Review Article

Airway devices in paediatric anaesthesia

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Access this article online
Website: www.ijaweb.org
DOI: 10.4103/ija.IJA_550_19
Quick response code

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ABSTRACT

Airway devices were first used in children since 1940 and thereafter an increasingly large number of paediatric airway devices have come into our armamentarium. To control and protect the airway in children during anaesthesia, in intensive care unit or in emergency department either tracheal intubation is performed under direct or indirect visualization of vocal cords with the help of laryngoscopes or video-laryngoscopes respectively or it can be done blindly or by using special instruments such as fiberoptic laryngoscope, lighted stylet or Bullard laryngoscope to name a few. Airway also can be maintained with the help of Laryngeal mask airways, oropharyngeal and nasopharyngeal airways. Updating our information and knowledge regarding these developments is pivotal to our practice of paediatric anaesthesia. With a thorough search of books, MEDLINE, MEDNET, clinical trials.gov.in, this article aims at focusing and understanding a brief basis of paediatric devices and their use.

Key words: Airway devices, paediatric, endotracheal tubes, supraglottic devices, fiberoptic bronchoscope, video-laryngoscope

INTRODUCTION

Children are not miniature adults. Due to several anatomical and physiological differences selection of their airway devices need careful consideration. Infants have a large head, long U shaped epiglottis, a large tongue and a mandibular angle of 140°. The epiglottis is narrow, floppy, relatively long and U-shaped, and angled backwards at 45°.[1,2] Functionally the narrowest part is located at the cricoid cartilage.[3] However, MRI studies indicate that the narrowest part can be the glottis which is a distensible organ.[4] Before 1940, tracheal intubation was rarely performed in children as airway equipments and airway physiology were yet to get developed.[5]

FACE MASK

The anaesthesia facemask forms the vital link between the patient's airway and the anaesthesia machine. A good fit should avoid pressure on eyes, seal without excessive pressure, have a low dead space. They may be flavoured. Transparent masks detect cyanosis, condensation of moisture, secretions and vomitus.

The common types are the Rendell-Becker-Soucek mask[6] provides excellent airtight seal without inflatable rim and ensuring minimal dead space. The masks with flexible lip or cushioned inflatable rim gives a good seal in patients with anatomical or mechanical problems. Endoscopic mask[7] (Patil-Syracuse Mask, airway endoscopy mask) allows fibre-optic intubation in anaesthetised spontaneously breathing children.

ORAL AND NASOPHARYNGEAL AIRWAY

Oral airways

They maintain an open airway during induction of anaesthesia and prevent patients from biting and occluding endotracheal tube. If the airway is too small it pushes the tongue backward and obstructs the oropharynx. It pushes the epiglottis down into the glottic aperture or uvula if airway is too large. The pharyngeal and laryngeal reflexes should be

How to cite this article: Swaika S, Ghosh S, Bhattacharyya C. Airway devices in paediatric anaesthesia. Indian J Anaesth 2019;63:721-8.

depressed before insertion to avoid gag reflex, laryngospasm or vomiting. Guedel's airway is the commonly used airway with a central lumen where suction catheter can be passed. Berman airway consists of two horizontal plates joined by a median ridge and suction catheter can be passed down either side of the ridge.

Nasopharyngeal airways

They relieve airway obstruction by opening the nasopharynx. Robertazzi's nasal airway or the Wendl's nasal airway is often used. Nasal airways are available in 12- to 36-Fr sizes.The diameter of the nasal airway is usually the same or even 0.5 mm larger than the tracheal tube (TT) that is appropriate for the child's age. They are contraindicated in haemorrhagic disorders and pathology of nasopharynx.

TRACHEAL TUBES

Disposable tracheal tubes[8,9] [Figure 1] made of polyvinylchloride (PVC) have replaced the red rubber tubes. Uncuffed tube size is often determined by a modified Cole's formula (ID in mm = age in years/4 + 4. cuffed tube - one size smaller). Uncuffed TTs were traditionally recommended for general anaesthesia in children below 8 to 10 years age.[10]

The cuffed tubes were avoided in children for fear of damaging airway from an overinflated cuff. With the cuffed tube there is reduced risk of aspiration and improved ventilation with less fresh gas flows and end tidal CO_2 monitoring. The cuffed tubes with high-volume low-pressure cuffs completely seal <15cm H_2O without increase of postintubation stridor. The cuffed tube size should be 0.5 mm smaller than the uncuffed tube.[11,12]

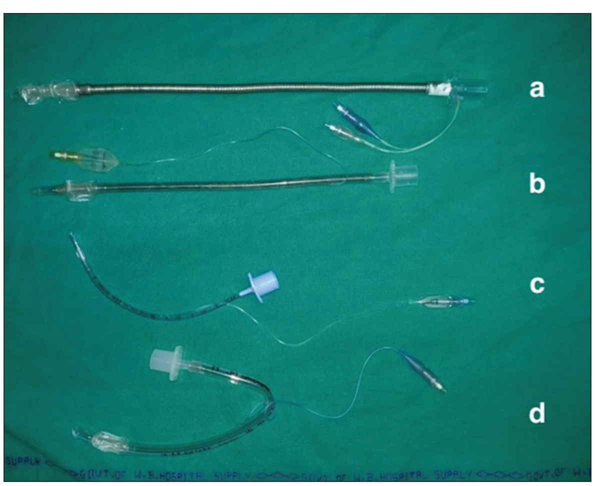

Figure 1: Tracheal tubes. (a) Lasertube. (b) Reinforced tube. (c) Cuffed endotracheal tube. (d) RAE South Pole

Micro-cuff tube

The cuffs in the micro cuff tubes are thinner, shorter, cylindrical, more compliant and sited closer to distal end without a Murphy eye. The recent micro-cuff tubes contain a black line as depth marker. Effective seal is attained when the cuff is inflated to <10cmH_2O pressure. There is no significant impact on the incidence of postintubation stridor when compared with uncuffed TTs.[13] The cost is high and there is limited availability.[7,13]

Precautions for safe use of cuffed tubes

The size is selected for children more than 2 years of age using the Moto Yama formula (ID = age/4 + 3.5).[7] The recommended TT size (ID) for children less than 2yrs are 2mm for premature less than 1kg, 2.5 mm for premature more than 1 kg and from 3 to 4.5 mm for term neonates to 2 years. The cuff pressure is not allowed to exceed 20 cm H_2O. The cuff pressure should be monitored throughout.

Preformed tubes

The preformed or RAE (Ring Adair Elwyn) tube is designed for surgery on head, neck and face. Oral version or South Polar has a preformed bend which rests on the patient's chin and away from the face. In the nasal version or North Polar, the bend rests on the patient's forehead. The black mark at the bend should be at the level of teeth or nares indicating proper placement. There is increased resistance to gas flow and suctioning is difficult.

Armoured tubes

They are indicated in head and neck surgery, abnormal patient positions and are resistant to kinking. These flexible tubes are made of rubber, silicone, PVC or soft plastic. The walls are strengthened by reinforcing spiral of nylon or metal. Bougie or stylet is required for introduction.

Laser-resistant tubes

Laser-resistant tubes like laser flex tube is a stainless-steel tube with matte finish to reflect the laser beam. The two cuffs are filled with coloured saline to detect puncture by laser beam. There is risk of airway injury in small children. The laser tubes made of white rubber have two cuffs (one inside the other). The shaft is covered with corrugated silver foil and Merocel sponge. Standard red rubber or PVC tube covered with aluminum or copper foil can be used. The cuff is covered with moist cotton.

AIRWAY DEVICES USED FOR LUNG ISOLATION

The common devices are Fogarty catheter, Arndt blocker, Uniblocker, Univent and double lumen tube.[14] Fogarty catheter and Arndt blocker are commonly used for younger children and Univent tube and double lumen tube for older children. Vascular balloon tipped catheters like Fogarty arterial embolectomy catheters are useful. 3-Fr size is suitable for infants 5-10 kg, 4-Fr size for 11-15kg. Single-lumen tracheal tube ensures simplest and quickest technique but slow lung collapse and inability to suction or deliver CPAP (continuous positive airway pressure) are its disadvantages. Univent tube is a conventional TT, available in two sizes, 3.5 and 4.5 mm ID, with bronchial blocker (OD 2mm) within a separate lumen but insertion is easier. The disadvantage of univent tube includes high resistance to gas flow, no central lumen within the BB (bronchial blocker) and useful within a narrow age group of 6-8 years. Double lumen tracheal tubes (DLTs)- smallest DLT is 26Fr, used for 8-10 years and 28 and 32Fr for above 10 years. The Marraro Pediatric Bilumen Tube is a special uncuffed bi lumen tube for use in infants and neonates.[15]

SUPRAGLOTTIC AIRWAY DEVICES

Supraglottic airway devices (SGAs) [Table 1 and Figure 2] create a seal around the pharynx and act as a conduit for ventilation, oxygenation and administration of anaesthetic gases.[16-19] The laryngeal mask airway (LMA) was invented by Archie Brain in 1988.

Laryngeal mask airways (LMAs) have been classified based on evolution (Cook and Stoddart) into First generation (classic, flexible, unique and Cobra perilaryngeal LMA) and second generation (Proseal, i-gel, laryngeal tube, Supreme, streamlined liner pharyngeal airway). Third generation (Baska) has no paediatric size. Depending on the sealing mechanism (Miller's classification), SGA s are divided into cuffed peri-laryngeal sealers (LMA family), cuffed pharyngeal sealers (Cobra and laryngeal tube) and uncuffed anatomically pre-shaped sealers, i-Gel, Ambu, Aura-i and AirQ are used for intubation.

Compared with the endotracheal tube, speed and ease of placement is higher in LMA. It avoids need of muscle relaxants and there is no hoarseness of voice. However, it presents lower seal pressures and higher incidence of gastric insufflations. The McNicol technique or rotational and lateral insertion with the cuff partially inflated has been used to improve the ease and success of insertion in children.

The commonly used supraglottic airway devices are summarised in Table 1.

SPECIAL ISSUES IN CHILDREN

Care needs to be taken when using SGAs in children.[20-22] There is obstruction due to down folding of the epiglottis,

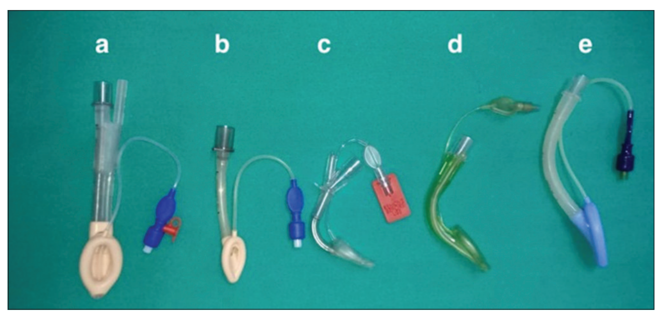

Figure 2: Supraglottic airway devices. (a) Proseal LMA. (b) Classic LMA. (c) LMA supreme. (d) AmbuAuraGain. (e) LMA classic

Table 1: Commonly used supraglottic devices in children

SAD	Sealing mechanism	Aspiration protection	Single usage	Paediatric sizes	Remarks
cLMA	Inflatable cuff with vol of air Size 1 (4 mL) Size 1.5 (7 mL) Size 2 (10 mL) Size 2.5 (14 mL)	×	×	Size1 (<5kg) 1.5 (5-10kg), 2 (10-20kg) 2.5 (20-30kg)	Reusable
LMA unique	Inflatable cuff	×	Yes	Similar	Seal pressures 17-22 cm H_2O
LMA Pro-seal	Inflatable cuff	Drainage channel	×	Similar	Posterior cuff-higher seal pressure of 27-32 cm H_2O
LMA supreme	Inflatable cuff	Drainage channel	Yes	Similar	Narrow curve - easier and stable placement
i-Gel	Pre-shaped	Drainage channel	Yes	Size1 (2-5kg) 1.5 (5-12kg) 2 (10-25kg) 2.5 (25-35kg)	Gel-like elastomeric material, adapts to the anatomic surface after introduction

SAD – Supraglottic airway device; cLMA – Classic laryngeal mask airway laryngospasm and lower leak pressures especially in small infants. Re-usable devices cause transmission of infection due to residual protein deposits and failure to denature prion. LMA is less invasive than ETT and preferred in children with upper respiratory tract infections. Significant cuff hyperinflation (90 to >120 cm H2O) is seen in children and hence routine use of cuff manometers is recommended. Gel displacement tests, bilateral chest movement and square wave capnography are used to assess the position of LMA.

LARYNGOSCOPES

The choice of laryngoscopes depends on the age of the child and user preference. The Macintosh curved laryngoscope[23-25] having reverse Z-shaped blade is popular in small children. Straight blades, for example, Miller (1946), Wisconsin, Wis-Foregger, Oxford (1952), Seward, are used to lift the epiglottis anteriorly.[5] The straight blade fits into a narrow mouth and gives better visualisation.[1,5] The Oxiport versions of both the Miller and the Macintosh blades are available in plastic single use version.[7] The light source used is a fibre-optic version. The McCoy levering laryngoscope allows mechanical manipulation of the blade tip to improve the glottic view.[26] Reusable blades can be washed, scrubbed and autoclaved or gas sterilised.[27]

Rigid optic laryngoscopes

Bullard laryngoscope is used in patients with limited mouth opening, facial fracture and cervical spine instability. It allows visualisation of the larynx without alignment of the three axes. Three sizes are available: paediatric (0-2 years), paediatric long (0-10 years) and adult.

AIDS FOR INTUBATION

Bougies are atraumatic guides over which a TT can be railroaded. Stylets are firm, malleable device that alter shape and curvature of a TT. Paediatric stylet for intubation has a radio opaque 8-Fr catheter with 35 cm length (Frova intubation catheter).[5,7]

OPTICAL INTUBATION STYLETS (INDIRECT SCOPES)

Shikani optical stylet is a malleable stainless steel fiberoptic stylet with video camera and light source. The paediatric version is 20cm long and introduced in a 2.5 mm TT. Bonfils retromolar intubation fiberscope helps intubation in children with small mouth opening. Trachlight is a plastic flexible wand with a light bulb and a retractable stylet. Light Wand and Surch-lite are lighted Intubation stylets.

OXYGEN DELIVERY DEVICES

Blow-by administration of O2

This device blows 2-6L O_2/minute. It is not recommended in premature infants as cold airstream causes reflex apnoea.

Oxygen hood

O_2 is administered through head box. FIO_2 delivered is variable. The device is user friendly. Rebreathing occurs if flow <2L/min.

Nasal prongs and catheters

O2 flow depends on the inspiratory flow rate, minute ventilation and expiratory pause. The nasopharynx acts as an oxygen reservoir. In infants <2 yrs of age FiO_2 of 0.5 is achieved by 150mL/kg.Side-streamcapnography can be done.

High-flow nasal oxygen therapy (HFNOT)

It is recommended for oxygenation and ventilation in children with minimal ventilatory efforts.The gas flow at 40-60L/min (>2L/kg/min) is used. FiO2 of 1.0 and PEEP of5 cm H_2O are given along with humidified gases.The temperature is kept at 33^0 C -34^0 C. These devices are used for acute hypoxaemic respiratory failure, to attain an apnoeic window during intubation, in cardiac surgery and de-recruitment of lung in tubeless airway surgery. In neonatal intensive care unit (NICU), family members can feed, hold and care for infants.

THRIVE (Transnasal humidified rapid inflation ventilatory exchange) and HFNOT

In 2013, Patel and Nouraei introduced warmed and humidified high-flow nasal oxygen using the OptiFlow™ system with the aim of delivering optimal preoxygenation in adult patients with known or anticipated difficult airways.[28,29]

Physiology of THRIVE

Ventilation occurs with a non-invasive nasal cannula. High-flow nasal oxygen enters the nose at 40-60L/min. (>2L/kg/min) and loops around the soft palate, and exits through the mouth creating a highly turbulent 'primary supraglottic vortex'.[30] Apnoeic ventilation is an interaction between the primary supraglottic vortex from above and cardiogenic oscillations from below. With THRIVE, the patient bypasses the nose-to-glottis resistor.

Equipments[31] used for children are Vapotherm 2000i and Optiflow Junior. They consist of nasal cannula, wide bore prongs, oxygen flow meter, air oxygen gas blender and gas analyser. Humidity is provided by disposable vapour transfer cartridge or a heated plate humidifier.

CRICOTHYROTOMY

All India Difficult Airway Association (AIDAA) recommends emergency surgical airway access whenever there is complete ventilation failure in children.[32] The small size of the cricothyroid membrane and cephalad position of the infant's larynx makes airway access techniques impractical and dangerous in small children.[33] An 18-G (neonate), 16-G (infant), or 14-G I.V can be used for cricothyrotomy.[7,33] Ventilation through a needle cricothyrotomy should always be done using a high pressure jet ventilation device like a Manujet or Sanders jet injector. A 16-G (infant) or 14-G (child) Ravussin Teflon catheter may also be used.

Cannula cricothyrotomy sets are not available for children. They are unsafe and are not recommended for use in children. A tracheostomy should be performed after a needle cricothyrotomy as early as possible in case the airway cannot be secured by noninvasive means.

VIDEOLARYNGOSCOPES

Video-laryngoscopy has made an impact in overall successful airway management both in the operating room as well as in intensive care unit.[21,34-37] It has the potential to become the first line option for intubation and for difficult airway. Studies have found that video-laryngoscopes (VLs) [Table 2 and Figure 3] are associated with better glottic visualisation, a higher success rate for difficult airways, and a faster learning curve, resulting in a higher success rate for intubations by novice physicians. Thus, unanticipated difficult intubations may be less frequent if video-laryngoscopy is used as the first-line approach.

During direct laryngoscopy, the larynx is viewed from outside the oral cavity at an angle of 15^0. During video-laryngoscopy, the digital camera and light source are mounted very close (2–3 cm) to the tip of the video-laryngoscope and close to the larynx, giving a wider angle (60°-80°).[36] Video-laryngoscopes provide a non-line-of-sight view through a screen display, providing greater visibility when advancing the tracheal tube into the trachea. Current paediatric VL has been introduced as a 'down-size' of the primary adult version.

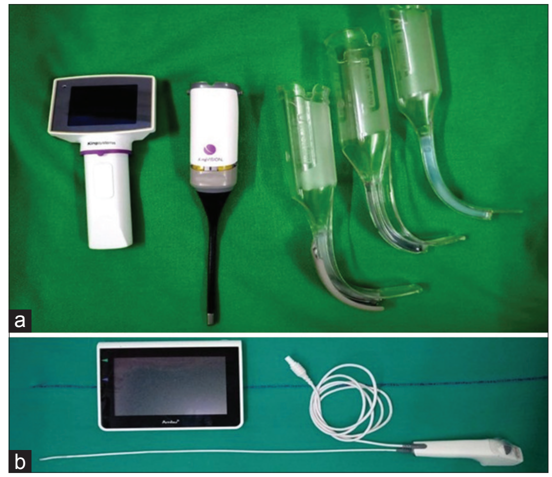

Figure 3: Video-laryngoscopes (from above downwards): (a) King Vision video-laryngoscope with disposable blades. From right to left: aBlade 1 and 2 non-channelled, 2C channelled. (b) AmbuaScope 3 (3.8/1.2)

Salient features of currently available paediatric video-laryngoscopes are summarised in Table 2.

Table 3 broadly summarises the sizes of facemasks, tracheal tubes, laryngoscopes and laryngeal masks used in paediatric practice.

FLEXIBLE FIBREOPTIC BRONCHOSCOPES

Peter Murphy first used the fibreoptic choledoscope in 1964 for nasal intubation.[38]

Technology of fibre-optics depends on the optical characteristics of thin noncoherent flexible glass fibres that undergo repeated reflection which enables reflection of light from a light source between the ends of the scope.[38-40]

The components are the eyepiece, dioptre-ring for focussing, a control lever that allows regulation of the distal end of the scope to be flexed and extended, a working channel for suction, injection of saline or local anaesthetics, oxygen insufflations and insertion of brushes and forceps and a charge -coupled device camera at the handle. [Figure 4] Ultrathin scopes for neonates and infants are available in 1.8, 2.2 and 2.7 mm sizes.[39,40]

Fibreoptic bronchoscopes facilitate endotracheal intubation in anticipated difficult airway, positioning of

Table 2: Paediatric video-laryngoscopes and flexible nonfibre videoscopes

Video-laryngoscope	Visualisation of glottis	Type of blade	Size	Recommendation	Characteristics
Glide-scope: original, ranger, cobalt	External monitor anti-fog mechanim	Angled blade models: original reusable Ranger: trans reflective reusable or single use Cobalt: blade protector no contact with patient Single use	Original: 2-5 Ranger: reusable3-4 Single use: 1-4 Cobalt: 1-4		Insertion along midline, over the back of the tongue
C-MAC Premium (KarlStorz) C-MAC S Pediatric Imager with single-use VL blade	C-MAC monitor allows simultaneous connection of several endoscope	Low blade height: 11.5mm Camera to distal tip: 19.5mm	Miller 0,1 Macintosh 0, 2 D-Blade Ped		For neonates and paediatric Meet the highest hygiene standard
Flexible intubation videoendo scope (FIVE) (KarlStorz)	Clear pixel-free images Integrated LED light source		Sizes: 3×51.5 and 4×65		FIVE3 for unexpected difficult airway
Retromolarintubation endoscope (KarlStorz)		Outer diameter 2 or 3.5 mm			Used in small mouth opening and emergencies Retromolar or medial intubation
KingVision	Anti-fog mechanism Portable battery -operated airway visualization system	Disposable blade ergonomically designed Size 2 and 3 channeled blade (ET 4.5-8 mm)	Size 1 and 2 for infant and paediatric	Hockey-stick-shaped	Model with channel requires greater oral aperture
Ambu aScope3	Ambu aView Monitor		aScope3 Slim (3.8/1.2 , bending angle 130°/130°)		Difficult airway PDT Secretion management Training No contamination
McGrath	External monitor 2.5″ anti-fog, camera mounted on blade	Single-use blade covers the reusable blade	Smallest size blade can be used in big children and adolescent	TT mounted on a stylet bent upward at 60°	Blade is introduced from midline in curved motion
Pentax Airway Scope (AWS-S200)	2.4″high-resolution colour LCD screen	Flexible image tube, ergonomic design	Disposable blade: right-sided groove for TT		
True View PCD paediatric	Oxygen insufflations (2-5L/min) Anti-fog Integratedoptical lens	True view EVO2 laryngoscope blade having fibre-optic light and 46°angulated tip			Special stylet provided
UEscope/ UEscopeMiller	Integrated 2.5″LCD monitor, anti-fogging	Angulated blade: reusable or single use	Reusable size: 1-4; disposable size: 2-4 and reusable Miller 1 Reusable Miller blade Size: 0 for neonates and 1 for infants and children <2 years Size 2 for 2-6 years Size 3 for >6 years		
Airtraq	External monitor	Anatomically shaped blade with tube channel Single use	Size: infant 2.5-3.5TT Paediatric -4-5.5TT Small - 6-7.5TT Paediatric nasotracheal		

bronchial blockers, inspection of airway for diagnostic purposes such as laryngeal pathology, post-radiation distortion, airway trauma, cervical spine injuries and extubation strategy after airway surgery.[39,40]

Nasotracheal trauma, laryngospasm, gastric distension and aspiration, subcutaneous emphysema and pneumomediastinum due to tracheal rupture are some of the complications.

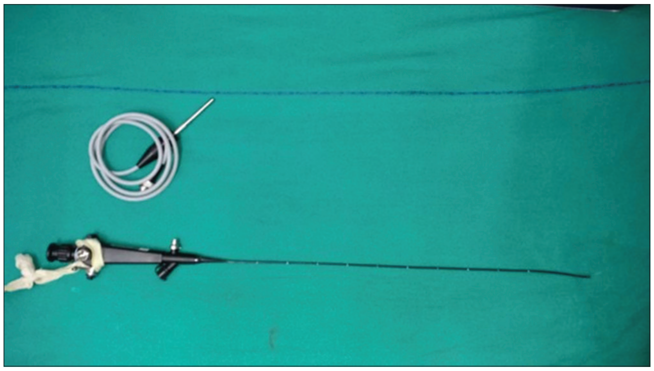

Figure 4: Fibreoptic intubation scope

Table 3: Size of common paediatric airway devices

	Preterm infant	Term infant	Paediatric
Face mask	0	1	2
Laryngoscope	0/00 (7.5cm)	1 (10 cm)	2
Endotracheal tube	2.5/3	3/3.5/4	To use formula, cuffed tube should be 0.5 mm smaller
LMA		1	<5 kg: 1
			5-10 kg: 1.5
			10-20: 2
			20-30: 2.5

LMA – Laryngeal mask airway

SUMMARY

Airway management of the paediatric patients is a challenge for anaesthesiologists. Anatomical and physiological changes continue till 10-12 years of age. The development of critical skill is utmost necessary for the anaesthesiologists for successful management of airway. The success of paediatric airway management lies not only with the expertise of anaesthesiologists but also with the development of modern airway devices and technologies.

Financial support and sponsorship

Nil

Conflicts of interest

There is no conflicts of interest.

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