Challenges in Pediatric Anesthesia

From the 2015 Comprehensive Anesthesiology Review, presented by the Cleveland Clinic Anesthesiology Institute

Pediatric Pharmacology

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Physiology of children: respiratory — respiratory rate and minute ventilation higher in children because of increased oxygen consumption; relative to adults, children tend to desaturate more quickly because they have fewer alveoli, “floppy” airways with tendency to collapse, and smaller diameter of airways with higher resistance; cardiovascular — in children, stroke volume depends on great extent on heart rate; in infants, bradycardia occurs in times of stress because sympathetic nervous system immature; liver — in neonates, gluconeogenesis inefficient, so dextrose often included in fluid replenishment formulas; because fewer proteins available for binding of drugs, concentration of free fraction of drugs may be increased and effects possibly prolonged and potentiated; central nervous system — not fully mature (including blood-brain barrier) until age 12 yr; morphine often avoided in neonates and infants because peak concentration in brain 3 times higher than that in adults; children more sensitive to all sedatives, especially those with altered respiratory drive (eg, obstructive sleep apnea [OSA]); metabolism of glucose and oxygen twice that of adults because of rapid growth and synaptogenesis

Pharmacology of inhalation agents: minimum alveolar concentration (MAC) highest in infants 1 to 6 mo of age; wash-in effect — while functional residual capacity (FRC) remains static, alveolar ventilation changes with age; because neonatal ratio of alveolar ventilation to FRC 5:1 (vs 1.5:1 in adults), alveolar concentration in neonates approximates inspired concentration, thereby allowing faster inhalation induction; halothane — common side effects in children include breath holding, laryngospasm, and dysrhythmias; sevoflurane — toxicity less likely than with halothane; causes less hemodynamic variability; risk for emergence delirium increased; delirium treated with, eg, opioids, propofol, and (in severe cases) dexamethasone; delirium may be associated with pain (incidence of delirium 3 times less when ketorolac or caudal anesthesia administered)

Propofol: painful on injection; dose higher in children (350 μg/kg/min) than in adults because distribution and metabolic rate higher; propofol infusion syndrome — caused by accumulation of toxic metabolites; seen when given ≥2 days at doses of ≥70 μg/kg/min; manifested as severe metabolic acidosis, rhabdomyolysis, bradycardia, and cardiac arrest; mortality rate high; mortality reduced when dialysis initiated early and other substrates (eg, carbohydrates) administered

Benzodiazepines: midazolam (Versed) often given as premedication; may be given orally (bioavailability 15%-20%) or intranasally (bioavailability 50%); some patients exhibit paradoxic excitable response

Ketamine: has analgesic and hypnotic properties; at high doses (>2 mg/kg), can cause airway obstruction and hypotension, especially in the presence of adrenal insufficiency; exerts effects by inducing catecholamine secretion; causes increased secretions, so concomitant administration of antiserotonin agent (eg, glycopyrrolate) should be considered

Opioids: immature blood-brain barrier in children increases risk for respiratory depression; fentanyl can quickly cause rigidity of chest wall and bradycardia secondary to immature sympathetic nervous system; remifentanil only medication that has increased clearance in neonates, compared with adults

Other medications: acetaminophen may be given intravenously, usually over 10 to 15 min; ketorolac — previously not given to neonates and infants because of concern about renal injury; however, safe to give in healthy hydrated patients with adequate voiding; codeine — has fallen out of favor; neither O-demethylation, nor conversion to morphine, nor clinical effect seen in poor metabolizers, who lack cytochrome P450 2D6 enzyme; polymorphisms in enzyme also produce ultra-extensive metabolism, which can lead to respiratory depression (particularly dangerous in patients with OSA or disruptive sleep patterns, who have upregulated opioid receptors secondary to chronic nocturnal hypoxia); dexmedetomidine — increasing in popularity; has protective effects against apoptosis and neurobehavioral disorders

Neuromuscular agents: nondepolarizing — when evaluating return of strength and function in infants <6 mo of age, hip flexion more useful than head lift, but function of orbicularis oculi best correlates with recovery of diaphragm and vocal cords; for rapid sequence intubation, rocuronium (1.2 mg/kg) may be used in place of succinylcholine if no difficulty in intubation anticipated

Succinylcholine: should be reserved for emergency intubation or when immediate securing of airway necessary (eg, laryngospasm, difficult airway, full stomach); may cause increase in intraocular or intracranial pressure, potassium release, induction of masseter spasm, and triggering of malignant hyperthermia (MH); when concerned about these side effects, consider whether risks outweigh those associated with substituting rocuronium (ie, possibility of losing

Educational Objectives

The goal of this program is to improve the anesthetic management of neonates and patients with congenital heart disease. After hearing and assimilating this program, the clinician will be better able to:

1. Explain the unique pharmacology of inhalation agents in infants.
2. Evaluate the role of propofol, ketamine, and neuromuscular agents in the anesthetic care of neonates and infants.
3. Choose appropriate fluid therapy for neonates and infants.
4. Employ appropriate anesthetic strategies for patients with pulmonary hypertension.

5. Identify the preferred anesthetic agents for patients with congenital heart disease.

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 her lecture, Dr. Rodriguez presents information related to the off-label or investigational use of a therapy, product, or device.
Anaesthetic tool becoming an intensive care liability

Fluid management:

In children: pharmacokinetic maturation.

Neonates.

Neonatal physiology:

Alina Bodas, MD, in the Pediatric Patient

Inhalation induction: negative feedback — if patient allowed to breathe spontaneously, respiratory center automatically tempers alveolar and minute ventilation; positive feedback — if overpressure used (eg, vaporizer dialed to 8%), which consistently delivers dose of agent with each breathe), alveolar fraction reached quickly; this can lead to hemodynamic compromise

Laryngospasm: risk factors in young children include recent illness or fever, findings on lung examination, otolaryngologic procedures, history of OSA, and exposure to tobacco or environmental pollutants; early detection and rapid intervention crucial; apply sustained jaw thrust and positive-pressure ventilation; can be treated with high-dose propofol or succinylcholine; in younger children, positive pressure tends to insufflate stomach and result in tight spasm

Apoptosis: defined as scheduled cell death triggered by intrinsic or extrinsic cellular events; risk highest during period of rapid brain growth (ie, from third trimester of pregnancy to age 3 yr); imbalance in apoptosis can lead to atrophy or cancer; most medications used in anesthesia implicated in causing neurodegeneration; however, opioids, nondepolarizing muscle relaxants, dexamethasone, and xenon have little or no effect.

Suggested Reading


Fluid and Electrolyte Management in the Pediatric Patient

Alina Bodas, MD, Staff Anesthesiologist, Department of Pediatric Anesthesia, Cleveland Clinic, Cleveland, OH

Neonatal physiology: characterized by higher fluid requirements per kilogram, higher metabolic rate, and increased insensible fluid losses, compared with adults; water loss inversely related to weight and gestational age; neonates have lower glomerular filtration rate and thus less ability to concentrate urine (premature babies can only concentrate to ≤400 mOsm, compared with ≤1200 mOsm in adults); survival time of red blood cells (RBCs) increases with age (40-60 days in premature infants, 80-100 days in term infants, ≥120 days in adults); at birth, glucose level >45 mg/dL needed to avoid neurologic injury; glucose levels important in premature infants and those born to diabetic mothers; glycogen stores can be depleted in 24 to 48 hr

Fluid management: electrolyte homeostasis — neonatal period divided into 3 phases; on day 1, urine output minimal and body weight stable; diuresis seen on days 2 and 3; by days 4 and 5, fluid requirements increase and urine output established; goals of fluid management — in operating room (OR), concerns include blood loss, third-space losses, and vasodilation (secondary to anesthetics); isotonic fluids generally given (in contrast to hypotonic fluids given in NICU); maintenance therapy — replenishes evaporative losses; typically, consists of dextrose added to fluids; 4 mL/kg/hr for patient ≤10 kg, 2 mL/kg/hr for every kilogram >10 kg and ≤20 kg, and 1 mL/kg/hr for every kilogram >20 kg; on day 1, dextrose 10% given; by day 2, add 0.2% normal saline; by day 7, dextrose concentration may be decreased; once adequate urine produced, administration of potassium may be started; glucose requirements — daily metabolic rate of infant 100 kcal/kg, compared with 40 kcal/kg in adults; hypoglycemia in neonates and infants in OR may be treated with 2.5 mL/kg of dextrose 10% or 5 mL/kg of dextrose 5%

Treatment of fluid deficits: replacement therapy calculated by multiplying number of hours infant without oral intake by hourly maintenance requirements, with one-half given over first hour, and remainder given over next few hours; for hypotension, give 10 to 20 mL/kg bolus; if still hypotensive, give second bolus; glucose usually unnecessary in OR because of hyperglycemic response to stress; however, consider adding dextrose for infants small for gestational age, premature, those with diabetic mother, or receiving total parenteral nutrition

Administration of blood products: 10 mL/kg packed RBCs raises hematocrit by 10%; 10 to 15 mL/kg of fresh frozen plasma increases coagulation factors by 25%; 10 to 15 mL/kg of platelets increases count by 50,000 to 100,000/μL; calcium needs to be given with massive blood transfusions; albumin most common colloid given for resuscitation in neonates

Suggested Reading


Anesthesia for the Child with Congenital Heart Disease

Kenneth J. Saliba, DO, Pediatric Cardiac Anesthesiologist, Department of Pediatric Anesthesia, Cleveland Clinic, Cleveland, OH

Patent ductus arteriosus: surgery indicated if medical therapy (nonsteroidal anti-inflammatory drugs) has failed; in patients older than neonate, general anesthesia used intraoperatively, but regional anesthesia can be considered for postoperative pain management

Coarctation of aorta: for critical coarctation, hemodynamics and blood gases should be stabilized before surgery; recurrent coarctation may be treated in catheterization laboratory with percutaneous balloon dilation

Intravenous vs inhalation induction: in patient with right-to-left shunt (eg, Tetralogy of Fallot), inhalation induction much slower; conversely, in patient with left-to-right shunt, intravenous induction slower

Indices of critical impairment in congenital heart disease (CHD): arterial saturation <75%, ratio of blood flow to pulmonary circulation to that in systemic circulation >2:1; pulmonary vascular resistance (PVR) >6 Wood units; polycythemia (hematocrit >60%) common in any patient with history of longstanding cyanosis

Common anomalies: Isolated ventricular septal defect: most common; patients prone to development of pulmonary hypertension; anesthetic management includes permissive hypercapnia and minimization of FiO2 to increase PVR; weaning from cardiopulmonary bypass typically requires inotropic agents and nitrous.
oxide; rhythm disturbances possible because suture line may include atrioventricular node
Atrial septal defect: can cause left-to-right or right-to-left shunt (lifesaving in certain circumstances, eg, tricuspid atresia); postoperative complications include postpericardiotomy syndrome, with symptoms of tamponade; repair in catheterization laboratory — possible for some lesions; complications include embolization of improperly seated devices (after repair, patients maintained on aspirin for several months because of potential for thrombus formation); deployment of device can affect conduction system and cause heart block
Atrioventricular septal defect: seen in patients with trisomy 21; associated with dysplastic septal leaflet of mitral valve resulting in mitral regurgitation
Pulmonary hypertension: seen in patients with longstanding left-to-right shunt; defined as mean pressure >25 mm Hg; consists of fixed and reactive components, with latter responsive to oxygen and nitrous oxide; anesthetic considerations — hypercapnia and pulmonary pressures increase with amount of sedation; avoid neuraxial blocks because of large swings in systemic vascular resistance and because patients usually taking anticoagulants; nitric oxide should be available and can be lifesaving; avoid laryngoscopy or placement and removal of endotracheal tube in light planes of sedation; maintain pre-load; laryngeal mask airway acceptable for short noncardiac procedures
Anesthetic agents for patients with CHD: benzodiazepines commonly used; opioids have long history of safety in patients with diseased myocardium; ketamine acts as myocardial depressant when given alone but can be given in low doses as infusion or in combination with other agents; etomidate induction agent of choice, especially in patients with severely depressed function; dexmedetomidine has many beneficial effects; propofol bolus not first choice in patients requiring sedation because fluid bolus and/or phenylephrine often required
Long QT syndrome: list of drugs that can prolong QT interval growing (propofol now on list; includes almost all anesthetics, except opioids); syndrome defined as QT interval >440 msec; can progress to torsades and ventricular fibrillation; light anesthetics, hypnothermia, hypomagnesemia, hypokalemia, and hypocalcemia can further prolong QT interval; ondansetron best avoided (although single dose safe); one minimum alveolar concentration of sevoflurane safe, but caution required when combined with other drugs; avoid local anesthetics with epinephrine; give sufficient analgesia to avoid increasing sympathetic tone
Prophylaxis for bacterial endocarditis: recommended agents include ampicillin, ceftriaxone, or cefazolin; recommended for patients with prosthetic heart valves, previous history of endocarditis, cyanotic lesions if unrepaired or during first 6 mo after complete repair, those with repairs with residual defects, and patients with documented valvular disease after cardiac transplantation
Wolf-Parkinson-White syndrome: delta wave upstroke of QRS complex pathognomonic; be cautious when passing central venous guidewire and avoid increasing sympathetic tone; have adenosine available and be familiar with dosing; balanced anesthetic approach recommended; dexmedetomidine best avoided (may inhibit provocation of pathways)

Suggested Reading


Acknowledgments

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1. The minimum alveolar concentration of inhalation agents is highest in which of the following?
   (A) Neonate  
   (B) Infant age 1 to 6 mo  
   (C) Toddler  
   (D) Adolescent

2. Which of the following explains the faster inhalation induction seen in children, relative to that in adults?
   (A) Larger tidal volume  
   (B) Larger blood volume  
   (C) Greater functional residual capacity (FRC)  
   (D) Higher ratio of alveolar ventilation to FRC

3. Which of the following is more likely when using sevoflurane rather than halothane in children?
   (A) Breath holding  
   (B) Laryngospasm  
   (C) Emergence delirium  
   (D) Dysrhythmias

4. When evaluating return of function after administration of neuromuscular agents to young infants, which of the following is the best correlate to function of the diaphragm and vocal cords?
   (A) Orbicularis oculi  
   (B) Raising of head  
   (C) Hip flexion  
   (D) Localization to pain

5. Which of the following anesthetic agents has little or no effect on apoptosis?
   (A) Midazolam  
   (B) Propofol  
   (C) Dexmedetomidine  
   (D) Sevoflurane

6. On the first day of life, the most appropriate maintenance fluid is which of the following?
   (A) Dextrose 5% with 0.45% saline  
   (B) Dextrose 10%  
   (C) Dextrose 10% with 0.2% saline  
   (D) Isotonic saline

7. Which of the following is the approximate daily metabolic rate in neonates?
   (A) 40 kcal/kg  
   (B) 80 kcal/kg  
   (C) 100 kcal/kg  
   (D) 140 kcal/kg

8. Which of the following is recommended for the anesthetic management of a child with an isolated ventricular septal defect?
   (A) Mild hyperventilation  
   (B) Mild hypoventilation  
   (C) 100% oxygen  
   (D) Phenylephrine

9. Which of the following is recommended for the anesthetic management of patients with pulmonary hypertension?
   (A) Permissive hypercapnia  
   (B) Neuraxial blocks  
   (C) Maintenance of preload  
   (D) Endotracheal intubation under light sedation

10. In a patient with congenital heart disease and severely depressed function, which of the following is the induction agent of choice?
    (A) Midazolam  
    (B) Ketamine  
    (C) Propofol  
    (D) Etomidate

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