Management of Perioperative Hemodynamic Crises in the Operating Room and Postanesthesia Care Unit

Priya A. Kumar, MD, Professor of Anesthesiology, University of North Carolina School of Medicine, Chapel Hill

Perioperative mortality: 0.3 deaths in 10,000 cases attributed to anesthesia vs overall perioperative death rate of 11 in 10,000; survival rate for cardiac arrest occurring in perioperative setting much better than in other settings; most common causes of hypotension, central line placement, narcotics, spinal anesthetics, and local anesthetics

Reversible causes of hemodynamic collapse

Gas embolism: can occur as complication of laser bronchoscopy, laparoscopy, central line placement, operation in sitting position, or spine procedure; in addition to following Advanced Cardiac Life Support (ACLS) guidelines, speaker recommends placing patients in head down position, with left side tilted down, and aspirating through central line

Local anesthetics: may result in systemic toxicity; several cases reports demonstrate that prolonged cardiopulmonary resuscitation (CPR) and placement on extracorporeal membrane oxygenation or cardiopulmonary bypass, along with administration of lipid emulsion (Intralipid), can result in good outcomes

Anaphylaxis: commonly associated with muscle relaxants and antibiotics; supportive measures as specified by ACLS should be performed, as well as administration of epinephrine and antihistamines; tryptase level should be drawn within 30 to 60 min to establish diagnosis of anaphylaxis

Severe bronchospasm or central line placement: consider tension pneumothorax or cardiac tamponade

Neuraxial anesthesia: consider high spinal, especially in young healthy patients with low resting heart rate

Electrolyte disturbances: hyperkalemia, hypokalemia, and hypocalcemia should be considered, especially in massive resuscitation scenarios

Malignant hyperthermia: associated with anesthesia

Hypotension: commonly associated with anesthesia and usually transient; when persistent, emergency attention required because perfusion to end organs may decrease

Algorithmic approach: facilitates diagnosis, but single algorithm may not be sufficient to find cause; hemodynamic crises categorized as patient related, surgery related, or anesthesia related

Categorization by physiology: abnormality in heart rate or rhythm; preload — cause of abnormality may include dehydration or hemorrhage; afterload — cause may be anesthesia related (eg, general or spinal anesthesia) or drug related (eg, angiotensin-converting enzyme inhibitors or angiotensin II receptor blockers); myocardial contractility — cause of abnormality preexisting cardiomyopathy or iatrogenic

Diagnostic modalities: pulse pressure variation (requiring arterial line); filling pressures as determined by pulmonary artery catheter (utility in emergency setting limited because insertion is time consuming); transesophageal echocardiography (TEE); speaker’s approach — use combination of algorithms to diagnose refractory hypotension; consider anesthetic Hs (eg, hypotension, hypoxia, hydrogen ion [acidosis], hyper/hypokalemia) and Ts (eg, toxins, pericardial tamponade, tension pneumothorax, thrombosis [coronary or pulmonary])

Perioperative cardiac arrests: usually witnessed and occur in ideal setting (high-quality resuscitation and resuscitation experts readily available); comorbidities usually known; focused, etiology-based treatment can be undertaken

Case example 1: 32-year-old patient underwent nephrectomy; renal mass extended into inferior vena cava; TEE in place to locate extent of mass; as surgeon dissected mass, patient suffered hemodynamic collapse; patient not responsive to fluids and vasopressors; hyperechoic density seen floating in right atrium on TEE, most likely tumor embolus; patient arrested and CPR started; cardiac surgeons paged; patient placed on cardiopulmonary bypass; masses removed from heart and pulmonary artery; nephrectomy completed; patient discharged from hospital without neurologic deficits

Case example 2: 28-year-old woman with 25-week twin gestation and eclampsia emerged intubated for acute shortness of breath; patient became hypoxic and increasingly difficult to ventilate; TEE demonstrated partial collapse of right lung surrounded by massive amount of fluid; left hemithorax showed even more fluid; increased intrathoracic pressure resulted in decreased venous return and, hence, decreased preload (decrease in preload may also occur in tension pneumothorax or pericardial tamponade as result of central line placement); improvement of hemodynamics seen after placement of emergency chest tubes and drainage of 2 L of fluid

Case example 3: 35-year-old patient with burns scheduled for skin graft procedure; became progressively hypotensive despite resuscitation with fluids; fluids administered via triple-lumen catheter placed through introducer catheter in groin; TEE showed normal left ventricular contractility, but left ventricular cavity almost completely collapsed, with contact between papillary muscles (sign of hypovolemia); volume status notoriously difficult to assess in patients with burns; improvement seen after triple lumen removed and rapid infusor connected directly to introducer catheter

Case example 4: patient with end-stage renal disease scheduled for renal transplantation; received alemtuzumab (Campath;
monoclonal antibody) and became hypotensive; no response to fluids or vasopressors; anaphylactoid reaction suspected; patient given epinephrine but continued to deteriorate; TEE performed after preload, afterload, and contractility addressed; intraventricular septum (IVS) found to be hypertrophied; hypertrophied IVS commonly occurs in patients with hypertension; usually asymptomatic in awake state, but under anesthesia, with preload and afterload reduced and contractility increased (ie, epinephrine effect), systolic anterior motion of mitral valve may be unmasked; mitral valve contacts IVS and occludes left ventricular outflow tract in systole; occurs in setting of hypovolemia, hypertrophy of IVS, decreased systemic vascular resistance, and increased contractility; management consists of volume loading, decreasing contractility, and increasing afterload; patient treated with fluids; epinephrine stopped; phenylephrine administered; case illustrates combination of patient cause (ie, hypertrophy), surgeon cause (ie, administration of alemtuzumab), and anesthesia cause (ie, decreased afterload).

**Perioperative cardiac arrests, continued:** involve potentially avoidable events in hands of resuscitation experts; result in huge malpractice claims and payouts and tarnished reputations; often result of failure to recognize deteriorating situation; *American Heart Association Consensus Statement—survival from cardiac arrest depends on 3 factors: early recognition, immediate action, and high-quality CPR.*

High-quality CPR: 5 key points; chest compression fraction defined as proportion of time compressions applied from onset of arrest to return of spontaneous circulation; fraction should be >80%, but often <80% due to interruptions in airway management or intravenous placement; 100 to 120 compressions per minute recommended; depth of compression should be >2 in (or more than one-third of anterior-posterior diameter of chest); allow for full release; excessive ventilation leads to poor outcomes; use low tidal volumes (ie, 8-10 breaths per minute); CPR should be monitored to ensure good quality; invasive monitoring of blood pressure desirable; diastolic blood pressure should be >25 mm Hg, end-tidal CO₂ >20 mm Hg, and coronary perfusion pressure >20 mm Hg (measured as difference between diastolic pressure and central venous pressure); team leader should monitor person delivering CPR for fatigue.

**Opioids**

_Peter K. Schoenwald, MD. Associate Professor of Anesthesiology, Cleveland Clinic Lerner College of Medicine at Case Western Reserve University, and Staff Anesthesiologist, Department of General Anesthesia, Anesthesiology Institute, Cleveland Clinic, Cleveland, OH_

**Opioid receptors:** μ-receptor prototypical morphine receptor; stimulation of μ-receptor results in greatest analgesic response; κ-receptor responsible for binding agonist-antagonist compounds; endogenous enkephalins bind to δ-receptor; orphanin FQ/nociceptin binds to receptor of same name; inhibition of substance P at nerve terminal net result of opioid effect.

**Pharmacodynamics:** central nervous system—activation of receptors results in pain relief but also sedation; in neuroanesthesia, opioids decrease cerebral blood flow and cerebrospinal fluid production, and thereby decrease intracranial pressure (providing end-tidal CO₂ remains normal); whether spikes on electroencephalography (EEG; particularly at high doses) represent seizure activity subject of debate (tonic-clonic movements can be seen [depends on specific opioid given], but represent EEG changes rather than seizure activity); pupillary constriction occurs due to inhibition of Edinger-Westphal nucleus; nausea and vomiting—complex relationship exists between chemoreceptor zone, vomiting center, and vestibular center; pain directly stimulates vomiting center, yet opioids indirectly stimulate chemoreceptor zone and vestibular center, particularly in patients with history of motion sickness; tailor dose to each patient to minimize risk for nausea and vomiting.

**Cardiovascular effects:** opioids considered hemodynamically stable drugs with exception of meperidine, which causes myocardial depression; opioids may cause bradycardia, breakthrough tachycardia, or hypotension; release of histamine or activation of centrally mediated sympathetic tone may have indirect effect; addition of nitrous oxide results in myocardial depression; addition of 50% nitrous oxide results in near halving of cardiac output and reduction in blood pressure.

**Respiratory effects:** decrease in CO₂ and O₂ responsiveness; decrease in rate and rhythmicity of breathing; decrease in tidal volume (as dose increases); apnea (may occur in awake patients [ask patients to breathe]); cough suppression; release of histamine (may affect patients with asthma).

**Musculoskeletal effect:** truncal rigidity (depends on agent and speed of delivery; most often occurs when patients lose consciousness, but can occur in awake patients; treat by administering deeper anesthesia or muscle relaxants).

**Gastrointestinal effects:** decrease in gut motility; decrease in lower esophageal sphincter tone; increase in intestinal muscle and rectal sphincter tone; increased risk for gastroesophageal reflux; increase in residual gastric volume and secretions.

**Biliary effect:** increase in biliary pressure (increase low in patient taking butorphanol or meperidine but high in patient taking fentanyl); spasm of sphincter of Oddi relieved using naloxone.

**Renal effects:** urinary retention (because of increase in smooth muscle tone); increase in tone of detrusor muscle and bladder sphincter; morphine can cause release of antiuretic hormone and may decrease glomerular filtration rate.

**Hormone responses:** opioids may be useful in achieving “stress-free anesthesia”; increase in dose of opioids correlated with inhibition of gonadotropin-releasing hormone and corticotropin-releasing hormone; release of growth hormone and prolactin increases with opiate use.

**Pharmacokinetics:** most opioids leave blood rapidly and accumulate in parenchymatous organs; <1% of opioids enter brain; opioids must be un-ionized and nonprotein bound to enter central nervous system; most opioids accumulate, especially with repeat doses; accumulation age dependent, with clearance delayed in very young and very old.

**Advantages and disadvantages of opioids:**

- **Advantages—** hemodynamic stability; decrease minimal alveolar concentration of inhalation agents; not associated with renal or hepatic toxicity; **disadvantages—** potential for recall; hypotension; various side effects; potential for abuse; application—used for conscious sedation, in high doses for stability, and for analgesia as adjunct to general anesthesia.

**Pregnancy:** safe to use (ie, no teratogenic effect); however, chronic opioid use in mother may lead to dependence in fetus, and withdrawal may occur in infant; potential for respiratory depression in neonate exists if opiates administered acutely during labor (fetus has poor blood-brain barrier, and opiates readily cross placenta).

**Specific agents**

- Morphine: least lipophilic opioid and therefore less likely to penetrate and accumulate in tissues; has high hepatic transformation and active metabolites; relies on urinary excretion, so use with caution in patients with renal failure; plasma kinetics do not follow clinical effects because penetration of blood-brain barrier low; not highly (30%) protein bound.

- Meperidine: currently used in low doses for shivering; metabolized to active metabolites that in sufficiently high doses cause seizures (should not be used in patient-controlled analgesia [PCA] for this reason).

- Fentanyl: 2 orders of magnitude more potent than morphine; extremely fat soluble (has rapid onset and short duration with one-time dose); has long elimination half-life; accumulates after repeated dosing.
Suggested Reading


Acknowledgments

Dr. Kumar spoke at the 27th Annual Carolina Refresher Course: Update in Anesthesiology, Pain, and Critical Care Medicine, held June 25-29, 2014, at Kiawah Island, SC, and presented by the University of North Carolina School of Medicine and the Medical University of South Carolina. For information about upcoming CME activities from the University of North Carolina School of Medicine, please visit med.unc.edu/cpd. For information about upcoming CME activities from the Medical University of South Carolina, please visit cme.musc.edu. Dr. Schoenwald spoke at Comprehensive Anesthesiology Review, held March 24-29, 2014, in Cleveland, OH, and presented by the Cleveland Clinic Anesthesiology Institute. For information about upcoming CME activities from the Cleveland Clinic Anesthesiology Institute, please visit ccf.cme.org/go/anesthesreview. The Audio Digest Foundation thanks the speakers and the sponsors for their cooperation in the production of this program.

Accreditation: The Audio Digest Foundation is accredited by the Accreditation Council for Continuing Medical Education to provide continuing medical education for physicians.

Designation: The Audio Digest Foundation designates this enduring material for a maximum of 2 AMA PRA Category 1 Credits™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

The American Academy of Physician Assistants (AAPA) accepts certificates of participation for educational activities designated for AMA PRA Category 1 Credits™ from organizations accredited by ACCME or a recognized state medical society. Physician assistants may receive a maximum of 2 AAPA Category 1 CME credits for each Audio Digest activity completed successfully.

Audio Digest Foundation is accredited as a provider of continuing nursing education by the American Nurses Credentialing Center’s (ANCC’s) Commission on Accreditation. Audio Digest designates each activity for 2.0 CE contact hours.

Audio Digest Foundation is approved as a provider of nurse practitioner continuing education by the American Academy of Nurse Practitioners (AANP Approved Provider number 030904). Audio Digest designates each activity for 2.0 CE contact hours, including 0.5 pharmacology CE contact hours.

Expiration: The CME activity qualifies for Category 1 credit for 3 years from the date of publication.

Cultural and linguistic resources: In compliance with California Assembly Bill 1195, Audio Digest Foundation offers selected cultural and linguistic resources on its website. Please visit this site: www.audiodigest.org/CLCresources.

Estimated time to complete the educational process:

- Review Educational Objectives on page 1: 5 minutes
- Take pretest: 10 minutes
- Listen to audio program: 60 minutes
- Review written summary and suggested readings: 35 minutes
- Take posttest: 10 minutes

The California State Board of Registered Nursing (CA BRN) accepts courses provided for AMA category 1 credit as meeting the continuing education requirements for license renewal.
1. Which of the following are associated with abnormalities in afterload?
   1. Dehydration
   2. Spinal anesthesia
   3. Cardiomyopathy
   4. Angiotensin-converting enzyme inhibitors

   (A) 1,2 (B) 2,4 (C) 3,4 (D) 2,3

2. Tension pneumothorax is associated with which of the following abnormalities?

   (A) Decreased preload (B) Increased afterload
   (C) Reduced myocardial contractility (D) All the above

3. Systolic anterior motion of the mitral valve is associated with ______ preload and ______ afterload.

   (A) Increased; increased (B) Decreased; decreased
   (C) Increased; decreased (D) Decreased; increased

4. The recommended rate of ventilation during cardiopulmonary resuscitation is ______ breaths per minute.

   (A) 6 to 7 (B) 8 to 10 (C) 11 to 13 (D) 13 to 15

5. During cardiopulmonary resuscitation, it is recommended that end-tidal CO₂ be kept above ______.

   (A) 10 mm Hg (B) 15 mm Hg (C) 20 mm Hg (D) 30 mm Hg

6. Activation of which of the following results in the greatest analgesic response?

   (A) µ-receptor (B) δ-receptor
   (C) κ-receptor (D) Orphanin FQ/nociceptin receptor

7. Which of the following opioids causes myocardial depression?

   (A) Morphine (B) Meperidine (C) Fentanyl (D) Hydromorphone

8. Which of the following agents causes the greatest increase in biliary pressure?

   (A) Meperidine (B) Morphine (C) Fentanyl (D) Alfentanil

9. Which of the following accurately characterizes the pharmacologic properties of morphine?

   (A) Not highly protein bound (B) Metabolites not active
   (C) High penetration of blood-brain barrier (D) Not excreted in urine

10. Which of the following opioids is the safest for use in patients with liver and kidney failure?

    (A) Fentanyl (B) Alfentanil (C) Sufentanil (D) Remifentanil

Answers to Audio Digest Anesthesiology Volume 57, Issue 03: 1-B, 2-A, 3-C, 4-B, 5-A, 6-D, 7-D, 8-C, 9-B, 10-B