

Anesthetic Considerations In Paediatric Patients

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PAEDIATRIC ANAESTHESIA

Paediatric patients present unique anatomic, physiologic and pharmacologic considerations for the management of anaesthesia in the presence of diseases that occur exclusively or with increased frequency in this age group. Neonates (up to 28 days of age) and infants comprise the age group in which differences from adults are most marked. Neonates are more likely to experience adverse perioperative cardiopulmonary events¹.

Pediatric patients deserve special considerations with respect to anatomic, physiologic and pharmacologic differences from adults.

ANATOMIC DIFFERENCES

Differences in airway anatomy make the potential for technical airway difficulties greater in infants than in teenagers or adults.

The airway of infants differs in five ways^{2,3}: (1) The relatively large size of the infants' tongue in relation to oropharynx increases the likelihood of airway obstruction and technical difficulties during laryngoscopy. (2) The larynx is located higher in the neck (at a level of C₄ versus C₆ in adults) thus making straight blades more useful than curved blades. (3) Epiglottis is shaped differently, being short and stubby and is angled over the laryngeal inlet; control with the laryngoscope blade is therefore more difficult. (4) The vocal cords are angled, so a blindly passed endotracheal tube may easily lodge in the anterior commissure rather than slide into the trachea and (5) The infant larynx is funnel shaped, the narrowest portion occurring at the cricoid cartilage. In adults, an endotracheal tube that passes the vocal cords will readily pass into the trachea because the glottic opening is the narrowest portion of the larynx. In infants or young children, an endotracheal tube that easily passes the vocal cords may be tight in the subglottic region because of narrowing at the cricoid cartilage. For this reason, uncuffed endotracheal tubes are usually preferred for patients younger than 6 years.

These differences i.e. the large head and tongue, mobile epiglottis and anterior position of the larynx, characteristic of neonates, makes the tracheal intubation easier with neonates head in a neutral or slightly flexed position than with the head hyperextended. Infants have often been described as obligate nasal breathers; however 8% of premature neonates and 40% of term newborns can convert to oral breathing in the presence of nasal airway obstruction. Almost all infants can easily convert to oral breathing by 5 months of age. Most infants can convert to oral breathing if the obstruction lasts more than 15 seconds⁴.

PHYSIOLOGIC DIFFERENCES

Physiologic differences between children and adults are important determinants when planning management of anesthesia in pediatric patients. Monitoring vital signs and organ function during the perioperative period is especially important, as neonates and infants have decreased physiologic reserves.

Respiratory system: The single most important difference that physiologically distinguishes pediatric patients from adults is oxygen

consumption. Oxygen consumption of neonates is more than 6 ml/kg which is about twice that of adults on a weight basis. To satisfy this high demand alveolar ventilation is doubled compared with that in adults. Because the tidal volume on a weight basis is similar for infants and adults, the increased alveolar ventilation is accomplished by an increased breathing rate⁵.

Cardiovascular system: Fetal circulation is characterized by high pulmonary vascular resistance, low systemic vascular resistance (placenta) and right to left shunting of blood through the foramen ovale and ductus arteriosus. At birth a number of events change hemodynamic interactions such that the fetal circulation becomes an adult type circulation⁶. Specifically, the placenta is removed from the circulation; portal blood pressure falls which causes the ductus venosus to close and blood becomes oxygenated through the lungs and exposure of the ductus arteriosus to oxygenated blood induces ductal closure.

As a result of the combined effects of lung expansion, exposure of blood to oxygen and loss of low resistance through placental blood flow, pulmonary vascular resistance decreases while peripheral vascular resistance rises rapidly. An increase in pressure on the left side of the heart (caused by the rise in peripheral vascular resistance) induces mechanical closure of the foramen ovale. Thus all three connections between the right and left side of the circulation close. Although closure of the ductus arteriosus probably occurs primarily in response to a rise in arterial oxygen concentration, its successful completion requires arterial muscular tissue⁷. The fact that such tissue is less prevalent in premature infants may account, in part, for the high incidence of patent ductus arteriosus in premature infants. Anatomic closure of the foramen ovale occurs between 3 months and 1 year of age. Functional closure of the ductus arteriosus normally occurs 10 to 15 hours after birth, with anatomic closure taking place in 4 to 6 weeks.

During this critical period, the infant readily reverts from the adult circulation to a fetal type of circulation, this state is called transitional circulation. Many factors (hypoxia, hypercarbia and anesthesia induced changes in peripheral vascular tone) can affect this precarious balance and result in a sudden return to fetal circulation. When such a flip flop occurs, pulmonary artery pressure increases to systemic levels, blood is shunted past the lungs through patent foramen ovale and the ductus arteriosus may reopen and allow blood to shunt at the ductal level. This explains why hypoxemic events in infants are often prolonged despite adequate pulmonary ventilation with 100% oxygen.

Risk factors increasing the likelihood of a prolonged transitional circulation include prematurity, infection, acidosis, hypoxia, hypercarbia, acidosis, hypothermia and congenital heart disease. Care must be directed to keep the infant warm, maintaining normal arterial oxygen and carbon dioxide tension and minimizing anaesthetic induced myocardial depression⁸.

A diagnosis of persistent fetal circulation can be confirmed by measuring the PaO₂ in blood samples obtained simultaneously from preductal (right radial) and postductal (umbilical, posterior tibial or dorsalis pedis) arteries. The presence of PaO₂ differences of more than 20mm Hg in these

simultaneously obtained blood samples confirms the diagnosis.

Stroke volume is relatively fixed by a non compliant and poorly developed left ventricle in neonates and infants. The cardiac output is therefore very dependent on heart rate. The sympathetic nervous system and baroreceptor reflexes are not fully mature. The infants' cardiovascular system maintains lower catecholamine stores and displays a blunted response to exogenous catecholamines. The vascular tree is less able to respond to hypovolemia with vasoconstriction. The hallmark of intravascular fluid depletion in infants and neonates is therefore hypotension without tachycardia. Cardiac calcium stores are reduced because of immaturity of the sarcoplasmic reticulum. Consequently, the neonate has a greater dependence on exogenous calcium and probably increased susceptibility to myocardial depression by potent inhaled drugs that have calcium channel blocking activity^{9,10}.

Distribution of body water: At birth total body water constitutes 80% of body weight, but it falls dramatically to around 60% by the end of the first year¹¹. Total body water content and extracellular fluid volume are increased proportionately in neonates. The ECF volume is equivalent to about 40% of body weight in neonates compared with about 20% in adults. By 18 to 24 months of age, the proportion of ECF volume relative to body weight is similar to that in adults. The increased metabolic rate characteristic of neonates results in accelerated turn overs of ECF and dictates meticulous attention to intraoperative fluid replacement. Intra operative fluid replacement often includes glucose although the clinical impression that pediatric patients are more susceptible than adults to hypoglycemia during fasting periods has been challenged^{12,13}.

Renal function: Renal function is markedly diminished in neonates and further diminished in preterm babies because of low perfusion pressure and immature glomerular and tubular function. Nearly complete maturation of glomerular filtration and tubular function occurs by approximately 20 weeks after birth, although maturation is somewhat delayed in premature infants.

Complete maturation of renal function occurs by about 2 years of age^{14,15}. Thus the ability to handle free water and soluble loads may be impaired in neonates and the half life of medications excreted by means of glomerular filtration will be prolonged^{16,17}.

Neonates are obligate sodium losers and cannot concentrate urine as effectively as adults. Therefore, adequate exogenous sodium and water must be provided during the perioperative period. Conversely, neonates are likely to excrete volume loads more slowly than adults and are therefore more susceptible to fluid overload. Premature neonates often possess multiple renal defects, including decreased creatinine clearance, impaired sodium retention, glucose excretion and bicarbonate reabsorption; and poor diluting and concentrating ability. These abnormalities increase the importance of meticulous attention to fluid administration in the early days of life.

Hematology: Characteristics of fetal hemoglobin (HbF) influence oxygen transport. For example, HbF has a P_{50} of 19 mm Hg compared with 26 mm Hg for adults, which result in a leftward shift of the fetal oxyhemoglobin dissociation curve. Subsequent increased affinity of hemoglobin for oxygen manifests as decreased oxygen release to peripheral tissues. This decreased release is offset by increased oxygen delivery provided by the increased hemoglobin concentrations characteristic of neonates. By 2 to 3 months of age, however, physiologic anemia results. After 3 months there are progressive increases in erythrocyte mass and hematocrit. By 4 to 6 months, the oxyhemoglobin dissociation curve approximates that of adults. In view of the decreased cardiovascular reserve of neonates and the leftward shift of the oxyhemoglobin dissociation curve, it may be useful to maintain the neonate's hematocrit closer to 40% than 30% as is often accepted for

older children. Calculation of estimated erythrocyte mass and the acceptable erythrocyte loss provides a useful guide for intraoperative blood replacement¹⁸. Average blood volume varies from 80 to 90 ml kg⁻¹ at birth. By 1 month of age, the blood volume varies between 70 and 80 ml kg⁻¹ as in adult.

The need for routine preoperative hemoglobin determination is controversial¹⁹. Routine preoperative hemoglobin determinations in children less than 1 year of age results in the detection of only a small number of patients with hemoglobin concentrations below 10 g/dl, this rarely influences management of anaesthesia or delays planned surgery. Because of the potential benefit of identifying anemia during infancy, preoperative hemoglobin testing may be justifiable only in this age group.

Thermoregulation: The infant is especially vulnerable to hypothermia because of both the large ratio of body surface area to weight and a limited ability to cope with cold stress. A premature infant even is more susceptible because of very thin skin and limited fat stores. This problem is compounded by cold operating rooms, wound exposure, intra venous fluid administration, dry anaesthetic gases and the direct effect of anesthetic agents on temperature regulation. The infant may compensate by means of shivering and non shivering (cellular) thermogenesis. The minimal ability to shiver during the first three months of life makes cellular thermogenesis (metabolism of brown fat) the principle method of heat production²⁰. Metabolism of brown fat is severely limited in premature infants and in sick neonates who are deficient in fat stores. Brown fat is a specialized adipose tissue located in interscapular and vertebral areas and surrounding the kidneys and adrenal glands. It is very important to address all aspects of possible heat loss during anaesthesia, as well as during transport to and from the operating room. Heat lost by conduction is reduced by placing the baby on a warm mattress and warming the operating room. Heat lost through convection is minimized by keeping the infant in an incubator, covered with blankets. The head should also be covered. Heat lost from radiation is decreased by the use of a double shelled isolette during transport. Heat lost through evaporation is lessened by humidification of inspired gases, the use of plastic wrap to decrease water loss through the skin and warming of skin disinfectant solutions. Hot air blankets are particularly useful²¹. Anaesthetic agents can alter many thermoregulatory mechanisms, particularly non shivering thermogenesis in neonates^{22,23}. Hypothermia is a serious problem that has been associated with delayed awakening from anesthesia, cardiac irritability, respiratory depression, increased pulmonary vascular resistance and altered drug responses.

Liver: At term, the functional maturity of the liver is somewhat incomplete. Most enzyme systems for drug metabolism are developed but not yet induced (stimulated) by the drugs that they metabolize. As an infant grows, the ability to metabolize medications increases rapidly for two reasons (1) Hepatic blood flow increases and more drug is delivered to the liver and (2) the enzyme systems develop and are induced^{17,24}. In general, two types of reactions take place in the liver. Phase I reactions which include oxidation, reduction, hydrolysis and phase II reactions, which involve conjugation with other molecules. Oxidation and reduction are weak in the neonate but increase to adult levels within a few days; conjugation reactions take 1-3 months to develop.

The plasma levels of albumin and other proteins necessary for binding of drugs are lower in term newborns (and are even lower in premature infants) than in older infants. This condition has clinical implications regarding neonatal coagulopathy (e.g. the need for vitamin K at birth), as well as for drug binding and pharmacodynamics; the lower the albumin value, the less protein binding and the greater the levels of free drug^{25,26}.

In addition drug binding to albumin may be altered in the presence of hyperbilirubinemia for some medications in the neonatal period²⁵.

Gastrointestinal System: At birth, gastric pH is alkalotic; by the second day of life, pH is in the normal physiologic range for older patients. The ability to coordinate swallowing with respiration does not fully mature until the infant is 4-5 months of age, thus resulting in a high incidence of gastroesophageal reflux in newborns, a very common problem in preterm infants²⁷.

Glucose homeostasis: Neonates have low glycogen stores that predispose them to hypoglycemia. Impaired glucose excretion by the kidneys may partially offset this tendency. Neonates at greatest risk for hypoglycemia are premature or small for gestational age, have been receiving hyperalimentation and were born to diabetic mothers.

PHARMACOLOGICAL DIFFERENCES

The response of infants and children (and particularly neonates) to medications is modified by many factors including body composition, protein binding, body temperature, distribution of cardiac output and maturation of the blood brain barrier, liver and kidneys^{16,17,24,25,26,28,29}. The body compartments (fat, muscle, water) change with age. Total body water content is significantly higher in premature than term infants and in term infants than 2 year olds. Fat and muscle content increases with age. These alterations in body composition have several clinical implications for neonates: (1) A drug that is water soluble has a large volume of distribution and usually requires a large initial dose to achieve the desired blood level (e.g. most antibiotics, succinylcholine); (2) Because neonates have less fat, a drug that depends on redistribution into fat for termination of its action will have a longer clinical effect (e.g. thiopental); and (3) a drug that redistributes into muscle may have a longer clinical effect (e.g. fentanyl).

In general, the potency of many drugs is greater in neonates and infants and less in children when compared with adults. Similarly, most medications will have a prolonged elimination half life in neonates and a shortened half life in children aged over 2 years, which gradually lengthens toward adulthood. Thus, compared with adults, neonates and infants frequently require reduced drug doses while children require increased doses in relation to their body weight.

A. Inhaled Anesthetics

Minimum alveolar concentration (MAC) of inhaled anaesthetics required in pediatric patients changes with age. Full term neonates require lower concentrations of volatile anaesthetics than do infants 1 to 6 months of age. E.g the MAC is about 25% less in neonates than in infants³⁰. Further, MAC in preterm neonates less than 32 weeks gestational age is less than MAC in preterm neonates 32 to 37 weeks gestational age and MAC for both of these age groups is less than that in full term neonates³¹. Decreased anaesthetic requirements in neonates may be related to immaturity of the central nervous system and to increased circulating concentrations of progesterone and beta endorphins. MAC steadily increases until 2 to 3 months of age; but after 3 months, the MAC steadily declines with aging, although there are slight increases at puberty. This fact of decreased anaesthetic requirement combined with the need for deeper planes of anaesthesia to achieve satisfactory conditions for endotracheal intubation, places the infant in a precarious position in that the margin between anaesthetic overdose (from a cardiovascular stand point) and inadequate depth of anaesthesia (for endotracheal intubation) is small³².

Avoidance of controlled respirations until an intravenous line is inserted, rapid reduction in the delivery of inspired anesthetic drug, especially with the initiation of controlled respirations after the administration of a muscle relaxant and in some cases substitution of narcotics for

inhaled drug are practices that improve safety³³.

Uptake and elimination of inhaled anaesthetics is more rapid in pediatric patients than in adults. The principle reasons for this appear to be increased respiratory rates and cardiac index and a greater proportional distribution of cardiac output to vessel rich organs. This rapid rise in blood anesthetic levels combined with the functional immunity of cardiac development probably explains in part why it is so easy to give an overdose to infants and toddlers. Age related differences in blood gas partition coefficient may also facilitate a more rapid rise in alveolar concentration in infants^{34,35}. The most important factor influencing the potential for anaesthetic overdose in neonates is the number of MAC multiples that can be delivered by the vaporizer e.g. a halothane vaporizer can deliver up to 5.75 MAC multiples versus 2.42 MAC multiples for a sevoflurane vaporizer.

i) Halothane: It has a sweet, nonpungent odour, allowing smooth induction and maintenance of anaesthesia. However, sevoflurane appears to be slightly less noxious and is increasingly being used for induction with a change to halothane or isoflurane after induction because of cost restraints. Studies have found no clinically important differences among halothane, enflurane and isoflurane in rapidity of awakening. A statistically significant but clinically unimportant difference is nearly always found in the rapidity of awakening when comparing halothane with either desflurane or sevoflurane (usually 3 to 5 minutes)^{36,37}. Most importantly, airway related problems occur less frequently with halothane and sevoflurane than with enflurane, isoflurane or desflurane. Halothane and sevoflurane are the anaesthetics of choice for the gaseous induction of anaesthesia³⁸.

Approximately 20% of absorbed halothane is metabolized in the liver, mainly by oxidation. This high degree of metabolism appears to be an important factor in the etiology of halothane hepatitis, which occurs in 1 in 10000 to 1 in 30000 adults exposed to the drug. By contrast, halothane hepatitis is exceedingly rare in children. Another concern with halothane is sensitization of the myocardium to arrhythmias because of exogenous and endogenous catecholamines. Most arrhythmias associated with halothane anaesthesia in children are caused by either hypercapnia or an inadequate level of anaesthesia. Up to 10µg/kg of epinephrine may be used with minimal risk of cardiac arrhythmias in pediatric patients³⁹.

Halothane is a potent myocardial depressant that can have profound effects on neonates and children with congenital heart disease.

Both halothane and sevoflurane have been shown to depress cardiac function but sevoflurane is considered to be less of a myocardial depressant⁴⁰. Bradycardia and hypotension due to halothane in infants can be prevented or treated by giving atropine 20µg/kg iv or im³³.

ii) Sevoflurane: Sevoflurane is halogenated solely with fluorine. Fluorination reduces solubility in both fat and blood, thereby reducing anesthetic potency while increasing the rate of uptake and elimination. As a result of its low blood solubility, induction of anaesthesia is more rapid with sevoflurane than with halothane, eyelash reflex being lost in 60-90 sec. Recovery is also more rapid after sevoflurane than halothane, although not as rapid as after desflurane⁴¹. Sevoflurane is less pungent than isoflurane and desflurane. Sevoflurane and halothane are approximately equal in terms of airway complications during induction of anaesthesia. There is no difference in the incidence of laryngospasm or bronchospasm but the incidence of coughing during induction with sevoflurane is slower & also sevoflurane causes less myocardial depression than halothane.

Areas of concern with sevoflurane are its relatively high rate of metabolism and instability with soda lime. Instability with soda lime results in the formation of compound A, nephrotoxic substance. Fresh gas flows of less than 1L/min are not recommended⁴². Other concerns

are higher incidence of emergence agitation than noted with halothane and seizure like activity during induction.

iii) Isoflurane: Isoflurane is claimed to have some advantages over halothane. Less myocardial depression, preservation of the heart rate and a greater reduction in cerebral metabolic rate for oxygen. But isoflurane has an irritant, ethereal odour that is associated with an increased incidence of airway problems such as coughing and laryngospasm during induction, maintenance and recovery from anaesthesia.

In infants and children equipotent concentrations of isoflurane and halothane produced similar reductions in blood pressure. However, although heart rate was reduced by halothane, it was either unchanged or increased in infants anaesthetised with isoflurane. Also, in contrast to halothane, the reduction in arterial blood pressure that occurs during isoflurane anaesthesia appears to be largely the result of a decrease in peripheral resistance rather than myocardial depression. These studies suggest that despite a similar reduction in blood pressure, isoflurane may be associated with greater cardiovascular reserve than halothane in infants and children⁴³.

iv) Desflurane: Like isoflurane, it has a markedly pungent ethereal odour making it unsuitable for inhalation induction of anaesthesia in children owing to a higher incidence of airway complications. It is also associated with emergence agitation. However, by virtue of its lower solubility in blood, recovery from anaesthesia maintained with desflurane is faster than that maintained with halothane or sevoflurane⁴⁴. Nitrous oxide does not contribute to the MAC of desflurane to the same degree that it does with other potent volatile anaesthetics. As it provides stable conditions of anaesthesia with rapid recovery, desflurane may be a useful agent for maintenance of anaesthesia with infants and children. Its high cost may be mitigated by the use of low flow rates in a circle system.

B. Drugs used to induce Anaesthesia

a) Thiopental and propofol

The dose of thiopentone varies with age. Children require relatively higher doses of thiopental and propofol compared to adults because of larger volume of distribution. The elimination half life is shorter and the plasma clearance is greater than in adults leading to rapid recovery in both the drugs. In contrast, neonates, particularly those depressed at birth, appear to be more sensitive to barbiturates and have less protein binding, a longer half life and impaired clearance. The thiopental induction dose for neonates is 3-4 mg/kg compared to 5-6 mg/kg for infants.

b) Ketamine

Ketamine, a phencyclidine derivative, in addition to intravenous and intramuscular routes, may be administered rectally (10 mg/kg), orally (6 to 10 mg/kg) or intranasally (3 to 6 mg/kg)⁴⁵. The combination of oral ketamine, oral midazolam (0.5 mg/kg) and oral atropine (0.02 mg/kg) provides a well sedated patient. Intravenous administration of doses as low as 0.25 to 0.5 mg/kg may be used to provide sedation/analgesia for painful procedures, whereas doses of 1 to 2mg/kg produce sedation sufficient for a smooth transition to general anaesthesia. Higher doses (upto 10 mg/kg intramuscularly) provide sufficient analgesia for insertion of invasive monitoring devices before induction of anaesthesia or in patients with limited venous access.

c) Benzodiazepines

i) Midazolam: Midazolam is the only benzodiazepine approved by the Food and Drug administration for use in neonates. The short elimination half life (~2 hours) in comparison to diazepam (18 hours)

offers an advantage for use as a premedicant in children, the half life being much longer (6 to 12 hours) in neonates. Midazolam is rapidly absorbed after intramuscular (0.1 to 0.15 mg/kg, maximum of 7.5 mg), oral (0.25 to 1.0 mg/kg; maximum of 20 mg), nasal (0.2 mg/kg) or sublingual (0.2 mg/kg) administration⁴⁶. The major problem with oral or sublingual administration is the strong aftertaste, but a variety of syrups may be used to disguise its aftertaste. Concern with nasal administration is possibility of CNS toxicity as a result of drug entering the CNS along neural connections (olfactory nerves).

d) Opioids

Opioids appear to be more potent in neonates than in older children and adults. Possible explanations include easier entry across the blood brain barrier, decreased metabolic capability or increased sensitivity of the respiratory centers.

i) Fentanyl: Fentanyl is the most commonly used narcotic in infants and children⁴⁷. Its major advantages relate to its rapid onset and brief duration of action. This narcotic is more lipophilic than meperidine; the potential effects of the blood brain barrier are of no importance with fentanyl. Fentanyl induces a very stable cardiovascular response while providing an anaesthetic state. Oral transmucosal administration (5 to 15 µg/kg, maximum of 400 µg) results in reasonably rapid absorption with peak blood level achieved within 15 to 30 minutes.

ii) Morphine: Morphine remains the most commonly used opioid for the management of severe pain in children and the standard with which other potent analgesics should be compared. The newborn has lower clearance of morphine and therefore a lower dose will result in higher plasma values because of a longer elimination half life⁴⁸. Term infants older than 10 days may clear morphine more rapidly and at a similar rate as adults. Infants older than 6 months probably have a normal adult response to morphine.

iii) Alfentanil: Alfentanil is eliminated more rapidly than fentanyl; its pharmacokinetics is independent of dose. This property may provide a margin of safety because the greater the administered dose, the greater the elimination. Clearance of alfentanil may be increased in children in comparison to adults. There is important patient to patient variability in pharmacokinetics and pharmacodynamics in neonates and in patients with impaired hepatic blood flow.

iv) Remifentanil: Remifentanil is the most recent addition to the opioids available for the care of children⁴⁹. Because remifentanil is broken down by nonspecific plasma and tissue cholinesterases, the importance of maturation of renal and hepatic function is minimal. This also helps explain the minimal difference in remifentanil's half life between infants and adults. This drug would appear to also have great utility in infants with hepatic or renal failure.

C. Muscle Relaxants: Morphologic and functional maturation of the neuromuscular functions are not complete until about 2 months of age, but the implications of this initial immaturity on the pharmacodynamics of muscle relaxants are not clear. Infants may be more sensitive to the effects of nondepolarising muscle relaxants, but the relatively large volume of distributions results in initial doses that are similar to those for adults. Immaturity of the hepatic or renal function could prolong the duration of action of muscle relaxants that are highly dependent on these mechanisms for their clearance.

a) Succinylcholine: Neonates and infants require more succinylcholine on a body weight basis than do older children to produce comparable degrees of neuromuscular blockade⁵⁰. Presumably this response reflects increased ECF volumes characteristic of this age group, resulting in larger volumes of distribution of succinylcholine. It is the only short acting relaxant that is effective when given intramuscularly in dose of

4-6 mg/kg. Reliable muscle relaxation occurs within 3 to 4 minutes and may last upto 20 minutes. Cardiac arrhythmias frequently follow intravenous administration, especially during halothane anesthesia. Intravenous administration of atropine (but not intramuscular administration of atropine as a premedication) reduces the incidence of arrhythmias. Cardiac sinus arrest may follow the first dose of succinylcholine but is more common after repeated bolus administration. Therefore, atropine should be given intravenously, just before the first dose of succinylcholine in all children.

The potential for complications like rhabdomyolysis, hyperkalemia, masseter spasm and malignant hyperthermia suggests that succinylcholine should not be used routinely. The intravenous use of this drug should be limited to patients who have a full stomach or to treat laryngospasm. Intramuscular administration is indicated for patients with difficult intravenous access when control of the airway is deemed essential. Until an ultrashort acting nondepolarising relaxant becomes available, succinylcholine remains the drug of choice when rapid onset of muscle relaxation is needed. High dose rocuronium may be a suitable alternative⁵¹.

b) Non Depolarising Muscle Relaxants⁵²

i) **Atracurium:** The volume of distribution is increased in infants compared with older children but the net result of these changes was a reduction in elimination half life. The adverse effects associated with atracurium relate mainly to histamine release⁵².

ii) **Vecuronium:** The volume of distribution is increased in infants. The elimination half life was also increased in infants compared with the older age groups. Vecuronium induced neuromuscular block is characterized by lack of histamine release and marked cardiovascular stability in all age groups.

iii) **Rocuronium:** Rocuronium has a clinical profile similar to that of vecuronium and atracurium but offers the advantage that it can be administered intramuscularly. Acceptable conditions for intubation are produced by rocuronium within 3 to 4 minutes after intramuscular administration in dose of 1-1.5 mg/kg. This onset time is similar to that produced with intramuscular succinylcholine; however the duration of action is approximately 1 hour which could be a distinct disadvantage for a brief procedure or difficult airway.

MONITORING

Decreased cardiovascular reserve, altered anesthetic requirements and exaggerated hypotensive responses during general anesthesia make monitoring the systemic blood pressure especially important in neonates and infants during the perioperative period. Selecting the proper cuff size is critical, as a cuff that is too large for the patient's arm results in falsely low readings. The peripheral artery selected for taking samples for BGA is uniquely important, as blood sampled from an artery that arises distal to the ductus arteriosus (left radial artery, umbilical artery, posterior tibial artery) may not accurately reflect the PaO₂ being delivered to the retina or brain in the presence of a patent ductus arteriosus. If retinopathy of the newborn is a consideration, a preductal artery, such as the right radial artery or temporal artery (risk of cerebral embolism with retrograde flushing) should be cannulated.

Monitoring body temperature is useful during the perioperative period to detect the development of hypothermia as well as the rare patient manifesting malignant hyperthermia. Monitoring end tidal carbon dioxide concentrations is reliable in children, although there are some limitations in neonates and infants. For example, because of small tidal volumes and high inspired gas flows, exhaled carbon dioxide concentrations may be diluted, producing falsely low values when measuring end tidal carbon dioxide concentrations.

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