degrees of AKI have lasting consequences: 37% of Stage 1 AKI persists or is worse 1–2 years after non-cardiac surgery (Figure.6).[37]

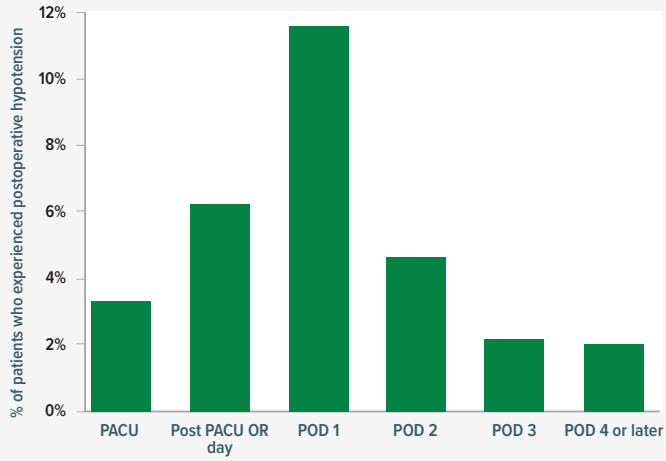

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Figure 4: Clinically meaningful hypotension (systolic pressure <90 and prompting intervention). In total, 2,860 of 14,687 patients (19.5%) experienced at least one episode of clinically meaningful hypotension after their surgery; 2,728 (95.4%) of those patients experienced a hypotensive episode by postoperative day (POD) 3. OR = operating room; PACU = postanesthesia care unit.[22]

DELIRIUM

Delirium is a common complication of cardiac surgery and is associated with morbidity and mortality.[38-42] The reported incidence of delirium after major non-cardiac surgery is about 10%, and increases markedly as patient age increases beyond 65 years.[43] The pathophysiology of delirium is multifactorial, but presumably includes inadequate brain perfusion that results when mean arterial pressure is less than the lower limit of autoregulation.[44-46]

The cerebral autoregulation threshold remains unclear, but there appears to be considerable inter-individual variation, and may be as high as 85 mmHg in some patients.[47,48] Consistent with this theory, hypotension is associated with delirium and cognitive decline (Figure 7),[49-51] although inconsistently.[52-54] Limited randomized data (n=199) indicate that hypotension causes delirium.[55]

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Hypotension	Outcome	Events in exposed vs. unexposed	aRR (95% CI),p-value
Intraoperative	Death, MINS, or stroke	464/4162 (11.1%) vs. 945/10525 (9.0%)	1.11 (0.98–1.25), 0.09
	Death	133/4162 (3.2%) vs. 169/10525 (1.6%)	1.41 (1.07–1.86), 0.02
	MINS	353/4138 (8.5%) vs. 807/10496 (7.7%)	1.04 (0.90–1.20), 0.58
	Stroke	32/4162 (0.8%) vs. 58/10525 (0.6%)	1.14 (0.85–1.54), 0.37
	Postop, hypotension	1133/4162 (27.2%) vs. 1595/10525 (15.2%)	1.65 (1.48–1.84), <0.001
	MI (Exploratory)	137/4162 (3.3%) vs. 309/10525 (2.9%)	1.05 (0.80–1.35), 0.74
	Death, MI, or stroke (Exploratory)	273/4162 (6.6%) vs. 472/10525 (4.5%)	1.23 (1.03–1.47), 0.03
Postoperative	Death, MINS, or stroke	439/2728 (16.1%) vs. 970/11959 (8.1%)	1.68 (1.53–1.85), <0.001
	Death	125/2728 (4.6%) vs. 177/11959 (1.5%)	2.20 (1.90–2.54), <0.001
	MINS	346/2703 (12.8%) vs. 814/11931 (6/8%)	1.63 (1.44–1.84), <0.001
	Stroke	24/2728 (0.9%) vs. 66/11959 (0.6%)	1.73 (0.67–4.51), 0.26
	MI (Exploratory)	153/2728 (5.6%) vs. 293/11959 (2.5%)	1.96 (1.66–2.32), <0.001
	Death, MI, or stroke (Exploratory)	266/2728 (9.8%) vs. 479/11959 (4.0%)	2.01 (1.72–2.33), <0.001

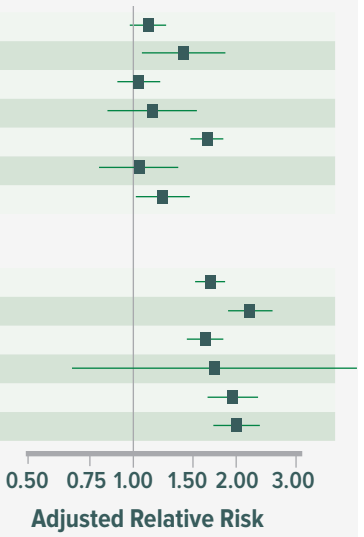

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Figure 5: Adjusted association between hypotension and postoperative death and vascular events in all 14,687 patients. aRR = adjusted relative risk.[22]

Phenylephrine and Norepinephrine Are Common Vasopressors to Treat Perioperative Hypotension

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Patients who have delirium after surgery are far more likely than others to develop long-term cognitive impairment;[56] however, it remains unknown whether the association is causal. Hypotension may also provoke overt—or far more commonly—covert strokes which are strongly linked to delirium.[57]

BLOOD PRESSURE MANAGEMENT

Intraoperative hypotension cannot be reliably predicted from baseline patient characteristics or the surgical procedure.[58] How best to prevent and treat perioperative hypotension remains unclear. There is remarkably little correlation between intraoperative cardiac index and blood pressure, and the assumption that maintaining adequate vascular volume prevents hypotension does not appear accurate. Furthermore, in one study, a third of all intraoperative hypotension occurred between anesthetic induction and surgical incision—and was thus obviously consequent to anesthetic drugs rather than volume shifts. Pre-incisional hypotension is as strongly associated with organ injury as subsequent hypotension.[59]

Continuous blood pressure monitoring detects more hypotension than measurements at 5-minute intervals,[60,61] thus allowing clinicians to intervene earlier.[61] An exciting recent development is an algorithm that predicts future hypotension from the arterial waveform.[62] Although a small trial reported less hypotension when management was guided by the index,[63] a larger one did not identify benefit.[64] The difference likely results from differences in the treatment algorithms, and a robust trial is clearly needed.

Vasopressors like phenylephrine or norepinephrine are commonly used to treat hypotension during surgery. Phenylephrine is by far the most commonly used pressor in the United States,[65] whereas norepinephrine is generally preferred elsewhere. Phenylephrine is a pure alpha agonist which raises blood pressure by increasing systemic vascular resistance, usually with a compensatory decrease in cardiac output.[66] In contrast, norepinephrine combines powerful α-adrenergic agonism with weak β-adrenergic agonist activity which helps maintain cardiac output. Consequently, while blood pressure is comparably maintained with each vasopressor,[67] phenylephrine reduces splanchnic blood flow and oxygen delivery.[68] Clinicians should avoid phenylephrine in patients with septic shock.[69]

Despite the theoretical advantages of preserved cardiac output and splanchnic perfusion

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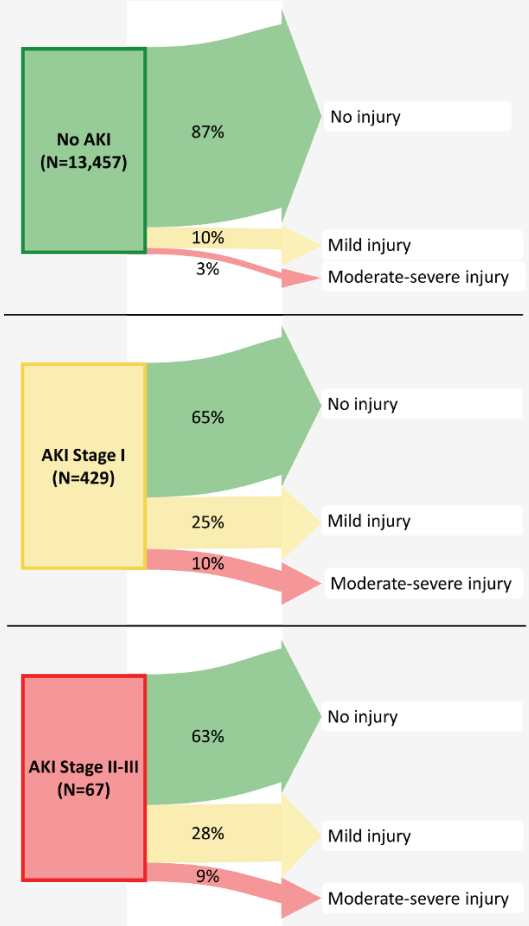

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Figure 6: Renal outcomes 1–2 years after surgery, according to postoperative acute kidney injury stage. Width of the arrows represents the percentage of patients from each exposure group having each stage of long-term renal injury.[37] A quarter of patients with stage I postoperative kidney injury (creatinine increase of ≥ 0.3 mg/dl or 1.5–1.9 times the baseline level) still had mild injury 1–2 years later, and 10% had even higher stage injury. A full third of the patients with stage I kidney injury thus had renal injury 1–2 years after surgery. Consequently, patients with postoperative stage I injury had an odds ratio (95%CI) of 2.3 (1.8, 2.9) for having long-term renal injury compared to patients without postoperative kidney injury. We thus conclude that in adults recovering from noncardiac surgery, even a mild postoperative increase in plasma creatinine, corresponding to stage I kidney injury, is associated with worse renal outcome 1–2 years after surgery and should therefore be considered a clinically important perioperative outcome.

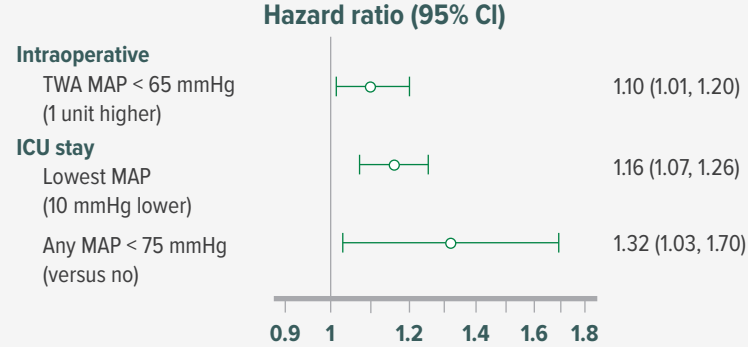

Figure 7: Adjusted hazard ratio of delirium in 908 postoperative patients who were admitted directly from an operating room to the surgical intensive care unit. Delirium was assessed with the Confusion Assessment Method for Intensive Care Unit patients at 12-hour intervals. 316 (35%) patients had delirium within the first 5 postoperative days in the surgical intensive care unit. Intraoperative hypotension, MAP <65 mmHg was significantly associated with higher odds of postoperative delirium.[50] TWA=Time Weighted Average

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Efforts To Avoid Perioperative Hypotension Seem Prudent

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with the use of norepinephrine, there is limited evidence of any outcome improvement in surgical patients.[70] Consequently both phenylephrine and norepinephrine are widely used in clinical practice, mostly based on clinical preference and availability. There is no convincing evidence that intraoperative low-dose vasopressors are themselves harmful, and allowing hypotension in an effort to avoid using vasopressors is probably unwise. Norepinephrine can be safely given through a central catheter or peripherally.[71] In a recent study of 14,328 patients, there were only 5 extravasation events and not a single patient experienced local tissue injury.[72]

General hospital floor hypotension is common, prolonged, and profound. It is likely that most perioperative hypotensive organ injury occurs postoperative rather than intraoperatively. The challenge is that blood pressure is usually measured intermittently. Even at 4-hour intervals, about half of all potentially serious hypotensive episodes are missed.[73] (Most hypoxemia is similarly missed with intermittent ward monitoring.[30]) Reliably detecting and treating ward hypotension will require continuous vital sign monitoring. But in the meantime, avoiding angiotensin converting enzyme inhibitors and angiotensin receptor blocks on the day of surgery helps,[22] as does restarting chronic antihypertensive medications only when clearly needed.

ASSOCIATION VERSUS CAUSALITY

Intraoperative hypotension is common. Depending on the definition and population, a quarter or more of all surgical patients have mean arterial pressures < 65 mmHg during surgery. Hypotension is also common postoperatively, with only about half of potentially serious episodes being detected by routine vital signs at 4-hour intervals.[73] Postoperative hypotension is often prolonged, and it seems likely that much—or even most—myocardial and renal injury develops postoperatively.

There is currently sparse evidence that the associations between hypotension and MINS and AKI are causal. But a small randomized trial (n=292) demonstrated that preventing intraoperative hypotension reduces the risk of major complications by 25%, which is biologically plausible.[74] Two large trials should identify what fraction (if any) of the observed associations are causal: POISE-3 (n=10,000, NCT03505723) is nearly finished and GUARDIAN (n=6,250, NCT pending) is about to start.

SUMMARY

Intraoperative and postoperative hypotension are associated with myocardial and renal injury. Associations are consistently reported from various populations using various thresholds and analytic methods, and persist after adjustment for known baseline factors. (The associations with baseline factors are far stronger than for hypotension, but hypotension differs in being modifiable.) Associations between hypotension and delirium are also reported, but the evidence remains weak.

There is currently little randomized data to characterize the extent to which observed associations might be causal. Large trials are in progress, but results will not be available for some time. The question, then, is how to manage blood pressure in the meantime.

Two factors deserve special consideration. The first is how likely is a causal relationship between hypotension and organ injury? Surely much of the observed associations result from unobserved confounding or are predictive rather than modifiable. But it also seems likely that at least a fraction is causal, and thus amenable to intervention. The second factor to consider is how difficult it is to keep intraoperative mean arterial pressure above 65 mmHg or

some similar threshold? In general, it is not difficult (or expensive) to keep intraoperative blood pressure well above the apparent harm threshold. In many cases, simply moderating anesthetic administration and skillfully managing fluids is sufficient. In others low- or moderate-dose vasopressors will be needed. There is no convincing evidence that administration of low-dose vasopressors is harmful. Preventing postoperative hypotension is far more challenging, but one helpful approach is to delay restarting chronic antihypertensive medications until clearly necessary.

Blood pressure—specifically hypotension prevention—is a modifiable factor that may reduce cardiovascular complications. Pending the results of robust trials, reasonable efforts to avoid perioperative hypotension seem prudent.

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REFERENCES

1. Li G, Warner M, Lang BH, et al. Epidemiology of anesthesia-related mortality in the United States, 1999-2005. *Anesthesiology.* 2009;110:759–765.
2. Pearse RM, Moreno RP, Bauer P, et al. European Surgical Outcomes Study group for the Trials groups of the European Society of Intensive Care M, the European Society of A: mortality after surgery in Europe: a 7 day cohort study. *Lancet.* 2012;380:1059–1065.
3. Bartels K, Karhausen J, Clambey ET, et al. Perioperative organ injury. *Anesthesiology.* 2013;119:1474–1489.
4. The Vascular Events In Noncardiac Surgery Patients Cohort Evaluation (VISION) Study Investigators: association between postoperative troponin levels and 30-day mortality among patients undergoing noncardiac surgery. *JAMA.* 2012;307:2295–2304.
5. Vascular Events in Noncardiac Surgery Patients Cohort Evaluation Study Investigators: association between complications and death within 30 days after noncardiac surgery. *CMAJ.* 2019;191:E830–E837.
6. Devereaux PJ, Sessler DI. Cardiac complications in patients undergoing major noncardiac surgery. *N Engl J Med.* 2015;373:2258–2269.
7. Thygesen K, Alpert JS, Jaffe AS, et al. Fourth Universal Definition of Myocardial Infarction (2018). *J Am Coll Cardiol.* 2018;72:2231–2264. doi: 10.1016/j.jacc.2018.08.1038. Epub 2018 Aug 25.
8. The Vascular Events in Noncardiac Surgery Patients Cohort Evaluation (VISION) Study Investigators: association between complications and death within 30 days after noncardiac surgery. *Can Med Assoc J.* 2019;191:E830–E837.
9. Beattie WS, Wijeysundera DN, Chan MTV, et al. Anzca Clinical Trials Network for the ENIGMA-II Investigators: implication of major adverse postoperative events and myocardial injury on disability and survival: a planned subanalysis of the ENIGMA-II trial. *Anesth Analg.* 2018;127:1118–1126.
10. Eikelboom JW, Connolly SJ, et al. Rivaroxaban with or without aspirin in stable cardiovascular disease. *N Engl J Med.* 2017;377:1319–1330.
11. Devereaux PJ, Duceppe E, Guyatt G, et al. Dabigatran in patients with myocardial injury after non-cardiac surgery (MANAGE): an international, randomised, placebo-controlled trial. *Lancet.* 2018;391:2325–2334.
12. Writing Committee for the Vision Study Investigators, Devereaux PJ, Biccard BM, Sigamani A, et al. Association of postoperative high-sensitivity troponin levels with myocardial injury and 30-day mortality among patients undergoing noncardiac surgery. *JAMA.* 2017;317:1642–1651.
13. Duceppe E, Borges FK, Tiboni M, et al. Association between high-sensitivity troponin I and major cardiovascular events after non-cardiac surgery (abstrract). *J Am Coll Cardiol.* 2020;75.
14. Devereaux PJ, Yang H, Yusuf S, et al. Effects of extended-release metoprolol succinate in patients undergoing non-cardiac surgery (POISE trial): a randomised controlled trial. *Lancet.* 2008;371:1839–1847.
15. Myles PS, Leslie K, Chan MT, et al. Anzca Trials Group for the ENIGMA-II investigators: the safety of addition of nitrous oxide to general anaesthesia in at-risk patients having major non-cardiac surgery (ENIGMA-II): a randomised, single-blind trial. *Lancet.* 2014;384:1446–1454.
16. Devereaux PJ, Sessler DI, Leslie K, et al. Poise-2 Investigators: clonidine in patients undergoing noncardiac surgery. *N Engl J Med.* 2014;370:1504–1513.
17. Devereaux PJ, Mrkobrada M, Sessler DI, et al. Poise-2 Investigators: aspirin in patients undergoing noncardiac surgery. *N Engl J Med.* 2014;370:1494–1503.
18. Salmasi V, Maheshwari K, Yang D, et al. Relationship between intraoperative hypotension, defined by either reduction from baseline or absolute thresholds, and acute kidney and myocardial injury after noncardiac surgery: a retrospective cohort analysis. *Anesthesiology.* 2017;126:47–65.
19. Mascha EJ, Yang D, Weiss S, Sessler DI. Intraoperative mean arterial pressure variability and 30-day mortality in patients having noncardiac surgery. *Anesthesiology.* 2015;123:79–91.
20. Sessler DI, Meyhoff CS, Zimmerman NM, et al. Period-dependent associations between hypotension during and for four days after noncardiac surgery and a composite of myocardial infarction and death: a substudy of the POISE-2 trial. *Anesthesiology.* 2018;128:317–327.
21. Liem VGB, Hoeks SE, Mol K, et al. Postoperative hypotension after noncardiac surgery and the association with myocardial injury. *Anesthesiology.* 2020;133:510–522.
22. Roshanov PS, Rochwerg B, Patel A, et al. Withholding versus continuing angiotensin-converting enzyme inhibitors or angiotensin II receptor blockers before noncardiac surgery: an analysis of the vascular events in noncardiac surgery patients cohort evaluation prospective cohort. *Anesthesiology.* 2017;126:16–27.
23. Bijker JB, Gelb AW. Review article: The role of hypotension in perioperative stroke. *Can J Anaesth.* 2013;60:159–167.
24. Bijker JB, Persoon S, Peelen LM, et al. Intraoperative hypotension and perioperative ischemic stroke after general surgery: A nested case-control study. *Anesthesiology.* 2012;116:658–664.
25. Sun LY, Chung AM, Farkouh ME, et al. Defining an intraoperative hypotension threshold in association with stroke in cardiac surgery. *Anesthesiology.* 2018;129:440–447.
26. Hsieh JK, Dalton JE, Yang D, et al. The association between mild intraoperative hypotension and stroke in general surgery patients. *Anesth Analg.* 2016;123:933–939.
27. Turan A, Cohen B, Rivas E, et al. Association between postoperative haemoglobin and myocardial injury after noncardiac surgery: a retrospective cohort analysis. *Br J Anaesth.* 2021;126:94–101.
28. Turan A, Rivas E, Devereaux PJ, et al. Association between postoperative haemoglobin concentrations and composite of non-fatal myocardial infarction and all-cause mortality in non-cardiac surgical patients: post hoc analysis of the POISE-2 trial. *Br J Anaesth.* 2021;126:87–93.
29. Ruetzler K, Yilmaz HO, Turan A, et al. Intra-operative tachycardia is not associated with a composite of myocardial injury and mortality after noncardiac surgery: A retrospective cohort analysis. *Eur J Anaesthesiol.* 2019;36:105–113.
30. Sun Z, Sessler DI, Dalton JE, et al. Postoperative hypoxemia is common and persistent: a prospective blinded observational study. *Anesth Analg.* 2015;121:709–715.
31. Kheterpal S, Tremper KK, Heung M, et al. Development and validation of an acute kidney injury risk index for patients undergoing general surgery: results from a national data set. *Anesthesiology.* 2009;110:505–515.
32. Walsh M, Garg AX, Devereaux PJ, et al. The association between perioperative hemoglobin and acute kidney injury in patients having noncardiac surgery. *Anesth Analg.* 2013;117:924–931.
33. Whitlock EL, Braehler MR, Kaplan JA, et al. Derivation, validation, sustained performance, and clinical impact of an electronic medical record-based perioperative delirium risk stratification tool. *Anesth Analg.* 2020;131:1901–1910.
34. Walsh M, Devereaux PJ, Garg AX, et al. Relationship between intraoperative mean arterial pressure and clinical outcomes after noncardiac surgery: toward an empirical definition of hypotension. *Anesthesiology.* 2013;119:507–515.
35. Sun LY, Wijeysundera DN, Tait GA, et al. Association of intraoperative hypotension with acute kidney injury after elective noncardiac surgery. *Anesthesiology.* 2015;123:515–523.
36. O'Connor ME, Hewson RW, Kirwan CJ, et al. Acute kidney injury and mortality 1 year after major non-cardiac surgery. *Br J Surg.* 2017;104:868–876.
37. Turan A, Cohen B, Adegboye J, et al. Mild acute kidney injury after noncardiac surgery is associated with long-term renal dysfunction: a retrospective cohort study. *Anesthesiology.* 2020;132:1053–1061.
38. Hakim SM, Othman AI, Naoum DO. Early treatment with risperidone for subsyndromal delirium after on-pump cardiac surgery in the elderly: a randomized trial. *Anesthesiology.* 2012;116:987–997.
39. Maldonado JR, Wysong A, van der Starre PJ, et al. Dexmedetomidine and the reduction of postoperative delirium after cardiac surgery. *Psychosomatics.* 2009;50:206–217.
40. Royse CF, Saager L, Whitlock R, et al. Impact of methylprednisolone on postoperative quality of recovery and delirium in the Steroids in Cardiac Surgery Trial: a randomized, double-blind, placebo-controlled substudy. *Anesthesiology.* 2017;126:223–233.
41. Shehabi Y, Grant P, Wolfenden H, et al. Prevalence of delirium with dexmedetomidine compared with morphine based therapy after cardiac surgery: a randomized controlled trial (DEXmedetomidine COmpared to Morphine-DEXCOM Study). *Anesthesiology.* 2009;111:1075–1084.
42. Turan A, Duncan A, Leung S, et al. Dexmedetomidine for reduction of atrial fibrillation and delirium after cardiac surgery (DECADE): a randomised placebo-controlled trial. *Lancet.* 2020;396:177–185.
43. Gou RY, Hshieh TT, Marcantonio ER, et al. One-year medicare costs associated with delirium in older patients undergoing major elective surgery. *JAMA Surg.* 2021;156:430–442.
44. Hayhurst CJ, Pandharipande PP, Hughes CG. Intensive care unit delirium: a review of diagnosis, prevention, and treatment. *Anesthesiology.* 2016;125:1229–1241.
45. Daiello LA, Racine AM, Yun Gou R, et al. Postoperative delirium and postoperative cognitive dysfunction: overlap and divergence. *Anesthesiology.* 2019;131:477–491.
46. Pan H, Liu C, Ma X, et al. Perioperative dexmedetomidine reduces delirium in elderly patients after non-cardiac surgery: a systematic review and meta-analysis of randomized-controlled trials. *Can J Anaesth.* 2019;66:1489–1500.
47. Ono M, Arnaoutakis GJ, Fine DM, et al. Blood pressure excursions below the cerebral autoregulation threshold during cardiac surgery are associated with acute kidney injury. *Crit Care Med.* 2013;41:464–471.
48. Ono M, Brady K, Easley RB, et al. Duration and magnitude of blood pressure below cerebral autoregulation threshold during cardiopulmonary bypass is associated with major morbidity and operative mortality. *J Thorac Cardiovasc Surg.* 2014;147:483–489.
49. Feng X, Hu J, Hua F, et al. The correlation of intraoperative hypotension and postoperative cognitive impairment: a meta-analysis of randomized controlled trials. *BMC Anesthesiol.* 2020;20:193.
50. Maheshwari K, Ahuja S, Khanna AK, et al. Association between perioperative hypotension and delirium in postoperative critically ill patients: a retrospective cohort analysis. *Anesth Analg.* 2020;130:636–643.
51. Hori D, Brown C, Ono M, et al. Arterial pressure above the upper cerebral autoregulation limit during cardiopulmonary bypass is associated with postoperative delirium. *Br J Anaesth.* 2014;113:1009–1017.
52. Hirsch J, DePalma G, Tsai TT, et al. Impact of intraoperative hypotension and blood pressure fluctuations on early postoperative delirium after non-cardiac surgery. *Br J Anaesth.* 2015;115:418–426.
53. Wesselink EM, Kappen TH, van Klei WA, et al. Intraoperative hypotension and delirium after on-pump cardiac surgery. *Br J Anaesth.* 2015;115:427–433.
54. Langer T, Santini A, Zadek F, et al. Intraoperative hypotension is not associated with postoperative cognitive dysfunction in elderly patients undergoing general anesthesia for surgery: results of a randomized controlled pilot trial. *J Clin Anesth.* 2019;52:111–118.
55. Brown CH 4th, Neufeld KJ, Tian J, et al. Effect of targeting mean arterial pressure during cardiopulmonary bypass by monitoring cerebral autoregulation on postsurgical delirium among older patients: A nested randomized clinical trial. *JAMA Surg.* 2019;154:819–826.
56. Brown CH 4th, Probert J, Healy R, et al. Cognitive decline after delirium in patients undergoing cardiac surgery. *Anesthesiology.* 2018;129:406–416.
57. Mrkobrada M, Chan MTV, Cowan D, et al. Perioperative covert stroke in patients undergoing non-cardiac surgery (NeuroVISION): a prospective cohort study. *Lancet.* 2019; 394:1022–1029.
58. Sessler DI, Khan MZ, Maheshwari K, et al. Blood pressure management by anesthesia professionals: evaluating clinician skill from electronic medical records. *Anesth Analg.* 2021;132:946–956.
59. Maheshwari K, Turan A, Mao G, et al. The association of hypotension during non-cardiac surgery, before and after skin incision, with postoperative acute kidney injury: a retrospective cohort analysis. *Anaesthesia.* 2018;73:1223–1228.
60. Naylor AJ, Sessler DI, Maheshwari K, et al. Arterial catheters for early detection and treatment of hypotension during major noncardiac surgery: a randomized trial. *Anesth Analg.* 2020;131:1540–1550.
61. Maheshwari K, Khanna S, Bajracharya GR, et al. A randomized trial of continuous noninvasive blood pressure monitoring during noncardiac surgery. *Anesth Analg.* 2018;127:424–431.
62. Davies SJ, Vistisen ST, Jian Z, et al. Ability of an arterial waveform analysis-derived hypotension prediction index to predict future hypotensive events in surgical patients. *Anesth Analg.* 2020;130:352–329.
63. Wijnberge M, Geerts BF, Hol L, et al. Effect of a machine learning-derived early warning system for intraoperative hypotension vs standard care on depth and duration of intraoperative hypotension during elective noncardiac surgery: the HYPE randomized clinical trial. *JAMA.* 2020;323:1052–1060.
64. Maheshwari K, Shimada T, Yang D, et al. Hypotension prediction index for prevention of hypotension during moderate- to high-risk noncardiac surgery. *Anesthesiology.* 2020;133:1214–1222.

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Anesthesia Patient Safety Foundation Panel

Clinician Safety: To Care is Human

Saturday, October 9, 2021

1:15 pm–2:15 pm PDT

Moderator:
Matthew B. Weinger, MD, MS

Matthew B. Weinger, MD, MS

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65. Farag E, Makarova N, Argalious M, et al. Vasopressor infusion during prone spine surgery and acute renal injury: a retrospective cohort analysis. *Anesth Analg.* 2019;129:896–904.
66. Ducrocq N, Kimmoun A, Furmaniuk A, et al. Comparison of equipressor doses of norepinephrine, epinephrine, and phenylephrine on septic myocardial dysfunction. *Anesthesiology.* 2012;116:1083–1091.
67. Morelli A, Ertmer C, Rehberg S, et al. Phenylephrine versus norepinephrine for initial hemodynamic support of patients with septic shock: a randomized, controlled trial. *Crit Care.* 2008;12:R143.
68. Reinelt H, Radermacher P, Kiefer P, et al. Impact of exogenous beta-adrenergic receptor stimulation on hepatosplanchnic oxygen kinetics and metabolic activity in septic shock. *Crit Care Med.* 1999;27:325–331.
69. Dellinger RP, Levy MM, Carlet JM, et al. International Surviving Sepsis Campaign Guidelines C, American Association of Critical-Care N, American College of Chest P, American College of Emergency P, Canadian Critical Care S, European Society of Clinical M, Infectious D, European Society of Intensive Care M, European Respiratory S, International Sepsis F, Japanese Association for Acute M, Japanese Society of Intensive Care M, Society of Critical Care M, Society of Hospital M, Surgical Infection S, World Federation of Societies of I, Critical Care M: Surviving Sepsis Campaign: international guidelines for management of severe sepsis and septic shock: 2008. *Crit Care Med.* 2008;36:296–327.
70. Mets B: Should norepinephrine, rather than phenylephrine, be considered the primary vasopressor in anesthetic practice? *Anesth Analg.* 2016;122:1707–1714.
71. Owen VS, Rosgen BK, Cherak SJ, et al. Adverse events associated with administration of vasopressor medications through a peripheral intravenous catheter: a systematic review and meta-analysis. *Crit Care.* 2021;25:146.
72. Pancaro C, Shah N, Pasma W, et al. Risk of major complications after perioperative norepinephrine infusion through peripheral intravenous lines in a multicenter study. *Anesth Analg.* 2019;131:1060–1065.
73. Turan A, Chang C, Cohen B, et al. Incidence, severity, and detection of blood pressure perturbations after abdominal surgery: a prospective blinded observational study. *Anesthesiology.* 2019;130:550–559.
74. Futier E, Lefrant JY, Guinot PG, et al. Effect of individualized vs standard blood pressure management strategies on postoperative organ dysfunction among high-risk patients undergoing major surgery: a randomized clinical trial. *JAMA.* 2017;318:1346–1357.

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The APSF now offers you the opportunity to learn about anesthesia patient safety on the go with the Anesthesia Patient Safety Podcast. The weekly APSF podcast is intended for anyone with an interest in perioperative patient safety. Tune in to learn more about recent *APSF Newsletter* articles with exclusive contributions from the authors and episodes focused on answering questions from our readers related to patient safety concerns, medical devices, and technology. In addition, special shows that highlight important COVID-19 information on airway management, ventilators, personal protective equipment, drug information, and elective surgery recommendations are available. The mission of the APSF includes being a leading voice for anesthesia patient safety around the world. You can find additional information in the show notes that accompany each episode at APSF.org. If you have suggestions for future episodes, please email us at podcast@APSF.org. You can also find the Anesthesia Patient Safety Podcast on Apple Podcasts or Spotify or anywhere that you listen to podcasts. Visit us at APSF.org/podcast and at @APSForg on Twitter, Facebook, and Instagram.

Allison Bechtel, MD
APSF Podcast Director

Pulse Oximetry and Its Origin in Japan

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Pulse oximeters measure oxygenation, not respiration, but ordinary people and even some medical professionals tend to overlook this.[1] It is a percutaneous measurement subject to various factors, but is highly reliable when there is no body movement and in patients with a good pulse. In cases of extremely low measurements, sometimes it is better to believe the numbers than the patient's clinical presentation.[2] As has been seen in the COVID-19 pandemic, patients may present with silent hypoxia[3,4] without symptoms.[5] Takuo Aoyagi was concerned about the lack of understanding of pulse oximeter measurements, even before the devices became popular with the public. This concern guided his research on establishing a theory of pulse oximetry in his later years. While skin color may not be a problem in Japan where there is little diversity, it is possible that other such reports will come out from other areas of the world.[6]

PULSE OXIMETRY: TWO BEGINNINGS

The invention of pulse oximetry started in Japan and is now used in both medicine and by ordinary people around the world. Surprisingly enough, two patents were filed at almost the same time in 1974. Takuo Aoyagi, on behalf of Nihon Kohden (patent filed March 29, 1974), and Akio Yamanishi, on behalf of Minolta (patent filed April 24, 1974), came upon this idea independently of one another.[7,8] Aoyagi's device, which came first, used a dye densitometer on the earlobe to measure cardiac output. He came upon his idea during an experiment to eliminate superimposed pulsation noise. His light source was an incandescent light bulb and his point of measurement was the earlobe, both of which made it difficult to develop a practical device and the project ended. Chances are that it was not pursued because the invention was a side product and did not align with the company's main project.

Aoyagi reported on his invention to his supervisor, and it just happened that a physician the supervisor was visiting heard about it, and work on a prototype was started. They were less interested in the significance of oxygen saturation and were mainly looking at new methods of measurement. Aoyagi reported that once the paper was published, there was no more mention of turning it into a clinical device. However, Aoyagi continued his research into establishing a theory of measurement through the years, and after a break of about 10 years, Nihon Kohden renewed its development. They allowed Takuo Aoyagi to pursue his research until the end and he fulfilled their expectations. Takuo Aoyagi presented his invention, the

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Announcing the 2022 Co-Sponsored APSF-FAER Mentored Research Training Grant

The Anesthesia Patient Safety Foundation (APSF) and Foundation for Anesthesia Education and Research (FAER), related organizations of the American Society of Anesthesiologists (ASA), have renewed their three-year agreement to offer the co-sponsored APSF-FAER Mentored Research Training Grant (APSF-FAER MRTG). The fourth APSF-FAER MRTG will be awarded as part of FAER's Spring 2022 Grant Cycle (more details below).

The APSF-FAER MRTG provides $300,000 over a two-year period to fund patient safety research directly related to the perioperative care of patients, as well as chronic pain and critical care medicine. Patient safety is defined as the avoidance, prevention, and improvement of adverse outcomes or injuries stemming from health care processes. In this co-sponsored grant's first three years, the APSF and FAER awarded $900,000 to the following researchers:

Alexander Arriaga, MD, MPH, ScD,
2019 APSF-FAER MRTG Recipient

Brigham and Women's Hospital (Boston, MA)

Increasing the Frequency of Debriefing After Perioperative Crises: Altering Trajectories that Impact Provider Burnout and Wellness

Timothy Gaulton, MD, MSc,
2020 APSF-FAER MRTG Recipient

University of Pennsylvania (Philadelphia, PA)

Mapping the Epidemiology of Perioperative Driving Safety and Behavior

Jonathan M. Tan, MD, MPH, MBI, CMQ
2021 APSF- FAER MRTG Recipient

Children's Hospital Los Angeles (Los Angeles, CA)

The Impact of Air Pollution and Neighborhood-Level Risk Factors on Pediatric Perioperative Respiratory Adverse Events

Those interested in applying for the 2022 APSF-FAER MRTG will need to submit a Letter of Intent (LOI) prior to submitting a full application. The submission window for LOIs for this grant will be open from December 1, 2021, through January 1, 2022. Information on the APSF-FAER MRTG can be found on FAER's website at FAER.org/APSF.

ABOUT THE FAER

For 35 years, FAER has been dedicated to developing the next generation of physician-scientists in anesthesiology. Charitable contributions and support to FAER help fuel the future of anesthesiology through scientific discovery. Funding priorities include: Research, Education, and Training. FAER has awarded over $49 million in research grants and programs since 1986. To learn more about FAER, visit our website at FAER.org. To donate to FAER, visit FAER.org/donate.

ABOUT THE APSF

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

The Anesthesia Patient Safety Foundation (APSF) is a related organization of the American Society of Anesthesiologists. APSF provides support for research and education in perioperative patient safety. Its past initiatives have resulted in significant contributions to the field of anesthesia patient safety. APSF has distributed over $13.5 million in funding for anesthesia patient safety research projects over its 30+ year history. For more information on APSF or to donate, please visit www.apsf.org.

Pulse Oximetry: A Long Road to Its Significance

From "Pulse Oximetry," Preceding Page

pulse oximeter, to Japanese anesthesiologists first in 1989 at The Japan Society for Clinical Anesthesia Academic Meeting in Tokyo, Japan. However, it wasn't until 2002, when the Japanese Society of Anesthesiologists gave Aoyagi an award for his contribution to society, that his name and Nihon Kohden's pulse oximeter became familiar to anesthesiologists in Japan.[9,10]

On another front, Akio Yamanishi's group was taking advantage of the new LED technology to develop fingertip plethysmography, and the development of a pulse oximeter was one of their primary projects. They succeeded in developing the world's first fingertip pulse oximeter. Ikuto Yoshiya (anesthesia professor at Osaka University at the time) and Yasuhiro Shimada (assistant professor at the same university) were involved, but their contributions were limited to improving precision through analysis.[11] Minolta started selling their device (OXIMET 1471) through Mochida Pharmaceuticals in June 1977, but rather than using LED as a light source, they used a combination of tungsten and fiberoptic cable, so although the device was usable, it was difficult to operate. It is possible that the red spectrum in LEDs at the time was not sufficient.

CLINICAL SIGNIFICANCE UNRECOGNIZED IN JAPAN

The OXIMET 1471 pulse oximeter that went on the market in 1977 seems to have been reviewed by several university academic anesthesiologists in Japan.[12] However, while the device was judged to be useful as a research measurement device, it did not take off as a clinical one. Only 200 devices in total were sold. Kunio Suwa (associate professor of Anesthesiology at Tokyo University) tried it out in 1992 on his own volition,[11-13] but unfortunately even then, as now, bureaucracy existed in Japan's medical device industry, slowing the development of innovations.

The first scientific meeting on pulse oximetry took place in Chartridge, outside London, in 1985, and the first international neonatal and pediatric meeting on pulse oximetry in Japan was held in Hakone, outside Tokyo, in 1987 (Figure 1).

RESEARCH MEASUREMENT DEVICES AND CLINICAL MONITORING DEVICES

Oxygenation values arbitrarily showed up from around 90% to 120% soon after attaching a probe to the patients finger in the early version of Minolta's OXIMET-1471.[12,13] The device had a calibration knob that adjusted digital

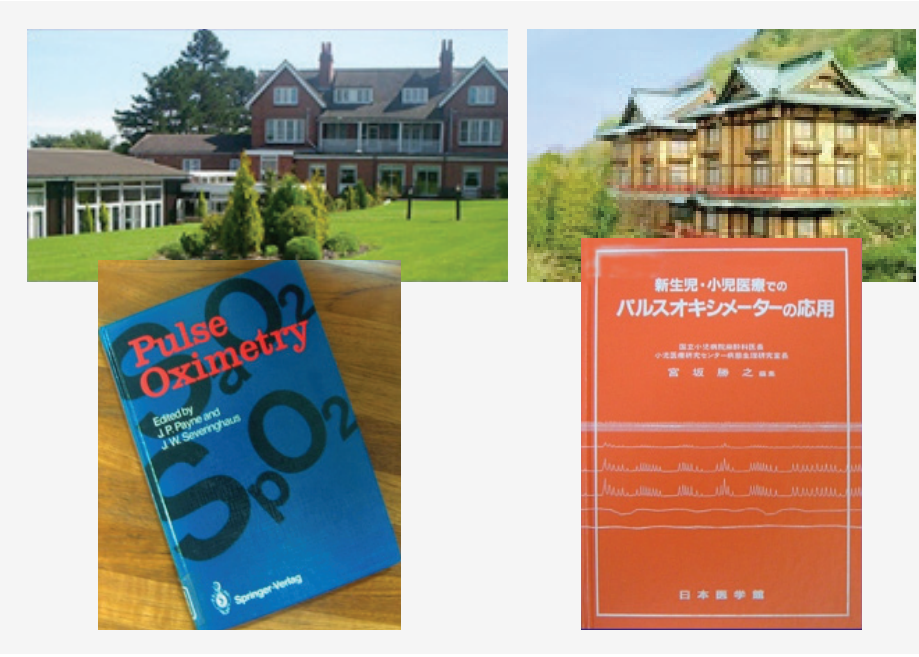

Figure 1: Top left: International conference at Chartridge Seminar House held May 1985 at a suburb of London with 50 participants—Definition of SpO_2, discussion of how to think about oxygen saturation. Bottom left: Published proceedings of the Chartridge Conference. Top right: May 1987, Hakone Fujiya Hotel in Kanagawa Prefecture—International conference on neonates and pediatric patients with about 20 participants—From $TcPO_2$ to SpO_2. Bottom right: Published proceedings of the Hakone Conference on Neonatal and Pediatric Applications.

Figure 2: Dr. Aoyagi showing his work on motion artifact to Dr. Byron Aoki, from the University of Hawaii (at the author's office when he was the head of the ICU at the National Center for Child Health and Development in Tokyo in 2002).

number values making it possible to make appropriate adjustments at the bedside. You could set blood gas values to match the patient's oxygenation at the start of measurement, so it would display correct values thereafter. The developers would say that if the display shows 100%, then you can believe that it really is 100%. The display also showed very specific values to one decimal point at each heartbeat (say 95.6%). In actual use, however, after calibration of the device to the patient's blood gas levels, it was not unusual to see numbers from 100% or much more, baffling clinicians. Still, with further improvement, it was a device that had great possibilities as a monitor.

FROM ANESTHESIA TO CRITICAL CARE IN JAPAN:

The Japanese Society of Anesthesiologists created their first safety guidelines (Monitoring Guidelines for Anesthesia Safety) and recommended use of pulse oximeters during anesthesia. This was seven years after ASA

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Pulse Oximetry and Its Inherent Limitations

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released their first Monitoring Guidelines for Anesthesia in 1986 in the US.[14] Half of the physicians who engaged in anesthesia did not have access to even one pulse oximeter in their institutions. Domestic competition was practically non-existent. Interest in pulse oximeters grew rapidly in the field of anesthesia, but when their use expanded from during anesthesia when patients didn't move to the recovery room, ICU and general wards, a big problem arose in how to deal with false alarms from body movement. When venous waves are superimposed on pulse waves, the convenient assumption of pulse oximeters that all pulsation is arterial pulsation no longer holds. In efforts to decrease false alarms, many strategies were tried such as temporarily freezing alarm information, prolonging the moving average time of the data, and extraction of the arterial waveform during synchronization with electrocardiograms, but none of these served as a fundamental solution (Figure 2).

EMERGENCE OF A SOLUTION TO FALSE ALARMS DUE TO MOTION

Yasuyuki Suzuki and I were studying the reliability of and problem of false alarms in respiratory monitors in pediatric ICUs at the National Children's Hospital in Tokyo and respiratory therapy in home care pediatric patients.[15] We had also introduced a project called the "Sound of Silence" to address the problem of alarm fatigue in pediatric anesthesia and pediatric ICUs such that all alarms were silenced within 3 times of beeping. Thus, we were able to obtain many hours of raw data and video recordings from pulse oximeters and patients. It was not a comparative study and it was not published, but this data on Japanese patients in pediatric ICUs helped strengthen strategies to deal with body movement, and thus low perfusion in adults.[16,17]

PULSE OXIMETRY: PROBLEMS WITH MULTI-WAVELENGTHS AND PRECISION

The theory of multi-wavelengths (5 wavelengths) was proposed in 2008[18] and was established by Aoyagi in 2015, but no product had been made, due to prolonged verification activities. In 2020, the topic of the clinical significance of measurement differences due to racial differences (skin color)[6] came up, but there was little basis for discussion because there was no theory and no way to compare numbers using a standardized calibration. However, we cannot neglect differences in skin color, race, adults, infants, body shape, and place of measurement of the device. It is impossible to standardize calibration using actual measurements on human beings who can't be standardized (no more than calibration can be standardized), between manufacturers and devices, different probes, etc. The road laid down for us by Aoyagi is of great importance to break the deadlock of the acceptance of differences of 1–2% especially in the low SpO_2 range and to establish a fundamental theory of pulse oximetry.

Figure 3: 2015 Tokyo IAMPOV Symposium (Last day, Auditorium at St. Luke's International University)—An international symposium on patient monitoring devices and technology related to circulation, oxygenation, and respiration. Left side in red circle: Takuo Aoyagi. Central area, front row from left to right: P. Bickler (UCSF), S. Weininger (FDA), S. Barker (Masimo) K. Miyasaka (St. Luke's), P. Kyriacou (U. London), B. Kopotic (Edwards), K. Shelley (Yale).

RESEARCH ON MULTI-WAVELENGTHS

An *in vitro* calibration method[19] for ISO was never established, but this was the same as saying the theory had not been established. The most recent ISO standard ended up mandating empirical calibration using blood sampling in healthy adults who are exposed to a non-physiological level of hypoxia. Thus, the accuracy of currently available pulse oximeters ignores such factors as race, age (adult or child), or individual devices. Hironami Kubota questions whether regular household devices really need to go through such a complicated calibration process. It is a very complicated issue.

Takuo Aoyagi started working on a complete theory and after verification with experiments with multi-wavelength simulation models that took into account light scattering and pulsation, and also the effect of surrounding tissue, he presented his work at the Innovations and Applications of Monitoring Perfusion, Oxygenation and Ventilation (IAMPOV) meeting in 2015 in Tokyo, Japan (Figure 3).[20] The main reason for his studies using multi-wavelengths was to improve precision. But since he wasn't looking at such factors as abnormal hemoglobin, it is possible his research was not considered important enough to result in product development.

THE SPREAD OF PULSE OXIMETERS IN SOCIETY AND THE ISSUES INVOLVED

Aoyagi feared that without a theory, the pulse oximeter number displayed might take on a life of its own, especially with its widespread use. Under the shadow of the great usefulness of the device for COVID-19, it is a concern that pulse oximeters are being used not just for operating room patients, but everyone and without a proper understanding of what the number means. Pulse oximeters cause little harm as electronic devices, but if the numbers are misinterpreted, critical harm can result. The current regulatory system to protect users from suffering this kind of harm is inadequate.

See "Pulse Oximetry," Next Page

Clinicians Should Educate the General Population on How to Interpret the Pulse Oximetry Number

From "Pulse Oximetry," Preceding Page

Clinicians should help inform people of possible dangers from these devices and educate them on how to interpret the number displayed. In the current state of affairs, where the appropriate use of pulse oximeters is not guaranteed, people won't even be able to tell if a device is poorly made as long as the number looks right. Even if there was a dangerous condition, no one would notice a problem as long as the number is within the "normal" range.

While it is necessary to educate users about correctly understanding the number, the regulations demanding proper education of the general public in Japan are vague. The manuals included in the devices say "seek a doctor's opinion if there is a problem," but this warning is of no use to the lay public because there is no way for them to know if there is a problem or not. Thus, the user is left believing in the device without adequate understanding, and no one including the company or government has responsibility for misuse of the device.

While the authorities in charge may be interested in the safety of electronic products, they may not be as interested in how the numbers displayed are interpreted or in the safety of the medical device. There are very few cases where clinicians are involved in product inspection. Our mission is to educate the public whenever we have a chance and provide them with the knowledge they need to evaluate products where medical quality and non-medical quality products are combined.

CONCLUSION

The lives of so many people have been saved and many more will be saved in the future, due to Takuo Aoyagi's invention.

Takuo Aoyagi presented his principle of pulse oximeters for the first time in 1974. The session was chaired by Tatsuo Togawa (professor of medical engineering at the Tokyo Medical and Dental University), a prominent scientist in the field. Togawa stated in 2011 that pulse oximeters have developed much more than could be imagined even then from Aoyagi's presentation.[21] The possibilities for pulse oximetry using multi-wavelengths are many, including the establishment of a standard method of calibration, improvement in the precision of measurements during low perfusion or body movement, and by including the measurement of other substances or metabolic situations. It may even be possible for it to act like pulse spectrophotometry, by expanding measurements beyond oxygenation such as blood sugar levels, which are now measured invasively.[22] This may not be as easy as it sounds to a clinician, but placing our hopes with the scientists following Takuo Aoyagi, I would like to express my gratitude for the great contributions made by him in this field.

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REFERENCES

1. Fu ES, Downs JB, Schweiger JW, et al. Supplemental oxygen impairs detection of hypoventilation by pulse oximetry. *Chest*. 2004; 126:1552-8.
2. Death of a male patient under observation at home. Local governor apologized. (In Japanese). https://www3.nhk.or.jp/news/html/20210109/k10012805851000.html. Accessed on Jan 9, 2021.
3. Wilkerson RG, Adler JD, Shah NG, et al. Silent hypoxia: a harbinger of clinical deterioration in patients with COVID-19. *Am J Emerg Med*. 2020;38:2243.e5–2243.e6.
4. Jouffroy R, Jost D, Prunet B: Prehospital pulse oximetry: a red flag for early detection of silent hypoxemia in COVID-19 patients. *Crit Care*. 2020;24:313. doi: 10.1186/s13054-020-03036-9.
5. Miyasaka K: Possibility of silent hypoxia without dyspnea: Use of pulse oximeters. *Yomiuri Newspaper*. May 21, 2020 (In Japanese)
6. Sjoding MW, Dickson RP, Iwashyna TJ, et al. Racial bias in pulse oximetry measurement. *N Engl J Med*. 2020; 383:2477–2478.
7. Aoyagi T, Kishi M, Yamaguchi K, et al. Improving ear oximeters. *JSMBE*. 1974;13:90–91 (In Japanese).
8. Miyasaka K. Anesthesiology and dawn of the pulse oximeter. *Masui*. 2018;67:S245–251 (In Japanese).
9. Severinghaus JW, Honda Y. History of blood gas analysis. VII. Pulse oximetry. *J Clin Monit*. 1987;135–138
10. Severinghaus JW: Takuo Aoyagi. Discovery of pulse oximetry. *Anesth Analg*. 2007; 105(6 Suppl):S1-4
11. Yoshiya I, Shimada Y, Tanaka K, et al. New noninvasive oxygen saturation measurement (OXIMET): Its measurement principle and performance. *ICU and CCU*. 1978;2:455–460 (In Japanese).
12. Suzukawa M, Fujisawa M, Matsushita F, et al. Our experience with a fingertip wave type oximeter. *Masui*. 1978; 27:600–606 (In Japanese).
13. Suwa K (ed). Pulse Oximeters. Igakutosho Shuppan, Tokyo 1992 (In Japanese).
14. Japanese Society of Anesthesiologists English Website, Standards & Guidelines, https://anesth.or.jp/users/english/news/detail/605bee53-44c0-4042-9fb0-113b9dcdd4c6#login-form-top. Accessed July 10, 2021.
15. Miyasaka K, Kondo Y, Suzuki Y, et al. Toward better home respiratory monitoring: a comparison of impedance and inductance pneumography. *Acta Paediatr Jpn*. 1994; 36:307–310.
16. Miyasaka KW, Suzuki Y, Miyasaka K. Unexpectedly severe hypoxia during sprint swimming. *Anesth*. 2002;16:90–91.
17. Barker SJ. "Motion-resistant" pulse oximetry: a comparison of new and old models. *Anesth Analg*. 2002;95:967–972.
18. Aoyagi T, Fuse M, Kobayashi N, et al: Multiwavelength pulse oximetry: theory for the Future. *Anesth Analg*. 2008;105:S53–S58.
19. International Standard. ISO 80601-2-61:2017. Medical electrical equipment—Part 2–61: particular requirements for basic safety and essential performance of pulse oximeter equipment. 2017.
20. Aoyagi T, Fuse M, Ueda Y, et al. Improving precision of pulse oximetry. The 4th International Symposium on Innovations and Applications of Monitoring Perfusion, Oxygenation and Ventilation (IAMPOV) 2015, Tokyo. https://iampov.org/2015-symposium/
21. Togawa T. Father of the pulse oximeter. *JSMBE*. 2011;49:310–312 (In Japanese).
22. Aoyagi T, Miyasaka K. The theory and applications of pulse spectrophotometry. *Anesth Analg*. 2002;94:S93–S95.

A 20/20 View of Ophthalmic Anesthesia: A Reflective Lens Aimed to Envision the Future

by Andres Macias, MD, FASA, and Fred E. Shapiro, DO, FASA

PAST AND PRESENT

Ophthalmic anesthesia dates to 1884 when ophthalmologist Karl Koller[1] first introduced the use of cocaine as a local anesthetic for ophthalmic surgery. The retrobulbar blockade was first described by Herman Knapp in 1884, and later Atkinson in 1936[2] described a retrobulbar technique that was adopted very quickly; however, due to a high incidence of complications the technique was abandoned over time.[3] Currently, at Massachusetts Eye and Ear Infirmary (MEEI), Boston, MA, we provide anesthesia services under local, regional, and general anesthesia for more than 16,000 ophthalmic procedures a year in both adult and pediatric patients.

SAFE OPHTHALMIC ANESTHESIA

The basic tenets for safe anesthesia care during elective eye procedures are to facilitate maximal pain relief, ease in the surgical procedure, quick recovery, and minimal risks associated with surgery and anesthesia.[4,5] Over the past 30 years, advancement of surgical techniques has allowed for short, effective, and safe patient care.

Most of the current ophthalmic procedures can be performed in ambulatory surgery centers (ASCs) and in the office-based surgical setting. A key component to this success is through selection of the appropriate patient, procedure, and location, all determined by clinical criteria and equipment demand. At MEEI, we provide clinical care at our main hospital campus, where we have both inpatient and outpatient services, and at our free-standing ASC. This arrangement allows flexibility when scheduling cases in order to improve efficiency at both locations.

PHARMACOLOGY

Over the years, our practice has evolved to meet the demand for faster, safer, and more efficient anesthesia. Essential to these goals has been the use of short- and long-acting local anesthetics. The goal of sedation is to decrease anxiety, while maximizing safety. Combined with the use of regional anesthesia, several choices of sedation and analgesic combination medications have been introduced to the practice within the last 25 years, such as remifentanil, dexmetomidine, and midazolam (see Table 1). These short-duration sedatives can be administered immediately before the regional block to reduce or eliminate the pain of needle insertion and injection of the local anesthetic.[5] Prolonged sedation is used with caution in select patients, and is generally preferably avoided, as an awake patient is needed for surgery. Some practices use small doses of propofol until the patient loses consciousness while the block is performed.

We always provide supplemental oxygen if performing an eye block and during the surgical intervention. At MEEI, we use a nasal canula at flows not higher than 5 l/min or a face tent. The face tent sits at the level of the patient's chin. It provides oxygenation while preventing the drapes from sitting on the patient's lower face (helping with the feeling of claustrophobia in some cases). An important observation is there is a small risk of CO_2 accumulation under the drapes. For short procedures the risk is minimal; however, for procedures longer than an hour, we recommend using CO_2 suctioning.

For eye blocks, we usually use a combination of lidocaine, bupivacaine, and the hyaluronidase enzyme. The combination of lidocaine 1.5% and bupivacaine 0.375% provides a block with rapid onset (between 5–10 minutes) and a duration of about 2 hours, which is enough for most procedures. Lidocaine should not be used in concentrations higher than 2% due to the risk of myositis if injected by error into one of the extraocular muscles. Duration and onset may be related to the volume injected although this is controversial. The enzyme hyaluronidase as an ancillary agent is usually used with local anesthetics.[5] Concentrations between 1 and 7.5 units/mL are most commonly used, but concentrations as low as 0.75 units/mL may be effective.[6] The addition of hyaluronidase is used to increase tissue permeability of the local anesthetic, promote dispersion of the local anesthetic, reduce the increase in orbital pressure associated with the injected volume, enhance the quality of the block, and reduce the risk of injury to the extraocular muscles if local anesthetic is injected in them.[5]

Table 1: Potential Medications* Used for Sedation During Ophthalmic Procedures

Medication	Dose range	Considerations
Midazolam	1–2 mg	Avoid or decrease dose in patients >70 years old due to concern of losing patient feedback during regional block. Consider modifying using low doses in patients with chronic kidney disease.
Remifentanil	25–50 mcg	May produce complete apnea in combination with other sedatives. Airway rescue equipment and ASA standard monitoring must be always available.
Dexmetomidine	8–20 mcg	May increase PACU time in patients presenting for cataract surgery, but not for other surgeries such as vitrectomy.

*Fentanyl and Propofol have also been used during these procedures.

PATIENTS

Proper communication with the patient, surgeon, and anesthesia professionals is essential. Patients should be advised and comprehend that they must lie flat (or semi-flat due to comorbidities), remain motionless, cooperate by providing clear communication, and express any concerns regarding claustrophobia or panic attacks, as needed. A focused medical history, including use of any anticoagulant or antithrombotic therapies, previous eye operations, and overall suitability for same-day surgery is also required. The physical exam should focus on airway assessment, detection of relevant abnormalities, including any conditions that may impede the ability to lie supine comfortably (e.g., back deformities or pain, severe congestive heart failure, chronic obstructive pulmonary disease, or claustrophobia). These are more relevant when topical or regional anesthesia is planned in association with sedation.

CONTROVERSIES:

NPO

Although controversial, we still recommend that our patients follow standard ASA fasting (NPO) guidelines to reduce risk of aspiration should there be a need to convert to general anesthesia.

See "Ophthlamic Anesthesia," Next Page

Anticoagulation May Be Continued for Elective Eye Procedures

From "Ophthlamic Anesthesia," Preceding Page

Table 2: Anesthesia Considerations for Common Eye Procedures for Claustrophobic and/or Uncooperative Patients

PATHOLOGY/LOCATION	PATIENT	TYPE OF ANESTHESIA	TYPE OF ANALGESIA
CATARACT/ANTERIOR CHAMBER	Severe Claustrophobia Unable to Cooperate	General Anesthesia or Regional	Topical Regional with Akinesia (Surgeon-dependent)
	Cooperative	Monitored Anesthesia Care (MAC)	
GLAUCOMA SURGERY	Severe Claustrophobia Unable to Cooperate	General Anesthesia or Regional	Topical Regional Oral and Systemic
	Cooperative	Monitored Anesthesia Care (MAC)	
	Severe Claustrophobia	General Anesthesia	Regional
POSTERIOR CHAMBER/ RETINA	Unable to Cooperate Complex Pathology	(Avoid Nitrous Oxide if gas injection in the eye)	Oral and Systemic
	Cooperative Simple Pathology	Monitored Anesthesia Care (MAC)	

Anticoagulation:

We recommend that patients with a high risk of clotting and embolic complications (due to cardiac or vascular pathologies) continue therapeutic doses of aspirin or warfarin throughout the perioperative period. Recent publications have shown no higher incidence of sight-threatening bleeding complications after regional anesthesia in patients taking aspirin, warfarin, or clopidogrel before cataract surgery, compared with patients not taking these drugs.[7] Similarly, recent literature has been published regarding concerns of increased bleeding risk in patients taking newer oral anticoagulants, such as apixaban, rivaroxaban, and dabigatran. At MEEI in Boston, our recent retrospective study on the continuation of these medications also did not result in a higher incidence of bleeding complications in patients presenting for elective eye surgery and receiving regional anesthesia as the primary technique.[8]

Gas injection:

Gas injection is mainly used during retina surgery. If general anesthesia is provided, patients should not receive nitrous oxide when gas is going to be injected in the eye (e.g., SF^6 or C^3F^8), or when gas was previously administered to create a "bubble" to internally tamponade the detached retina, unless an ophthalmologist has documented that the bubble has been completely absorbed. Although SF^6 is usually completely absorbed by 10 days, and C^3F^8 by six weeks, there are case reports of blindness due to use of nitrous oxide after 25 days for SF^6 and after 41 days for C^3F^8.[9] Patients who have received one of these gases must be identified. At MEEI, we place a wrist band that includes the name of the gas injected as well as the date

See "Ophthalmic Anesthesia," Next Page

Table 3: Eye Procedure Complications and Management Strategies[9]

Complication	Manifestation	Treatment
Retrobulbar hemorrhage (compartment syndrome)	Tense orbit with significant resistance to retropulsion, no ocular motility, decrease in visual acuity, bulbar chemosis, and complete ptosis.[10-12]	Lateral canthotomy, Inferior cantholysis, Inferolateral anterior orbitotomy
Eye perforation/ penetration	Hypotonic eye, loss of vision on postoperative evaluation, evidence of retinal detachment and/ or laceration on exam[13]	Consult with a retina specialist, vitrectomy most likely needed
Intra-arterial injection of local anesthetic	Brainstem anesthesia (Symptomatology can differ between each case of brainstem anesthesia and it can include different combinations of confusion, unconsciousness, irregular breathing, apnea, numb throat, dysphagia, hypotension, hypertension, bradycardia, tachycardia, cardiovascular instability, convulsions, shivering, dysarthria, and hemi-, para-, or quadriplegia). Symptoms appear 2–10 minutes after injection[14]	May require cardiopulmonary resuscitation, intubation, and vasopressor support. Recovery with appropriate support may take 10 to 60 minutes
Intrathecal injection of local anesthetic	Brainstem anesthesia[14]	May require cardiopulmonary resuscitation, intubation, and vasopressor support
Allergic reaction to local anesthetic	Very uncommon but possible. Clinical symptoms of anaphylaxis	Follow anaphylaxis resuscitation
Allergic reaction to hyaluronidase	Immediate reactions may present with periorbital edema and chemosis developing within a few minutes of administering the anesthetic mixture with the enzyme. Delayed reaction may mimic periorbital inflammation (up to 36 hours after block with the enzyme)[15]	Surgical treatment may be needed due to the increased IOP. Systemic steroids may be needed
Venous air embolism	Hemodynamic instability, pulseless electrical activity (PEA), arrest[16]	Hemodynamic support, follow PEA algorithm
Intramuscular injection	Diplopia due to myositis. Most commonly due to inferior rectus injection[17]	Avoid lidocaine in concentrations higher than 2%. May need surgical or mechanical correction
Oculocardiac reflex	Severe bradycardia with asystole in some cases. May last less than 30 seconds	Stop stimulation, may need atropine in rare occasions
Gas injection	Potential increase in intraocular pressure due to gas expansion in the eye	Avoid nitrous oxide and identify patients who are receiving or have received intraocular injection of gas

Ophthalmic Anesthesia, Cont'd

From "Ophthalmic Anesthesia," Preceding Page

and time in order to alert any providers in case of a potential emergency.

PROCEDURES

The most common procedures performed at our ASC are cataract, glaucoma, retina, oculoplastics, and strabismus surgeries. At our main campus, we include eye trauma, pediatric exams under anesthesia, transplant of limbal cells, gene therapy injections in the eye, and complex corneal transplants. For the most common ophthalmic surgical procedures, at our institution the anesthesia professional performs extraconal blocks. Other blocks such as intraconal blocks, topical, Sub-Tenon's (episcleral), and intracameral injections of preservative-free local anesthetic are performed by the surgeon.[18] Anesthesia considerations for those patients with claustrophobia or who are uncooperative are depicted in Table 2.

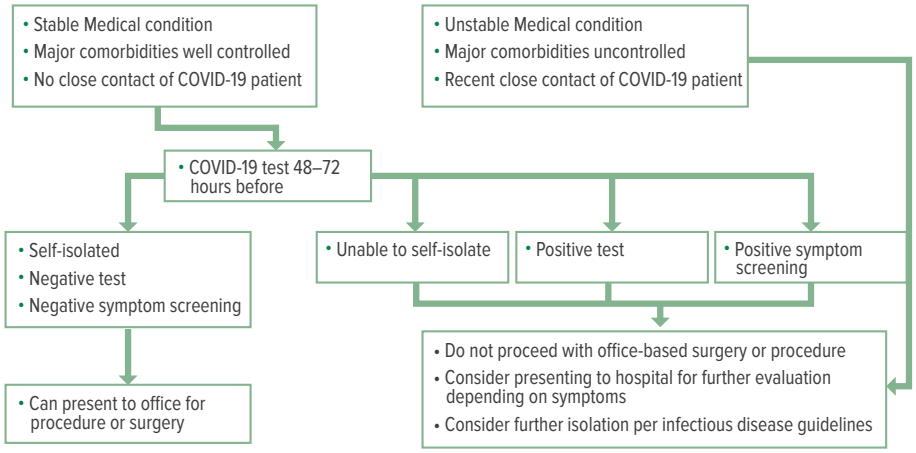
General anesthesia is more commonly provided to patients with history of claustrophobia, patients unable to lie flat for the duration of the surgery, pediatric patients, and patients presenting for complex interventions that may take more than two hours.

TRAINING

Cataract surgery is one of the most common outpatient surgeries performed in ASCs, and the risk of complications related to eye blocks as well as a wrong-side surgery is always present. Although uncommon in the hands of well-trained skilled anesthesia professionals, these complications can carry devastating effects in the life of any patient. Therefore, we suggest that proper training in anesthesia for ophthalmic surgery is essential and should be included in all residency programs.

Regional anesthesia techniques for the eye are safe when performed by experienced providers or under the supervision of someone properly trained. Presently, there is a lack of training in anesthesia residency and regional anesthesia fellowships programs with regards to ophthalmic procedural regional anesthesia techniques. At MEEI, we have instituted a regional anesthesia rotation for residents and regional anesthesia fellows. The regional anesthesia fellows spend two weeks learning how to perform eye blocks. At the same time, they learn how to handle our high patient workflow while maintaining safety and efficiency. Anesthesia professionals should be very well versed in both the anesthetic performance and patient management for eye surgeries.

Figure 1: COVID-19 Testing and Screening Algorithm



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COMPLICATIONS

As with any other intervention, complications can occur when performing eye blocks. Table 3 depicts eye procedure complications and the associated treatment strategies.

SPECIAL CONSIDERATIONS DURING COVID-19 PANDEMIC

The COVID-19 pandemic has affected the way we provide anesthesia to our ophthalmic population like other specialties. In our institution, PCR testing is mandatory for any patient requiring general anesthesia, and it is optional for any patient going under sedation as there is a potential need for mask ventilation (an aerosol-generating procedure [AGP]) if oversedation takes place. It is crucial to ensure that patients undergoing office procedures have stable medical conditions, are not experiencing any symptoms of COVID-19, have not had close contact with a confirmed COVID-19 patient (i.e., less than 6 feet distance with at least 15 minutes of exposure), and present with a negative COVID-19 test within 72 hours of the procedure.[19] In Figure 1, Young et al. suggest a testing and screening algorithm for the office-based setting.

RECOMMENDATIONS IN THE COVID-19 ERA

Another challenge involves deciding the amount of PPE to be used, considering that the number of COVID-19 cases is constantly in flux with some areas experiencing more cases than others. There are two algorithms to address areas of low prevalence and high prevalence of COVID-19 cases (less than and greater than 4 cases per 100,000 population, respectively) (see Figure 2).

There must be a conversation between the surgeon and anesthesia professional, when conversion from a monitored anesthesia care case to a general anesthetic is required and COVID-19 testing is limited or unavailable. We recommend rescheduling the case and ordering a COVID-19 PCR test within 72 hours of the surgical date, for any elective cases that require transition from sedation to general anesthesia.[20] There are occasional circumstances, when a patient may become agitated or develop a panic attack during surgery and conversion from sedation to general anesthesia is necessary, and full PPE is required.[19] As noted, these events are very rare in our practice.

The COVID-19 pandemic has changed many aspects of our lives, including many changes to our medical practices aimed to reduce or minimize the risk of community and hospital transmission of the SARS-CoV-2 virus. Part of identifying this risk is recognizing which procedures produce aerosolized particles and which, as seen by the algorithms below, result in modifications in PPE usage for the procedure being performed.

Several studies have examined if ophthalmological procedures in fact result in the aerosolization of particles. A study of 30 phacoemulsification studies detected no intraoperative aerosolization in any of the cases regardless of technique.[20] Noureddin et al. used a sophisticated aerosol monitor to detect aerosolization in phacoemulsification cataract surgeries in porcine subjects. They also concluded that it was not an aerosol-generating medical procedure.[21]

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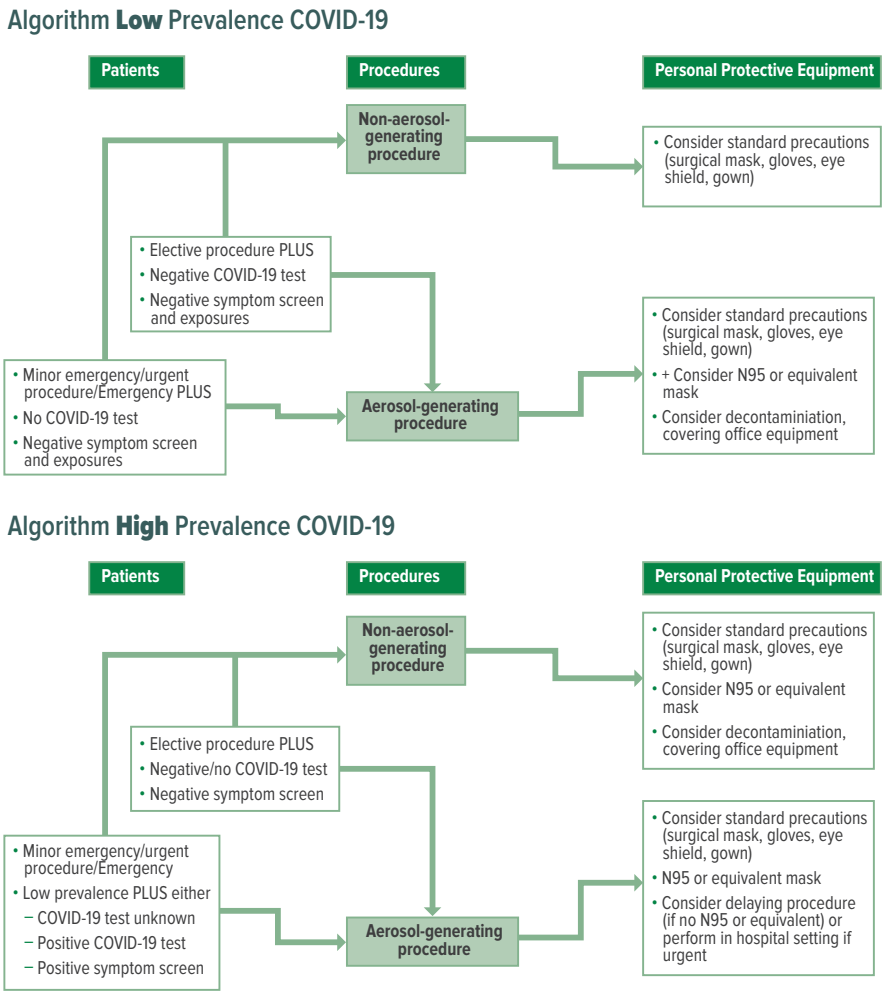
Ophthalmic Anesthesia During COVID-19 Pandemic

From "Ophthalmic Anesthesia," Preceding Page

Figure 2: COVID-19 Personal Protective Equipment (PPE) Algorithms for Low Versus High Prevalence COVID-19 Areas



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Results of these studies indicate that ophthalmologists may safely perform these surgeries by adhering to traditional droplet precautions during the COVID-19 pandemic.

In consideration of this data regarding these nonaerosol producing procedures, the algorithms will have to be adjusted accordingly, and the type of anesthesia will also need to be reconsidered. Although a procedure such as phacoemulsification may not generate aerosol particles, endotracheal intubation for general anesthesia can result in potential aerosolization. Until the Centers for Disease Control (CDC) updates their policies with new recommendations, the current algorithms should be maintained.

We are now learning that acute infection with COVID-19 is not the end of the road. Patient selection criteria must now include determination of COVID status, vaccination status, and prior infection with long-standing comorbidities. The well recognized COVID-19 "long-hauler" status can include lingering fatigue, dizziness, shortness of breath, chest pain, muscle and/or joint pain, loss of smell or taste, depression or anxiety, memory or concentration problems, blood clots and vessel problems, and even sustained organ damage to the heart, lungs, or brain.[22]

OUR FUTURE VISION

As new techniques continue to evolve, we recognize that the trend of performing elective ophthalmic procedures in the ambulatory setting will continue to grow. Commensurate with this, we appreciate a continued increase in an elderly and sicker patient population that will require elective eye interventions. For example, we recently encountered patients presenting to the OR with left ventricular assist devices (LVAD) for elective eye surgery. In order to continue to maintain a safe and appropriate environment, we recommend developing ongoing policies that support appropriate patient, procedure, and location selection. In the past five years, there have been reports claiming that complications related to eye blocks have occurred due to the use of incorrect techniques or settings. Therefore, we strongly believe that it is prudent to implement a formal educational program that includes clinical and technical skills, interpersonal and interprofessional communication, practice management, policies, simulation training, standards, guidelines, and regulations. At the MEEI, we have been successful in implementing this educational curriculum and created the official *MEEI Manual* for ophthalmic procedures to accompany the curriculum as a "pocket" resource. To share our program globally, along with the MEEI Manual release in 2022, we envision the availability of both live and virtual MEEI/HMS Continuing Medical Education (CME) opportunities.

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REFERENCES

1. Altman AJ, Albert DM, Fournier GA. Cocaine's use in ophthalmology:our 100-year heritage. *Surv Ophthalmol.* 1985;29:300-306. doi: 10.1016/0039-6257(85)90154-7.
2. Polania Gutierrez JJ, Riveros Perez E. Retrobulbar block. [Updated 2021 Apr 7]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021. Accessed July 7 2021. Available at: https://www.ncbi.nlm.nih.gov/books/NBK557448/
3. Davis DB, Mandel MR. Posterior peribulbar anesthesia: an alternative to retrobulbar anesthesia. *J Cataract Refract Surg.* 1986;12:182–184.
4. Macias, AA, Bayes J, McGoldrick, KE. Anesthesia for elective eye surgery. UpToDate. 2021. Accessed June 25 2021. Available at: https://www.uptodate.com/contents/anesthesia-for-elective-eye-surgery?search=elective%20eye%20surgery&source=search_result&selectedTitle=1~150&usage_type=default&display_rank=1.
5. Rüschen H, Aravinth K, Bunce C, Bokre D. Use of hyaluronidase as an adjunct to local anaesthetic eye blocks to reduce intraoperative pain in adults. *Cochrane Database Syst Rev.* 2018; 3:CD010368.

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Iron Deficiency Anemia During and After Pregnancy: How Can We Make a Difference?

by Jack M. Peace, MD, and Jennifer M. Banayan, MD

INTRODUCTION

Anemia is a frequently encountered condition on the labor floor. Coupled with the potential for massive blood loss in the peripartum period, management of maternal anemia is critical to keeping mothers and their babies safe. Antepartum anemia has been associated with adverse maternal and neonatal outcomes, including preterm labor, miscarriage, growth restriction, cesarean delivery, and intrauterine infection.[1,2] Postpartum anemia has been associated with depression, fatigue, and impaired cognition.[3]

Iron deficiency is the most common cause of anemia in the peripartum period. Iron replacement therapies have been extensively studied and have been regularly shown to improve hematologic indices,[4] but to date, no studies have demonstrated consistent improvement in maternal or neonatal clinical outcomes. This requires us to ask the question: how can we make a meaningful difference in the treatment and management of maternal anemia so as to improve clinical outcomes? How can we as anesthesia professionals partner with our obstetric colleagues to decrease the impact of anemia on childbirth? Here, we highlight our current understanding of maternal anemia, its treatment, management strategies, and future areas for research.

LEVERAGING THE PERIOPERATIVE HOME

Anesthesia professionals are well-equipped to prepare patients for elective, high-blood-loss surgery, and society-level guidelines establish recommendations for the treatment of anemia across the perioperative spectrum.[5] Yet, few of these recommendations make specific reference to the pregnant population. Antepartum consultation with an anesthesia professional is often performed for hematologic conditions, such as thrombocytopenia or heritable coagulopathies, but rarely for anemia. By the time an anemic parturient reaches the care of an anesthesia professional, the window for treatment has often closed. Forging partnerships between obstetricians, hematologists, and anesthesia professionals could help address the timely diagnosis and management of maternal IDA.

SCOPE OF THE PROBLEM

Anemia is one of the most common medical conditions in pregnancy, affecting nearly one in three pregnant women globally.[6] The incidence and degree of iron deficiency anemia (IDA) vary significantly across the course of pregnancy and by population, reflecting the complex interplay of preexisting nutritional deficiencies and iron homeostasis during pregnancy. For example, in low and middle-income countries, IDA may affect up to half of pregnancies, regardless of gestational age.[7,8] Even in the developed world, significant racial disparities exist: in one study, African American women had more than three times the rate of IDA as non-Hispanic white women.[9] The connection between IDA and poor pregnancy outcomes is not hard to imagine: increases in hemorrhagic shock, cardiovascular failure, peripartum transfusion, and higher rates of infection all accompany maternal anemia.[10-12] Additionally, emerging research is beginning to show that peripartum IDA affects not only the mother, but the fetus as well. A large, recent cohort study of over half a million children demonstrated an association between maternal anemia and neurodevelopmental disorders.[13] These findings demonstrate the importance of managing this common condition.

TREATMENT OF IRON DEFICIENCY ANEMIA

The mainstay of IDA treatment in pregnancy is oral iron supplementation. Oral iron supplements are inexpensive, readily available, have simple storage requirements, and have an established safety record. However, oral iron supplementation is often limited by gastrointestinal side effects, such as nausea, dyspepsia, or constipation, which may occur in more than half of patients.[14] Studies that have focused on improvements in maternal hematologic parameters (e.g., hemoglobin, ferritin) have found modest improvements in these values with oral iron supplementation.[4] However, studies have failed to demonstrate consistent improvement in other maternal or fetal outcomes, such as decreased transfusion requirements, improved recovery, or higher birthweight.

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Ophthalmic Anesthesia, Cont'd

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6. DeBroff BM, Hamilton RC, Loken RG, et al. Retrobulbar anesthesia with 7.5 vs. 0.75 IU/mL of hyaluronidase. *Can J Ophthalmol.* 1995;30:262.
7. Benzimra JD, Johnston RL, Jaycock P, et al. The Cataract National Dataset electronic multicentre audit of 55,567 operations: antiplatelet and anticoagulant medications. *Eye*. (Lond). 2009;23:10–16.
8. Macias A, et al. Evaluating the outcomes and safety of peribulbar anesthesia for patients taking direct oral anticoagulants. *EC Ophthalmology* 10.2 (2019):120–124.
9. Seaberg RR, Freeman WR, Goldbaum MH, Manecke GR Jr. Permanent postoperative vision loss associated with expansion of intraocular gas in the presence of a nitrous oxide-containing anesthetic. *Anesthesiology.* 2002;97:1309–1310.
10. Macias AA, Bayes J, McGoldrick KE. Anesthesia for elective eye surgery. UpToDate. 2020 Mar. Accessed July 8, 2021. Available at: https://www.uptodate.com/contents/anesthesia-for-elective-eye-surgery#H115132139.
11. Huebert I, Heinicke N, Kook D, et al. Dual platelet inhibition in cases of severe retrobulbar hemorrhage following retrobulbar and peribulbar anesthesia. *J Cataract Refract Surg*. 2015;41:2092–2101.
12. Takaschima A, Marchioro P, Sakae TM, et al. Risk of hemorrhage during needle-based ophthalmic regional anesthesia in patients taking antithrombotics: a systematic review. *PLoS One.* 2016;11:e0147227.
13. Edge R, Navon S. Scleral perforation during retrobulbar and peribulbar anesthesia: risk factors and outcome in 50,000 consecutive injections. *J Cataract Refract Surg.* 1999; 25:1237–1244.
14. Kostadinov I, Hostnik A, Cvenkel B, Potočnik I. Brainstem anaesthesia after retrobulbar block. *Open Med.* 2019;14:287–291.
15. Rajalakshmi AR, Kumar MA. Hyaluronidase hypersensitivity: A rare complication of peribulbar block. *Indian J Ophthalmol*. 2016;64:160–162.
16. Moon YE. Venous air embolism during vitrectomy: rare but potentially fatal complication. *Korean J Anesthesiol*. 2014;67:297–298.
17. Hussain N, McCartney CJL, Neal JM, Chippor J, Banfield L, Abdallah FW. Local anaesthetic-induced myotoxicity in regional anaesthesia: a systematic review and empirical analysis. *Br J Anaesth.* 2018;121:822–841.
18. Macias AA, Bayes J, McGoldrick KE. Anesthesia for elective eye surgery. https://www.uptodate.com/contents/anesthesia-for-elective-eye-surgery?search=elective%20catararact%20surgery&source=search_result&selectedTitle=2~150&usage_type=default&display_rank=2. Accessed September 1, 2021.
19. Young S, Osman BM, Urman RD, Shapiro FE. Patients, procedures, and PPE: safe office-based anesthesia recommendations in the COVID-19 era. *Best Prac Research Clin Anaesthesiol*. 2020 Nov. https://doi.org/10.1016/j.bpa.2020.11.006
20. Wong JKW, Kwok JSWJ, Chan JCH, et al. Aerosolization and fluid spillage during phacoemulsification in human subjects. *Clin Ophthalmol.* 2021;15:307–313.
21. Noureddin GS, Iovieno A, Eslami M, et al. Quantification of aerosol generation during cataract surgery. *J Cataract Refract Surg*. 2020 Nov 30. doi: 10.1097/j.jcrs.0000000000000530. Epub ahead of print.
22. COVID-19 (coronavirus): Long-term effects. Mayo Clinic. Mayo Foundation for Medical Education and Research (MFMER). 2021. Accessed July 6 2021. Available at: https://www.mayoclinic.org/diseases-conditions/coronavirus/in-depth/coronavirus-long-term-effects/art-20490351.

Peripartum Iron Deficiency Anemia is a Common and Significant Problem

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The reasons for this may be severalfold. Diagnosis of iron-deficiency anemia may be delayed in pregnancy: an initial complete blood count (CBC) at a first trimester visit showing anemia may not be followed up with until iron studies can be performed at a subsequent visit, which may be a month or two later. Earlier intervention has clinical plausibility to have a greater impact on maternal and fetal outcomes. Also, studies in this area have generally been smaller, and have lacked consistent methodology.[15] Additional large-scale studies with consistent treatment protocols may help establish a clinical benefit for early treatment of maternal iron deficiency.

SAFETY OF INTRAVENOUS IRON

Intravenous iron has emerged as an alternative therapy for women with IDA who are intolerant of oral supplementation, have an insufficient response, require rapid correction of deficiency, or who have malabsorptive disorders. With the advent of newer, lower molecular weight iron dextran and non-dextran iron formulations, concerns about anaphylaxis with older parenteral iron formulations have given way to an established safety record in pregnancy.[15] Adverse reactions occur less frequently than with oral iron supplementation, and tend to be minor (e.g., skin staining, transient bronchospasm).[16] However, because these are parenteral formulations, they require at least one clinic visit, and are substantially more expensive than oral supplementation. Additionally, no guidelines exist about whether fetal heart rate monitoring should occur during infusion of these compounds, and few studies that study these medications in women comment on fetal heart rate monitoring.[17] A single case study describes severe fetal bradycardia during infusion of an intravenous iron product (ferric derisomaltose), necessitating emergent cesarean delivery.[18] Though a number of studies have established the safety of these compounds, more work needs to be done to establish protocols to ensure maternal and fetal safety during their administration.

OUR ROLE

Reflex iron testing, developed in the preanesthesia clinic[19] could be used by obstetricians to help diagnose and treat IDA earlier in pregnancy. Obstetricians could refer patients who require IV iron to perioperative anemia clinics, where monitoring and clinical infrastructure currently exist. Promising reductions in perioperative transfusions have been seen with ultra-short-term treatment of anemic cardiac surgery patients.[20] Adapting these treatments to pregnant women may help limit the peripartum consequences of anemia. Several institutions have begun treating women in perioperative iron clinics, which presents additional opportunities for clinical research to evaluate the efficacy of this mode of care.

Treatment of prenatal anemia doesn't always succeed, and hemorrhage can occur unexpectedly in the peripartum setting, even in patients without pre-existing anemia. This requires anesthesia professionals and obstetricians to make collaborative decisions on when it is appropriate to transfuse a peripartum patient. In large studies of nonobstetrical patients, there were no benefits (and an increase in harms) associated with a liberal transfusion strategy.[21] Similar findings have been observed in peripartum patients.[22] This has led both the American Society of Anesthesiologists and the American Association of Blood Banks to issue recommendations in favor of conservative blood transfusion strategies (i.e., transfusion threshold Hb < 7 vs. <10).[23,24] However, there are limits to threshold-based approaches to transfusion. Postpartum hemorrhage often occurs quickly, and requires an anesthesia professional to weigh the benefits of transfusion (i.e., improved tissue perfusion) against the potential risks (e.g., infection, TACO, TRALI). Other perioperative strategies, like the use of blood salvage[25] and antifibrinolytic therapy,[26] have the potential to decrease the rate of peripartum transfusion even further.

Combining these strategies into comprehensive patient blood management programs can help institutions protocolize the treatment of anemia early in pregnancy that may reduce the number of unnecessary blood transfusions. One such program included clinical pathways for diagnosis, educational materials, laboratory protocols, and standardized iron prescriptions (Figure 1).[27] After implementation, the rate of ferritin testing increased tenfold, and the number of transfusions fell by 50%. Similar programs have demonstrated a decrease in rates of anemia at admission and a reduction in the rate of transfusion.[28,29] These and other such programs may finally help providers realize the potential of antenatal iron deficiency treatment to improve maternal and fetal outcomes.

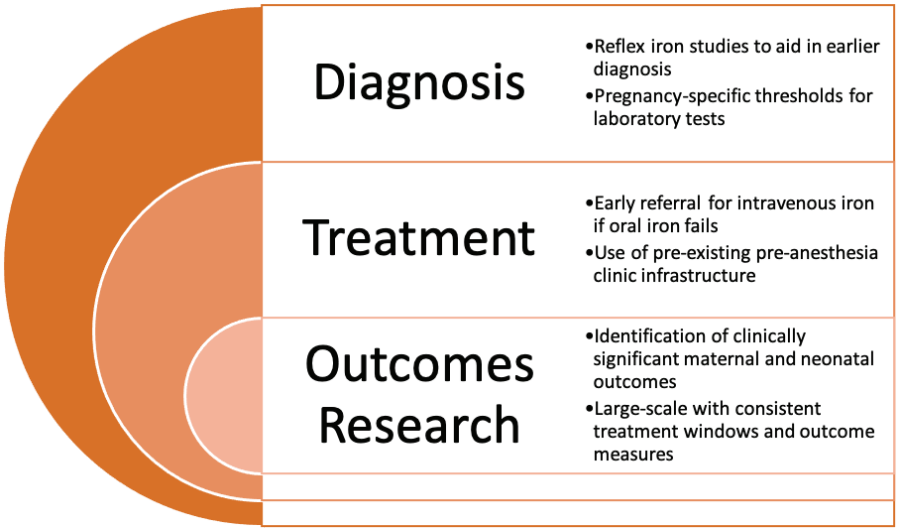

Figure 1: Opportunities for improvement in the diagnosis, treatment, and study of maternal iron deficiency anemia.

POSTPARTUM ANEMIA

Though relatively poorly studied, postpartum anemia is linked to a number of adverse maternal outcomes including fatigue, depression, and impaired cognition. It should come as no surprise that antenatal anemia and postpartum hemorrhage are significant predictors of postpartum anemia.[30] And unlike antepartum IDA, postpartum IDA often occurs suddenly, with a significant loss of iron stores at or around delivery. Treatment of postpartum IDA with oral iron is subject to the same compliance and tolerance issues of antepartum therapy. Because of this, intravenous iron therapy is emerging as a first-line therapy to rapidly restore iron lost at delivery, and has already been shown to elicit a faster and more significant rise in hemoglobin when compared with oral iron therapy.[3]

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Peripartum Iron Deficiency Anemia Remains a Common Problem

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Administration of intravenous iron may help avoid some of the morbidity associated with blood transfusion, given evidence that some portion of postpartum transfusions of packed red blood cells may be inappropriate.[31,32] Namely, a recent non-inferiority trial of over 500 women with non-symptomatic postpartum anemia were randomized to RBC transfusion or non-intervention.[22] This study suggested only slightly lower fatigue scores in transfused women. In the future, direct comparison of transfusion and intravenous iron treatment may help determine optimal treatment of women with postpartum IDA while minimizing unnecessary blood transfusions.

CONCLUSION

Peripartum IDA remains a common and significant problem, linked to a variety of detrimental clinical outcomes for women and their babies. Yet, iron supplementation has not been consistently shown to ameliorate those outcomes. Opportunities for collaboration between anesthesia professionals, obstetricians, and hematologists are many, and leveraging the tools of the perioperative home may provide avenues for improving maternal and fetal clinical outcomes. In the meantime, awareness of the safety issues surrounding the consequences and treatment of peripartum IDA is paramount for anesthesia professionals responsible for the care of these patients.

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Jack Peace, MD, has no conflicts of interest. Jennifer Banayan, MD, serves as editor of the APSF Newsletter.

REFERENCES

1. Prefumo F, Fichera A, Fratelli N, Sartori E. Fetal anemia: diagnosis and management. *Best Pract Res Clin Obstet Gynaecol.* 2019;58:2–14.
2. Butwick AJ, McDonnell N. Antepartum and postpartum anemia: a narrative review. *Int J Obstet Anesth*. 2021:102985.
3. Sultan P, Bampoe S, Shah R, et al. Oral vs intravenous iron therapy for postpartum anemia: a systematic review and meta-analysis. *Am J Obstet Gynecol.* 2019;221:19-29.e13.
4. Abraha I, Bonacini MI, Montedori A, et al. Oral iron-based interventions for prevention of critical outcomes in pregnancy and postnatal care: an overview and update of systematic reviews. *J Evid Based Med*. 2019;12:155–166.
5. Warner MA, Shore-Lesserson L, Shander A, et al. Perioperative anemia: prevention, diagnosis, and management throughout the spectrum of perioperative care. *Anesth Analg*. 2020;130:1364–1380.
6. Stevens GA, Finucane MM, De-Regil LM, et al. Global, regional, and national trends in haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non-pregnant women for 1995-2011: a systematic analysis of population-representative data. *Lancet Glob Health*. 2013;1:e16-25.
7. Black RE, Victora CG, Walker SP, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet.* 2013;382:427–451.
8. McLean E, Cogswell M, Egli I, et al. Worldwide prevalence of anaemia, WHO Vitamin and Mineral Nutrition Information System, 1993-2005. *Public Health Nutr.* 2009;12:444–454.
9. Mohamed MA, Ahmad T, Macri C, Aly H. Racial disparities in maternal hemoglobin concentrations and pregnancy outcomes. *J Perinat Med*. 2012;40:141–149.
10. Milman N. Anemia—still a major health problem in many parts of the world! *Ann Hematol.* 2011;90:369–377.
11. VanderMeulen H, Strauss R, Lin Y, et al. The contribution of iron deficiency to the risk of peripartum transfusion: a retrospective case control study. *BMC Pregnancy Childbirth*. 2020;20:196.
12. Drukker L, Hants Y, Farkash R, et al. Iron deficiency anemia at admission for labor and delivery is associated with an increased risk for cesarean section and adverse maternal and neonatal outcomes. *Transfusion.* 2015;55:2799–2806.
13. Wiegersma AM, Dalman C, Lee BK, et al. Association of prenatal maternal anemia with neurodevelopmental disorders. *JAMA Psychiatry.* 2019;76:1294–1304.
14. Cancelo-Hidalgo MJ, Castelo-Branco C, Palacios S, et al. Tolerability of different oral iron supplements: a systematic review. *Curr Med Res Opin*. 2013;29:291–303.
15. Qassim A, Grivell RM, Henry A, et al. Intravenous or oral iron for treating iron deficiency anaemia during pregnancy: systematic review and meta-analysis. *Med J Aust.* 2019.
16. Govindappagari S, Burwick RM. Treatment of iron deficiency anemia in pregnancy with intravenous versus oral iron: systematic review and meta-analysis. *Am J Perinatol.* 2019;36:366–376.
17. Jose A, Mahey R, Sharma JB, et al. Comparison of ferric Carboxymaltose and iron sucrose complex for treatment of iron deficiency anemia in pregnancy-randomised controlled trial. *BMC Pregnancy Childbirth.* 2019;19:54.
18. Woodward T, Kay T, Rucklidge M. Fetal bradycardia following maternal administration of low-molecular-weight intravenous iron. *Int J Obstet Anesth.* 2015;24:196–197.
19. Okocha O, Dand H, Avram MJ, Sweitzer B. An effective and efficient testing protocol for diagnosing iron-deficiency anemia preoperatively. *Anesthesiology.* 2020;133:109–118.
20. Spahn DR, Schoenrath F, Spahn GH, et al. Effect of ultra-short-term treatment of patients with iron deficiency or anaemia undergoing cardiac surgery: a prospective randomised trial. *Lancet.* 2019;393:2201–2212.
21. Carson JL, Stanworth SJ, Roubinian N, et al. Transfusion thresholds and other strategies for guiding allogeneic red blood cell transfusion. *Cochrane Database Syst Rev.* 2016;10:Cd002042.
22. Prick BW, Jansen AJ, Steegers EA, et al. Transfusion policy after severe postpartum haemorrhage: a randomised non-inferiority trial. *BJOG.* 2014;121:1005–1014.
23. Management ASoATFoPB. Practice guidelines for perioperative blood management: an updated report by the American Society of Anesthesiologists Task Force on Perioperative Blood Management. *Anesthesiology.* 2015;122:241–275.
24. Carson JL, Guyatt G, Heddle NM, et al. Clinical practice guidelines from the AABB: red blood cell transfusion thresholds and storage. *JAMA.* 2016;316:2025–2035.
25. Goucher H, Wong CA, Patel SK, Toledo P. Cell salvage in obstetrics. *Anesth Analg.* 2015;121:465–468.
26. O'Brien KL, Shainker SA, Lockhart EL. Transfusion management of obstetric hemorrhage. *Transfus Med Rev.* 2018;32:249–255.
27. Abdulrehman J, Lausman A, Tang GH, et al. Development and implementation of a quality improvement toolkit, iron deficiency in pregnancy with maternal iron optimization (IRON MOM): a before-and-after study. *PLoS Med*. 2019;16:e1002867.
28. Flores CJ, Yong A, Knights E, et al. Maternity iron, anaemia and blood management in South Australia: a practice-based evidence for clinical practice improvement. *Vox Sang*. 2020;115:735–744.
29. Guinn NR, Cooter ML, Maisonave Y, et al. How do I develop a process to effectively treat parturients with iron deficiency anemia? *Transfusion.* 2020;60:2476–2481.
30. Butwick AJ, Walsh EM, Kuzniewicz M, et al. Patterns and predictors of severe postpartum anemia after Cesarean section. *Transfusion.* 2017;57:36–44.
31. Butwick AJ, Aleshi P, Fontaine M, et al. Retrospective analysis of transfusion outcomes in pregnant patients at a tertiary obstetric center. *Int J Obstet Anesth.* 2009;18:302–308.
32. Parker J, Thompson J, Stanworth S. A retrospective one-year single-centre survey of obstetric red cell transfusions. *Int J Obstet Anesth.* 2009;18:309–313.

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RAPID Response
to questions from readers

Air Entrainment by Extension Connectors to Central Venous Catheter

by Michael T. Kuntz, MD, and Alfonso Casta, MD

INTRODUCTION

Central venous access is often necessary during cardiac anesthesia to administer intravenous fluids and inotropic agents during resuscitation. We identified an instance in which the connection between a central venous catheter and an intravenous line extension failed to seal, resulting in air entrainment with slow aspiration. The problem resolved with selection of an alternative extension. Identification of this problem can avoid potential patient harm.

CASE

A 7-month-old male infant, 6.31 kg, was taken to the operating room for biventricular conversion for complex congenital heart disease including pulmonary atresia, intact ventricular septum, and atrial septal defect. After induction of general anesthesia, a single lumen central venous catheter was placed in the left internal jugular vein (3 Fr. x 8 cm, Cook Medical, Ref C-PUM-301J). A Baxter catheter extension (Ref. 2N1194, Figure 1) was first attached to the catheter. After slow aspiration through this extension, air was seen entraining into the aspirate at the catheter-extension connection site. Air entrainment persisted after verifying the luer locking connection was secure, and that the aspiration syringe was well seated. This extension piece was removed and a Smith Medical three-way stopcock/extension (Ref. MX43660, Figure 2) was placed. Air was once again noted to entrain during aspiration. Finally, a different Baxter catheter extension (Ref. 2N2238, Figure 3) was connected to the central venous catheter. Aspiration through this extension did not demonstrate air entrainment, indicating that a secure connection was possible.

DISCUSSION

Air entrainment during catheter aspiration may indicate an inadequate seal between the catheter and extension. This could result in air entrainment into infusing fluid, or conversely, leakage of infusing medications and incomplete delivery to the patient. Both of these circumstances pose risk for patient harm. The potential for air to enter the venous system through central venous catheters has been well documented.[1-3] This may result in both cardiovascular and neurologic complications. In the most extreme cases, central venous catheter related air embolism has resulted in death.[4] Timely identification of a poor seal and selection of an alternative extension is essential to avoiding adverse events. Interestingly, this problem has not been noted on all occasions when using the 3 Fr. x 8 cm catheter in question. This inconsistency highlights the importance of checking the connection with aspiration of blood prior to administration of medications via the catheter.

Since all of the connectors used were standard Luer connectors, we do not know if the individual components involved had a manufacturing variance, or if an insecure connection is more likely when interconnecting devices from different manufacturers. Nevertheless, as a result of this experience, providers in our department were instructed to avoid using the extensions shown in figures 1 and 2 when using the 3 Fr. x 8 cm catheter, and instead use the extension in figure 3. In addition, we advised that aspiration of blood to confirm adequacy of seal between catheter and extension tubing be regularly performed. The extensions in figures 1 and 2 are still routinely used to connect to arterial line catheters without evidence of leaks despite the much higher pressure in the lumen suggesting that the standard Luer connector can function well on these devices.

Aspirating central venous catheters after placement may help detect poor seal between the catheter and extension tubing. Anesthesia professionals and other health care providers should be aware of the potential for a poor connection, which should prompt the selection of an alternative extension that does not entrain air.

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The authors have no conflicts of interest.

REFERENCES

1. Khaliq MF, Shoaib M, Tariq SM, Khan MT. Cerebral air embolism from a central venous catheter: a timely reminder of the importance of rapid diagnosis. *BMJ Case Rep.* 2018 Aug 16;2018:bcr2018225120. doi: 10.1136/bcr-2018-225120.
2. Muth CM, Shank ES. Gas embolism. *N Engl J Med.* 2000;342:476–482.
3. Opeskin K, Burke MP, Lynch M. Cerebral and spinal gas embolism. *J Clin Neurosci.* 1998;5:469–471.
4. Pinho J, Amorim JM, Araújo J, et al. Cerebral gas embolism associated with central venous catheter: systematic review. *J Neurol Sci.* 2016;362:160–164.

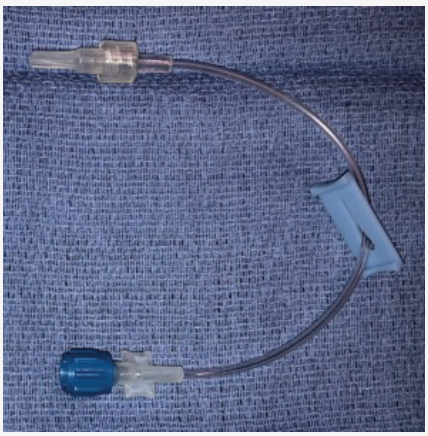

Figure 1: Baxter catheter extension (Ref. 2N1194), which resulted in air entrainment.

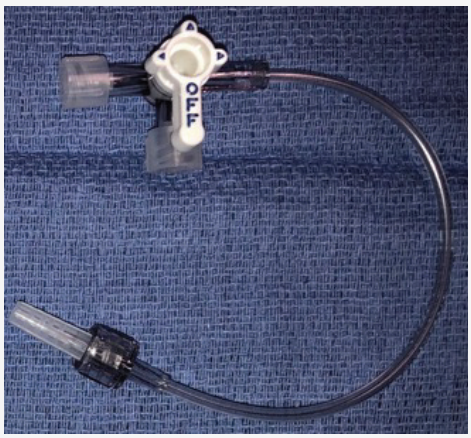

Figure 2: Smith Medical three-way stopcock/extension (Ref. MX43660), which resulted in air entrainment.

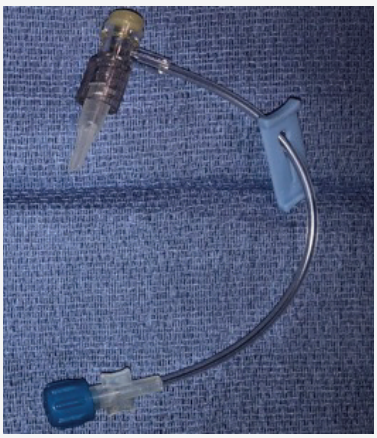

Figure 3: Baxter catheter extension (Ref. 2N2238), which resulted in no air entrainment

RAPID Response
to questions from readers

The "Luer" of a Simple Device

by Jeffrey M. Feldman, MD, MSE

Luer connectors are ubiquitous in patient care and generally serve the purpose for which they were designed—to allow caregivers to quickly make a leak-free connection and maintain a continuous lumen. The success of this basic design is evidenced by the multitude of different devices that use this same basic connection and continue to be used daily.[1] We have known for many years however, that this simple connector can lead to patient injury due to leaks or disconnections and when devices intended for different purposes are inadvertently interconnected, e.g., connecting a vascular infusion to an epidural catheter.[2] New designs for preventing misconnections have been available for more than a decade. As a formal response: ISO 80369 is a seven-part standard that "provides the methodology to assess non-interconnectable characteristics of small-bore connectors based on their inherent design and dimensions in order to reduce the risk of misconnections between medical devices or between accessories for different applications."[3] Despite efforts to implement the ISO 80369 standards to prevent misconnections, widespread adoption has yet to be realized.[4,5] Part 7 of the standard pertains to connectors for intravascular or hypodermic applications and adopts the current luer fitting for those connections The new standard does not alter the basic design of using a tapered fitting to create a leak-free connection so strategies for making a secure connection are germane to all of the new connectors.

In this issue of the newsletter, Michael Kuntz, MD, and Alfonso Casta, MD, from Boston Children's Hospital report an experience where presumably compatible luer connectors allowed air to be entrained into the vascular tubing when a syringe was used to aspirate and check the connection. After trying different tubing sets to make the connection, all fitted with a "standard" Luer connection, they identified a combination that eliminated the air entrainment. This report raises questions about the consistency of manufacturing these connectors and the potential for misfit despite adherence to the basic standard. Whether their experience is due to variations in manufacturing the actual device, a weakness in the standard, or extreme conditions of negative pressure outside of the specification for testing for air leaks, it is impossible to know for certain. It is interesting to note that the two connectors that were associated with air entrainment were "fixed-skirt" luer connectors whereas the tight connection was obtained with a "swivel-skirt." More on the details of these two types of luer-lock connectors is in the article by Bruce Hansel, PhD. Fixed-skirt connectors have the potential to engage and cause a twisting force (torque) on the tubing attached to each component, whereas swivel-skirt connectors can be engaged without exerting torque on the connection.

The original standard for the Luer connection, ISO-594, consists of two parts, Part One: General Requirements and Part Two: Lock Fittings. The general requirements describe the tolerances for all of the dimensions of the basic Luer fitting along with procedures for gauging (sizing) the components, and testing for leak of air and fluids, separation force, and stress cracking.[6,7] Manufacturers have their components tested to ensure that they comply with the standards' requirements so that interconnection between all devices adherent to the standard is possible. The new standard for intravascular connectors, ISO 80369-7, essentially follows the original standard with some new limitations on the material properties and more stringent requirements for the precision of the dimensions intended to foster more secure connections. Connectors compliant with ISO 80369-7 should be backwards compatible with connectors compliant with ISO 594, but not necessarily vice versa.

To best understand how to use Luer connectors safely, we are fortunate to have commentary from Bruce C. Hansel, PhD, CCE, Principal & Chief Scientist, Accident and Forensic Investigation for ECRI Institute, with a focus on vascular connectors. Bruce Hansel has investigated patient injuries related to Luer connectors and provides an educational commentary on the Luer design as well as use strategies to mitigate the potential for patient harm. While we do not have enough information to identify what differences, if any, exist between different manufacturers of Luer designs that can contribute to a less than secure connection, Hansel provides valuable insights into how the Luer connection can be used to greatest effect.

The Luer connector is so simple to use, it is easy to be "lured" into thinking that it does not matter how we make the connection. While we are likely to see slow but progressive adoption of the new standard for preventing misconnection between incompatible applications, the basic use of a tapered connector will continue, especially for vascular access. Proper use can help to minimize leaks and disconnects that can lead to patient injury.

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Jeffrey Feldman is a consultant for Micropore Inc. and Becton Dickinson.

REFERENCES

1. Brown J. The life and death of the luer. https://www.mddionline.com/components/life-and-death-luer. Accessed July 11, 2021.
2. Sentinel Event Alert. Managing risk during transition to new ISO tubing connector standards. 2014;53:1–6. https://www.jointcommission.org/-/media/deprecated-unorganized/imported-assets/tjc/system-folders/assetmanager/sea_53_connectors_8_19_14_finalpdf.pdf?db=web&hash=5259E85202D5CE621294E9C46E8ED86C&hash=5259E85202D5CE621294E9C46E8ED86C. Accessed Aug 29 2021.
3. ISO 80369-1:2018 Small-bore connectors for liquids and gases in healthcare applications—Part 1: General requirement. https://www.iso.org/standard/64419.html. Accessed July 11, 2021.
4. Logan M, Hancock T. Improving patient safety: collaboration, innovation, connection: organization provides information on new connector ISO standards. *APSF Newsletter.* 2014;29:15–16. https://www.apsf.org/article/improving-patient-safety-collaboration-innovation-connection-organization-provides-information-on-new-connector-iso-standards/ Accessed August 11, 2021.
5. Sentinel Event Alert 53: Managing risk during transition to new ISO tubing connector. https://www.jointcommission.org/resources/patient-safety-topics/sentinel-event/sentinel-event-alert-newsletters/sentinel-event-alert-53-managing-risk-during-transition-to-new-iso-tubing-connector-standards/. Accessed July 11, 2021.
6. Conical fittings with a 6% (Luer) taper for syringes, needles and certain other medical equipment—Part 1: General Requirements. ISO 594/1–1986.
7. Conical fittings with a 6% (Luer) taper for syringes, needles and certain other medical equipment—Part 2: Lock Fittings. ISO 594/1-1986.

RAPID Response
to questions from readers

Managing Luer Connections

by Bruce C. Hansel, PhD, CCE

LUER FITTINGS

Named after German instrument maker, Hermann Luer, Luer fittings are among the earliest medical fittings designed to provide leak-free connections between syringes and needles and maintain a continuous lumen for fluid flow. The mated fittings are cone-shaped with a 6% taper. When pressed together, the compression of the inner wall against the outer wall of the taper is designed to produce a leak-free connection. The use of the Luer connection is most associated with vascular access; however, it has been used for other medical applications as well (e.g., enteral connections and pneumatic connections). To eliminate hazardous, often fatal, cross connections, the recently developed ISO 80369 standard Luer fitting limits its use to vascular applications only.

Luer fittings are manufactured most commonly from plastic; however, they can also be made from glass or metal. The new standard for intravascular connectors, ISO 80369-7, imposes restrictions regarding the softness of plastic fittings to help ensure that the connection will not deform under pressure.

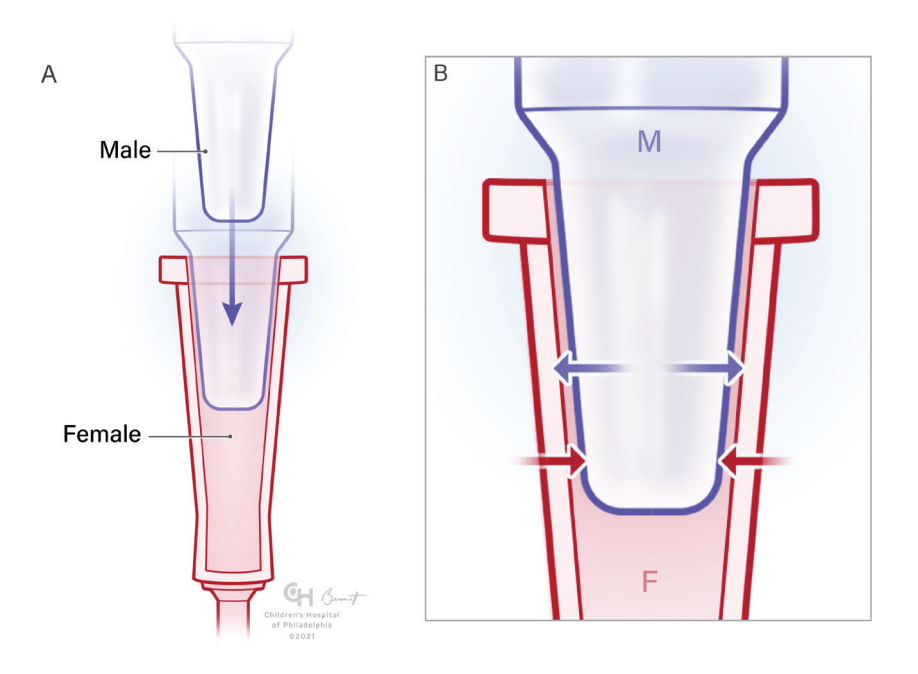

Figure 1: A) Male and female Luer taper connectors unengaged. B) Luer Taper connectors engaged to form a leak-free connection. Arrows indicate compressive forces between the inner and outer walls of the taper. The connection is secured by the combination of compressive forces and friction between the contact surfaces. Note that dry connections are typically less likely to disconnect than when the taper surfaces are wet.

TYPES OF LUER FITTINGS/ CONNECTIONS

The Luer Taper fitting often referred as the Luer Slip, is the original design and relies solely on the compression forces and resulting friction between the opposing conical surfaces to maintain a leak-free connection (Figure 1). Accidental separation is possible with this design whenever pulling force is inadvertently applied to the connection. As a way to mitigate accidental separation, Luer-lock fittings were developed and are comprised of a male taper with an associated threaded "skirt" and a female taper having flanges to engage the threads called "lugs" (Figure 2). When the two fittings are screwed together, the tapered surfaces are compressed in the same manner as the taper connection; however, with the addition of the threaded coupling, the connection cannot be simply pulled apart.

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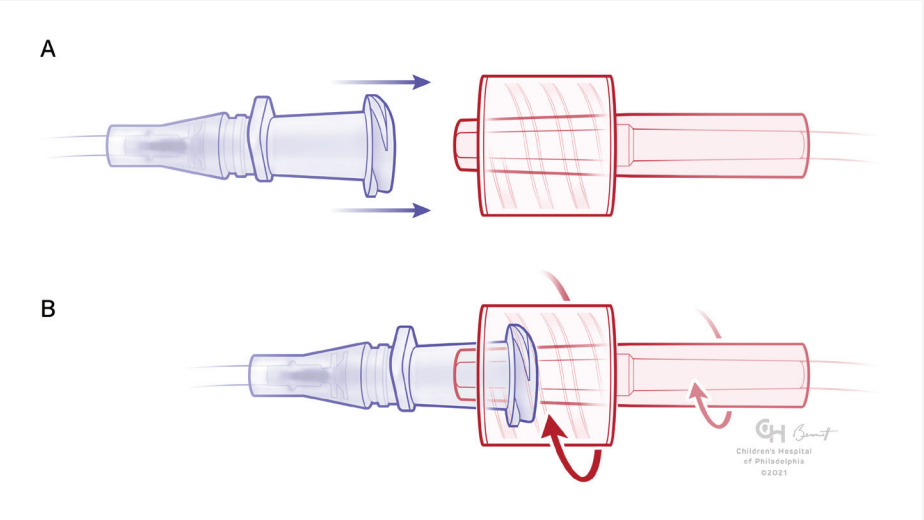

Figure 2: A) Male Luer-Lock with fixed-skirt and receiving female component unengaged. B) Fixed-skirt male component "locked" in place. Note that a fixed-skirt connector can put a twisting force (torque) on any tubing attached to the connectors.

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Luer Lock Fittings Do Not Make a Locking Connection

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There are two versions of the Luer-lock connector. The male Luer-lock fitting may have a "fixed" skirt in which the skirt and Luer taper are a single piece or it may have a "swivel" skirt in which the skirt and taper are separate pieces (Figures 2 and 3). The swivel skirt allows for the taper fit to be engaged and then secured with the skirt without imparting any twist to the intravenous tubing.

LUER MISCONCEPTIONS

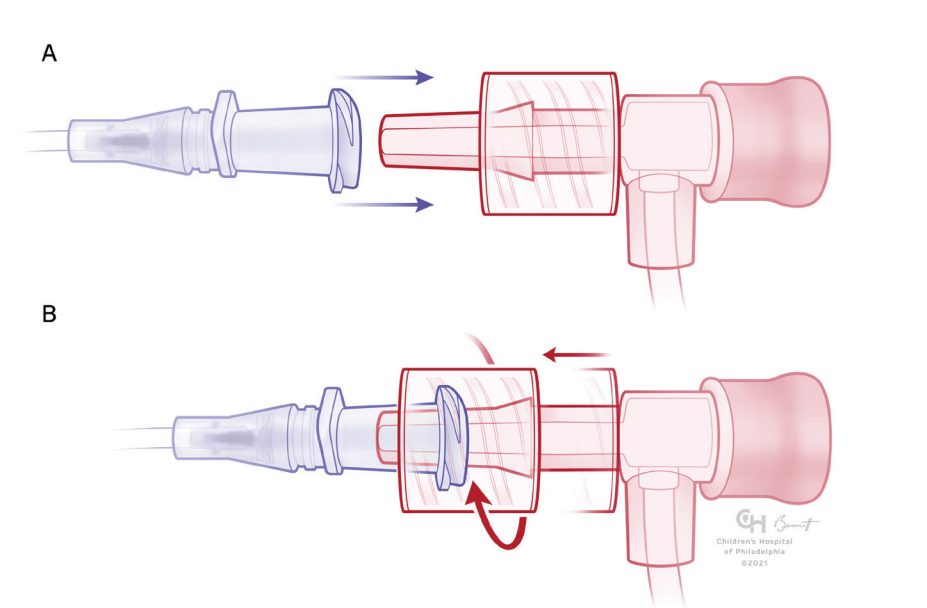
Despite the name, Luer-lock, these fittings do not make a true "locking" connection. When the connection is made, there is no associated latching mechanism. Furthermore, the skirt does not provide additional leak protection. Luer-lock connections are also vulnerable to unintended separation; while not easily pulled apart, they are subject to accidental unscrewing. The Luer-lock connection requires the skirt to be unscrewed to separate the tapers. With the proliferation of bulkier Luer components, the opportunity for accidental unscrewing has increased due to the greater torque (i.e., leverage) that can be applied to the Luer-lock connection. For example, a syringe connected to a three-way Luer stopcock can easily loosen the luer-lock connection perpendicular to the syringe. ECRI has adopted the term "Luer leverage" for such circumstances. Because the skirts have very coarse threads, it only takes ~¼ turn to loosen the connection between the male and female tapers.

As an example of the ramifications of Luer leverage, a patient died from hemorrhage and air embolism attributed to a jugular sheath disconnection from a hemostasis valve with an integral 6-inch sideport connected to the sheath using a Luer-lock connection. At the time the sheath was placed, its hub was sutured to the patient's skin, preventing the female hub from rotating. At some point, the IV tubing connected to the hemostasis valve sideport tubing was pulled, applying sufficient torque to unscrew the Luer-lock which led to exsanguination from the sheath and entrainment of air.

COMPLICATIONS OF LUER CONNECTION DUE TO PARTIAL OR TOTAL SEPARATION

Luer separations result in four types of complications that can happen separately or in combination: infection, blood loss, air embolism, and medication leakage at the connection. Blood loss and/or air embolism will be the focus of this section. Separations can be complete or partial. Partial separations occur when the components appear to be connected, but are not tight enough to prevent a leak, and can be difficult to detect.

All that is required for blood loss or air embolism to occur is a leak between the vascular system and the atmosphere, and a pressure gradient favorable for bleeding or air entrainment. The degree of blood loss or air ingress is proportional to the magnitude of the pressure gradient, the resistance in the leak and the length of the conduit. When the pressure in the tubing lumen is higher than ambient air pressure, blood can leak out of the Luer connection. Conversely, if the pressure in the lumen is lower than ambient air pressure, air can potentially enter the bloodstream. Loss of blood or ingress of air resulting from naturally occurring pressure gradients are passive events. When pressure or vacuum applied by devices such as syringes and pumps are involved, these are active events, and pressure gradients are generally much greater than naturally occurring pressures. For example, during a Luer disconnection of a hemodialysis catheter blood loss can occur at a very high rate.



Figures 3: A) Male Luer-Lock with swivel-skirt and receiving female component unengaged. B) Swivel-skirt male component engaged. Note that the swivel skirt allows the Luer taper to be engaged first and then secured with the skirt to avoid any twisting force on the attached tubing.

LUER CONNECTION MANAGEMENT

Despite the fact that the Luer-Lock is not a truly secure connection, there are strategies for use that can mitigate the potential for complications from leaks or separations. This section will focus on mitigation strategies for Luer-lock connections, but the majority apply to the Luer taper connections as well.

MAKING THE CONNECTION(S)

- When possible, make the connection using dry male and female Luer components. Since the connection integrity depends on the friction between the male and female Luer taper, dry fittings will be more secure than wet fittings (i.e., those having solution or blood on/in the tapers or the skirt). Even so, wet connections are often unavoidable (or even preferable), and can be completed without leaks when done properly.
- Luer fittings should only be tightened by hand. Use of grasping instruments should be avoided because the fitting can be damaged, increasing the potential for leak or air ingress. Grasping instruments can be used with caution to separate Luer fittings when/if the connection is too tight to separate by hand.

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Luer Lock Fittings Do Not Make A Locking Connection, cont'd

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- Avoid making Luer connections with fittings made from different materials (i.e., metal to plastic).
- Be careful not to cross-thread the male Luer skirt threads on the lugs of the female taper. Because the male taper extends beyond the end of the threaded skirt, the tapers engage before the skirt and help to maintain the alignment of the fittings. When using the swivel skirt design, retracting the skirt and making the taper connection first will also help with alignment.
- Finally, make no more connections than necessary. The number of connections is directly proportional to the risk of an unwanted separation.

MAINTAINING THE CONNECTION(S)

Once the Luer connection is made, it needs to be protected from forces that can separate the connections. Such forces can be mitigated in following ways:

- Maintain some slack in the lines near Luer connections to indwelling catheters.
- Run lines in a manner that prevents them from being snagged when moving the patient, surrounding equipment or other persons. Note that too much slack increases this risk.
- Avoid Luer leverage by minimizing the use of devices that extend perpendicularly from the adjacent Luer connections. To the degree possible, orient such devices so that if they are snagged or lines connected to them are pulled, they will not unscrew the adjacent Luerlock.
- Unused Luer ports should be maintained with solid (non-vented) Luer caps. Stopcocks and pinch clamps should not be relied on as the sole means of preventing leakage or air ingress at unused Luer fittings.

MONITORING THE CONNECTION(S)

The following points are useful guidance based upon experience with accident investigation.

- To simplify monitoring Luer connections, avoid locations that conceal the connection and/or make the connection difficult to access, such as under bed clothes or beneath drapes. In particular, never cover any connections to extracorporeal circulation equipment which may fail to detect disconnections until potentially life threatening blood loss or air ingress has occurred.
- Inspect the lines proximal and distal to the Luer connection for potential entrapment that could permit separation forces to be applied to the connection. For example, drooping lines that could be snagged by foot traffic around the patient.
- Inspect IV lines downstream from their connections for the presence of air segments. When air is detected, the tightness and condition of the upstream connections should be assessed.
- Inspect dressings that cover Luer connections for wetness or blood. When possible, use clear dressings that permit direct observation of the connection.

Like any medical device, the potential for patient harm from a Luer connection can be reduced by understanding the design considerations, potential for injury, and strategies for proper use. Following the guidance provided here should reduce the potential for a Luer-related adverse event or outcome.

Bruce C. Hansel, PhD, CCE, is principal & chief scientist, Accident and Forensic Investigation, ECRI.

The information in this article is based upon the author's experience from many years of medical accident investigation.

The author has no conflicts of interest.

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Marjorie Stiegler, MD, APSF Director of Digital Strategy and Social Media.

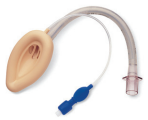
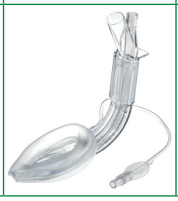
The Laryngeal Mask Airway: Expanding Use Beyond Routine Spontaneous Ventilation for Surgery

by Shauna Schwartz, DO, and Yong G. Peng, MD, PhD, FASE, FASA

INTRODUCTION

The laryngeal mask airway (LMA) was invented in 1983 by Archie Brain, MD, as an alternative airway device to the facemask and endotracheal tube (ETT).[1] Since the establishment of the classical LMA, the device has undergone multiple improvements and modifications (Table 1). The LMA can provide a better quality of ventilation over a mask alone and with less instrumentation to the airway than tracheal intubation.[2] Advantages of the LMA include the ease of use and less injury to airway tissues than ETTs, although trauma can result from forceful use of LMAs.[3-6] With the LMA, there are fewer hemodynamic disturbances and postoperative complications than with an ETT.[2] The LMA has been widely used in surgery requiring general anesthesia and as a rescue device for difficult airways.[7] In the updated difficult airway algorithm, developed by the American Society of Anesthesiologists, the LMA is a priority apparatus for emergency noninvasive airway access.[7] Many clinical investigations and much research have demonstrated that the LMA is a safe and reliable airway device.[2,6,8,9] However, debate continues regarding nonstandardized use of the LMA in clinical settings, including with positive pressure ventilation (PPV) and muscle relaxants, in laparoscopic surgery, and with obese patients (Table 2). Concerns regarding LMA use can be categorized as follows: (1) inadequate seal of the LMA due to malposition; (2) airway injuries ranging from throat discomfort to permanent tissue damage; (3) aspiration risk; (4) safety of mechanical ventilation as opposed to spontaneous ventilation; and (5) safety in obese patients. Nonroutine uses of the LMA and potential safety issues will be discussed in this review.

Table 1: Evolution of the Laryngeal Mask Airway (LMA)[1, 6, *]

Name	Type	Image	Material	Advantages	Disadvantages
LMA Classic	First generation		Silicone	Original design, less pharyngolaryngeal trauma, respiratory problems vs. ETT, rescue device	Low OSP,[†] increased cost with processing
LMA Unique	First generation		Polyvinyl chloride	Disposable form of classical LMA	Low OSP
LMA FasTrach™			Polyvinyl chloride and silicone	Intubating LMA to guide blind, difficult intubations	Bulky, no pediatric sizes, increased cost of processing
LMA Flexible			Polyvinyl chloride and silicone	Wire-reinforced tubing, head and neck procedures	Low OSP, increased cost with processing
LMA ProSeal™	Second generation		Silicone	Gastric suction port, built in bite block, high OSP	Bulky, folding of mask can obstruct the gastric port, increased cost of processing
LMA Supreme	Second generation.		Polyvinyl chloride	Disposable version of ProSeal LMA	Bulky, folding of mask can obstruct the gastric port

*More supraglottic devices exist and are manufactured by a variety of companies. This table includes first- and second-generation devices discussed in the review.
[†]OSP: oropharyngeal seal pressure. Lower OSP increases gastric insufflation and risk of aspiration.[1]

LMA PLACEMENT AND SIZE SELECTION

The LMA may be easily placed following induction of general anesthesia, with or without a muscle relaxant.[10] In a study by Hemmerling et al., the success rate of first attempt insertion was 92% with the use of muscle relaxant versus 89% without muscle relaxant.[10] If the LMA size selected is too small, it may not create an adequate seal, leading to leakage, which may result in insufficient ventilation.[11] If the device is too large, it may lead to reduced adaptability, also resulting in a poor seal or leak. This may also result in soft tissue, lingual nerve injury, or even pharyngeal damage if it was forcefully placed. Size 4 and 5 LMAs are appropriate in most average female and male adults, respectively. In a study by Asai et al., leaks were reduced with placement of the larger size LMAs in both males and females.[11] Minimal inflation volumes were used to create an adequate seal, resulting in less pressure measured on the pharynx.[11] Brimacombe et al. investigated pharyngolaryngeal complaints in 300 patients comparing LMA use with low cuff volumes and LMA with high cuff volumes and found a higher incidence of sore throat and dysphagia in the latter group.[3] In a prospective study of 5,264 patients, Higgins et al. found that the incidence of a sore throat with an ETT versus an LMA was 45.4% and 17.5% of patients, respectively.[4] Although the incidence of a sore throat may be higher with ETTs compared with LMAs, inappropriate LMA size and high cuff pressures may also contribute to significant pharyngolaryngeal complications; thus, importance should be placed more on minimizing intracuff volume.[4-6,11] In a Cochrane review, Mathew et al.

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Non-Standard Uses of LMA

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pooled 15 randomized controlled trials with 2,242 patients to assess whether it was better to remove the LMA under deep anesthesia or when patients are awake. The review concluded that there was not sufficient high-quality evidence to determine if one method was superior to the other.[12]

ASPIRATION RISK WITH LMA

A frequent concern regarding LMA use is the risk for aspiration, particularly when PPV is applied. The most common contraindications to LMA placement include patients at risk of aspiration such as during pregnancy, trauma, preexisting gastroparesis, intestinal obstruction, or emergency surgery in nonfasted patients. Table 3 provides an overview of absolute and relative contraindications to the LMA. In appropriately fasted patients, several studies have identified the risk of aspiration with an LMA as extremely low.[8,9] Brimacombe et al. reported the incidence of pulmonary aspiration with an LMA to be 2 per 10,000 compared with 1.7 per 10,000 for an ETT and facemask, in a similar patient cohort.[9] In a study performed by Bernardini and Natalini with 65,712 surgical procedures, including 2,517 laparoscopic surgeries and major abdominal surgeries, there was no significant difference in the rate of aspiration for the classic LMA in comparison with an ETT while using PPV.[8] In a meta-analysis, Park et al. compared second-generation LMAs to ETTs in 1,433 patients undergoing laparoscopic surgery and found no difference in oropharyngeal leak pressure, gastric insufflation, or aspiration.[6] The lack of difference in oropharyngeal leak pressure suggests a degree of airway protection and sufficient mechanical ventilation even against an insufflated abdomen.[6] LMAs have been successful in laparoscopic procedures, but caution with use is warranted. Second-generation devices may be more appropriate for laparoscopic surgery with higher oropharyngeal seal pressure and gastric suction port.[6]

Some second-generation LMAs contain a gastric channel for placement of an orogastric tube to prevent aspiration (Table 1). In a large observational study, 700 appropriately fasted patients underwent general anesthesia for cesarean section with the LMA Supreme™.[15] There were no reported cases of aspiration using the LMA Supreme™ with placement of an orogastric tube through the gastric port.[15]

Positive inspiratory pressure greater than 15 cm H_2O has been suggested to lead to incompetence of the lower esophageal sphincter and result in insufflation of air into the stomach with the potential for aspiration.[16] Devitt et al. assessed the leak fractions, measured from subtracting expiratory volume from inspiratory volume divided by inspiratory volume, and gastric insufflation comparing classical LMAs versus standard endotracheal intubation at various inspiratory pressures. The leak fraction increased with increasing positive pressure delivered through the LMA and remained low and unchanged in the ETTs. At an inspired pressure of 15 cm H_2O, the gastric insufflation with LMA use was 2.1%, while it was 35.4% with a pressure of 30 cm H_2O.[17] In a Cochrane review comparing the ProSeal™ LMA, a second-generation LMA with a gastric suction port and a posterior cuff for an improved seal, with Classical LMA with PPV, Qamarul Hoda et al. concluded that there was no significant difference in rates of regurgitation.[18] Both older and newer generations of the LMA have been successfully used without clinical signs of aspiration if inspiratory pressures are limited to 15 cm H_2O or lower.[17,18]

Table 2. Summary of Non-Standard Uses of the Laryngeal Mask Airway (LMA)

Non-standard use	Concerns	Conclusions
Mechanical ventilation compared to spontaneous ventilation	Gastric insufflation, aspiration with high inspiratory pressures Inability to self-regulate anesthesia depth	Adequate ventilation can be achieved with various ventilatory modes Minimize inspiratory pressures to decrease risk of gastric aspiration
Use of muscle relaxant	Facilitate mechanical ventilation	May benefit LMA insertion and surgeries
Laparoscopic surgery	Aspiration risk with insufflated abdomen	Likely acceptable in properly fasted patients with second-generation devices
Obese patients	Poor pulmonary compliance Ventilation difficulty	Acceptable for some obese patients, further study warranted prior to recommendation for routine use in morbid obesity Successful as a temporary rescue device

Table 3. Absolute and Relative Contraindications to LMA[8,9,13,14]

Absolute Contraindications	Relative Contraindications
Trauma	Major abdominal surgery
Nonfasted patients	Pregnancy >14 weeks
Bowel obstruction	Prone position
Emergency surgery	Airway surgery
Delayed gastric emptying	Laparoscopic surgery
	Obesity, BMI >30
	Decreased lung compliance with PIP >20 cm H_2O
	Altered mental status

BMI = body mass index; LMA = laryngeal mask airway; PIP = peak inspiratory pressure

SPONTANEOUS VENTILATION VS. MECHANICAL VENTILATION

A benefit of LMA use is that it is less stimulating to a patient than an ETT; therefore, less anesthesia is often required.[19] Due to increasing comfort with use and the development of a new generation of devices, LMAs are routinely used safely with mechanical ventilation.[18,20-24] Radke et al. assessed the redistribution of ventilation by using electrical impedance tomography in patients undergoing general anesthesia with an LMA.[22] They observed no redistribution of ventilation with patients breathing spontaneously, and found ventral redistribution under both pressure-controlled ventilation (PCV) and pressure support ventilation (PSV).[22] Consequences of ventral distribution of ventilation include increased dead space and atelectasis.[21,24] The use of volume control ventilation (VCV) with an LMA results in less compliance and higher peak inspiratory pressures compared to PCV. PCV, an alternative mode of ventilation, limits the inspired pressure to maintain a set tidal

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Obesity and the LMA

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volume.[22] End-tidal carbon dioxide was higher, tidal volumes were smaller, and oxygen saturation was lower in patients undergoing spontaneous breathing (SB) compared to PCV, VCV, and PSV modes.[21,23] Brimacombe and Keller found improved oxygenation and ventilation with the LMA by using PSV compared with continuous positive airway pressure (CPAP).[21]

There was no difference in gastric insufflation, airway or cardiovascular complications, or problems ventilating patients in a study by Keller et al. comparing spontaneous ventilation to PPV.[24,25] In a Cochrane review, the classic LMA was compared to the ProSeal™ LMA undergoing PPV.[18] The ProSeal™ LMA had a better seal, suggesting that it may be more suitable for PPV; however, overall the quality of evidence was low.[18] In a randomized controlled trial, Capdevila et al. examined various modes of ventilation, VCV, PSV, and SB, on emergence time and intraoperative ventilation.[23] Time to classic LMA removal was prolonged in patients undergoing VCV compared with PSV or SB.[23]

OBESITY AND THE LMA

Another area of controversy is LMA use in obese patients. Physiological changes seen in obese patients make them a challenging population, including a restrictive lung pattern due to abdominal contents limiting diaphragm motion and yielding less respiratory compliance.[20] Insufflation during laparoscopic procedures can further impair lung compliance and make ventilation difficult.[20] Cheong et al. found that in patients with a body mass index (BMI) over 30, there was a 2.5 times increased risk of having ventilatory problems.[26] Zoremba et al. assessed postoperative lung function and saturations in obese patients (BMI 30 to 35) undergoing minor peripheral surgery with a ProSeal LMA™ vs. ETT.[27] and found ventilation was adequate in both groups while postoperative pulmonary complications were decreased in the LMA group.[27] Keller et al. showed that the ProSeal™ LMA was temporarily effective in ventilating obese patients with a BMI >35 prior to intubation.[28] Although second-generation LMAs have been used in obese patients, further studies should be done to investigate the safety of LMA use in obese patients.

SUMMARY

LMA design has evolved and clinical use has expanded significantly in recent decades. Evidence suggests that LMA use is safe with mechanical ventilation in appropriately fasted patients while minimizing the inspiratory pressures applied. Second-generation devices may minimize leak and limit gastric insufflation compared to first-generation LMAs. Muscle relaxant may be considered and has been shown to facilitate LMA insertion and mechanical ventilation. Use of LMA in obese patient remains controversial. Studies have proved successful ventilation of obese patients with a BMI below 30. However, in patients with higher BMIs, ventilation may be impaired due to physiologic changes in obesity. The LMA should always be considered as a rescue device for difficult ventilation or intubation, regardless of patient size. Appropriate LMA indications continue to be debated. It is important to recognize the potential complications and relative contraindications to the LMA and adjust a clinical algorithm, which would optimize the use of the LMA in airway management.

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REFERENCES

1. Sharma B, Sahai C, Sood J. Extraglottic airway devices: technology update [published correction appears in *Med Devices (Auckl)*.2018;1127]. *Med Devices (Auckl)*. 2017;10:189–205.
2. Brimacombe J. The advantages of the LMA over the tracheal tube or facemask: a meta-analysis. *Can J Anaesth*. 1995;42:1017–1023.
3. Brimacombe J, Holyoake L, Keller C, et al. Pharyngolaryngeal, neck, and jaw discomfort after anesthesia with the face mask and laryngeal mask airway at high and low cuff volumes in males and females. *Anesthesiology*. 2000;93:26–31.
4. Higgins PP, Chung F, Mezei G. Postoperative sore throat after ambulatory surgery. *Br J Anaesth*. 2002;88:582–584.
5. Figueredo E, Vivar-Diago M, Muñoz-Blanco F. Laryngo-pharyngeal complaints after use of the laryngeal mask airway. *Can J Anaesth*. 1999;46:220–225.
6. Park SK, Ko G, Choi GJ, et al. Comparison between supraglottic airway devices and endotracheal tubes in patients undergoing laparoscopic surgery: a systematic review and meta-analysis. *Medicine (Baltimore)*. 2016;95:e4598.
7. Updated by the Committee on Standards and Practice Parameters, Apfelbaum JL, Hagberg, CA Caplan RA, et. al. The previous update was developed by the American Society of Anesthesiologists Task Force on Difficult Airway Management, Caplan RA, Benumof JL, Berry FA, et al; Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. *Anesthesiology*. 2013;118:251–270.
8. Bernardini A, Natalini G. Risk of pulmonary aspiration with laryngeal mask airway and tracheal tube: Analysis on 65 712 procedures with positive pressure ventilation. *Anaesthesia*. 2009;64:1289–1294.
9. Brimacombe JR, Berry A. The incidence of aspiration associated with the laryngeal mask airway: A meta-analysis of published literature. *J Clin Anesth*. 1995;7:297–305.
10. Hemmerling TM, Beaulieu P, Jacobi KE, et al. Neuromuscular blockade does not change the incidence or severity of pharyngolaryngeal discomfort after LMA anesthesia. *Can J Anaesth*. 2004;51:728–732.
11. Asai T, Howell TK, Koga K, Morris S. Appropriate size and inflation of the laryngeal mask airway. *Br J Anaesth*. 1998;80:470–474.
12. Mathew PJ, Mathew JL. Early versus late removal of the laryngeal mask airway (LMA) for general anaesthesia. *Cochrane Database of Syst Rev*. 2015;(8):CD007082.
13. Teleflex. LMA Better by Design. Accessed July 26, 2020. https://www.lmaco-ifu.com/ifu?category=1
14. Kallar SK, Everett LL. Potential risks and preventative measures for pulmonary aspiration: new concepts in preoperative fasting guidelines. *Anesth Analg*. 1993;77:171–182.
15. Yao WY, Li SY, Sng BL, et al. The LMA Supreme™ in 700 parturients undergoing Cesarean delivery: an observational study. *Can J Anesth*. 2012;59:648–654.
16. Bouvet L, Albert ML, Augris C, et al. Real-time detection of gastric insufflation related to facemask pressure–controlled ventilation using ultrasonography of the antrum and epigastric auscultation in nonparalyzed patients: a prospective, randomized, double-blind study. *Anesthesiology*. 2014;120:326–334.
17. Devitt JH, Wenstone R, Noel AG, O'Donnell MP. The laryngeal mask airway and positive-pressure ventilation. *Anesthesiology*. 1994;80:550–555.
18. Qamarul Hoda M, Samad K, Ullah H. ProSeal versus Classic laryngeal mask airway (LMA) for positive pressure ventilation in adults undergoing elective surgery. *Cochrane Database Syst Rev*. 2017;7:CD009026.
19. Wilkins CJ, Cramp PG, Staples J, Stevens WC. Comparison of the anesthetic requirement for tolerance of laryngeal mask airway and endotracheal tube. *Anesth Analg*. 1992;75:794–7
20. Miller RD. Miller's Anesthesia. 7th ed. Philadelphia, PA: Churchill Livingstone/Elsevier; 2010.
21. Brimacombe J, Keller C, Hörmann C. Pressure support ventilation versus continuous positive airway pressure with the laryngeal mask airway: a randomized crossover study of anesthetized adult patients. *Anesthesiology*. 2000;92:1621–1623.
22. Radke OC, Schneider T, Heller AR, Koch T. Spontaneous breathing during general anesthesia prevents the ventral redistribution of ventilation as detected by electrical impedance tomography: a randomized trial. *Anesthesiology*. 2012;116:1227–1234.
23. Capdevila X, Jung B, Bernard N, et al. Effects of pressure support ventilation mode on emergence time and intra-operative ventilatory function: a randomized controlled trial. *PLoS One*. 2014;9:e115139.
24. Keller C, Sparr HJ, Luger TJ, Brimacombe J. Patient outcomes with positive pressure versus spontaneous ventilation in nonparalysed adults with the laryngeal mask. *Can J Anaesth*. 1998;45:564–567.
25. Soni N, Williams P. Positive pressure ventilation: what is the real cost? *Br J Anaesth*. 2008;101:446–457.
26. Cheong G, Siddiqui S, Lim T, et al. Thinking twice before using the LMA for obese and older patients-a prospective observational study. *J Anesth Clin Res*. 2013;4:2.
27. Zoremba M, Aust H, Eberhart L, et al. Comparison between intubation and the laryngeal mask airway in moderately obese adults. *Acta Anaesthesiol Scand*. 2009;53:436–442.
28. Keller C, Brimacombe J, Kleinsasser A, Brimacombe L. The Laryngeal Mask Airway ProSeal™ as a temporary ventilatory device in grossly and morbidly obese patients before laryngoscope-guided tracheal intubation. *Anesth Analg*. 2002;94:737–740.

Advancements in Quantitative Neuromuscular Monitoring

by J. Ross Renew, MD, FASA, FASE

THE CALL FOR MONITORING

When patients become hypotensive in the operating room, the anesthesia professional immediately delivers the necessary treatment. Whether it be intravenous fluids or vasoactive medications, clinicians have been trained to acutely intervene and avoid clinical deterioration. How do anesthesia professionals know that their intervention has been successful? Do they assume that the bolus of phenylephrine was adequate because they are familiar with the pharmacodynamics of this drug and expect all patients to respond in a predictable manner? Do they palpate the carotid artery following a bolus of intravenous fluids to ensure that they have restored intravascular volume and achieved hemodynamic stability? Of course not. In fact, anesthesia professionals go to great lengths to ensure they have accurate devices such as an appropriately sized blood pressure cuff or even an intra-arterial catheter that provides real-time, quantitative blood pressure measurements. This group of providers expects their intervention will have the desired effect, but innate vigilance compels them to verify and not rely on predictive pharmacodynamics or subjective assessments such as palpating the pulse.

This practice pattern must be broadened to neuromuscular blockade management. Administering a neuromuscular blockade antagonist such as sugammadex or neostigmine, waiting several minutes, and then extubating a patient's trachea without confirming adequate recovery is analogous to administering phenylephrine without rechecking the blood pressure and confirming this intervention was successful. Similarly, palpating the response of the thumb to a train-of-four stimulation with a peripheral nerve stimulator (PNS) and subjectively determining whether adequate recovery has been achieved is a comparable practice to palpating the carotid artery during volume administration. Anesthesia professionals rely on state of the art technologies to maintain homeostasis of patients and must not exclude neuromuscular blockade management from such efforts.

The reluctance among the anesthesia community to adopt quantitative (or objective) monitoring is a curious phenomenon that has sparked its own collection of literature. An international survey of >2500 anesthesiologists revealed significant gaps in knowledge regarding fundamentals of neuromuscular blockade management as respondents answered only 57% of the questions correctly. Of greater concern may be the fact that 92% of respondents that provided incorrect responses were inappropriately confident in their wrong answer.[1]

There is also an emerging belief that the introduction of sugammadex negates the need for quantitative monitoring. While this reversal agent has certainly allowed for faster neuromuscular blockade antagonism and at deeper levels of blockade, sugammadex administration without monitoring can still result in up to 9.4% of patients having residual weakness at the time of extubation.[2] Such knowledge gaps and misplaced confidence have certainly been obstacles, while inconsistent training has also been described as a barrier to monitoring.[3] Finally, there has historically been a paucity of user-friendly, reliable quantitative neuromuscular monitors that interested clinicians can access.[4]

The lack of routine quantitative monitoring is a problem that persists worldwide, but momentum continues to build with renewed interest in this topic among anesthesia professionals. Expert panels have called for routine monitoring,[5] while anesthesia societies have established guidelines recommending the use of quantitative monitoring whenever neuromuscular blocking agents (NMBA) are administered.[6-8] Industry has responded with new monitors and innovations that should enhance patient safety. This article will review some of the state of the art technologies that are currently available for clinicians seeking to utilize quantitative neuromuscular monitoring.

MONITORING MODALITIES

The use of a peripheral nerve stimulator (PNS) is qualitative and even experienced anesthesia professionals are unable to reliably detect fade when the train-of-four ratio (TOFR) exceeds 0.4.[9] Furthermore, evidenced-based protocols that incorporate targeted NMBA administration, routine neuromuscular blockade antagonism, and the "optimal use" of a peripheral nerve stimulator can still leave 35% of patients with residual weakness.[10] The limited role of the PNS should be relegated to a device that is used if there is no access to quantitative monitors or as a device that provides qualitative information while anesthesia professionals transition to quantitative monitors.[5]

Quantitative monitors are typically classified based on the methods by which the device obtains objective measurements (also known as their monitoring modality). However, such devices can also be classified based on whether they are hand-held, standalone monitors or if they are incorporated into the anesthesia work station. Handheld monitors offer the flexibility to obtain objective measurements outside of the operating room. Postoperative residual weakness is certainly not an intraoperative-specific patient safety threat and portable monitors allow for diagnosis in the recovery room or intensive care unit. Monitors incorporated into the anesthesia workstation consist of integrated modules that allow for seamless communication of objective measurements into the electronic medical record. Understanding the needs of your practice will prove invaluable when choosing a monitoring modality and whether you need a portable or integrated monitor.

Mechanomyography

While not commercially available, every new device is compared to mechanomyography (MMG). This historic gold standard has a cumbersome setup that takes careful calibration as it obtains objective measurements by measuring the isometric contraction force following neurostimulation. When interpreting peer-reviewed literature on new quantitative monitoring technologies, the highest level of evidence currently results from direct comparison with MMG.

Acceleromyography

Acceleromyography (AMG) is one of the most investigated and utilized forms of quantitative monitoring.[4] Based on Newton's second law of motion (Force = Mass × Acceleration), AMG objectively measures the response to neurostimulation using a transducer that is fixed to the muscle of interest. Traditionally, standard electrocardiogram (ECG) electrodes are placed over the ulnar nerve and the acceleration of the adductor pollicis muscle is measured following neurostimulation (Figure 1). This configuration is very similar to employing a peripheral nerve stimulator at the hand, except for the additional transducer fixed to the thumb. AMG has also been used at alternative monitoring sites such as the foot (flexor hallucis brevis), and the face (orbicularis oculi/corrugator supercilii). While the setup of AMG can be intuitive, there are important caveats to using this monitoring modality. The "reverse fade" phenomenon in which baseline, unparalyzed TOF exceed 1.0 has been well described when monitoring with AMG.[11] While the exact mechanisms remain unclear, reverse fade can have significant implications when determining whether a patient has achieved adequate neuromuscular recovery prior to extubating the trachea. Normalization is a process that places all TOFRs in the context of the baseline TOFR (current TOFR / baseline TOFR) and can account for baseline TOFRs exceeding 1.0. Rather than defining adequate recovery of neuromuscular function as a TOFR >0.9, adequate recovery is truly achieved when the normalized TOFR > 0.9, when measured with AMG.

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A Variety of Quantitative Monitoring Modalities Are Available

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Furthermore, normalization decreases bias in relation to the MMG. The use of a preload device, which stabilizes the motion of the thumb, and the performance of calibration prior to administration of NMBA, which can also enhance precision of AMG monitoring, are both mandatory when conducting research in this field.[12] However, these additional steps are not necessarily required during the course of clinical care. In contrast, routine normalization is strongly encouraged to avoid overestimating the degree of neuromuscular recovery at the end of the operation.

Perhaps the most important caveat to consider when monitoring with AMG is the fact that the muscle of interest (typically the thumb) must be able to freely move following neurostimulation. Tucking the arms during surgical positioning can have a significant impact on the clinician's ability to obtain reliable measurements with AMG. Additionally, AMG monitoring in awake patients can prove challenging as spontaneous movement at the monitored site can produce artifact.

While there are important nuances clinicians must be familiar with prior to implementing AMG monitoring, recent advances in the modality have made AMG more accessible. Three dimensional transducers are now incorporated into newer AMG devices that allow for better quantification of the complex motion of the thumb following neurostimulation. Also, the incorporation of preload devices into newer devices improves precision without having to obtain and place extra equipment.[13] Additionally, wireless configurations of AMG monitors have been developed that utilize bluetooth technology to transmit quantitative measurements from the monitoring site to a display incorporated into the anesthesia workstation (personal communication). AMG monitors are available either as handheld units or modules that can be incorporated into the anesthesia workstation.

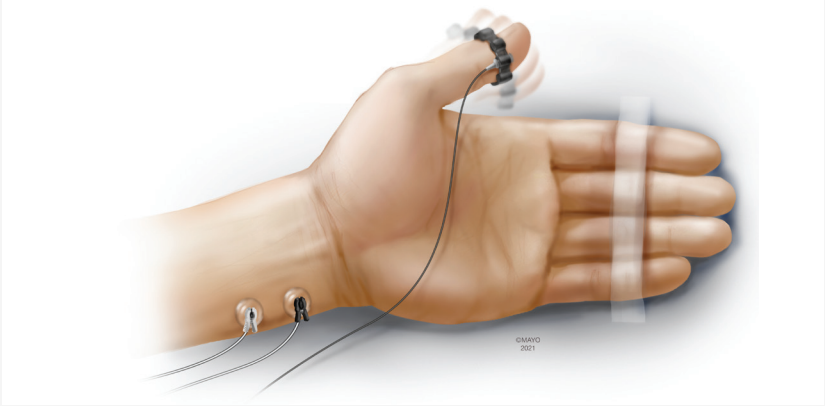

Figure 1: Acceleromyography

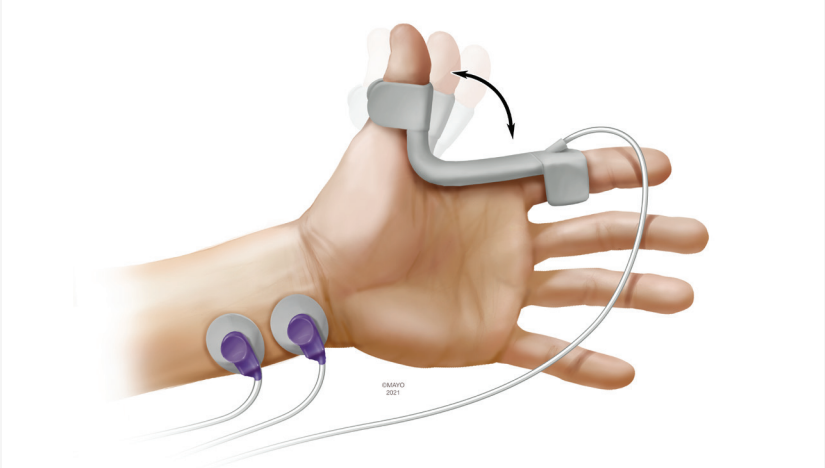

Figure 2: Kinemyography

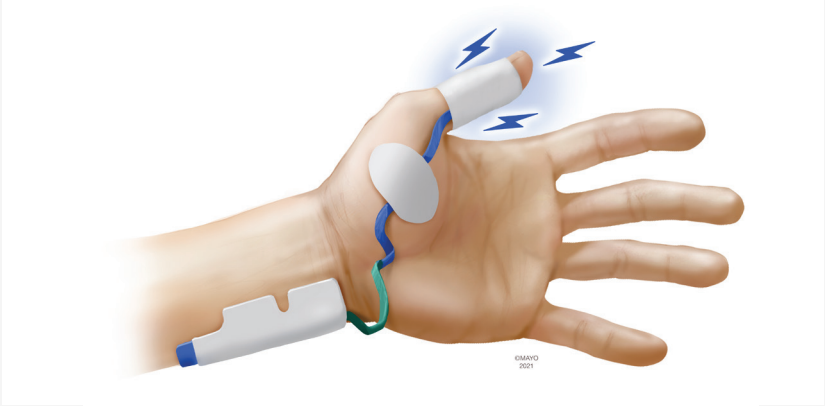

Figure 3: Electromyography

All figures are original produced by author.

Kinemyography

Kinemyography (KMG) is closely related to AMG as a monitoring modality. During KMG monitoring, a piezoelectric sensor is placed in the groove between the thumb and index (Figure 2). Following ulnar nerve stimulation, the adductor pollicis muscle contracts and the piezoelectric sensor bends. The degree of bend is then translated to objective measurements. The sensor serves as its own preload device and KMG is not subject to the reverse fade phenomenon as with AMG. Previous reports have demonstrated wide limits of agreement between MMG and KMG.[14] Like AMG, KMG is also dependent on the thumb being able to freely move and tightly tucking the arms during surgical positioning can preclude its use. Patient movement during emergence can also impact KMG monitoring, as does repositioning the sensor over the course of the perioperative period. Currently, the only available KMG-based device is a module that is incorporated into the anesthesia workstation.

Electromyography

Electromyography (EMG) has been considered by many experts as the new gold standard, given its high level of agreement with MMG[15-17] and the fact that EMG provides reliable quantitative measurements even when

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Implementing Quantitative Monitoring in Your Practice Can Be Challenging

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the arms are restricted during surgical positioning. EMG measures combined muscle action potentials (CMAPs) across the neuromuscular unit rather than motion or any surrogate for motion. The amplitude of CMAPs is directly proportional to the number of activated muscle fibers (and thus the force of contraction). EMG is subject to interference from electrocautery and amplitude of CMAPs can increase 2–3% for every 1°C decrease in skin temperature.[18]

EMG devices are available in either portable, handheld units or incorporated into the anesthesia workstation. Most manufacturers utilize proprietary electrodes to stimulate and measure CMAPs that are placed over the hand. As EMG monitoring is not disrupted when the arms are tucked, seeking alternative sites is not as important with EMG, although monitoring at the foot has been described and is an option should neither hand be available.[19] When monitoring at the hand, three muscle groups have been utilized to measure CMAPs following ulnar nerve stimulation. Similar to AMG and KMG, the sensing electrodes can be placed over the adductor pollicis muscle (Figure 3). The first dorsal interosseous muscle, located in the interspace between the thumb and index finger can also be monitored. Finally, the adductor digiti minimi (5th digit) is innervated by the ulnar nerve and is a suitable monitoring site with EMG. Despite being the oldest monitoring modality, there has been significant recent interest in EMG as evidenced by several new EMG-based monitors being introduced to market.

Cuff-based Monitoring

A new device that incorporates objective monitoring within the blood pressure cuff has recently been developed.[20] Also referred to as the modified-cuff technique, cuff-based monitoring appears to be inspired by compressomyography, a now-defunct monitoring modality that showed initial promise.[21] Cuff-based monitoring involves inflation of the blood pressure cuff to roughly 60 mmHg followed by electrodes within the cuff providing neurostimulation. Pressure changes are detected following muscle contraction and these pressure changes are used to provide clinicians objective data regarding the level of neuromuscular blockade. Early investigations have shown that monitoring the upper arm may have different neuromuscular properties than the distal muscles of the hand and cuff-based monitoring may not be interchangeable with EMG- or AMG-based monitoring at the hand.[22] While cuff-based monitoring technology is appealing as it monitors two important parameters (blood pressure and level of neuromuscular blockade), further investigation is warranted to delineate its repeatability and reproducibility across various clinical scenarios.

IMPLEMENTING MONITORING INTO YOUR PRACTICE

Obstacles certainly exist when implementing significant practice changes, particularly when many in the anesthesia community fail to acknowledge the persistent problem that is postoperative residual weakness. The decision to change and introduce monitoring to your practice can be intimidating as it involves stepping out of one's comfort zone, putting in extra time, and learning a new skill. Concerns may arise regarding such change negatively impacting workflow and efficiency. Fortunately, the application of quantitative monitors has been demonstrated to only add an additional 19 seconds to the start of a case.[23] Once the decision has been made to implement monitoring, the decision on how to proceed can also seem daunting. Certainly, understanding the culture of your practice is critical as described by Todd et al. when this group implemented department-wide EMG monitoring after observing an unacceptable number of patients encountering respiratory distress in the recovery room.[24]

Becoming familiar with emerging monitoring technologies will certainly improve the chances for successful implementation and changing practice. The specific monitor or modality is just one part of the change as the decision to change practice is much more important and often times is far more challenging. This change will undoubtedly require additional work; however, we owe it to our patients to deliver state of the art care.

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REFERENCES

1. Naguib M, Brull SJ, Hunter JM, et al. Anesthesiologists' overconfidence in their perceived knowledge of neuromuscular monitoring and its relevance to all aspects of medical practice: an international survey. *Anesth Analg*. 2019;128:1118–1126.
2. Kotake Y, Ochiai R, Suzuki T, et al. Reversal with sugammadex in the absence of monitoring did not preclude residual neuromuscular block. *Anesth Analg.* 2013;117:345–351.
3. Thomsen JLD, Marty AP, Wakatsuki S, et al. Barriers and aids to routine neuromuscular monitoring and consistent reversal practice—a qualitative study. *Acta Anaesthesiol Scand.* 2020;64:1089–1099.
4. Soderstrom CM, Eskildsen KZ, Gatke MR, Staehr-Rye AK. Objective neuromuscular monitoring of neuromuscular blockade in Denmark: an online-based survey of current practice. *Acta Anaesthesiol Scand.* 2017;61:619–626.
5. Naguib M, Brull SJ, Kopman AF, et al. Consensus statement on perioperative use of neuromuscular monitoring. *Anesth Analg.* 2018;127:71–80.
6. Lucas DN, Russell R, Bamber JH, Elton CD. Recommendations for standards of monitoring during anaesthesia and recovery 2021. *Anaesthesia*. 2021 Jun 18. doi: 10.1111/anae.15528.
7. Dobson G, Chow L, Filteau L, et al. Guidelines to the practice of anesthesia—revised edition 2020. *Can J Anaesth*. 2019;64:75–91.
8. Indications of neuromuscular blockade in anaesthesia. Short text. *Ann Fr Anesth Reanim*. 2000;19 2:352s–355s.
9. Viby-Mogensen J, Jensen NH, Engbaek J, et al. Tactile and visual evaluation of the response to train-of-four nerve stimulation. *Anesthesiology.* 1985;63:440–443.
10. Thilen SR, Ng IC, Cain KC, Treggiari MM, Bhananker SM. Management of rocuronium neuromuscular block using a protocol for qualitative monitoring and reversal with neostigmine. *Br J Anaesth*. 2018;121:367–377.
11. Claudius C, Skovgaard LT, Viby-Mogensen J. Is the performance of acceleromyography improved with preload and normalization? A comparison with mechanomyography. *Anesthesiology.* 2009;110:1261–70.
12. Fuchs-Buder T, Claudius C, Skovgaard LT, et al. Good clinical research practice in pharmacodynamic studies of neuromuscular blocking agents II: the Stockholm revision. *Acta Anaesthesiol Scand.* 2007;51:789–808.
13. Murphy GS, Szokol JW, Avram MJ, et al. Comparison of the TOFscan and the TOF-Watch SX during Recovery of Neuromuscular Function. *Anesthesiology.* 2018;129:880–888.
14. Motamed C, Kirov K, Combes X, Duvaldestin P. Comparison between the Datex-Ohmeda M-NMT module and a force-displacement transducer for monitoring neuromuscular blockade. *Eur J Anaesthesiol*. 2003;20:467–469.
15. Engbaek J, Ostergaard D, Viby-Mogensen J, Skovgaard LT. Clinical recovery and train-of-four ratio measured mechanically and electromyographically following atracurium. *Anesthesiology*. 1989;71:391–395.
16. Kopman AF. The relationship of evoked electromyographic and mechanical responses following atracurium in humans. *Anesthesiology*. 1985;63:208–211.
17. Harper NJ, Bradshaw EG, Healy TE. Evoked electromyographic and mechanical responses of the adductor pollicis compared during the onset of neuromuscular blockade by atracurium or alcuronium, and during antagonism by neostigmine. *Br J Anaesth*. 1986;58:1278–1284.
18. Engbaek J. Monitoring of neuromuscular transmission by electromyography during anaesthesia. A comparison with mechanomyography in cat and man. *Dan Med Bull*. 1996;43:301–316.
19. Kern SE, Johnson JO, Orr JA, Westenskow DR. Clinical analysis of the flexor hallucis brevis as an alternative site for monitoring neuromuscular block from mivacurium. *J Clin Anesth.* 1997;9:383–387.
20. Veiga Ruiz G, Garcia Cayuela J, Orozco Montes J, et al. Monitoring intraoperative neuromuscular blockade and blood pressure with one device (TOF-Cuff): a comparative study with mechanomyography and invasive blood pressure. *Rev Esp Anestesiol Reanim*. 2017;64:560–567.
21. Dahaba AA, Bornemann H, Holst B, Wilfinger G, Metzler H. Comparison of a new neuromuscular transmission monitor compressomyograph with mechanomyograph. *Br J Anaesth*. 2008;100:344–350.
22. Krijtenburg P, Honing G, Martini C, et al. Comparison of the TOF-Cuff® monitor with electromyography and acceleromyography during recovery from neuromuscular block. *Br J Anaesth.* 2019;122:e22–e24.
23. Renew JR, Hex K, Johnson P, et al. Ease of application of various neuromuscular devices for routine monitoring. *Anesth Analg*. 2021;132:1421–1428.
24. Todd MM, Hindman BJ, King BJ. The implementation of quantitative electromyographic neuromuscular monitoring in an academic anesthesia department. *Anesth Analg*. 2014;119:323–331.

Time-Out Checklists Promote Safety in Nonoperating Room Anesthesia

by Candace Chang, MD, MPH, and Ryan Dudley, MD

INTRODUCTION

Time-out checklists reduce morbidity and mortality from surgical procedures.[1] While these checklists are now ubiquitous in operating rooms, their adoption in other procedural areas is inconsistent, but no less important. The challenges of nonoperating room anesthesia (NORA) include ineffective team dynamics, remote location from assistance, unfamiliar procedures, and physical obstacles present in the work environment.[2,3] In addition, studies have shown that patients receiving NORA tend to be older and have more comorbidities when compared to patients in the OR (operating room).[4] The added complexities of a remote location with unique physical set up and staff that may be unfamiliar with working in NORA locations make the time-out checklist even more important in establishing common ground to ensure optimal patient care. The purpose of this review is to highlight important elements for designing and implementing a NORA checklist based on experience at our institution.

Many aspects of a time-out checklist are similar for both the OR and NORA locations, but there are some elements unique to, or more crucial to emphasize, in the NORA location. For example, waiting until the patient is prepped and draped before initiating the time-out is common practice in the OR. However, we recommend performing the time-out with the patient in the NORA location before induction of anesthesia, given potential idiosyncrasies of the procedures. For example, positioning for a Computerized Tomography (CT)-guided procedure may depend on an initial CT scan; it is inconvenient to convert to prone positioning after the patient is already intubated and supine on the CT carriage. Another possibility is the necessity of lung isolation for a procedure, which radiologists may forget to communicate to the anesthesia professionals ahead of time.

CHECKLIST

Our time-out checklist focuses on four essential categories: 1. patient; 2. procedure; 3. team; and 4. emergency response.

1. Patient—The patient information contained in the NORA checklist is very similar to that used in the OR. The usual patient identifying information, weight, and allergies are covered here. Additional information may include pregnancy test results, COVID-19 status, and coagulation studies. Disposition of the patient should also be discussed. In NORA locations, proceduralists are often consultants, not the primary care team, which highlights the need for discharge plans to be clarified, including the location of post-anesthesia care and whether the patient will be admitted or discharged home after the procedure.

2. Procedure—Patient positioning, length of the intervention, discussion of potential complications, and anticipated post-procedural pain should be discussed, especially if the anesthesia professional is not as familiar with the procedure. Patients undergoing general anesthesia need proper positioning and padding, deep venous thrombosis prophylaxis, and temperature management. Staff in NORA locations may not be as accustomed to implementing these interventions and may need to gather appropriate equipment.

PATIENT INFO	STAFF
Name: Date of Birth: Weight (kg): Allergies/comorbidities: Labs (COVID, pregnancy, INR): D/C Disposition:	Proceduralist: Anesthesia: RN: Tech: Clinic/Front Desk RN: 1 2 3 Staff with N95/PPE:
PROCEDURE INFORMATION	**EMERGENCY CONTACT**
Position: Anesthesia Machine check: Y/N Consents: Anesthesia exp: Procedure exp:	Anesthesia 1st Contact: OR Front Desk: On Call Anes. Pager: Caregiver:

Figure 1. Example of a NORA time-out checklist, showing the four main categories: patient, procedure, team members, and emergency contact.

3. Team—Team dynamics can be challenging, as members of the procedural team may not routinely work with anesthesia professionals. Establishing rapport with introductions may facilitate better teamwork and plays a crucial role in emergency response. The whole team should participate in the time-out to ensure everyone's questions have been answered and there is a shared understanding of the plan of care. At our institution, the anesthesia team was unsuccessful in establishing a time-out practice at one NORA location until we involved the entire team of physicians, nurses, and technicians in the process.[5]

4. Emergency response—One of the biggest challenges in NORA is its remote location, far from immediate availability of additional anesthesia personnel and life-saving equipment. Therefore, ensuring availability of emergency contact numbers for additional providers and anesthesia technicians is essential when help is needed. We have established a system of writing these contact numbers on a time-out whiteboard, ensuring all team members have this information and that someone other than the anesthesia team can call for help when needed. The location of the nearest code cart and malignant hyperthermia cart should be verified during the time-out.

For the time-out, we use a large whiteboard with prompts for all the key elements of the checklist (see Figure 1). We found that the visual cue of the elements of the checklist is key to a successful time-out. The visualized checklist creates a shared understanding of the plan of care, facilitates active participation, and ensures access to essential information throughout the procedure.

CONCLUSION

Establishing a time-out checklist requires more than simply providing a whiteboard and expecting people to use it. Like any quality improvement project, engaging the whole team is key to successful implementation. A successful time-out should include the issues proceduralists, anesthesia professionals, nurses, technicians, and patients have determined to be important to discuss prior to the procedure. Following implementation of the checklist, solicitation of feedback is crucial to long-term success. Having an anesthesia professional focused time-out alone is unlikely to be successful without engagement of other team members. Anesthesia professionals are often focused on hands-on tasks associated with placing lines and monitors, preparing for induction, and may be distracted from leading the time-out. We believe in emulating common OR practice where the proceduralist or circulating nurse leads the time-out. After implementation of the time-out, assessing compliance can establish expectations and ensure that the time out is integrated into the workflow of NORA locations.

Preventing adverse events and setting the stage for optimal response to unexpected events requires advance team preparation. Consistently performing a time-out before a patient is anesthetized for a NORA procedure establishes common ground for team members.

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Perioperative Surgical Home Initiative Markedly Reduces the Incidence of Acute Kidney Injury After Total Joint Arthroplasty

by Aldo Carmona, MD, Christopher Roscher, MD, Daniel Herman, MD, Robert Gayner, MD, Ajith Malige, MD, Brian Banas

The American Society of Anesthesiologists (ASA) defines a perioperative surgical home (PSH) as "a team-based model of care created by leaders within the ASA to help meet the demands of a rapidly approaching health care paradigm that will emphasize gratified providers, improved population health, reduced care costs and satisfied patients." The PSH model of care was used by a team at St. Luke' s University Health Network to reduce the incidence of Acute Kidney Injury (AKI) after elective total joint arthroplasty (TJA).

AKI is a known complication after total joint arthroplasty. Rates reported in the literature vary from 2 to 15% for elective cases.[1] The incidence of AKI may be underreported due to several factors. The absence of a creatinine measurement on postoperative day one, inconsistency in measuring urine output postoperatively, lack of recognition of AKI based on KDIGO criteria,[2,3] and institutional differences in coding may all contribute to underreporting. An episode of AKI postoperatively may have negative short and long-term implications for patients[4] and increased costs to the health care system.[5,6]

In 2016, a PSH-led initiative to reduce hypotension and AKI in our elective TJA population was initiated. A multidisciplinary team of anesthesia professionals, nephrologists, orthopedic surgeons, internal medicine hospitalists, nurses, EPIC analysts and a quality resource specialist was assembled. A protocol was developed and implemented with the following elements (Table 1):

- Screening of patients through our SOC (Surgical Optimization Center)
- Medication adjustment (ACE/ARBs/NSAIDs, diuretics) and standardized perioperative fluid replacement
- Standardized anesthetic management via ERAS protocol
- Withholding antihypertensive medications if systolic BP < 130
- Implementation of nursing-driven fluid protocol to allow postoperative treatment of hypotension (Table 2)

Table 1: Surgical Optimization Center AKI Risk Evaluation

• Hold ACE/ARBs/diuretics day before and after surgery
• Hold NSAIDs for 10 days prior to surgery
• Pre- and postop Nephrology consult for GFR<45 or AKI event in prior 3 months
• Nephrology interventions include: BP control (SBP 130-140 target), volume optimization, gentle prehydration day of surgery in select patients, avoiding nephrotoxic agents.

Table 2: Summary of Nursing Postop Hypotension Protocol

• Maintain SBP > 100
• BP checks q 1 hr x 4 hrs post procedure, then q 4 hrs x 12 hrs if systolic BP>100
• If SBP<100:
– Confirm in contralateral arm
– Administer 1 L bolus lactated ringers over 30 minutes and re-check BP in 1 hour
– If systolic BP < 90 after bolus, or <80 at any time, physician notified.

All patients undergoing TJA were included (Table 3). There were no exemptions for patients with pre-existing renal disease or revision surgery. Hypotension decreased from 12.7% to 5.9% and AKI from 6.2% to 1.2%. Further details of our PSH initiative were published in *The Journal of Arthroplasty* in June, 2018.[7]

Since this publication, further enhancements were made to the protocol. They included:

- Increased preoperative focus on high-risk patients with preoperative nephrology consultation for patients with GFR < 45 mL/min and addition of gentle preprocedure intravenous hydration where indicated
- Addition of continuous postoperative vital signs monitoring including continuous pulse oximetry and automated vital signs gathering and real-time input into Electronic Medical Record (EMR) using Masimo Root and Patient SafetyNet Technology, (Irvine, CA).
- Further leveraging of EMR to improve protocol compliance, as well as rates of early detection of significant vital signs abnormalities (i.e., use of "smart alerts," improved resolution of early-warning scoring systems via updating of EMR with continuous, real time vital sign monitoring)

After demonstrating success and sustainability at a single site, the protocol was expanded to additional network hospitals performing TJA. This included 21 additional surgeons performing procedures at nine hospitals. After network expansion, similar reductions in perioperative AKI from baseline were observed (5.9% to 0.6%) (Figure 1).

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Table 3: Patient Characteristics for the Perioperative Surgical Home Initiative to Reduce the Incidence of Acute Kidney Injury after Total Joint Arthroplasty

		1/2016–6/2016	7/2016–11/2018	>11/2018	Total
		Preprotocol	Protocol Phase 1 (single hospital)	Protocol Phase II (nine hospitals)	
Gender	Male	303	382	630	1315
	Female	521	567	819	1907
Age	<49 years	53	74	68	195
	50–59 years	216	212	337	765
	60–69 years	286	339	539	1164
	70–79 years	193	245	386	824
	80 years +	76	79	119	274
Total Hip		478	488	663	1629
Total Knee		498	511	711	1720

PSH Model Led to Reduced AKI in Patients Undergoing Total Joint Arthroplasty

From "Kidney Injury," Preceding Page

Overall, length of stay during this time period decreased from 2.75 days to 2.12 days ($p< 0.01$). Mortality rate was unchanged and 30-day readmissions were reduced from 3.8–3.2%, a trend which did not reach statistical significance.

At our University Hospital, based on KDIGO criteria, we have had a single case of AKI since November 2018 in 1,210 consecutive procedures (primary, revision, or previous renal disease all included) at the time of this publication.

In summary, a multidisciplinary approach in the PSH model has led to sustained reductions of a significant complication following an elective surgical procedure. It has also raised awareness to the value of enhanced vital sign monitoring and avoidance of hypotension in the perioperative setting. A growing body of evidence suggests that perioperative hypotension is both common and underdiagnosed. Post-operative AKI may be a marker of global hypoperfusion, and cardiac troponin elevations in TJA patients have also been reported.[8] Furthermore, hypotension is an important risk factor for perioperative myocardial injury after noncardiac surgery, which has been associated with worse perioperative outcomes.[9] It is plausible that further improvement to patient care can be realized by expansion of real-time vital signs monitoring to other patient populations at increased risk for perioperative hypotension and AKI.[10,11] Finally, although initiated by anesthesia professionals, the collaborative and multidisciplinary nature of this project was critical to its success. These outcomes could not have been achieved or sustained without our physician and nonphysician colleagues' input and collaboration. This is a hallmark of a mature Perioperative Surgical Home and a model for future patient improvement projects.

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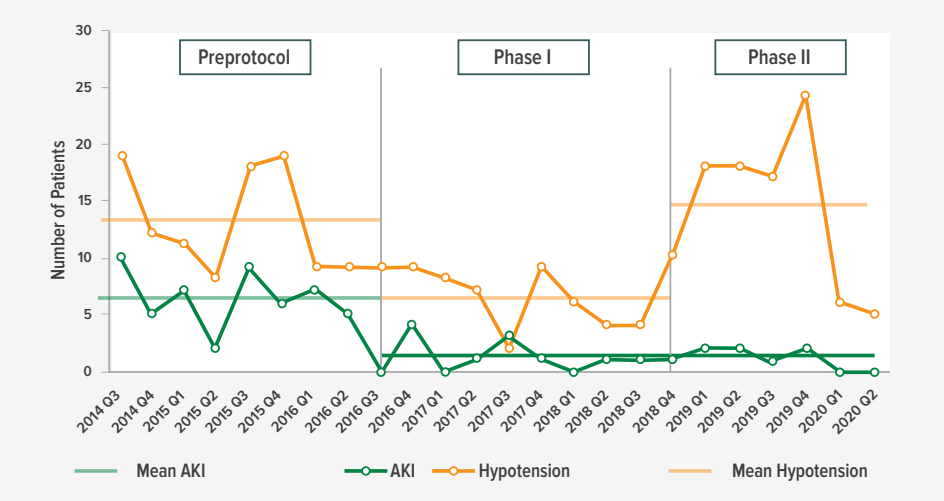

Figure 1: Changes in the frequency of perioperative hypotension and AKI before and during the 2 phases of the PSH initiative.

REFERENCES

1. Kimmel LA, Wilson S, Janardan JD, et al. Incidence of acute kidney injury following total joint arthroplasty: a retrospective review by RIFLE criteria. *Clin Kidney J.* 2014;7:546–551.
2. Kidney Disease: Improving Global Outcomes (KDIGO) Acute Kidney Injury Work Group: KDIGO clinical practice guideline for acute kidney injury. *Kidney Int Suppl.* 2012;1:1e138.
3. Luo X, Jiang L, Du B, et al. A comparison of different diagnostic criteria of acute kidney injury in critically ill patients. *Crit Care.* 2014;18:R144.
4. Coca SG, Yusuf B, Shlipak MG, et al. Long-term risk of mortality and other adverse outcomes after acute kidney injury: a systemic review and meta-analysis. *Am J Kidney Dis.* 2009;53:961–973.
5. Che1tow GM, Burdick E, Honour M, Bonventre N, Bates DW. Acute kidney injury, mortality, length of stay and costs in hospitalized patients. *JAM Soc Nephrol.* 2005;16:336570.
6. Silver SA, Chertow GM. The economic consequences of acute kidney injury. *Nephron.* 2017;137:297-301.
7. Lands VW, Malige A, Carmona A, et al. Reducing hypotension and acute kidney injury in the elective total joint arthroplasty population: a multi-disciplinary approach. *J Arthroplasty.* 2018;33:1686–1692.
8. Bass AR, Rodriquez T, Hyun G, et al. Myocardial ischemia after hip and knee arthroplasty: incidence and risk factors. *Int Orthop.* 2015;39:2011–2016.
9. Sessler D, Khanna A. Perioperative myocardial injury and the contribution of hypotension. *Intens Care Med.* 2018;44:811–822.
10. Futier E, Lefrant JY, Guinot PG, et al. Effect of individualized vs. standard blood pressure management strategies on postoperative organ dysfunction among high-risk patients undergoing major surgery: a randomized clinical trial. *JAMA.* 2017;318:1346–1357.
11. Wu X, Jian Z, Ying J, et al. Optimal blood pressure decreases acute kidney injury after gastrointestinal surgery in elderly hypertensive patients: a randomized study: optimal blood pressure reduces acute kidney injury. *J Clin Anesth.* 2017;43:77–83.

Time-Out Checklists

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The NORA time-out also increases awareness of anticipated events during the procedure, and facilitates methods for accessing additional help when needed. This process will ensure that routine procedures proceed more smoothly as concerns can be discussed ahead of time, and also helps establish the appropriate actions should an adverse event occur. Given the complexities of working in NORA, such advance preparation could prevent significant morbidity and even mortality.

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REFERENCES

1. Haynes AB, Weiser TG, Berry WR, et al. A surgical safety checklist to reduce morbidity and mortality in a global population. *N Engl J Med.* 2009;360:491–499.
2. Chang B, Kaye AD, Diaz JH, Westlake B, Dutton RP, Urman RD. Interventional procedures outside of the operating room: results from the National Anesthesia Clinical Outcomes Registry. *J Patient Saf.* 2018;14:9–16.
3. Walls JD, Weiss MS. Safety in non-operating room anesthesia (NORA). *APSF Newsletter.* 2019;34:3–4, 21. https://www.apsf.org/article/safety-in-non-operating-room-anesthesia-nora/. Accessed February 14, 2021.
4. Nagrebetsky A, Gabriel RA, Dutton RP, Urman RD. Growth of nonoperating room anesthesia care in the United States: a contemporary trends analysis. *Anesth Analg.* 2017;124:1261–1267.
5. Dudley R, Chang C. Time out for pediatric radiation therapy—a patient safety initiative. Poster session presented at 66th Annual Update in Anesthesiology, Park City, UT. February 2021.

LETTER TO THE EDITOR:

Perioperative Handovers in Low- and Middle-Income Countries

by Marta Ines Berrio Valencia, MD, MSc

Perioperative handovers involve knowing how to communicate in an efficient, organized, and coordinated manner. There are increasing publications about handovers in the literature, but most of them come from affluent nations. There is a lack of published information about perioperative handovers in low-income countries. The limited reporting on the topic in middle-income nations mainly deals with the intensive care unit (ICU) or the postanesthetic care unit environments. This situation could be caused by the lack of incentives for research in countries with fewer resources, but other potential explanations could apply to these nations.

Many anesthesia professionals do not receive education in handovers in medical and anesthesia curriculums; others do not use a standardized tool for a handover. In addition, recently, fewer human resources are located in the operating rooms because many anesthesia professionals have shifted their responsibilities to the needed support in the critical care units during the coronavirus pandemic. This has undoubtedly increased time constraints to develop standardized handovers and also has increased production pressure. The current organizational objectives might not be aligned with the importance of performing efficient handovers, which could result in no allocated professional time for education in proper patient handovers. On the other hand, proper training of professionals could reduce overall health care costs and increase production and satisfaction among patients and health care workers in the future. Another limitation in low- and middle-resources countries is the lack of integration of a handover into the electronic medical record (EMR). This integrated handover with the EMR could streamline the process of face-to-face communications such as the one presented by Mershon et al. in a recent *APSF Newsletter*.[1]

Recommendations for effective handovers suggest that the leader should check that all the relevant members are present and verify that the patient is hooked up to monitors and is stable before starting the handover.[2,3] During the handover, one person should speak at a time in an organized and coordinated manner.[4] The code status, the contingency plans with the use of "if-then" statements, the goals of treatment[4] or an explicit indication of no anticipation of adverse contingencies,[5] the action list with "who and when" will perform the pending tasks, a shared mental model with the active participation of the receiving team, and verbal confirmation of accepting the patient are all key components to the handover process success. A more advanced process entails several structured processes, including continuous feedback, readback, closed-loop communication, and cross-monitoring.[6,7] It means that handovers require ongoing education,[8] considering the experiences and backgrounds of the stakeholders.

Despite the barriers, having efficient leaders in anesthesia could motivate colleagues to embrace the challenge, engage with stakeholders, and expose the danger of not performing handovers to the institution to get support. For example, an anesthesiology leader could design a universal information form that fits straightforward cases and tailors to a specific surgical population during a small-scale implementation. The next phase would be receiving feedback from all stakeholders as a multidisciplinary collaborative approach, promoting its use, and emphasizing the importance of the structure of handovers through different resources such as institutional emails and meetings to empower staff to work as a team. Finally, the appropriate evaluation of the process, compliance, and professional satisfaction would require organizational support.

In conclusion, improving perioperative handovers in low- and middle-income countries will be a long journey, but it is a must for better teamwork dynamics and patient safety. Thanks to the APSF for being a leader in education in handovers and paving the way for many anesthesia professionals.

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REFERENCES

1. Mershon BH, Greilich PE. The MHC story: accelerating implementation of best practices through improved organizational macro-ergonomics updates from the Perioperative Multi-Center Handoff Collaborative (MHC). https://www.apsf.org/wp-content/uploads/newsletters/2021/3601/APSF3601.pdf. Accessed June 23, 2021.
2. Methangkool E, Tollinche L, Sparling J, Agarwala AV. Communication: is there a standard handover technique to transfer patient care? *Int Anesthesiol Clin*. 2019;57:35–47.
3. López-Parra M, Porcar-Andreu L, Arizu-Puigvert M, Pujol-Caballé G. Cohort study on the implementation of a surgical checklist from the operating room to the postanesthesia care unit. *J Perianesth Nurs*. 2020;35:155–159.
4. 8 tips for high-quality hand-offs. https://www.jointcommission.org/-/media/tjc/documents/resources/patient-safety-topics/sentinel-event/sea_8_steps_hand_off_infographic_2018pdf.pdf. Accessed June 23, 2021.
5. Jorro-Barón F, Suarez-Anzorena I, Burgos-Pratx R, et al. Handoff improvement and adverse event reduction programme implementation in paediatric intensive care units in Argentina: a stepped-wedge trial. *BMJ Qual Saf*. 2021 Apr 23;bmjqs-2020-012370. doi: 10.1136/bmjqs-2020-012370. Online ahead of print.
6. Berrio Valencia MI, Aljure OD. From intensive care unit to operating room: what about the transition of care of liver transplanted patients? *Can J Anaesth*. 2019;66:613–615.
7. Pocket Guide: TeamSTEPPS. Team strategies & tools to enhance performance and patient safety. https://www.ahrq.gov/teamstepps/instructor/essentials/pocketguide.html. Accessed June 23, 2021.
8. Agarwala AV, Lane-Fall MB, Greilich PE, et al. Consensus recommendations for the conduct, training, implementation, and research of perioperative handoffs. *Anesth Analg*. 2019;128:e71–e78.

Hiding in Plain Sight: Compassion as an Antidote to Burnout in the Post-COVID Era

by Christopher Cornelissen, DO, FASA; Brent Lee, MD, MPH, FASA; Stephen Rivoli, DO, MPH, MA, CPHQ, CPPS; Barbara Gold, MD, FASA, MHCM

CLINICAL VIGNETTE

DW is an anesthesia professional at a community hospital who takes call from home and just finished her last case at midnight. She was nodding off to sleep at 2:00 am when she was alerted by the OR front desk that she was needed to provide anesthesia for an elderly patient with a small bowel obstruction. Exhausted and less than enthusiastic about returning to the hospital, she met the patient in the holding area and went through the usual preoperative routine. The patient was frightened and apologized profusely to the operating room team that they all had to be called in to provide care in the middle of the night. DW reassured the patient that this was her job and that she spent many years training to do exactly this—to care for people that are ill and in pain, irrespective of the hour. The surgery proceeded without incident and in the recovery room, the patient was relieved and profoundly appreciative to the team for making it through surgery. DW recounted that when she left the hospital later that morning, she was exhausted yet invigorated and recharged from helping this frightened and distressed patient who benefited from her expertise. Despite her physical exhaustion, she was not upset or angry but felt connected to her colleagues and reaffirmed in her role as an anesthesia professional able to care for this patient during a time of great need.

THE CURRENT STATE

In October 2018, the *APSF Newsletter* described the trend of increasing burnout among anesthesia professionals.[1] Burnout is a syndrome resulting from chronic and unmanaged workplace stress, characterized by decreasing work effort, cynicism, and low physical and emotional energy levels.[2,3] Drivers of burnout can be divided into seven categories (see Table 1).[3,4] While studies to characterize and combat burnout are occurring, the phenomenon continues to escalate. In 2014, burnout rates of 50% were reported among anesthesia professionals and continue to be cited as a perioperative patient safety priority in 2021.[5,6] A survey conducted among members of the American Society of Anesthesiologists in March 2020 during the initial phases of the pandemic assessed burnout and demonstrated 59% were at high risk of burnout and nearly 14% met criteria for burnout syndrome.[7] The AANA has identified a paucity of research on burnout among anesthesia professionals while underscoring the threat of contributing factors such as increasing emotional exhaustion.[8]

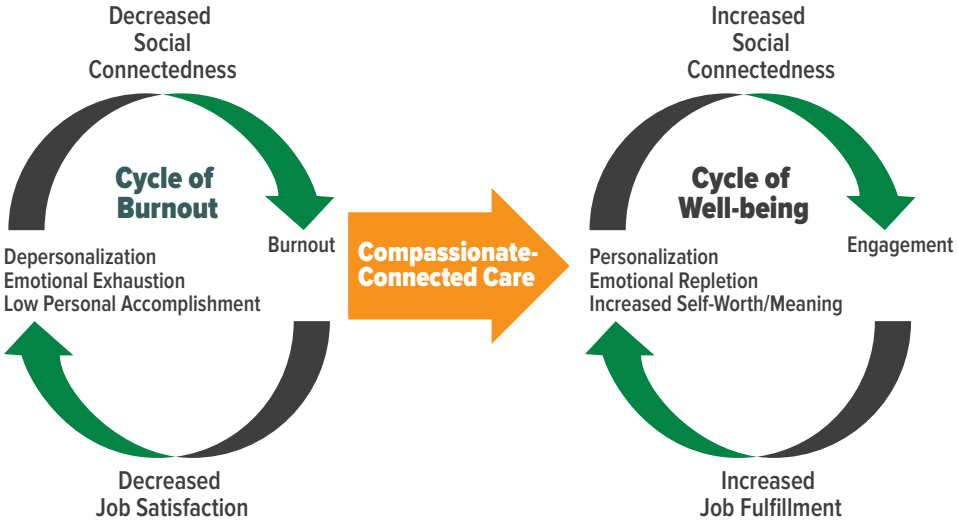

Figure 1. Cycles of Burnout and Well-Being.

BARRIERS TO EXPERIENCING CONNECTEDNESS

The COVID-19 pandemic which is associated with an increase in the prevalence of burnout among health care workers, has exacerbated many of the factors which contribute to burnout.[1,9] In a survey targeting the experiences of health care workers involved in the COVID-19 pandemic, 76% of respondents reported exhaustion and burnout and over one-third noted a lack of adequate emotional support.[10] Common concerns included an increase in emotional exhaustion (82%), difficulty with sleep (70%), physical exhaustion (68%), and work-related dread (63%).[10] A recent *Washington Post* article on the experiences of an anesthesiologist involved in airway management during COVID-19 compared the stress to working beside a nuclear reactor.[11]

A perceived lack of support in the workplace has been identified as one of the most important factors contributing to burnout.[7] In a pre-COVID environment, attempts to mitigate burnout at the institutional level included implementing tools such as flexible scheduling to enhance provider satisfaction, education for providers on the causes and symptoms of burnout, promotion of enhanced work-life integration, and providing resources to promote resilience and self-care.[1,3] However, during the height of the pandemic, many health promotional activities such as exercising in a gym, connecting in-person with friends and family, or traveling were significantly curtailed leading individual health care providers to cope on their own. COVID-19 has only amplified the limitations of existing approaches. As we slowly emerge from the pandemic, what are more effective strategies to mitigate burnout and promote clinician well-being? (See Figure 1.)

Many frontline workers have intuitively discovered during this pandemic that compassionate-connected care can be an effective antidote to neutralize each of the three hallmarks of burnout: emotional exhaustion, lack of personal accomplishment, and depersonalization (Figure 1).[12] The crux of the argument for compassionate care to mitigate burnout and enhance the anesthesia professional's connection to their profession lies in the idea that while empathy is simply

Table 1. Drivers of burnout and engagement in physicians.

Workload and job demands
Efficiency and resources
Meaning in work
Culture and values
Control and flexibility
Social support and community at work
Work-life integration

Adapted from *Mayo Clin Proc*[3,4]

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Compassionate Care May Help Rejuvenate Health Care Professionals

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the recognition and understanding of someone's pain and suffering, compassion is the "emotional response to another's pain or suffering, involving an authentic desire to help."[13,14] In other words, compassion involves not just feeling someone else's pain but taking the action to alleviate or eliminate it. By the very definition of the specialty of anesthesiology, anesthesia professionals are the experts at eliminating physiologic pain and suffering and derive satisfaction from seeing the direct impact of those actions in the service of others. These acts of compassionate care can be rejuvenating.

In addition to combatting burnout, the other benefits of compassionate care include improved patient safety, higher patient satisfaction, and even decreased cost of care.[15-18] Expanding compassion in clinical practice can increase social connectedness that extends beyond our patients and includes our colleagues and coworkers. It is important to note that the factors that have contributed to burnout, are in fact the very same barriers that prevent clinicians from connecting to their patients. These barriers include spending nonnegotiable time on clerical and billing functions in the electronic health record (EHR), production pressure that leads to hurrying and not connecting with patients, and taking short cuts due to staffing shortages. Given these powerful benefits of compassionate care, we, in partnership with our institutions should work to eliminate the barriers

and create systemic conditions that increase the ability of clinicians to connect with their patients and with each other.

SYSTEMIC CHANGES FOSTER ORGANIZATIONAL COMPASSION

To further mitigate burnout, health care institutions should foster a workplace culture of compassion to extend beyond patients and also include colleagues and coworkers. Strong interpersonal relationships are an important contributor to one's physical and emotional well-being.[19,20] In fact, strong human relationships may be a better predictor of one's health than traditional markers such as lipid levels.[15] Feeling connected both at home and at work can protect against burnout.[7] Additionally, institutions play an important role in breaking the cycle of burnout and can be crucial in emphasizing a culture of compassion for colleagues and in helping one another cope with the stressors that exist in anesthesia practice.

Various system-level interventions have been proposed to address the cycle of burnout, including assessing mental health needs, providing consistent childcare opportunities for frontline workers, allowing work hour flexibility, providing adequate personal protective equipment and COVID-19 testing, and offering reassurance that clinicians will not be relocated to other fields or suffer financial cuts.[21] Furthermore, to enhance compassion at the organizational level, institutions must continue to adjust expectations of increased productivity, excessive documentation, and administrative burden which are drivers of burnout. These external factors have been identified to increase pressure on health system leaders, managers and practice leaders.[22]

Numerous programs have been described that focus on enhancing the patient-caregiver relationship, which also remind clinicians why they entered the profession (Table 2). For example, the Schwartz Center Rounds enable health care providers to develop increased insight into social and emotional aspects of patient care, increasing the level of compassion towards patients, and decreasing feelings of stress and isolation.[16] Some institutions have spearheaded programs that feature organizational compassion cultivation training that can improve self-reported mindfulness, self-compassion and compassion toward others.[17] Though originating in a pre-pandemic environment, programs such as these may be extremely useful now to mitigate the effects of burnout in anesthesia professionals and other frontline health care workers and could be widely promoted by health care institutions in a spirit of promoting organizational compassion.

CONCLUSION

Stress and burnout can affect all health care providers. It existed long before the pandemic and will likely grow until we are able to recultivate the deep sense of professional satisfaction that comes with caring compassionately for the sick. Stated another way, "The practice of medicine has always been demanding and exhausting, and it always will be. It is the loss of the ability to care and the buffering of stress and exhaustion that come from caring deeply for and

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Table 2: Compassionate Care Resources for Health Care Providers.

Center for Mindful Self-Compassion	https://centerformsc.org/train-msc/
Cleveland Clinic- Communicate with H.E.A.R.T.	https://my.clevelandclinic.org/departments/patient-experience/depts/experience-partners/licensed-programs/communicate-with-heart
Compassion Resilience Toolkit	https://compassionresiliencetoolkit.org/healthcare/
Hillebrand Center for Compassionate Care in Medicine- University of Notre Dame	https://compassionatecare.nd.edu/healthcare-professionals/
Massachusetts General Hospital Empathy and Relational Science Program	https://www.massgeneral.org/psychiatry/research/empathy-and-relational-science-program
T. Denny Sanford Institute for Empathy and Compassion- University of California, San Diego	https://empathyandcompassion.ucsd.edu
The Schwartz Center For Compassionate Healthcare	https://www.theschwartzcenter.org/programs/schwartz-rounds/

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improving the quality of life of patients that have led to the current crisis of dissatisfaction and lack of well-being among many physicians."[18]

As DW in the clinical vignette experienced, it was during a time of stress that she was able to reflect on the connectedness to her patient and colleagues in her role as an anesthesia professional. We must be steadfast in combating the forces that impede the delivery of compassionate care and contribute to burnout. Whether they are financial pressures, production pressures or forces challenging the emotional connection formed with our patients, these pressures will always be part of the perioperative care landscape. In response, institutions in partnership with clinicians, can work to improve workplace support and, by extension, the ability for clinicians to provide compassionate care that is healing for patients and rejuvenating for clinicians such as DW. This is foundational to our commitment to deliver the safe, compassionate care that is emblematic of anesthesia professionals.

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REFERENCES

1. Tarantur N, Deshur M. Anesthesia professional burnout- a clear and present danger. *APSF Newsletter.* 2018;33:43–44. https://www.apsf.org/article/anesthesia-professional-burnout-a-clear-and-present-danger/ Accessed August 11, 2021.
2. Maslach C, Jackson S, Leiter M. Maslach Burnout Inventory. Maslach Burnout Inventory Manual (Fourth edition), Menlo Park, CA: Mind Garden, Inc. https://www.mindgarden.com/maslach-burnout-inventory-mbi/685-mbi-manual.html. Accessed July 5, 2021.
3. Shanafelt TD, Noseworthy JH. Executive leadership and physician well-being: nine organizational strategies to promote engagement and reduce burnout. *Mayo Clin Proc.* 2017;92:129–146.
4. Shanafelt TD, Mungo M, Schmitgen J, et al. Longitudinal study evaluating the association between physician burnout and changes in professional work effort. *Mayo Clin Proc.* 2016;91:422–431.
5. Warner MA. Improving perioperative patient safety: a matter of priorities, collaboration and advocacy. *APSF Newsletter.* 2021;36:3–4. https://www.apsf.org/article/improving-perioperative-patient-safety-a-matter-of-priorities-collaboration-and-advocacy/ Accessed July 5, 2021.
6. Del Grosso B, Boyd AS. Burnout and the nurse anesthetist: an integrative review. *AANA J.* 2019;87:205–213.
7. Alfonso A, Cadwell J, Staffa S, et al. Burnout rate and risk factors among anesthesiologists in the United States. *Anesthesiology.* 2021;134:683–696.
8. Farina CA, Horvath C, Lekhnych F, et al. Clinician burnout: how will we come through the fire? Guest editorial. *AANA J.* Online content August 2020:54–58. https://www.aana.com/docs/default-source/aana-journal-web-documents-1/farina-ge-r.pdf?sfvrsn=8fa2df1_4 Accessed July 5, 2021.
9. Kane, L. Death by 1000 cuts 2021: Medscape national physician burnout and suicide report. https://www.medscape.com/slideshow/2021-lifestyle-burnout-6013456 Accessed July 5, 2021.
10. Mental Health Screening Survey 2020, Mental Health America. https://mhanational.org/mental-health-healthcare-workers-covid-19. Accessed July 5, 2021.
11. Saslow, E. You're basically right next to the nuclear reactor. *The Washington Post*, https://www.washingtonpost.com/nation/2020/04/05/youre-basically-right-next-nuclear-reactor/?arc404=true. Accessed July 5, 2021.
12. Trzeciak S, Mazzarelli A. Compassionomics: the revolutionary scientific evidence that caring makes a difference. *Studer Group Publishing,* USA, 2019.
13. Wilkinson H, Whittington R, Perry L, et al. Examining the relationship between burnout and empathy in healthcare professionals: a systematic review. *Burn Res.* 2017;6:18–29.
14. Thirioux B, Birault F, Jaafari N. Empathy is a protective factor of burnout in physicians: new neuro-phenomenological hypotheses regarding empathy and sympathy in care relationship. *Front Psychol.* 2016;7:763. doi: 10.3389/fpsyg.2016.00763. PMID: 27303328; PMCID: PMC4880744.
15. Waldinger R. What makes a good life? Lessons from the longest study on happiness. TEDXBeaconStreet. https://www.ted.com/talks/robert_waldinger_what_makes_a_good_life_lessons_from_the_longest_study_on_happiness. Accessed July 5, 2021.
16. Lown BA, Manning CF. The Schwartz Center Rounds: Evaluation of an interdisciplinary approach to enhancing patient-centered communication, teamwork and provider support. *Acad Med.* 2010; 85:1073–1081.
17. Scarlet J, Altmeyer N, Knier S, et al. The effects of compassion cultivation training (CCT) on health-care workers. *Clinical Psychologist*, 2017;21:116–124.
18. Schwenk TL. Physician well-being and the regenerative power of caring. *JAMA.* 2018;319:1543–1544.
19. Hawkley LC, Thisted RA, Masi CM, et al. Loneliness predicts increased blood pressure: 5-year cross-lagged analysis in middle-aged and older adults. *Psychol Aging*. 2010;25:132–141.
20. Valtorta NK, Kanaan M, Gilbody S, et al. Loneliness and social isolation as risk factors for coronary heart disease and stroke: systematic review and meta-analysis of longitudinal observational studies. *Heart.* 2016;102:1009–1016.
21. Almeida M, DeCavalcante G. Burnout and the mental health impact of COVID-19 in anesthesiologists: A call to action. *J Clin Anesth.* 2021;68:110084. doi: 10.1016/j.clinane.2020.110084.
22. Hofmeyer A, Taylor R, Kennedy K. Fostering compassion and reducing burnout: How can health system leaders respond in the COVID-19 pandemic and beyond? *Nurse Educ Today.* 2020;94:104502. doi: 10.1016/j.nedt.2020.104502.

Primum Non Nocere But What Happens Next?

by Stephanie Lynn Davidson, DO, FASA

I was asked to write an article about second victim syndrome (SVS) as it was suggested that I may be an expert in the area. Let me state up front, I do not self-proclaim to be an expert in the area of SVS. I can say I've been a practicing anesthesiologist for 20+ years and during that time I am certain that I have experienced SVS on numerous occasions. Furthermore, on October 1, 2017, I was thrust into duty running point for an operating room caring for over 200 victims of the Las Vegas Mass Casualty Event[1] arriving at our trauma center Emergency Department over several hours. In processing this experience and in sharing the lessons learned from it, I came to understand that many patient-related adverse events are not over when the event ends. Therein lies my academic introduction to SVS. The multiple lectures that my husband (Nicholas Fiore Jr., MD, a pediatric surgeon) and I have given on our experience were incomplete without a discussion on SVS. The imprint this event left on me is indelible and every time I tell my story, the anxiety it produces gives way to a sense of healing after an emotional and psychological wrestling match.

The term *second victim syndrome* was coined by Albert Wu in 2000 and refined by Scott et al. in 2009[2] to describe the state of mind of a health care provider whose patient has experienced an unanticipated adverse event, medical error, or care-related injury as the "first victim." Second victims are health care providers who are involved in an unanticipated adverse patient event, in a medical error and/or patient-related injury, and are traumatized by the event. Frequently, these individuals feel personally responsible for the patient outcome. Many feel as though they have failed their patient and start to second guess their clinical skills and knowledge base. The term SVS has become internationally recognized by health care providers and managers as well as policy makers because it is memorable and invokes a sense of urgency. Simply put, the psychological trauma that follows a stressful event often with negative outcomes creates a second victim, the health care provider. Studies have shown that nearly 80% of health care providers experience and are psychologically impacted by a significant adverse event at least once in their career.[3] It is estimated that patient safety incidents (PSIs) occur in one out of seven hospitalized patients.[4] System failures occurring before a health care provider even enters the picture can lead to medical errors and unforeseen outcomes. Since PSIs can range from mostly near misses up to permanent harm or death, hospital systems increasingly realize their role in providing an institutional support system. Whether it be systemic error or provider-related, we feel liable for the outcome. A health care provider

involved in a PSI has an increased chance of developing post-traumatic stress disorder (PTSD).[4]

What do we know about the SVS? First, we must accept that it is extremely common. The prevalence is estimated to be 10.4–43.3% of providers following a traumatic experience.[5] Each of us will express our own reaction. These reactions can be emotional, cognitive, and behavioral. Our coping strategies can impact our patients, other providers, and our families, as well as ourselves. Some providers may feel not worthy of being labeled a second victim. The night of October 1st, one of our PICU nurses felt she had made no contribution to the care of our over 200 patients. She was stationed at one of the double doors from the ED to the OR and spent her time repeatedly hitting the door plate which opened the door allowing caregivers to pass back and forth. I told her I personally ran back and forth down that hallway over one hundred times to care for patients and I never waited for the doors because she was there. She experienced emotional trauma that evening as we all did.

How do we cope with SVS? Our mental health and how we respond to emotional stress is a unique part of each of us. We process, understand, cope, and come out the other side after a traumatic experience at our own pace. If we are not able to recognize the signs of SVS and learn how to cope we may end up developing physical symptoms including chest pain, headaches, poor concentration, hypervigilance, or sweating, to name a few.[6] Coping mechanisms to help rebuild or maintain personal physical strength and health include the following:

- Returning to daily activities which includes exercise, reading, socializing, journaling, or findings one's personal best.
- Interacting with family members who can provide comfort.
- Learning to process emotions and understand the experience.
- Finding and receiving help from friends and colleagues.
- Most importantly, knowing when to seek professional help.

Signals that you may need to seek out professional help from SVS may come from experiencing dreams and thoughts that evoke painful emotions and interfere with daily life. Others may notice dramatic changes in their behavior and try to assist you. If you experience thoughts of hurting yourself, seeking professional assistance and guidance through the healing process is a must. Your ability to cope may be influenced by your current personal circumstances, past experiences, and your core values and beliefs. Strength of relationships with loved ones and, of course, one's personal self-care and self-love are vital.

Intervention can help guide you through your experience and help you in processing your emotions.

As important as coping is resiliency. Through time and with maturity, one learns to bend without breaking. This requires acquisition of the tools to withstand the traumatic event and learn to recover quickly from difficult situations. Realizing the importance of a strong support network will help combat common reactions. We may experience mental and physical exhaustion, and may feel dazed, numb, sad, helpless, and anxious. These feelings can spiral downward, with the second victim replaying and reliving the experience over and over. Without intervention, long-term sequelae may evolve into PTSD, depression, suicidal thoughts, and/or alcohol or drug abuse.

I believe that we all have multiple SVS-producing experiences during our careers, some more powerful than others. Any time we feel responsible for an unexpected outcome, adverse event, or clinical error, it affects us. How can it not? The compassion and desire to help someone is at the very core of health care providers and makes us vulnerable to becoming the second victim. For example, when a partner calls you to recount a stressful patient experience resulting in an undesired outcome, whether or not patient harm ensues, aren't they simply expressing their feelings as a second victim? When something negative happens, as simple as missing an IV or more serious such as missing a STEMI, we first judge ourselves and feel responsible. You may have been in a situation where you "did all you could" and the outcome was not as favorable as you hoped. If this

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experience is not processed by our personal protective mechanisms in time, we may begin experiencing doubt, anxiety, depression, anxiousness, or even denial and fear of repeating the same mistake. Whether the patient's course culminates into a prolonged hospital stay or in a malpractice proceeding, we struggle to carry on. A basketball shooting guard on a cold streak may keep asking for the ball, believing his next shot will always go in. We often don't respond the same way. Instead, we wonder if everyone knows what happened. We ask will it pass and will our reputation be irreversibly affected? How can all this not lead towards the dreaded burnout syndrome? We are taught early in medicine to compartmentalize our feelings. Move on. Accept the outcome. Learn from it and do not repeat it. Don't let it get into your head. Family and friends may see this behavior as seemingly harsh, unsympathetic, or stoic when it involves personal family members.

Many have contributed to our understanding and treatment of SVS. Among those is Kathy Platoni, PsyD, who specializes in the treatment of PTSD and war trauma.[7] Throughout her career as a U.S. Army Psychologist, in both active and Army reserve status, she developed programs addressing combat stress control, and emphasized the importance of debriefings and crisis management. As a survivor of the Fort Hood Massacre herself she learned from personal experience and her well-known quote "Trauma is so very unforgettable" is often referenced.[7] She is an outspoken advocate declaring that a mass shooting is an act of terrorism.

Barbara Van Dahlen, another leader in the field of SVS, created **giveanhour** in 2005 to provide free mental health care to active duty, National Guard and Reserve service members. Their mission is to develop national networks of volunteers capable of assisting those that have experienced acute and chronic traumatic stress-related conditions that arise in our society. More recently **giveanhour** has partnered with ***#FirstRespondersFirst*** to offer mental health services during the COVID-19 pandemic. Their activities highlighted that SVS is not always directly related to a violent event. For example, a planned difficult airway where you call for assistance that evolves into a prolonged difficult intubation may leave you questioning your skills, decisions, the situation, and possibly yourself. While writing this review, I had a resident miss two IV attempts on an 18-month-old. After the case, she expressed how horrible she felt about the situation and that she hurt the baby. She expressed her concerns that she wasn't good enough to pursue pediatric anesthesia. We sat and we talked, a debrief of sorts, and went through the difficulties and successes of our day. I assured her with time, training, and dedication she would overcome this one obstacle.

The stages to recovery from SVS are well-described, not unlike the Kubler-Ross stages of response to death or loss.[8] Initially, the second victim has feelings of chaos and accident response, an initial loss of control provoked by the event. Ideally, the negative effect of the adverse event is limited by colleagues who help provide ongoing care and prevent additional harm. The second victim then replays the event in their mind and may have difficulty focusing or concentrating due to intrusive reflections. Again, peers play a vital support role as the victim works to restore personal integrity. This is not the end, however, as the inquisition and investigation ensues, possibly culminating in litigation. As one endures this stage, it's important to receive emotional first aid and seek peer or professional support. Finally, the second victim is hopefully able to move on and recover. Some practitioners, unfortunately, limit their practice and even leave clinical practice as a result of their traumatic experience.

On the first anniversary of the October 1st Las Vegas Mass Casualty Event, our hospital set up a lunchtime memorial for survivors and caregivers alike, an anniversary wake of sorts, to provide comfort for each other and search for meaning in the unspeakable terror we experienced together. Such an event is a circle that never closes, a story without an ending– but we were united by the understanding that we, and life, must go on. We cried till we laughed. We told stories and took pictures, celebrated life and life lost. And in the end, we all walked out the door of the meeting hall, together, tattooed with that experience and the belief that we would go on.

We as anesthesia professionals carry a substantial daily burden. Patient needs, practice demands, family requirements, and "satisfaction scores" from both our patients and the hospital system continually weigh on us. In today's immediate world, with instantaneous access to information from the internet, there is no tolerance for a poor outcome. Patients often arrive with their own WebMD diagnosis, treatment plan, and prognosis that they expect to play out without a hitch. This places our clinical practice under an increasing amount of scrutiny. In other professions mistakes are more readily accepted and at times even expected. How often do we take our vehicle in for service only to have to return back to the garage within a week when the 'service light' comes back on? We accept this, we tell ourselves this was not an unexpected outcome, and we just deal with it. In medicine "the light" coming back on is unquestionably unacceptable. The demands

and expectations that are placed on us hourly, daily, monthly, can lead to burnout. Burnout is higher in health care than any other industry. Our personal expectations continue to push us daily. But how far? When do our safety and our patient's safety become jeopardized? Managing the SVS, in ourselves and others, is an important component of professionalism. We should recognize the cause and teach ourselves how to mitigate the effects.

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REFERENCES

1. Woods A. "Is this real?': Seven hours of chaos, bravery at Las Vegas hospital after mass shooting". *The Arizona Republic*. November 11, 2017.
2. Scott SD, Hirschinger LE, Cox KR, et al. The natural history of recovery for the healthcare provider 'second victim' after adverse patients events. *Qual Saf Health Care*. 2009 5:325–530.
3. Vanhaecht, K, Sevs, D, Schouten L, et al. Duration of second victim symptoms in the aftermath of patient safety incident and association with the level of patient harm: a cross-sectional study in the Netherlands. *BMJ Open*. 2019,9:e029923.
4. Wu, AW, Shapiro, J, Harrison R, et al. The impact of adverse events on clinicians: what's in a name? *J Patient Saf*. 2020 16:65–72.
5. Seys D, Wu AW, Van Gerven E, et al. Health care professionals as second victims after adverse events: a systematic review. *Eval Health Prof*. 2013:36:135–162.
6. Karydes, H. Second Victim Syndrome: a doctor's hidden struggle. *Physician*, May, 2019.
7. Platoni, K. Personal bio. *Google*. 2021. www.drplatoni.com Accessed May 19, 2021.
8. Scott, S. The second victim phenomenon: a harsh reality of heath care professions. https://psnet.ahrq.gov/perspective/second-victim-phenomenon-harsh-reality-health-care-professions. Accessed May19,2021.

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