

The difficult paediatric airway

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Introduction

There are few areas of anaesthesia management more frightening and more difficult than the child with acute respiratory distress. In addition to the anatomical differences among infants, children and adults, the problem is compounded by the inability to reason with the child to obtain his or her cooperation. The object of this presentation is to define the important anatomical differences that make the paediatric patient unique. An understanding of normal airway anatomy and physiology facilitates better management of difficult airways.

Anatomical structures

The infant airway differs from the older paediatric patient in five ways:¹⁻⁴

1. The infant larynx is located higher in the neck, i.e. it is situated at the mid-third cervical vertebra (C3) in the premature infant, between C3 and C4 in the term infant and between C4 and C5 in the teenager or adult (Figure 1).⁵ Therefore, the angle for insertion of a laryngoscope blade is slightly different. In part, this explains the preference for the use of straight blades in infant laryngoscopy.
2. The infant's tongue is relatively large. Upper airway obstruction readily occurs because of the tongue and the smaller distance between the tongue and the hard palate. The position of the tongue is more difficult to control with a laryngoscope blade.
3. The infant's epiglottis is short, stubby and angled away from the axis of the trachea. The adult's epiglottis is broad, floppy and parallel to the axis of the trachea. The infant's epiglottis may be difficult to control with a laryngoscope blade.

4. The infant's vocal cords have a lower attachment anteriorly than posteriorly than the adult vocal cords, that are perpendicular to the axis of the trachea. It is for this reason that nasotracheal tubes that are blindly passed are often caught in the anterior commissure.
5. Just as it is in the paediatric patient, autopsy data demonstrate that in the adult, the narrowest portion of the airway is at the level of the cricoid cartilage.⁷ However, generally, the narrowing is of such a degree that an endotracheal tube that passes the glottic opening will readily pass into the trachea. The range in diameter for adult females is 10-16 mm, and for adult males, 13-

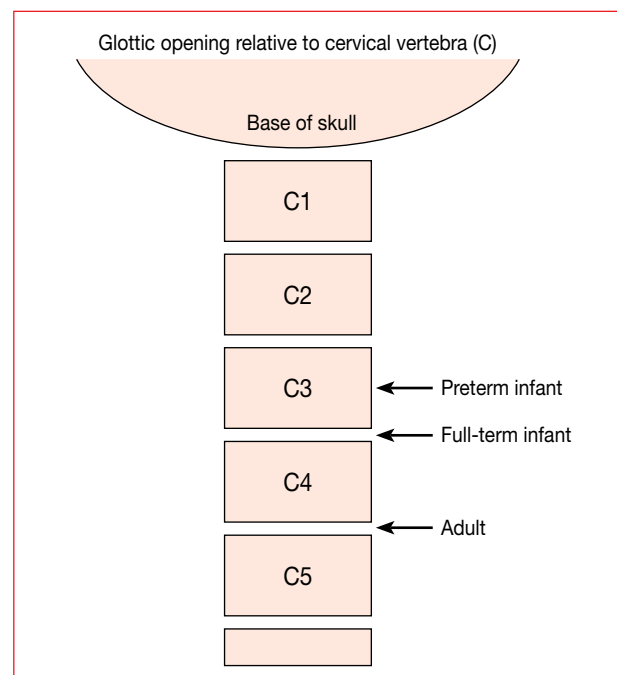


Figure 1: Position of the larynx in infants and adults⁶

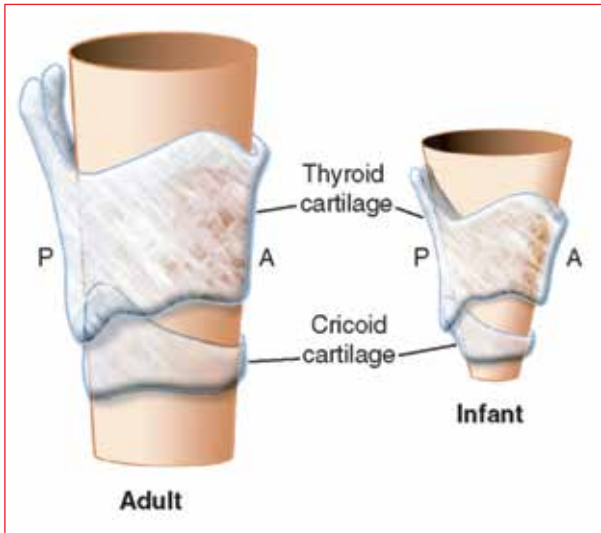


Figure 2: A comparison of the adult and infant larynx⁶

19 mm.⁸ Thus, the likely reason that endotracheal tubes pass easily through the glottic opening into the trachea of adults is that overall, the narrowest portion of the airway is still larger than the most commonly used endotracheal tube sizes. Generally, this apparent subglottic narrowing in adults is not evident unless there is a need to pass a larger diameter endotracheal tube, such as a double lumen tube.

The narrowest portion of the airway is also at the level of the cricoid cartilage in the infant and young paediatric patient, but this is much more pronounced because of the incomplete development of the thyroid and cricoid cartilages.⁹ Thus, an endotracheal tube may readily pass the vocal cords and become “tight” in the subglottic region. This is a normal anatomical variant that must be considered whenever passing an endotracheal tube in a paediatric patient. The paediatric larynx can be considered to be “funnel-shaped” and the adult larynx, “nearly cylindrical” (Figure 2).

Physiology

The infant is an obligate nose breather in the sense that many are unable to coordinate the movement of their laryngeal structures with respiratory effort. Anything that impairs air passage through the nares may result in severe upper airway obstruction in the neonate, e.g. choanal atresia. The majority of infants are able to coordinate respiration and laryngeal function by 3-5 months of age.¹⁰ Infant and young paediatric patients have immature laryngeal, tracheal and bronchial structures. The elastic nature of these structures makes them particularly susceptible to mechanical compression, stretching and distortion by internal or external pressure differences. It is for this reason that care must be taken where fingers are placed when holding a mask onto the face. We have

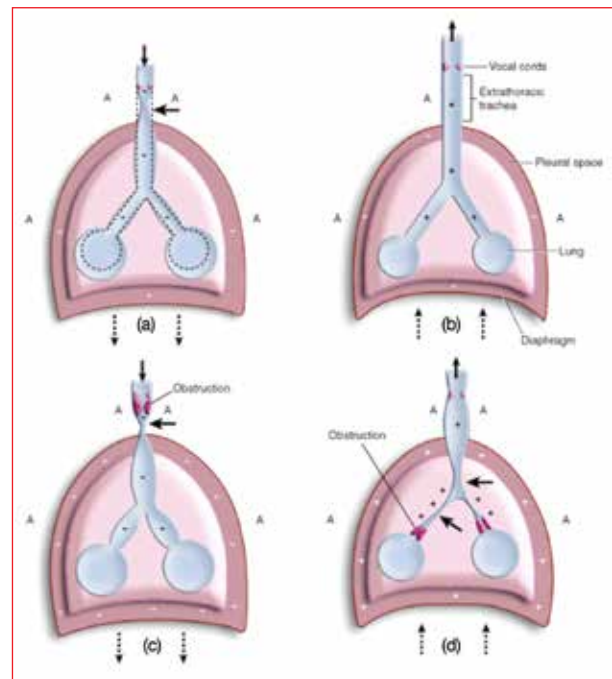
observed near total airway obstruction because of fingers “pulling up the chin” which were, in fact, compressing and obstructing the larynx.

In the past, excessive extension of the head at the atlanto-occipital junction was thought to stretch the trachea and cause upper airway obstruction. However, a video study of such manoeuvres did not confirm this to be true.¹¹ The trachea is particularly susceptible to dynamic airway collapse at the thoracic inlet where the pressure differential between the atmosphere and the intratracheal pressure is greatest.^{12,13}

Figure 3 a demonstrates the “normal” effects of pressure differentials between the trachea and bronchi. Note that there is a small degree of dynamic tracheal collapse at the thoracic inlet upon inspiration, whereas there is dilatation of the intrathoracic trachea and bronchi.

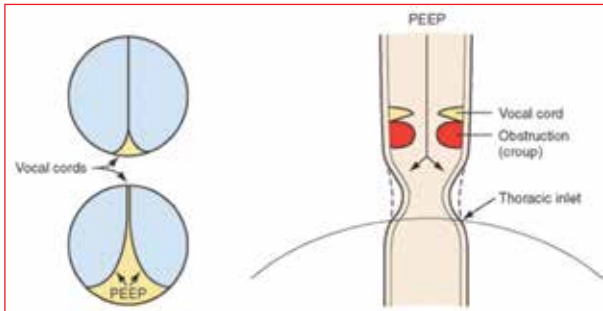
Figure 3 b demonstrates normal expiration.

Figure 3 c illustrates what happens when upper airway obstruction is superimposed upon the normal dynamic tracheal movements. The dynamic tracheal collapse is greatly exaggerated and adds to pathological airway obstruction. When the child becomes agitated or attempts to take a deep breath against this upper airway obstruction, dynamic collapse worsens because the pressure differential between the atmosphere and that within the trachea at the thoracic inlet is even greater. This exaggerated dynamic tracheal collapse may be avoided or reduced by minimising procedures that will upset the child [drawing blood, starting



A: atmospheric pressure, - = negative to A, + = positive to A

Figure 3 a-d: Airway dynamics during (a) normal inspiration, (b) normal expiration, (c) upper airway obstruction and (d) lower airway obstruction⁶



PEEP: positive end-expiratory pressure

Figure 4: The effects of positive end-expiratory pressure on lower airway obstruction⁶

an intravenous (IV) catheter and drawing blood gases), and if necessary, applying positive end-expiratory pressure (PEEP) while allowing the child to breath spontaneously.

Figure 3 d illustrates lower airway obstruction, for example, asthma or an intrathoracic foreign body. PEEP will increase intratracheal pressure above the thoracic inlet and reduce the pressure differential between the intratracheal pressure below the thoracic inlet, and therefore prevent exaggerated dynamic tracheal collapse (Figure 4).

Frequently, the simple act of providing 5-10 cmH₂O PEEP will reverse this dynamic tracheal collapse and allow oxygenation. Collapse of intrathoracic airways in the presence of obstructed expiration also occurs. This effect is exaggerated in the crying, agitated child who attempts to forcefully exhale. PEEP may also help offset this pressure differential. In part, these functional anatomical changes account for the inspiratory stridor diagnostic of upper airway obstruction, and the expiratory stridor and wheezing characteristics of lower airway obstruction. This also explains the rapid worsening of symptoms when the child is upset.

Another important factor is that infants and small children have a considerably higher oxygen consumption than adults.¹⁴ Under anaesthesia, the highly compliant chest of the infant is susceptible to mechanical compressive forces, for example, a surgeon leaning on the chest, while the potent anaesthetic agent's effects upon intercostal muscle function reduce the functional residual capacity.^{15,16} Either or both of these factors result in rapid desaturation in the infant, because the functional oxygen reserve is relatively less in the infant than it is in the adult patient.

The composition of the muscles of respiration is different in children younger than two years of age than in older children or adults. The amount of type I muscle fibres which allow for repetitive motion without fatigue is less in the diaphragm and intercostal muscles of children who are under two years of age, and is even smaller in the neonate (Figure 5).¹⁷ This difference in muscle fibre composition accounts for the frequency of apnoea in infants who have an increased respiratory workload.

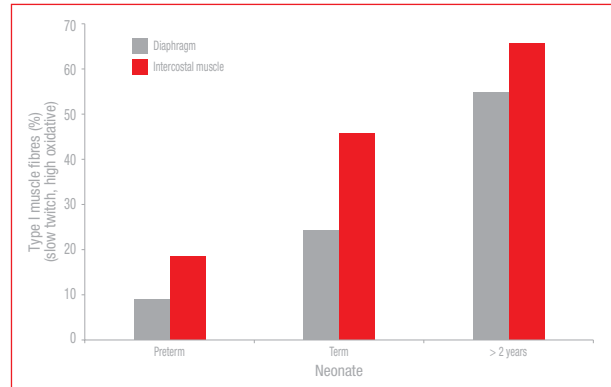


Figure 5: Comparison of type I muscle fibres in neonates and children who are older than two years⁶

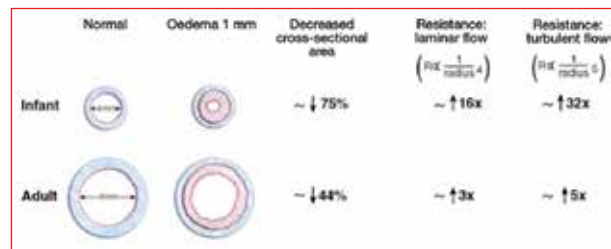


Figure 6: Airway resistance under different conditions⁶

Infants and small children have reduced respiratory reserve. Therefore, they rapidly fatigue, retain carbon dioxide and eventually develop respiratory failure.

An additional factor is the relative effects of airway oedema upon the work of breathing. Resistance to airflow is inversely proportional to the radius of the lumen to the fourth power for laminar flow and to the fifth power in the case of turbulent flow (Figure 6). Airway oedema has a profound effect upon the respiratory work in an agitated child. This is explained by the fact that the mucosal lining of the child's airway makes up a greater proportion of the airway diameter up to approximately five years of age, thus explaining the child's susceptibility to airway oedema with infection or trauma (intubation).⁹

Positioning the patient

Placing the patient in the appropriate position is of paramount importance when attempting laryngoscopy and intubation. Two manoeuvres are needed: anterior displacement of the cervical spine (a folded towel or blanket under the head) and extension at the atlanto-occipital junction (pulling up on the chin, i.e. the "sniffing position"). Anterior displacement of the cervical spine is not necessary in a child who is younger than five years of age, since, in a younger patient, the head is relatively large in proportion to the rest of the body. Thus, placing the child flat on the operating room table will naturally result in anterior displacement of the cervical spine. This position aligns the oral, pharyngeal and tracheal axes and provides easy access to the trachea in

patients with a normal anatomy. The same position should also be used in most patients with an abnormal anatomy.

Patient evaluation

The most important aspect of planning an intubation approach in a child with a difficult airway is to gain as much information about the child as possible. An evaluation must always begin with taking the history and conducting a physical examination. An evaluation of previous anaesthetic records may reveal management techniques that were successfully employed in the past, as well as approaches that were not successful. The physical examination is extremely helpful, especially if this examination can be performed while the child is in the presence of his or her parents so that he or she can be evaluated while in a calm, nonagitated state.

First, the evaluation should focus on what is obvious. Does the child have normal facies? Does the child have a tracheostomy or tracheostomy scar? Will the child be given oxygen? Is there any evidence of stridor, cyanosis or clubbing? Is the child breathing rapidly? Is the child breathing through the nose or mouth? Is the child coughing? How does the child interact with his or her parents? How does the child interact with you, the anaesthesiologist? Each of these observations will provide valuable information that can be used to help to formulate an anaesthetic plan. If a child has abnormal facies, is this part of a syndrome? (If there is one congenital malformation, there may well be another less obvious one, e.g. congenital heart disease). Often, an external ear deformity is associated with midfacial hypoplasia syndromes, as well as renal and cardiac abnormalities.

Next, the clinician should focus on the physical examination, while bearing in mind that the examination of the paediatric patient is one of opportunity, i.e. when the child is quiet, the heart and lungs should be listened to and the abdomen palpated for liver and spleen. (Often, congestive heart failure in children is associated with hepatosplenomegaly). When the child cries, how far the mouth can open should be ascertained, as well as the configuration of the hard and soft palate and the size of the tongue and tonsils. The distance between the ramus of the mandible and the thyroid cartilage can also be assessed. If every paediatric patient is examined in this careful manner, experience is formed to enable comparison of those children who constituted a difficult laryngoscopy vs. those who were easy. In general terms, if there is minimal distance between the ramus of the mandible and the thyroid cartilage, then usually, the child has an "anterior" larynx and may comprise a difficult laryngoscopy. The so-called "anterior larynx" is a malformation of the larynx that results in a posterior

displacement of the base of the tongue, rather than a true anterior displacement of the larynx.

Once the history has been taken and the physical examination completed, then attention can be given to an appropriate laboratory examination. It is important not to focus all attention on the airway since there may well be other systems that also require careful evaluation prior to anaesthesia. Obviously, radiological studies should be obtained where appropriate. If the child has a syndrome, then the anaesthesiologist must be familiar with that syndrome prior to anaesthetic induction. Some syndromes are associated with cervical spine abnormalities which may make laryngoscopy particularly difficult because of fusion of the cervical spine (Goldenhar's syndrome), or an unstable cervical spine that necessitates minimal flexion or extension of the cervical spine (Down syndrome and some forms of mucopolysaccharidosis).¹⁸⁻²⁰

Equipment

Perhaps the most important aspect of airway management is to have an appropriate array of airway management adjuncts, so as to have age- and size-appropriate equipment immediately available. It is best if this equipment is in a central location, for example, a cart for difficult airways, that can be mobilised on an elective or emergent basis. The suggested contents of such a cart are listed in Table I. However, each practitioner is encouraged to develop experience with a broad variety of airway adjuncts and then choose those that seem to provide the most help. This will minimise the contents of the difficult airway cart, while allowing the practitioner to maintain skills with several now-familiar, but less commonly used aids for airway management. This list should in no way be viewed as a specific endorsement of a particular product or manufacturer.

The laryngeal mask airway (LMA) is perhaps the single most important rescue device for clearing an obstructed airway, as well as providing a conduit for fibre-optic intubation, while delivering adequate anaesthesia and maintaining oxygenation (Table II).

An appropriate selection of endotracheal tube sizes, as well as an educated estimate of the distance for insertion, is also important prior to beginning airway management (Tables III and IV).

Planning the anaesthetic

Once the anaesthesiologist has evaluated the child, previous anaesthetics and medical records and laboratory and radiological data, and determined what the surgical needs will be, an anaesthetic "game plan" may be formulated. One of the trademarks of a good anaesthesiologist is a well-

Table I: Items to consider for inclusion in an emergency intubation cart

Drawer 1
LMA Classic™ disposable sizes 1, 1.5, 2, 2.5, 3, 4 and 5 LMA ProSeal™ disposable sizes 1.5, 2, 2.5, 3, 4 and 5 LMA Fastrach™ sizes 3, 4, 5 Air-Q LMA™ with special tracheal tube introducers: 1, 1.5, 2, 2.5, 3.5, 4.5 Endotracheal tubes for Fastrach™: sizes 6, 6.5-mm, 7-mm, 7.5-mm and 8-mm internal diameter Endotracheal tube stabilisers for Fastrach™ Size and weight charts for LMA™
Drawer 2
Transtracheal (VBM) catheters: infant (16-gauge), child (14-gauge), adult (13-gauge) Emergency Transtracheal Airway Catheter™ Magill forceps adult and paediatric Miller blades sizes 0, 1, 2, 3 and 4 MAC blades sizes 1, 2, 3 and 4 Wis-Hipple blade size 1.5 Oxyscope blades sizes 0 and 1 (with oxygen tubing) Handles (medium and short) C-X2 batteries Oxygen Y connector Albuterol adaptor (3) for metered-dose administration Syringes (5 ml and 10 ml, 5 each) Intravenous catheters Swivel adaptors (Portex and Sontex) #3 straight connectors X2
Drawer 3
Preparation forceps or tongue-grabbing forceps Safety glasses Lens paper Surgical lubricant 2% lidocaine jelly 4% lidocaine solution Atomiser to spray topical lidocaine Suction catheters, sizes 8, 10 and 14 (French) Yankauer suction (paediatric and adult sizes) Defogger Silicone spray Halogen light bulb Disposable teeth guards
Drawer 4
Face masks: Neonate; infant; toddler; child; small, medium and large adult Frie endoscopy mask: Infant, child and adult Bronchoscopy airways: Infant, child and adult Bite blocks: Infant, child and adult Ovassapian airways Nasal trumpets: sizes #12-34 (French) Oral airways 90, 80, 70, 60, 50, 00 and 000
Drawer 5
Ambu bag with reservoir Enk Oxygen Flow Modulation set Jet ventilator Stylettes: Paediatric and adult Endotracheal tube exchange catheters with both Luer lock and 15-mm outer-diameter adaptors sizes 3-mm, 4-mm, 5-mm and 7-mm outer diameter Retrograde catheter with extra guidewire Extension cord with converter from Hubbell to a three-pronged plug
Other equipment
Fibre-optic scope with light source Lighted stylets Optical stylets Storz and Shikani devices

* Items with outdates, LMA: laryngeal mask airway

Table II: Characteristics of laryngeal mask airways

Mask size	Patients' weight	Maximum cuff volume (ml)	Largest ETT (mm ID)
1.0	Neonates and infants up to 5 kg	4	3.5
1.5	Infants from 5-10 kg	7	4.0
2.0	Infants and children from 10-20 kg	10	4.5
2.5	Children from 20-30 kg	14	5.0
3.0	Children and small adults over 30 kg	20	6.0, cuffed
4.0	Normal and large adolescents and adults	30	6.0, cuffed
5.0	Large adolescents and adults	40	7.0, cuffed

ETT: endotracheal tube, ID: internal diameter

Table III: Age vs. recommended endotracheal tube size (internal diameter)⁶

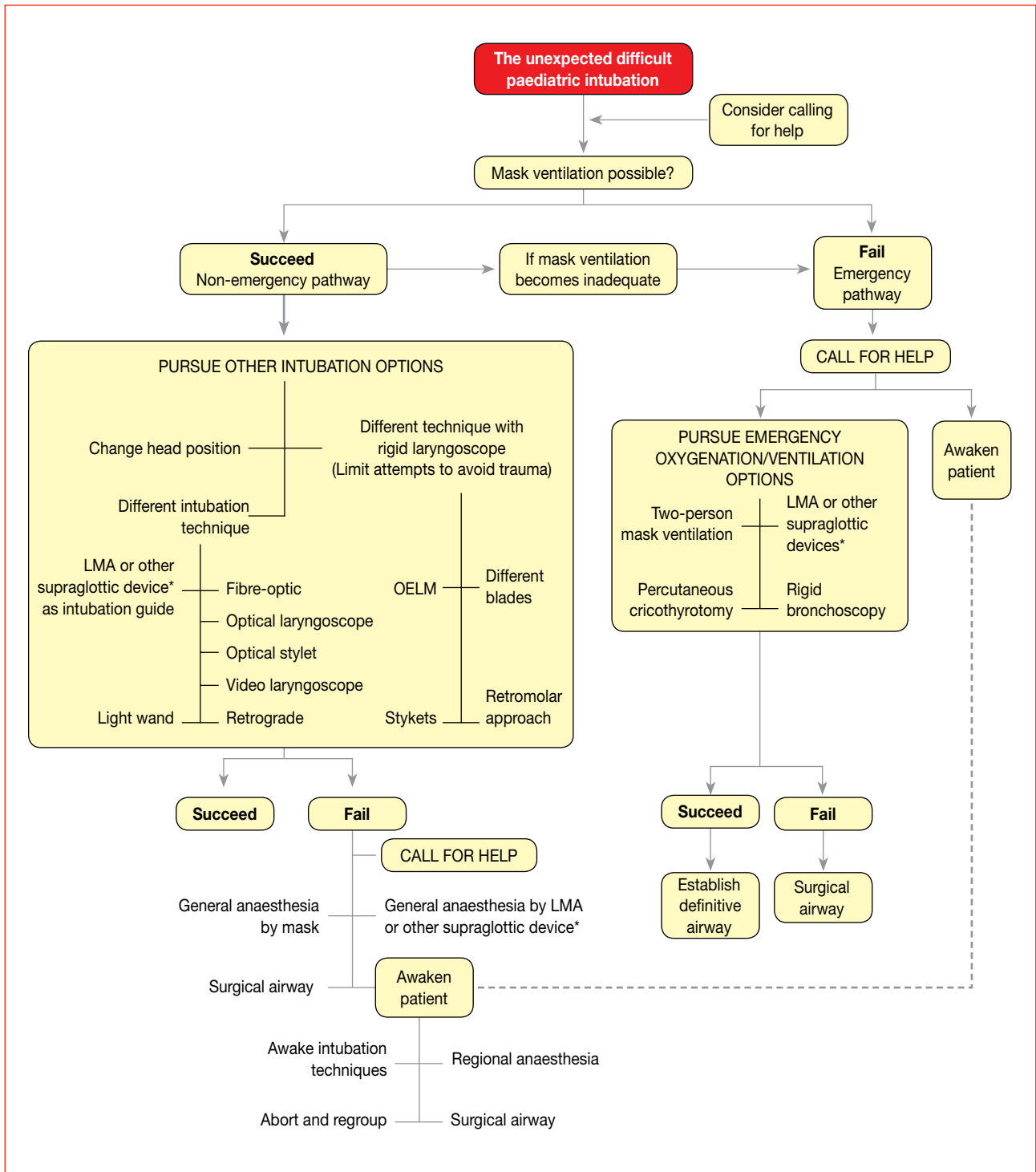
Age	Endotracheal tube size
Premature < 1 000 g	2.5
Premature 1 000-2 500 g	3.0
Term	3.0
6 months	3.5
1 year	4.0
18 months	4.5
2 years	5.0
Older than 2 years	$\frac{\text{Age (years)}}{4} + 16$

Table IV: Distance of insertion (centimetres, even with teeth)⁶

Age	Distance of insertion
Premature	6-8
Term	9-10
1 year	11
2 years	12
Older than 2 years	$\frac{\text{Age (years)}}{2} + 12$

considered strategy, an informed patient, the flexibility to change the plan as the situation demands and consultation with colleagues (the ear, nose and throat surgeon and another anesthesiologist), so as to have extra skilled help available should an emergency arise. In particular, it should be possible to rapidly alter the anaesthetic plan in the event of adverse psychological or physiological responses by paediatric patients to the operating room and its associated procedures.

Prior to entering the operating room, the anesthesiologist should have made a decision on the appropriate size endotracheal tube to use, the distance of insertion and what size oral airway would be most useful (Tables III and IV). The use of cuffed endotracheal tubes in children has undergone a resurgence.²¹⁻²⁴ The most important reason for deciding to use a cuffed tube is to ensure that there is a leak around the cuff when the cuff is deflated, and to make sure that



* Consider using ProSeal™ laryngeal mask airway if the child is at risk of aspiration or if high-inflation pressures are needed.
 LMA: laryngeal mask airway , OELM: optimal external laryngeal manipulation

Figure 7: Paediatric modification of American Society of Anesthesiologists' difficult airway algorithm²⁵

when the cuff is inflated, there is still a leak of between 20-30 cmH₂O. New, thin-walled, low-pressure cuffed endotracheal tubes may offer advantages. However, current experience is limited and the cost is approximately fivefold greater than standard cuffed endotracheal tubes.

The need to administer or avoid a premedication, and the timing and route of administration, should also have been

determined. The need for premedication is based upon the type of airway problem, the age and cooperation of the patient and the nature of the surgical procedure. In general terms, most patients with a compromised airway are not candidates for premedication, except perhaps for an anxiolytic. However, patients having elective surgical procedures, who may have a difficult airway but do not

have evidence of airway obstruction, may benefit from premedication, particularly if it is desirable to establish IV access prior to induction of anaesthesia. A paediatric modification of the American Society Anesthesiologists' difficult airway algorithm²⁵ is shown in Figure 7. However, new airway devices such as the ProSeal™ LMA, FastTrack™ LMA, Air Q and others that allow ventilation at higher peak inflation pressures or a blind technique for successful intubation should be included in this algorithm.

Anatomical problems

A complete understanding of normal airway anatomy is required in order to be able to manage patients with abnormal airway anatomy. Most infants, as well as patients with a large tongue, can be expected to develop upper airway obstruction as soon as they lose consciousness, because the distance between the hard palate and the tongue is less than that in older patients or those with a normal-sized tongue. Often, it is desirable to maintain spontaneous ventilation, as administration of a muscle relaxant will stop breathing and could result in a situation in which it is not possible to intubate or ventilate.

In addition, if fibre-optic techniques fail, then breath sounds may be of assistance for correct endotracheal tube insertion. The epiglottis is nearly always at the centre of the base of the tongue, except in the case of tumours, and the laryngeal inlet is immediately posterior to the epiglottis. I teach residents to insert the laryngoscope blade down the centre of the tongue (and not on the right side of the mouth), identify the epiglottis, and then move the body of the blade to the right side, while keeping the tip within the vallecula in order to be able to sweep the tongue over to the left. This permits the identification of normal anatomy, while avoiding trauma to the laryngeal structures. This is particularly important in patients with difficult airway anatomy, since trauma can result in bleeding, swelling and further distortion of an already abnormal airway.

If the laryngeal inlet cannot be directly visualised, for example, in midfacial hypoplasia, Goldenhar's Syndrome, Treacher Collins Syndrome and Pierre Robin Syndrome, a stylet can be placed within the endotracheal tube. Bend the very tip almost at a 90-degree angle, insert the tip of the endotracheal tube just posterior to the epiglottis and listen for breath sounds. By knowing that the laryngeal inlet is directly behind the epiglottis, an educated guess can be made as to where the laryngeal inlet is located. Maintaining spontaneous respiration is vital for this technique. It is also extremely important to ensure an adequate depth of anaesthesia so as to avoid laryngospasm. The same technique may be applied to a patient with abnormal cervical vertebral anatomy, either because of malformation, fracture or congenital dislocation. Once breath sounds are heard

within, the endotracheal tube is advanced off the stylet. This allows the endotracheal tube to make a 90-degree bend around the base of the tongue. This technique is particularly valuable in situations in which a fibre-optic scope is not available, or where blood and secretions prevent or complicate its use.

A smooth mask induction of anaesthesia is always desirable, and in particular in those patients with an abnormal airway. Sevoflurane or halothane are the agents of choice for the induction of anaesthesia in children, since they are the least irritating to the airway. Concerns about halothane-associated hepatitis are poorly founded, because only two paediatric deaths have been attributed to halothane hepatitis, despite millions of paediatric applications. Halothane has been demonstrated to be superior to all anaesthetic agents in diminishing the incidence of laryngospasm. Since nearly twice as many minimum alveolar concentration (MAC) multiples of halothane can be delivered compared to sevoflurane, it remains the agent of choice in children with airway obstruction and in patients who may require prolonged laryngoscopy. Alternatively, because maintaining an adequate depth of anaesthesia may be difficult with sevoflurane, a background infusion of propofol may be utilised.

A retromolar or lateral approach (Figure 8) to rigid laryngoscopy allows visualisation of the laryngeal inlet in some children. External pressure applied to the larynx may also be of value. A modified laryngoscope, the Oxyscope™ (Heine Optotechnik, Germany), delivers 2 l/minute of oxygen, and if connected to the anaesthesia circuit, anaesthetic agent at the tip of the blade during laryngoscopy. Use of the blade has been demonstrated to maintain oxygenation better than standard laryngoscopy techniques.

Special equipment

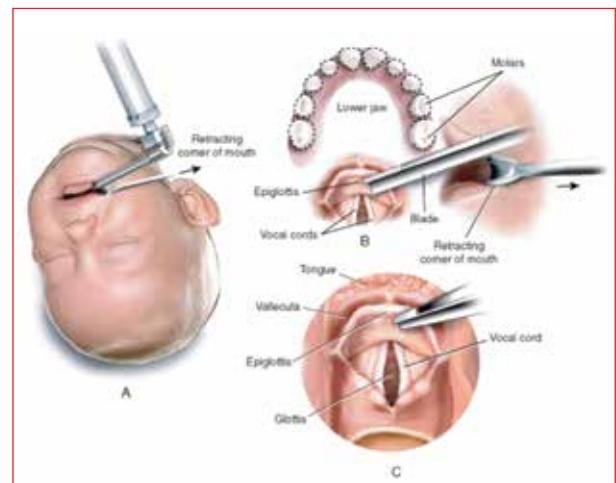


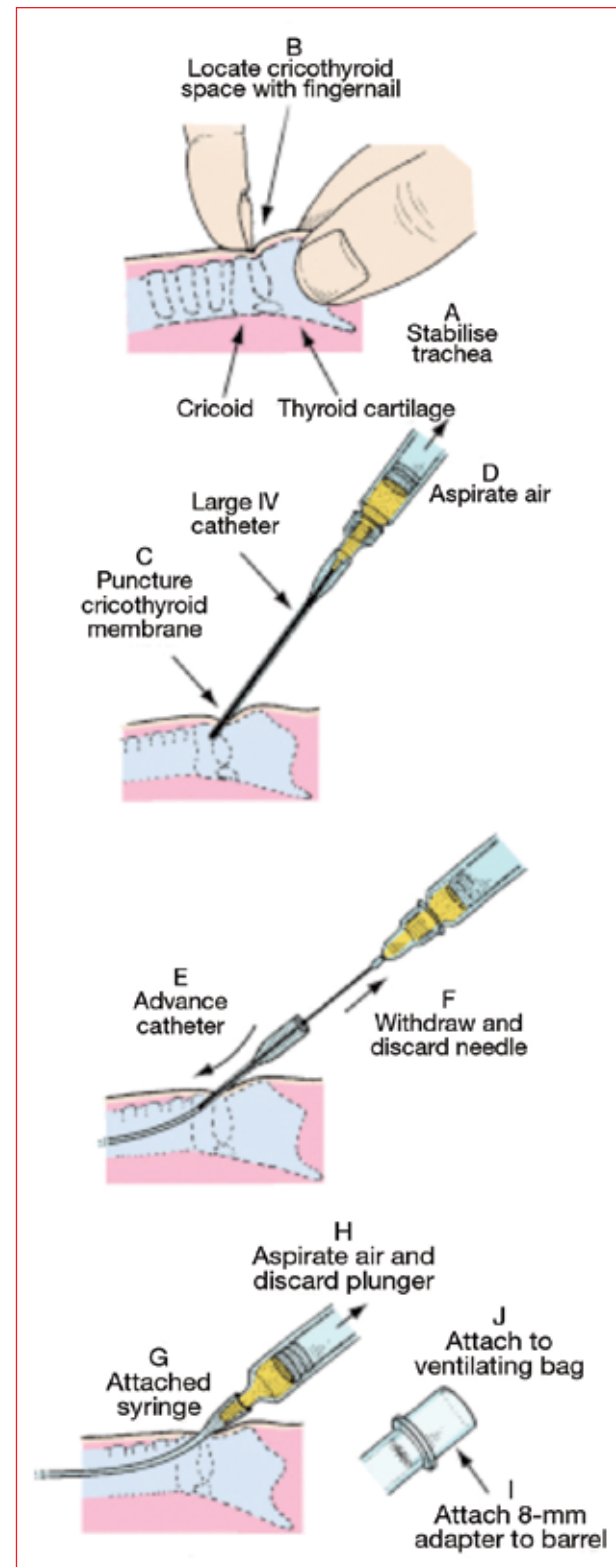
Figure 8: Retromolar or lateral approach to rigid laryngoscopy⁶

Fibre-optic laryngoscopy is an extremely helpful technique. It is important to gain facility with this device on “normal” patients since knowledge of the anatomy is vital to the successful application of fibre-optic techniques. The time to develop this skill is not while managing a patient with a difficult airway.^{26,27} Using the LMA as a temporising measure, and then as a conduit for fibre-optic intubation, is perhaps the most commonly used approach to the difficult paediatric airway now.²⁸⁻³³ Alternatively, the Frei endoscopy mask, a special face mask that allows continued administration of oxygen and inhalation agent, but which contains a clear membrane through which a fibre-optic scope can be passed, may be used.

Other equipment includes several versions of optical stylets [Shikani (Clarus Medical, USA) and Storz (Karl Storz, Germany)]. These devices consist of a metal stylet that contains a fibre-optic illumination fibre and a fibre-optic vision fibre that are connected to an eyepiece or a video monitor. The light source may be external or battery-powered and attached to the housing at the base of the eyepiece. The latter version facilitates easy transport in an emergency outside of the traditional operating room location.^{34,35} These devices are described for use either with or without rigid laryngoscopy. There are slight differences between them. Both provide an adaptor to hold the endotracheal tube that allows delivery of oxygen through the tip of the tube, but the Shikani device requires removal of the 15-mm adaptor, whereas the Storz device uses the 15-mm adaptor to hold the tube in place. The paediatric Shikani optical stylet is slightly malleable and can accommodate a 3-mm internal diameter (ID) endotracheal tube. A 2.5-mm ID endotracheal tube fits but is tight, whereas the Storz device is not at all malleable, but readily accommodates a 2.5-mm ID tracheal tube.^{34,36-39} One further difference is that the quality of light (on battery mode) seems a bit brighter with the Storz device.^{26,40,41}

Other airway devices that may be of value include the laryngeal tube (VBM Medizintechnik, Germany), which is a single-lumen tube closed at the distal end with a small cuff attached at the tip (distal cuff), with a larger balloon cuff in the middle part of the tube (proximal cuff). The proximal cuff provides a seal in the upper pharynx and the distal cuff seals the oesophageal inlet. Two openings lie between the two cuffs and the device is positioned so that the more distal opening faces the glottis. The cuffs are inflated through a single pilot tube and balloon, through which cuff pressure can be monitored. There are three black lines on the tube near a standard 15-mm connector. These indicate adequate depth of insertion when aligned with the teeth. The laryngeal tube is available in four types (standard, disposable laryngeal tube, laryngeal tube suction II, and disposable laryngeal tube suction II), and in six sizes, including those that are

designed for children.⁴² Specially marked and color-coded syringes are supplied to ensure proper cuff inflation. The Cobra-PLA™ (perilaryngeal airway) (Engineered Medical Systems, USA) is a disposable supraglottic device that is marketed as having the same indications as the LMA, but



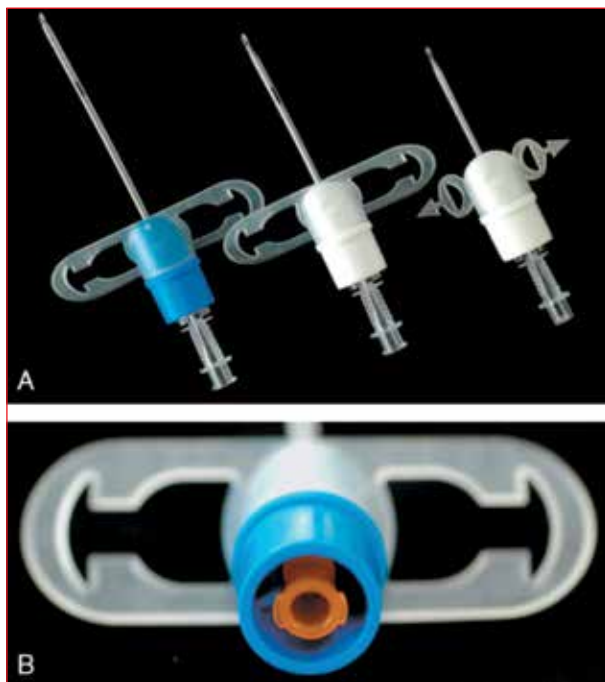
IV: intravenous

Figure 9: Technique of percutaneous cricothyroidotomy⁶

creates a seal higher in the hypopharynx using a cylindrical inflatable cuff. The distal end of the device sits over the larynx, but is not inflatable.⁴²⁻⁴⁴ A long midline slit in the distal end of the device allows the passage of a fibre-optic scope and endotracheal tube.

Some investigators have performed a cricothyroid puncture and advanced a flexible guide wire retrograde into the larynx. This can provide a guide to aid the passing of an oral endotracheal tube. However, this bears the risk of tracheal damage or bleeding. Even elective tracheostomies may be quite difficult.⁴⁵ Finally, if the situation occurs in which intubation and ventilation are not possible, then it is necessary to proceed to a surgical airway. If a surgeon is not immediately available, and to avoid the use of scalpels, a cricothyrotomy with either an IV catheter or a system similar to an IV catheter is recommended (Figure 9).⁴⁶ If the patient is still breathing spontaneously, then just the simple delivery of oxygen will be life-sustaining. There is no need to be concerned about hypercarbia since this is generally well tolerated.⁴⁷

When performing a percutaneous cricothyroidotomy (Figure 9), the head should be extended in the midline with a rolled towel or folded sheet beneath the shoulders. While standing to the left of the patient, the trachea should be stabilised with the right hand (A). The cricothyroid membrane is located with the index fingertip of the left hand between the thyroid and cricoid cartilages (B). This space is so narrow (1 mm) in an infant that only a fingernail can discern it. The trachea is then stabilised between the middle finger and thumb of



Figures 10 a and b: Ventilation catheter recommended for percutaneous cricothyroidotomy

the left hand, while the fingernail of the index finger marks the cricothyroid membrane. A large IV catheter (12 to 14 gauge) is then inserted through the cricothyroid membrane (C) and air is aspirated (D). The catheter is advanced into the trachea through the membrane and the needle is discarded. The intraluminal position is reconfirmed by attaching a 3-ml syringe (E) and aspirating for air (F). A 3-mm adaptor from a paediatric endotracheal tube can be attached to any IV catheter (G). Ventilation is accomplished by attaching to a breathing circuit with a standard 22-mm connector (H). An alternative would be to leave the barrel of the 3-ml syringe attached to the IV catheter, insert an 8-mm endotracheal tube adaptor to the syringe barrel, and then attach to a ventilating system with a standard 22-mm adaptor.⁴⁷

An alternative to using a simple IV catheter would be to utilise a device that is designed for jet ventilation.

The Ventilation-Catheter (VBM, Germany) is available in three sizes: 16 gauge (infant), 14 gauge (child) and 13 gauge (adult). It consists of a slightly curved puncture needle within a Teflon[®], kink-resistant cannula (Figure 10 a). The system is inserted similarly to that described in Figure 9. This cannula has two lateral eyes at its distal end and a combined Luer lock and 15mm-adaptor (surrounding the Luer lock) at its proximal end (Figure 10 b), thus allowing either jet or standard ventilation. It also has a fixation flange and foam neck tape to secure the airway.

References

1. Vandam LD. Functional anatomy of the larynx. *Week Anesth Update*. 1977;1:2-6.
2. Eckenhoff JE. Some anatomic considerations of the infant larynx influencing endotracheal anaesthesia. *Anesthesiology*. 1951;12(4):401-410.
3. Negus VE. *The comparative anatomy and physiology of the larynx*. New York: Grune and Stratton; 1949.
4. Wilson TG. Some observations on the anatomy of the infantile larynx. *Acta Otolaryngol*. 1953;43:95-99.
5. Hudgins PA, Siegel J, Jacobs I, Abramowsky CR. The normal paediatric larynx on CT and MR. *AJNR. Am J Neuroradiol*. 1997;18(2):239-245.
6. Litman RS, Fiadjoe JE, Stricker PA, Coté CJ. The pediatric airway. In: Coté CJ, Lerman J, Anderson BJ, Saunders WB, editors. *A practice of pediatric anesthesia for infants and children*. 5th ed. 2013.
7. Hinton AE, Herdman RC, Martin-Hirsch D, Saeed SR. Parental cigarette smoking and tonsillectomy in children. *Clin.Otolaryngol*. 1993;18(3):178-180.
8. Seymour AH, Prakash N. A cadaver study to measure the adult glottis and subglottis: defining a problem associated with the use of double-lumen tubes. *J Cardiothorac Vasc Anesth*. 2002;16(2):196-198.
9. Eckel HE, Koebke J, Sittel C, et al. Morphology of the human larynx during the first five years of life studied on whole organ serial sections. *Ann Otol Rhinol Laryngol*. 1999;108(3):232-238.
10. Miller MJ, Carlo WA, Strohl KP, et al. Effect of maturation on oral breathing in sleeping premature infants. *J.Pediatr*.

- 1986;109(3):515-519.
11. Wheeler M, Roth AG, Dunham ME, et al. A bronchoscopic, computer-assisted examination of the changes in dimension of the infant tracheal lumen with changes in head position: implications for emergency airway management. *Anesthesiology*. 1998;88(5):1183-1187.
 12. Wittenborg MH, Gyepes MT, Crocker D. Tracheal dynamics in infants with respiratory distress, stridor, and collapsing trachea. *Radiology*. 1967;88(4):653-662.
 13. Kushner DC, Harris GB. Obstructing lesions of the larynx and trachea in infants and children. *Radiol Clin North Am*. 1978;16(2):181-194.
 14. Cross KW, Tizard JPM, Trythall DAH. The gaseous metabolism of the newborn infant. *Acta Paediatr*. 1957;46(3):265-285.
 15. Froese AB, Bryan AC. Effects of anaesthesia and paralysis on diaphragmatic mechanics in man. *Anesthesiology*. 1974;41(3):242-255.
 16. Tusiewicz K, Bryan AC, Froese AB. Contributions of changing rib cage-diaphragm interactions to the ventilatory depression of halothane anaesthesia. *Anesthesiology*. 1977;47(4):327-337.
 17. Keens TG, Bryan AC, Levison H, Ianuzzo CD. Developmental pattern of muscle fiber types in human ventilatory muscles. *J Appl Physiol*. 1978;44(6):909-913.
 18. Borland LM, Colligan J, Brandom BW. Frequency of anaesthesia-related complications in children with Down syndrome under general anaesthesia for noncardiac procedures. *Paediatr Anaesth*. 2004;14(9):733-738.
 19. Puschel SM, Findley TW, Furia J, et al. Atlantoaxial instability in Down syndrome: roentgenographic, neurologic, and somatosensory evoked potential studies. *J Pediatr*. 1987;110(4):515-521.
 20. Nargoziyan C. The airway in patients with craniofacial abnormalities. *Paediatr Anaesth*. 2004;14(1):53-59.
 21. Cox RG. Should cuffed endotracheal tubes be used routinely in children? *Can J Anaesth*. 2005;52(7):669-674.
 22. Dullenkopf A, Schmitz A, Frei M, et al. Air leakage around endotracheal tube cuffs. *Eur J Anaesth*. 2004;21(6):448-453.
 23. Fine GF, Borland LM. The future of the cuffed endotracheal tube. *Paediatr Anaesth*. 2004;14(1):38-42.
 24. Goldmann K. Recent developments in airway management of the paediatric patient. *Curr Opin Anaesthesiol*. 2006;19(3):278-284.
 25. American Society of Anesthesiologists Task Force on Management of the Difficult Airway. Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. *Anesthesiology*. 2003;98(5):1269-1277.
 26. Holm-Knudsen R. The difficult paediatric airway: a review of new devices for indirect laryngoscopy in children younger than two years of age. *Paediatr Anaesth*. 2011;21(2):98-103.
 27. Doherty JS, From SR, Gildersleve CD. Paediatric laryngoscopes and intubation aids old and new. *Paediatr Anaesth*. 2009;19 Suppl 1:30-37.
 28. Jagannathan N, Sohn LE, Mankoo R, et al. A randomized crossover comparison between the Laryngeal Mask Airway-Unique™ and the air-Q Intubating Laryngeal Airway in children. *Paediatr Anaesth*. 2012;22(2):161-167.
 29. Karim YM, Swanson DE. Comparison of blind tracheal intubation through the intubating laryngeal mask airway (LMA Fastrach) and the Air-Q. *Anaesthesia*. 2011;66(3):185-190.
 30. Trevisanuto D, Parotto M, Doglioni N, et al. The Supreme Laryngeal Mask Airway (LMA): a new neonatal supraglottic device: comparison with Classic and ProSeal LMA in a manikin. *Resuscitation*. 2012;83(1):97-100.
 31. Yun MJ, Hwang JW, Park SH, et al. The 90 degrees rotation technique improves the ease of insertion of the ProSeal laryngeal mask airway in children. *Can J Anaesth*. 2011;58(4):379-383.
 32. Baker PA, Brunette KE, Byrnes CA, Thompson JM. A prospective randomized trial comparing supraglottic airways for flexible bronchoscopy in children. *Paediatr Anaesth*. 2010;20(9):831-838.
 33. Seet E, Rajeev S, Firoz T, et al. Safety and efficacy of laryngeal mask airway Supreme versus laryngeal mask airway ProSeal: a randomized controlled trial. *Eur J Anaesthesiol*. 2010;27(7):602-607.
 34. Shikani AH. New "seeing" stylet-scope and method for the management of the difficult airway. *Otolaryngol Head Neck Surg*. 1999;120(1):113-116.
 35. Saruki N, Saito S, Sato J, et al. Swift conversion from laryngoscopic to fiberoptic intubation with a new, handy fiberoptic stylet. *Anesth Analg*. 1999;89(2):526-528.
 36. Wodey E, Tirel O, Bansard JY, et al. Impact of age on both BIS values and EEG bispectrum during anaesthesia with sevoflurane in children. *Br J Anaesth*. 2005;94(6):810-820.
 37. Reyntjens K, Foubert L, De WD, et al. Glycopyrrolate during sevoflurane-remifentanyl-based anaesthesia for cardiac catheterization of children with congenital heart disease. *Br J Anaesth*. 2005;95(5):680-684.
 38. Firth PG. Anaesthesia for peculiar cells: a century of sickle cell disease. *Br J Anaesth*. 2005;95(3):287-299.
 39. Firth PG, Head CA. Sickle cell disease and anaesthesia. *Anesthesiology*. 2004;101:766-785.
 40. Hurford DM, White MC. A comparison of the Glidescope and Karl Storz DCI videolaryngoscopes in a paediatric manikin. *Anaesthesia*. 2010;65(8):781-784.
 41. Vlaten A, Aucoin S, Litz S, et al. A comparison of bonfils fiberscope-assisted laryngoscopy and standard direct laryngoscopy in simulated difficult paediatric intubation: a manikin study. *Paediatr Anaesth*. 2010;20(6):559-565.
 42. Kaya G, Koyuncu O, Turan N, Turan A. Comparison of the laryngeal mask (LMA) and laryngeal tube (LT) with the perilaryngeal airway (cobraPLA) in brief paediatric surgical procedures. *Anaesth Intensive Care*. 2008;36(3):425-430.
 43. Hooshangi H, Wong DT. Brief review: the Cobra Perilaryngeal Airway: CobraPLA and the Streamlined Liner of Pharyngeal Airway (SLIPA) supraglottic airways. *Can J Anaesth*. 2008;55(3):177-185.
 44. Szmuk P, Ezri T, Narwani A, Alfery DD. Use of CobraPLA as a conduit for fiberoptic intubation in a child with neck instability. *Paediatr Anaesth*. 2006;16(2):217-218.
 45. Wrightson F, Soma M, Smith JH. Anesthetic experience of 100 paediatric tracheostomies. *Paediatr Anaesth*. 2009;19(7):659-666.
 46. Coté CJ, Hartnick CJ. Paediatric transtracheal and cricothyrotomy airway devices for emergency use: which are appropriate for infants and children? *Paediatr Anaesth*. 2009;19 Suppl 1:66-76.
 47. Coté CJ, Eavey RD, Todres ID, Jones DE. Cricothyroid membrane puncture: oxygenation and ventilation in a dog model using an intravenous catheter. *Crit Care Med*. 1988;16(6):615-619.