The Difficult Paediatric Airway

A Theron

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INTRODUCTION \(^{(1, 2)}\)

Airway and respiratory complications are the most common cause of morbidity during general anaesthesia in children. Paediatric airway management is essential in the anaesthesia management for infants and children. Anaesthesiologists, in particular paediatric anaesthesiologists, are the “go to” people for any airway difficulty happening anywhere in the hospital.

Dealing with the expected difficult airway one should take the maximum precaution and ensure the availability of the most senior anaesthetist, but for the unexpected difficult airway in paediatrics one is frequently without help and sometimes without a plan. Although several complicated algorithms have been proposed for the unexpected paediatric airway, a simple structured algorithm is not yet available. Mostly, the Difficult Airway Society’s (DAS) simple protocol for adults is being used in paediatrics and locally adapted versions thereof.

In spite of all the rapid advances, regarding equipment, tubes and new techniques that have taken place over the last 30 to 40 years, some brilliant and very helpful, we still need to acquire a certain amount of skills to assess and manage the normal and difficult airway in paediatric anaesthesia. With all this development in mind, we frequently have to review our practices and skills and utilize these in improving the quality of care we provide to our patients.

THE ANATOMY AND PHYSIOLOGY OF THE PAEDIATRIC AIRWAY \(^{(3, 4, 5)}\)

The airway changes in size, shape and position throughout development from the neonate to the adult. Knowledge of the functional anatomy of the airway in children forms the basis of understanding the pathological conditions that may occur.

In the foetus, the rapid growth of the brain causes a predominance of neural influences, while in the neonate and young child, the nose is a major role player. Later, because of changes in feeding requirements and the development of speech, the pharynx also influences the development of the skull base.
Table 1. Important Anatomical Differences, Potential Implications and Basic Manoeuvres to Optimize

<table>
<thead>
<tr>
<th>Anatomical Differences</th>
<th>Potential implications</th>
<th>Basic Manoeuvres to Optimize</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Head</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>↑Head and occiput : body size→ neck flexion</td>
<td>potential airway obstruction in supine position</td>
<td>Neck or shoulder roll</td>
</tr>
<tr>
<td><strong>Nose</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obligate nasal breathers</td>
<td>↑ Resistance to airflow → increase the work of breathing Easily obstruct by blood, secretions, oedema</td>
<td>NP AW Careful suction</td>
</tr>
<tr>
<td>Small nasal apertures</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pharynx</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nasopharynx</td>
<td>Adenoids in roof and post wall</td>
<td>Atrophy with age Nasal obstruction Dislodge during instrumentation</td>
</tr>
<tr>
<td>Oropharynx</td>
<td>Waldeyer’s ring, the adenoids, lingual and bilateral palatine tonsils</td>
<td>Inflammation→ airway obstruction laryngoscopy difficulty due poor vision and associated masseter spasm</td>
</tr>
<tr>
<td>Laryngopharynx</td>
<td>Large tongue</td>
<td>Airway obstruction</td>
</tr>
<tr>
<td>Larynx</td>
<td>Birth C4 Age 6 C5 Cricoide narrowest point up to 8yrs</td>
<td>Cephalad position + more acute angle → impairs visualization Oedema →severe AW compromise/ AW trauma</td>
</tr>
<tr>
<td>Cricothyroid membrane</td>
<td>Smaller Neonate L 2.6 mm W 3mm Thyroid underneath hyoid bone Adipose tissue</td>
<td>Limit size of devices passed Landmarks difficult to identify →Fatal Injuries</td>
</tr>
<tr>
<td>Epiglottis</td>
<td>Narrow, softer and more horizontal More deeply furrowed V shaped &gt;4yrs: more firm</td>
<td>Poor vision with LG</td>
</tr>
</tbody>
</table>
**Figure 1. The Relative Effect of Airway Oedema**

<table>
<thead>
<tr>
<th>Normal</th>
<th>Edema 1 mm</th>
<th>Decreased X-sectional area</th>
<th>Resistance Laminar flow (Re = radius^4)</th>
<th>Resistance Turbulent flow (Re = radius^5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant</td>
<td>~ ↓ 75%</td>
<td>~ ↑ 16x</td>
<td>~ ↑ 32x</td>
<td></td>
</tr>
<tr>
<td>Adult</td>
<td>~ ↓ 44%</td>
<td>~ ↑ 9x</td>
<td>~ ↑ 5x</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 4**
Relative effects of airway edema in an infant and an adult. The normal airways of an infant and an adult are presented on the left; edematous airways (1mm circumferential, reducing the diameter by 2mm) on the right. Note that resistance to airflow is inversely proportional to the radius of the lumen to the fourth power for laminar flow (beyond the fifth bronchial division) and to the radius of the lumen to the fifth power for turbulent flow (from the mouth to the fourth bronchial division). The net result in an infant with a 4mm diameter airway is a 75% reduction in cross-sectional area and a 32-fold increase in resistance to airflow, compared with a 44% reduction in cross-sectional area and a 5-fold increase in resistance to airflow in an adult with a similar 2mm reduction in airway diameter. (Reproduced with permission from Cote CJ, Lerman J, Todres ID: A practice of Anesthesia for Infants and Children, Saunders Elsevier, 2009)

**Figure 2. The Funnel Shaped Larynx in Infants**

**Figure 5**
Configuration of the larynx in an adult (a) and an infant (b). Note that in both adult and infant the larynx is somewhat funnel-shaped, with an exaggeration of this shape in the infant. (Reproduced with permission from Cote CJ, Lerman J, Todres ID: A practice of Anesthesia for Infants and Children, Saunders Elsevier, 2009)
Table 2. Laryngeal Innervation\(^{(3, 6)}\)

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Sensory</th>
<th>Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior Laryngeal (internal division) of CN IX</td>
<td>Superior Laryngeal (internal division) of CN IX</td>
<td>Superior Laryngeal (internal division) of CN IX</td>
</tr>
<tr>
<td>Superior Laryngeal (external division) of CN IX</td>
<td>Superior Laryngeal (external division) of CN IX</td>
<td>Superior Laryngeal (external division) of CN IX</td>
</tr>
<tr>
<td>Recurrent Laryngeal Nerve</td>
<td>Recurrent Laryngeal Nerve</td>
<td>Recurrent Laryngeal Nerve</td>
</tr>
</tbody>
</table>

Afferent impulses from the base of the tongue, the valleculae and stimulation of the pharyngeal wall by the laryngoscope blade lead to the reflex circulatory responses during direct laryngoscopy. A smaller additional response is produced by the passage of an endotracheal tube through the vocal cords.

Table 3. Summary of the Important Physiological, Anatomical and Pharmacological Differences in Infants and Children\(^{(7)}\)

<table>
<thead>
<tr>
<th>Physiologic</th>
<th>Anatomic</th>
<th>Pharmacologic</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR dependent cardiac output</td>
<td>Noncompliant LV</td>
<td>Immature hepatic biotransformation</td>
</tr>
<tr>
<td>Faster HR</td>
<td>Residual foetal circulation</td>
<td>Decreased FA/FI</td>
</tr>
<tr>
<td>Lower BP</td>
<td>Difficult venous and arterial access</td>
<td>Rapid induction and recovery</td>
</tr>
<tr>
<td>Faster RR</td>
<td>Large tongue and head</td>
<td>Increased MAC</td>
</tr>
<tr>
<td>Lower lung compliance</td>
<td>Narrow nasal passages</td>
<td>Larger Vd for water soluble drugs</td>
</tr>
<tr>
<td>Greater chest wall compliance</td>
<td>Anterior and cephalad larynx</td>
<td>Immature neuromuscular junction</td>
</tr>
<tr>
<td>Lower FRC</td>
<td>Long epiglottis</td>
<td></td>
</tr>
<tr>
<td>Higher ratio of BSA to BW</td>
<td>Short trachea and neck</td>
<td></td>
</tr>
<tr>
<td>Higher total body water content</td>
<td>Prominent adenoids and tonsils</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weak intercostal and diaphragmatic muscles</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High resistance to airflow</td>
<td></td>
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</tbody>
</table>
ASSESSMENT OF THE PAEDIATRIC AIRWAY \(^{(2, 3)}\)

Paediatric airway assessment may be difficult, because infants and children cannot provide a history and may resist physical examination. Performing special investigations may be troublesome or even impossible. In emergencies, time for special investigations may be limited by the urgency of the situation.

**Important Aspects of the History**

- Current and past medical history – including birth history and subsequent development
- Current or previous respiratory illness; presence of a cough and its nature
- Surgical history – surgery to airways, injury to airway
- Anaesthesia – any previous intra-operative complications, in particular if airway related, or malignant hyperthermia
- Specific enquiry into breathing, feeding and phonation, snoring and sleep apnoea

**Focus Points during Examination**

- General appearance – Facial, distress, failure to thrive (FTT), BMI
- Nasal flaring
- Signs of respiratory distress
- Mouth-breathing or drooling
- Signs of previous trauma or surgery to head and neck
- Evidence of neuromuscular disease, congenital abnormalities or dysmorphic features
- Anatomical variants of normal (micrognathia, small mandible, small mouth or decreased mouth opening)
- Patency of nasal apertures, any nasal discharges
- Inspect the tongue, teeth, pharynx and palate if possible
- Loose teeth! (between 6-12 years of age/ with any trauma)
- Neck examination – deformity, limited mobility of cervical spine, cervical lymphadenopathy
- Chest – shape, RR, degree of expansion, mode of breathing and chest wall recession, tracheal deviation and auscultation of the lungs
- Child’s voice and cry – high pitch, hoarseness, weak cry
- Inspiratory versus expiratory stridor or both
Investigations

- Spirometry – FEV1; flow volume loops
- Pulse oximetry (in the absence of shock/poor perfusion)
- Transcutaneous measurement of O2 tension in the newborn
- Arterial blood gas – useful, but traumatic and can aggravate underlying airway obstruction

Imaging

- Non-invasive (but may require sedation/ GA)
- Standard radiographs – airway anatomy with fluoroscopy as additional tool
- CT and MRI – providing anatomical detail compared to endoscopy

Endoscopy

- Rigid brochoscopy – always under GA
- Flexible fibreoptic bronchoscopy – can be used with or without GA and provide good views of the nasal fossa, choanae, pharynx and larynx, even in the neonate. As well as providing dynamic views of upper airway function.
- Microlaryngoscopy – always under GA, allows detailed examination of pharynx and larynx

Sleep Studies

- For the continuum of snoring to upper airway resistance syndrome and obstructive hypopnoea syndrome to obstructive sleep apnoea
- Polysomnography – to assess severity of sleep disordered breathing, with measurements of upper airway pressure - flow characteristics
- Nasendoscopy – site of obstruction during sleep
IMPORTANT PREDICTORS OF DIFFICULT INTUBATION

- Mandibular hypoplasia
- Limited mouth opening
- Facial asymmetry including ear abnormalities
- Syndromes
- Obstructive Sleep Apnoea Syndrome (OSAS)
- Stridor
- Neck abnormalities

Obesity is an ever increasing problem in society and also in children and young adolescents. Obese children are twice as likely to have a critical incident as obese adults and 10 times more likely than normal children. Only 5% of all obesity can be ascribed to cerebral or endocrine dysfunction or hereditary disease, syndromes such as Prader-Willi, Cushings, Frohlichs and Laurence-Moon-Biedl syndrome account only for 1% of all obese children.\(^{(8)}\)

SPECIFIC SYNDROMES ASSOCIATED WITH DIFFICULT AIRWAYS\(^{(8, 9)}\)

1) Pierre Robin Syndrome:
   - Micrognathia
   - Relative macroglossia
   - With / without cleft lip or palate
   - Often more cephalad larynx

2) Treacher Collins Syndrome (mandibulofacial dysostosis):
   - Hypoplastic zygoma & mandible,
   - Macrostomia
   - Cleft or high arched palate
   - Abnormal dentition can occur

3) Goldenhar Syndrome (Oculo-auriculo-vertebral dysplasia):
   - Micrognathia
   - Cleft palate
   - Unilateral mandibular hypoplasia
   - May occur with the Klippel Feil anomaly where the neck is short and immobile
The anomalies of the second branchial arch and cleft occur most commonly. A pre-auricular fistula or skin tag may serve as marker for a difficult intubation, as the mentioned deformities develop during faulty fusion of the component of the first and second branchial arches.

Other rare syndromes might present with facial stiffness and trismus and therefore might contribute to potential difficult intubations. These include Freeman-Sheldon syndrome (whistling face), Schwarz-Jampel syndrome (clown face) and arthrogryposis multiplex congenita.

Other more common syndromes, that present fairly frequent to theatre, are also associated with potential difficult intubation such as Down’s syndrome and Turner’s syndrome, mainly due to the large tongue, small mouth and decreased subglottic diameter.

**MANAGEMENT OF THE DIFFICULT INTUBATION IN CHILDREN**

The golden rule remains (drilled in since DA): “It is never a sin if you are unable to intubate, but it is criminal if you do not ventilate and oxygenate.”

A comparison of paediatric and adult anaesthesia closed malpractice claims revealed that of the paediatric claims that were due to inadequate ventilation, 89% could have been prevented.

In Pennsylvania Children’s Hospital a retrospective cohort showed that in 1070 children (between ages 3-10) who underwent RSI for anaesthesia, difficult intubation was encountered in 1.7% and transient oxyhemoglobin desaturation occurred in 3.6%. Severe hypoxemia was more likely in children <20 kg than other children (p<0.001). There were no children who could not be intubated, and there were no long-term or permanent complications.

The basic structure of the DAS guideline includes 3 sections

A) Oxygenation
B) Tracheal Intubation
C) Rescue

Prevention of a difficult airway situation and basic rules to overcome airway problems are also include in section A and B.
The Expected Difficult Intubation

The benefit of the planned surgery should always be measured against the risk of the anaesthetic management. Issues surrounding the need for surgery and optimal timing of surgery should happen as a combined decision between surgical and anaesthetic teams and also including the child and parents/carers.

Always discuss with parent/guardian:
- The anaesthetic plan
- Reasons for the choice of anaesthesia
- Potential risks and complications
- The possibility and implications of a rescue airway/tracheostomy

All discussions and plans should be clearly documented and consent should be taken as appropriate.

Premedications

The majority of anaesthetists feel that the use of sedative are contraindicated in children with obstructed/potentially obstructed airways. However the screaming terrified salivating child is difficult to approach and therefore individualizing patients is more important.

Consider:
- Midazolam 0.3-0.5mg/kg po
- Vallergan 2mg/kg po
- Atropine 30-40ug/kg po with peak effect up to 90min
- Atropine 20ug/kg IM with peak effect after 25min
- Analgesia if appropriate: Paracetamol po
- Ketamine 3-5mg/kg po/IM

Choice of Anaesthetic Technique

The main principle of managing the difficult airway in children is to maintain spontaneous ventilation until the airway is secured. Awake techniques are mostly not appropriate in the paediatric population, therefore inhalational techniques are favoured. Maintaining spontaneous ventilation retain a degree of muscle tone in the upper airway and allow time to view structures, and use alternative equipment such as fiberoptic bronchoscope (FOB) or attempt to intubate. The use of muscle relaxants can potentially lead to difficulty with ventilation and thus a “can’t intubate, can’t ventilate” situation, and therefore can not be advised.
Golden Rules
- *Ensure that all equipment is at hand and checked before the patient is in OT*
- *Get good assistance, another experienced anaesthetist*
- *Plan ahead, and have plans A, B, C, D of what to do if things do not go to the initial plan*
- *Do not be afraid to wake up or proceed with a surgical airway if necessary*

Techniques to consider

Basic approach:
- Full monitoring
- Gas induction with Sevoflurane or Halothane and 100% Oxygen
- IV access
- Deepened to facilitate direct laryngoscopy

Awake techniques has been described in neonates using:
- Topical local anaesthesia
- Railroading ETT over small FOB through a LMA

Children refusing gas induction or where a mask does not fit:
- IV induction with low dose propafol 0.5-1mg/kg to maintain SV and obtain LOC
- IV Ketamine 1-2mg/kg or IM Ketamine 3-5mg/kg
- Deepened on Sevoflurane for laryngoscopy
- Some prefer TIVA

With early airway obstruction consider the following:
- Lateral position to allow the tongue to fall forward
- Vigorous jaw thrust
- Nasal airway
- Consider a nasal airway even earlier to maintain airway and allow more time to assess airway

Laryngoscopy:
- Conventional rigid laryngoscopes – try to minimize the number of attempts, as this can cause trauma and bleeding
- Gum elastic bougie/ introducer
- Alternative route
Equipment and Techniques

Conventional Rigid Laryngoscopes – Macintosh vs. straight / Miller blade

- Poor view with Macintosh in micrognathia and infants – no space to compress the normal size tongue/ relatively large tongue.
- Narrow straight blade can overcome this problems in a “paraglossal manner” (also called the retromolar/The Far lateral/ right molar approach) - the blade must be advanced in the space between the tongue and lateral pharyngeal wall on tonsillar fossa, therefore the straight axis is shorter and insertion of the ETT may be aided by using the gum elastic bougie or stylet.
- With relative macroglossia in infants and children with micrognathia, a straight blade should be blade of choice.
- Miller blades / ENT rigid Storz Laryngoscopes with light attachment.
- Two video laryngoscopes with standard paediatric blades are new – used in teaching, but also useful in the difficult intubation scenario: The paediatric video laryngoscope (Storz), and the Glidescope (Verathon, Bothell, WA, USA). Currently only a few case reports in literature.
- McCoy laryngoscope is also now available in paediatric sizes (1&2) on Seward blade.

Supraglottic Airways - the classic Layngeal Mask Airway (cLMA)

- Numerous roles, such as to free the hands of the anaesthetist, but also as an alternative to tracheal intubation in some short cases, as well as a rescue airway to maintain oxygenation.
- Can also be effectively used to facilitate fibreoptic intubation.
- All the current data makes the cLMA essential as part of the management of the difficult paediatric airway.

- LMA was used on 34 children with craniofacial and mucopolysaccaride disorders and found to be good to adequate in all patients, in no patients did the LMA provide a poor airway.
- This compares to data from normal patient who had a clear airway in 98%.
- Fibreoptic views was either full/ partial in 54% and the rest all had view of the epiglottis, thus with some manipulation of the FOB the patients could be intubated if needed.
- Insertion of LMA’s in children: Ghai et al in a RCT in India of 168 children between ages 6 months and 6 years found that the success and ease of insertion of LMA was significantly better with the partially inflated cuff and rotational technique compared to the standard or lateral techniques. \(^{(12)}\)
Other Supraglottic Airways

- **Proseal LMA (PLMA):** Has an increased depth of the bowl and a wedge shaped dorsal cuff to improve the seal, it also has an oesophageal drain to reduce gastric distension during PPV. Placement can be done by either digital manipulation or using the supplied introducer. The PLMA may be the airway of choice in older children with a full stomach. It is available in sizes 1.5 – 5 and recently use in children from all ages is rapidly increasing. Saunders et al showed a high success rate of the PLMA in all ages and sizes for both placement of the tube and gastric tube insertion well over 90% on first attempt.
- **The cuffed oropharyngeal airway (COPA):** Variety of sizes, not used commonly, but main use is to facilitate FOB.
- **I – gel:** Is a more recent addition and there is some literature on airway rescue in adult literature, but none for children.

Fibreoptic Intubation in Paediatrics

- Flexible fibreoptic bronchoscopes with or without a suction channel.
- Ultra-thin bronchoscopes without suction ports have a diameter of 2.2–2.5 mm. These are used for fibreoptic intubation in neonates and infants using a railroading technique.
- Bronchoscopes with a suction channel have an outer diameter of anywhere from 2.8–4 mm and above. These often have poorer optical quality, as the suction channel takes up considerable space at the expense of light bundles.

**General requirements for fiberoptic intubation success**

- Maintenance of good oxygenation and deep inhalational anaesthesia, allowing the operator time to view airway structures
- Topical anaesthesia of the airway
- Good planning and availability of all necessary equipment
- Skilled assistance, with everybody briefed with the plan and backup plans
- Equipment for backup plan at hand and checked (e.g. cricothyroidotomy device and high pressure ventilating device)

**Choice of route for fiberoptic intubation**

**The nasal route**

- TMJ problems and limited MO or surgical access
- Nasal preparation is critical to success
- Vasoconstrictors: Pseudoephedrine/ Oxymetazoline/ nasal pack soaked in adrenaline (1:10000), as epistaxis can lead to failed intubation
• Maintenance of anaesthesia: Nasal airway in the other nostril connected to a breathing circuit/ specially designed endoscopy mask
• Topical anaesthesia: Lignocaine jelly melting into the nostrils or lignocaine (3mg/kg) down the fibreoptic suction port or through an epidural catheter inserted through the suction port and advanced onto the glottis
• Choice of ETT: Attention to the right size. Smaller cuffed tube may be best versus uncuffed and repeated attempts

The oral route

• Avoid potential nasal trauma
• Angle the larynx more acutely
• Anaesthesia can be maintained through nasal airway/ specially adapted mask
• LMA now commonly used device to maintain anaesthesia and to act as a conduit for the FOB

Fiberoptic intubation through a LMA

• Blind intubation techniques via the LMA have been described in children with difficult airways, this is not reliable and has a potential for trauma and should only be attempted if a bronchoscope is not available.
• The LMA is first inserted with the patient breathing spontaneously, once the patient is in a deep enough plane of anaesthesia, a fiberoptic bronchoscope is introduced into the LMA until a view of the cords is obtained. Topical lidocaine is then sprayed onto the larynx via the suction channel and the bronchoscope is driven into the trachea and the carina visualized.

• There are then a number of ways to accomplish tracheal intubation through the LMA
  ➢ Railroading over the bronchoscope:
    A preloaded tracheal tube can be railroaded over the bronchoscope through the LMA. This has been demonstrated in a wide range of age groups. (Including a case of the EXIT procedure in a child with dysgnathia complex.) The problem then encountered is how to remove the LMA and bronchoscope without dislodging the ETT. Options to overcome this:
    ETTs joined either by wedging the two together, taping them together or with an adapted female-to-female connector. Or by using the overlength croup tube made by Portex.

  ➢ Using a guidewire and airway exchange catheter:
    A long J-tipped guidewire can be inserted via the suction channel into the trachea and the fiberoptic scope carefully removed. If the
A fiberoptic 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 the Cook airway exchange catheter (Cook UK Ltd, Letchworth, England), is then railroaded over the guidewire through the LMA. Once in place, the guidewire is removed and the position of the airway exchange catheter verified by capnograph. Only when correct placement of the exchange catheter has been confirmed is the LMA 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 and after insertion of the stiffening device the choice of the tracheal tube is less critical as it can easily be changed.

- **Using an airway exchange catheter without a guidewire:** An ultrathin fiberoptic bronchoscope is lubricated with saline and a Cook airway exchange catheter is fitted over it. The loaded bronchoscope is passed through the LMA and into the larynx and the airway exchange catheter advanced under direct vision into the trachea. The LMA is then removed and a tracheal tube railroaded over the catheter into the trachea. This may be preferable to preloading an ETT as the airway exchange catheter will pass more easily into the trachea.

**Other Techniques**

The Bullard rigid laryngoscope is a fiberoptic laryngoscope with a 90 degree bend to assist good visualization of the larynx. The paediatric size of this scope is popular amongst some paediatric anaesthetists for the intubation of infants with mandibular hypoplasia. An intubating stylet or bougie is usually required to complete intubation.

A Rigid bronchoscope can be used to railroad an ETT in a difficult airway situation.

A small Hopkin’s Rod bronchoscope can mount a small ETT (without connector). This is a particularly good technique when upper airway pathology is present such as supraglottic cysts or pathology on the tongue base.

The paediatric Bonfils intubation fibrescope (Karl Storz GmbH, Tuttingen, Germany) is a rigid bronchoscope with a curved tip (40 degrees). A 3.5mm tracheal tube can be railroaded over this device. Bein et al. recently evaluated this device in paediatric practice and found it difficult to use. They report a high failure rate and increased intubation time. They did, however, use the device alone without using a conventional laryngoscope.
The Unexpected Difficult Intubation \(^{(2, 10)}\)

The unexpected difficult intubation is not a problem as long as the patient is breathing spontaneously and/or a patent airway can be maintained. If however, the child has been paralysed and proves to be difficult to intubate, but easy to ventilate the techniques for the anticipated / unexpected difficult intubation can be utilized.

The situation that we all fear is the difficult to ventilation, difficult to intubation scenario after paralysis in the routine or emergency situation. If this should occur following a Rapid Sequence Induction then attempts should be made to awaken the child, while maintaining oxygenation. If a longer acting muscle relaxant has been given the principles of management are again to maintain oxygenation and ventilation by the best and safest means possible.

Table 4: Cause for Unexpected Face Mask and Tracheal Tube Ventilation Problems

<table>
<thead>
<tr>
<th>Cause for Unexpected Face Mask Ventilation Problems</th>
<th>Cause for Unexpected Tracheal Tube Ventilation Problems</th>
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<tbody>
<tr>
<td>Exclude and treat anatomical obstruction</td>
<td>Exclude and treat</td>
</tr>
<tr>
<td>• Reopening the airway</td>
<td>• D: Displacement of tracheal tube</td>
</tr>
<tr>
<td>• Oro/naso – pharyngeal airway (nasal obstruction)</td>
<td>• O: Obstruction of tracheal tube</td>
</tr>
<tr>
<td>• Two-hand – jaw thrust/open mouth/chin lift – facemask ventilation and two person ventilation</td>
<td>(Secretions, blood, tracheal wall, pouch, tracheal foreign body)</td>
</tr>
<tr>
<td>Exclude and treat functional obstruction</td>
<td>• P: Pneumothorax</td>
</tr>
<tr>
<td>• Upper airway</td>
<td>• E: Equipment problems</td>
</tr>
<tr>
<td>• Inadequate anaesthesia</td>
<td>• S: Stomach – ↑ intra-abdominal pressure</td>
</tr>
<tr>
<td>• Laryngospasm</td>
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<tr>
<td>• Lower Airway</td>
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<td>• Thoracic rigidity</td>
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<td>• Bronchospasm</td>
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<td>• Overinflated stomach (air)</td>
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Figure 3. Difficult Airway Society (guidelines 2004) (10)

Failed intubation, increasing hypoxaemia and difficult ventilation in the paralysed anaesthetised patient: Rescue techniques for the "can't intubate, can't ventilate" situation

failed intubation and difficult ventilation (other than laryngospasm)

Face mask
- Oxygenate and ventilate patient
- Maximum head extension
- Maximum jaw thrust
- Assistance with mask seal
- Oral ± 6 mm nasal airway
- Reduce cricoid force - if necessary

Failed oxygenation with face mask (e.g. SpO2 <90% with FiO2 1.0)

Call for help

LMA™ Oxygenate and ventilate patient
- Maximum 2 attempts at insertion
- Reduce any cricoid force during insertion

Oxygenation satisfactory and stable: maintain oxygenation and awaken patient

"can't intubate, can't ventilate" situation with increasing hypoxaemia

Plan D: Rescue techniques for "can't intubate, can't ventilate" situation

Cannula cricothyroidotomy
- Equipment: Kink-resistant cannula, e.g. Portex (Cock) or Raviusin (VBM)
- High-pressure ventilation system, e.g. Manujet III (VBM)
- Technique:
  1. Insert cannula through cricothyroid membrane
  2. Maintain position of cannula - assistant’s hand
  3. Confirm tracheal position by air aspiration - 20 ml syringe
  4. Attach ventilation system to cannula
  5. Commence cautious ventilation
  6. Confirm ventilation of lungs, and exhalation through upper airway
  7. If ventilation fails, or surgical emphysema or any other complication develops - convert immediately to surgical cricothyroidotomy

Surgical cricothyroidotomy
- Equipment: Scalpel - short and rounded (no. 20 or Minirach scalpel)
- Small (e.g. 6 or 7 mm) cuffed tracheal or tracheostomy tube
- 4-step Technique:
  1. Identify cricothyroid membrane
  2. Stab incision through skin and membrane
  3. Enlarge incision with blunt dissection (e.g. scalpel handle, forceps or dilator)
  4. Insert tube and inflate cuff
- Ventilate with low-pressure source
- Verify tube position and pulmonary ventilation

Notes:
1. These techniques can have serious complications - use only in life-threatening situations
2. Convert to definitive airway as soon as possible
3. Postoperative management - see other difficult airway guidelines and flow-charts
4. 4 mm cannula with low-pressure ventilation may be successful in patient breathing spontaneously

Difficult Airway Society guidelines Flow-chart 2004 (use with DAS guidelines paper)

Figure 7
Figure 4. The Proposed Algorithm for the Unexpected Paediatric Difficult Airway (2)

(C) Rescue

Maintain two-hand – two person facemask ventilation with ease-stepup alternative airway to provide some oxygen to the patient while preparing/performing procedures below

- Patients all ages
  - Surgical Cricotomy

- Patients aged > 8 years
  - Cannula Cricotomy

- If Operator and Equipment available
  - Surgical Tracheostomy

- If Operator and Equipment available
  - Rigid Bronchoscopy

After Care

(Debriefing - Medical Alert Bracelet - Difficult Airway Registry)

Figure 1
Unanticipated difficult pediatric airway algorithm consisting of three parts: Oxygenation, tracheal intubation, and rescue [Adapted from Difficult Airway Society (DAS)]. (13)
A) OXYGENATION

Failed Oxygenation Plan A

- The call for assistance/help is paramount with or before starting failed oxygenation Plan A. This includes the call for the dedicated airway trolley or bag.
- Failure of basic facemask ventilation indicates either a serious functional or an underlying anatomical/structural problem.
- If common functional and anatomical problems have been addressed, it is required to visualize vocal cords in spite of decreasing oxygen saturations to exclude and treat glottis foreign bodies or massive aspiration.
- If the vocal cords are visualized, a suitable tracheal tube is used to intubate the trachea. If tracheal intubation rectifies the problem and improves oxygenation, the proposed procedure can be continued as planned, if not move on to the next step of the protocol.
- If in doubt of the tracheal tube position and location and if oxygenation and ventilation do not improve, remove the tracheal tube.

Difficult facemask ventilation in children is rare (<0.02%) and ventilation is almost never impossible to perform. This is in contrast to adult data where in a reported 0.15% it is impossible to mask ventilate despite adjuncts, experienced operators, and sufficient neuromuscular blockade.

Failure of oxygenation Plan A, it is crucial to call for experienced help. The two most common problems are functional obstruction in the form of inadequate depth of anaesthesia and laryngospasm. It is also important to rule out any potential foreign bodies (coins, chewing gum/sweets/forgotten throat pack/possible aspiration), once anatomical and functional causes are ruled out. This can only be done by thorough direct laryngoscopy in the face of deteriorating oxygenation.

Failed Oxygenation Plan B

- The insertion of the laryngeal mask airway (LMA) or another suitable supraglottic airway device(SAD) to improve problems with oxygenation, if not rectified by the previous set of actions.
- A change of the size or make of the LMA may be beneficial.
- If the LMA/SAD is successful, it is important to investigate underlying pathology, which may include flexible laryngoscopy through the LMA, with subsequent tracheal intubation through the LMA.
- The proposed surgical procedure may proceed if the problem is completely resolved or the trachea is successfully intubated and oxygenation / ventilation is possible.
- If the above is not achieved, it is prudent to wake the patient and postpone surgery.
- Only in life saving surgery, it may be justified to proceed with a LMA / SAD.
Some may argue that the insertion of the LMA or SAD should precede direct laryngoscopy to address potential anatomical problems, but there are no studies supporting either view. However, there is no benefit in inserting a LMA or SAD, if a foreign body obstructs the upper airway.

The LMA has been demonstrated to be effective for both the difficult tracheal intubation management (as a conduit) and for the unexpected / expected difficult ventilation in children.

Different types of LMA’s may be easier to introduce with similar or even better sealing pressures. The intubating LMA (iLMA) is only available for children weighing more than 30 kg but has been used with success in children from 25 kg. The role of older (Combitube) and newer SADs such as i-Gel, Laryngeal Tube, and Cobra is yet to be established in children.

The current recommendation is for the cLMA or iLMA, but as new emerging evidence become available, future recommendations may change regarding SAD.

**B) TRACHEAL INTUBATION**

**Basic Rules for Successful Direct Laryngoscopy**

First attempt should be performed in optimal conditions with:

- Age-related optimal position of the head and neck
- Adequate levels of anaesthesia
- With or without muscle paralysis
- Pre-oxygenation
- External laryngeal manipulation to obtain an optimal direct laryngoscopic view.

This should always be followed by clinically and capnographic verification of tube position and confirming the optimal position.

**Failed Intubation Plan A:**

- Calling for additional experienced help early after the first failed tracheal intubation attempt.
- Calling for the dedicated difficult airway trolley / bag / box.
- Optimize conditions for the second intubation attempt. (same check list as above)
- Consider alternative equipment such as different laryngoscope blades and/or adjuncts such as a gum elastic bougie.
- In children <12months alternative techniques such as the paraglossal or retromolar approach using a straight blade to visualize the vocal cords.
• New visualization aids, such as optical and light stylets, endoscopic laryngoscopes, and others do have a place in the algorithm provided local expertise is available and maintained.
• Total intubation attempts should be limited to three, as the paediatric airway is very susceptible to trauma.
• After two unsuccessful attempts, a more experienced anaesthetist should attempt the next intubation.
• Oxygenation and adequate level of anaesthesia should always be maintained during these manoeuvres. The basic oxygenation and ventilation rules should be applied between each intubation attempt.
• Difficult intubation during a rapid sequence induction, an adequate depth of general anaesthesia, sufficient muscle paralysis, and gentle facemask ventilation are keys to successful management.

Failed Intubation Plan B.

• A LMA / intubating LMA (iLMA) must be inserted and satisfactory ventilation and oxygenation confirmed.
• Fibreoptic tracheal intubation through the LMA / iLMA.
• A full or partial glottic view can be obtained in more than 50% with the epiglottis seen in 40 to 50% of the patients, allowing the trachea to be intubated. The fiberscope can be withdrawn, leaving the LMA and tracheal tube in place.
• If prolonged intubation is anticipated or surgical access is required, an airway exchange catheter can be used as a guide for safe removal of the LMA over the tracheal tube and to reinsert a tracheal tube of choice.
• The patient should be oxygenated during the fiberoptic intubation and airway catheter exchange procedure.
• If apnoeic oxygenation techniques are used, avoid hyperinflation of the lungs.
• Although successfully used in adults by highly experienced users, blind insertion of the tracheal tube through the LMA / iLMA should be avoided.
• A maximum of two attempts should be used, after which consideration to postpone surgery and wake-up of the patient if ‘Failed intubation Plan B’ fails.
• Alternatively, it is possible to continue using the LMA in an urgent or life-threatening situations and if oxygenation and ventilation can be maintained.
• If it is impossible to advance the tracheal tube to mid-trachea do not ever use force, but place the LMA / iLMA and view the problem areas with the fibreoptic scope, to exclude or verify problems such as tracheal stenosis, webs or other anatomical abnormalities.
• Also exclude other causes of “difficulty to oxygenate” such as massive pulmonary aspirations, tracheal tube displacements and obstructions, pneumothorax, large intra-abdominal pressures, and equipment malfunction.
The incidence of unexpected difficult or failed intubation in otherwise healthy children is low. Limited data suggests an incidence of 0.08% in healthy and 0.42% in all children failing tracheal intubation after three attempts. This data is supported by a previous report of difficult intubations of 0.095% in children <16 years old with a higher incidence in children <1 year old (0.24%).

The incidence of unexpected failed tracheal intubation is low, subsequently the evidence base for the use of alternative laryngoscopes, blades, and techniques is very small. Therefore the proposed algorithm allows for local expertise and personal preference (“the open-box approach”).

Gum elastic bougies are useful adjuncts to facilitate the placement of the tracheal tube. However, this should be used under vision and only advanced if at least part of the glottic opening is visible, as to avoid unnecessary trauma of the airway.

New emerging and ‘classic’ visualization and intubation aids such as the Airtraq, Bonfils, Glidescope, optical and light stylets, and others will need to be evaluated to establish their role in managing the unexpected difficult paediatric tracheal intubation.

Fibreoptic tracheal intubation is considered the gold standard of difficult paediatric airway management. However, this technique requires appropriate equipment and assistance, as well as expertise and training. Setup and maintenance costs are high, but this piece of equipment should be included on every difficult paediatric airway trolley.

Fibreoptic tracheal intubation through the LMA / iLMA as described in the proposed algorithm is a simple and easy to learn technique for failed tracheal intubation in children. However, if this is not available, a ‘blind’ insertion through the LMA / iLMA may be preferable to a retrograde intubation or surgical access to the airway.

Alternatively, the safe option is to postpone surgery and wake the patient up if ‘Failed intubation Plan B’ of the unexpected difficult paediatric airway algorithm fails.
C) RESCUE

- Rigid bronchoscopy in the hands of an experienced operator and with the equipment immediately available, is an option to establish an airway in patients of all ages with compromised air exchange. The rigid bronchoscope once in place can be used to place an airway exchange catheter for subsequent tracheal intubation. However, regular and specialized training is required and experienced operators are not always available.

- Emergency percutaneous cricothyroidotomy cannula and / or an emergency surgical cricothyroidotomy are rather anecdotic than a clinically proven paediatric technique.

- Surgical cricothyroidotomy is the invasive procedure of choice for emergency access of the airway in patients, regardless of age, when conventional airway control is not possible. However, in neonates and small children a surgical incision followed by insertion of a cannula may be more appropriate and less traumatic.

Cannula cricothyroidotomy in infants and children has high incidence of complications and some recommends it is not to be used in patients below 5–6 years. The trachea of infants and small children is small in size, elastic, flaccid, mobile and difficult to locate, and can fully collapse if a transcutaneous insertion is performed.

Neonates and infants lack a functional cricothyroid membrane. In neonates, it is important to appreciate that the gap between the cricoid and the thyroid cartilage does not allow passage of a 2.0-mm ID tracheal tube. Therefore emergency surgical cricithyrotomy should not be done in infants and neonates as the tube has a larger diameter than patient's cricothyroid membrane and this would cause severe airway trauma.
EMERGENCY SURGICAL PAEDIATRIC AIRWAY (11)

Emergency Surgical Cricothyrodotomy

Generally described as a five-step technique:

1. Prepare the skin and position the patient with the neck in extension and the trachea and larynx thus forced forward (if there is no cervical spine injury), this can be facilitates with a folded blanket or towel roll to make palpation of the structures easier.
2. Palpate the center of the thyroid cartilage and with the fingernail move caudad until the indentation of the cricothyroid membrane is located.
3. Make a stab incision through the thin cricothyroid membrane with a scalpel blade.
4. Use a hook or retractor to separate the skin.
5. Pass an endotracheal tube through the stab wound into the trachea.

Complications result from:
- misidentification of structures
- laceration of aberrant vessels
- incorrect position of the airway device

Cricothyrotomy by a Percutaneous Needle / Catheter / Trochar technique

This technique involves the following steps:

1. Skin preparation and position with the neck extended and the trachea and larynx forced forward (if there is no cervical spine injury), e.g. with a folded blanket or towel roll.
2. Palpate the center of the thyroid cartilage and with the fingernail move caudad until the indentation of the cricothyroid membrane is located.
3. Puncture the cricothyroid membrane in a caudad direction using a large bore intravenous catheter with syringe attached and aspirate for air to confirm intratracheal position. If air cannot be aspirated then the catheter needle tip is misplaced and this step is repeated.
4. After aspiration of air, advance the catheter off the needle into the trachea, withdraw the needle and syringe and again attach the syringe to the catheter, again aspirate for air to reconfirm.
5. Attach the catheter to the adapter of a 3.0 mm ID endotracheal tube which then allows connection with any standard bag valve device. Alternatively attach the barrel of a 3-ml syringe to the i.v. catheter and place an 8 mm ID endotracheal tube adapter in the barrel of the syringe.
THE PROPOSED PROTOCOL

The proposal is a simple, stepwise, and easy to memorize algorithm for the management of the unexpected difficult paediatric airway. The 'open boxes' to allow institutional adaptation based on the local expertise and availability of equipment, as well as personal preferences.

The simplicity, the inclusion of basic rules and the separation of steps A-B-C makes the proposal suitable for non-paediatric anaesthetists and nurse anaesthetists familiar with mixed / adult protocols.

The main difference in paediatric airway management is that unexpected ventilation and oxygenation problems by far outnumber problems of tracheal intubation. This is primarily a result of functional airway problems. This is not
covered by the adult algorithms and can be mainly addressed by the prevention and basic rules section.

**Prevention and Basic Rules:**

Regular training and skills assessment under supervision is critical to obtaining adequate skills and maintaining these skills, especially for the occasional paediatric anaesthetist.

Basic principles, such as thorough preoperative assessment and having all age appropriate equipment ready and available and adhering to basic principles, such as pre-oxygenation are paramount.

The majority of morbidities and mortalities in paediatric airway management are attributed to inexperience, failure to recognise and overcome functional airway obstruction and not due to failure to intubate.

Patients with a documented or anticipated difficult airway should be managed by and referred to hospitals with adequate resources. Aftercare is very important, this should include discussion at a local M+M, parent / guardian should be informed of the problem and be made aware of this repeating on subsequent anaesthesia. A paediatric difficult airway register would be ideal.

The introduction of a modified version of the proposed algorithm into clinical teaching, simulation training, and international society / local recommendations may improve management of unexpected difficult paediatric airways.

**IN SUMMARY**

- Maintenance of oxygenation and ventilation are paramount.
- Attempts at rigid laryngoscopy should be performed in optimal conditions.
- Multiple and prolonged attempts at laryngoscopy are associated with morbidity and this will not be fully apparent until fiberoptic examination or extubation. Therefore, it is recommended to limit the number of attempts to four.
- Blind techniques have a high failure rate and are potentially traumatic.
- Awaken patient and postpone surgery if possible.
- In the failed intubation, increasing hypoxaemia and difficult ventilation scenario in the paralysed patient, optimize ventilation by using firstly the two handed ventilation technique and / or the cLMA. If those techniques fail one must consider invasive techniques such as canula cricothyroidotomy.
- Canula cricothyroidotomy requires a high pressure ventilation source with a reducing valve.
- Training in these techniques is essential.
CONCLUSION

A cornerstone of good medicine is maintaining safety, simplicity, and effective practice. Ignoring these basic principles can lead to unforeseen problems which may not be immediately obvious.

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REFERENCES

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