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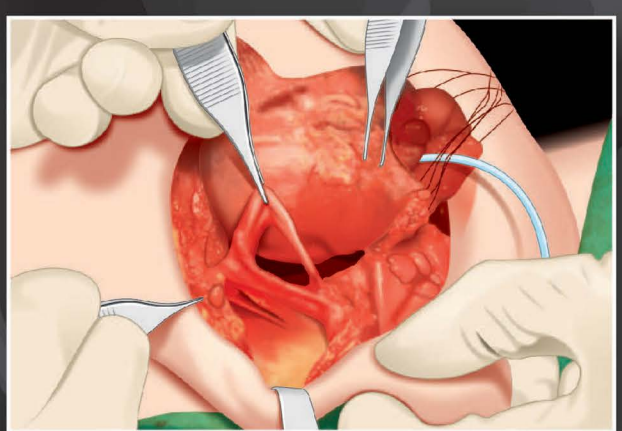

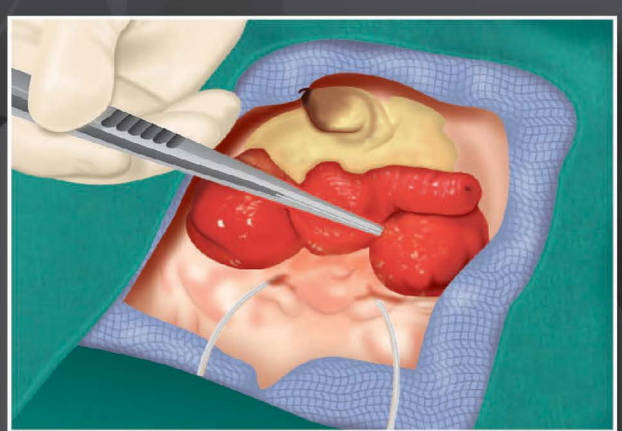

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Special Anesthetic Consideration in Infants Toddlers

Annie Amin, Igor Tkachenko

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INTRODUCTION

The pediatric patient requires unique pharmacologic, anatomic, physiologic and psychological consideration. It is important for the anesthesia provider to understand the nuances of the pediatric anesthesia patient to provide the most comprehensive care. Caring for pediatric patients also demands learning to alleviate the fear and anxiety of their families. For complex patients, a multidisciplinary approach with subspecialty teams is often necessary.

ANATOMIC AND PHYSIOLOGIC CONSIDERATIONS

Pediatric Airway

Knowledge of pediatric airway anatomy is a critical component for overcoming the technical problems of anesthetizing a pediatric patient. The pediatric airway differs from the adult in five ways.[1] The pediatric airway has been described as funnel-shaped with the narrowest portion at the level of the cricoid cartilage. The narrowest portion of the adult airway is at the level of the vocal cords. Recent imaging and bronchoscopic studies, however, suggest that the shape of the pediatric airway may be elliptical-like the adult airway.[2] The larynx in a child is more cephalad and located at C3–C4; the adult larynx is located at C4–C5. The epiglottis is stiffer, narrower and omega-shaped, making it likely to obstruct the laryngeal inlet, which makes direct laryngoscopy difficult.[3] The tongue is large, predisposing to upper airway obstruction. Because the vocal cords are angled anteriorly, an endotracheal tube passed blindly can lodge on the anterior commissure.

Cardiac

The infant cardiovascular system is not fully developed at birth. The myocardium is immature with less organized myocytes that lack sufficient sarcoplasmic reticulum and a mature T-tubule system.[4] Thus, the infant myocardium depends on extracellular calcium concentration for contraction and is sensitive to substances that decrease ionized calcium levels such as blood products and albumin. Cardiac output is largely determined by heart rate because stroke volume cannot be increased significantly. Bradycardia, which can cause profound hypotension and circulatory collapse, should be treated aggressively; medications that cause bradycardia should not be used. Infants are sensitive to the cardiac depressant effects of inhalational and intravenous anesthetics.

Respiratory

Neonatal breathing is a continuation of the system that was present intrapartum. During the first 2–3 weeks of life, the response to hypoxemia is a transient increase in ventilation followed by a sustained depression. In premature infants, the transient increase in ventilation is abolished in cold environments, so it is important to maintain neutral temperatures in the operating room.[5] The biphasic response is attributed to muscle fatigue, rather than a central neuronal effect.[6] The response to hypercarbia is an increase in ventilation, but to a lesser extent in preterm infants. The response increases with postnatal age.

Infants and neonates are prone to oxygen desaturation during the induction of anesthesia and surgery. The time to oxygen desaturation increases with age; thus, neonates are the highest risk population.[7] Compared to adults, oxygen consumption is higher in children and infants.[8] Infants have highly-compliant chest walls and poorly-compliant lungs.[9] Consequently, the volume at which lower airways are closed (closing capacity) is higher than the functional residual capacity. At spontaneous respiration, infants have a small degree of atelectasis, exacerbated by general

anesthesia or neuromuscular blockade. The addition of positive-end-expiratory pressure (PEEP) to positive-pressure ventilation may combat those changes. The use of continuous-positive airway pressure (CPAP) during general anesthesia with a laryngeal mask airway has been shown to decrease the work of breathing and can prevent muscle fatigue in infants and children.[10]

Postoperative apnea is a serious consideration after surgery for term and preterm infants. Risk factors include history of apnea, neurologic disease, chronic lung disease, anemia, extent of surgery, and postconceptual age.[11] In preterm infants, the risk is the highest when post-conceptual age is less than 46 weeks, with some risk up to 60 weeks. Apnea is most common within the first 12 postoperative hours. If there are no episodes of apnea within 12 hours, infants can be safely discharged home. The monitoring period should be prolonged after an apneic episode. At our institution, we admit all preterm infants less than 60 weeks postconceptual age and all term infants less than 45 weeks postgestational age for 23-hour observation with continuous cardiopulmonary monitoring. Inpatient admission also should be considered for children with a history of upper airway obstruction or obstructive sleep apnea, regardless of age.

Temperature Regulation

Pediatric patients undergoing major surgery are at risk for hypothermia. Amount the detrimental effects of hypothermia are impaired coagulation cascade and platelet function, increased rate of wound infection, cardiac arrhythmias, prolonged recovery room stays, and decreased enzymatic function and drug metabolism.[12] In the operating room, internal redistribution, which is the transfer of heat from the body core to the periphery, is responsible for the initial decline in temperature. After redistribution, transfer of heat to the environment is by radiation, convection, evaporation, and conduction.

Infants and neonates are more susceptible to heat loss from their high-ratio of weight-to-surface area, large heads, and limited store of subcutaneous fat.[13] To generate heat, infants metabolize brown fat (nonshivering thermogenesis), thus increasing oxygen consumption. This response is attenuated under general anesthesia. The main risk-factors for hypothermia in infants and neonates are major surgery and operating room temperatures less than 23°C.[14] Infants are better able than neonates to stabilize their temperatures in warm environments. Convective forced-air warmers, humidified air, and warmed intravenous fluids help to combat hypothermia in the operating room environment.

Pharmacologic Considerations

Before selecting doses or administering drugs to pediatric patients, their physiologic profiles and the pharmacokinetics of the drug should be considered. Infants and toddlers are unique in absorption, distribution, metabolism and excretion of drugs. Dosing can be based on patient age, weight, body surface area, or a combination. Age-based dosing takes into account physiology and the maturation of organ systems, but fails to assess variations among age groups. Weight-based dosing fails to consider differences in drug clearance because of age. Dosing according to body surface area is the most accurate; however, it is difficult to calculate quickly and can lead to overdoses.[15] A combination utilizing age, weight, and body surface area is the safest.

Infants have neutral gastric pH for the first 2 weeks of life, which may affect the absorption of oral drugs. Gastric acid reaches adult levels by 2–3 years of age.[16] Intestinal motility, slow in the first-week of life, quickly stabilizes. The bioavailability of drugs administered rectally is inconsistent because of variation in venous drainage. Drugs administered high in the rectum are subject to first-pass metabolism; drugs administered low in the rectum are delivered systemically. Intramuscular administration is unreliable in neonates as blood flow to the muscles varies in the first 2–3 weeks of life. There also is significant pain associated with intramuscular injections. Percutaneous administration in infants and neonates can be faster due to thin skin is not recommended until 1 year of age.

Before intravenous administration of drugs in pediatric patients the difference in distribution, metabolism and excretion must be considered. In young infants and neonates, the content of total body water is high and the fat content is low, which results in a high-volume of distribution for water-soluble drugs.[16] Larger initial doses of drugs are needed for the larger volume of distribution. Protein binding is reduced in neonates. Lower overall protein concentrations and a decreased affinity for drug binding can lead to higher-plasma levels of protein bound drugs.[17] Enzymatic activity of the liver in neonates is not mature and can lead to toxic levels of drugs. For drugs

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eliminated by the kidney, age-appropriate dosing is used because of maturation of the kidneys. A safe and effective dosing strategy considers the changes in organ maturation in infants and neonates to achieve therapeutic levels and prevent toxicity.

Special Considerations for the Ex-premature Infant

Complications of premature birth are a potential cause of morbidity and mortality during the first several years of life. Nearly every system is affected by prematurity, and infants and toddlers should undergo a thorough evaluation to ensure optimization of their medical status prior to surgery. A multidisciplinary approach with subspecialty teams is often necessary.

Common neurologic sequelae are cerebral palsy, neonatal seizures, intra or periventricular hemorrhage and hydrocephalus. Even in the absence of clear abnormalities, ex-premature children are prone to postoperative apnea.[18] Decreased lung compliance, lung volumes and increased airway reactivity contribute to episodes of rapid desaturation in perioperative periods and affect baseline oxygen requirements. Neonates respond to deoxygenation with activity in the parasympathetic system, which can result in bradycardia and low cardiac output or cardiac arrest. Lung prematurity histologically manifests as hyperplasia of airway smooth muscle, impaired alveolarization, pulmonary inflammation and an increase in pulmonary artery muscularization.[19] Use of mechanical ventilation and high oxygen concentration contributes to pulmonary compromise and future bronchopulmonary dysplasia (BPD). Patients with persistent pulmonary hypertension and BPD benefit from early diagnosis and treatment to improve outcomes.[20] Invasive use of intraoperative monitoring, inotropes, and pulmonary vasoactive drugs may be beneficial especially during longer procedures with laparoscopic and robotic techniques. Pulmonary vasoconstriction from hypercarbia and acidosis in addition to decreased venous return cause decreased cardiac output, and if unrecognized and untreated, lead to hypoperfusion and end-organ failure.

The presence of congenital cardiac disease makes perioperative management even more challenging. The incidence of congenital heart disease in premature is twice that in infants born at term.[21] The incidence of patent ductus arteriosus (PDA) in preterm infants is 20–60%; it increases with prematurity and low birth weight. There is an inverse relationship between birth weight and incidence of PDA. PDA is observed in 40% of infants with a birth weight less than 2,000 g and in approximately 80% of infants less than 1,200 g.[22] Complications of persistent PDA include congestive heart failure, respiratory failure, diastolic hypotension, and increased risk of apnea and metabolic acidosis.

Necrotizing enterocolitis (NEC) and gastroesophageal reflux disease (GERD) are common complications of prematurity. Depending on the extent of the bowel resection with NEC, short-gut syndrome may develop and which significantly impairs nutrition and may lead to anemia, coagulopathy and liver dysfunction. Untreated acid reflux can cause laryngospasm, laryngitis, tracheitis, and chronic cough, thus aggravating respiratory problems in ex-premature children.[23] A combination of severe GERD, laryngospasm and bradycardia are known causes of sudden infant death syndrome and acute life-threatening events.[24] Incidence of aspiration has been reported in up to 6% of ex-premature children. A number of ex-premature infants undergo Nissen fundoplication to moderate symptoms and prevent complications.

Prolonged intubation in premature children also can result in subglottic stenosis or tracheomalacia. Abnormal pulmonary function in preterm children without BPD mostly resolves before they start school, but in preterm children with a history of BPD, pulmonary function remains abnormal during school age and even adolescence.[25] Evaluation of infants and older children with a history of stridor or breathing difficulties is indicated before administration of anesthesia and airway management.

Perioperative Anxiety

Perioperative anxiety is not a unique problem for children, but its management presents a challenge for the anesthesia, surgery, and nursing teams. The level of anxiety, ability to understand the procedure and coping mechanisms are different in infants and toddlers. Approximately 40–60% of children undergoing surgical procedures experience perioperative anxiety.[26] Separation from parents, an unfamiliar environment, and fear of pain trigger anxiety and emotional or physical distress. Children express separation and stranger anxiety as early as 10 months of age; anxiety peaks by 1 year and continues to be a normal response until age 5. The highest risk is between ages 1–3.[4]

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The level of separation anxiety varies from mild to severe. It is expressed as crying, screaming, fighting, or trying to escape. If untreated, severe anxiety might pose a risk of emotional and physical injury to the child, and substantial emotional distress to the parents. In response to perioperative stress, children may manifest maladaptive behaviors postoperatively such as increased separation anxiety, feeding difficulties, nightmares, enuresis and fear of physicians. In one study, maladaptive behaviors lasted 6 months in 21% of children.[27] Besides age, factors that contribute to the level of anxiety in children include temperament (shy, inhibited, dependent, or withdrawn), parental anxiety, previous hospital experience and reaction to vaccination.[27]

Two perioperative situations creating anxiety in children are separation from parents and acceptance of induction of anesthesia. Different pharmacologic and behavioral interventions reduce anxiety, enhance coping skills, and improve psychological and clinical outcomes. According to one many pediatric patients in the United States are taken to the operating room without parents or a sedative premedication.[28] In many other institutions, including ours, parents are offered participation in induction of anesthesia in non-sterile induction rooms or in operating room, after changing into scrubs to maintain a sterile environment. Mask induction for nonemergent procedures in patients with no aspiration risks can reduce pain and discomfort.

One review of 17 clinical trials, however, failed to confirm the benefits of parental presence during induction to reduce anxiety or improve cooperation of children. Still, calm parents may be helpful and should not be discouraged from participation in induction of anesthesia.[29] Success hinges on the preparation of parents with a thorough explanation and discussion of the events anticipated in the operating room. Ideally, family preparation for an elective procedure begins well in advance with complete information on the upcoming procedure and anesthetic choices.[30] Parental presence during induction may improve parental satisfaction and the relationship between parents and the healthcare team. According to Ryder et al, 92.8% of parents believed their presence at induction was *considerably or extremely* helpful to the child, and 62.6% of parents believed their presence was *considerably or extremely* helpful to the anesthesia care provider.[31] At our institution we allow 1 parent to be present during induction but there are data showing benefits with 2 parents present in the operating room.[32] Overall distraction techniques are also beneficial in reducing anxiety. Nonprocedural talk, humor, actual choices with clear limitations for the child, and interpretation of visible medical equipment was shown to reduce anxiety in the pediatric population.[33] Excessive medical talk, reassuring, apologetic or emphatic statements, interpretation of nonvisible medical equipment, and unlimited choice are considered to undesirable behavior in healthcare providers.

There are a number of pharmacological agents for premedication and anxiolysis in children. Pharmacologic agents currently used for preoperative premedication include midazolam (oral, rectal, intranasal), ketamine (oral, intranasal, rectal), clonidine (oral), fentanyl (oral transmucosal) and clonidine (oral).[26] Barbiturates such as methohexital and thiopental can be administered rectally, and benzodiazepines such as diazepam or lorazepam can be administered orally. The most commonly used pharmacological agent for oral premedication in children is midazolam. Oral midazolam has predictably rapid onset (15–20 min), no effect on oropharyngeal secretions, reliable anxiolysis and amnesia, and negligible cardiovascular or respiratory depression in otherwise healthy children. Multiple trials have shown that oral midazolam effectively reduces both separation and induction anxiety in children (grade A recommendation).[34] A number of children, however, refuse to take oral midazolam because it tastes bitter. Yet approximately 14% of pediatric patients experienced anxiety in spite of administration of oral midazolam.[35] Intramuscular administration of some pharmacological agents is faster but accompanied by pain and discomfort at the injection site. It is important to identify patients who are at high-risk of separation and preoperative anxiety and utilize one or a combination of interventions to reduce anxiety in patients and their parents.

CONCLUSION

A thorough perioperative treatment plan for pediatric patients considers all of their differences from adults in metabolism, organ development, physiology, and developmental maturity along with the concerns of their parents. The best outcomes are often achieved with a strong team approach and excellent communication with the perioperative team.

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