# A Guide to Pediatric Anesthesia

Craig Sims
Dana Weber
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*Editors*

*Second Edition*

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# Ten Current Issues in Pediatric Anesthesia and Where to Find Them

1. **Emergence Delirium**
   Young children sometimes wake from anesthesia crying and unhappy. There are many reasons for this, although sevoflurane dysphoria is commonly blamed. See Chap. 2.
2. **The Uncooperative Child**
   Many children become anxious during induction of anesthesia, and their anxiety may cause them to become uncooperative. There are many ways to reduce children's anxiety. See Chap. 3.
3. **Videolaryngoscopes**
   Many types of videolaryngoscopes are now available in sizes suitable for children. Their use is being informed by new studies, including the PediRegistry study of difficult airway management in children. See Chap. 4.
4. **Reducing Perioperative Respiratory Complications**
   Respiratory complications are the leading cause of morbidity in pediatric anesthesia, and there has been a surge in studies looking at the risk factors for them and how to modify the risk. See Chap. 11.
5. **Shorter Fasting Times for Clear Fluids**
   It is now realized clear fluids leave the stomach quickly, and allowing them up to 1 h or less before anesthesia has become common. See Chap. 5.
6. **Neurotoxicity of Anesthetic Agents**
   There is laboratory evidence that many anesthetic agents, including volatiles, affect the developing brain of neonates. See Chap. 2.
7. **The Airway**
   Many anesthetists do not like caring for children because of difficulties managing the pediatric airway. See Chap. 4 for many practical tips.
8. **RSI and Cricoid Pressure**
   The adult technique of rapid sequence induction is dangerous if directly applied to young children. There are calls to abandon the technique and cricoid pressure altogether. See Chap. 1.

9. **Reducing Pain and Distress During Procedures**
   Holding a child down to perform a procedure is becoming less and less acceptable. Many techniques and drugs are now used to make procedures more comfortable and less distressing for the child, parents, and staff. See Chap. 27.
10. **Hypotonic IV Fluids for Children**
    Hypotonic, dextrose-containing solutions have been traditionally used for IV fluids in children. The risk of hyponatremia from these fluids is so high that salt-rich fluids are recommended nowadays. See Chap. 5.

# Useful Formulae in Pediatric Anesthesia

## Weight

Body weight for infants = (age in months/2) + 4 kg (APLS)

Body weight for children 1–10 years = (age + 4) × 2 kg (UK Resuscitation Council)

Body weight for children older than 10 years = age × 3.3 kg (large variation in normal adolescent weight however) (APLS)

## Blood Pressure

Expected systolic blood pressure for children older than 1 year = 80 + (age in years × 2) mmHg.

## Fluids

Maintenance fluid rate in mL/h: (4:2:1 rule)

4 mL/kg first 10 kg weight + 2 mL/kg next 10 kg weight + 1 mL/kg for rest of weight (e.g., for a 19 kg child: (10 × 4) + (9 × 2) = 58 mL/h).

Minimum 10% dextrose infusion for neonate day one (4 mg/kg/min) in mL/h = 2.5 × weight in kg (e.g., 3 kg neonate needs at least 7.5 mL/h 10% dextrose)

## ETT Size

Uncuffed ETT size for a child over 2 years: Age/4 + 4 = ETT size (inside diameter, mm) (modified Cole formula)

Cuffed ETT size for a child over 2 years: Age/4 + 3.5 = ETT size (ID, mm) (Motoyama formula)

## ETT Depth

Position at vocal cords = ID size of ETT (e.g., 4.5 ETT should be 4.5 cm at vocal cords)

Oral ETT length (at lips in cm) = age/2 + 12

Nasal ETT length (at nostril in cm) = age/2 + 15 (and diameter of correct-size nasal ETT same as oral ETT for children)

Neonates: Oral ETT length (at lips in cm) = weight(kg) + 6

Neonates: Nasal ETT length (at lips in cm) = (weight(kg) × 1.5) + 7

## Suction Catheter for ETT

Size of suction catheter for ETT (in French Gauge) = 2 × size of ETT (ID)

## Urinary Catheter

Urinary catheter size (FG) = 2 × size of ETT (ID)

## CVC

Depth for central line placement in right IJV = 10% of height (e.g., 8 cm in an 80 cm long child)

# Contents

# An Overview of Pediatric Anesthesia

# 1

Craig Sims and Tanya Farrell

'Pediatric' or 'child' applies to someone aged less than 18 years. The American Academy of Pediatrics defines 'pediatric' as less than 21 years, while some centers use 16 years. An infant is a child aged between 1 and 12 months. The term 'neonate' applies to the first 4 weeks of life. Children make up a quarter of the population in most Western countries and a higher proportion in developing countries. Pediatric anesthesia is very common—5.5% of children have an anesthetic each year, and about half are preschool age. The commonest indication for anesthesia is ENT surgery, but children often need anesthesia for procedures such as scans and dental treatment that an adult would tolerate without anesthesia.

Pediatric anesthetists have several special attributes described by the late Dr. Kester Brown: they have expertise in caring for neonates and infants during anesthesia and surgery; they understand the anesthetic implications of congenital disease and disability; and they have knowledge of the psychological, physiological, pharmacological and anatomical differences with age.

## 1.1 Safety of Pediatric Anesthesia

Anesthesia for children has become very safe. Parents can be reassured that the profession has taken many steps over the years to reduce risk. These steps include analysis of past incidents (anesthesia was the first specialty to perform incident monitoring), embracing new monitoring technologies, improved specialist training and taking

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advantage of safer drugs. The overall mortality from anesthesia alone in a healthy, older child is approximately 1 in 50,000 to 1 in 100,000. Tertiary pediatric centers report overall mortality at 24 h after anesthesia and surgery at about 13 per 10,000 anesthetics. Anesthesia-related mortality in this group is reported as 0.7 per 10,000.

Morbidity is common with anesthesia in children. More than half of critical incidents are respiratory incidents and are mostly airway related such as laryngospasm, bronchospasm, hypoxia, and hypoventilation. The risk increases with decreasing age, because of smaller airway diameter and a predisposition to develop apnea and airway obstruction from airway irritation (Fig. 1.1). Infants and young children also desaturate rapidly. Children 3 years and younger have a higher risk than older children. Infants are particularly at risk, with critical incidents four times more likely compared to older children. Surveys show critical incidents (again most commonly respiratory) occurring in 3–5% of infants. Risk is also increased by underlying pathology including congenital disease, the urgency of the procedure, and the hospital setting (Table 1.1).

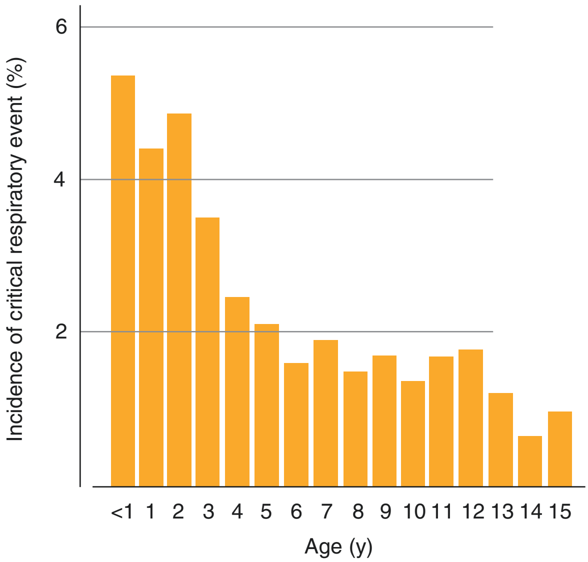


**Fig. 1.1** The incidence of critical respiratory events (those requiring immediate intervention and that led (or could have led) to major disability or death) during anesthesia in children of different age groups. Based on data from APRICOT study, Lancet Respir Med 2017; 5:412–25

**Table 1.1** Patient, surgical and anesthetist factors that may increase the risk of anesthesia in children

| Factors increasing risk of morbidity and mortality | | | |
|---|---|---|---|
| | High risk | Medium risk | Low risk |
| Age | Neonates, infants | 1–3 years | >3 years |
| ASA status | 3–5 | 2 (includes recent URTI) | 1 |
| Surgery | Cardiothoracic, neurosurgery, scoliosis surgery | Airway and dental surgery | Peripheral, minor surgery |
| Emergency surgery | Increases risk | | |
| Experience of the anaesthetist | Increased risk with small case load of children of similar age to patient | | |

**Keypoint**
Most critical incidents are respiratory and airway related. Proficiency in airway management is the cornerstone of safe pediatric anesthesia practice.

The risk of morbidity is lower if the anesthetist is experienced and has a large pediatric case load (Table 1.2). Although there are no formal requirements for anesthetists caring for children, it is generally agreed that practitioners anesthetizing children aged 3 years and less should regularly anesthetize this age group, and anesthetists caring for children aged less than 1 year should regularly anesthetize infants. Neonatal anesthesia should be performed by those who have a fellowship in pediatric anesthesia.

**Keypoint**
Children aged less than 3 years, and especially aged less than 1 year are at a higher risk from anesthesia than older children.

## 1.2 Organization of Services

If you are anesthetizing a child in a non-pediatric hospital it is important to make sure it is safe to do so. Several factors determine if a child can be safely cared for at a particular facility. Broadly, there are factors relating to the patient and the type of surgery planned (Table 1.3), and factors relating to the hospital such as the level of staffing, equipment and facilities (Table 1.4). An older child undergoing day stay surgery has different health facility requirements compared with an infant with coexisting medical problems requiring overnight admission after surgery.

The Australian and New Zealand College (ANZCA) guideline PS29 (2019) and the United Kingdom College guidelines (2018) discuss staffing for the care of children in non-pediatric hospitals. These policies particularly apply to infants and neonates because of their greater risk. Anesthetists looking after children should have

**Table 1.2** The pediatric caseload of the anesthetist affects the rate of complications

| Number of anesthetics given per year | Complications |
|---|---|
| 1–100 children | 7/1000 |
| 100–200 children | 2.8/1000 |
| More than 200 children | 1.3/1000 |

Based on Auroy and Ecoffey, Anesth Analg 1997

**Table 1.3** Patient factors to consider in determining level of staff and facilities needed to safely care for children

| Patient factor |
|---|
| Age of child, esp. if <12 months |
| Type of surgery |
| ASA status/General health of the child |
| Overnight admission |
| Emergency procedure |

**Table 1.4** Summary of requirements to safely anesthetize children (based on ANZCA PS29 and RCOA guidelines)

| Organization of services | |
|---|---|
| Staff | Experience and case load to maintain competency in relevant ages and case mix of:<br>anesthetist<br>assistant<br>recovery<br>ward nurses |
| Equipment | In addition to equipment and facilities needed to safely anesthetize adult patients:<br>Size-appropriate breathing circuit, airway equipment and monitoring<br>Anesthetic machine and ventilator suitable for ages of children being anesthetized<br>Suitable fluid administration devices (may include burette)<br>Resuscitation drugs and equipment (including defibrillator and pads suitable for children)<br>Ability to control temperature of OR<br>Beds and cots suitable to contain child and prevent falls |
| Facilities | Ability for parents to accompany child to theater and be present in recovery<br>Separated areas from adults-wards, OR, PACU<br>Accommodation for parents if overnight admission<br>Links to tertiary pediatric centers for advice and transfer of patients if postoperative problems occur<br>Pharmacy knowledgeable in pediatric doses<br>Acute pain service, HDU/ICU if relevant to case-mix |
| Governance | Local hospital group with oversight of scope of practice and suitability of staff involved<br>Local protocols and regulations for selection of patients and aspects of their care<br>Gradual implementation of any changes and ongoing quality assurance |

training in the relevant age group, and should not anesthetize children if they are not comfortable to do so due to either lack of recent experience or inadequate case load. Having a second anesthetist to help should be considered for infants and children ASA3 status or higher. The anesthetic assistant and perioperative staff should have training in the care of children. Not all children can be cared for in tertiary children's hospitals, so most countries have networks in which information, guidelines and training are exchanged between central specialist and peripheral general hospitals. As part of this, there is generally a lead consultant to oversee provision of pediatric anesthetic services in general hospitals.

## 1.3 Preoperative Assessment

As in adults, assessment of children before anesthesia includes a history and examination, aiming to assess previous anesthetic problems and the severity of co-existing diseases. It is also an opportunity to establish rapport with the child and parents, assess the child's behavior and reassure the parents with your manner and professionalism. Most children are healthy and active, although there is always the possibility of an unrecognized abnormality or syndrome. Some children have dysmorphic

**Table 1.5** Facial dysmorphic features that may indicate a congenital syndrome

| Dysmorphic feature |
|---|
| Widely spaced eyes (hypertelorism) |
| Beaked or other nose abnormality |
| Low hairline on forehead |
| Low slung or malformed ears |
| Craniosynostosis |
| Microcephaly |

features suggesting an underlying syndrome (Table 1.5). If a child has one congenital malformation it is more likely that there will be another. Common conditions to specifically ask about include preterm delivery, recent upper respiratory tract infection, obstructive sleep disorder, developmental concerns and bleeding disorders.

Examination needs to take into consideration the modesty of the child, particularly with school-aged children and adolescents. Examination may occasionally reveal a previously unrecognized heart murmur (see Chap. 20, Sect. 20.3.1), signs of asthma or URTI (see Chap. 11, Sects. 11.2 and 11.3), or loose teeth. The most important aspect of airway assessment is mandibular size (see Chap. 4, Sect. 4.2). Investigations such as hemoglobin, CXR and urinalysis are not routinely performed in healthy children undergoing minor surgery. Hemoglobin is not tested because significant anemia is rare in children and mild anemia does not affect the decision to proceed with anesthesia. Some centers use the Sickledex test in patients at risk of sickle cell anemia.

Pre-anesthetic clinics are not always used for healthy children. Clinics are unlikely to reveal significant medical problems, are inconvenient for the family, and do not influence the most likely reason for cancellation of surgery, which is a viral illness just before surgery. Assessment is commonly by a telephone interview before admission and review by the anesthetist on the day of surgery. However, this approach reduces the time available for informed consent for anesthesia.

### 1.3.1 Loose Teeth

Children lose deciduous teeth from 5 years of age. A very loose tooth may dislodge and be aspirated during anesthesia and is sometimes removed (with parental permission) after induction. The tooth needs to be very loose before trying this, and usually has no visible root (it is resorbed). If the tooth is not very loose it can be surprisingly difficult and unpleasant to remove, and the gum may bleed. A tooth that is not on the verge of falling out can be watched carefully during airway manipulation and checked at the end of the case to make sure it has not been dislodged.

## 1.4 Consent

The legal age for consent is usually between 16 and 18 years, depending on the jurisdiction. Consent for a child is therefore obtained from the parent or legal guardian. However, there is growing recognition of the rights of younger people. It is usual to at least obtain the *assent* (permission) to proceed with anesthesia and surgery in older school aged children, even though they may not be able to give legal consent. Further complicating this area is the increasing recognition by courts of children's abilities to make their own decisions about treatment. Some health areas have policies in place that allow children as young as 14 years to consent to treatment. However, these policies are not a replacement for laws and it is still usual to obtain parental consent when the child is younger than 16–18 years.

Young people at 16 years of age have the legal ability in most countries to make decisions about their own care, and they must be presumed to be competent to make such decisions unless it can be shown otherwise. A valid refusal of surgery by a child who is competent should usually be respected. Legal advice should be sought if the procedure is felt to be in their best interests despite their refusal, especially if the refusal of treatment could result in death or serious harm.

Children younger than 16 years can consent if they demonstrate Gillick-competency. The Gillick competency test establishes the legal principles to decide a child's ability to make health care decisions. The Gillick case considered consent for prescription of the oral contraceptive to a 16 year old girl, and whether or not a parent's permission was required. The findings of this case have been used to determine consent issues in general. For a child to be deemed competent to decide about their healthcare they must have the ability to understand the factual, moral and emotional consequences of their decision. Competence is not reliant on a fixed age, and competence for one situation does not imply competence for all. The child's age is still considered—the younger the child, the less likely the child can understand the implications of their decision and be considered Gillick-competent.

**Keypoint**

Although some adolescents are mature enough to consent to anesthesia and surgery, it is wise to obtain the parent's consent in most perioperative situations.

In certain life-threatening circumstances, society allows the wishes of a child or the parents to be overridden. This is firstly because a child is unlikely to competently rationalize life and death decisions, especially when they are so easily influenced by authority figures. Secondly, society is unwilling to allow any person to make life and death decisions for someone else, including one's own child. Hence laws make it possible in an emergency to override the wishes of a person aged less than 18 years. The exact legal mechanisms for this vary between jurisdictions, and the involvement of the hospital's medical administrator is usual. These emergency provisions only apply if the procedure is critical and life-saving—a blood transfusion in severe hypovolemic shock may be permitted, but not force feeding an anorexic child who is not critically ill. As a practical matter, it is best to negotiate a compromise before proceeding to the courts for permission. Consent to treatment is more likely to be given when the child's and parent's wishes and concerns are considered.

Fortunately for pediatric anesthetists, consent issues are usually resolved by the time a child presents for surgery. However, consent issues for anesthetists may arise at the time of induction—is it reasonable to proceed when the child withdraws their hand from the IV cannula, or pushes away the facemask? Children older than about 8–10 years who are developmentally normal probably should not be restrained. Fear is often a large part of the child's refusal, and this can be allayed with discussion, parental involvement, involvement of play therapists in children having many anesthetics, and pharmacological premedication if agreed. Younger children are probably not able to understand the importance of their treatment and it may be reasonable to restrain the child and proceed if other strategies fail. Supervising the parent to help restrain a younger child can help parents to accept this course of action. Although restraining a 2 or 3 year old child is straightforward and not uncommon, restraining a young school-aged child is unpleasant for the child, parent and staff, and should be avoided as much as possible by paying attention to the behavioral management aspects of the child. The age beyond which restraint is not reasonable depends on many surgical, patient, practical, societal and reality factors. A great deal of judgement is involved from case to case. Sometimes during induction, a decision must be made quickly to take one path or another before the child's cooperation deteriorates further.

### 1.4.1 Blood Transfusion in a Jehovah's Witness Child

A blood transfusion critical to survival of the child (usually as determined by more than one doctor) can be given legally without the consent of the parents. In fact, doctors have a legal obligation not to allow a child to die by withholding treatment. In the elective situation, children older than 14–16 years may be able to refuse a transfusion themselves, but the legality of this would need to be determined before proceeding with surgery.

When a child's parents refuse permission for a blood transfusion, they are usually only trying to do what is best for their child. Indeed, anesthetists should be trying to minimize blood transfusion in every child-there are many risks of transfusion, and children have a long life ahead for these risks to become apparent.

Confrontation over this issue can be minimized by listening to the parents, telling them all the things that you will do to try and avoid blood products, and telling them that you are legally obliged not to let their child die. There is no need to force parents to explicitly agree with this plan and thus refute their own beliefs. There is also little to be gained from a confrontation with parents who are under stress about their child's anesthesia and surgery when the likelihood of transfusion is extremely low. As medical providers, the legal obligation is straightforward and most parents are aware of this. Ongoing argument serves only to put parents and sometimes the child under further stress.

## 1.5 Intravenous Access

A short 24G or 22G cannula in the dorsum of the hand is the commonest method of securing IV access in children. The finer 24G cannula may be more difficult to insert, but it is less likely to be felt by the child. The lack of feeling may allow a second attempt to insert the IV if the first attempt failed. The 24G cannula is the usual size for neonates and small infants, but in older children it tends to kink when the child moves post op.

### 1.5.1 Positioning of the Awake Child for IV Access

Tapes and equipment should be prepared before inserting the cannula to facilitate quick fixation, as the child may move and dislodge the cannula. If the child lies on the bed, blankets can be placed to hide their hand and restrict movement. Younger children can also sit across the parent's lap, with the child's arm brought under the parent's arm (Fig. 1.2). This position hides the hand from the view of the child and parent and helps to keep the hand still by placing the child at a mechanical disadvantage.

### 1.5.2 Assistance

A good assistant is vital to maximize the chances of successful venipuncture. Just using a tourniquet for a young child is unlikely to work. It is important that the assistant holds the child's hand and arm correctly, aiming to distend the veins and prevent withdrawal of the child's hand. The assistant needs to hold the forearm tight enough to act as a tourniquet, but not so tight that the hand turns white from arterial compression. The assistant also gently retracts the child's skin up the limb, which helps to fix the vein. The assistant's other hand can be placed across the child's elbow joint, which helps prevent sudden limb movement if the child feels the needle (Fig. 1.3). The anesthetist can stabilize their own arm by resting their elbow on something to compensate for sudden movements by the child.

### 1.5.3 Tips for Venipuncture

If no veins are visible, using the index finger to very gently feel the dorsum of the hand may detect the faint bulge of an underlying vein. It is best to try this before using antiseptic, as this makes the skin very slightly sticky and much harder to feel subtle variations. Sometimes a faint blue tinge can be seen as an indication of a vein. The child's feet can also be used for induction. IV insertion in the foot, however, is more painful than in the hand. An IV can be left in the foot for post op use depending on the child's age, length of stay and postoperative ambulation.

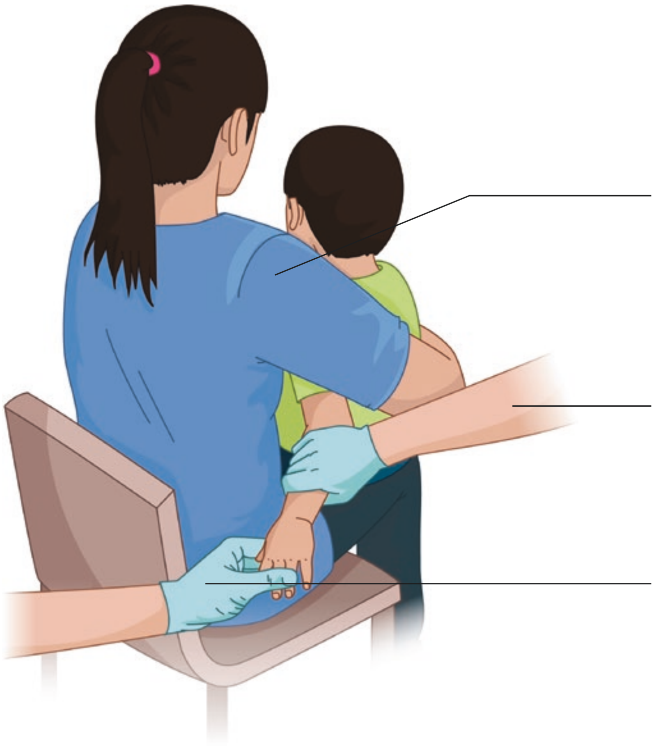


**Fig. 1.2** Positioning the clingy or uncooperative toddler for insertion of an IV. All equipment, including tape, is prepared beforehand. The child sits sideways across the seated parent's lap and is distracted with stickers or a toy. The parent's arm hugs the child's back and the child's arm is brought under the parent's arm. An assistant stabilizes the child's arm and squeezes it as a tourniquet. The anesthetist holds the child's hand and stabilizes it for insertion of the cannula

Some veins are constant in position and can be accessed on the basis of landmarks only. These sites are:

1. The long saphenous vein just in front of the medial malleolus—feel for the groove in the malleolus that contains the vein.
2. Between the fourth and fifth metacarpal bones on the dorsum of the hand;
3. The cephalic vein on the lateral aspect of the forearm—it tends to be in line with the skin crease between the thumb and index finger, 1–3 cm proximal to the wrist.

Injection of air bubbles is always avoided in children as they may have undiagnosed congenital heart disease or a patent foramen ovale allowing bubbles to cross into the arterial circulation. Care to remove air bubbles is required every time a venous line is used.

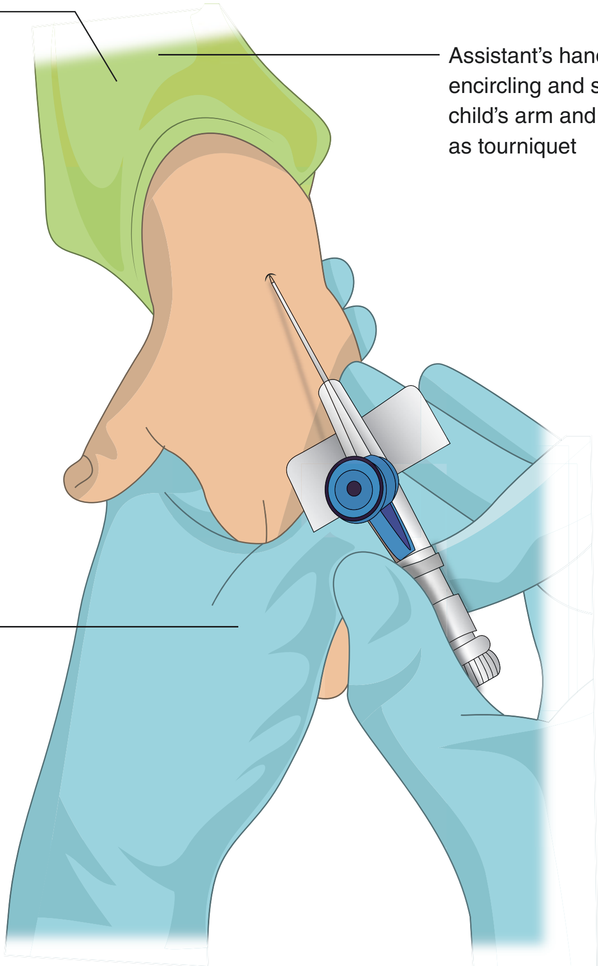


**Fig. 1.3** The assistant's hand encircles the child's forearm. It acts as a tourniquet, retracts the skin on the dorsum of the hand, and prevents the child pulling away

### 1.5.4 Equipment to Find Veins

Transillumination with visible light can help find veins in some neonates. Several devices use near infrared light to highlight veins. These are sometimes useful for superficial veins, but do not necessarily increase the rate of first attempt success. They have not been rigorously studied and are difficult to recommend. Ultrasound is useful for vascular access, but not so much for superficial, collapsible veins on the dorsum of the hand. Nevertheless, in difficult cases it can help identify veins in the cubital fossa, forearm or saphenous vein. Some have suggested using a thin gel pad between the probe and skin to increase the distance between the probe and vein, and to reduce compression of the vein by the probe.

## 1.6 Induction

Both inhalational and intravenous induction are suitable for children, and there is often an institutional preference for one or the other. There are advantages and disadvantages to each induction type (Table 1.6). IV induction became more popular after the introduction of topical anesthetic creams. However, an IV can still be sited using nitrous oxide/oxygen and distraction. Possibly the greatest advantage of the IV induction is that IV access is present from the outset, and IV inductions have a lower incidence of adverse respiratory events compared to inhalational induction.

Some children still hate needles even though they may be old enough to understand the anesthetic cream will work. Inhalational induction requires skill in distraction and behavioral management to enable the child to keep the mask on long enough for the volatile agent to work. Parental presence at induction is standard in most pediatric hospitals and is discussed in the Chap. 3.

During induction, there is a period in which the child can be distracted and kept calm, but after which stress and fear can make the induction increasingly difficult. It is important to be organized with an induction plan, to brief your assistant before starting and make sure that all equipment is ready to use.

### 1.6.1 Inhalational Induction

Sevoflurane is the only available inhalational agent suitable for induction. A routine induction includes 66% nitrous oxide in oxygen for 20–40 s, followed by 8% sevoflurane. The timing of nitrous administration is critical—if too short, the child may reject the mask when sevoflurane is started, and if too long the child will either lose interest and cooperation or become dysphoric from the nitrous oxide. Induction is possible without nitrous, but it is more likely that the mask will be rejected. If the T-piece is used for induction, it is best to give the child a few breaths at 0.5% sevoflurane before increasing to 8% (the fresh gas flow enters T-piece very close to the facemask, and the sudden smell of 8% sevoflurane may be noticed by the child). In a circle circuit, sevoflurane washes into the circuit more slowly and can be started at

**Table 1.6** Advantages and disadvantages of IV and inhalational induction

| IV induction | Inhalational induction |
|---|---|
| IV access present | No needle |
| Less cooperation from child required | Gradual loss of airway |
| Less excitatory movement | No pain from propofol |
| No smelly gas | Faster wake up than after IV induction |
| Less pollution | Parent can see what is happening to child |

8% after nitrous oxide has been given as before. There is no need to incrementally increase the sevoflurane during induction as this slows induction and increases excitatory phenomena. The child's cooperation is needed for a calm inhalational induction, and techniques to help achieve this are discussed in Chap. 3, Sect. 3.4.

**Keypoint**
There is no need to incrementally increase sevoflurane concentration during gas induction—this slows induction and increases the incidence of excitatory phenomena. The incremental technique is a hangover from the technique of halothane induction.

Some airway obstruction is common after consciousness is lost due partly to excitatory phenomena that occur with sevoflurane (see Chap. 2, Sect. 2.6.5), and partly due to loss of upper airway tone. CPAP and gentle jaw thrust are used to overcome this. Nitrous oxide can be eliminated at this stage if desired and sevoflurane given in 100% oxygen. An oral airway should not be inserted at this stage. It is important to maintain the sevoflurane at 8% until a deeper level of anesthesia is reached and this partly obstructed, excitatory stage has ended. Listening to the heart rate and observing tidal volume will also give a guide to depth and the need to reduce the sevoflurane concentration. Cardiovascular depression occurs with high concentrations of sevoflurane, but in these early stages of inhalational induction it is the airway that will cause problems, not hypotension.

### 1.6.2 Intravenous Induction

IV access is obtained and anesthesia is induced with propofol. Co-induction techniques using benzodiazepines and opioids are uncommonly used in children because it is less important in children to blunt the hemodynamic responses to induction and intubation, and the priority is often to induce an upset child as quickly as possible. Preoxygenation and application of monitors before induction are omitted in many centers to reduce the child's anxiety.

### 1.6.3 Rapid Sequence Induction

The classic rapid sequence induction technique used in adults is not suitable for children. Children quickly become hypoxic during apnea, and although preoxygenation can reduce this, children may be difficult to preoxygenate correctly. The consequence of these factors is a hurried, 'crash' intubation with the risk of morbidity. Children must be gently mask- ventilated between induction and intubation. Cricoid pressure protects the stomach from inflation during mask ventilation. If mask ventilation cannot be achieved during cricoid pressure, the pressure is reduced or it is removed completely if ventilation is still difficult.

**Keypoint**
The adult technique of RSI with apnea before intubation is a dangerous technique in children. RSI in children includes gentle mask ventilation before intubation.

The technique of RSI is now questioned as it prioritizes aspiration over everything else and increases other risks. These risks include hypoxia, awareness, hemodynamic changes, and a hurried, traumatic intubation that may be more stressful and difficult than it might otherwise have been. The role of cricoid pressure is also questioned, as there is no clear evidence it is of benefit. It is difficult to perform correctly, and anatomical variations mean even properly performed cricoid might not compress the esophagus. Young children have a soft, compliant trachea and cricoid pressure can obstruct their airway. As a result, cricoid pressure is often omitted in neonates and infants, and some anesthetists also omit it in older children. Head-up tilt and the child's lower esophageal sphincter tone are relied on instead of cricoid pressure. Cricoid pressure is still strongly recommended in children with intestinal obstruction.

**Keypoint**
Cricoid pressure is often omitted in neonates and infants because it compresses and obstructs the soft trachea. Its role in older children is also being questioned. Cricoid pressure is still recommended in children with intestinal obstruction.

Classic rapid sequence induction includes intubation within 1 min of induction. In children, 'rapid' does not need to be so rapid because there is mask ventilation and no period of apnea to manage. Whether intubation is performed within 1 min or a longer period becomes less important. Some authors argue it is more important to check there is complete muscle relaxation before intubation, rather than intubating within an arbitrary time. As a result, the rapid onset of muscle relaxation becomes less important. Although suxamethonium may be used for rapid sequence induction in children, non-depolarizing relaxants are commonly used—they have a relatively fast onset in children and ventilation with volatile anesthetic agents before intubation enhances their effect. The high doses of relaxants used in adults is not necessary in younger children.

Finally, use of a rapid sequence induction does not mandate a cuffed ETT. Either a cuffed or uncuffed ETT may be chosen for children with full stomachs—uncuffed ETTs have a long history of safe use in children in this situation. If suxamethonium has been used to facilitate intubation with an uncuffed ETT that then needs to be changed because of excessive leak, consider giving a long-acting relaxant before the tube change. Many would re-apply the cricoid pressure during the tube change if it was used for the initial intubation.

## 1.7 Maintenance

The choice of technique during maintenance follows the same principles as with adults. The choice of airway management and type of ventilation depends on a variety of patient, procedure and anesthetic factors. Neonates and small infants are commonly intubated and ventilated for all but the briefest case. Otherwise great care must be taken with the issues of rebreathing, respiratory muscle fatigue, and loss of a clear airway. Furthermore, as the patient is so small, the surgical field is close to the airway and it is difficult to instrument the airway during surgery if problems arise.

Another important difference between children (especially preschool age) and adults is that more care is required during maintenance to ensure calm and safe emergence. Pain and delirium are two important reasons for children waking upset and distressed, and these can be minimized during maintenance. Unlike adults who may suffer in silence from inadequate analgesia, children will let everyone know if they are uncomfortable or distressed.

### 1.7.1 Hypothermia

Hypothermia during anesthesia is common in both children and adults. Children, however, are more at risk—they have a large surface area relative to body weight, so heat production is relatively low compared to environmental losses. Infants and neonates also have reduced ability to generate heat because of absent or reduced shivering. A child's head is large in proportion to the rest of the body, and the head is a site of significant heat loss if it is not covered.

Most heat is lost through the skin via radiation and convection. Losses are minimized by keeping the child covered, warming the OR (typically to about 21 °C for children, higher for neonates) and using a forced air warmer.

Conductive heat loss may be large if gel pads are placed under the child to prevent pressure injuries. These gel pads are made of dense visco-elastic polymer with a large thermal mass and will draw heat from the child. They should either not be used, or pre-warmed with a forced air warmer. Only about 10% of heat loss is through the airway, and passive humidification is adequate in pediatric anesthesia. Equipment to keep children warm during surgery is discussed in the Chap. 5.

## 1.8 Recovery

The facilities required for pediatric recovery are the same as for adults and are covered in professional and College guidelines. Staff should have experience in pediatric recovery and receive ongoing training in resuscitation. Staffing numbers in