

Management of the difficult paediatric airway

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Difficulties with airway management and tracheal intubation occur relatively commonly in infants and children. Minor difficulties due to anatomical and physiological differences between paediatric patients and adults arise frequently; the more severe difficulties are usually associated with specific conditions, some of which are listed in Table 1. Although airway problems may involve pathology in the upper or lower airway, this article deals mainly with problems involving the upper airway and difficult intubation.

Anatomy and physiology

In infants, the tongue is large relative to the mandibular space and the larynx more cephalad (C2–3 compared with C4–5 in an adult). The high position of the epiglottis is necessary to allow the

infant to breathe and swallow simultaneously. The oral cavity is devoid of teeth and therefore airway obstruction can occur more easily. The epiglottis is hard, narrow and Ω -shaped and protrudes over the larynx at a 45° angle. The relatively high position and inclination of the larynx in infants make a straight laryngoscope blade (e.g. the Miller 0 or the infant Magill) a good choice for these patients, while children over the age of 1 year can generally be managed with a curved blade (e.g. size 2 Macintosh). The narrowest part of the upper airway in children is the cricoid ring; by contrast, the narrowest part of the upper airway in adults is the laryngeal inlet. The smaller size of the paediatric airway means that a small decrease in diameter may cause significant airway obstruction.

Oxygen consumption in the neonate is approximately 7 ml kg⁻¹ min⁻¹ and this decreases

Key points

Anatomical and physiological differences between the paediatric and adult airway can lead to problems with intubation.

The more severe airway difficulties are usually associated with specific conditions.

Maintenance of spontaneous ventilation during anaesthesia is of paramount importance.

Expert assistance is essential and the facility for emergency tracheal access should be immediately available.

The laryngeal mask has an important role in the management of the difficult paediatric airway.

Table 1 Conditions associated with difficult airway management in children

| | |
|---|---|
| Craniofacial | |
| Pierre Robin syndrome | Micrognathia, relative macroglossia with or without cleft palate. Airway obstruction thought to improve with age. Small number require tracheostomy due to excessive airway obstruction and feeding difficulty |
| Treacher Collins' syndrome | Mandibular and malar hypoplasia associated with a high arched palate and often a cleft palate. Outer and inner auricular problems and minor eye problems |
| Goldenhar's syndrome | Oculo-auriculovertebraldysplasia. Unilateral facial hypoplasia. 60% mandibular hypoplasia, 20% congenital heart disease and 40% Klippel Feil anomaly of the cervical spine |
| Crouzon's syndrome | Exophthalmus, hypertelorism, craniosynostosis with hypoplastic mandible |
| Lysosomal enzyme defects | |
| Mucopolysaccharidoses | Group of disorders which develop progressive thickening of tissues due to deposition of partially degraded mucopolysaccharides in cells. Airway obstruction is progressive, as is difficulty to intubate. Life expectancy varies with type but Hurler's disease (the proto type condition) die before the age of 10 years from respiratory failure. Bone marrow transplantation is an option for some conditions. |
| Congenital swellings | |
| Cystic hygroma | May affect the tongue, pharynx and neck causing airway problems and potential anaesthetic problems |
| Haemangioma | Can affect tongue as well as lower airway. Increase in size until the age of 1–2 years, causing progressive airway obstruction |
| Temperomandibular joint problems | |
| Still's disease | TMJ ankylosis with potential cervical spine immobility or instability |
| Cockayne-Touraine syndrome | Premature ageing with TMJ ankylosis |
| Acquired pathology | |
| Thermal injury | May be due to facial swelling, microstomia or due to later neck contractures |
| Abscesses | Dental, neck or retropharyngeal abscesses may all cause varying degrees of difficulty |
| Tumour | Intra-oral or facial tumours |
| Post-radiation injury | Fibrosis can limit mouth opening |

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gradually during childhood to around $3.5 \text{ ml kg}^{-1} \text{ min}^{-1}$ in the adult. The higher per kg oxygen requirements of infants and children means that airway obstruction will produce hypoxia more rapidly.

Recognition of the difficult airway

Patients presenting major difficulty in airway management often have a recognized condition (Table 1). Should they not fall into this category, then one must retain a high index of suspicion. It is often difficult to perform tests of prediction (e.g. Mallampati test) in children and it is often not possible to test mouth opening or even neck movement in smaller children. An examination of the head and neck (looking at the AP and lateral aspects), checking for dysmorphic features, ear anomalies, micrognathia and teeth problems is necessary. Examination of mouth opening may require more ingenuity but is very worthwhile. Previous anaesthetic records must be sought but, in the case of progressive problems such as the mucopolysaccharidoses, they may not reflect the degree of airway obstruction at the time of presentation.

Anaesthetic management

Pre-operative preparation and informed consent

The risks involved should be discussed with the parent and, if appropriate, the child. If it seems likely that intubation will not be possible using standard methods, a choice will have to be made between abandoning the procedure or using an alternative method of intubation, such as fibre-optic intubation. If the benefits of the procedure are greater than the risks of the intubation then it is reasonable to go ahead.

Premedication

Atropine can be given either orally or intramuscularly in a dose of $20 \mu\text{g kg}^{-1}$ to dry secretions. The use of sedative drugs to produce anxiolysis should be balanced against the risk of exacerbating airway obstruction and should be used with extreme caution.

Preparation

A full range of paediatric airways, including nasal and laryngeal mask airways should be available, as should a full range of laryngoscopes including straight and curved blade types and the McCoy laryngoscope. Expert assistance is essential. In addition to experienced operating department practitioner or nursing assistance, it is often helpful to enlist the help of another

experienced anaesthetist. The facility for emergency tracheal access (e.g. cricothyrotomy kits) should be immediately available.

Induction of anaesthesia

The principle behind safe induction of anaesthesia in the difficult airway is the maintenance of spontaneous ventilation. In adult practice, this may be achieved by awake techniques. However, in paediatric practice this is generally not practical. A gaseous induction using 100% oxygen with either sevoflurane or halothane is the technique of choice. The aim is to attain a plane of anaesthesia which is deep enough to allow laryngoscopy. If the airway becomes obstructed following loss of consciousness, it can be improved by turning the patient into the lateral or even semi-prone position. A nasal airway can also be useful at this early stage and is better tolerated than an oropharyngeal airway. Should the patient become apnoeic during induction, it is important to avoid assisting ventilation. Application of continuous positive airways pressure at this time will usually maintain oxygenation until spontaneous respiration resumes. It may be difficult to obtain sufficient depth of anaesthesia for laryngoscopy because of the obstructed airway. In this case, the insertion of a laryngeal mask airway will usually improve matters. Should it prove impossible to secure the airway, the anaesthetist must either allow the patient to wake or, if that is not an option, to gain access directly to the trachea either by cricothyrotomy or formal tracheostomy. Muscle relaxants should be avoided before the airway is secure in order to avoid the potentially disastrous 'can't ventilate, can't intubate' scenario.

Conventional techniques to aid intubation include the use of bougies and stylets which are available in paediatric sizes. The McCoy laryngoscope can also be useful. However, for many of these cases, fibre-optic intubation is indicated.

Fibre-optic intubation

Two types of fibre-optic bronchoscope are available: bronchoscopes with a suction channel (adult bronchoscopes) or ultra-thin bronchoscopes without a suction channel. Bronchoscopes with a suction channel have an outer diameter of 3.5–4 mm and a tracheal tube as small as 4.0–4.5 mm can be railroaded over them. Ultra-thin bronchoscopes are suitable for use in neonates and infants. They have an outer diameter of approximately 2.2 mm so that a 2.5 mm tracheal tube can be railroaded over them. However, the absence of a suction channel to clear secretions is a disadvantage of these ultra-thin instruments, which can

also be difficult to direct on account of their 'whippy' nature. Also, they are easily damaged.

When using a fibre-optic bronchoscope for intubation, the first requirement is to maintain a clear airway to allow time for the anaesthetist to visualise the airway. The second requirement is to introduce the tracheal tube into the airway. In many cases, the tracheal tube can be loaded onto the bronchoscope and then railroaded into the trachea. However, if the wrong size of tube is chosen, the airway may be traumatised. An alternative technique is to use either a guidewire and/or a Cook airway exchange catheter (Cook UK Ltd, Letchworth, UK) as described below.

Route of fibre-optic intubation

The fibre-optic bronchoscope can be introduced via the nasal or the oral routes. The nasal route is commonly used in adult practice as the angles to the larynx are more favourable. However, in paediatric practice, bleeding caused either by the fibre-optic scope or tracheal tube can create problems. This route is especially useful in patients with temporomandibular joint problems. Maintenance of anaesthesia can be achieved with a nasal airway in the other nostril connected to the breathing circuit. The oral route avoids potential nasal bleeding but the angles to the larynx are more acute. Anaesthesia can be maintained via a nasal airway or a specially adapted face-mask. However, the laryngeal mask airway is now the more commonly used device. It can be used as an alternative to intubation or as a conduit for the fibre-optic bronchoscope to view the larynx.

Intubation through a laryngeal mask airway

The laryngeal mask airway is first inserted with the patient breathing spontaneously. Once the patient is in a deep enough plane of anaesthesia, a fibre-optic bronchoscope is introduced into the laryngeal mask airway until a view of the cords is obtained. Topical lidocaine is then sprayed onto the larynx via the suction channel and the bronchoscope is inserted into the trachea and the carina visualized. There are then a number of ways to accomplish tracheal intubation.

Railroading the tube over the bronchoscope

A preloaded tracheal tube is railroaded over the bronchoscope. This can be awkward to do through the laryngeal mask airway and, subsequently, it may be difficult to remove the airway without dislodging the tube. The choice of the tracheal tube is also critical. Choosing too big a tube will result in failure to intubate the trachea and necessitate repeating the whole procedure with a smaller tube.

Using a guidewire and airway exchange catheter

A long J-tipped guidewire is inserted via the suction channel into the trachea and the fibre-optic scope carefully removed. If the fibre-optic scope is too big for the child's trachea, the scope can sit above the cords and the guidewire inserted through the cords under direct vision. Following removal of the bronchoscope a 'stiffening' device, such as a Cook airway exchange catheter, is railroaded over the guidewire through the laryngeal mask airway into the trachea. Once the catheter is in place, the guidewire is removed and its position verified by capnography. Only when correct placement of the catheter has been confirmed is the laryngeal mask airway removed. A tracheal tube can then be railroaded over the catheter. The advantages of this technique are that it can be used in children of any age, suction is available during the initial bronchoscopy and, following insertion of the stiffening device, the choice of the tracheal tube is less critical as it can be changed easily.

Using an airway exchange catheter without a guidewire

An ultra-thin fibre-optic bronchoscope is lubricated with saline and a Cook airway exchange catheter is fitted over it (e.g. a 2.2 mm fibre-optic bronchoscope will accept a size 11 airway exchange catheter). The loaded bronchoscope is passed through the larynx and the airway exchange catheter is advanced under direct vision into the trachea. The laryngeal mask airway is then removed and a tracheal tube railroaded over the catheter. This may be preferable to preloading a tracheal tube as the airway exchange catheter will pass more easily into the trachea.

Unable to intubate or ventilate scenario

The only objective in this situation is to maintain oxygenation. The options are to perform a needle cricothyrotomy or a formal tracheostomy.

Needle cricothyrotomy

Cricothyrotomy is difficult in a small child and carries many risks of its own. There are purpose-made kits available and these should be immediately available in every paediatric anaesthetic room (e.g. Patil Emergency Cricothyroidotomy Set size 6, Cook UK Ltd, Letchworth, UK). Every paediatric anaesthetist should gain knowledge of how to use this equipment. Newer cannulae have both a 15 mm and a Luer lock connector. It is not possible to ventilate a patient with a self-inflating bag via a needle cricothyrotomy. The maximum pressure from a bag is insufficient to drive gas through the cannula. The

cannula should be connected via the Luer lock connection to an oxygen flowmeter via a Y-connector. The oxygen flow rate is initially set at the child's age in years. Ventilation occurs by occluding the open end of the Y-connector with a thumb for 1 sec. If this does not cause the chest to rise, the flow should be increased by increments of 1 litre min⁻¹.

Expiration cannot occur through the cannula or through a separate cannula inserted through the cricothyroid membrane. Expiration must occur via the upper airway, even in situations of partial upper airway obstruction. If upper airway obstruction is complete, the gas flow must be reduced to 1–2 litre min⁻¹. This will provide some oxygenation but little ventilation. Insufflation will buy a little time in which to secure a surgical airway. Complications of this procedure include bleeding, pneumothorax, pneumomediastinum, subcutaneous emphysema, tracheo-oesophageal fistula, infection, haematoma and catheter dislodgement.

Special considerations in neonates

Difficult intubation in the neonatal period presents extreme challenges. One can perform a direct laryngoscopy with the patient awake or use a bronchoscopic technique under general anaesthesia.

Awake intubation

This entails direct laryngoscopy and intubation after the administration of atropine 20 µg kg⁻¹ as previously described. An oxyscope, which administers oxygen during laryngoscopy is useful. Awake intubation techniques are potentially traumatic, especially when the laryngeal structures are not visible and blind intubation is performed. There are also concerns about stress-induced physiological changes such as increases in blood pressure, heart rate, oxygen consumption and anterior fontanelle pressure, which may increase the risk of intracranial haemorrhage in premature infants. Awake fibre-optic intubation has been described in a neonate with Goldenhar syndrome through the laryngeal mask airway using nebulised lidocaine to anaesthetize the airway.

Bronchoscopic techniques

Anaesthesia is induced and maintained as described earlier but with reduced concentrations of volatile agents reflecting lower MAC values and an increased sensitivity to the respiratory and cardiovascular effects of these drugs in neonates. Fibre-optic intubation is performed using an ultra-thin bronchoscope over which a 2.5 mm tracheal tube can be railroaded. This technique can be performed through a laryngeal mask airway if preferred, or

directly via the oral or nasal routes with anaesthesia maintained via a nasopharyngeal airway. Rigid bronchoscopic equipment may also prove useful in cases where fibre-optic techniques prove difficult. The Storz ventilating bronchoscope (Karl Storz UK Ltd, Dundee, UK) can be used to maintain anaesthesia and oxygenation during visualization of the larynx. A bougie is threaded through the bronchoscope into the trachea and the bronchoscope removed. An appropriately sized tracheal tube can then be railroaded into the trachea. Should these techniques fail, a surgical tracheostomy will be necessary.

Fetal surgery

Fetal surgery has now become a treatment option for certain life-threatening diseases. Airway diseases which present indications for fetal surgery include large neck masses such as cystic hygromas, with anticipated difficult intubation at birth, and congenital high airway obstruction (CHAOS). In these diseases, the airway is secured before birth with the EXIT procedure (*ex utero* intrapartum therapy). The EXIT procedure entails firstly delivering the head of the fetus through a controlled hysterotomy and managing the airway by direct laryngoscopy, bronchoscopy and intubation while fetal gas exchange is maintained via the placenta. If a tracheal tube cannot be inserted, a tracheostomy is performed. Fetal gas exchange can be maintained for up to 60 min. Thereafter, the mass can be resected in controlled circumstances. This procedure has obvious advantages but depends on good prenatal diagnosis and excellent teamwork.

Key references

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See multiple choice questions 117–121.