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Pediatric Anesthesia: Techniques and Risk Reduction

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ABSTRACT

Anesthesia is used for a number of invasive procedures in children. The anesthetic technique chosen for each child must be tailored to the nature of the surgical procedure, the patient, and the needs of the surgeon. Clearly, not all children can be managed the same way. One must take great care to understand each child's background as well as the surgical problem facing them. In terms of anesthetic management specifically, there are certain guidelines that can be followed to prevent complications from occurring or to be able to deal with the complications that may arise in a systematic and thoughtful way. The intention of the following brief chapter is to review basic anesthetic techniques used in children, the anatomic and physiologic differences encountered with various age groups, and the care and consideration necessary to prevent complications from occurring when delivering anesthetic care to children. (Murray-Torres et al.2021)

The use of anesthesia for the treatment of children is a common occurrence. Most general anesthetics produce states indistinguishable from normal sleep and allow for safe and humane surgical techniques. Activity and exploratory behavior are normal human developmental events that naturally decline over time, secondary to maturation of the central nervous system. Individual sensitivity to general anesthetics varies greatly. Prudence dictates starting the anesthetic slowly, measuring the child's threshold of response to the nearly chosen dose of anesthetic, and then either continuing to raise the dose to produce an anesthetic level of response or modifying the technique chosen. When an anesthetic state is attained, steady-state levels of anesthetic concentration should usually be maintained throughout the procedure. Examiner activity continues undiminished but may be less predictable in nature. Abuse of general anesthesia may cause injury to the mother and/or child. Overall, anesthetic techniques currently available for use with children offer approximately similar degrees of safety and predictable outcomes.

1. Introduction to Pediatric Anesthesia

Pediatric anesthesia is unique. Children are not small adults; their responses and needs vary markedly depending on factors such as maturity and underlying pathology. The pediatric anesthesiologist is often involved in the care of a wide variety of patients, from the vigorous neonate needing minor surgery to the failing neonate needing lifesaving surgery. In addition, they must have the knowledge of a neonatologist and a pediatrician, as well as the capabilities to stabilize life-threatening situations. All of this has to be done in a calm and orderly way that reassures the parents, guiding them through their anxieties. Experience has allowed the development of a variety of techniques to optimize the safety of any procedure requiring general anesthesia.

Pediatric anesthesia requires the ability to gain the trust of the child with reassurance, friendliness, and humor. The pediatric anesthesiologist needs patience, empathy, and the realization that the health and welfare of the child are paramount in all matters. However, one must be in command – "be firm but kind and remember to use the white-coat amplifier in the presence of unruly children." With rare exceptions, health will be synonymous with avoiding anything that is bad or painful. Because most children will interpret the operating room as a genuinely uncomfortable and unwanted area of overhanging anxiety, the slightest suggestion that the anesthesiologist is the embodiment of relief from the anticipation or anxiety is most effective in gaining instant loyalty. Therefore, the phrase "I know you want to feel better – that’s what I am here for" is the most time-proven and only effective pediatric anesthesia rule. (Matava et al.2020)

1.1. Definition and Scope

Charles Judson Mundy IV I. Introduction A. Definition 1. Anesthesia for patients in the pediatric age group includes anesthetic agents and techniques used when this type of patient is undergoing a procedure, surgery, or examination. The initial cohorts of intended anesthetic recipients in this age group include the neonate, infant, toddler, child, and adolescent. 2. Defining the exact ages of each of these pediatric subgroups is controversial and is influenced by the culture or country in which the care is provided. Clearly, neonates of large size may be assessed and presented for surgery using techniques and doses similar to those of young infants or toddlers. When the intrauterine or past neonatal comfort zone has been established for a small premature infant, some neonatal surgical procedures may be performed or completed during prolonged gestation or early infancy, while no chronological age criteria need to exclude the term infant from pediatric age designation. 3. An adverse anesthetic outcome for any neonate, infant, toddler, child, or adolescent, due to exposure to anesthetic agents and/or techniques, should be recognized, treated, studied, and, to the maximum extent, understood and avoided by the anesthesia provider who provides anesthesia. Inherently, these scenarios occur more frequently as the patient ages. (Faulk et al.2021)

1.2. Importance of Pediatric Anesthesia

Despite the potential negative impacts of general anesthesia, it is a very important tool. Not only does it allow for surgical procedures that save lives, thereby facilitating growth and development, but it is also absolutely necessary in certain conditions. For example, the correction of congenital defects of the heart, such as unstable newborns. In these cases, in addition to the benefits of the surgical treatment, the reduction in circulating volume, the improvement in the oxygenation of the blood, and the reduction in the energy expenditure that mechanical ventilation entails are key to the survival of these patients. On the opposite side of the scale, some panels and characteristics of our children make their management very difficult and delicate, and this increases the risk of the procedure. The anesthesiologist today has safer anesthetic drugs and therapies that improve the condition of the patient, personalized monitoring that detects alterations very early, and knowledge that allows adapting the process to the individual needs of each patient. However, it would be wise to choose the patient to avoid putting him at risk, premedicating him, immobilizing him, and accompanying him. This is not yet possible, and to put the patient in a position of maximum safety also requires great experience, training, and dedication to our task. Furthermore, given the levels of anxiety present in the act of anesthesia and the risks inherent in the medication, it will never be possible to carry out anesthesia procedures with acceptable levels of insecurity. Therefore, the presence of well-trained personnel who deal with the monitoring of the organic functions of the patient and who respond to incidents with speed, intelligence, and dexterity is also essential. (Warner et al.2022)

2. Physiological Differences in Pediatric Patients

A pediatric patient's physiological response to tracheal intubation is determined by their level of physical and cognitive development. Adult doses of muscle relaxants can cause a strong resistance and closed chest symptoms in a pediatric patient with underdeveloped competition muscle, and can cause pneumothorax or severe arrhythmia. The phrenic nerve contains as many dense endplates in a four-year-old child as in an adult, and closing a muscle fiber by 50% causes apnea. Anesthesia can be performed with a small amount of muscle relaxant; however, neuromuscular monitoring is required in case unnecessary muscle relaxants need to be used. During anesthesia and intubation, it is necessary to consider these muscle characteristics and to avoid muscle relaxants that are one-time drugs that take a long time to excrete based on the pediatric physical status, safety, and effective dose.

In emergency induction, intubation time, and examination, children younger than three years had a higher chance of airway-related problems. Preventing airway spasm before the start of induction is important. It is critical to ensure all administration and provide a calming environment in addition to age-appropriate explanation and position to gain the patient's trust during hospital visits. Drug administration bolus doses are higher than in adults due to the insufficient intravascular capacity that children have and that surgical bleeding causes mucus and coagulation in the respiratory system. For pulmonary distribution, only one-third of the adult drug is used, so the loading dose is based on the length of the limb. Preoperative and intraoperative infusion fluid is required at a rate of 24 mL/kg/day in six hours. The total amount of blood is about 150 mL/kg, while the pulmonary requirement is a rapid 30 mL/kg. A child must be an active participant in the clinical transfer station for emergency intubation. (Yager et al.2024)

2.1. Cardiovascular System

The anesthesiologist's ability to assess and treat the unique interactions that occur between anesthesia and surgical stress, carried out with a knowledge of the specific physiologic systems and their functional development in infants and children, is the main benefit of the pediatric anesthesia consultant. Accompanying risks are the result of the profound influence that anesthetics exercise upon these various physiologic systems. In recent years, the study of perioperative complications in adults and children has been extensively reviewed. Nearly half of the pediatric anesthesia malpractice claims were found to result from cardiovascular or respiratory system problems, and adult survey data suggest similar proportions.

The development of the cardiovascular system continues after birth. Normal neonatal and pediatric values for heart rate, blood pressure, central venous pressure, and related physiologic variables have been calculated and statistically analyzed. The anesthesiologist must consider and understand the significance of these circulating catecholamine substances on the cardiovascular system. Blood volume, the result of the active transfer and autotransfusion of placental blood from the fetus to the newborn during birth itself, and the subsequent reduction of body water does not reach the adult level for some weeks. Hemoglobin in the breastfed infant is significantly higher than that in both formula-fed and cow's milk-fed infants. Infants are capable of developing a high rate of erythropoiesis and circulate a high percentage of fetal hemoglobin in a physiologically functional hematological response during anemia, hypoxia, high output congestive heart failure, altitude exposure, or surgical manipulation of the splanchnic circulation. Since the degree of risk of general anesthesia induction is directly related to the morbid state of the child, the anesthesiologist should inspect the peripheral blood smear and red blood cell sitting. (Sullivan & Fairchild, 2022)

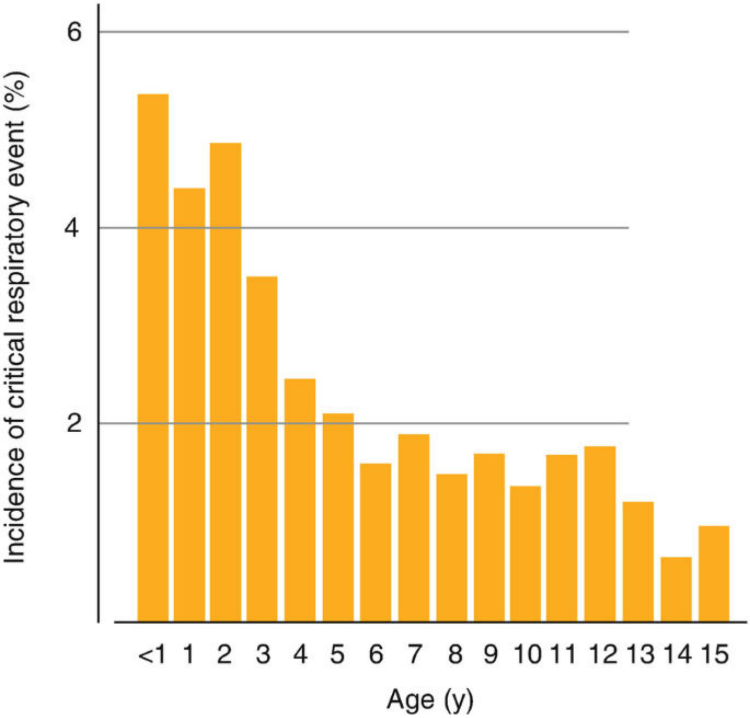
2.2. Respiratory System

Pediatric upper airway anatomy and physiology is quite different from that of adults, particularly in small children. Children have relatively large heads, large tongues, and proportionately smaller and softer airways. The relatively large tongue is one of the primary reasons that small children have a very different problem than do adults with regard to airway issues, notably upper airway obstruction. This tendency toward upper airway obstruction is amplified when children are supine or unconscious postoperatively. Despite this, the size of the child's head is generally used to estimate the size of the endotracheal tube. However, the size of the trachea is unrelated to the size of the head. Children also have longer, more flexible chests. Excessive chest wall compliance in children, particularly small infants, and associated minimal transdiaphragmatic pressure can lead to paradoxical ventilation during manual or mechanical ventilation. On the other hand, children have a smaller functional residual capacity in relation to their body weight because of relatively lower oxygen storage and increased oxygen consumption. The smaller lung size, increased airway resistance, and most importantly, the high RTM significantly decrease the oxygen stores, thus reducing the margin of safety in the apneic patient. Premature and neonatal patients are particularly at risk for apnea because of their low oxygen storage and the profound effects of anesthesia and surgical stimulation on these diminutive patients. (Ruckwongpatr et al.2021)

3. Anesthetic Agents and Techniques for Pediatric Patients

Most pediatric anesthetics are administered as inhalation mixtures. After a mask inhalation induction, the mixture contains enough oxygen to prevent hypoxemia during the time from the onset of NREM to that of REM sleep, and only a few minutes of mask induction are needed for high tension to develop. At the end of REM sleep, the anesthetic mixture can be changed without respiratory stimulation; this is especially important whenever the anesthetic mixture contains some nitrous oxide. The anesthetic mixture and inspired concentration can be adjusted quickly in response to variations in the surgical stimulus. Lightening of anesthetic depth or even the resumption of spontaneous, purposeful movements can be achieved within a minute. Immediately after the surgical stimulus ceases, the inspired concentration of the less soluble anesthetic can quickly be raised to produce the depth of anesthesia desired for transfer to the PACU. The necessary amount of the more soluble anesthetic will then have accumulated in the child's tissues during its period of less soluble administration. (Apai et al., 2021)

The volume of the pediatric lung approaches the adult volume; the child's volume-to-weight ratio is already adult-like; thus, the uptake and distribution kinetics of volatile anesthetics in awake children are similar to those in adults. After children attain balanced anesthesia, the uptake and distribution kinetics differ from those in adults. In the absence of data for the pediatric body, such as the blood-gas partition coefficient, the solubility coefficient, or the oil-gas partition coefficient, that differ from those in an adult of similar body proportions, the induction and recovery results would be similar to those in an adult if the alveolar and/or arterial blood partial pressures of anesthetic were similar.



3.1. Inhalational Anesthetics

The wide use of inhalational anesthetics (IAs) is explained mainly by the features of their application, such as strict dosage control in the process of induction, emergence, and maintenance of anesthesia. This is achieved by anesthetic vaporizers, devices that assure the intimate contact of anesthetic with alveoli. IAs can be breathed through different breathing systems: closed breathing systems or systems with gas waste. Closed breathing systems are known as the Circle system. Despite the presence of the Circle system special simulator for pediatric patients, the minimum ventilation minute volume of pediatric lungs is not enough for minimization of monotony, saturation of inhaled gases with carbon dioxide, and the delivery of fresh gas to the patient. It is a cause of the need to use higher fresh gas flow to ensure normocapnia.

The use of the Bain system with FGF of 8–10 min-1 allows reducing the volume of isoflurane needed for induction by 3 to 4 factors. At smaller flows, there was not enough isoflurane action. In all patients with insufficiency of inspiratory concentration of isoflurane, there was persistent reflex hypertonia of masseter muscles. It resulted in failed standard brisk mask ventilation technique and hypoxemia during procedures. The adjunctive techniques of LMA mask ventilation showed insufficient efficiency. Nevertheless, the percentage of three LMA inflation attempts with the smallest number of ventilation hernias and three LMA attempts with one LMA reflex displacement was the smallest number of cases among all groups. In patients with insufficiency of inspiratory concentration of isoflurane, the additional dose of 1 mcg/kg fentanyl associated with muscle relaxants for catheter fixation under mask removal improved the removal time. Correct maintenance of isoflurane general anesthesia in spontaneously breathing patients was achieved at the fresh gas flow of 5–8 L/min; it was impossible at a fresh gas flow of 2.5–5 L/min. After tracheal intubation, even the low IAs concentrations of isoflurane were sufficient for adequate maintenance of general anesthesia and elimination of laryngospasm and inspiratory gasping, regardless of the FGF volume. The isoflurane FGF requisite decreased from 8 L/min for spontaneous breathing to 2 L/min for mechanically ventilated patients. (Larrea et al.2022)

3.2. Intravenous Anesthetics

Pediatric induction with IV anesthetics is often challenging for the pediatric anesthesiologist due to the rapidity with which the drugs work, their lack of analgesic action, and the presence of a fearsome mask following the injection of the drugs. The most likely reason that propofol has become the most favored pediatric IV anesthetic is the speed with which it goes to work. Tolerance has proven to be a useful property in the situations we typically face, because masking becomes very threatening when a child is treated in the play area rather than in an operating room. Etomidate is used less frequently, but its simplicity of use and proven safety in pediatric anesthesia make it an attractive agent for both induction and sometimes for the maintenance of anesthesia.

Intradose ketamine has been a favorite technique for young anesthetic induction for several years because its subanesthetic dose speeds induction, blunting the volatility of separation anxiety. When masking a child occurs, it can be performed during the effects of the ketamine. The use of intradose midazolam allows for the most confident parental presence and is often the most desired induction approach when parental presence is requested at induction. It is difficult to hide that this approach provides a third-best option to mask induction.

4. Monitoring and Safety Protocols in Pediatric Anesthesia

Adapting monitoring equipment in pediatric anesthesia is essential considering age and physical differences compared to adult patients. The pediatric anesthesiologist must rely on various clinical parameters and techniques for preventing and recognizing adverse events in children. Several pediatric specialty societies recommend the minimum standards for monitoring pediatric patients during anesthesia. These parameters and standards are different for children than adults in the preoperative, perioperative, and recovery periods. Intraoperative monitoring starts before anesthetic induction and continues throughout the intraoperative period until the child is fully recovered and discharged from the post-anesthetic care unit and post-anesthetic discharge area. Monitoring depends on the status of the child before the surgery, the nature of the surgery, the type of anesthetic, and the period of recovery postoperatively. Monitoring standards currently do not consider the child's history, comorbidity, and the type of surgery. Recent technological advances have been introduced and were not considered in the guidelines. (Smith et al.2022)

4.1. Vital Signs Monitoring

Vital sign monitoring is central to any anesthetic exposure. In addition to the equipment used for monitoring the vital signs of an adult, the anesthetist can monitor the pulse oximetry of a neonate by attaching a sensor to the neonate's foot. The electrocardiogram of a neonate can also be monitored by using the same equipment. A good rule to remember while monitoring the vital signs of a child under endotracheal or laryngeal mask anesthesia is that even minor variations in vital signs have the potential for significant deleterious outcomes. Close supervision, hyperventilation, inadequate analgesia (as evidenced by tachycardia), or inadequate anesthesia (as evidenced by hypertension) in an underage neonate is capable of instigating severe myocardial dysfunction, which may lead to a negative energy balance. Within minutes, this can be the difference between life and death. (Kurtz et al.2021)

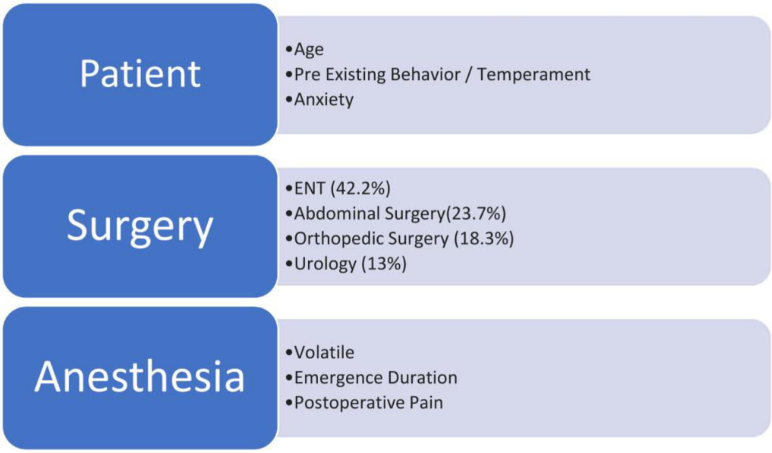
4.2. Capnography

Mass spectrometers and infrared detectors are the most common types of capnometers. Mass spectrometers are expensive and fragile due to the pumps and delicate instruments required to separate gases. Infrared capnography works by measuring infrared light at an absorbable wavelength into which CO2 hydrocarbons register. O2 does not affect this calibration. By plotting the density of the CO2 waveforms generated against the patient's ventilation, a CO2 waveform can then be plotted. A negative space waveform that rises to a zero level represents inspiration and the presence of CO2. When CO2 falls to zero, it represents expiration. Small airways and partial airway obstructions are easily missed with normal capnography. If capnography detects how much CO2 is being expelled and how much oxygen is being utilized, it will be possible to diagnose and treat conditions such as embolisms and circulatory shunting. (Waugh & Harwood, 2022)

5. Specific Considerations for Different Age Groups

Anesthetic management for surgical procedures in infants and children requires an understanding of the patient's growth and development, as well as the ability to provide a safe but non-traumatic anesthetic. The type of patient, the procedure, and the surgeon dictate the nature of the anesthetic management. The severity of illness, the degree of anxiety, and the degree of parental involvement contribute to the patient's behavior. The goals of pediatric anesthesia include the establishment and maintenance of a secure airway, the blunting of autonomic responses to stress, the prevention and treatment of complications such as pain and nausea, the balance between the effects of anesthetics on the potential morbidity posed by stressful procedures, and developing patient tolerance or desensitization for medical experiences, as well as the provision of the potential for rapid awakening and recovery in specialized circumstances.

One complicating factor in anesthetizing the pediatric patient is the patient's traversal through the developmental stages. The experience of the elderly anesthesiologist who has had the opportunity to anesthetize infants up to adults can indeed be critical. As the level of development increases, so does the child's ability to understand the perioperative experiences, and understanding and behavior become increasingly related to age. Frustrations and dramatic differences continue to limit the older anesthesiologist's attempts to predict responses to pediatric patients by trying to recapture fragmented past insights on child behavior. Thus, an understanding of normal growth and development of organ systems is basic to managing a child safely. This chapter concentrates on similarities and differences in normal physiological development of children of different ages and the acute alterations that occur when children are exposed to either the stresses of anesthetic premedication, induction, and maintenance of anesthetized phases of surgery associated with medical illnesses. (Akbarnia et al., 2022)



5.1. Neonates

Newborns and older infants respond differently to various stimuli. These differences are based on various parameters, such as the final development of the nervous system, the appearance and abolition of the sympathetic nervous system, and the different development of structures responsible for temperature adjustment and metabolism. The proportion of body surface area increases in the infant with a decreased body fat content, which makes the body heat less resistant to atmospheric conditions. Brown fat cells are present in a significant proportion. The major sympathetic lesion that influences thermoregulation is a deficit or immaturity of norepinephrine synthesis. The central nervous system in newborns is still in the course of modification, and the structures involved in temperature adjustment do not have the same thermoregulatory ability as in the case of older children.

The golden hour—the neonatal period shortly after birth—is an essential period due to the rapid changes in vital functions and a switch from a fetus to an independent circulating system and respiratory tract. For the child to pass the golden hour stably, specific conditions are needed, as well as a therapeutic attitude. Changing from the uterine environment to conditions outside the uterus represents a true adaptation test. These conditions should be maintained, and in case of abnormalities, must be supported. The neonatal period is one of higher anesthetic risks. Neonates sometimes require surgical interventions under general endotracheal anesthesia for various reasons: congenital malformations, respiratory distress syndrome, infections, pneumothorax, or metabolic disorders, or require an endotracheal tube to be positioned intraoperatively for patients undergoing surgery under local anesthesia. Neonatal orotracheal intubation is performed more frequently than what is recorded in the medical literature. After abdominal, retroperitoneal, thoracic, or nasal surgery, it is useful to maintain a correct surgical operative position over some hours or days depending on the prognosis of the surgery or the postoperative state of the neonate. Circumcision, urinary diversion interventions, inguinal hernioplasty, gastrostomy, and other types of surgery also require general anesthesia. (Saynhalath et al.2021)

The main anesthetic problems of a neonate are presented by the anatomical and physiological peculiarities which can adapt and influence the deposition and elimination of the inhaled anesthetics: the large frontal skull, the membranous fontanelle, the high water content in the brain tissue, the unharmonious problems in the pH—pCO2 field, the lower expression of alpha-1-globulin, albumin, and lactate, bilirubin at the end of metabolism, the larger portion of phenobarbital active functions, caused by the replacement of the phospholipids which are passed to extrauterine life for 24 hours to mature anatomofunctionally, the only means of thermoregulation, less capillarization of the muscles, and less heat production in thermogenesis, the height of the body fluctuating slightly as a function of the relative balance of the liquids and not at all as in the fetus as a direct effect on humidity.

5.2. Infants

The first 12 months of life is a time of very rapid growth and greatly increasing percentages of total body water, muscle mass, and oxygen consumption, with decreasing percentage body fat. Consequently, very young infants are less able than older children to buffer even a small absolute fluid or blood loss; to maintain blood sugar levels and a good nutritional balance; to warm themselves from a cold insult; or to eliminate drugs, gases, and vapors. Their decrease is largely from a phenomenon called perinatal vasoconstriction, which causes increasing fetal losses of these wastes by way of their hepatic and renal blood supplies rather than their usual routes. The consequence is prolonged half-lives of drugs the liver detoxifies, and an overall lower effectiveness of waste removal until the neonate's liver and kidneys grow in size and blood flow. (Liu et al.2024)

Infants and very young pediatric patients have an increased body surface area, which can account for a disproportionate heat loss when they are not optimally treated and draped for their surgeries and anesthesias. Their small body masses are capable of exuding extra heat, but can also rapidly cool from too much uncovered peritoneum, from unwarmed colonic irrigation fluid, and from using cold drugs, gases, and vapors for anesthesia. Moreover, should their core body temperature drop 1 degree centigrade, their surfactant production and lung compliance can promptly decrease by one-third. With preterm delivery, surfactant synthesis can be delayed or inadequate, leading to a marked increase in their likelihood to develop patent ductus arteriosus and bronchopulmonary dysplasia, with their associated risks of hypoxia and hypercarbia.

5.3. Toddlers and Preschoolers

Several features distinguish the performance of anesthesia in toddlers from that in infants. Toddlers have greater tidal volumes, higher oxygen demands, and airway musculature that gives them more resistance to the necessary airway maneuvers. In addition, they say "mommy, no," which is an entirely different expression than the facial expression of an infant with a laryngoscope in his or her mouth. The first lesson in providing anesthesia for toddlers is to recognize their autonomy and separation from the parents. Admission procedures should encourage the development of trust and rapport between the toddler and the anesthesia provider. This trusting relationship enables premedication without parental presence, allows the anesthesia provider to be present at induction of anesthesia without parental presence, and facilitates the transfer of the child from the responsibility of the parents to the responsibility of the anesthesia provider.

The ideal induction of anesthesia in a toddler is quick, easy, and preferably without volatile anesthetic vapors. In real life, a combination of sevoflurane and nitrous oxide has made this goal reasonable. Several principles of induction are worth mentioning: • Ensure a good mask fit prior to induction. • Use communication within the coping capacity of the toddler and offer distraction as desirable ways to get the mask in place. • Avoid excessive oxygen flow in toddlers by decreasing the gas to less than their gas demand. Little effort is needed to blow 4% sevoflurane into the breathing zone of a satisfied toddler. • Avoid the aroma of anesthesia by breaking the seal between the mask and the mask rest. • Inject a premedication just as the child is ready to go to sleep (or it can work against your other effects). Once the child is asleep, make sure you reestablish the circuit. (Maren and Berit2021)

5.4. School-Age Children

The following suggestions are made to assist an anesthetist in performing pediatric regional blocks: The choice of technique is dependent on the patient's condition, the procedure being performed, or patient and family preference. There are four techniques. The selection of local anesthetics and dose should be based on patient age, weight, health, needle insertion depth, and identification of crucial structures for the block chosen. Adverse drug reactions to local anesthetics, as well as a history of epilepsy, have been reported to occur with standard peripheral nerve blocks for children. Local anesthetics are not recommended for use, particularly in children with certain diseases or a known exposure risk. School-age children are offered the same type of anesthesia options as teenagers and adults for a variety of surgical procedures. School-age children are medically suitable to undergo elective, ambulatory, dental, otorhinolaryngological, subumbilical, and some other minor surgical procedures for any of the standard anesthetic techniques. The concept of patient-centered care suggests that, whenever feasible and suitable, regional anesthetics should be provided to a patient who requires surgery. Regional anesthesia provides several benefits. In comparison to general anesthesia, sensory and motor deficits are smaller in area. As patients regain spontaneous movement and sensation, hospital stay is usually shorter. When compared to surgical block, powerful narcotics and toxins are not used. When hospitalization is not required, it is cost-effective. (Almasi et al.2020)

5.5. Adolescents

Adolescent surgical patients are a unique group. Typically, their size, weight, airway anatomy, and drug response place them intermediate between young children and adults, but this is highly variable. Their weight can be from a small underweight adult, requiring adult-sized central venous catheters and special consideration with one-lung ventilation, to a small child, which has dangers with accidental extubation and risks of drug administration errors. In half the cases, breast development in girls or testicular size, at least two centimeters, in boys, indicates that puberty is present. This can create special privacy and emotional issues when disrobing or in the intensive care unit. In preadolescents, when physical development is minimal, we use the same guidelines as for young children. When adolescents appear similar to adults, we can usually provide adult care. Adolescent patients should be encouraged to communicate their desires and concerns, show respect for their modesty, and listen to ensure that they understand procedures and recovery. Pre-surgery group and individual discussions, including written information, should be given. They can express confusing fears that need resolution. These patients should then be encouraged but not forced to act as a member of the operative team by asking them to move from the stretcher onto the operating room table to show control of their own body. (Petersenn et al.2023)(Virgone et al.2021)

6. Emergencies and Crisis Management in Pediatric Anesthesia

Emergencies are rare in pediatric anesthesia. Monitors are helpful, but clinical signs are of paramount importance. One must anticipate not only the common problems, e.g., oxygenation, laryngospasm, and hypercarbic acidosis, but the unconventional ones as well. The average 3-year-old child can hold his breath for 90 seconds with marked ventilation and hemodynamic stability during that time, only to progress to total cardiorespiratory collapse after 120 seconds. The normally hyperdynamic circulation of the pediatric patient, lacking in reserve, is unforgiving of ventricular dysrhythmias, especially during acute blood loss and anemia. Nausea and vomiting rarely occur in the very young, but much more serious CNS disturbances may present as laryngeal reflexes.

Little ones cool quickly after induction, either because they fall asleep at a supraphysiologic level of metabolism or due to exhausting end-expiratory outflow all at once. Impaired thermodynamic regulation often makes them 'late warmers' and non-shivering. Care must be taken to avoid hyperthermia, which is potentially neurotoxic and carries the risk of elastic filament destruction in the development of postoperative atelectasis. In sudden progressive lethal external compression, the single best intervention is to secure the child's airway and ventilate very gently using the lowest tidal volumes attainable. It may only be possible to save one life at the expense of the other, and there is therefore no single 'best' option on which to act first. Rapid turnover times between rooms and minimally invasive surgery have nothing to do with safety, protection of patient rights, comfort, development, or long-term outcomes from proposals that should always be consensual.

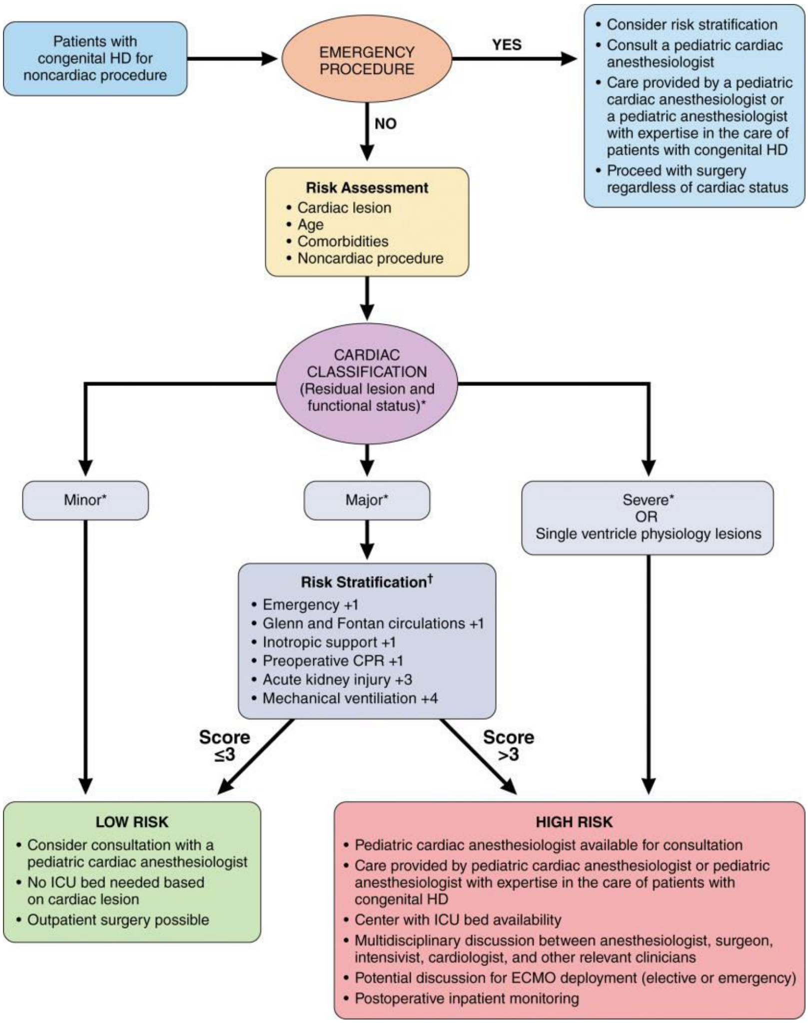
6.1. Malignant Hyperthermia

Malignant hyperthermia is a rare, life-threatening syndrome usually triggered by the administration of volatile anesthetic gases or by depolarizing neuromuscular blocking agents. It is inherited as an autosomal dominant trait with variable penetrance of the responsible mutations, located on chromosome 19. Early clinical signs of the syndrome include tachycardia, generalized muscular rigidity, and hypercarbia; hyperthermia may develop subsequently. Once clinical signs of malignant hyperthermia develop, the most important goal of management is to stop the synthesis of excess heat and to decrease the metabolic rate. This is achieved by stopping all potentially hyperthermia-triggering anesthetic agents, including halothane, isoflurane, enflurane, and invasive monitoring, following the administration of dantrolene. During this time, invasive monitoring is established. If it has not been placed earlier, arterial and central venous catheters are inserted urgently. Hypercarbia further increases the risk of excessive heat production; therefore, spontaneous ventilation should be instituted unless severe muscle rigidity or other signs of impending respiratory failure are present. After hyperventilation has begun, side effects of pancuronium or vecuronium that are due either to decreased plasma cholinesterase activity or an unknown sensitivity to their effects may contribute to signs similar to malignant hyperthermia. (Gregory & Weant, 2021)

6.2. Anaphylaxis

Anaphylaxis in the operating room can present as bronchospasm, hypotension, or both. If bronchospasm is severe, an inspired gas mixture may not provide uniform distribution of inspired oxygen. Mask or endotracheal ventilation may be difficult. Complete airway obstruction rarely occurs. If a child presents with bronchospasm on induction of anesthesia, a bronchodilator should be given—by inhalation, if circumstances allow—to confirm the diagnosis and to relieve that part of airway obstruction caused by bronchospasm. If ventilation becomes inadequate, the trachea should be intubated promptly, as PEEP using intermittent assisted ventilation for pulsed expiration violates one of the four rules for airway control. The four rules are 1) confirmed placement of an endotracheal tube, as recognized before a patient leaves the induction area; 2) no gas leak at 25 to 30 cm H_2O inflation pressure; 3) end-tidal CO_2 curve; and 4) signs of life with stimulation.

Endotracheal intubation allows positive pressure ventilation with high inspired concentrations of oxygen. Small doses of antiarrhythmics and anxiolytics may be recommended after anaphylaxis, for the child with a clearly identified cause, such as an injection of penicillin. However, in few cases are specific causes identified. Some signs of systemic redistribution of anaphylaxis present in both animals and humans earlier have been seen in the cerebral circulation. Data suggest that cerebral anoxia might explain previously diagnostic difficulties with humans during anaphylaxis. Further, no choice of agent for general anesthesia is free of serious concerns related to treatment of or resistance to endothelial function effects of anaphylaxis histamine. Treatment of the airway may be complex and should be reviewed for individual patients. After the reaction is clearly controlled or anesthesia is terminated, the child should be transferred to a pediatric intensive treatment unit if airway edema presents a threat of airway occlusion. (Taxak et al.2023)



7. Risk Factors and Complications in Pediatric Anesthesia

The risk of anesthesia to a child varies considerably with age and the child's clinical status. The surgical procedure may also contribute to an increase in risk. There are certain circumstances in which the anesthetist should pay particular attention to possible risk in the pediatric patient. Among the predisposing factors that may increase the risk of anesthesia are hypovolemia, anemia, malnutrition, dehydration, hypoxia, maternal infection, coexisting metabolic or systemic disorders in the patient, intraventricular hemorrhage, convulsions, shock, and trauma. Complications and emergencies may be minimized if a careful history and physical examination are done before the patient is anesthetized. Medications, somatic and psychic reactions, as well as recovery, must be evaluated carefully by an experienced person. Postanesthesia complications must be met with reassurance, explanation, and parents should be given sufficient information on the child's condition and the potential of the particular complication.

Complications of pediatric anesthesia may include: hangover paralysis, hypoxemia, respiratory arrest, drug overdose, drug reactions, sudden and unexpected death, hyperthermia, hypothermia, hypotension, bradycardia, unexpected hyperventilation, acid-base changes, unexpected clotting problems, anemia, convulsions, laryngospasm, bronchospasm, bronchorrhea, aspiration, clenched jaw, edema of the tissues of the airway, obstruction of the airway, croup, anesthetic machine malfunction, fire or explosion, spill of hazardous substances on and in the vicinity of the patient, electrocautery burn, surgical complication causing hemorrhage or pain out of proportion to the injury, air embolus, accidental intravascular injection, unrecognized manifestations of a preexisting acute appendicitis, and postnatal dependence on the effects of opioids. The mature physician anesthesiologist assesses each infant on the basis of chronological age, mental and physical condition, each developmental stage, the degree to which the infant is a separate entity, the solemn responsibility of restoring an infant's physical and emotional well-being with skill and care, and the necessity of monitoring infants postoperatively for such effects as serum glucose and hematocrit alterations, active and open infants' support of life throughout adolescence. (Vitale et al.2022)

7.1. Neurotoxicity

Given that the study of pediatric anesthetic neurotoxicity is relatively new, and that the literature is predominantly generated by a small handful of select animal trials, the actual risk to the pediatric patient from anesthetic agents, and the secondary inflammatory/metabolic components influencing long-term neurological outcomes, is poorly defined. The known neurodegeneration effects of ambient general anesthetics in the brain are characterized by an increased apoptosis rate, alterations in synapse numbers, and a general decrease in body and head size when anesthetized animals are compared to controls. There is widespread support for an association effect between general anesthesia and impaired neuropsychological development in patients when anesthetic exposure occurs in the perinatal period. Effects from environmental agents at critical periods of early brain development can have both immediate and lifelong effects on the developing brain. These can result in structurally minuscule modifications or outright neuropsychological defects, and can be related to abnormal activity in the mitotic spindle motor protein Nde1. Adult brains have very low, if any, expression of Nde1, and it is primarily distributed in neural stem cells during embryonic development. (Ecoffey et al.2022)

7.2. Postoperative Nausea and Vomiting

Nausea and vomiting occur frequently in children after surgery. Strategies for minimizing vomiting risk include opioid-sparing analgesic techniques; selection of anesthetic agents with a low emetic risk; prophylaxis with antiemetics providing broad-spectrum antagonism; and, when appropriate, locoregional anesthetic techniques to provide profound sympathetic neural blockade in surgical fields that are associated with a high risk of gastrointestinal irritation. Factors associated with increased risk of postoperative nausea and vomiting include female gender, previous postoperative sickness, anticipated major surgery, and postoperative opioid administration. Promising studies have recently been published correlating genotype-linked risk or hormone assays and risk in women.

Nausea and vomiting are frequently associated. Nausea is also a multisensory experience caused by a complex combination of contributing factors. The most reliable contributing factors for postoperative nausea and vomiting are outlined. When it does occur, successful treatment relies on the administration of an effective antiemetic that is consistently able to interrupt the emetic pathway at the receptor level. Combination antiemetic therapy reduces incidence compared with single-agent therapy in many studies, but this is at a cost to the patient, in terms of antiemetic side effects or cost. Pre-existing risk factors to consider before selecting antiemetic combination therapy for a particular patient include the onset and duration of anesthetic administration, postoperative opioid administration, dexamethasone administration, and the costs and complications of managing, which should form the foundation of any future risk models.

8. Preoperative Preparation and Parental Involvement

Since the safe administration of general anesthesia requires the expertise and cooperation of a well-prepared patient, the responsibility for preoperative care begins with the anesthesiologist. Regardless of the patient's age, the basic aim of consistent and individualized preoperative care is to reduce the perioperative stress (both physical and emotional) as much as possible. The pediatric anesthesiologist faces a variety of challenges relating to the many different reactions of anxious patients, the clinical assessment of pediatric patients (the importance of detailing a medical history is always exacerbated by the dependent and vulnerable nature of such a history being provided by a parent), the performance of the most straightforward and reliable technique of anesthesia possible, the close collaboration anticipated with the anesthesiologist, and the rapid and assured management of conditions such as critical obstruction of the upper respiratory tract. (Carli, 2020)

The pediatric anesthesiologist must always be in communication with and have the trust of the parents so that they can help the patient to understand the process. Experience proves again and again that parental anxiety and misgiving about anesthesia is often rooted in a lack of understanding that can be traced to a lack of communication between the parents and the anesthesiologist. Parents who feel that they are being informed and listened to generally display better cooperation. Successful nursing care of the child in the preoperative unit plays an equally important role and requires an appropriate knowledge of pediatric nursing. The institutional policies of the preoperative unit also play an important role and should take into account the special requirements of pediatric patients.

9. Ethical and Legal Issues in Pediatric Anesthesia

Anesthesia is an important part of pediatric and adult medical practice. The response to our role as anesthetists must include the larger ethical and legal issues faced by all members of society. We must balance confidentiality, informed consent, and competence with our duty to preserve and protect life. This chapter leads us through this process, providing a framework that will help us achieve integrity and competence in our professional practice. Ethical problems are situations involving conflict of values. Certain aspects applied to pediatric anesthesia practice include the participation of the anesthesiologist as a member of the clinical care team providing perioperative care, balancing the respect for patient autonomy with beneficence or non-maleficence in an emergency, shared decision-making in giving anesthesia to a child with limited choices, and pediatric anesthesia research. The various ethical underpinnings of these issues are discussed. Legal aspects discussed include the requirements for informed consent, parental authority to make healthcare decisions for their children, limiting child autonomy surrounding the decision-making for anesthesia, termination of therapeutic support, futility, and brain death. The major case law surrounding these topics is presented. Reluctance to allow elective surgical procedures is fortunately decreasing, allowing us to better care for pediatric patients. Ethical behavior is foremost the responsibility and role of each individual anesthesiologist and physician. Promptly and comfortably examining one’s code of ethical conduct will only maintain and improve the demands for high-quality professional behavior. (Módolo et al.2024)

10. Future Directions and Innovations in Pediatric Anesthesia

In the future, there is potential to develop non-pharmacological methods of achieving sedation. It has been shown that music has a positive impact in two aspects of minor surgery: silence and wound care during music presented lower procedures for children and greater satisfaction in a group of adults. Exposure to videos, as opposed to midazolam for preoperative anxiety, shows promising results in a pilot study. Aromatherapy in the form of a mask to decrease the smell of anesthetic gas has had promising results in a randomized controlled trial. It is possible that intraoperative use of these strategies would be of similar or greater benefit. Patient movement is an alarming phenomenon, particularly when dealing with young children with airway instrumentation. Music video goggles have shown promising results in children, not only decreasing anxiety but also decreasing the amount of sevoflurane consumption required in children with basal preconditions. This factor becomes even more important when considering the longer-term outcomes of early and repeated exposure to anesthetic drugs in these children.

A campaign has been developed with multiple brochures aimed at reducing exposure to anesthetic medication in bariatric patients and encouraging mobility and early progress in post-operative feeding during respiratory sedation. Aimed at critically ill children who are exposed to long periods of sedation, haloperidol has been shown to be neurotoxic yet remains the first-line sedative in practice, while midazolam has its own potential hazards with neurotoxicity, tachyphylaxis, and metabolic complications. Dexmedetomidine has less neuro-apoptotic potential, is licensed down to the age of six months, and has been shown to preserve femoral artery pressure, diuresis, and has shown an efficacy of up to 60% in the PICU setting. With only one unit requiring intervention in 150 children, it suggests that the need for a higher level of care may be lower with the addition of dexmedetomidine. It raises concerns about its potential withdrawal side effects; if it is necessary to wean critically ill children off the drug, a comparison of clonidine versus dexmedetomidine infusions and sedation of ventilated children shows that clonidine may be a suitable sedative in resource-limited settings. (Mercadante, 2023)

11. Resultes

The pain of intramuscular injection of intravenous agents is a practical problem. The Mark2 has a color-coded syringe system to facilitate quick and accurate sedation depth measurement and a GPS needle system to reduce intramuscular injection pain. In this study, the Mark2 syringe system reduced the intramuscular pain in pediatric patients who needed same-day surgery with ambulatory anesthesia. As a new technology to overcome the pain of intramuscular injection during same-day surgery in pediatrics, Mark2 may have not only the ability to check the amount of sedatives efficiently but also reduce the amount of pain suffered by pediatric patients, allow them to go to sleep more easily, and remind them of pleasant events. In this prospective, double-blind, randomized controlled trial, pediatric patients without topical anesthesia were allocated into two groups: the usual-dimensional intravenous induction group and the UIKit group. The primary outcome was the pain of propofol injection. In a secondary outcome, mask holding time and onset of action of propofol were measured. A total of 394 patients were enrolled. There were no significant differences in the mean pain score during mask induction. The usual-dimensional intravenous propofol injection is better than the usual-dimensional technique of real accelerated care patient education and real-time distraction tool in terms of the pain of propofol injection in pediatric patients.

12. Conclusion

In conclusion, pediatric anesthesia is safe and rewarding but depends on a sound knowledge of the techniques required in infants and children. Risk reduction, and therefore improved safety, may be achieved by cooperative practice between all those who are involved in the care of this special group of patients, particularly with the cooperation of the pediatric anesthetist and the pediatric surgeon. This ideal pattern of teamwork, although not always easy, is worth working towards. Stimulated by the actions of parents' groups and accurate self-audit, the last 10 years have seen a trend for repeated successful modifications in anesthetic techniques to reduce risks in our small patients. Such a trend is likely to continue while the effort is geared to maintaining awareness of our potential problems and encouraging a scientific healthy skepticism about the risks of new techniques. Anesthetic records have a valuable role to play in these matters.

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