Chapter

10 General Principles of Safe Anaesthesia in Children*

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Introduction

Patient safety is the avoidance of unintended or unexpected harm to people during the provision of health care. Anaesthetists have been leaders in patient safety for decades. In the United Kingdom, wholesale reform of children's surgical delivery was undertaken after review of paediatric surgical outcomes in the 1990s, and in cardiac surgery, after an anaesthetist noted poor patient outcomes in children undergoing the arterial switch operation (see Kennedy 1996 in 'Further Reading').

Safety related to anaesthesia extends from institutional considerations through to preassessment, risk stratification, conduct of anaesthesia and postoperative care to safe discharge. It is too simplistic to see it as only limited to the operative period. This misses the bigger picture regarding keeping children safe. Anaesthetists providing care for children should be satisfied that the entire pathway provides the best possible outcomes for children in a holistic way. Patient safety can be improved by:

- Building psychologically safe teams
- Learning from when things go wrong (Safety II) and near misses, with the emphasis on prevention and system change rather than blame
- Learning from when things go right (Safety II)

Children comprise a quarter of the world's population, and many will require anaesthesia at some time during childhood. Most children undergoing surgery are fit and healthy. In the United Kingdom, approximately 40% of cases are undertaken in non-specialist district general hospitals. There are many situations where children require 'specialised paediatric anaesthesia', for instance neonates and infants, those undergoing complex surgery or those with significant comorbidity. At the time of writing, the first paediatric 'Getting It Right First Time' (GIRFT) report has highlighted unwarranted variation in the delivery of paediatric surgery. This is likely to result in further centralisation of services, especially for neonates and infants. It is essential that wherever children are cared for, staff are appropriately trained, there is suitable equipment and the child is in an environment that is child- and family-friendly. Ideally, specialist and non-specialist centres should work closely together in clinical networks to provide comprehensive services for children. Regular clinical attachments and joint meetings should help to foster links and enable non-specialist anaesthetists to maintain their skills. There is clearly a tension between centralising provision of paediatric care and maintaining skills in teams of non-specialists.

Guidance on the provision of appropriate anaesthetic services for children has been published (see 'Further Reading'). The main principles include:

- Children should be separated from and not treated alongside adults undergoing surgery. The specific needs of adolescents and young people should be recognised.
- Anaesthesia should be undertaken or overseen by staff who have undergone appropriate training and maintain regular paediatric practice. The anaesthetic assistant, recovery and ward staff must possess specific paediatric skills.
- Staff should undergo regular paediatric resuscitation training.
- There should be acute pain services for children.
- There should be neonatal, high-dependency and intensive care services as determined by

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the nature of the surgery undertaken in that hospital.
- Where a child presents to a non-specialist centre with a life-threatening condition, and it is not feasible to transfer the child, the most senior appropriately experienced anaesthetist available should care for that child.
- Guidelines for the management of common emergencies in children, including resuscitation, anaphylaxis and management of the head injured child should be readily available.
- Wherever possible, parents (or carers) should be involved in care and decisions about the child.

Risks of Anaesthesia

Mortality

General anaesthesia in children without comorbidity undergoing elective surgery is very safe, with a risk of death as a direct result of anaesthesia being 1:100,000 to one in a million. It is difficult to determine the risk of death for an individual child undergoing anaesthesia, as this must be put in the context of their preoperative state and the surgery they are undergoing.

In a large North American survey, the most common cause of perioperative cardiac arrest was cardiovascular, most likely due to hypovolaemia from blood loss or hyperkalaemia from transfusion of stored blood. Respiratory causes were the next most frequent cause, most commonly airway obstruction in recovery due to laryngospasm. Equipment-related cardiac arrest occurred mainly due to vascular injury from central venous lines. Medication-associated cardiac arrest is less frequent since the decline in halothane use. Children at greatest risk of perioperative cardiac arrest and mortality due to anaesthesia are those with heart disease, or pulmonary hypertension, and those under one year of age, with the highest-risk group being neonates undergoing cardiac surgery. Where there is increased risk due to comorbidity or anticipated anaesthetic or surgical difficulty, it is essential that this is discussed with the patient where relevant, parents or carers and documented in the medical records.

Morbidity

There are some common events and risks for children and young people undergoing anaesthesia for routine surgery. The risks will vary between individuals, the anaesthetic technique used and the nature of the surgery. They can be categorised as being:

- Very common (>1:10) – agitation on waking (mainly one to six years of age); sore throat; nausea and vomiting (particularly in older children); temporary changes in behaviour, such as anxiety, sleep problems, bedwetting
- Common (1:10–1:100) – minor lip or tongue injury, discomfort at injection site
- Uncommon (1:100–1:1,000) – respiratory problems requiring treatment, skin damage (mainly in longer procedures)
- Rare (1:1,000–1:10,000) – need for unplanned intensive care (higher risk in children under one year, especially neonates), corneal abrasion, damage to teeth
- Very rare (1:10,000–1:100,000 or more) – anaphylaxis (1:40,000), awareness (1:60,000), death as a direct result of anaesthesia (1:100,000–1:million), long-term disability (<1:100,000)

Awareness may occur more commonly in children than adults, although fortunately children rarely develop symptoms of posttraumatic stress disorder. Risk factors for awareness appear to be intubation (greater stimulation) and the use of nitrous oxide (possibly associated with use of a lower concentration of inhaled volatile agent).

In the Anaesthesia Practice in Children Observational Trial (APRICOT), the overall incidence of perioperative severe critical events in the UK cohort was found to be 3.3% (cf. 5.2% overall). Cardiovascular instability (1.3%), comprising hypotension, arrhythmias and bleeding, followed by laryngospasm (1.1%), were the most frequent critical events. Postanaesthetic stridor, bronchospasm and aspiration were the next most common. It is now incumbent on anaesthetists to explicitly discuss risks of all procedures that are associated with an anaesthetic. This includes regional blocks, central and arterial lines. We have limited data about how to quantify these risks for individual children, though it is probable that neonates and smaller infants are at greater risk of line-related morbidity such as clots and limb damage.

Occasionally parents may ask whether anaesthetics, especially repeated anaesthetics, can have a detrimental effect on their child's development. In the past decade, concerns have been raised from animal studies suggesting that anaesthetic agents that function as NMDA antagonists or GABA agonists cause

neuroapoptosis in the immature mammalian brain. This led to concerns about general anaesthesia in preterm and newborn infants. There is currently insufficient information to suggest that this is a problem in humans. Recent studies suggest that there are no adverse long-term effects on the brain of a single short anaesthetic in young children, but some have suggested that multiple anaesthetics before the age of four years may be associated with learning difficulties, although this is not proven. The consensus of experts is that it is unethical and harmful to deny anaesthesia to neonates and small infants if they require it, and there is no reason to change clinical practice at present. If surgery is required, children should be given an anaesthetic. The uncertainty provides a clear opportunity not to perform unnecessary surgery!

Preparation for Theatre

It is essential that all children undergo anaesthesia assessment prior to coming to theatre (see Sury et al. 2015 in 'Further Reading'). As well as determining comorbidity and establishing fitness for anaesthesia, this provides an opportunity to discuss the anaesthesia plan and associated risks. The need for premedication will depend on the perceived state of anxiety of the child, the preference of the anaesthetist and the type of surgery being undertaken. Parents may be able to offer advice on their child's likely behaviour, but it is not uncommon for a child to appear calm and unperturbed during the preoperative visit yet become extremely distressed and uncooperative on arrival in the anaesthetic room. If premedication and/or topical analgesia are required, it is important to get the timing of its administration right. The most common premedication is midazolam via the buccal or oral route. Occasionally the children who would most benefit from anxiolysis either refuse or spit it out. Intranasal dexmedetomidine is an alternative but may take over 60 minutes to take full effect. Children must be in a suitable, non-stimulating environment to maximise the effect of any premedication given.

For topical analgesia, tetracaine 4% gel (Ametop®) and lidocaine 4% cream (LMX 4®) work within 45 minutes, whilst EMLA® takes an hour to be effective. Ethyl chloride spray can make the skin less sensitive for a few minutes and is favoured by some older children but is flammable and should be used with caution in environments with a lot of electrical equipment.

There is increasing recognition that restraining children to undertake unpleasant procedures is psychologically harmful. This long-term view should be considered when dealing with a premedication failure. It may be preferable to delay surgery and build long-term trust with health care professionals than to pursue anaesthesia using physical restraint. For some anxious children, it can be beneficial to insert a cannula on the ward prior to their transfer to theatre.

If the procedure is being undertaken in a theatre that is not regularly used for children, the anaesthetist must take particular care to ensure that the appropriate equipment for a child is available and is in working order. This includes ensuring the appropriate ventilator settings. For most children, this will be pressure-controlled ventilation, and the default settings for volume-controlled ventilation suitable for an adult may cause harm in smaller children. Theatre temperature may need to be increased if an infant or small child is to be operated on. Children can lose heat rapidly, and warming equipment should be available for all children. Warming equipment can be very effective and should never be used without monitoring core temperature.

All children must be weighed accurately before theatre as all drug and fluid prescriptions are weight-based. In children with a high BMI, lean body weight (LBW) should be calculated, as this may be required to calculate some drug doses. Drugs and fluids should be drawn up and prepared carefully, using appropriately sized syringes and giving sets.

Parental Presence during Induction

Parental presence during induction can be extremely helpful, and at the authors' institution both parents/carers are allowed to remain with the child until they are asleep. Exceptions include infants and children with a difficult airway and those who are very small or sick, when it is preferable to ask the parents/carers to leave prior to induction. Many studies have shown that parental presence leads to a reduction in both the child's and parents' anxiety. For small children, induction is often undertaken in the parent's arms or with them sitting on their lap. Both parents and children overwhelmingly support parental presence at induction, although some parents may find the experience upsetting. It is important to explain to parents what to expect and give them the option of not being present should they not wish to be.

For children who are particularly anxious, it may be less distressing if they are allowed to come to theatre in their normal clothes. For adolescent children, anxieties about modesty should be anticipated; they too may feel more comfortable if not compelled to wear a revealing theatre gown. Hair clips and other accessories, if still in place, can be removed once the child or young person is asleep.

WHO Surgical Safety Checklist

The WHO Surgical Safety Checklist (SSC) was designed to prevent communication failures and reduce readily avoidable surgical complications. Whilst the physical act of 'ticking a box' may not necessarily prevent all adverse events, the checklist is a framework on which the correct attitudes and behaviours towards teamwork and communication can be encouraged. The Surgical Safety Checklist should be used for all cases commencing with a team brief to ensure that all team members are acquainted, that all are clear what surgeries are to be performed and that any special equipment that may be needed is available. Figure 10.1 shows the standard routine at the authors' institution.

Wrong-Sided Nerve Blocks

Contributory factors to the performance of a wrong-sided nerve block include:

- Distraction in the anaesthetic room
- Prolonged period between the WHO SSC 'sign-in' and performance of the nerve block
- Covering up of the surgical mark to keep the patient warm
- Repositioning of the patient or where blocks are performed infrequently

To reduce the risk of wrong-site anaesthetic nerve blocks occurring, a 'Stop before You Block' check was introduced in the United Kingdom by the Safe Anaesthesia Liaison Group (SALG) and Regional Anaesthesia UK (RA-UK). The check is recommended after the WHO SSC 'sign-in' and before the insertion of the block needle for unilateral regional blocks. The check should be performed by the anaesthetist and anaesthetic assistant and includes visualisation of the surgical arrow indicating site of surgery and double-checking the consent form for operative site. More recently, SALG and RA-UK have published an updated national standard operating procedure, 'Prep, Stop, Block', which enhances the message of 'Stop Before You Block', with the 'stop' moment occurring just before needle insertion.

Induction

The choice of intravenous or gas induction is determined by the preference of the child, parent and anaesthetist, although the lack of suitable veins may dictate an inhalational induction. As awareness of climate change increases, departments and individual practitioners may wish to move towards more intravenous inductions. Where appropriate, the child should be given the choice. Many children are frightened of needles, whilst others may have previous experience of a gas induction and not want to repeat it. Some children, of course, want neither, and it can sometimes be challenging to proceed without some form of therapeutic restraint or protective holding. Having the parent present to assist can be helpful.

Sevoflurane is the most common means of gaseous induction. There is no 'correct' or 'best' means of using it. For some children, a gradual increase of the vapour works well; for others, moving rapidly to or starting at 8% is preferable. Nitrous oxide speeds up induction, and initial sedation with nitrous oxide and oxygen may make acceptance of a face mask easier.

Some children will tolerate a mask relatively easily, others less so. Applying a mask forcibly to a small child is oppressive and can lead to a more challenging induction at the time and at future surgery. It is often easier and less threatening to use a cupped hand as a 'mask', holding it close to the nose and mouth. At the authors' institution, a range of flavoured lip balms are stocked in each theatre. Children are encouraged to apply their favourite lip balm to the interior of the mask to increase compliance.

The most used intravenous induction agent is propofol, although this can be very painful on administration, especially when given through small veins. Higher doses (3–5 mg kg^{-1}) are needed in small children compared to adults. Thiopentone (5–7 mg kg^{-1}) is seldom used these days but remains a useful alternative, as it is not associated with pain on injection.

Airway Management

Many small infants partially obstruct during induction of anaesthesia, and the insertion of an oropharyngeal airway may be beneficial if the

Surgical safety checklist

Great Ormond Street Hospital for Children NHS Foundation Trust

Sign in

Led by the anaesthetist

Before induction of anaesthesia

1 Identity of child checked against patient ID band printed, list & consent

2 Surgical site marking

3 Ward preoperative checklist

4 Anaesthetic machine & CGO position checked

5 Allergy status

6 Paracetamol/antibiotics given on ward?

7 PEG/NG aspirated?

8 Procedure-specific checks
- Stop before you Block!
- One-off surgical set has it been checked?
- If blood is needed, is it available

Time out

Led by a member of the theatre team

Before start of surgery

1 Introduce any new team members since team brief?

2 Surgeon, Anaesthetist and Scrub Practitioner verbally confirm:
- Child's identity
- Procedure, site and position
- Imaging

3 Ensure anaesthetist confirms:
- ASA
- Allergies
- Antibiotics
- Local anaesthetic dose
- Any new concerns since induction?

4 Ensure scrub nurse confirms:
- All relevant equipment available
- TEDs and FLOWTRONS applied
- Warming
- Pressure areas checked

5 Procedure-specific checks?

6 Infection status?

Sign out

Led by the circulating nurse

Before any team member leaves the OR

1 What have we done?

2 Have we checked against the consent?

3 Are all counts complete? (Instrument, swab, throat pack, sharps, guide wires)

4 Are specimens labelled and how are we sending them?

5 Have there been any equipment problems?

6 What are the postoperative plans?

7 Procedure specific checks?

8 Infection status?

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Figure 10.1 Surgical safety checklist.

Surgical safety checklist

Great Ormond Street Hospital for Children NHS Foundation Trust

Team brief

Led by the surgeon, nurse or anaesthetist

Before starting the list

1 INTRODUCTIONS

2 REVIEW EACH CASE ON THE LIST:

- **Concerns**
- **Anticipated blood loss**
  - Where is the blood?
- **Any special equipment, loan sets or one off sets?**
- **Imaging**
- **Infection status?**
- **Surgical Site Infection Bundle**
  - Antibiotics?
  - Warming?
- **Thromboprophylaxis?**
- **Pregnancy testing?**
- **Can we give a drink?**
- **Is a throat pack needed?**
- **Consent for Research Study if applicable?**

3 WHO IS SCRUBBING/OPERATING?

4 ANY STAFFING/TIME ISSUES?

5. ANY OUTSIDE ISSUES?

- e.g. ICU beds

6 CONFIRM LIST ORDER

7 WHO IS SENDING?

Team debrief

Led by the surgeon, nurse or anaesthetist

At the end of the list

1 REVIEW THE PRINTED LIST:

- **How well was the Surgical Safety Checklist done today?**
- **What worked well today? If relevant complete a praise form.**
- **Were there any staffing, equipment or prosthesis issues?**
- **What could improve for next time?**
- **Were there any avoidable delays?**
- **Did any incidents occur which require a Datix? If yes who will complete the Datix form?**

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Figure 10.1 (*cont.*)

obstruction is not relieved by repositioning of the airway. Airway management will depend on the type of surgery. Tracheal tubes are secured with adhesive tape, and it is important to ensure this does not stick to the mucosa of the lips. In small infants, the skin can be fragile, and tape should be removed with care at the end of surgery. It is very easy to inflate the stomach with air when ventilating a small child by face mask. This can impede ventilation, and a nasogastric tube should be inserted to deflate the stomach if this occurs.

It is common practice to extubate neonates and infants fully 'awake', when their airway reflexes have returned, and they are breathing regularly. For some older infants who are breathing spontaneously, it may be appropriate to perform a 'deep' extubation, but this will usually require the minimum alveolar concentration (MAC) of the volatile agent to be around 1.5. Extubating an infant between these two extremes can lead to breath-holding or laryngospasm.

Laryngospasm

Perioperative laryngospasm is a life-threatening complication that occurs more commonly in children than in adults, particularly in small infants. In the APRICOT study, laryngospasm was one of the most frequent respiratory complications (0.2–6.7%). It most frequently occurs during induction or immediately after extubation, sometimes with no apparent precipitating cause. Often it is due to the airway being stimulated too early during induction or the tracheal tube being removed too early at the end of surgery. Blood or secretions at the larynx can also precipitate laryngospasm.

Partial laryngospasm is characterised by a high-pitched inspiratory noise with increased respiratory effort but minimal visible sign of airflow. If laryngospasm is complete, there will be no airflow or noise. Its effective management requires early recognition and prompt and aggressive treatment, as hypoxia can rapidly ensue. Management of laryngospasm involves the following actions:

- Remove the laryngospasm stimulus.
- Apply CPAP with high-flow 100% oxygen via a tight-fitting face mask (the reservoir bag should be 'tight').
- Apply jaw thrust and small rapid breaths, avoiding gastric inflation if possible.
- Alert the anaesthetic assistant, who should prepare the appropriate intubation equipment and tracheal tube as quickly as possible.
- Ensure the oximeter and electrocardiogram (ECG) remain attached.
- If the laryngospasm does not resolve rapidly, consider deepening anaesthesia with propofol (1 mg kg^{-1}).
- If there is still no improvement (14% of cases in the APRICOT study), administer suxamethonium 1 mg kg^{-1} IV and atropine 20 mcg kg^{-1} and ventilate by hand; it may not be necessary to intubate. Suxamethonium 4 mg kg^{-1} IM may be used if the IV cannula has been displaced at the end of surgery.
- Consider passing a nasogastric tube after laryngospasm has resolved.

Laryngospasm will usually settle without the need for intervention other than the application of continuous positive airway pressure (CPAP) with high-flow oxygen. Occasionally, at the end of surgery, it may be difficult to break the laryngospasm, and it may be necessary to re-institute anaesthesia, re-intubate and leave the tracheal tube in place until the patient is fully awake. Negative pressure pulmonary oedema may occur in young people after severe laryngospasm.

Rapid Sequence Induction

In theory, classic rapid sequence induction (RSI) should be used in all children at risk of regurgitation and aspiration. This includes those requiring emergency surgery who may not be appropriately fasted, particularly those with proximal bowel obstruction, and in the child with posttonsillectomy haemorrhage who may have a stomach full of blood. However, there are practical limitations that make classic RSI difficult in infants and usually inappropriate:

- Attempts to pre-oxygenate a frightened and uncooperative small child may be counterproductive.
- It is not always possible to obtain venous access in small infants to administer an intravenous induction agent and a rapidly acting muscle relaxant. Inhalational induction may therefore be necessary.
- The high oxygen consumption seen in infants leads rapidly to hypoxia if ventilation is avoided before intubation.

- The cricoid ring is higher. Cricoid pressure can make intubation more difficult and may not actually 'obstruct' the oesophagus effectively.

For these reasons, many experienced paediatric anaesthetists will adopt a pragmatic approach in small infants with a potentially full stomach and will gently ventilate whilst waiting for the muscle relaxant to work, with gently applied cricoid pressure. Rocuronium 1 mg kg^{-1} is the standard muscle relaxant, but as apnoea is not a fundamental component of this 'controlled RSI', many will use a slower, non-depolarising agent such as atracurium. Suxamethonium is rarely used these days. For the older child, a classic RSI can be utilised.

Teeth

For children in the middle of orthodontic treatment, it is important to establish whether their braces are fixed or can be removed. It is also very important to establish whether a child has any loose deciduous teeth. If very loose, it may be necessary to remove a tooth after induction to prevent it being dislodged and lost or inhaled during airway manipulation. This possibility should be explained to the parents during the preoperative visit. The tooth must be kept safe and handed to the parents after the procedure.

Occasionally a permanent tooth may be unintentionally avulsed during airway manipulation. It is important to be aware that this can be successfully salvaged if acted upon immediately. There is a 30-minute golden window for this, and a guideline such as that in Figure 10.2 should be followed.

Intravenous Lines

These should be well secured and preferably visible throughout the procedure. It is surprisingly easy for extravasation to occur in small infants, especially if fluid boluses are given rapidly under high pressure. When a child arrives in theatre with an IV line already in situ, it must be inspected carefully and tested prior to being used for induction. The skin over the cannula tip should be visible, and this will necessitate the removal of any dressings that may have been applied to prevent the child displacing the cannula. Pain on injection of saline should give rise to suspicion that the line has 'tissued', although it may also be due to phlebitis in a long-standing line. It is not always possible, of course, for IV lines to be visible throughout the procedure. Before the child is covered with drapes, it is important to ensure the line is working well. Many cannulae in children are placed over or near wrist and ankle joints, and ease of injection can be very positional. This must be resolved before the child is covered. If a line becomes more difficult to inject into or if fluids slow down during the procedure, the possibility of extravasation should be considered and the site inspected. Clear drapes mitigate against undetected extravasation but are not always readily available.

At the end of the operation, all IV lines must be flushed with saline to avoid the possibility of flushing of residual drugs into the circulation later. There have been several reports to National Reporting and Learning Service in England of harm due to flushing of residual anaesthetic drugs in IV cannulae in children. It is the responsibility of the anaesthetist to make sure that residual anaesthetic agents in IV lines are cleared prior to the child leaving their care.

Extravasation

There are some drugs that can cause severe tissue injury in the event of extravasation and in some cases can lead to skin necrosis and nerve or tendon injury. Severe injury may necessitate later surgical release of contractures and skin grafting. Tissue damage may occur due to extravasation of cytotoxic drugs, hyperosmolar substances, highly acid or alkaline solutions, drugs formulated in alcohol or polyethylene glycol or vasoconstrictor drugs (causing local ischaemia). Occasionally damage may occur due to high-volume extravasation causing mechanical tissue ischaemia. Drugs most likely to cause problems during anaesthesia include:

- X-ray contrast media
- Thiopentone
- Ketamine
- Atracurium
- Sodium bicarbonate
- Magnesium sulphate 20%
- Calcium chloride or gluconate
- Vasoactive drugs
- Glucose >10%

Established treatment protocols for extravasation injury must be readily available. Immediate management involves minimising the concentration of the drug at the site of extravasation by stopping the injection and aspirating as much of the drug as possible from the cannula. Where there has been significant leakage of a tissue-damaging drug,

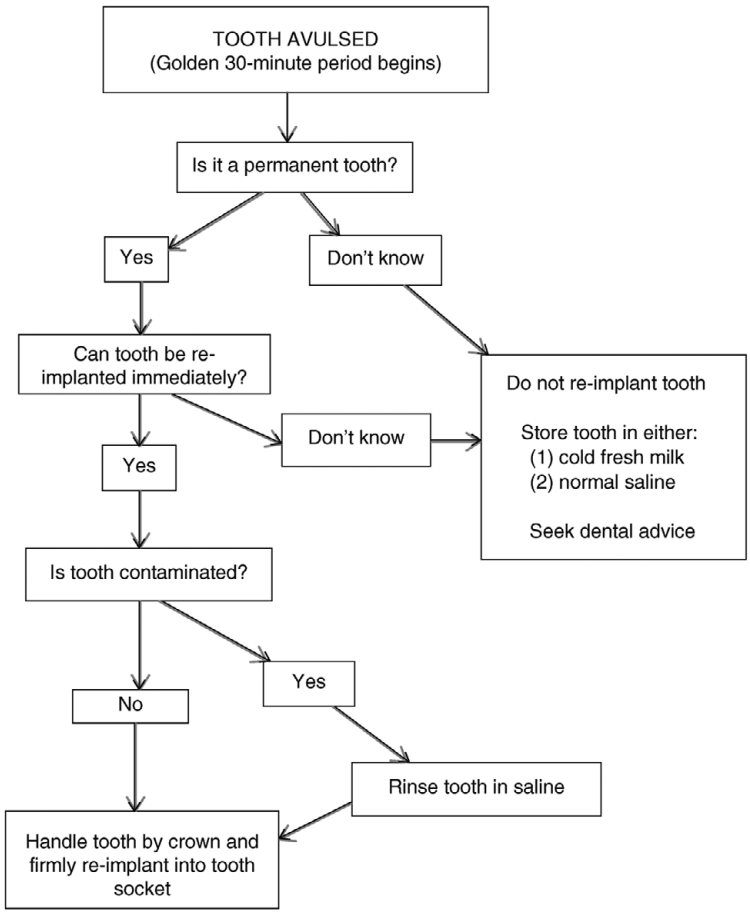

Figure 10.2 Management of avulsed tooth during general anaesthesia. From Soneji B, Forde K, Mason C, Dental Department, Great Ormond Street Hospital NHS Foundation Trust.

saline washout should be performed. This involves making multiple skin incisions around the site of extravasation. Saline is then injected through one or more of the incisions with a blunt needle to flush extravasated drug out through the other puncture sites. It may be necessary to obtain input from the plastic surgery service.

Positioning

This will be dictated largely by the surgical procedure, and most cases will be supine. The head should not be rotated beyond 65°, particularly in paralysed children, as this can lead to C1–2 facet dislocation. This atlanto-axial rotary subluxation can occur in children because of ligamentous laxity, poorly developed cervical musculature, horizontally orientated facet joints and wedge-shaped cervical vertebrae. The head should be supported in a gel ring to prevent abnormal rotation.

Care should be taken to ensure that all pressure points are well padded, particularly when the patient is in the prone or lateral position. Care must be taken to protect the eyes when the patient is prone. If the arms are extended above the head, which may be necessary in some radiological investigations, they should be supported in such a way that there is no tension at the shoulder to avoid the possibility of a brachial plexus injury.

Acute Major Anaphylaxis during Anaesthesia

Anaphylaxis is a severe life-threatening generalised or systemic hypersensitivity reaction. The reported incidence of perioperative anaphylaxis is one in 10,000, with an incidence of 2.7 per 100,000 in children (NAP6). Clinical presentation includes:

- Pharyngeal or laryngeal oedema
- Acute severe bronchospasm
- Hypotension
- Tachycardia
- Skin/mucosal changes

Unlike in adults, bronchospasm and/or high airway pressures are the commonest presentation (National Audio Project 6, NAP6) in children, and a change in ventilatory parameters is often the first indication to alert the anaesthetist. Severe bronchospasm, with difficulty ventilating the lungs, will lead to a rapid fall in oxygen saturation. In severe cases, it can be exceedingly difficult to ventilate the lungs, and end-tidal CO_2 may rise due to hypoventilation. A fall in end-tidal CO_2 may be seen if the bronchospasm is so severe that there is little alveolar ventilation. Hypotension may occur rapidly, and bradycardia is more common than in adults (18% vs 12.6%, NAP6).

The most likely causes of a drug-induced anaphylactic reaction in a child are antibiotics (penicillin or cephalosporins), lidocaine, radiological contrast media and latex. Due to the small number of cases reported in children, NAP 6 was not able to make any firm conclusions concerning the risk rates with different drugs, but atracurium, cefuroxime, suxamethonium, aprotinin and cryoprecipitate were all implicated. Reaction to muscle relaxants does not appear to be as common in children as in adults, possibly because they are used less frequently than in adults (24.7% vs 47%, NAP6).

The treatment of a severe anaphylactic reaction is summarised in Box 10.1. Adrenaline is the cornerstone of treatment and should be administered early. Where the treatment has been prolonged, or infusions of adrenaline or noradrenaline have been necessary, the patient should be admitted to a high-dependency or intensive care unit for postoperative monitoring.

Even in cases where the situation is resolved promptly, the patient should remain in hospital overnight, as in up to 20% of cases there can be a biphasic reaction with recurrence of symptoms up to 12 hours later.

Full documentation of the episode is essential. As soon as the patient has stabilised, blood

Box 10.1 Emergency management of severe anaphylaxis.

- Discontinue suspected agent and maintain anaesthesia
- Call for help. Stop or do not start non-essential surgery
- Give 100% oxygen and ensure adequate ventilation (intubate if necessary)
- Give adrenaline bolus, 1 mcg kg^{-1} i.v. (0.1 ml kg^{-1} of 1:**100,000**)
  [1:**100,000** solution made by diluting 1 ml of 1:**10,000** up to 10 ml]
- Repeat adrenaline bolus as necessary for resistant hypotension or bronchospasm; start continuous infusion if multiple boluses required
- Give rapid i.v. crystalloid bolus, 10–20 ml kg^{-1} (Hartmann's solution of similar) and repeat until hypotension resolved
- CPR if necessary

For adrenaline resistant bronchospasm

- Salbutamol 5–15 mcg kg^{-1} i.v. over 5 min or
- Aminophylline 5 mg kg^{-1} i.v. over 20 min

For resistant hypotension

- Start noradrenaline infusion 0.05–0.5 mcg kg^{-1} min^{-1}

AFTER initial resuscitation, consider

- Hydrocortisone 4 mg kg^{-1} i.v.
- Chlorphenamine

6 months	250 mcg kg^{-1} i.v.
6 m–6 y	2.5 mg
6–12 y	5 mg
>12 y	10 mg

- Check blood gas and treat acidosis if present
- Check coagulation and treat as appropriate
- Take clotted blood sample for serum tryptase as soon as patient is stable. Plan for repeat sample at 1–2 hours and > 24 hours
- Plan transfer of patient to an appropriate critical care area

samples for mast-cell tryptase (5 ml into a plain tube) should be taken as these will help to determine whether there was mast-cell degranulation. Peak levels occur between 1 and 2 hours, and repeat samples should be taken at 1, 2, 4 and 12 hours to document the reaction. The immunology service should be contacted to investigate the patient further.

Latex Allergy

A substantial number of patients and medical staff have developed sensitivity, and in some cases an allergy, to latex. All departments should have a protocol for managing such patients, the most important measure being establishing a latex-free environment. This should be standard in UK operating theatres, with all supplies being latex-free. Powdered latex gloves are previously thought to have caused most aerosolised latex particles. These are no longer available in National Health Service (NHS) hospitals.

Patients should be highlighted on the theatre list and consideration given to placing them first. Any latex products should be removed from the theatre – usually latex gloves. Patients at high risk for serious reactions fall into three groups:

(1) Those with a history of latex anaphylaxis, confirmed by positive antibody testing
(2) Those with a history of allergy to latex, with urticaria, eye swelling, central dermatitis or bronchospasm
(3) Those with no previous reaction, but who have:
    - Spina bifida
    - Genito-urinary anomalies
    - Multiple surgical procedures
    - Documented reactions to IV drugs

There appears to be cross-sensitivity to peanuts and to some fruits such as kiwi, banana or avocado, so allergy to these should raise an index of suspicion. Previous recommendations for premedication of latex-sensitive patients with steroids, antihistamine and H_2-receptor antagonists are no longer advised, as this does not prevent a reaction, nor does it affect the severity of a reaction.

Departments should have clearly documented protocols in the operating theatres and recovery areas detailing what equipment is latex-safe and what should be avoided. Latex-free anaesthetic equipment is now widely available. When drawing up drugs, care should be taken to ensure all bungs are latex free – the vast majority are. Should a severe reaction occur, management is as for acute major anaphylaxis.

Recovery

It is important to provide a thorough handover to the recovery room or intensive care staff at the end of the procedure. This should include details of intraoperative analgesia, antiemetics and antibiotics that have been given or charted for postoperative administration, any airway or venous access difficulties that have been encountered and any other adverse events. If topical anaesthesia has been applied to the larynx, it is important to advise when the patient can drink. We usually advise that this should be at least two hours after the larynx was sprayed. A simple aide-memoire such as that shown in Figure 10.3 works well in ensuring that no vital information is missed. Recovery handover is another important stop point to check that all intravenous lines have been adequately flushed with saline to avoid later inadvertent administration of residual anaesthetic agents.

Emergence Delirium

Behavioural disturbance during early emergence from anaesthesia, usually involving agitation, hyperactivity with flailing movements, inconsolable crying and disorientation, has been recognised for many years, and a Paediatric Anaesthesia Emergence Delirium (PAED) scale has been developed. It is particularly common in preschool children and appears to be more common following the use of sevoflurane and desflurane. The use of total intravenous anaesthesia (TIVA) with propofol reduces the risk of emergence delirium. It can be very distressing to recovery staff and to parents who witness it and usually assume their child is in pain. However, it appears to be unrelated to postoperative pain as it can occur in non-painful procedures such as radiological investigations. There is still no clear understanding of the aetiology of emergence delirium and consequently no widely accepted prophylactic strategy. Midazolam does not appear to prevent it, whether given as premedication or during anaesthesia. Some studies have shown that propofol, fentanyl, ketamine, clonidine and dexmedetomidine may be effective. Emergence delirium usually resolves over a period of 10–15 minutes, but when a

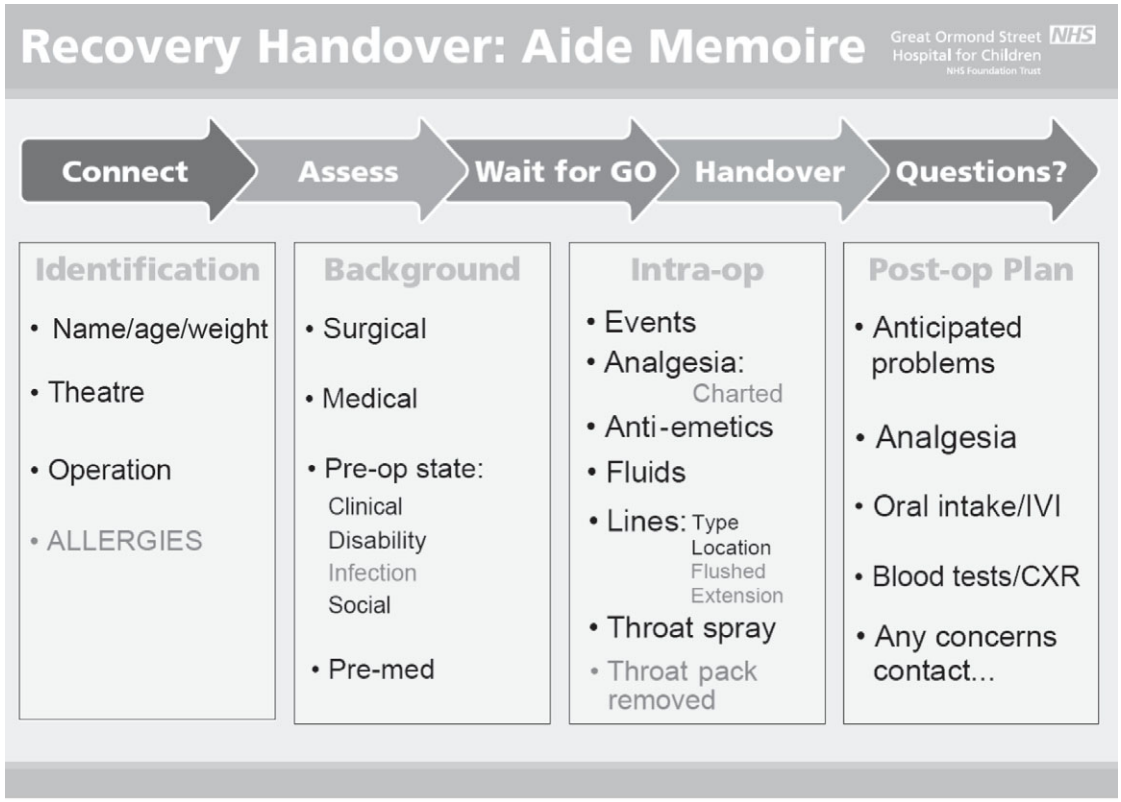

Figure 10.3 Recovery handover aide-memoire.
Department of Anaesthesia, GOSH, Updated November 2020.

child is very agitated it can be ameliorated with a 0.5–1 mg kg^{-1} bolus of propofol.

Areas for Future Development

Paediatric anaesthesia appears safe when undertaken in well-planned, appropriately resourced environments. Despite this snapshot, observational studies have shown surprisingly high rates of severe critical events. Additionally, good outcomes of anaesthesia should extend to include psychosocial well-being and avoidance of hospital induced phobias.

As electronic anaesthetic recording becomes a standard of care, opportunities for contemporaneous big data to understand safety risks should become reality.

Areas for quality improvement include standardisation of serious critical event definitions; increased reporting; development of evidence-based protocols for management of serious critical events; development and rational use of paediatric perioperative risk assessment scores; implementation of current best practice in provision of competent paediatric anaesthesia services in Europe; development of specific training in the management of severe perioperative critical events; and implementation of systems for ensuring maintenance of skills.

Further Reading

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