Update in Anaesthesia

Paediatric difficult airway management

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Summary

Unexpected difficult airways in paediatric practice are rare. Many problems can be prevented by routine pre-operative airway assessment, pre-oxygenation, and preparation of equipment. A simple step-wise approach to management improves outcome. Anaesthetists have a responsibility to be familiar with airway algorithms and make pragmatic modifications to account for available resources.

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INTRODUCTION

Airway management in children is generally straightforward in experienced hands. Problems are more common for the non-paediatric anaesthetist, and are a major cause of anaesthesia-related morbidity and mortality. Genuine 'difficult airways' are rare in children compared to adults and many are predictable. However, differences in adult and paediatric physiology mean irreversible hypoxic damage occurs more quickly in children if there is an airway problem. Simple step-wise strategies are essential. Many guidelines exist for the management of difficult airways in adults, but there are few specifically designed for use in children.

The aim of this article is to outline the basic principles of paediatric airway assessment and to discuss the management of unexpected and expected difficult paediatric airways.

Evidence to support best practice is difficult to obtain for unpredictable events such as management of the paediatric difficult airway, and there is a lack of high quality data. Many new devices and techniques are available, but most are evaluated in healthy children or simulated 'difficult' situations. Due to this lack of evidence, guidelines are often based on a consensus of expert opinion, which may have a bias against newer devices and techniques, or indeed bias towards the latest technique that has gained popularity. This review takes a pragmatic and cautious approach in applying existing guidelines to settings where experts and a range of technology are not always available.

BACKGROUND

Management of the difficult airway can be divided into three critical areas:

1. Difficult mask ventilation
2. Difficult tracheal intubation
3. Can't intubate and can't ventilate (CICV).

The incidence of difficult airways in children is unknown. The incidence of impossible mask ventilation is reported as 0.15%, and is more frequently encountered by inexperienced paediatric anaesthetists. Difficult intubation ranges from 0.05%, rising to 0.57% in children less than one year of age.[1] Difficult intubation is more common in children with cleft lip and palate (4.7%) and cardiac abnormalities (1.25%), most likely related to associated syndromes or limited cardiac reserve.

An audit of difficult airway management in the UK in 2001 (the 4th National Audit Project, NAP 4), prospectively measured major airway complications in almost 115,000 patients undergoing anaesthesia.[2] Children comprised a small proportion of the total population, and complications were rare (only 7-8% of total complications).

Common contributing factors to bad outcomes were:

- Poor airway assessment
- Poor planning
- 'Failure to plan for failure'
- Repeated attempts at intubations
- Lack of monitoring (oxygen saturation and capnography)
- Slow response to hypoxia resulting in bradycardia leading to cardiac arrest
- Failure to use devices such as the laryngeal mask airway (LMA) when faced with a difficult intubation.

One of the key findings in NAP4 was the 'failure to plan for failure'. Airway management plans should always include a back-up plan to use if the first plan fails. Whenever unexpected difficulties occur, seek experienced help immediately. Another key finding of NAP4 was that repeated attempts at intubation can cause severe airway oedema in children and worsen the situation, hence their recommendation, 'a change of approach is required, not repeated use of a technique that has already failed'.

Many countries have adult guidelines for management each of difficult airways, but few have child specific guidelines. The Association of Paediatric Anaesthetists of Great Britain and Ireland (APA) published paediatric guidelines in 2012, which are shown in Figures 1-3 and form the basis for management of the unexpected difficult airway discussed here.[3]

AIRWAY ASSESSMENT

Proper airway assessment, proper planning for airway management, and the use of monitoring are essential basic principles for safe anaesthesia in children.

Airway assessment may be considered in two parts:

Will facemask ventilation be difficult?

- A tumour or abnormal face shape may prevent the facemask from sealing easily over the face.
- Syndromes associated with midface hypoplasia
- Children with severe obstructive sleep apnoea (e.g. tonsillar hypertrophy).

Will intubation be difficult?

Factors that may predict difficult intubation in children include:

- Mandibular hypoplasia e.g. syndromes such as Pierre Robin
- Poor mouth opening
- Obstructive sleep apnoea
- Stridor
- Syndromes associated with facial asymmetry. Note ear abnormalities are often associated (e.g. Goldenhar syndrome).

Various tests and scoring systems have been suggested for use in adults. Many have a very poor sensitivity and/or specificity and are not validated in children. However, assessment of the following is essential. The anaesthetist may need some ingenuity to achieve these assessments in a small uncooperative child!

- Mouth opening
- Range of neck movement
- Mandibular hypoplasia - micrognathia makes intubation difficult. Assess the airway by observing the child in side view rather than from the front.
- Mandibular hyperplasia - ameloblastoma may cause jaw protrusion and can make laryngoscopy and intubation difficult
- Inspection of the oral cavity (e.g. for intraoral masses).

The Mallampati score can be used for older children who are cooperative. Even though there is no validated scoring system in infants and young children, the anaesthetist must still make a risk assessment, and decide on the anticipated difficulty of intubation. This airway assessment must be documented in the anaesthetic record.[4]

PLAN FOR AIRWAY MANAGEMENT

After airway assessment, a structured plan for airway management is required before induction of anaesthesia. The plan must consider:

- Choice of airway e.g. facemask, supraglottic airway device or tracheal tube
- Mode of ventilation e.g. spontaneous ventilation or positive pressure
- Monitoring e.g. pulse oximeter (minimum); end tidal carbon dioxide.

Due to a lower functional residual capacity (FRC) and higher metabolic rate, oxygen saturation falls much faster in infants and young children than adults. Preoxygenation before induction of anaesthesia establishes a reservoir of oxygen in the lungs by displacing nitrogen. This means a patient can remain oxygenated for longer than otherwise expected, which gives more time to address unexpected airway problems. Therefore preoxygenation is an important part of the airway management plan and should form part of normal anaesthetic practice wherever possible, even in children.

THE UNEXPECTED DIFFICULT AIRWAY

Problems with airway management may be due:

1. Difficult mask ventilation
2. Difficult tracheal intubation
3. Can't intubate and can't ventilate (CICV).

The first step is to administer 100% oxygen and call for help. Another pair of hands is always useful.

The next step is to consider – is this a problem with the equipment or the patient? All equipment should be checked prior to induction of anaesthesia to minimise the chance of equipment failure.

1. Difficult mask ventilation

A simple algorithm for the management of difficult mask ventilation is given in Figure 1: Difficult mask ventilation algorithm. http://www.apagbi.org.uk/sites/default/files/images/APA1-DiffMaskVent-FINAL.pdf

Difficult mask ventilation – equipment problems

Equipment failure should be excluded quickly – check the mask, circuit, and oxygen supply. Always have a self-inflating bag available in case of equipment problems.

Difficult mask ventilation – patient factors

These can be divided into anatomical or functional problems.

Anatomical problems associated with difficult mask ventilation may be due to poor head positioning, large adenoids/tonsils, or due to airway obstruction from cricoid pressure (if used).

Functional problems may arise in the upper or lower airways. Upper airway obstruction may be due to inadequate depth of anaesthesia and laryngospasm; lower airway problems include inflation of the stomach (very common in infants), bronchospasm or chest wall rigidity (rare).

Management of difficult mask ventilation:

- Adjust the head position – does the child need a head roll (or should the head roll be removed)
- Use simple airway opening manoeuvres (chin lift, jaw thrust)
- Apply positive end expiratory pressure (PEEP)
- Adjust cricoid pressure if it has been used
- Insert an oropharyngeal airway (if the patient is deep enough)
- Increase depth of anaesthesia
- Ventilate using a two-person technique (one holding the mask with two hands, the other ventilating by squeezing the bag)

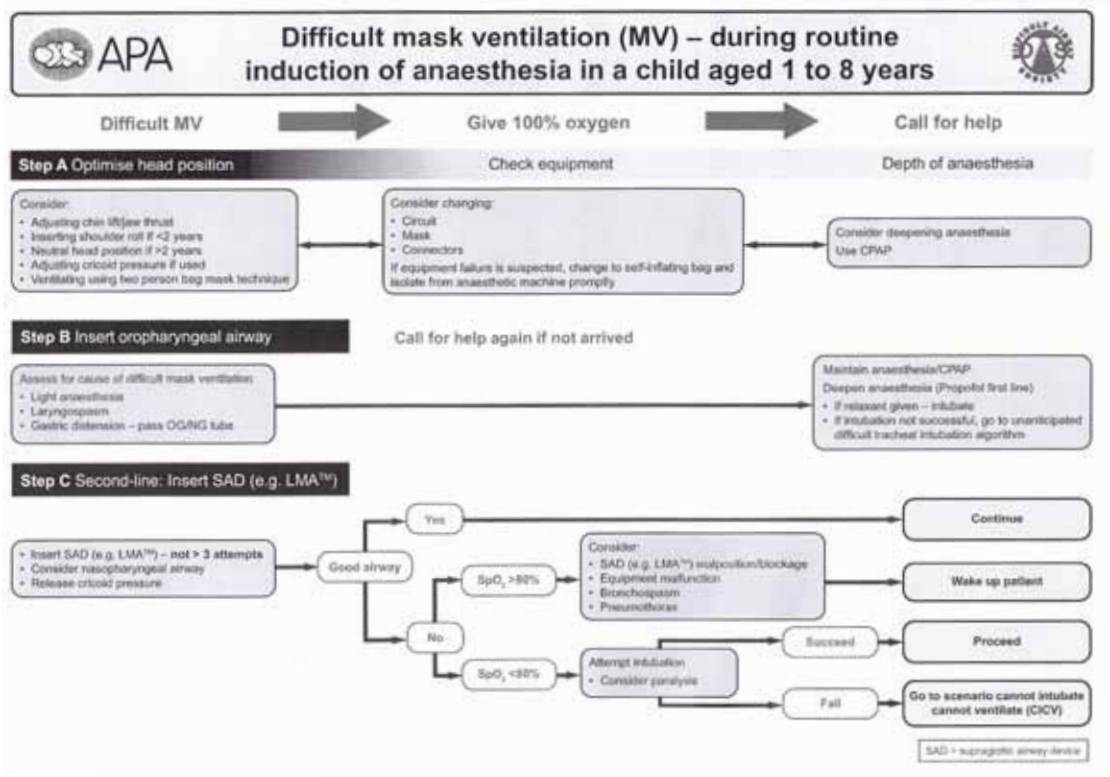

Figure 1: *Difficult mask ventilation algorithm. Reproduced with kind permission of Association of Paediatric Anaesthetists from: http://www.apagbi.org.uk/sites/default/files/images/APA1-DiffMaskVent-FINAL.pdf*

- Pass a nasogastric tube to deflate the stomach.

If mask ventilation is impossible despite all the above measures or the child's oxygen saturation begins to fall:

EITHER insert an LMA (if available),

OR deepen anaesthesia, attempt to visualise the vocal cords and intubate the trachea.

There is no randomised controlled trial to assess which is the best response, but insertion of an LMA is recommended first, and then intubation (Figure 1).

If oxygenation and ventilation is satisfactory through the LMA or tracheal tube then it is safe to proceed with surgery.

If in doubt, wake the child up.

2. Unexpected difficult tracheal intubation

A simple algorithm for the management of unexpected difficult tracheal intubation is given in Figure 2: Difficult tracheal intubation algorithm. http://www.apagbi.org.uk/sites/default/files/images/APA2-UnantDiffTracInt-FINAL.pdf

The key point is, if tracheal intubation fails, DO NOT simply repeat what has just failed. Multiple attempts at intubation may traumatise the airway and will cause airway oedema, which may make the child impossible to intubate. Intubation attempts must be limited to a maximum of three or four (Figure 2).

If the first intubation attempt fails, it is essential to make changes that improve the chance of successful intubation. These may include:

- Change of personnel (a more senior anaesthetist);
- Change of position
- Change of equipment.

Visualisation of the larynx and successful tracheal intubation are improved by:

- Proper positioning of the child,
- External laryngeal manipulation
- Adequate depth of anaesthesia and adequate muscle paralysis (if this has been used).

Simple aids such as a bougie or stylet may make intubation straightforward even when the view of the larynx is poor. An alternate laryngoscope may also be used if available and if the operator is familiar with its use.

Straight bladed laryngoscopes are traditionally used in children under one year old, but may be useful in older children, or in patients with relative macroglossia. They can be used with a paraglossal or retromolar technique. McCoy levering laryngoscopes are also available for paediatric use, based on a Seward blade (sizes 1 and 2) and may improve the view of the larynx, particularly if the view is obstructed by a large epiglottis.

In addition to straight bladed and McCoy laryngoscopes, new alternate laryngoscopes have been developed recently (see table 1). High quality evidence supporting efficacy is largely absent in the life-threatening scenario of unexpected failed intubation. Firm recommendations cannot be made so many algorithms suggest alternate laryngoscopes/techniques 'should be considered'.

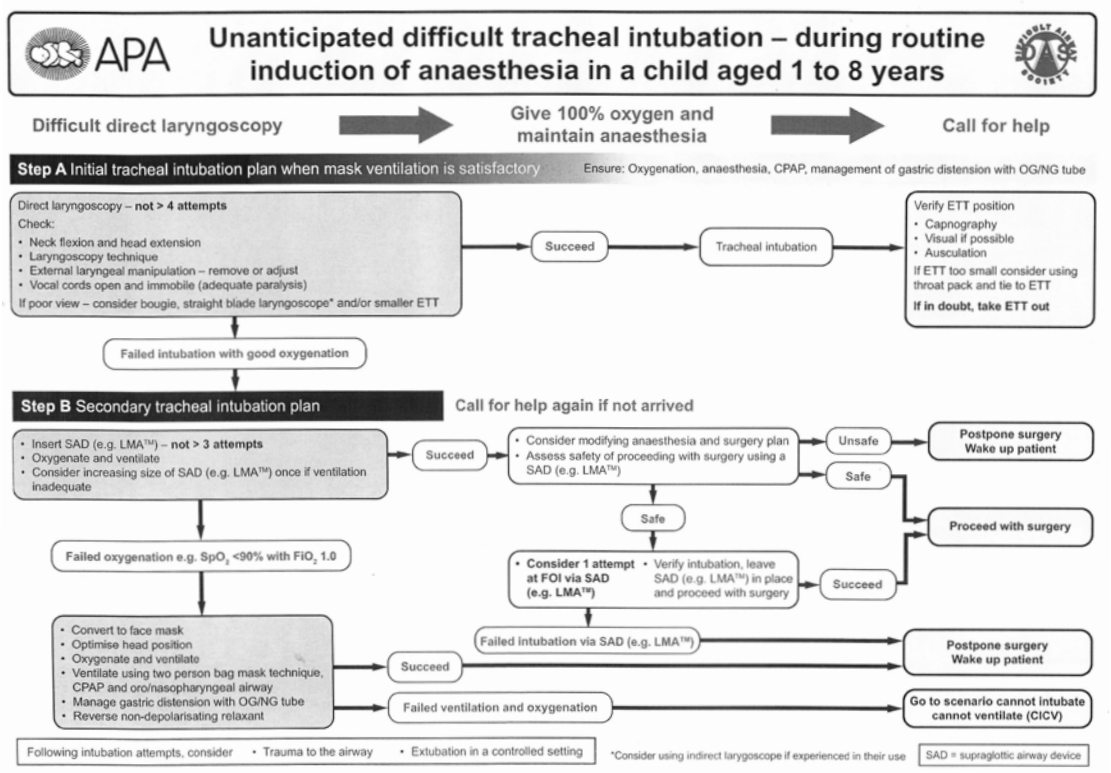

Figure 2*: Difficult tracheal intubation algorithm. Reproduced with kind permission of Association of Paediatric Anaesthetists from: http://www.apagbi.org.uk/sites/default/files/images/APA2-UnantDiffTracInt-FINAL.pdf*

Table 1. *Classification of rigid indirect laryngoscopes*

Classification	Description of technique	Examples
'Non-guided' devices	Provide an indirect view of larynx but require direction of tracheal tube towards larynx.	Bullard laryngoscope Glidescope Storz DCI Videolaryngoscope Storz C-MAC laryngoscope
'Guided' devices	Provide indirect view and act as a conduit for passage of tracheal tube.	Airtraq
Optical stylets	Provide indirect view via rigid or semi-rigid stylet, with a 'loaded' tracheal tube for railroading.	Bonfils and Brambrink Shikani Lightwand

Alternate techniques

Traditional laryngoscopes (curved, straight or McCoy levering blades) give a direct view of the larynx. Alternate techniques use an indirect approach with flexible or rigid equipment.

- Flexible indirect laryngoscopy, in the form of fibreoptic intubation, is the established 'gold standard' for the management of the predicted difficult airway in adults (see below).
- New rigid indirect laryngoscopes are available, including in paediatric sizes. Rigid indirect laryngoscopy has a place in the unexpected difficult tracheal intubation algorithm. The choice of device depends on local availability and expertise.

If visualising the larynx is impossible, then an LMA should be inserted. LMAs provide a clear airway in the vast majority of children. This allows delivery of ventilation, oxygenation and anaesthetic gases with a lower risk of gastric insufflation. The LMA may also be used as a conduit for fibreoptic intubation (FOI) where necessary, or in older children, the specifically designed intubating LMA, may be used.

If LMA insertion fails, then oxygenation and ventilation must be provided by mask ventilation.

3. Cannot intubate, cannot ventilate (CICV) - 'rescue techniques'

A simple algorithm for the management of 'cannot intubate, cannot ventilate' is given in Figure 3 : Can't intubate can't ventilate algorithm. http://www.apagbi.org.uk/sites/default/files/images/APA3-CICV-FINAL.pdf

Rescue techniques for the CICV situation have been extensively researched in the adult literature, but their use in paediatric emergencies is more anecdotal than evidence-based. The choice is between a surgical or needle (cannula) technique for cricothyroidotomy. The technique for cannula cricothroidotomy is shown in Figure 3, and for surgical

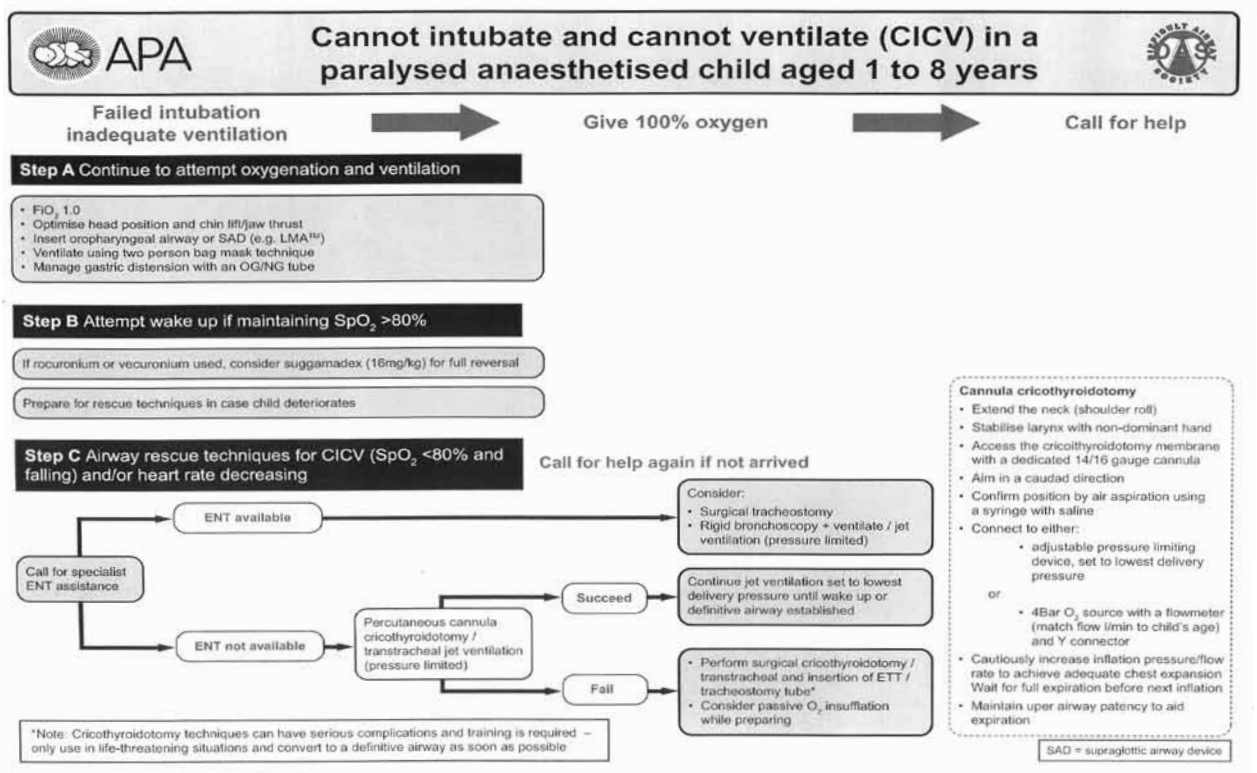

Figure 3*: Can't intubate can't ventilate algorithm. Reproduced with kind permission of Association of Paediatric Anaesthetists from: http://www.apagbi.org.uk/sites/default/files/images/APA3-CICV-FINAL.pdf*

Table 2. *Technique for surgical cricothyroidotomy*

1.	Position the patient so that the neck is fully extended so that the trachea and larynx are pushed forward
2.	Locate the cricothyroid membrane and stabilise the trachea
3.	With a scalpel blade make a stab incision through the skin and cricothyroid membrane*
4.	Insert a tracheal hook or retractor at the lower edge of the incision
5.	Pass an appropriately sized tracheal or tracheostomy tube
6.	Ventilate patient and assess effectiveness
7.	Secure the tube
Arterial forceps, the scalpel blade and tracheal dilators may be used to dilate the orifice.	

cricothyroidotomy, in Table 2.

Since there is no randomised controlled trial of one technique versus another, the choice should be determined by local experience and availability of equipment. This includes utilising the surgeon who may be more experienced than the anaesthetist. Adult evidence suggests surgical cricothyroidotomy is preferable, so this is recommended in older children.

The important factor is that at least one technique is actually attempted by someone in the CICV situation when the oxygen saturations are less than 80% and falling and/or the heart rate is decreasing.

The CICV situation is a particular challenge in infants and small children, due to important anatomical differences:

- The trachea is small, elastic, flaccid and mobile, and so prone to collapse during insertion of a transtracheal device.
- The cricothyroid membrane is much smaller, with an average size of only 2.6 x 3mm, smaller than the smallest tracheal tubes.
- It is more difficult to locate the cricothyroid membrane than in adults due to a differing orientation of the hyoid bone and the cricoid and thyroid cartilage. This orientation also increases the chance of laryngeal trauma during cricothyroidotomy.
- It is easier to locate the space between the tracheal rings rather than the cricothyroid membrane.

Together these factors mean it may be more appropriate in infants and small children to perform a surgical tracheostomy.

All 'rescue techniques' have significant potential for complications so should only be performed in life threatening situations. Clearly, all the steps for difficult facemask ventilation should be tried first. If muscle relaxants have been used and can be reversed, wake the child up.

THE EXPECTED DIFFICULT AIRWAY

If the preoperative airway assessment alerts the anaesthetist to expected difficulties in airway management then there are three key questions:

1. Does the anaesthetist have the necessary paediatric airway experience?
2. Does the hospital have the necessary paediatric equipment?
3. Does the relative benefit of the planned surgery outweigh the possible risks of anaesthesia?

If there is any doubt, full discussion should take place with the parents (or carers), child, surgeons and anaesthetists. It may be appropriate for the child to be referred to specialist hospital or wait for a more experienced paediatric anaesthetist to attend.

The anaesthesia plan must be carefully considered, including what to do if tracheal intubation is unsuccessful; will the child be woken up, or will a tracheostomy be necessary. The anaesthesia plan should be communicated clearly to the whole theatre team including surgeons and nursing staff. Difficult airway equipment must be checked and prepared.

The primary plan for management of the expected difficult paediatric airway will likely be one of the following:

1. Laryngoscopy anticipated to be difficult but may be possible: Attempt laryngoscopy and intubation. If fails, consider repositioning and try alternate laryngoscopes if available, or insert LMA and perform fibreoptic intubation (FOI) via LMA.
2. Laryngoscopy predicted to be impossible: Perform nasal FOI or insert LMA and perform FOI via LMA.
3. Laryngoscopy and LMA insertion known to be impossible: perform nasal FOI.
4. Laryngoscopy, LMA insertion and nasal FOI not available or known to be impossible: perform tracheostomy either using inhalational anaesthesia via face mask or intravenous ketamine especially if face mask anaesthesia impossible.

Blind intubation through an LMA is NOT recommended in children due to risk of airway trauma. Attempts at FOI should be limited to two and if unsuccessful, consider waking child, or continue with surgical procedure on an LMA. In situations where LMAs are unavailable, ventilation by face mask is the alternative. If neither LMAs nor FOI are available, the surgeon and anaesthetist need to discuss whether the benefits of surgery outweigh the risk of attempting anaesthesia in a child with a known difficult airway with insufficient equipment to provide safe management. This is a very difficult decision and will depend on the individual merits of each case.

Premedication

The use of sedative premedication in a child with a potential airway problem is controversial. A frightened, screaming child producing lots of secretions and in whom it is difficult to place monitoring, intravenous cannula, and even approach to do an inhalational induction, is also a risk.

Therefore, a small dose of sedative premedication, such as midazolam 0.3-0.5mg.kg^{-1} is often appropriate. Atropine is useful as an antisialogue (30-40 micrograms.kg^{-1} PO or 20 micrograms.kg^{-1} IM). Peak effect of atropine is 90 minutes if given PO, 25 minutes if given IM.

Anaesthetic technique

The most important principle in managing the difficult airway in children is to maintain spontaneous ventilation until the airway is secure.

'Awake' techniques require good patient co-operation, which is rarely possible in children. Therefore, the child must be anaesthetised so the choice is between an inhalational or intravenous technique. The variety of airway problems encountered in children means the anaesthetic must be tailored to the individual situation:

- Large extraoral tumours may mean a face mask will not fit the child's face, so an inhalational induction is impossible and IV induction/sedation must be used instead.
- Large intraoral tumours prevent laryngoscopy and the use of an LMA - nasal fibreoptic intubation (FOI) should be used.
- Conditions such a noma (cancrum oris) often cause severe limitation of mouth opening - nasal FOI is likely to be required.
- Other problems such as partial mouth opening, severe retrongathia or bony abnormalities (ameloblastoma) often make laryngoscopy difficult but do permit the insertion of an LMA if laryngoscopy proves impossible.
- Burns contractures causing fixed flexion of the neck may be released prior to intubation using ketamine anaesthesia and with local infiltration.

The variety of clinical conditions mean a one-size-fits all approach is impossible. The best technique will depend on the equipment and expertise available, as well as the nature of the difficult airway.

Inhalational induction, using halothane or sevoflurane in 100% oxygen, is generally recommended Intravenous access may be established either before or after induction but must occur before airway instrumentation. The general technique is to deepen anaesthesia until laryngoscopy is tolerated or LMA inserted or FOI performed depending on the airway management plan.

If inhalational induction is impossible, small doses of IV induction agent should be given to induce loss of consciousness but still preserving spontaneous ventilation. Propofol 0.5-1mg.kg^{-1} or ketamine 0.5-1mg.kg^{-1} should be given and titrated to effect.

If inhalational induction is not possible due to pain, for instance, from an infected facial mass/tumour (rather than because of a large extraoral tumour meaning a face mask will not fit), give a small dose of ketamine, then apply the face mask and deepen anaesthesia by spontaneous inhalation with sevoflurane or halothane. In our experience, this combination provides better conditions for laryngoscopy than when using intravenous ketamine alone.

Nasal fibreoptic intubation – general

- Maintain anaesthesia either with incremental doses of ketamine or inhalational anaesthesia either via a nasal airway in the other nostril connected to the breathing circuit or using a specially designed facemask with a port for insertion of the fibreoptic bronchoscope.

Table 3. *Size compatibility of tracheal tubes, bronchoscopes and LMAs*

Tracheal tube size	2.5	3.0	3.5	4	4.5	5	6
Will fit through classic LMA size:	1	1	1.5	2	2	2.5	3
Will fit over bronchoscope Outer Diameter:	2.0mm	2.5mm	2.8mm	3.5mm	3.5mm	4.1mm	5mm
Will fit over AEC size:	7F	8F	8F	11F	11F	11F	14F

[Note: different brands of LMA vary in their internal diameter. It is important to determine the compatibility of equipment within your own department.]

- Use a topical vasoconstrictor to prevent bleeding from the nose during FOI, as otherwise this may make intubation impossible. Pseudoephedrine, ephedrine, phenylephrine, oxymetazoline, or nasal packs soaked in 1:10,000 adrenaline may be used, depending on local availability.
- Apply topical lidocaine to the nose and oropharynx. Larger fibreoptic laryngoscopes often have a channel through which local anaesthesia can be injected. Alternatively an epidural catheter can be passed through the suction port (if present) and local anaesthetic injected through this. Be careful not to exceed the maximum dose of lidocaine (3mg.kg^{-1} i.e. 0.3ml.kg^{-1} of a 1% solution).

The correct size of tracheal tube is critical to success. Too large a tube will fail and require the bronchoscope to be withdrawn and the procedure repeated. Too small may make subsequent positive pressure ventilation difficult. It is sensible to use a small cuffed tube if available, rather than repeated bronchoscopy.

Fibreoptic intubation through an LMA

There are three main techniques available:

1. Railroad the tracheal tube over the fibreoptic bronchoscope into the trachea
2. Railroad an airway exchange catheter (AEC) over the bronchoscope into the trachea.
3. Pass a soft tip wire through the suction channel of the bronchoscope into the trachea, then pass an AEC or similar over the wire as a guide for the tracheal tube.

The choice of technique depends upon size of the child, the size of the LMA, and the diameter of available bronchoscope (Table 3). Removal of the LMA once the tracheal tube is in situ may be challenging. Options include:

- Leave the LMA in situ
- Use a long tracheal tube (croup tube)
- Fix two tracheal tubes together over the FOB; the LMA may be withdrawn over the tracheal tubes.
- Use an AEC.

Tracheostomy

A tracheostomy should be performed by an experienced practitioner, normally an ENT surgeon. Inhalational anaesthesia or small incremental doses of ketamine (as above) may be given to supplement local infiltration anaesthesia. The child should breathe 100% oxygen by facemask.

DIFFICULT AIRWAY CART

The equipment available in different institutions will vary considerably. It is good practice to organise airway equipment in such a way that it is readily accessible in an emergency. Many hospitals use a 'difficult airway cart' to do this. This is simply a trolley or cart where all the useful equipment for managing difficult airways is stored according to the step-wise approach to managing a difficult airway.

For example, using the algorithms presented in this review, the difficult airway cart could consist of a series of drawers or boxes containing:

Drawer 1: simple laryngoscopes and airway adjuncts.

Drawer 2: alternative laryngoscopes and LMAs.

Drawer 3: equipment for fibreoptic intubation

Drawer 4: equipment for CICV situations.

Whatever the availability and variety of equipment, the difficult airway cart (or boxes) should always be stored in the same place, close to the operating rooms, and the contents regularly checked. The cart should be physically present in the operating room for any child with an anticipated difficult airway; and can be quickly fetched when faced with an unexpected problem.

CONCLUSION

Unexpected difficult airways in paediatric practice are rare. Many problems can be prevented by routine pre-operative airway assessment, pre-oxygenation, and preparation of equipment. A simple step-wise approach to management improves outcome. Anaesthetists have a responsibility to be familiar with airway algorithms and make pragmatic modifications to account for available resources.

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