Postoperative Mortality – And How to Prevent It

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Intraoperative mortality has decreased by a factor of 10 in recent decades and is now so rare that it is hard to quantify (Lancet Reg Health West Pac 2023;37:100787; Eur J Anaesthesiol 1998;15:520-3). Consequently, clinicians and family often conclude that patients who arrive stable in the recovery unit have survived the most dangerous part of their perioperative experience. They have not, and their risk of dying in the next 30 days is more than 100 times higher than it was during surgery.

Postoperative mortality, defined as mortality within 30 days of surgery, remains roughly 1%, accounting for about 4 million deaths per year worldwide (more than from HIV, tuberculosis, and malaria combined). If the 30 days after surgery were considered a disease, it would be the third-leading cause of death worldwide (Lancet 2019;393:401).

Major causes of postoperative mortality

The most common causes of postoperative mortality are uncontrolled bleeding and cardiovascular complications. Sepsis is a distant third (JAMA 2017;317:1642-51).

Serious respiratory complications are rare, but nearly all preventable. Bleeding is not directly under anesthesia control, but there is overwhelming evidence that tranexamic acid reduces bleeding and transfusion requirements (N Engl J Med 2022;386:1986-97). Consequently, tranexamic acid should probably be used more often than it is.

Myocardial injury after noncardiac surgery (MINS) is the most common postoperative cardiovascular complication, occurring in about 8 million patients worldwide each year. It is defined by elevated peak postoperative troponin concentration with or without signs and symptoms of myocardial ischemia. Mortality is strongly correlated with troponin elevation (Figure 1).

More than 90% of MINS is asymptomatic. The diagnosis is therefore typically missed unless patients have scheduled troponin screening. At least four national bodies, including the American Heart Association, recommend a schedule of troponin screening in moderate- to high-risk surgical patients (Circulation 2021;144:e287-05). Troponin should be measured preoperatively and for two to three days after surgery in moderate- to high-risk patients because more than 90% of 30-day myocardial injury occurs during the initial two postoperative days (JAMA 2017;317:1642-51).

About 20% of preoperative high-sensitivity troponin assessments exceed the upper limit of normal (Clin Biochem 2011;44:1021-4). Elevated preoperative values do not indicate an infarction, nor do they meet the definition of MINS, which requires a concentration increase (JAMA 2017;317:1642-51). Elevated preoperative troponin concentrations should be considered an indication of high cardiovascular risk.

Diagnosis of myocardial injury is defined by elevated postoperative troponin concentrations that are believed to be consequent to myocardial ischemia. A challenge is that the thresholds defining troponin elevation depend on the assay generation and type. We suggest the following thresholds based on available literature:

1. Non-high sensitivity (fourth-generation) troponin T ≥0.03 ng/ml (JAMA 2012;307:2295-304).
2. High-sensitivity troponin T ≥56 ng/L; or high-sensitivity troponin T 20-64 ng/L and a ≥5 ng/L increase from baseline (JAMA 2017;317:1642-51).
3. High-sensitivity troponin I (Abbott assay) ≥60 ng/L (J Am Coll Cardiol 2020;75:110).
4. High-sensitivity troponin I (Siemens assay) ≥75 ng/L (Clin Chem 2023;69:492-9).

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.

Occasionally, patients will have preoperative troponin concentrations exceeding the thresholds in items 2-5. When that happens, clinicians should try to distinguish acute myocardial injury from chronic elevations. Whenever possible, troponin should be resampled because concentrations will usually change substantially in patients having an acute injury but otherwise remain nearly constant if they represent chronic elevation. For patients with a chronic elevation or an acute injury before surgery, a new myocardial injury after surgery requires identification of a new elevated troponin,
as per points 1-5 above. In such cases, the troponin elevation must be a 20% rise beyond the chronic troponin value or beyond the last measurement of the acute preoperative myocardial injury that was clearly demonstrated to have peaked and was coming down.

MINs is a type 2 supply-demand myocardial infarction (Circulation 2021;144:e287-05). MINs is strongly associated with subsequent type 1 infarctions in the ensuing months or years (Lancet 2018;391:2325-34). There is currently no known safe prophylaxis for myocardial infarction. Beta blockers reduce risk but cause strokes; clonidine, aspirin, avoiding nitrous oxide, and tranexamic acid have no effects one way or the other (N Engl J Med 2022;386:1986-97; Lancet 2008;371:1839-47; N Engl J Med 2014;370:1494-503; N Engl J Med 2014;370:1504-13; Lancet 2014;384:1446-54). However, both intraoperative and postoperative hypotension are associated with myocardial injury and myocardial infarctions (Figure 2) (Anesthesiology 2017;126:47-65; Anesthesiology 2018;13:317-27; Anesthesiology 2020;13:510-22; Br J Anaesth 2018;120:77-83). (Baseline factors such as history of cardiovascular disease are stronger predictors but are not modifiable.) Trial evidence for hypotension prevention remains equivocal, but a large trial is in progress (NCT04884802). Postoperative anemia and uncontrolled pain are also associated with myocardial injury after noncardiac surgery (JAMA 2017;318:1346-57; J Am Coll Cardiol 2021;78:1753-64; Ann Intern Med 2023;176:605-14).

Patients with MINs should be evaluated by cardiology (Heart 2022;108:695-702). Few will require invasive management such as cardiac catheterization. Since MINs patients have a high risk of subsequent infarctions, it is important that they be connected with physicians who can provide long-term care. They should also be considered for long-term treatment with aspirin, statins, and angiotensin-converting enzyme inhibitors. The only trial specific to MINs patients evaluated chronic anticoagulation in 1,754 randomized patients. Anticoagulation reduced the risk of major cardiovascular events over the subsequent one to two years by 28% (Lancet 2018;391:2325-34). Obviously, tachycardia and hypertension should be controlled as in all patients. Lastly, patients with MINs need to understand that they had a major cardiovascular event. They should be counseled about lifestyle changes that may reduce their future risk, including smoking cessation, healthful eating, and exercise.

Risk factors for postoperative respiratory depression include sleep apnea, obesity, morbid obesity, advanced age, and preexisting cardiovascular disease – none of which are modifiable (Anesthesiol 2020;131:1012-24). However, most critical ward respiratory events are probably triggered by opioids, which are under our control. Opioid-induced respiratory depression is typically diagnosed using surrogate measures such as hypventilation and/or oxygen desaturation (J Pain Palliat Care Pharmacother 2013;27:62-70; PLoS One 2018;13:e0194553). It is usually a diagnosis of exclusion and probably much underreported (Anesth Analg 2020;131:1012-24; Anesthesiology 2010;112:226-38).

The incidence of respiratory compromise on hospital wards, when defined by the need for interventions such as the administration of naloxone, is roughly 2% (BR J Anaesth 2016;116:632-40). The incidence rises to 20% when respiratory compromise is characterized by prolonged periods of oxygen desaturation and may be even higher when identified by episodes of bradypnea (Anesth Analg 2020;131:1012-24; Anesth Analg 2015;121:709-15). Respiratory complications are thus common, and, like myocardial injury, are frequently missed. Patients who experience opioid-related adverse events stay an average of five extra days in the hospital and are more often readmitted (16% vs 9%) (J Pain Palliat Care Pharmacother 2013;27:62-70).

How continuous ward vital sign monitoring can help

Monitoring practices within hospital wards have largely remained unchanged over the past half century, even though patients are now usually much sicker. Vital signs are nominally assessed at four- to six-hour intervals, with variable compliance (Int J Nurs Stud 2021;115:103849). Vital sign frequency matters because half of all serious postoperative cardiorespiratory episodes occur on surgical wards and most are preceded by hours of abnormal vital signs (Resuscitation 2016;105:123-9; Crit Care Resusc 2011;13:162-6). There is considerable evidence that detection of serious vital sign abnormalities is much delayed when monitoring is intermittent. For example, oxygen desaturation remains common on surgical wards. In a cohort of patients recovering from major surgery, saturation was <90% in more than 10% of all blinded continuous measurements by the second postoperative day (Figure 3). More than 10% of patients experienced a full hour with saturation <85%. Put another way, 20% of patients exhibited an average of 10 minutes of saturation below 90% per hour throughout their entire hospitalization. Nurses taking vital signs at four-hour intervals missed about 90% of all hour-long episodes with saturation <90% (Anesth Analg 2015;121:709-15). Missed episodes do not result from failure to take vital signs, nor because the process of obtaining vital signs stimulates patients to breathe better. Instead, missed episodes are a direct consequence of intermittent monitoring, with most events occurring between assessments (BR J Anaesth 2021;127:760-8).

Hypotension is also common on postoperative wards. Hypotension is frequently missed when vital signs are assessed at four-hour intervals. For example, in a cohort of patients recovering from major surgery, 18% experienced continuous episodes with MAP <65 mmHg (very low for a ward patient) lasting at least 15 minutes (Figure 4) (Anesthesiology 2019;130:550-9). In a broader population, hypotension on postoperative wards was less common but still substantial (J Clin Anesth 2023;89:111159). As might be expected, patients on monitored wards are half as likely to have a cardiopulmonary arrest (J Am Heart Assoc 2016;5:e003638).

Hypotension on postoperative wards is associated with myocardial injury and infarction, which are thought to result largely from supply versus demand mismatch. The combination of hypotension and hypoxemia might therefore be especially detrimental, although curiously, they almost never coincide (Anesthesiology 2018;128:317-27; Anesthesiology 2020;130:550-98).

Figure 4: Blinded (unavailable to clinicians) continuous mean arterial pressure measurements in 512 surgical inpatients. About 13% of patients had at least 30 continuous minutes with mean arterial pressure <65 mmHg, half of which were missed by nurses taking vital signs at four-hour intervals. From Turan and colleagues (Anesthesiology 2019;130:550-98).

Figure 5: Modern untethered wearable systems can now continuously evaluate a combination of physiologic variables such as blood pressure, heart rate and rhythm, oxygen saturation, respiratory rate, temperature, activity, body position, and location in ward patients. Real-time patient information from ward monitoring along with other patient-specific clinical information (electronic record, lab results) might go to an AI engine that will identify a fraction of patients (perhaps 10%) who are currently at risk and project information about these selected patients to a command center clinician for review. After review, the clinician – preferably an anesthesiologist – alerts the ward team to patients who need attention. Timely identification of high-risk patients will presumably allow clinicians to anticipate serious complications and intervene to prevent them, rather than trying to rescue patients thereafter. From Seissler and Saugel (BR J Anaesth 2019;122:504-6).
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133:510-22; Br J Anaesth 2018;120:77-83). Postoperative hypertension, tachycardia, and bradycardia are better detected with continuous monitoring than intermittent monitoring, but are less problematic than hypotension and desaturation (J Clin Anesth 2023;89:111159).

Continuous vital sign monitoring generates huge amounts of artifact-laden data. Nurses are not trained to deal with such data quantities, especially when compromised by frequent artifacts. And, of course, they already have full-time nursing responsibilities. Nonetheless, nurses do not object to continuous monitoring and report generally positive experiences (Int J Environ Res Public Health 2023;20:5794). There are better approaches, though.

With advances in technology, real-time vital sign data will soon be processed through artificial intelligence networks that can rapidly distinguish noise from clinically concerning trends. These filters will likely incorporate information from electronic records (e.g., date and type of surgery), last opioid dose, and known risk factors. Smart systems will evaluate patients’ trajectories, possibly identifying those at risk of injury before any specific vital sign crosses a static alert threshold, and well before serious clinical adverse events. The goal of such technology is to bring patients with adverse trajectories to the attention of a clinician—preferably an anesthesiologist—who can consider their current status, inspect relevant records, and make informed recommendations to ward clinicians (Figure 5).

Ward clinicians will then be positioned to intervene and prevent injury. Continuous ward monitoring is a new field, and much remains to be done. Available devices are limited, lack critical functions, and are often poorly validated. For example, blood pressure is arguably the single most important vital sign, and it is the hardest to measure accurately. Consequently, many continuous monitoring devices do not yet include blood pressure.

Continuous monitoring clearly detects vital sign abnormalities that are missed with intermittent monitoring. It is less obvious whether continuous monitoring provokes clinical interventions that reduce vital sign deviations. Two unpublished trials suggest that it does (N = 150 (NCT05280574) and N = 900 (NCT04574908)). The real question, though, is whether continuous vital sign monitoring reduces the risk of hard outcomes. Because event rates are low, huge trials will be needed to determine whether continuous monitoring improves substantive clinical outcomes such as myocardial injury and critical respiratory events.

Conclusions, and a way forward
Intraoperative mortality is now so rare that it is hard to quantify. In marked contrast, the postoperative period is the world’s third-leading cause of death. A third of 30-day deaths occur during the initial hospitalization—that is, while patients are under direct physician management in our highest-level health care facilities. Postoperative mortality is thus the major perioperative problem. Major bleeding and cardiovascular events are the most common causes. However, respiratory arrests also contribute and are largely preventable.

Two overriding factors contribute to preventable postoperative mortality: intermittent vital sign monitoring and lack of anticipatory medical management. Continuous wearable and untethered vital sign monitoring is already available. We know that continuous monitoring identifies serious vital sign abnormalities that are otherwise detected late or missed entirely. The other important factor is that ward surgical patients often get only cursory management of underlying medical problems. These preexisting conditions are often poorly controlled preoperatively and subsequently aggravated by the stress and inflammation of surgery. Many postoperative deaths are caused by just such aggravated underlying conditions.

Anesthesiologists are experts at interpreting continuous physiological data and responding to subtle deviations in real time to prevent catastrophic events. We also have a good understanding of underlying surgical and medical issues. Anesthesiologists are well positioned to move past the three-decade-old “failure to rescue” concept (waiting for disaster then trying to recover), instead moving toward preventing critical events by recognizing patient instability and intervening before patients are injured (Med Care 1992;30:615-29).

Our profession needs a fourth branch of anesthesia: intense postoperative management. The associated organizational, personnel, and financial challenges are substantial. However, intense postoperative management will potentially save tens of thousands of lives annually just in the United States.

Previous generations of anesthesiologists deservedly enjoyed a glorious legacy for solving intraoperative mortality. Now it is our turn. Together, we can solve postoperative mortality—earning ourselves a comparable shining legacy. Carpe diem. ■

Disclosure: Dr. Sessler is an advisor for Perceptive Medical and a consultant for Health Data Analytics Institute.