ANESTHESIOLOGY


THE ART AND SCIENCE OF ANESTHESIOLOGY

Opioids: Managing Pain in Patients with Neurocritical Illness
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Carbon dioxide (CO\(_2\)): most concerns about opioids relate to CO\(_2\) and its elimination; CO\(_2\) produced by glycolysis and aerobic metabolism; each molecule of glucose yields 2 molecules of acetyl coenzyme A, which in turn yield 4 molecules of CO\(_2\); CO\(_2\) penetrates blood-brain barrier; converted to protons and bicarbonate through carbonic anhydrase in cerebrospinal fluid, or enters medullary chemoreceptors

Regulation of breathing: nuclei (primarily those in pons and medulla) responsible for initiation of breathing; cortex also involved in respiration; pre-Bötzinger complex (located in medulla) found to act as respiratory pacemaker in animals (not fully proven in humans); carotid body and aortic body transmit signals related to O\(_2\) to respiratory center; CO\(_2\) more important than O\(_2\) for regulation of breathing

Effects of opioids on breathing: opioids affect all aspects of control of breathing; respiratory drive accelerates at PCO\(_2\) 40 mm Hg; opioids decrease respiratory drive; PCO\(_2\), 48 mm Hg indicates 50% reduction in CO\(_2\); clearance and indicates significant problem with minute ventilation or dead space; opioids induce hypercapnia; slight increase in PCO\(_2\) indicates significant decrease in elimination of CO\(_2\)

Sedation: study of titration of morphine in postanesthesia care unit (PACU) indicated 15 mg of morphine causes sharp increase in sedation; humans can experience pain while sedated; sedation undesirable side effect of opioids that can interfere with neurologic examination and mask pain; anticholinergic effect proposed as mechanism of sedation by opioids

Cerebral blood flow: relationship between CO\(_2\) and cerebral blood flow nearly linear from PCO\(_2\), 40 mm Hg to 100 mm Hg (important in relation to intracranial pressure)

Pain in neurocritical patients: historical solution to dismiss pain and disregard concerns about opioids; headache chief complaint following subarachnoid hemorrhage, but guidelines do not address management of pain; patients experience moderate to severe pain throughout hospital stay; patients with PCA again found to consume almost twice as much fentanyl as patients without; subsequent editorial questioned safety of PCA

Educational Objectives
The goals of this program are to improve the perioperative pain management of neurosurgical patients, the perioperative safety of patients with malignant hyperthermia (MH), and the cost-effectiveness of providing sedation. After hearing and assimilating this program, the clinician will be better able to:

1. Evaluate analgesic options for neurosurgical patients.
2. Implement strategies for the safe treatment of pain with opioids.
3. Assess the suitability of a freestanding surgical center for the care of patients with MH.
4. Project the effect of deployment of computer-administered personalized sedation system on anesthesia practice.

5. Maximize value by integrating new technologies and expanding the provision of sedation.

Faculty Disclosure
In adherence to ACCME Standards for Commercial Support, Audio Digest requires all faculty and members of the planning committee to disclose relevant financial relationships within the past 12 months that might create any personal conflicts of interest. Any identified conflicts were resolved to ensure that this educational activity promotes quality in health care and not a proprietary business or commercial interest. For this program, members of the faculty and planning committee reported nothing to disclose. In his lecture, Dr. Morad presents information related to the off-label or investigational use of a therapy, product, or device.
intraoperative local anesthetics including scalp blocks; dexamethasone beneficial and potent analgesia; administer long-acting opioids intraoperatively; use of remifentanil allows rapid emergence and performance of neurologic examination but does not provide pain relief; for spine cases, speaker uses methadone (has $N$-methyl-$D$-aspartate antagonist properties and achieves smooth level of analgesia); regularly assess sedation postoperatively using objective scale; utilize acetaminophen and adjuncts; titrate opioids to continuously measured respiratory goals; assess ventilation as well as oxygenation; consider PCA

**Suggested Reading**


**Patients with Malignant Hyperthermia in the Ambulatory Surgery Center: A Bad Idea**

Michael A. Phelps, MD, Clinical Instructor, Department of Anesthesiology and Critical Care Medicine, Johns Hopkins University School of Medicine, Baltimore, MD

Malignant hyperthermia (MH): patient known to be MH-susceptible inappropriate for treatment in ambulatory surgery center; rare life-threatening disorder involving uncontrolled calcium release from sarcoplasmic reticulum; triggered by volatile anesthetics and succinylcholine; can cause sustained muscle contractions and can lead to lactic acidosis, rhabdomyolysis, hyperkalemia, renal failure, and multiorgan failure; mortality 75% without treatment and 11.7% when treated with dantrolene; in 1983, Grinberg et al reported 3 cases of MH crisis after nontriggering anesthetics

Tests required for suspected MH crisis: arterial blood gases, myoglobin, lactate, electrolytes, and creatinine phosphokinase; most ambulatory surgery centers not equipped to perform these tests

Flushing volatile anesthetic from anesthesia machines: flushing for 20 min inadequate in modern anesthesia workstations; Brandom (2009) — after use of 1.5% isoflurane in Fabius GS machine, fresh gas flow of 10 L/min for 150 min required to reduce isoflurane to 5 ppm in inspiratory limb of circle breathing circuit; even after 150 min, concentration rose above 5 ppm when fresh gas flow reduced to 3 L/min

Maximum safe concentration: unknown for MH-susceptible patients; swine models suggest 5 ppm of anesthetic gas as safe threshold

Exposure to volatile anesthetics in PACU: Sessler et al (1998) analyzed gas in PACU; National Institute of Occupational Safety and Health 5% without ceiling of 2 ppm for volatile anesthetics; desflurane exceeded ceiling 50% of time and reached concentration of 6 ppm; Byhahn et al (2001) found concentrations of sevoflurane in PACU exceeded 5-ppm threshold by factor of 3

**Audience comment #1:** patient aged 9 yr developed MH during pediatric eye muscle procedure; speaker recognized symptoms within 16 min and initiated dantrolene therapy; child transferred to regional hospital and discharged 1.5 days later without complications; pediatric surgeon requested bringing child back to ambulatory center 1 mo later; other freestanding surgery centers in community would accept patient known to be MH-susceptible with preparation in advance; Malignant Hyperthermia Association consulted; speaker agreed to accept child in ambulatory center; insurance company insisted procedure be performed in hospital

**Audience comment #2:** ophthalmologist scheduled patient for cataract surgery in new freestanding center; patient had severe chronic bronchospastic obstructive pulmonary disease and cardiac ischemia with angina; procedure completed safely and patient discharged; ophthalmologist scheduled patient for second eye 3 mo later; anesthesiologist rejected case and recommended in-hospital procedure

**Audience comment #3:** primary sign of MH in children — cardiac standstill secondary to hyperkalemia; charcoal-activated filters now available; capable of reducing trace elements of gas to <5 ppm within 90 sec

**Audience comment #4:** audience member discloses he is founder and inventor of device for blocking inhaled anesthetics; flushing of Fabius machine requires 105 min to reach 5 ppm threshold; audience member reemphasizes that 5-ppm threshold derived from swine models

**Audience comment #5:** child aged 6 yr playing outside on hot day developed contractures; succinylcholine administered in emergency department; child died; example of unrecognized MH-related process

**Suggested Reading**


**Computer-Assisted Personalized Sedation for Procedures**

Steven D. Boggs, MD, MBA, Associate Professor of Anesthesiology, Icahn School of Medicine at Mount Sinai, New York, NY; Director, Operating Room, and Chief, Anesthesia Service, James J. Peters Veterans Affairs Medical Center, Bronx, NY

Advancements in technology: information delivery systems have changed dramatically over last 35 yr; agent-specific vaporizers have replaced copper kettles; blood pressure monitoring now automated; cost of computers has decreased over last 70 yr; treatment of biologic disease lags behind computer advancements; in 2012, colon cancer second leading cause of death in United States, with >100,000 cases diagnosed and >50,000 deaths; in 50- to 75-yr age group, 25% have never had screening colonoscopy, and of these, 25% have no insurance

Increasing demand for anesthesia: anesthesia expanded rapidly into “sedation space,” primarily for patients in American Society of Anesthesiologists (ASA) classes 1 and 2; supply of anesthesiologists projected to decrease after 2017, according to RAND study commissioned by ASA

Rationale for sedation: sedation provided to improve acceptability of procedures for patients and to facilitate performance of procedures; rates of cecal intubation and polyp detection during endoscopy higher with sedation; propofol provides more rapid onset, shorter duration of effect, more rapid recovery, fewer side effects, greater patient satisfaction, and similar rates of adverse events, compared with standard regimen of midazolam combined with narcotic

Models for sedation during endoscopy: procedures can be done without sedation; sedation options — provided by anesthesiologists, anesthesia care teams, or certified registered
nurse anesthetists; standard regimen of nonpropofol sedation administered by nonanesthesiologists; propofol administered by nonanesthesiologists (more common in Europe than United States); propofol administered by nurses; computer-assisted personalized sedation (CAPS)

**European experience:** propofol administered by nonanesthesiologists used extensively in Germany and Switzerland; outcomes no worse than those in United States; in Germany, 90% of colonoscopies accomplished with sedation, 97% use propofol, and 2% involve anesthesiologist

**Number of US procedures:** 98 million procedures eligible for moderate sedation performed in 2005; in 2015, 106 million procedures projected; for comparison, 40 million general surgical cases performed in 2011; market size for moderate sedation estimated $5 billion (in 2009 dollars); of this market, 40% considered suitable for CAPS; CAPS suitable for endoscopy, cardiology, general surgery, and many other specialties

**Safety of endoscopy:** Quine et al (1995) evaluated safety of upper endoscopy in 2 regions of United Kingdom and found mortality rate of 1 per 2000 cases because of lack of indwelling intravenous catheters, lack of supplemental O₂, and inadequate monitoring; *Rex et al* (2009) — examined ~650,000 cases of propofol sedation directed by endoscopists and found 4 deaths and 11 intubations; mask ventilation required in ~1 patient per 1000; if anesthesiologist present for all sedation cases and all deaths prevented, estimated cost per life-year saved $5.3 million

**CAPS system protocol:** administer loading dose over 3 min; continuous infusion and bolus doses given as indicated by physiologic response and procedural stimulation; CAPS system not PCA, not targeted anesthesia, and not closed-loop system; typical dose of propofol ~70 mg for esophagogastroduodenoscopy and ~106 mg for colonoscopy

**ASA guidelines for monitoring:** current CAPS systems meet criteria for sedation and analgesia for nonanesthesiologists; current systems utilize capnography and pulse oximetry, measure heart rate and blood pressure, and employ automated response monitor to determine level of consciousness

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**Acknowledgments**

Dr. Morad spoke at the Seventh Neurocritical Care for the General and Surgical Intensivist, presented by the Department of Anesthesiology and Critical Care Medicine, the Department of Neurology, and the Office of Continuing Medical Education of the Johns Hopkins University School of Medicine, and held March 11-13, 2016, in Baltimore, MD. For information on other CME opportunities presented by the Johns Hopkins University School of Medicine, please visit hopkinscme.edu. Dr. Phelps spoke at the 29th Annual Scientific Meeting of the Ophthalmic Anesthesia Society, presented by the Ophthalmic Anesthesia Society and held September 11-13, 2015, in Chicago, IL. For information on upcoming CME opportunities from the Ophthalmic Anesthesia Society, please visit eyeanaesthesia.org. Dr. Boggs spoke at the 69th Postgraduate Assembly in Anesthesiology, presented by the New York State Society of Anesthesiologists and held December 11-15, 2015, in New York, NY. For information on upcoming CME opportunities from the New York State Society of Anesthesiologists, please visit nysaa-pga.org. The Audio Digest Foundation thanks the speakers and the sponsors for their cooperation in the production of this program.

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**Estimated time to complete the educational process:**

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<tr>
<td>Review Educational Objectives on page 1</td>
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<td>Take pretest</td>
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**Suggested Reading**

1. A PCO₂ of 48 mm Hg indicates a _______ reduction in CO₂ clearance.
   (A) 30%  (B) 40%  (C) 50%  (D) 60%

2. The relationship between CO₂ and cerebral blood flow is nearly linear within which of the following ranges of PCO₂ values?
   (A) 20 mm Hg to 80 mm Hg  (C) 40 mm Hg to 100 mm Hg
   (B) 30 mm Hg to 90 mm Hg  (D) 50 mm Hg to 120 mm Hg

3. Studies have demonstrated that patients provided with patient-controlled analgesia (PCA) after intracranial surgery consume _______ fentanyl, compared with patients who received as-needed analgesia.
   (A) 50% more  (C) Three times as much
   (B) Twice as much  (D) Equivalent amounts of

4. A study that compared patients with and without opioid PCA after intracranial surgery found that those who received PCA had:
   (A) Lower minimum respiratory rate  (C) Lower maximum hourly opioid dose
   (B) Lower minimum saturation  (D) Less sedation

5. Which of the following is the mortality rate for untreated malignant hyperthermia (MH) events?
   (A) 45%  (B) 55%  (C) 65%  (D) 75%

6. According to a 2009 study, how long must a Fabius GS machine exposed to 1.5% isoflurane be flushed to decrease the isoflurane concentration to an acceptable threshold for MH-susceptible patients?
   (A) 60 min  (B) 90 min  (C) 150 min  (D) 180 min

7. According to animal models, which of the following is considered a safe concentration of volatile anesthetic gas for MH-susceptible patients?
   (A) 5 ppm  (B) 10 ppm  (C) 15 ppm  (D) 25 ppm

8. All the following are advantages of using propofol during endoscopy instead of midazolam combined with a narcotic, EXCEPT:
   (A) More rapid onset  (C) Significantly lower rates of adverse events
   (B) More rapid recovery  (D) Greater patient satisfaction

9. What proportion of the market for moderate sedation is suitable for computer-assisted personalized sedation (CAPS)?
   (A) 20%  (B) 40%  (C) 60%  (D) 80%

10. Experience with CAPS systems has shown that rescue with mask ventilation is required approximately _______ times per 1000 procedures.
    (A) 1 to 2  (B) 3 to 4  (C) 5 to 7  (D) 8 to 10

Answers to Audio Digest Anesthesiology Volume 58, Issue 23: 1-A, 2-C, 3-C, 4-D, 5-A, 6-D, 7-A, 8-B, 9-C, 10-B

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