Physiologic changes that affect practice of anesthesia

Expanding elderly population: number of Americans ≥65 yr of age increased from ≈2 million in 1900 to ≈40 million in 2010, and projected to more than double over next 30 yr; US Department of Health and Human Services performed National Hospital Discharge Survey (2006) found ≈28% of procedures requiring administration of anesthesia performed in patients >65 yr of age; elderly population 2.5 times more likely than younger patients to undergo procedures requiring general anesthesia (GA); data predict number of surgical cases in 2020 to be 25% to 45% greater than in 2000 (attributable to increase in elderly population and their need for procedures requiring anesthesia); elderly patients experience higher rates of complications and mortality from complications because of high prevalence of comorbid disease and reductions in organ system reserve; rates of myocardial infarction, cardiac arrest, pulmonary issues requiring ventilatory support, strokes, and comas markedly increase in patients >80 yr of age, compared with patients <80 yr of age; cost of medical care increasing dramatically and projected to increase from ≈$500 billion to nearly $900 billion over next 10 yr

Physiologic changes that affect practice of anesthesia

Airway: extension of neck decreased due to osteoarthritis; peripheral vascular disease increased, particularly in carotid artery and cerebral vascular system, which causes increased cerebrospinal insufficiency (especially with neck extension during laryngoscopy and intubation); mask fit and ventilation difficult in edentulous patients; mouth opening limited due to osteoarthritic changes; decreased cardiac reserve reduces tolerance of cardiac effects during laryngoscopy and intubation; blunted airway reflexes increase risk for passive aspiration

Physiologic age: organ function peaks in 30s, preserved in 40s, and begins to decline in 50s; speed of decline varies with state of health and organ reserve; acute or chronic debilitation may cause marked drop in organ function; careful history helps identify issues

Vascular system: decreased elastin production and collagen damage result in decreased arterial elasticity and compliance; stiffening of vascular system results in increased peripheral vascular resistance (afterload) and induces cardiac changes over time; cardiac changes — ventricular hypertrophy and diastolic dysfunction lead to dependence on atrial function for late diastolic filling and inability to tolerate changes in volume status (hypo- and hypervolemia should be avoided)

Autonomic changes: decreased response to β-adrenergic stimulation; elderly patients often present with resting bradycardia; decreased inotropic and chronotropic response to exercise and stress result in dependence on volume status to generate cardiac output; dampened baroreceptor reflexes lead to labile blood pressure in response to changes of position, induction of general anesthesia, and sympathoexcitation induced by regional anesthesia (RA)

Pulmonary: decreased lung compliance (due to loss of parenchymal elasticity and calcification of costochondral joints) reduces chest wall compliance, which results in decreases in vital capacity, expiratory flow (FEV1), and diffusion capacity; increased residual volume, closing capacity, dead space, and ventilation-perfusion (V/Q) mismatch also occur

Body composition: adipose tissue replaces lost muscle mass, which alters fluid dynamics of body components; decreased total body water and intravascular volume affect pharmacokinetics of drugs

Pharmacokinetics: effects of body on specific drug after its administration, through mechanisms of absorption, distribution, and metabolism; increase in body fat increases lipid reservoir and volume of distribution of fat-soluble medications; most anesthetic drugs (eg, induction agents, sedative hypnotic drugs, and narcotics) lipid soluble; increased volume of distribution in elderly results in increased duration of action; with water-soluble drugs (eg, muscle relaxants, propofol), decreased total body water results in high initial plasma concentration; liver — decreased albumin (possibly exacerbated by poor nutrition) results in decreased protein binding and increased free fraction of drugs; reduced liver parenchyma results in reductions in hepatic metabolism and bile secretion, and causes increased duration of action and decreased clearance of drugs metabolized in liver; kidney — decrease in cortical mass of kidneys and decrease in glomerular filtration rate (GFR) reduce renal clearance of anesthetic drugs; neuroaxial changes — reduced volume of cerebrospinal fluid (CSF) increases intrathecal concentrations of equivalent doses, with resulting high levels and increased duration of spinal blockade; similar effects occur after epidural blockade due to epidural fibrosis and foraminal narrowing

Pharmacodynamics: biochemical and physiologic effects of drugs and mechanisms of action on body, through uptake, movement, and binding; central nervous system (CNS) — cerebro atrophy with decreased white matter causes increased sensitivity to hypnotic drugs, opioids, benzodiazepines,

Educational Objectives

The goal of this program is to improve anesthesia management in the geriatric patient, and to improve anesthesia safety by applying lessons learned from real cases. After hearing and assimilating this program, the clinician will be better able to:

1. Outline age-associated physiologic changes and their implications for anesthesia
2. Adjust drug dosages based on the pharmacokinetics and pharmacodynamics of the elderly
3. Explain the difference between postoperative delirium and postoperative cognitive dysfunction
4. Minimize the risk for fires in the operating room

5. List the primary concerns when providing anesthesia for a patient who is a heart transplant recipient

Faculty Disclosure

In adherence to ACCME Standards of 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, the faculty and planning committee reported nothing to disclose.
and inhaled agents; peripheral nervous system — decreased myelination and decreased conduction velocity increase sensitivity to local anesthetics

Dose requirements: mean alveolar concentration (MAC) requirement significantly decreased in elderly; formula available to calculate MAC fraction based on age, but general rule follows linear decrease of 0.6%/yr or 6%/decade; 40-yr-old patient with MAC requirement of 1 will require 0.76 MAC fraction at age 80 yr; adjustment applies to all inhaled anesthetics; midazolam — lipid-soluble drug administered for anxiolysis; because half-life increases with age and cerebral atrophy increases sensitivity, reduction of dose by 50% to 75% and avoidance of repeat doses indicated; propofol — lipid soluble, but immediate onset of action depends on volume of distribution; initial injection into reduced intravascular volume results in high concentration; increased volume of distribution when administering propofol infusion results in prolonged half-life; CNS atrophy increases sensitivity, which necessitates reduced dose and reduced bolus for induction of anesthesia by 20% to 60%; lean body mass should be used to calculate dose; reduce concentration of infusion by 50% (in those that run for >60 min, duration of action markedly increased due to context-sensitive half-time); fentanyl — same principles of increased volume of distribution for lipid-soluble medications apply (diminished liver function requires reduction of dose, with careful titration); morphine — slightly more water soluble, but same principles apply; requires careful titration to allow for delayed peak effects; active metabolites (ie, morphine-6-glucuronide) accumulate, especially in patients with renal insufficiency

Muscle relaxants: water-soluble medications (eg, rocuronium, vecuronium) show higher plasma concentrations for given dose; decreased liver function prolongs half-life; reduced dose and use of nerve stimulator to guide intraoperative boluses recommended; succinylcholine — also water soluble (same principles apply); liver dysfunction decreases level of pseudocholinesterase, so dose based on lean body mass; K levels should be checked in patients with decreased renal function; avoidance of repeat doses or infusions prevents phase II blocks

Postoperative dementia (POD) and postoperative cognitive dysfunction (POCD): POD — acute temporary confusional state; manifested by transient and vacillating levels of consciousness, orientation, and cognition; POCD — persistent deterioration of orientation, cognitive function, and mental performance after surgery and anesthesia; both conditions associated with increased postoperative morbidity, mortality, length of hospital stay, nursing home placement, loss of ability to perform activities of daily living, and cost of medical care; risk factors — advanced age, preoperative baseline mental status, and medications administered; long-acting benzodiazepines, narcotics, and anticholinergic agents increase risk for POD and (possibly) POCD; other risk factors include depression, abnormal serum electrolytes, hypoalbuminemia, dehydration, blood loss, use of tobacco, respiratory complications, duration of surgery, infection, and major surgery (eg, hip, vascular, cardiac)

Anesthesia and POCD: animal studies provide evidence for anesthesia-induced cognitive dysfunction; mice demonstrate impaired memory and diminished learning capacity after exposure to volatile anesthetics during surgical procedures; however, such effects not observed when animals exposed to anesthetics without surgery, which suggests that systemic inflammation plays role; histologic evaluation of brain tissue from mice shows changes consistent with Alzheimer disease or apoptosis; human studies — require baseline cognitive evaluation before and after administration of anesthesia; literature shows some cognitive impairment ±48 hr postoperatively attributable to anesthesia; GA more likely than RA to cause short-term cognitive impairment; risk greater with sevoflurane than with desflurane, and lower with monitored anesthesia care; no permanent cognitive dysfunction noted when studies extended to 2 to 6 mo postoperatively; 5% to 20% of elderly patients develop POCD, but no clear cause or potentially preventive actions known; review of Alzheimer disease database shows rate of cognitive decline constant regardless of whether patients undergo surgery

Cases from the Real World

Barbara S. Gold, MD, Professor of Anesthesiology, University of Minnesota Medical School, Minneapolis

Case 1: 5-yr-old presents for tonsillectomy and adenoidectomy for treatment of recurring tonsilitis; otherwise healthy; examination unremarkable; inhalational induction of anesthesia and intubation uneventful; after removal of first tonsil, pledge burst into flames; flame extinguished with saline (endotracheal [ETT] tube did not ignite); area irrigated, dexamethasone (eg, Decadron, Dexasone, Diodex) administered, and airway inspected, with removal and replacement of ETT; course in postanesthesia care unit (PACU) uneventful; anesthesiologist and surgeon discussed events with parents; pediatric intensivist contacted, and child transferred to pediatric hospital; discharged next day without sequela; result — institution now uses only cuffed ETT for tonsillectomy and adenoidectomy; N2O omitted if FiO2 cannot be kept <30%; FiO2 kept to <30% and N2O omitted if uncuffed ETT used; all pledgets soaked in saline; suction cautery used in oropharynx; saline kept close at hand

Surgical fires: more common in days of flammable anesthetics (eg, ether, cyclopropane); insidious hazard; oxygen accumulates under drapes; at times, alcohol preparation agents not allowed to fully dry; recognition of risk by clinicians limited, with little collaboration and no availability of technologic remedies (eg, fire-retardant drapes); operating room (OR) fires rare but considered high priority medical error; anatomy of OR fires — primarily affect face, head, neck, and upper chest, with airway also affected (injury to rest of body infrequent); almost all events involve oxygen-enriched area; misconceptions — drapes fire retardant; betadine skin preparation flammable; obtaining fire extinguisher should be first response (all 3 erroneous); fire triangle — surgeon responsible for heat, perioperative staff manages fuel (eg, drapes), and anesthesia provider handles oxygen source; fuel — many objects (eg, gauze, sponges, towels, drapes, plastics) flammable; ignition sources — cautery; fiberoptic scopes; lasers; microscopes; hyperthermia units; oxygen — supplemental O2; N2O

Categories of fire risk: 0 to 1 — usual hazard; 2 — additional hazard, but no action required (eg, patient receiving monitored anesthesia care with supplemental oxygen for surgical procedure on toe); 3 — requires different approach from all staff in OR; 3-point system, with one point each awarded for open oxygen source (face mask or nasal cannula), use of ignition source or heat-generating device (eg, cautery, endoscope); surgery above xiphoid; all staff made aware (included in presurgical brief); anesthesia provider communicates form of oxygen delivery (eg, ETT, open source) and alerts team if patient requires FiO2 >30% during case; open-source oxygen delivered at ≤30%, as appropriate; surgeon alerts anesthesia team before activating ignition source to allow interruption of flow of oxygen for ≥1 min; area around face flushed with air when >30% open-source oxygen required

Algorithm for procedures above xiphoid process (Anesthesia Patient Safety Foundation [APSF]): if patient at risk for surgical fire requires >30% supplemental O2, secure airway with ETT or supraglottic device (not possible for all patients or procedures, so communication with surgeon required); fire in ETT — pull out ETT; stop flow of gases; remove all
flammable material from airway; have another person extinguish burning material; reintubate patient; provide saline lavage to cool tissue; reestablish ventilation and perform bronchoscopy; APSF video about surgical fire available on website (www.apfs.org/resources video.php)

**Case 2:** 17-yr-old high school baseball player presents for elbow arthroscopy 4 yr after heart transplantation; cardiac catheterization revealed clear coronary arteries and ejection fraction (EF) 68%; examination unremarkable; intracavitary block and induction of GA uneventful; asystolic pauses noted during case, but patient remained hemodynamically stable; patient extubated, taken to PACU, and admitted to pediatric intensive care unit, with no further episodes of asystolic pause

**Anesthesia issues after heart transplantation:** denervated heart; risk for rejection (decreases EF); infection (due to immunocompromise); allograft coronary artery disease; hypertension; during transplantation, diseased heart removed, but atrial cuff retained; arteries cut and cardiac plexus interrupted; recipient atrium remains innervated but hemodynamically unimportant; donor atrium controls response of transplanted heart (2 P waves possible); recipients very dependent on volume (unable to increase heart rate); they respond to α- and β-adrenergic receptors, but not to Valsalva or carotid sinus massage; often have elevated intrinsic rate; anesthesia implica-
tions — heart rate does not increase acutely, and cardiac output preload-dependent; response to indirect-acting agents (eg, atro-

**Suggested Reading**

Cheng DC, Ong DD: Anesthesia for non-cardiac surgery in heart-transplanted patients. Can J Anaesth 1993 Oct;40(10):981-6; Collins KK et al: Atrial tachyarrhythmias and permanent pac-
gement of paediatric organ recipients in nontransplant surgery.

**Acknowledgements**

Dr. Hong was recorded at Anesthesiology Update 2013, held November 16, 2013, in Los Angeles, CA, and sponsored by the Depart-
ment of Anesthesiology, David Geffen School of Medicine at UCLA. Dr. Gold was recorded at Aspen Anesthesia — New Develop-
ments and Controversies, held February 2-9, 2013, in Snowmass, CO, and sponsored by Holiday Seminars. For information on upcoming meetings sponsored by Department of Anesthesiology, David Geffen School of Medicine at UCLA, please visit cme.ucla.edu, and for those sponsored by Holiday Seminars, please visit holidayseminars.com (or check our website, Audio-Digest.org, under “Upcoming Meetings”). 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 Accredita-
tion 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 Credit™ Physicians

**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 lin-
guistic resources on its website. Please visit this site: www.audiodigest.org/CLResources.

**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

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

Audio-Digest Designates each activity for 2.0 CE contact hours, including 0.5 pharmacology CE contact hours.

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.

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

**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

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

Audio-Digest Designates each activity for 2.0 CE contact hours, including 0.5 pharmacology CE contact hours.

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.

**Expiry:**

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 lin-
guistic resources on its website. Please visit this site: www.audiodigest.org/CLResources.

**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
1. Organ function peaks between 20 and 29 yr of age.
   (A) True (B) False

2. Which of the following changes in the autonomic nervous system is commonly observed in elderly patients?
   (A) Resting tachycardia
   (B) Increased response to β-adrenergic stimulation
   (C) Increased baroreceptor reflexes
   (D) Decreased inotropic and chronotropic response to exercise and stress

3. Pharmacokinetics of the elderly patient result in ______ duration of effect from lipid-soluble medications and ______ initial plasma concentrations with water-soluble medications.
   (A) Increased; high
   (B) Increased; low
   (C) Decreased; high
   (D) Decreased; low

4. Which of the following drugs has both water-soluble and lipid-soluble characteristics?
   (A) Midazolam (B) Propofol (C) Fentanyl (D) Rocuronium

5. Select the true statement about postoperative cognitive dysfunction.
   (A) The rate of cognitive decline in patients with Alzheimer disease is accelerated after general anesthesia
   (B) Exposure to desflurane is more likely to cause cognitive impairment than exposure to sevoflurane
   (C) Cognitive impairment attributable to anesthesia has been observed ≤48 hr postoperatively
   (D) Postoperative cognitive dysfunction has been documented to persist ≤6 mo after general anesthesia

6. Which region(s) of the body is(are) most commonly affected by surgical fires?
   (A) Face, head, neck, and upper chest (C) Abdomen
   (B) Eyes (D) Hands

7. Which of the following statements about prevention of and response to operating room fires is correct?
   (A) Surgical drapes are fire retardant
   (B) Betadine is flammable
   (C) Obtaining a fire extinguisher is the first course of action
   (D) None of the above

8. To help prevent fires in the presence of open-source oxygen, the flow of oxygen should be stopped for ______ before cautery is used.
   (A) 15 sec (B) 30 sec (C) 45 sec (D) 60 sec

9. It is possible for a denervated heart to show 2 P waves on electrocardiography.
   (A) True (B) False

10. A transplanted heart shows the most significant rate response to which of the following?
    (A) Valsalva maneuver (C) Direct-acting β agonist
    (B) Carotid massage (D) Indirect-acting agent

Answers to Audio-Digest Anesthesiology Volume 56, Issue 05: 1-A, 2-D, 3-C, 4-B, 5-A, 6-D, 7-C, 8-A, 9-C, 10-B