Principles of paediatric anaesthesia

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Abstract

This article provides an overview of the practical aspects of paediatric anaesthesia, with particular emphasis on airway and fluid management. Common dilemmas that may be encountered during preoperative assessment are highlighted, including the child with asthma, obstructive sleep apnoea and the particularly anxious child. In light of the findings of the fourth National Audit Project (NAP4), strategies for managing the child with the difficult airway are discussed. The rationale for the use of isotonic perioperative fluids is outlined, along with the management of intraoperative blood loss. The increasingly recognized problem of emergence delirium is also discussed.

Keywords Asthma; blood loss; difficult airway management; emergence delirium; fluid management; obstructive sleep apnoea

Royal College of Anaesthetists CPD Matrix: 1B02, 2A01, 2A03, 2A05, 2D02, 2D04

Learning objectives

After reading this article, you should be able to:

- identify the perioperative significance of conditions affecting the airway including asthma and obstructive sleep apnoea
- formulate a management plan for dealing with the anxious or uncooperative child, and the child suffering from emergence delirium
- discuss the anaesthetic management of the child with the difficult airway and the anticipated difficult intubation
- outline the recommendations for intraoperative and postoperative fluid management in children, including administration of blood components

Preparation and preoperative assessment

All patients should be seen by an anaesthetist before undergoing a general anaesthetic. The aim of preoperative assessment is to identify pre-existing medical conditions and any potential anaesthetic risk factors, plan perioperative care and also to answer questions and allay fears.

Appropriate and timely assessment, ideally a couple of weeks before the procedure, will allow any treatable illnesses, such as upper respiratory tract infections, to be dealt with in time for surgery, and it will also allow any necessary investigations to be performed and acted upon.

Herbal medicines are increasingly used in the general population and they, as well as traditional medicines, can be a cause of drug interactions.

Latex allergy is a common cause of intraoperative anaphylaxis in children. This should be considered in children with conditions requiring repeated exposure to latex, such as spina bifida and cerebral palsy, as well as atopic children, and those with allergies to certain nuts and fruits (bananas, kiwi, avocado).

Vaccinations elicit inflammatory responses and this may lead to confusion if an anaesthetic is given soon after, as any vaccine-related fever may be wrongly attributed to postoperative complications. There is no contraindication to vaccinating children before elective surgery but it is considered good practice to delay surgery for 2 days after an inactivated vaccine and 14–21 days for live attenuated vaccines so as to avoid such misinterpretations.

Examination of well children may reveal little, but it is reassuring for parents to see a thorough assessment being made. Routine preoperative blood tests are not required in healthy children undergoing minor surgery, but should be reserved for children with specific medical conditions which may require particular perioperative management, such as renal impairment and electrolyte abnormalities. Mild anaemia is not uncommon in children and does not require treatment before surgery.

Several topical local anaesthetic creams are available, namely EMLA (eutectic mixture of local anaesthetics, containing prilocaine 2.5% and lidocaine 2.5%), ametop (amethocaine 4%) and LMX4 (lidocaine 4%), which take roughly 1 hour, 45 minutes and 30 minutes, respectively, to work.

Paracetamol and non-steroidal anti-inflammatory drugs are commonly prescribed preoperative analgesics, and anxiolytics are becoming more widely used.

The majority of children presenting for routine surgery will be healthy, although childhood obesity is an increasing problem. For those children with comorbidities, clinical networks have an important role in providing specialist guidance and support.

Commonly encountered anaesthetic dilemmas

Asthma

Not all children who wheeze have asthma as wheezing can also be a manifestation of a respiratory tract infection in an otherwise well child. Wheezing is associated with a greater risk of perioperative bronchial hyperreactivity.[1] Well-controlled asthmatics tolerate anaesthesia much better than those with poor control. The severity of asthma can be determined according to the frequency of use of inhalers, whether agents other than inhalers are required, whether oral steroids have been prescribed in recent weeks, and whether there have been any hospital admissions with or without admission to intensive care (British Thoracic Society guidelines).

Elective surgery should be postponed if the child has had a chest infection or an exacerbation of asthma within 2–4 weeks prior to the date of surgery.

Anaesthetic management should involve continuation of regular inhaled medication, often with an extra dose of Ventolin prior to transfer to theatre. The aim of anaesthesia is to avoid

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airway irritation. Depending on the procedure, it is better to avoid intubation if possible, and drugs that cause histamine release (atracurium and morphine) should be used circumspectly in all but mild asthmatics. Propofol is an appropriate induction agent but ketamine should be considered in brittle asthmatics due to its intrinsic bronchodilator properties.

If the child has been on a recent course of oral steroids, then perioperative supplementation may be required. There is evidence to suggest that non-steroidals have no detrimental effect in mild asthmatics but should probably be avoided in brittle asthmatics, particularly in those with nasal polyps.[2]

Upper respiratory tract infection (URTI)

The average child has up to seven episodes of URTI a year. Although it is advisable to avoid an anaesthetic for 2–4 weeks after an URTI due to airway irritability, morbidity remains low in otherwise well children.[3,4] Adverse events such as laryngospasm, bronchospasm and airway obstruction are more likely in children under 1 year of age, and in asthmatics, those having airway surgery and when an endotracheal tube is used.

Obstructive sleep apnoea (OSA)

Adenotonsillar hypertrophy is the most common cause of snoring in children, although obesity is increasingly a problem. About 15% of children who snore have OSA (prolonged partial upper airway obstruction and/or intermittent complete obstruction that disrupts normal ventilation during sleep). OSA can lead to failure to thrive, day time fatigue and behavioural problems, and in severe cases eventually pulmonary hypertension and right heart failure.

If the clinical features of OSA are present then an ECG and pulse oximetry should be performed. If the ECG shows evidence of right ventricular strain, this should be investigated further with an echocardiogram. Polysomnography is considered the gold standard in the UK to determine the severity of OSA, and involves analysis of ECG, EEG, EOG, EMG, saturations and abdominal and chest wall movements during stages of sleep. However, it is time consuming and generally not performed if the clinical diagnosis of OSA is clear.

Anaesthetic considerations in OSA include the avoidance of sedative premedication and long acting opioids that can cause airway obstruction by reducing pharyngeal tone and inhibiting central responses to hypoxia and hypercapnoea. Airway obstruction may result in cardiovascular compromise and pulmonary oedema. Inhalational induction has the potential advantage of maintaining airway patency but can predispose to worsening airway obstruction and negative pressure pulmonary oedema. Intravenous induction is more likely to result in apnoea but ventilation via face mask and intubation are rarely a problem. Short-acting anaesthetic agents should be used where possible to allow rapid recovery. If intubation is necessary, it is probably safer to extubate awake as a deep extubation may be more likely to result in obstruction during emergence.

Postoperatively sleep apnoea can worsen, so nursing overnight in a high-dependency area is advisable.

The anxious child

Half (40–60%) of children experience significant preoperative anxiety. It is now well known that preoperative anxiety leads to adverse postoperative clinical outcomes, with both short- (emergence delirium) and long-term behavioural issues (sleep disturbance and separation anxiety). Concerns differ for different age groups (Table 1).[5]

Children with learning disabilities are more likely to have heightened anxiety and the disturbance of their routine may make them uncooperative and sometimes aggressive. It is important that they receive timely preoperative information appropriate to their age and level of understanding, familiarization with the ward and staff as appropriate, and a considered account of what to expect to satisfy their concerns.

Strategies to reduce anxiety include behavioural techniques and sedative premedication (especially oral midazolam 0.5 mg/kg and oral clonidine 4–5 μg/kg). There is evidence that behavioural interventions such as computer packages, video games, clowns and play therapists, improve compliance and reduce emergence delirium.[6] However, these techniques are time consuming and costly.

The benefit of parental presence in the anaesthetic room remains controversial, although the evidence suggests that a calm parent is helpful to the child while parental anxiety is very much transferred to the child. Parental presence overall is probably more helpful to the parent than the child.

Airway challenges

Laryngospasm

This is more commonly encountered in paediatric practice rather than adults and is particularly common in the hands of less experienced anaesthetists.

Being aware of what can trigger laryngospasm (commonly secretions or blood on the vocal cords) and following some very simple strategies can reduce the incidence significantly. Such simple techniques include inserting supraglottic airway devices, such as the laryngeal mask airway (LMA) only once an adequate depth of anaesthesia has been achieved, and removing any LMA while still in a deep plane of anaesthesia in situations where secretions may otherwise be trapped on the vocal cords (e.g. child with an upper respiratory tract infection).

Laryngospasm usually settles with high-flow oxygen and continuous positive airway pressure (CPAP), but if it continues, propofol 1 mg/kg IV can relax the vocal cords and, failing that suxamethonium 0.1–0.2 mg/kg IV should be used. Rarely, anaesthesia needs to be deepened and an intubating dose of suxamethonium given in order to secure the airway again until the child is fully awake.

Developmental differences in causes of childhood anxiety

Infants	Less likely to experience anxiety from parental separation, accept parental surrogates
1–3 years	Experience separation anxiety
3–6 years	Concerns about body mutilation requiring simple explanations
7–12 years	More explanation required, need to feel in control
Adolescence	Concern about pain, awareness and losing control

Table 1

The difficult or compromised airway

Major airway difficulties in children are thankfully rare, and routine airway management is easy in experienced hands. However, difficulties in airway management are a main reason for paediatric anaesthesia related morbidity and mortality in inexperienced hands.[7]

In children, the most common causes of presentation with airway compromise are infections and congenital abnormalities. Mandibular hypoplasia is typically associated with difficult intubation while macroglossia is associated with both difficult ventilation and difficult intubation.

Anaesthesia should be undertaken preferably by two experienced anaesthetists, one of whom should be a consultant. It may be appropriate to have an ENT surgeon standing by to perform a tracheostomy if necessary. Communication with the child and parents and all members of the team is essential.

In most acute cases an inhalational induction will be performed and intravascular access gained once the child is deep (or before induction if they are cooperative). Spontaneous ventilation should be maintained until the airway is secured. CPAP and jaw thrust are often required and an oral airway inserted when a suitable depth of anaesthesia has been achieved. Intubation should be attempted at a deep plane of anaesthesia while the child is breathing spontaneously. Successful intubation may require a bougie or an alternative laryngoscope blade. If the larynx cannot be visualized, it may then be appropriate to attempt intubation with an alternative or 'see around the corner' laryngoscope such as the Storz or Glidescope videolaryngoscope, before attempting intubation with the flexible fibreoptic bronchoscope, according to skill and availability of equipment. Should intubation be unsuccessful due to unrecognizable anatomy or obstruction, it may be possible to secure the airway with an LMA or it may be necessary to wake the child if clinically appropriate. The priority at all times is to maintain oxygenation. In the event that the airway cannot be secured and the child is deteriorating, a 'front of neck' rescue technique will be required.

It is important to be aware of the following findings from NAP 4 (National Audit Project):

'Airway assessment was often inadequate and planning for problems was poor. Repeated attempts at intubation were shown to be detrimental when what was needed was a change of approach to managing the airway. Supraglottic devices were not used in many situations where they may have had a vital role.'

The Association of Paediatric Anaesthetists of Great Britain and Ireland (APAGBI) Difficult Airway Guidelines stress the importance of supraglottic devices in difficult mask ventilation, the unanticipated difficult intubation, and the 'can't intubate can't ventilate' scenario.

The anticipated difficult intubation[8]

In paediatric practice, most difficult intubations are thankfully anticipated, and this allows ample time for planning. The first thing to decide is the relative risk/benefit of doing the procedure and, if it is either unnecessary or could wait, serious consideration needs to be given before deciding to go ahead.

Next the primary plan and contingency plans should be discussed with experienced colleagues and with the family, including the point at which to abandon and wake the child up. Documentation of these discussions is essential.

Although sedative premedication is relatively contraindicated where there is potential airway compromise, it is safer to have a cooperative child rather than a crying anxious child who may be more likely to obstruct their airway. A cautious dose of midazolam (0.3 mg/kg) may be appropriate in such cases.

Antimuscarinics are not routinely used but are effective antisialogogues (atropine 30–40 μg/kg orally).

The aim of induction is again to maintain spontaneous ventilation until the airway is secured, usually by inhalational induction but a cautious dose of intravenous propofol (1 mg/kg) and even total intravenous anaesthesia (TIVA) may be used. By maintaining airway tone and patency, this allows time to attempt intubation with different devices. If conventional laryngoscopy is unsuccessful, the temptation to try again several times must be resisted as this will cause more trauma and make intubation harder. There should be a familiarity with alternative scopes such as the Storz and Glidescope videolaryngoscopes, as these have a proven role in difficult intubations.

The LMA can be used as an alternative to intubation if clinically appropriate, or as a conduit to enable intubation to take place, either by railroading an endotracheal tube over a fibreoptic bronchoscope and passing this through the LMA; or passing a guidewire through the bronchoscope suction port, removing the bronchoscope and railroading an airway exchange catheter over the wire through the LMA.

Rescue techniques

The use of these techniques in paediatrics is not particularly evidence based. There is no 'correct technique' for a particular age of child. Anaesthetists are generally more comfortable with percutaneous rather than surgical techniques. However, identifying the cricothyroid membrane in neonates and infants can be difficult and the thyroid cartilage is often less prominent, so a transtracheal approach may be safer, either with a cannula or an endotracheal or tracheostomy tube. Various different devices are on the market and it is advisable for departments to choose one and be familiar with that choice.

Perioperative fluids

Perioperative fluid management has been the subject of National Patient Safety Agency patient safety alerts because of the problem of perioperative hyponatraemia, which occurs when hypotonic fluids are given at a time of increased anti-diuretic hormone (ADH) release.[9] Such non-osmotic ADH release is known to occur perioperatively as well as in association with pain, anxiety, pyrexia, sepsis, nausea and hypovolaemia, and also certain medical conditions (respiratory, CNS, metabolic and endocrine).

Hyponatraemia is defined as a plasma sodium (Na) less than 135 mmol/litre. Children develop symptoms of hyponatraemia at higher plasma sodium concentrations than adults, as they have reduced space for brain swelling and an impaired ability to adapt compared with adults.

Isotonic fluids (Ringer's lactate, plasmalyte 148, 0.9% saline) administered perioperatively should prevent the development of hyponatraemia and can also be used to treat it. Isotonic fluids should be continued into the postoperative period for a number of days depending on the extent of surgery, as ADH levels remain high especially after more major surgery. Fluid restriction

postoperatively (usually 70–80% of maintenance rates) will also help reduce the risk of hyponatraemia, but careful clinical monitoring is necessary in order to avoid dehydration and an increased plasma sodium level.

Ringer's lactate and Plasma-Lyte 148 have a more physiological concentration of chloride ions than 0.9% saline (Table 2), and they do not have the associated risk of hyperchloraemic acidosis. This makes them the preferred choice of perioperative isotonic fluid.

Dextrose-containing fluids are not generally needed intraoperatively, even in infants, due to the stress response of surgery maintaining blood glucose. Exceptions would be preterm infants or neonates in the first 48 hours, prolonged surgery in infants, those with pre-existing dextrose requirements and those on total parenteral nutrition, where glucose (2.5% or 5%) should be added or blood glucose monitored.

Postoperatively, dextrose-containing fluids should be prescribed in order to maintain normoglycaemia and prevent ketosis. Fluids commonly given in the immediate postoperative period are dextrose 5%/saline 0.45% (after more minor surgery where there is minimal ADH release) or dextrose 5%/saline 0.9% in younger children, and Ringer's lactate or Plasma-Lyte 148 in older children. Plasma-Lyte with 5% dextrose has recently become available and may replace maintenance with dextrose 5%/saline 0.9%.

Allowable blood loss

Measured blood losses are often an underestimate, especially in small babies, and children compensate for large losses with minimal clinical signs. Measurement of haemoglobin (Hb), haematocrit and acid–base status are ideal but require a means of sampling, and a combination of measurement and clinical signs should be used to estimate losses.

APAGBI consensus guidelines on what is an acceptable allowable blood loss and Hb differ according to age but it is considered that a normally well child older than 3 months will tolerate a Hb of 7.0 or a haematocrit of 0.25%. There is no consensus under that age as it depends on the degree of prematurity and condition of the child.

Allowable blood loss (ABL) is calculated using Hb concentration (Hb) and estimated blood volume (EBV) as follows:

$$\text{ABL (ml)} = \text{EBV} \times (\text{initial Hb} - \text{allowable Hb})/\text{initial Hb}$$

It should be replaced with crystalloid and/or colloid. After the ABL has been exceeded, blood should be given in the ratio 2:1 packed red cells:colloid. Packed red cells 4 ml/kg raises the Hb by 1 g/dl. Fresh frozen plasma (FFP) should be considered after loss of 1/2 blood volume (10–20 ml/kg aliquots), and platelets after loss of 1 blood volume (10–20 ml/kg).

Major haemorrhage can be defined as the loss of one circulating blood volume within 24 hours or 50% within 3 hours. Coagulopathy in major haemorrhage generally becomes an issue after replacement of one circulating volume. FFP is given after loss of 1 blood volume. Cryoprecipitate should be given to correct a low fibrinogen and is generally given with platelets after two blood volume losses.

Large volumes of cold blood can cause hypothermia and hyperkalaemia so all blood should be warmed.

Calcium (Ca) should be considered after rapid transfusion of blood and colloid, as ionized Ca levels drop as a result of citrate toxicity. The level should be measured if possible and if Ca is less than 1 mmol/litre, 0.3 ml/kg 10% Ca gluconate should be given. Otherwise a good rule of thumb is to give 1 ml Ca gluconate/100 ml colloid and 0.5 ml Ca gluconate/100 ml blood.

Hyperkalaemia from transfusion of stored irradiated blood is treated with 10% Ca gluconate 0.5 ml/kg, and may require nebulized salbutamol or dextrose and insulin. Citrate toxicity also causes hypomagnesaemia which can be treated with intravenous Mg sulphate 50% 0.1 ml/kg.

Tranexamic acid is used increasingly in children. Its effectiveness for reducing blood loss in orthopaedic and general surgery has been shown in adults. In children, randomized controlled trials have shown reduced blood loss in scoliosis surgery, complex cardiac surgery and an improved surgical field in cleft palate repair. It is generally given as a 15 mg/kg bolus followed by an infusion of 2–5 mg/kg/hour.

Differences in pH, Na and Cl content of isotonic solutions

Solution	pH	Osmolarity (mOsm/l)	Na (mmol/l)	Cl (mmol/l)
0.9% Na Cl	5.5	308	154	154
Hartmann's	5–7	278	131	111
Plasmalyte 148	6.5–8	295	140	98

Table 2

Emergence delirium measurement scales

Cravero scale

Behaviour	Score
Obtunded with no response to stimulation	1
Asleep but responds to stimulation	2
Awake and responsive	3
Crying	4
Thrashing requiring restraint	5

PAED scale

Behaviour	Not	A little	More	A lot	Extremely
Makes eye contact	4	3	2	1	0
Purposeful actions	4	3	2	1	0
Aware of surroundings	4	3	2	1	0
Restless	0	1	2	3	4
Inconsolable	0	1	2	3	4

Watcha scale

Behaviour	Score
Asleep	0
Calm	1
Crying but consolable	2
Crying, not consolable	3
Agitated	4

Table 3

Postoperative emergence delirium (ED)

This is a transient state of irritation and disassociation after anaesthesia, and may involve crying, kicking or thrashing. The incidence is unknown as there is not a definite threshold for diagnosis. However, with the increasing use of short-acting volatile agents (sevoflurane and desflurane) and short-acting opioids, emergence issues are not unusual.

It is more likely to occur in the 2–5 year age range especially after painful procedures, although it can occur after non-painful procedures. Preoperative anxiety is a risk factor and children who are more emotional or impulsive are more prone to ED postoperatively.

Several scales have been developed for measuring ED (Table 3).[10] A score of 4 or more on the Cravero scale for at least 5 minutes despite attempts at consoling, is indicative of ED. The Paediatric Anaesthesia Emergence Delirium Scale (PAED) is difficult to use in clinical practice as it scores certain behaviours from 0 to 4 and adds them to achieve a final score, whereas the Watcha scale is simpler to use.

Although self-limiting, ketamine (0.25 mg/kg IV at end of procedure), clonidine (2–3 μg/kg IV) and fentanyl (1 μg/kg IV 10 minutes before end of procedure) have been shown to reduce ED, as has propofol given either as TIVA or as a bolus (1 mg/kg) before wake up. Midazolam appears to have no beneficial effect. ◆

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