GASTROINTESTINAL SYSTEM

Gastric pH is alkalotic at birth. By the second day of life, pH is in the normal physiologic range as adults. The volume and acid concentration of the gastric fluid reaches the lower limit of adult value by 3 months of age and attains adult value by 2 years of age.[21] Peristalsis in the distal third of oesophagus is not as developed as in adults. Approximately, 40% of newborns will regurgitate and peristalsis may take several months to mature.[22] Newborns are thus susceptible to gastrointestinal reflux.

THERMOREGULATION

The combination of increase in heat loss from the body due to various factors, reduced efficacy of thermoregulatory responses and less ability to produce heat make infants vulnerable to hypothermia. Large skin surface area to body mass ratio in preterm and term infants causes more heat loss than adults during anaesthesia. They have a thin layer of subcutaneous fat and reduced keratin content in skin, predisposing them to further heat loss through the process of conduction and evaporation. In addition, they have relatively large size of head, skin of the head makes up to 20% of total skin surface area.[23] This can account for up to 85% of body heat loss from the highly perfused brain through thin skull bones and sparse scalp hair.[24]

The ambient neutral temperature at which oxygen demand is minimal and temperature regulation can be done by physical process of vasoconstriction is 32°C to 35°C in neonates and 28°C in adults.[25] Thus active heat producing processes need to be invoked earlier as body temperature falls in infants than adults.

Heat generation is done by various processes, of which nonshivering thermogenesis is the main mechanism in infants while shivering thermogenesis by involuntary muscle activity is used in older children and adults. Nonshivering thermogenesis becomes less effective after first year of life when shivering thermogenesis takes over and becomes the most important mechanism of heat production. Nonshivering thermogenesis is metabolic heat production above basal metabolism in brown fat and to a lesser degree in white fat, by fatty acid metabolism and causes diversion of a high percentage of cardiac output through brown fat. This mechanism is active within hours after birth and can continue up to 2 years of age.[26] It can be inhibited by inhalational anaesthetics, intravenous agents, like propofol and fentanyl, β-receptor blockade or by sympathectomy.[27,28] Though it is the main source of heat production, the effects are restricted beyond a certain limit.

During anaesthesia and surgery, various factors predispose infants and children to hypothermia in addition to the fact that general anaesthesia also reduces the threshold for cold defence. Hypothermia can lead to hypoventilation or apnoea, anaesthetic overdose, metabolic acidosis, may exacerbate preexisting cardiopulmonary pathology and can have adverse effects on immune function. Thus maintaining body temperature by active or passive warming, e.g. warming the operating room, placing the baby on warming mattress, keeping babies covered and use of humidified inspiratory gases, is vital part of anaesthetic management in children.

RELEVANT DIFFERENCE IN RELATION TO REGIONAL ANAESTHESIA

Regional anaesthesia is an integral part of perioperative pain management in paediatric patients. With the advent of ultrasound imaging techniques, precise deposition of drug in the vicinity of nerve and reduced volume of local anaesthetic required, thereby reducing the toxicity, has further boosted the use of regional anaesthesia in this subset of patients.[29] Studies have shown that risk of complications with regional anaesthesia is low and preventable in children.[30,31]

General Considerations

Myelination of nerve fibres is incomplete at birth, thus local anaesthetics can easily penetrate nerve fibres and onset time for block is fast. Because of the same reason, dilute solutions of local anaesthetics produce same degree of block as undiluted solutions. Duration of action, however, is short due to greater vascular absorption of local anaesthetic.

Bones in neonates are mainly cartilaginous and ossification of nuclei can be easily damaged with sharp needles. Hence it is imperative to use short bevelled needles and avoid bone contact while performing a block.

Perineurovascular sheaths are loosely attached to underlying nerves, muscles, vessels, etc. This results in increased spread of small volume of local anaesthetic along the nerve path producing excellent blocks

Absorption through rectal route is also variable. Contents and formulation of rectal drug, rectal contractions and depth of rectal insertion, all affect absorption and relative bioavailability.

Factors, like reduced skeletal-muscle blood flow and inefficient muscular contractions, reduce rate of intramuscular absorption of drugs, this is offset by the relatively higher density of skeletal-muscle capillaries in infants than in older children resulting in increased absorption of intramuscular drugs in neonates and infants.

Neonates have a larger relative skin surface area, increased cutaneous perfusion and thinner stratum corneum which increase absorption of topically applied drugs. This can result in harm particularly with repeat dosing of drugs, like lidocaine-prilocaine cream (EMLA).[11] The higher ratio of total body surface area to body mass in infants and young children also affects drug absorption through these routes. Intrapulmonary route is sometimes used as an alternative emergency route for drug delivery in newborns. Drug deposition and systemic absorption after the intrapulmonary administration of a drug depends on developmental changes in the anatomy of the lung and its ventilatory capacity.

The bioavailability through transmucosal, oral or nasal routes has been found to be higher in children when compared to adults, e.g. fentanyl when given as lozenges is rapidly absorbed. The dose, therefore, needs to be adjusted accordingly.

In younger age groups, the greater fraction of the cardiac output distribution to the vessel-rich tissue group and the lower tissue/blood solubility affect the onset time of inhaled anaesthetic gases and vapours and is generally more rapid in infants than in adults. Solubilitity plays considerable role on the uptake of inhalational agents in children. The solubility in blood of inhalation agents is 18% less in neonates than in adults while the solubility in the vessel-rich tissue group is approximately one-half of those in adults[12] due to the greater water content and decreased protein and lipid concentration in neonatal tissues. Solubility of the less-soluble agents, such as nitrous oxide, is a little affected by age.

INTRAVENOUS ANAESTHETICS

Propofol

Propofol is a highly lipophilic drug, its rapid onset and short duration of action makes it a useful induction agent in paediatric age group. As compared to thiopentone, elimination half-life is shorter and clearance is faster, thereby resulting in faster and more clear-headed recovery after single induction dose.

In infants, the volume of distribution is high and clearance is in a maturing phase. Clearance is only 10% that of the mature value at 28 weeks gestation and 38% at term. Term neonates will achieve 90% of an adult clearance (1.83 L min^{-1} 70 kg^{-1}) by 30 weeks after birth.[13] Younger children have larger systemic clearance values than adult and older children. In children older than 3 years, volumes and clearance should be weight adjusted.[14]

Due to variation in pharmacokinetic variables, requirement of propofol in children is greater than adults and varies among children of different age. Induction dose of propofol in children less than 2 years is 2.9 mg/kg and 2.2 mg/kg for children aged 6–12 years. Introduction of elaborate delivery systems, advances in microprocessor technology and increased complexity of pharmacokinetic modelling have resulted in use of propofol especially in children for total intravenous anaesthesia (TIVA) and further to target controlled infusions (TCI).

Propofol is useful for brief and repeated sedation in children undergoing radiological procedures, radiotherapy and during transport from one care giving unit to another. It should be used with caution in children with defects in lipid metabolism as it may cause propofol infusion syndrome[15] and in children with history of egg allergy.[16]

Thiopentone

In neonates, there is a reduced requirement of thiopentone as compared to infants 1 to 6 months of age due to lower body fat and muscle content, decreased protein binding and greater penetration in brain despite a large volume of distribution. Elimination half-life is also longer as compared to older children. Children have a significantly high cardiac output and a rapid rate of total clearance of thiopentone, thus half-life is short as compared to adults.

Induction dose of thiopentone for infants is 7–8 mg/kg and for children is 5–6 mg/kg, however, dose should be reduced to 4–5 mg/kg in neonates and malnourished children. A 10% solution of thiopentone may be administered rectally in dose of 30 mg/kg.[8]

3

Operation Theatre Setup for Paediatric Surgical Patients

Anurag Krishna

...my purpose is here to doo theym good that have moste need, that is to save children: and to share the remedies that god hath created for the use of man...

Thomas Phaire
(The Boke of Chyldren 1553)

- **Safety considerations**
- **Infrastructure of a paediatric OR**
- **Baby-friendly, family-centred care**
- **Transfer to and from OR**

INTRODUCTION

As caregivers for sick children that need surgery, it is our responsibility to provide children with the best possible care in a safe operating room environment with best-in-class clinical outcomes. What will become a differentiator is that we do all this while giving our little patients and their anxious parents an experience that is pleasant and stress free. This chapter briefly touches upon the science of paediatric surgical operating room set up; and describes in some detail the art of caring for children.

The overarching principles for children's surgery[1] are that:

- Children are treated safely.
- They are treated in an environment that is suitable and responsive to their needs.
- Their parents are involved in the care and decision making.
- The care being delivered is of optimal quality.
- All involved in care are suitably trained and supported.

SAFETY CONSIDERATION

The elements that provide a safe environment are—personnel, processes and infrastructure.

Personnel

All children must be treated by appropriately trained professionals. Naturally, the surgeon must be qualified, credentialed and must hold the necessary privileges to perform the index surgical procedure. While it is accepted that some routine paediatric surgical procedures may be performed in general hospitals, it has been adequately demonstrated that for some index and complex procedures, best outcomes are achieved if the cases are done in high volume centers.[2–10] More recently, many paediatric surgical operations are done as day case surgeries. While these should be encouraged as much as possible, however, they place much more

Fig. 4.6. Uncuffed ETT

Traditionally, non-cuffed tube has been used in children up to the size of 5.5, 6 and cuffed tube beyond that size[4,5] (Fig. 4.6). The advantage of cuffed tube is to minimize theatre pollution and decrease the cost of gases by reducing the fresh gas flow. Most of the cuff tubes available in the market are not specifically designed for children and are smaller version of adult tubes. Wess, et al. demonstrated how most of the contemporary available cuffed tubes have no standardized approach to cuff size, the cuff placement, the laryngeal marker, etc. (Fig. 4.7).[6] They developed a Microcuff tube to avoid these shortcomings which is a polyurethane make, soft, gentle to tissue with a 10 cm H_2O pressure and placed close to the tip of the tube[7] (Fig. 4.8). However, the outer diameters at the cuff of these tubes are so wide (7.5 for a 3.5 ID tube) that one will choose a smaller size increasing resistance. The diameter of the cuff is wider than the ID of trachea so the cuff will get wrinkled and provide an uneven seal. It is about 7–8 times more expensive so cannot be used routinely in all cases.

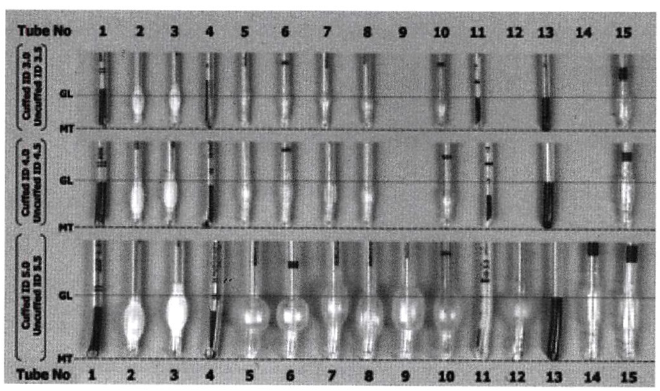

Fig. 4.7. Cuffed tubes (Wess et al) showing the non-standardized cuffs, marking and placement.

With such development, it is tempting to change over to cuffed tube in all children including neonates and that is what has happened over last few years gradually. The other justification for not using non-cuff tube is that the traditional recommendation was not based on any scientific evidence. Safe use of the uncuffed tube for so many decades probably in millions of children is not real evidence!! Resulting in a case of irony of argument.

There is a large evidence of injury to larynx and subglottic region by the ETT especially a large size uncuffed tube or a cuffed tube. Often the cuff size is so wide (in some makes) that it partially remains in the larynx. So whenever a cuff tube is used for monitoring, the cuff pressure is mandatory. The size of the uncuffed tube should be determined by the formulae 3.5 + age in years.[8] An audible air leak around the ETT at a pressure of 20 cm H_2O should be looked for to choose the right tube.

Moulded preformed tubes, like RAE, and reinforced tubes, are especially useful in head and neck surgery (Figs 4.9 and 4.10).

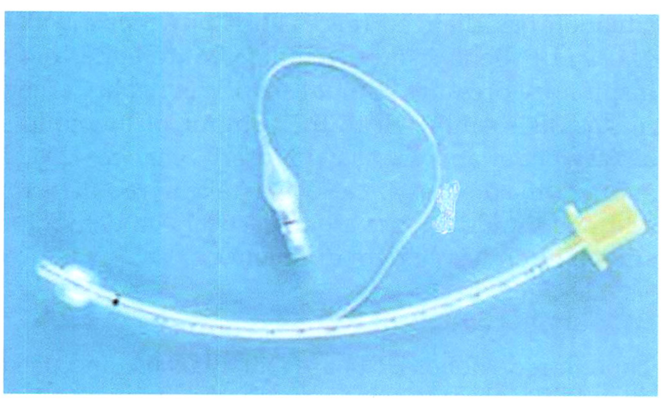

Fig. 4.8. Microcuff tube

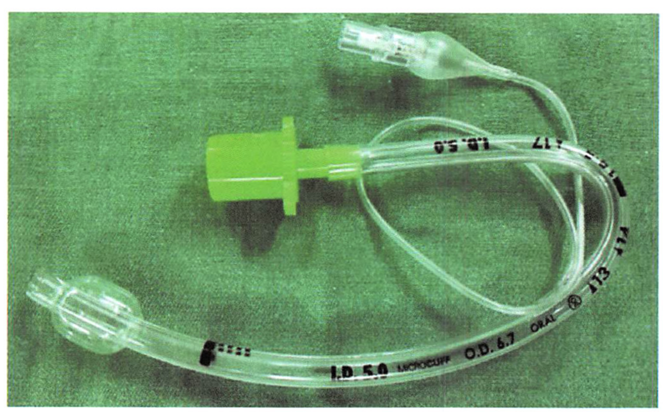

Fig. 4.9. RAE tube