Chapter 27: Advanced Airway Techniques

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INTRODUCTION

FOCUS POINTS

1. Knowledge of proper supraglottic airway insertion techniques, tests for position and performance, and maneuvers to correct malpositions are critical to successful use and the prevention of complications.
2. Video laryngoscopy provides better views of the glottis compared to direct laryngoscopy, although intubation times may be prolonged. Skill acquisition in elective cases before use in complex difficult airway situations is recommended. Corrective maneuvers in the "Can see, can't intubate" situation must be learned.
3. Difficult airway management in pediatric patients is associated with a high incidence of severe complications. Risk factors for complications are: greater than two laryngoscopy attempts, direct laryngoscopy persistence (direct laryngoscopy for first three attempts), and weight under 10 kg.
4. Supplemental oxygenation during pediatric difficult airway management is an important intervention that may reduce the incidence of severe complications.
5. Fiberoptic intubation in the small infant is challenging and requires great attention to every detail. Practicing this technique in elective normal airways is likely to result in greater rate of successful intubation when faced with a difficult airway.
6. Adequate preparation and planning decreases the need for surgical airway access. Use of a small angiocatheter technique is the preferred initial approach for front of neck access in children 1 to 8 years of age.
7. Simple airway maneuvers such as two-handed mask ventilation and adjunctive airway devices are critical in management of the difficult pediatric airway.

SUPRAGLOTTIC AIRWAY DEVICES

Supraglottic airway devices (SGAs) are devices with a ventilation opening(s) located above the glottis. Other terms that have been used include extraglottic airway devices (EADs) and periglottic airway devices (PADs). Supraglottic airway devices have also been abbreviated as SADs, but this usage is less common than SGAs. In general, SGAs may be considered a hybrid device between a face mask and an endotracheal tube (ETT). Over 30 devices are currently on the market but only a few of these are clinically useful in pediatric patients.

CLASSIFICATION OF SGAs

SGAs may be classified by brand type or by degree of sophistication.[1] The Laryngeal Mask Airway™ is the first brand and remains the most commonly used brand. Since its development in the late1980s, several brands have been developed and are increasingly being used in anesthetic practice (Figure 27-1). Other brands are classified as the non-LMA™ family of devices.

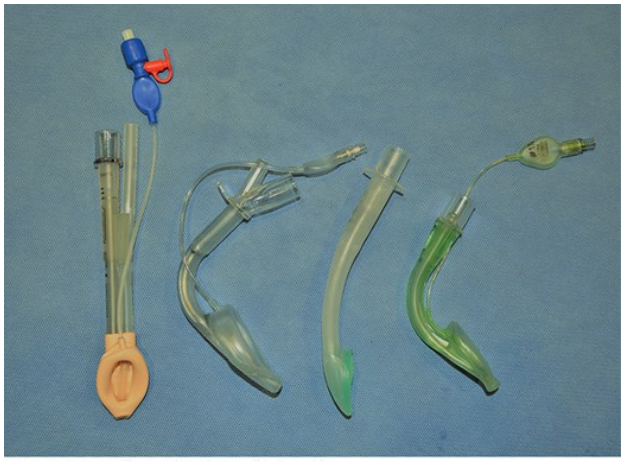
Figure 27-1

Supraglottic airway devices. Left to right: LMA Classic, LMA Flexible with Cuff pilot valve, LMA Flexible PVC, LMA Unique, Cobra Perilaryngeal Airway, LMA Unique Silicone Cuff, Ambu Aura-i laryngeal mask, Air-Q ILA, LMA ProSeal, LMA Supreme, i-gel, Ambu AuraGain, LMA Protector, LMA Gastro. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)

First-generation devices are basic airway tubes, consisting essentially of a mask bowl, an airway tube, and an inflation line. Second-generation devices have a separate channel for gastric access (Figure 27-2). This channel allows decompression of the stomach and may offer more safety.[2–6]

Figure 27-2

Second-generation SGAs. Left to right: LMA ProSeal, LMA Supreme, i-gel, Ambu AuraGain. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)



More recently, third-generation devices have been developed (Figure 27-4). These are highly sophisticated devices that are designed for advanced surgical procedures or endoscope insertion.

The Laryngeal Mask Airway™

The Laryngeal Mask Airway™ (LMA™, LMA Company, Henley, England, the United Kingdom) was invented by Dr. Archie Brain, a British anesthetist, in 1988.[7] It gained the Food and Drug Administration (FDA) approval in 1991. Over 200 million uses have been reported.

The LMA Classic™

The LMA Classic is the original SGA. It is made of medical grade silicone. When correctly placed, it creates a low-pressure seal with the supraglottic tissues and pharynx. The manufacturer guarantees each device for up to 40 uses. It is a general purpose LMA and is used for minor peripheral surgical procedures and radiological imaging such as magnetic resonance imaging. The maximum allowable cuff pressure is 60 cm H_2O.[8]

LMA Unique™

The LMA Unique™ (Teleflex® Inc., Morrisville, NC, the United States) is the same device as the LMA Classic except that it is made of medical grade polyvinyl chloride (PVC). It is designed for single use and the prevention of disease transmission. The indications for use are the same as the LMA Classic. In the United States, the LMA Unique has largely replaced the LMA Classic.

LMA Unique Silicone Cuff

The LMA Unique Silicone Cuff incorporates an integral intracuff pressure monitor. This obviates the need for a separate manometer. Cuff pressure monitor is rarely used despite mounting evidence of significant iatrogenic complications from cuff overinflation.[9] Routine cuff manometry has been recommended by several authors and may become a standard requirement in the near future.[10–13]

LMA Flexible

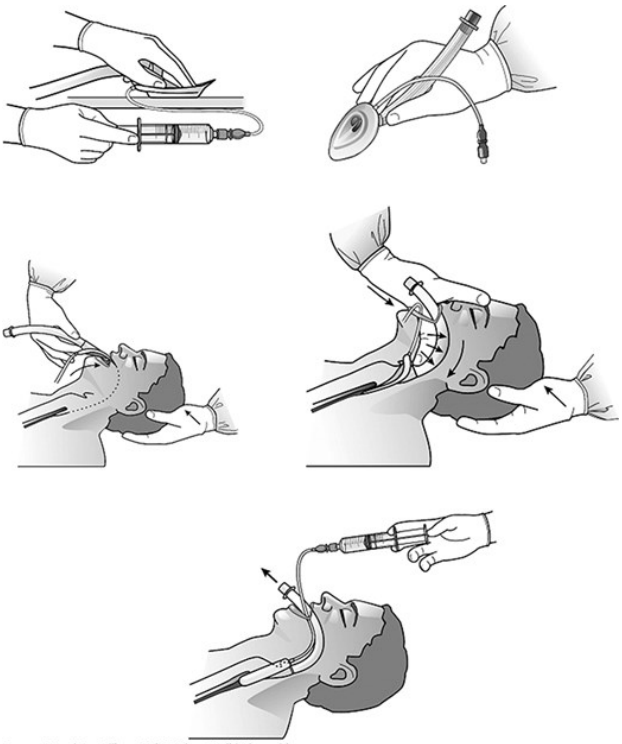
The LMA Flexible™ is a special purpose LMA designed for head and neck procedures. It is made of steel reinforced silicone or PVC airway tube to reduce the risk of kinking. The silicone version is extremely floppy and may be difficult to insert by novice users. The longer, narrower, and extremely flexible airway tube allows for fixation in any position. It is used extensively for pediatric ophthalmologic procedures, especially eye muscle surgeries. It is also used for adenotonsillectomy by expert users, especially in certain European and Commonwealth countries. It is estimated that 15% to 60% of anesthesiologists in the United Kingdom and Australia use the Flexible LMA for adenotonsillectomy.[14] Such widespread use is uncommon in the United States. The insertion technique is similar to the LMA Classic, but may be difficult for inexperienced users. Stabilization of the posterior aspect of the mask bowl on the hard palate usually facilitates insertion.

Classic Insertion Technique for First-Generation LMA™ Devices

Following inhalational induction with sevoflurane and intravenous access, propofol (1 to 2 mg/kg) may be administered to facilitate insertion. If intravenous access proves difficult, the LMA can usually be inserted under deep vapor anesthesia in most children. Generous lubrication of the posterior aspect of the mask is important for smooth insertion and reduced risk of traumatic placement (Figure 27-3). Spontaneous ventilation is commonly utilized but low-pressure mechanical ventilation (<15 cm H_2O peak pressures) may be used. The lower esophageal sphincter (LES) pressure is lower in pediatric patients; therefore high inflation pressures may cause gastric insufflation.

Figure 27-3

First-generation LMA™ insertion technique. (Image courtesy of Teleflex Incorporated. © 2020 Teleflex Incorporated. All rights reserved.)



LMA ProSeal

The LMA ProSeal™ is the original second-generation LMA device.[15] Adult sizes were introduced in 2000 and pediatric sizes followed 3 years later. Half sizes were introduced in 2004. It is made of medical grade silicone and is reusable up to 40 times. A drain tube for gastric access runs alongside the airway tube and exits at the tip of the mask. Larger sizes (sizes 3 and higher) have an additional dorsal cuff for improved seal. The wedge-shaped mask provides better plugging of the hypopharynx and an enhanced seal.[16–19] Leak pressures are 5 to 15 cm H_2O higher than the same size LMA Unique.[2] The airway tube is steel reinforced and has an integral bite block proximally and an insertion strap distally. Three insertion techniques have been described: (1) digital (index finger in insertion strap), (2) use of an introducer tool in insertion strap, and (3) bougie-assisted. The manufacturer recommends inserting the device fully deflated and well lubricated. Separation of the alimentary and airway tracts occurs when the device is correctly placed. Diagnostic tests have been described[20–22] but are rarely performed. The ProSeal LMA may be used for invasive mechanical ventilation and for advanced surgical procedures.[23] Reported complications with its use are glottic insertion, mask fold over, epiglottic downfolding, and upper airway obstruction.

LMA Supreme

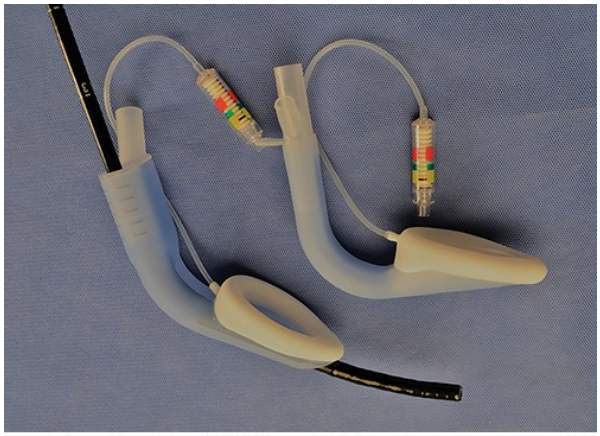
The LMA Supreme™, like the LMA ProSeal, is a second-generation SGA that is designed for advanced surgical procedures.[24] It is made of medical grade PVC and is designed for single use. Unlike the ProSeal, it lacks a posterior cuff. The airway tube is pre-curved and elliptical in shape and is bisected into two separate channels by the drain tube, which facilitates gastric access. The mask bowl is cone-shaped and provides a better plug of the hypopharynx and the glottis, thus providing a better overall seal. Leak pressures are similar to the ProSeal LMA.[25,26] In a study comparing the LMA Supreme to the LMA Unique, Jagannathan and coworkers observed no added benefit of increasing intracuff pressure from 40 to 60 cm H_2O as leak pressures were essentially unchanged.[27] Gastric insufflation rates were lower with the LMA Supreme, an advantage when invasive mechanical ventilation is used. The manufacturer recommends insertion with the mask fully deflated and with the head in the neutral or sniffing position. The manufacturer also recommends applying a piece of tape from cheek to cheek over the fixation tab prior to cuff inflation. This reduces the likelihood of outward migration during cuff inflation and may improve the seal with the airway and hypopharynx. When correctly placed, separation of the airway tract and the alimentary tract is achieved. The LMA Supreme may therefore be suitable for more invasive surgical procedures. Diagnostic tests for the LMA Supreme and ProSeal have been described but these are rarely performed.[28] The device is available in all sizes and half sizes and may be used as a conduit for intubation.

Newer Devices (Third-Generation Devices)

In recent years, new special purpose advanced LMAs have been developed. These include the LMA Protector and the LMA Gastro (Figure 27-4). There is no evidence that these devices are in wide use in pediatric patients. The size 3 is the smallest size and may be suitable for teenage patients.

Figure 27-4

Third-generation LMA devices. LMA Gastro with endoscope and LMA Protector. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)



Source: Herodotos Ellinas, Kai Matthes, Walid Alrayashi, Aykut Bilge: *Clinical Pediatric Anesthesiology*

Complications of LMA use are airway activation, oxygen desaturation, airway trauma, sore throat, hoarseness, and nerve injury. Many of these complications are the result of cuff overinflation and use of nonstandard insertion techniques.

Non-LMA™ Supraglottic Airway Devices (See Figures 27-1 & 27-2)

Air-Q Intubating Laryngeal Airway

The Air-Q® Intubating Laryngeal Airway (Cookgas, St. Louis, MO, the United States) is a non-LMA™ SGA used for routine anesthesia and as a conduit for intubation. It is manufactured of medical grade silicone. The design features appear to have advantages over earlier SGAs as a conduit for intubation in small children.[29,30] The wider, shorter, and curved airway tube as well as the detachable 15-mm connector allow for easier placement of the ETT and removal of the air-Q after intubation. It is available in three pediatric sizes: 1, 1.5, and 2. The weight recommendation and insertion technique are the same for the first-generation LMA™ devices. The manufacturer also recommends a gentle jaw lift to move the epiglottis more anteriorly and off the path of the advancing device. The larger sizes may be used for older children. Because of the wider airway tube, a larger ETT may be inserted through a relatively small air-Q. A fiberoptic bronchoscope (FOB) is recommended for intubation through the air-Q. A removal stylet is available to facilitate removal of the air-Q following endotracheal intubation.

Ambu Devices

The Ambu AuraOnce (Ambu USA, Columbia, MD, the United States) is a single-use SGA with a preformed curve. The Ambu Aura-i laryngeal mask is a modification of the original AuraOnce that is designed to facilitate intubation. Pediatric size recommendations are similar to the LMA™ with some consideration for the patient's height. The airway tube of the Aura-i is shorter, wider, and stiffer than the same-size AuraOnce. An integral bite block is present in the proximal portion. All pediatric sizes are available for clinical use. Insertion technique is similar to other first-generation devices. The Aura-i performed similarly to the air-Q as a conduit for tracheal intubation in children.[31]

Ambu-AuraGain

This second-generation SGA incorporates a drain tube in addition to the other features of the AuraOnce and Aura-i. It therefore can be used for routine anesthesia, as a conduit for intubation, and for more invasive procedures. It is available in all pediatric sizes. Markings on the device indicate its size, maximum ETT size, and maximum gastric tube size.

i-gel

The i-gel™ (Intersurgical Ltd., Wokingham, Berkshire, the United Kingdom) is a single-use second-generation SGA developed by Dr. Muhammed Nasir, a British anesthetist. Pediatric sizes were introduced in 2009. It is made of a thermoplastic elastomer gel and lacks a cuff. Its larger size may offer more stability and less risk of axial rotation. The airway tube has an integral bite block. The mask has an epiglottic rest for prevention of epiglottic downfolding. It is available in five full sizes and two pediatric half sizes (1.5 and 2.5). An integral drain tube is available in sizes 1.5 and higher. Despite the absence of a cuff, the i-gel appears to provide high seal pressures comparable to other second-generation SGAs.[32–35] It may also be used as a conduit for intubation.

DIRECT LARYNGOSCOPY

Direct laryngoscopy (DL) is used to visualize the glottis by aligning the oral, pharyngeal, and laryngeal axes. It is also called "line of sight" intubation, as a straight line is created between the eye and the glottis. An ETT can then be easily placed through the glottis and into the trachea. Endotracheal intubation is indicated for many elective and emergency procedures, especially when controlled mechanical ventilation is required. Prior to performance of DL, a thorough history and physical examination must be performed. Any contraindications or indicators of difficulty must be identified and documented.

Equipment, supplies, suction, and medications must be carefully prepared and assistance must be immediately available. Several formulae for the appropriate ETT size in pediatric patients have been described. The most widely used is **(Age + 16)/4** for an uncuffed ETT.[36] This formula is for children 2 years or older. Another commonly used method is to use the tube that approximates the size of the child's small finger. Despite a lack of scientific validation, this method has proven clinically useful.[37] Two uncuffed tubes with an internal diameter of 0.5 mm

smaller and larger should be immediately available should they be required. The leak pressure (the airway pressure at which an audible leak is heard) should be between 15 and 25 cm H_2O. This range allows for effective positive pressure ventilation without excessive mucosal pressure. If no audible leak is heard above 25 cm H_2O, a decision should be made whether to downsize the tube. The ease of initial tube placement and surgical duration are important considerations. A dose of dexamethasone (0.5 mg/kg) should be administered, if no contraindications exists, for airway swelling and postoperative nausea and vomiting prophylaxis. If a cuffed ETT is chosen, a half-size reduction is recommended. A full-size reduction may be required in certain patients at higher risk for airway swelling. When a cuffed tube is used, the gas leak can be easily controlled by inflating the cuff.

The initial depth of the ETT (cm) is as follows:

Oral: 3 × [ETT internal diameter (mm)]

Nasal: 3 × [ETT internal diameter (mm)] + 2 cm

An alternate formula is as follows:

Oral: (Age/2) + 12 cm

Nasal: (Age/2) + 15 cm

Historically, straight Miller-type blades are used for intubation in infants and small children under 8 years. They are believed to offer a better mechanical advantage when lifting the floppy epiglottis. Curved Macintosh blades may be used in older children over 8 years. Most experienced laryngoscopists can use both blade types interchangeably in infants and small children.

Standard practice for oral intubation begins with first extending the head and slightly flexing the neck.[38,39] Next, the blade (held in the left hand) is introduced from the right side of the mouth and the tongue is simultaneously "swept" to the left and displaced into the submental space. Gentle advancement of the blade will expose the tip of the epiglottis. The tip of a straight blade "lifts" the epiglottis from behind, exposing the glottic aperture. A curved blade is advanced in front of the epiglottis and into the vallecula. A gentle lifting action indirectly displaces the epiglottis and exposes the glottis. All "lifting" actions must be in the upward and forward direction. The teeth or gum line should never be used as a pivot point to lift the laryngeal structures as this can result in airway trauma. External laryngeal manipulation may facilitate visualization of the glottis.

NASOTRACHEAL INTUBATION

Nasotracheal intubation (NTI) was first described by Kuhn in 1902,[40] and then popularized in the 1920s by Magill.[41] This technique is commonly used for dental procedures, intraoral surgeries, or circumstances where orotracheal intubation is not an option (eg, intraoral mass or trismus). The nasal route is also an important path for fiberoptic intubation (FOI) as it provides a more direct route when compared to the oral route. The medial wall of the nasal cavity is formed by the nasal septum. The lateral wall is formed by the medial wall of the orbit and characterized by three nasal conchae (turbinates). With the inferior turbinate being the most prominent, it has the highest risk of being sheered with passage of an ETT, which would lead to massive epistaxis. Superiorly, the nasal cavity narrows toward the cribriform plate of the ethmoid bone, which separates it from the anterior cranial fossa. The nasotracheal route is contraindicated in patients with suspected basilar fractures since damage to the cribriform plate can lead to intracranial placement of the ETT. The sphenopalatine artery provides a majority of the blood supply to the nasal cavity. It forms anastomoses with other arteries in the anterior portion of the nasal septum called Kieselbach's plexus, also known as Little's area. This location is the most common source of epistaxis with placement of a nasal ETT. This technique is contraindicated in patients with a significant coagulopathy given the risk of bleeding. Assessment of the patient prior to this technique should include an evaluation for nasal polyps or septum deviation. Preparation for the procedure includes topicalization of the nasal airway with vasoconstrictors such as oxymetazoline or cocaine to minimize epistaxis, and the use of serial dilation with incrementally sized nasopharyngeal airways (NPAs) lubricated with a local anesthetic such as lidocaine. The right naris is traditionally preferred over the left since it makes subsequent laryngoscopy easier and facilitates use of the Magill forceps (Figure 27-5). With insertion of the ETT into the naris, the bevel should be facing the lateral wall, thereby orienting the tip of the tube toward the medial wall and away from the turbinates located on the lateral wall. The ETT should be passed posteriorly and parallel to the hard palate. Any resistance should not be forced forward, but rather withdrawn, rotated, and advanced again. A loss of resistance indicates passage into the oropharynx, at which point direct or video laryngoscopy should be performed to visualize the ETT. Using a Magill forceps, the tip of the ETT should be aligned with the glottic opening and then advanced (Figure 27-6). In situations where direct or video laryngoscopy is not possible, fiberoptic remains the gold standard. Abrons and co-workers recently described a NPA guided, bougie assisted (Seldinger technique), NTI.[42] The authors observed similar intubation success rates, decreased incidence and severity of nasopharyngeal trauma, and decreased requirement for transoral manipulation with a Magill's forceps.

Figure 27-5

Magill forceps. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)

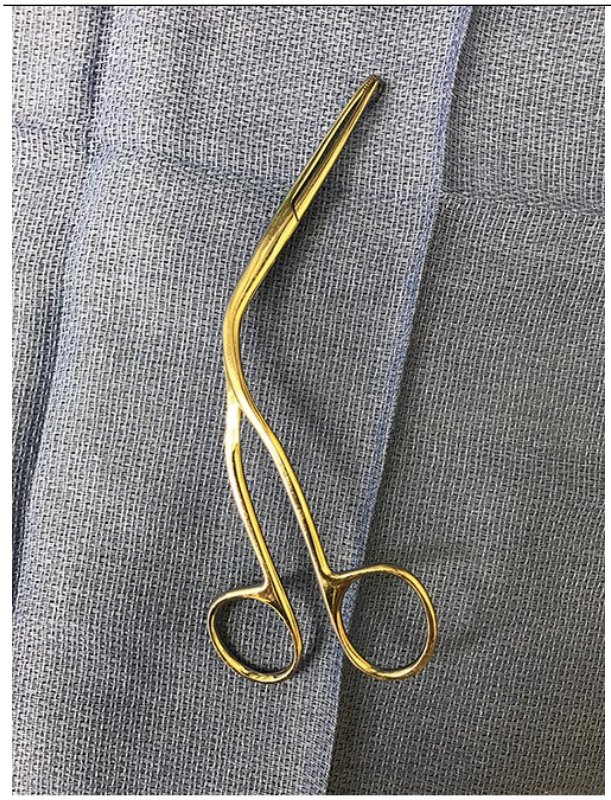
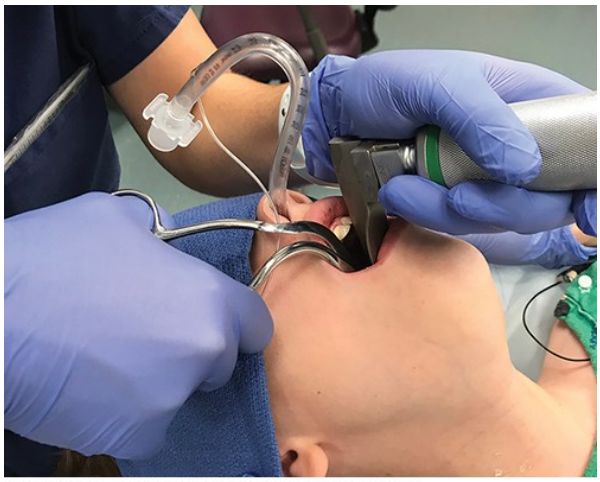


Figure 27-6

Demonstrating advancement of a nasotracheal tube with a Magill forceps under visualization with direct laryngoscopy. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)



ENDOTRACHEAL TUBES

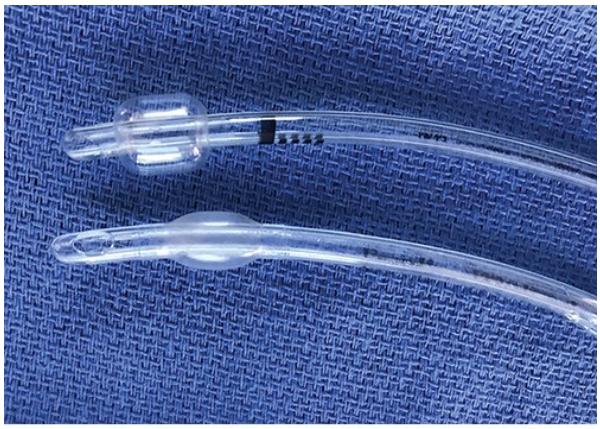
Microcuff

Microcuff tubes (Microcuff Pediatric Tracheal Tube, Microcuff GmbH, Weinheim, Germany; Microcuff PET, Kimberly Clark, Health Care, Atlanta, GA, the United States) are unique high-volume/low-pressure cuffed ETTs. The hallmark of the microcuff is its ultra-thin (10 µm) polyurethane cuff, which replaces the thicker (50 to 70 µm) PVC cuff of traditional ETTs (Figure 27-7). With removal of the Murphy eye, the cuff is placed more distally on the shaft of the tube to ensure cuff placement below the subglottis. The cylindrical shape of the cuff makes uniform and

complete contact with the tracheal wall without the formation of folds or channels. This allows for an airway seal at cuff pressures of approximately 10 cm H_2O, significantly lower than the 20 cm H_2O routinely required of traditional cuffed ETTs. Microcuff tubes have the potential to reduce tracheal mucosal edema, post-extubation stridor, and minimize the tube exchanges seen with sizing uncuffed ETT.[43] As with all ETTs, microcuff tubes require routine cuff pressure evaluation during their use. With ultra-thin polyurethane being highly permeable to nitrous oxide, these tubes are exceptionally vulnerable to hyperinflation with nitrous oxide use. When adopting the use of microcuff tubes, it is important to consider a cost–benefit analysis, since the cost of microcuff tubes can be several times that of traditional ETT.

Figure 27-7

The cuff of a Microcuff® endotracheal tube (top) next to a traditional endotracheal tube cuff (bottom), note the more distal, uniform, and cylindrical cuff of the Microcuff tube. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)



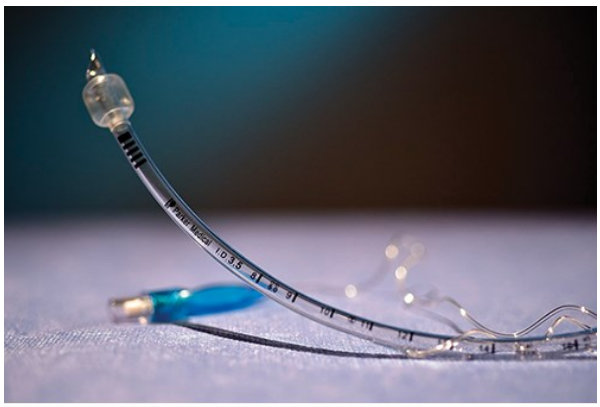
Source: Herodotos Ellinas, Kai Matthes, Walid Alrayashi, Aykut Bilge: *Clinical Pediatric Anesthesiology*

Parker Flex-Tip

This ETT is designed to facilitate atraumatic intubation past the vocal cords, large nasal turbinates, or other possible areas at risk for trauma. The flexible, curved, and tapered tip of the tube allows for smooth passage while limiting the risk of it getting hung up (Figure 27-8). Other unique features of the tube include a downward facing bevel, and a murphy eye on each side of the tip. This tube is available in various designs, such as nasal, reinforced, uncuffed, and oral.

Figure 27-8

Parker Flex Thin-Cuff endotracheal tube. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)



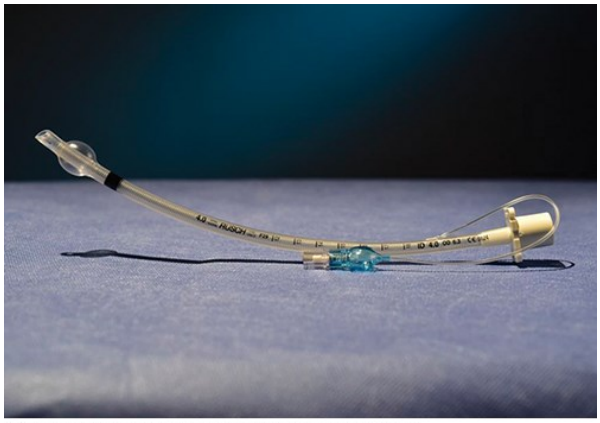
Source: Herodotos Ellinas, Kai Matthes, Walid Alrayashi, Aykut Bilge: *Clinical Pediatric Anesthesiology*

Reinforced

Armored or reinforced tubes are defined by the flexible spiral wire that fortifies the wall of the ETT (Figure 27-9). The flexibility of the wire allows the tube to hold any formed shape and makes it kink-resistant. These features make the tube ideal for situations where there might be a risk for obstruction or kinking by surgical equipment, airways with unique angles, or prone positioning. While these tubes are kink-resistant relative to standard ETTs, they can be kinked by significant force. Once kinked, the spiral wire will not re-expand; therefore, it is important to safeguard against any significant force that might permanently kink and obstruct the tube. It is always prudent to use a bite block whenever possible when using a reinforced tube.

Figure 27-9

Reinforced endotracheal tube. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)



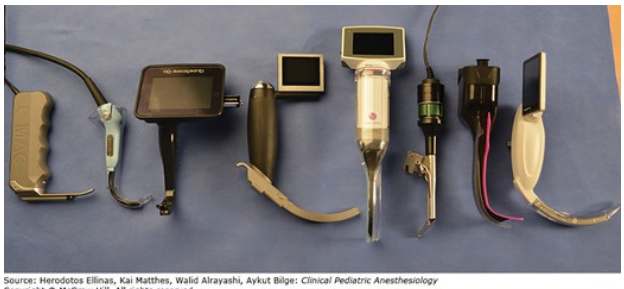
Source: Herodotos Ellinas, Kai Matthes, Walid Alrayashi, Aykut Bilge: *Clinical Pediatric Anesthesiology*

VIDEO LARYNGOSCOPY

Video laryngoscopes are devices that provide an indirect view of the larynx by using miniaturized video cameras and a light source. The image is transmitted to a display screen. Video laryngoscopes provide a wide angle and magnified view of the glottis and pharynx. In general, video laryngoscopes provide a one to two grade improvement in the Cormack and Lehane grade when compared to DL. Intubation times are, however, prolonged when compared to DL.[44-47] Their ability to see around the corner offers advantages in certain difficult intubation situations. Several devices have been introduced over the past 15 years and some of these are shown in Figure 27-10.

Figure 27-10

Video laryngoscopes. Left to right: C-MAC, GlideScope Cobalt baton and Stat blade, GlideScope Go portable monitor, McGrath MAC Series 5, King Vision, Truview PCD, Airtraq, McGrath MAC. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)



Source: Herodotos Ellinas, Kai Matthes, Walid Alrayashi, Aykut Bilge: *Clinical Pediatric Anesthesiology*

Classification of Video Laryngoscope Blades

Video laryngoscopes are classified into three groups: standard geometry blades (nonangulated video laryngoscope blades), hyperangulated blades (angulated video laryngoscope blades), and channeled devices. Normal geometry blade types are similar to the commonly used Macintosh and Miller DL blades and include the C-MAC, Storz DCI, Truview, and GlideScope® Direct. The hyper-angulated blades are the GlidesScope, King Vision, McGrath series 5, McGrath MAC, and the Storz D-Blade. Video laryngoscopes with a guiding channel are as follows: the Airtraq, King Vision, and Pentax Airway Scope. An overview of video laryngoscopes is presented in Table 27-1.

Table 27-1

Overview of Commonly Used Video Laryngoscopes

Brand	Manufacturer	Blade Type	Pediatric Blades	Anti-Fogging Mechanism	Oxygen Insufflation	Use for Direct Laryngoscopy	Recording Capability	Blade Use	Field of View (Degrees)
GlideScope	Verathon Inc.	Hyperangulated	Yes	Yes	No	No	Yes	Single and reusable	45–53
C-MAC	Storz	Standard geometry and hyperangulated D-blade	Yes	Yes	Yes (separate attachment on blade)	Yes	Yes	Reusable and single	80–90
TruView PCD	Truphatek	Standard geometry	Yes	Yes (by oxygen flow)	Yes	No	Yes	Reusable	42
King Vision	Ambu Medical	Hyperangulated and channeled	Yes	Yes	No	No	Yes	Single	54
McGrath MAC	Aircraft Medical and Medtronic	Standard geometry	Yes	No	No	Yes	No	Single	N/I
PAWS	Pentax and Ambu Medical	Channeled	Yes	No	No	No	Yes	Single	N/I
Airtraq	Prodol Meditech and Teleflex	Channeled	Yes	Yes	No	No	Yes	Single	60

N/I, no information.

Source: Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas, Dr. Edgar E. Kiss, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas, Dr. Asif Khan, Boston Children's Hospital/Harvard Medical School.

Standard Geometry Blades (Nonangulated Video Laryngoscope Blades)

C-MAC Video Laryngoscope (Karl Storz, Tuttlingen, Germany)

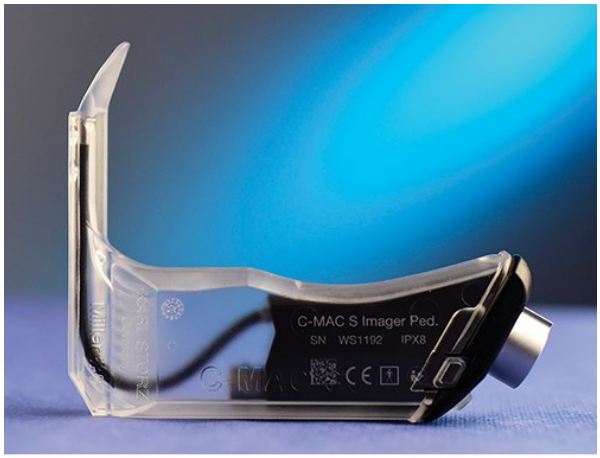
This is the latest iteration of the Storz DCI system (Figure 27-11). It is a normal geometry blade, similar to the Macintosh and Miller blades. The complex optical system consists of a high-definition miniaturized camera, very bright LED, and a wide-angle lens. The image is transmitted by cable to a 7-inch monitor. A portable pocket monitor is also available. Miller #0, #1, and MAC #0 blades are available for infants and young toddlers. Disposable Miller 0 and 1 blades have recently been introduced and are used with the pediatric C-MAC imager (Figure 27-12).

Figure 27-11

C-MAC. New C-MAC standard pediatric blades and D blade (top right). (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)

Figure 27-12

C-MAC S Pediatric Imager with single use Miller #0 blade. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)

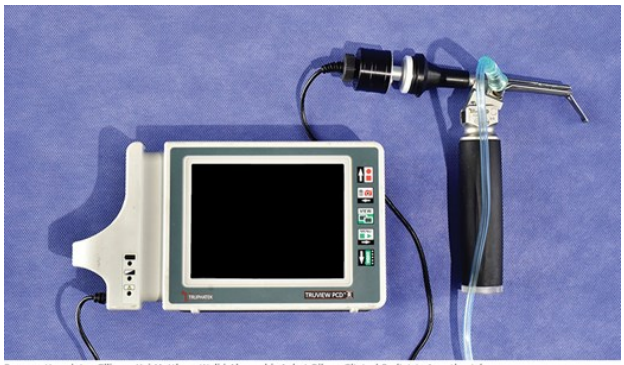


Truview Picture Capture Device (PCD) Video Laryngoscope (Truphatek International Limited, Netanya, Israel)

The Truview PCD has reusable steel blades for use in infants and adults (Figure 27-13). The optical tube has a lens and a prism. A 46-degree inferior refraction provides an improved view of the larynx. A side port for deep oxygen insufflation is also available. The oxygen flow also defogs the lens and clears secretions. Use of the Truview PCD has been shown to delay oxygen desaturation during laryngoscopy in children.[48]

Figure 27-13

Truview PCD video laryngoscope. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)



Hyperangulated Blades

GlideScope® Video Laryngoscope (Verathon Medical, Bothell, WA, USA)

The GlideScope® video laryngoscope is the first modern video laryngoscope and was introduced in 2001.[49] The Cobalt system is the most commonly used in children (Figure 27-14). It consists of the video baton, which is enshrouded by a disposable blade. Sizes 0, 1, 2, and 2.5 are available for pediatric patients. Olomu and co-workers found a high first-attempt success rate and improved glottic views in infants and children weighing less than 10 kg.[50] Sizes 3 and 4 are used in older children and have a larger video baton. Recently, the GlideScope® Spectrum system (Figure 27-15) was introduced into pediatric practice. The camera and LED are integrated into the blade, removing the need for a separate baton. The black single-use blades are more ergonomic, have a lower profile, and allow for improved maneuverability. Images are transferred to the monitor via a "smart connector" cable that attaches to a High-Definition Multimedia Interface (HDMI) output on the blade. Furthermore, the brighter LED light and reduced ambient light distortion provide a much higher image resolution. Sizes 1 and 2 blades are available for pediatric use and are accompanied by an appropriately curved stylet (Gliderite®). Both blades were found to be highly effective for intubation in normal infant, difficult infant, and child manikin models.[51]

Figure 27-14

GlideScope Cobalt system with appropriately styletted endotracheal tube. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)

Figure 27-15

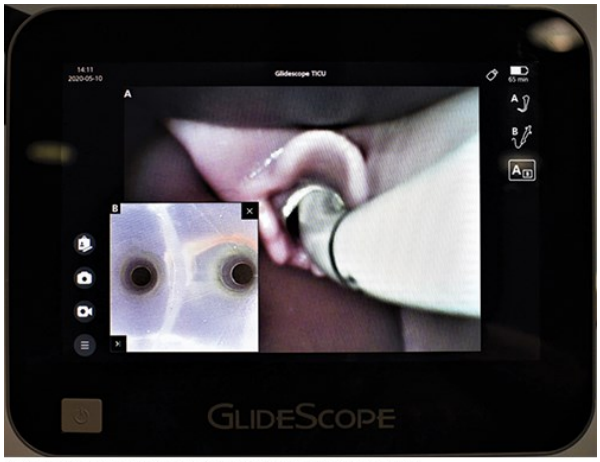
GlideScope Spectrum with pediatric Glidrite® stylet. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)

Steps for proper use of the GlideScope® video laryngoscope are as follows: prepare and check equipment, select patient-appropriate baton/blade, select appropriate ETT, insert stylet into ETT and shape to approximate the curve of the blade, slowly insert the blade midline into the mouth and visualize oropharyngeal structures looking for any abnormalities, center the uvula in the middle at the bottom of the screen, advance the blade slowly until the tip of the epiglottis is visualized, continue advancing the blade until the best view of the glottis is obtained, center the image as close as possible to the imaginary center of the monitor, and insert the tube directly behind the blade or from the right side. Look in the mouth to follow the tube until the tip of the tube appears on the monitor, advance the ETT to the glottic opening, and slowly remove the stylet.

In "can see, can't intubate" situations, the following steps may be beneficial: ensure image is centered on the display screen, gently back up the stylet and advance ETT slowly while rotating the ETT clockwise or counter-clockwise, and aligning the glottic aperture with the ETT by intentionally decreasing the airway grade (by decreasing the traction on the tongue). Reverse loading of the ETT on the stylet may also be attempted. This is done by placing the Murphy eye of the ETT anteriorly. Stylet withdrawal returns ETT to its original form in a rotational movement facilitating intubation. A FOB may also be used as a maneuverable stylet to advance the ETT into the trachea. Most recently, Verathon has released a new monitor for comprehensive airway visualization. The GlideScope® Core™ (Figure 27-16) offers a high-resolution 10-inch touchscreen monitor with simultaneous (picture-in-picture) display. This allows simultaneous displays of both the video laryngoscope and flexible digital scope (BFlex™) images. Each of these modalities may be used alone or in combination (see the section "Hybrid (Combined) Techniques"). The monitor also has an integral pulse oximeter for line-of-sight monitoring of oxygenation during difficult airway management.

Figure 27-16

GlideScope Core touchscreen monitor. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)



C-MAC Video Laryngoscope (Karl Storz, Tuttlingen, Germany)

The pediatric D (Dörges) blade is a hyperangulated blade designed for extremely difficult airways (Figure 27-11). It allows the use to "see around the corner." This blade may be unsuitable for small infants. An adult-size blade is also available and may be used in older children. Single-use adult D blades for use with an adult imager have recently been introduced.

King Vision Video Laryngoscope

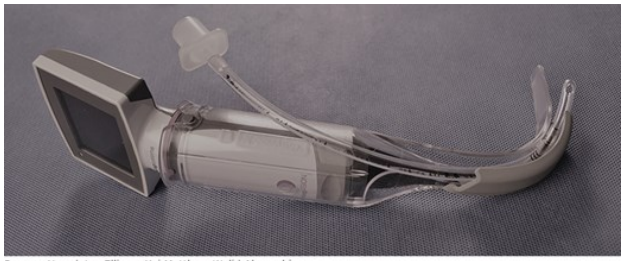
The King Vision® Video Laryngoscope (Ambu USA, Columbia, MD, the United States) is a portable hyperangulated blade for indirect laryngoscopy. The video baton has an integrated camera, an LED light source, and a portable monitor (Figure 27-17). The disposable blade enshrouds the baton and the image is projected on a 2.4-inch monitor. Sizes 1, 2, and 2C (Channeled) blades are available for pediatric use (Figure 27-18). Even though no recording capability is available on the portable monitor, an output port allows projection to compatible monitors in the operating room. A 10-mm mouth opening is required for the standard blade, while the channeled blade requires a 13-mm mouth opening. A recent study comparing the King Vision Video laryngoscope to a standard Miller direct laryngoscope found the King Vision to be equally effective for tracheal intubation in children 2 years or younger.[52]

Figure 27-17

King Vision video laryngoscope (regular). (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)

Figure 27-18

King Vision blade with guiding channel. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)



McGrath Series 5

The McGrath® Series 5 (Aircraft Medical, Edinburgh, UK) is the original portable video laryngoscope (Figure 27-10). The adjustable steel blade may be fastened from the equivalent of a size 3 to 5 MAC blade sizes. The blade may also be disarticulated from the handle and inserted into the mouth before rearticulation. Only one disposable blade size is available.

McGrath MAC

The McGrath® MAC (Aircraft Medical, Medtronic Medical, Dublin, Ireland) is the improved version of the McGrath Series 5. The ergonomic handle houses a lithium battery and a larger monitor (Figure 27-10) Unlike series 5, the steel blade is not adjustable. The device comes with a standard size 3 blade and two smaller pediatric blades (sizes 1 and 2). Four standard blade sizes (1-4) are available for clinical use. Recently, a hyperangulated size 3 X-blade was introduced for the very difficult airways. A new third generation device has also recently been introduced, with higher image resolution, brighter LED light, and auto shut-off to conserve battery drainage.

Channeled Devices

Airtraq Optical Laryngoscope

The Airtraq® (Prodol Meditec, Vizcaya, Spain) is the prototype channeled device (Figure 27-19). The optical tube consists of a series of prisms and lenses that transfer the image to an eyepiece. A camera head or an adapter can then transfer the image to an external monitor, a clip-on monitor, or a smartphone screen. The specialized Airtraq camera can also project the image wirelessly to a larger monitor such as an iPad. Color-coded devices are available in several sizes from infants to adults. The gray and purple colors are for infant and young toddlers, respectively (Figure 27-20). The device is inserted in the midline and advanced slowly until the epiglottis is visualized. Further advancement to the vallecula or gently lifting of the epiglottis provides a clear and magnified view of the glottis. Centering the image on the monitor appears to facilitate insertion. The ETT is slowly advanced through the glottis and into the trachea. The proximal part of the ETT is then "peeled away" from the guiding channel. The Airtraq may be used with a FOB as part of a combined technique should ETT advancement proves difficult. The Airtraq provides a better view of the larynx compared with DL, but time to intubation is longer.[53]

Figure 27-19

Airtraq SP with Wi-Fi Camera and endotracheal tube. (Image courtesy of Teleflex Incorporated. © 2020 Teleflex Incorporated. All rights reserved.)

Source: Herodotos Ellinas, Kai Matthes, Walid Alrayashi, Aykut Bilge: *Clinical Pediatric Anesthesiology*

Figure 27-20

Infant Airtraq with endotracheal tube. (Used with permission, from Dr. Edgar E. Kiss, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)

Source: Herodotos Ellinas, Kai Matthes, Walid Alrayashi, Aykut Bilge: *Clinical Pediatric Anesthesiology*

FIBEROPTIC BRONCHOSCOPES

The history of bronchoscopy began in the late 1870s when Gustav Killian used a rigid bronchoscope to successfully extract a foreign body from a farmer's respiratory tract.[54,55] However, it was not until 1968 that Machida Endoscope and Olympus produced the FOB initially proposed by Shigeto Ikeda in 1966. The FOB was quickly recognized for its unique characteristics and became an instrument of choice for difficult intubation management and other diagnostic purposes. Olympus, Pentax, Vision Sciences, Ambu, and Karl Storz are current major manufacturers of various bronchoscopes.[56–61]

Design

The handle, insertion tube, and flexible tip are the three main parts of the fiberscope. A light source that is either battery powered or connected to an external light source is attached to the handle. The visual section of the handle located proximally is composed of an eyepiece and lens, a video output adaptor, or a video screen with an integrated camera. The focus is adjusted by a focus ring near the handle (Figures 27-21 and 27-22). The insertion tube is the part of the FOB that goes into the patient and ranges from 50 to 65 cm in length, depending on the manufacturer. Its outer diameter (OD) determines the minimum internal diameter (ID) of the ETT in which the FOB can pass. The neonate and infant FOB made by Pentax and Olympus have the smallest external diameter of 2.4 and 2.2 mm, respectively, and will accommodate an ETT as small as 2.5 mm (ID). The flexible tip can bend as much as 350 degrees using the controller on the back of the handle. However, the glass fibers are sensitive to excessive bending and pressure especially if the tip of the FOB is still in the ETT, which can damage the scope (Figure 27-23). The working channel runs the length of the FOB to the tip of the scope. This channel allows for administration of medication and adding suction. Connecting oxygen to the working channel should be avoided in infants and some children as this may cause overinflation of the lungs resulting in barotrauma.[62–64] "Single-use" FOB either with a disposable sheath-like protective barrier (Vision Sciences) or completely disposable digital bronchoscopes (Ambu® aScope™, Storz Five S, and Verathon BFlex™) have recently been developed to help avoid cross-contamination and protect immunocompromised patients (Figures 27-24 through 27-26). These "non-fiber-optic" scopes use a CMOS (complementary metal oxide semiconductor) sensor, thereby eliminating fiberoptic wires that are prone to breakage.[65–67]

Figure 27-21

Parts of the fiber-optic bronchoscope. Top: neonate fiber-optic bronchoscope (FOB). Bottom: child/adult-sized FOB. The handle consists of the working channel (A), lens (B), distal flexible tip control lever (C), light source adaptor port (D), suction valve port (E), and focus ring (F). (Used with permission, from Dr. Edgar E. Kiss, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)

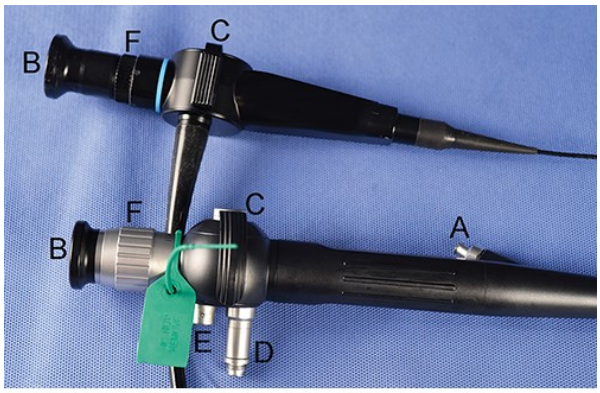


Figure 27-22

Handle of a neonate intubating bronchoscope. The thumb is positioned to maneuver the flexible tip up or down while the other opposite hand guides the distal end of the insertion tube. (Used with permission, from Dr. Edgar E. Kiss, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)

Figure 27-23

Various sizes of intubating fiber-optic bronchoscopes. (A) Olympus neonate bronchoscope with external diameter of 2.2 mm, lacking a working channel; (B), (C), (D) Karl Storz FOBs sizes 2.8-, 3.7-, 5.2-mm external diameter include a working channel. Penny included for scale. (Used with permission, from Dr. Edgar E. Kiss, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)

Figure 27-24

Ambu aScope single-use digital scope. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)

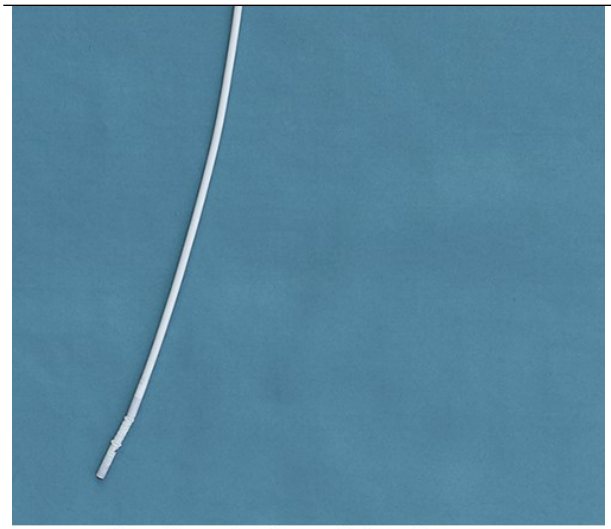


Figure 27-25

Storz Five S single-use digital scope (pediatric). (Image courtesy of KARL STORZ. ©2020KARL STORZ Endoscopy-America, Inc. All rights reserved.)

Figure 27-26

Verathon Bflex single-use digital scope. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)

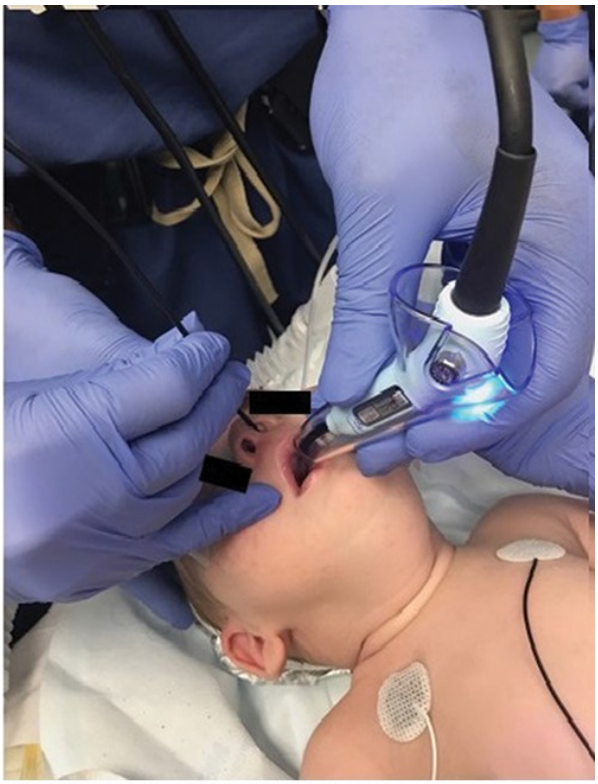
Indications and Contraindications for Use of Fiberoptic Intubation in Pediatrics

Fiberoptic intubation (FOI) has become the "gold standard" for patients where traditional DL may be difficult or even impossible. It can be used to intubate in various patient positions, through the nasopharynx or orally, troubleshoot ventilation problems, and confirm ETT position during conventional ventilation or single lung ventilation. In patients with concern for an unstable cervical spine, FOI has been shown to result in minimal cervical spine motion.[68] Due to the wide range of syndromes with the possibility of associated congenital abnormalities in infants and children, the FOB is an important tool for managing the pediatric difficult airway.[69,70] The contraindications for FOI are few but include lack of skill and training with the FOB, near complete total airway obstruction, and significant amounts of blood in the airway that may obscure the distal lens.[62] Passing the ETT blindly over the FOB may cause trauma to airway

structures, especially the vocal cords. A combined technique with video laryngoscopy (Figure 27-27) or direct laryngoscopy can allow for better visualization of the ETT passage past the cords.

Figure 27-27

Combined technique. Video laryngoscopy used to aid in visualization of nasal endotracheal tube passage through the cords over the fiber-optic scope. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)



Planning and Techniques

The anesthetic management of the pediatric patient with a difficult airway starts with a thorough review of the medical record including all prior anesthetics and a detailed history and physical examination. Usually, the ability to mask ventilate or not is a critically important factor and greatly influences the airway management plan. If the FOB is chosen to be deployed or as a backup, all components should be checked for functionality and visually inspected for damage. Once the appropriate FOB size is selected for the patient, the ETT is loaded onto the lightly lubricated insertion tube and held in place proximally by a piece of tape. Some newer digital scopes have a tube-holding mechanism. All other routine and backup airway management devices should be inspected prior to induction of anesthesia.

Adolescents and young adults will have the greatest success rates of awake FOB intubation with mild sedation and local anesthetic topicalization of the airway. However, a vast majority of patients with difficult airways also have coexisting developmental delays that will make an awake attempt nearly impossible.[71] For this reason, FOB intubation in infants and children are mostly performed under general anesthesia (GA) or moderate to deep sedation depending on the situation. Patient preparation without intravenous access includes premedication with an oral anxiolytic (midazolam 0.5 to 0.7 mg/kg). If the patient has intravenous (IV) access, midazolam intravenously (0.1 mg/kg up to 2 mg) usually provides enough anxiolysis for separation from the parents. Intramuscular ketamine combined with midazolam and glycopyrrolate as well as intranasal dexmedetomidine or midazolam with lidocaine administration are also options in uncooperative patients. In patients who still do not tolerate peripheral intravenous access after premedication, inhalation induction with a non-pungent inhalational agent (sevoflurane) is acceptable. The vasodilatory effect of inhalation anesthetics aids in obtaining an IV access shortly after induction. The recent advent of vein-viewer technology and improved ultrasound-guided PIV techniques increase the likelihood of success.

After the patient is brought to the operating suite and standard anesthesia monitors are placed, anesthesia is induced either via the inhalational or intravenous routes. Maintenance of spontaneous ventilation is desirable while performing FOI until a definitive airway is established. Spontaneous ventilation can be achieved with titration of propofol and minimizing any narcotics. Due to its narrow therapeutic margin, propofol may cause apnea and must therefore be administered very slowly in this situation. Ketamine has a lower incidence of apnea and may be titrated to desired effect. Dexmedetomidine is devoid of airway depressive effects but may cause intraoperative hypotension and prolonged sedation during recovery. Supplemental oxygen should be provided during FOI attempts through either nasal cannula, high-flow nasal cannula, or oral RAE tube taped to side of mouth.[72] A modified NPA with a 15-mm ETT connector may also be used with an anesthesia breathing system (Figure 27-34). Glycopyrrolate at the antisialogogue dose of 5 mcg/kg should be administered prior to FOI attempts, especially if ketamine is used.

Nasotracheal intubation offers the most direct route for passage of the FOB into the trachea. The bed is lowered and the patient is positioned with the head in a neutral position. An ETT tube

half-size smaller than for the oral route should be used for NTI. Oxymetazoline 0.05% or phenylephrine 0.5% intranasal sprays increase the nasal airway lumen size and decrease the risk of bleeding. Lidocaine 2% to 4% spray/gel/paste may also be applied intranasally but may not be necessary if the patient is under GA. The FOB is inserted into one of the nares and advanced under direct visualization. A lubricated breakaway NPA may be used in older children to aid in passage of the FOB.[73] Care must be taken not to damage the adenoid tissue. The "spray as you go" of local anesthetic consisting of lidocaine 2% or 4% helps avoid hemodynamic changes during attempts making sure to avoid LA toxicity.[74] A jaw thrust and/or tongue pull will help open the posterior oropharynx for better exposure of airway structures. Gauze is used to pull the tongue forward but a stitch at the tip of the tongue may also help in extreme circumstances. The tip of the FOB usually requires some degree of forward flexion to advance through the vocal cords but quickly needs to be relaxed or retroflexed to continue down the trachea. The ETT is then advanced over the FOB into the trachea being mindful of any resistance met along the way. Forcing the ETT when resistance is met may cause trauma, vocal cord injury, or damage to the FOB.

For oral FOIs, the FOB is inserted through the mouth, down the midline avoiding any blind advancement and follows the same steps outlined above. Care must be taken when progressing below the level of the vocal cords, keeping in mind that the funnel-shaped infant larynx is narrowest at the level of the cricoid cartilage.[75]

Failure of FOB-Assisted Intubation

The lack of experience with the FOB has been heralded as the most common cause of failure of FOIs. A support system of experienced personnel who are ready to assist and quickly troubleshoot will likely increase the success rates and minimize the risks. Other reasons for difficulties include the FOB tip exiting through the Murphy's eye of the ETT, hanging up at the arytenoids, and mistaking the esophagus for the trachea due to indentation-like rings in the esophageal anatomy. Since fogging, blood, and secretions can make identifying structures difficult, some have advocated concurrent use of the video laryngoscopy to visualize the passage of the FOB and ETT through the vocal cords.[62,76]

PRINCIPLES OF DIFFICULT AIRWAY MANAGEMENT

The American Society of Anesthesiologists (ASA) defines a difficult airway (DA) as: "The clinical situation in which a conventionally trained anesthesiologist experiences difficulty with face mask ventilation of the upper airway, difficulty with tracheal intubation, or both." The overall incidence of difficult laryngoscopy (Cormack and Lehane grade III/IV) in pediatric patients is 1.35% with a higher incidence in infants (4.7% vs. 0.7%) compared to older children.[77] Fiadjoe et al. found an incidence of 2 to 5 difficult intubations per 1000 intubations based on findings from the Multicenter Pediatric Difficult Intubation Registry (PeDIR).[78] Predictors of DA include micrognathia (small jaw), midface hypoplasia, obstructive sleep apnea, microtia (especially when bilateral), and neck immobility. The six most common syndromes associated with difficult intubation are Pierre Robin sequence, hemifacial microsomia, Klippel–Feil sequence, Treacher Collins syndrome, epidermolysis bullosa, and Hurler syndrome (unpublished report from the Multicenter PeDIR database). The majority of DA patients have a known syndrome whereas a small fraction have an unknown syndrome or no syndrome at all. Management of the difficult airway begins with a detailed history and physical examination. A history of any coexisting medical problems, especially congenital heart disease, should be sought. Records of prior anesthetic management should be carefully reviewed.

Physical examination should focus on mouth size and opening, jaw size, tongue size and neck mobility. Imaging of the airway and associated structures may be required in a small subset of patients with severe disease. Such imaging may include plain radiographs, computerized tomography, magnetic resonance imaging, and ultrasonography. A comprehensive plan for airway management should include the following: experience of the staff/team, sedation/induction technique, availability of ancillary devices/techniques, method of intubation, method of oxygenation during and between attempts, and a logical order of technique/device selection. The common adage is that plans A, B, and C must be clearly defined and communicated to all team members. A plan for rescue and extubation must also be made. Team members should always debrief following DA management. Most institutions will have a difficult airway cart in the operating room and at other locations, such as the pediatric intensive care unit and the emergency department. Their contents will depend on local needs and preferences. In general, it should include a wide array of basic and advanced airway devices and a device for a surgical airway.

COMPLICATIONS OF DIFFICULT AIRWAY MANAGEMENT

Complications of difficult airway management are classified as severe and nonsevere.[78] Severe complications include severe hypoxemia, pneumothorax, severe airway trauma, aspiration, esophageal intubation with delayed recognition, emergent surgical airway, and cardiac arrest. Non-severe complications are minor airway trauma, pharyngeal bleeding and epistaxis, arrhythmias without hemodynamic consequences, bronchospasm, laryngospasm, esophageal intubation with immediate recognition, and short-lived hypoxemia (10% below preintubation saturation and lasting <45 seconds). Risk factors for severe complications are weight under 10 kg, greater than two intubation attempts, and persistence with direct laryngoscopy (DL for first three attempts).[78] Administration of supplemental oxygen during difficult airway management can prevent severe hypoxemia and other severe complications. For use of nasal cannula, modified oral RAE tube to the side of the mouth, and use of a modified NPA see the section "Ancillary Airway Techniques."

EXTUBATION OF THE DIFFICULT AIRWAY

Post-extubation respiratory complications occur very frequently.[79] Extubation planning is therefore a critical part of difficult airway management. Consideration must be given to location of the planned extubation, staffing, and techniques to maintain an airway. Most importantly, equipment for reintubation must be immediately available. If airway trauma occurred during difficult airway management, steroids should be given and delayed extubation may be indicated. An airway exchange catheter or guidewire may be used for airway access following extubation. In general, awake extubation is recommended following difficult airway management. Extubation planning should be documented and clearly communicated to all staff caring for the patient. Special attention must be given to location, timing, and position of extubation. Complications of a poorly conducted extubation are airway activation, excessive coughing, hypoxemia, upper airway obstruction, and airway trauma.

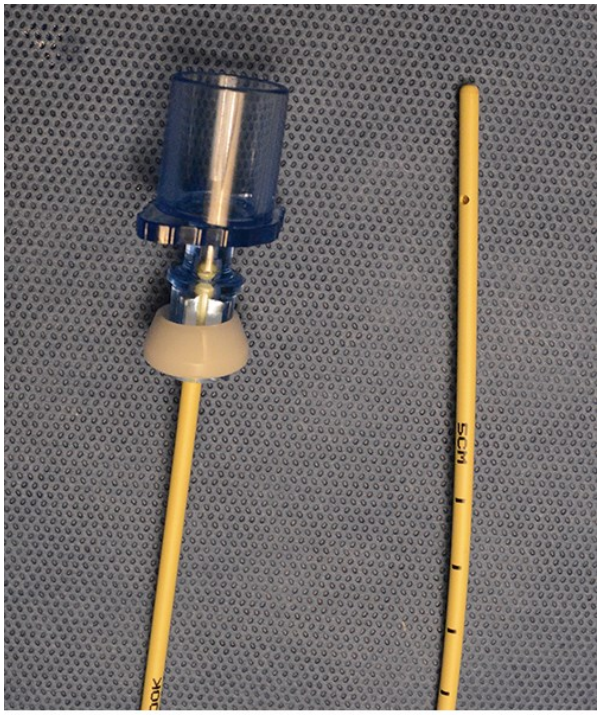
Airway Exchange Catheters

The indications for ETT exchange are varied and include change in ETT size or type, change in ETT route (ie, nasal to oral or vice versa), ruptured or leaking cuff, or ETT obstruction. Exchange of an ETT can be easily facilitated using an airway exchange catheter (AEC). An AEC is a semi-rigid thin catheter with a hollow lumen and a blunt tip. The long length of the AEC allows for it to be threaded into an ETT to maintain access to the airway when the ETT is removed. A replacement ETT can be simply "railroaded" over the AEC left in place, thereby easily facilitating tube exchange. When advancing the replacement ETT over the AEC, direct or video laryngoscopy can be used to displace the tongue and any soft tissue obstructing the path of the ETT. Replacement of the ETT under visualization can also prevent the ETT from getting caught in the piriform fossa or blocked by the arytenoid cartilages. Most exchange catheters allow for

ventilation, in an emergency situation, through their hollow lumen and distal holes. For the Cook airway exchange catheters (Cook Critical Care, Bloomington, IN), a Luer-Lock jet adapter and a 15-mm connector allow for jet ventilation and connection to the anesthesia circuit, respectively (Figure 27-28). An AEC may also be placed prior to extubation of a suspected difficult airway or critically ill patient who might fail extubation and require reintubation. If placed before removal of the ETT and left in place post-extubation, the AEC can act as a quick and easy conduit for reintubation.

Figure 27-28

Cook Airway Exchange Catheter (8.0F) showing Rapi-Fit™ 15-mm adapter. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)



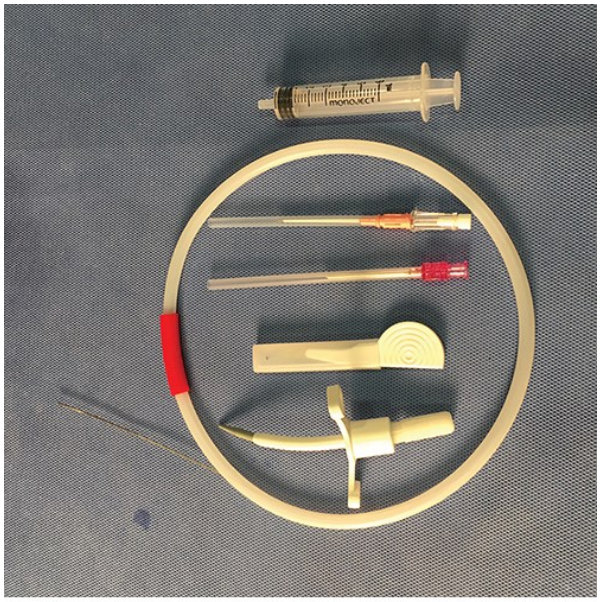
FRONT OF NECK ACCESS (FONA) IN PEDIATRIC PATIENTS

FONA refers to all invasive airway access techniques performed in the anterior neck, from the cricothyroid membrane (CTM) to the anterior tracheal wall. The incidence of emergency front of neck access (FONA) in pediatric patients is extremely low.[80] When they occur, they are associated with a high mortality rate.[80] Many anesthesiologists have never and will likely never perform one in their careers. From birth to adolescence, trachea length doubles, tracheal diameter triples, and tracheal cross-sectional area increases sixfold.[81] The neonatal CTM measures 2.6 mm × 3.0 mm compared to 10.4 mm × 8.2 mm wide in the adult. The mean newborn tracheal length is about 4 cm.

FONA is indicated in "can't intubate, can't oxygenate" situations. FONA in pediatric patients can be achieved by one of four methods: small cannula (angiocatheter) cricothyroidotomy, large cannula cricothyroidotomy (Seldinger), large cannula cricothyroidotomy (non-Seldinger or scalpel), and emergency tracheostomy by a surgeon. Anesthesiologists are generally more familiar and comfortable with the angiocatheter and Seldinger techniques. In the small cannula technique, a 14–18G angiocatheter is introduced into the inferior aspect of the of the CTM. Aspiration of air confirms intratracheal placement. The catheter is advanced and the needle removed. The catheter may be connected to a jet ventilator or other similar devices. Care must be taken to ensure upper airway patency to avoid the risk of barotrauma. Injury to surrounding structures must be avoided. Various brands are available for large cannula technique in children and adults. The Melker Emergency Cricothyrotomy Catheter set (Seldinger, Cook Medical, Inc., Bloomington, IN, USA) is available in a 3.5 mm and 4.2 mm internal diameter sizes (Figure 27-29). A cut down (scalpel) set is also available in a 5.0 mm internal diameter size. A Universal Set, consisting of both types, is also available but only in the 5.0 mm internal diameter size (Figure 27-30). In the Seldinger technique, a needle is inserted through a small skin incision over the cricothyroid membrane. Tracheal entry is confirmed by aspiration of air. A guidewire is placed and the needle or catheter is removed. A tapered dilator and catheter are inserted as a unit over the wire and into the trachea. The guidewire and dilator are then removed as a unit leaving the catheter in place. A guidewire may also be used with an existing small cannula (angiocatheter). In the surgical approach, a vertical midline incision is made over the cricothyroid membrane and carried down to the laryngeal structures. A horizontal incision is made near the inferior edge of the cricothyroid membrane. Tracheal hooks are used to retract the inferior margin of the thyroid cartilage superiorly. The CTM incision is then dilated using a Trousseau dilator or simply widened by gently turning the blade. The catheter-dilator assembly is inserted into the trachea as a unit and the dilator removed. Alternatively, an appropriately sized ETT may be placed. There is increasing evidence that the small cannula (angiocatheter) technique should be the first FONA technique in children 1 to 8 years of age.[82] Complications of FONA are bleeding, creation of a false passage, and damage to surrounding structures. Anesthesiologists should familiarize themselves with these techniques using manikin or animal models, especially at review courses and conferences.

Figure 27-29

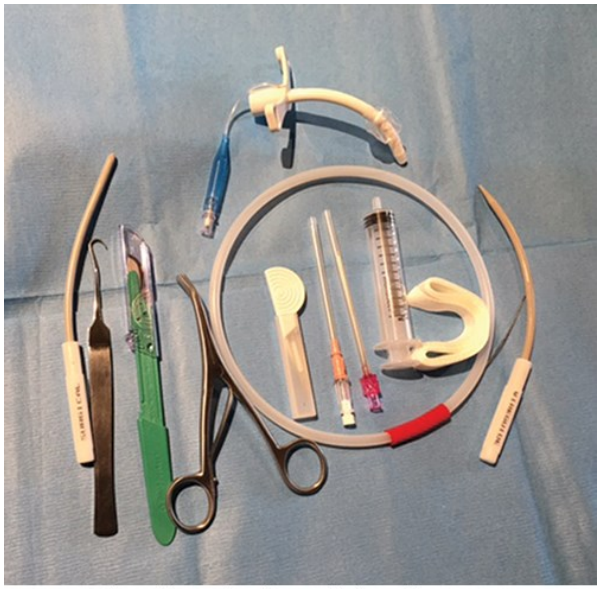
Melker Emergency Cricothyrotomy Set (Seldinger). (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)



Source: Herodotos Ellinas, Kai Matthes, Walid Alrayashi, Aykut Bilge: *Clinical Pediatric Anesthesiology*

Figure 27-30

Melker Emergency Universal Cricothyrotomy Set (Seldinger and Scalpel). (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)



Source: Herodotos Ellinas, Kai Matthes, Walid Alrayashi, Aykut Bilge: *Clinical Pediatric Anesthesiology*

HYBRID (COMBINED) TECHNIQUES

The recognition that no individual technique guarantees success has led to the utilization of hybrid (combined) techniques. Hybrid techniques utilize two or more modalities for management of the difficult airway. The most commonly used hybrid techniques are as follows: FOB intubation through a supraglottic airway (Figures 27-31 and 27-32), video laryngoscopy–assisted FOI, and retrograde-assisted FOI.[33,76,83–90] When a fiberoptic or digital bronchoscope is used in combination with a video laryngoscope, simultaneous upper and lower airway visualization is achieved. This typically requires two separate monitors depending on local availability. The new GlideScope Core™ (Figure 27-16) picture-in-picture modality allows both views to be displayed simultaneously on a touchscreen monitor (see the section "GlideScope"). Practitioners must gain experience in the performance of these techniques to minimize the risk of serious complications.

Figure 27-31

Ambu AuraGain laryngeal mask with ETT and gastric suction catheter. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)

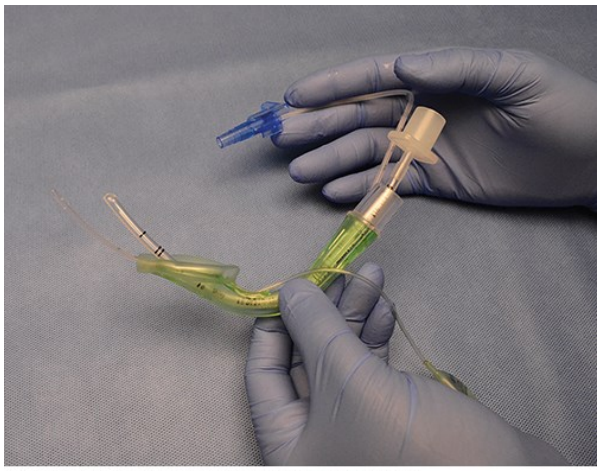
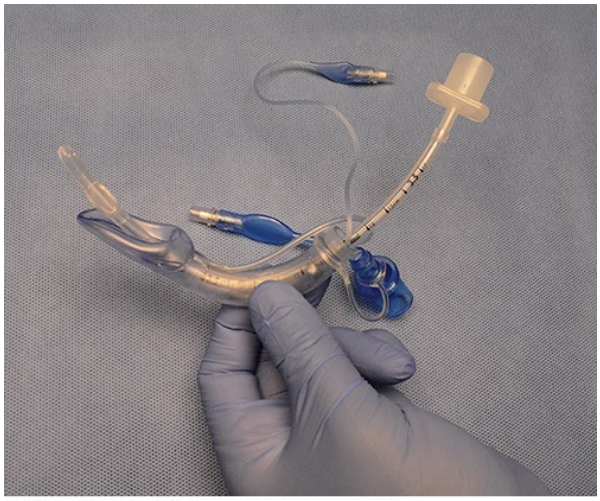


Figure 27-32

Air-Q ILMA with ETT. Note the detachable 15-mm connector. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)



Ancillary Airway Techniques

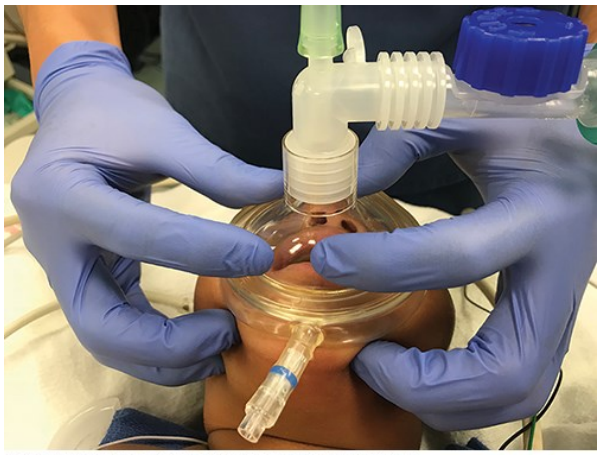
Two-Handed Mask Ventilation

There will be situations with mask ventilation when the ability to obtain an adequate seal or maintain a patent airway for ventilation can be difficult to accomplish with one hand. If an oral or nasal airway does not result in improved ventilation, two-handed mask ventilation should be considered. With this technique, one person uses both hands to mask seal the patient, while a second person compresses the reservoir bag to ventilate. When mask sealing with both hands, the left and right hands are both applying a jaw thrust while the thumbs and index fingers are maintaining a seal (Figure 27-33). This maximizes the ability to lift the mandible, thereby elevating the hyoid bone and tongue off the posterior pharyngeal wall and alleviating any soft tissue obstruction. The second person has the ability to feel the effectiveness of ventilation via the reservoir bag, while also applying CPAP to the airway if necessary. This technique can also be accomplished by a solo anesthesia provider, where the provider performs a two-handed mask seal while the anesthesia machine is activated to ventilate the patient.

Figure 27-33

Two-handed mask ventilation. Note the placement of the third and fourth fingers on the mandible, and not the soft tissue. (Used with permission, from Dr. Patrick N. Olomu, University of

Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)



Nasopharyngeal Airways

The NPA is a plastic or rubber cylinder of various sizes that is placed in the naris to alleviate airway obstruction between the tongue and the posterior pharyngeal wall. The appropriate size NPA for each patient is based upon the visual width of the naris, which is typically similar to the width of the patient's fifth finger. The ideal position of the NPA is approximately 10 mm above the epiglottis and should ideally clear the tongue base.[91] The distance from the naris to the angle of the mandible is the approximate length the NPA needs to achieve this ideal position. Prior to insertion, the NPA should be lubricated with a water-based lubricant to facilitate passage. Use of lidocaine gel may improve patient tolerance. In addition to this, the nasal passage should be inspected for patency, nasal polyps, or any septal deviation that might complicate placement of an NPA. The naris can be topicalized with vasoconstrictor sprays or drops to minimize the risk of epistaxis. Upon insertion, the NPA should be advanced gently with the concave side parallel to the hard palate. This will result in the NPA advancing downward toward the posterior nasopharynx, rather than upwards toward the cribriform plate of the ethmoid bone which can lead to intracranial placement of the NPA. Difficulty with passage of an NPA can be overcome with a 90 degrees counterclockwise rotation of the NPA, use of a smaller size, or switching to the other naris. In the awake or semiconscious patient, where a gag reflex remains intact, an NPA is an alternative airway device to an oropharyngeal airway (OPA). It also has advantages over an OPA in situations of oral trauma and limited mouth opening. Furthermore, as a less stimulating airway device, it can be used in situations of increased intracranial pressure. Upon emergence, the NPA can be an excellent device if there is any concern of residual airway obstruction, as commonly seen in pediatric patients undergoing adenotonsillectomy for severe obstructive sleep apnea. Contraindications to use of an NPA are bleeding disorders, anticoagulation, or suspected basilar skull fractures. An NPA can be connected to the anesthesia circuit with the 15-mm connector from an ETT (Figure 27-34). Newer designs with a Flex-Tip®, a slidable depth ring, and a 15-mm connector (Figure 27-35) are now available (Parker Medical and Mercury Medical, Clearwater, FL, the United States). The correct NPA French size is the ETT internal diameter multiplied by 4. Ventilating through an NPA can be a beneficial technique when managing a difficult airway or performing FOI.

Figure 27-34

A nasopharyngeal airway in place that has been connected to the anesthesia circuit via a 15-mm adapter from an endotracheal tube. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)

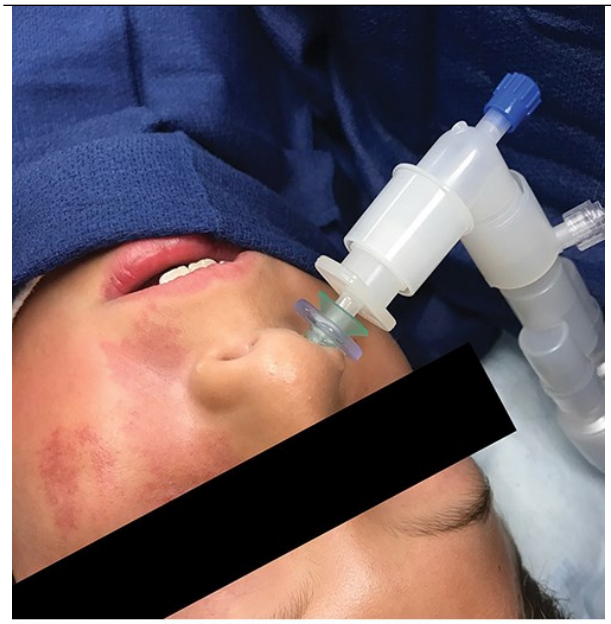
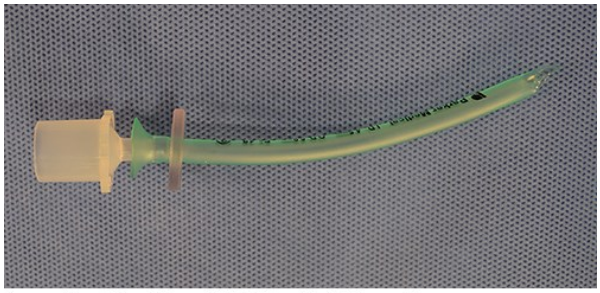


Figure 27-35

Nasopharyngeal airway with a Flex-Tip®, slidable depth ring, and a 15-mm connector. (Used with permission, from Dr. Patrick N. Olomu, University of Texas Southwestern Medical Center/Children's Health System of Texas - Dallas.)



VIDEOS

Video 27-01: Insertion technique for LMA Unique. Note fully deflated mask.

Play Video

Video 27-02: Insertion technique for LMA Supreme. Note tape application prior to mask inflation to prevent outward migration and loss of seal.

Play Video

Video 27-03: Insertion technique for the Air-Q Intubating laryngeal airway.

Play Video

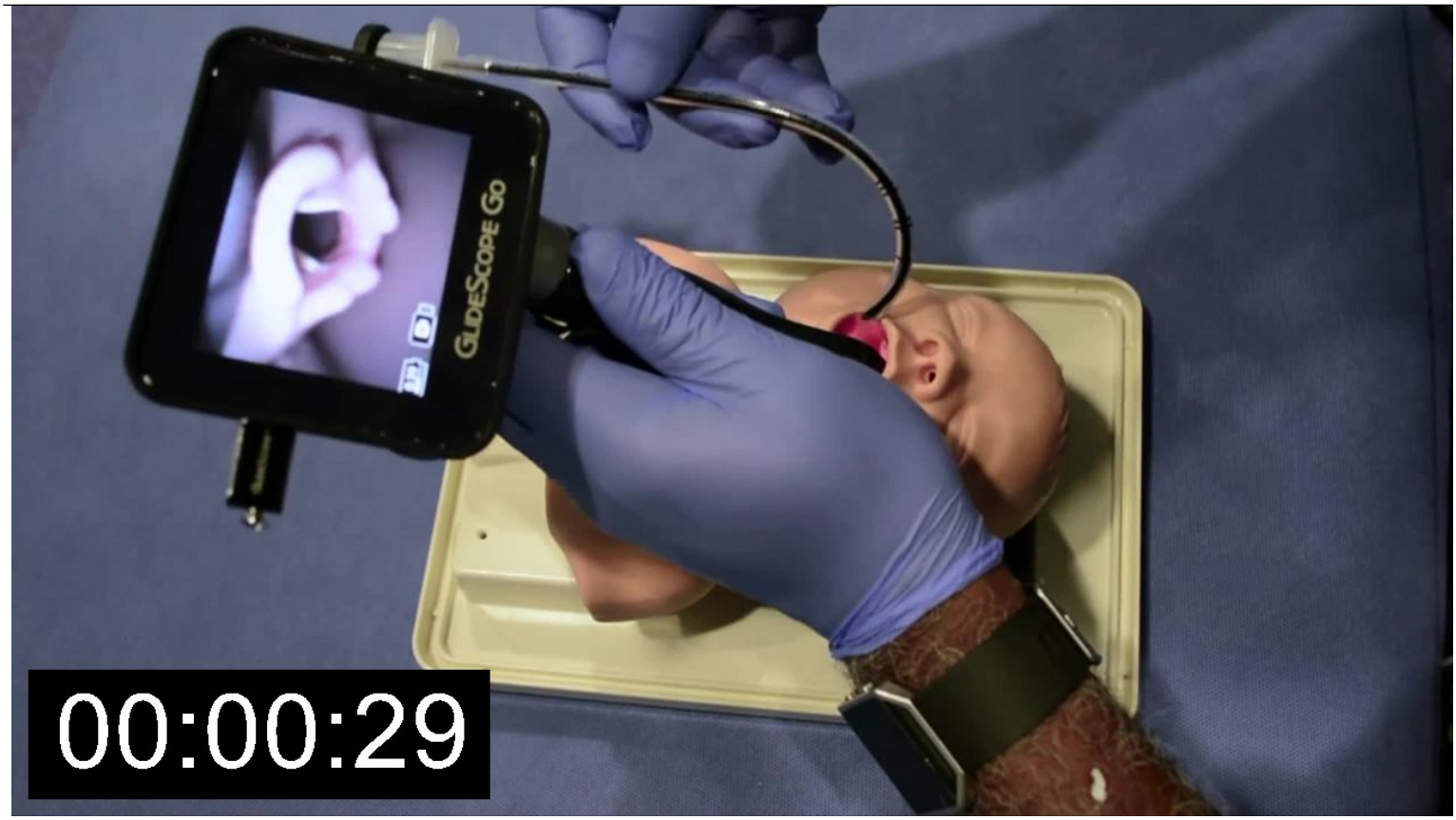
Video 27-04: Insertion of the Ambu AuraGain laryngeal mask.

Play Video

Video 27-05: Video intubation with GlideScope Cobalt blade and generic stylet.

Play Video

Video 27-06: Video intubation with portable GlideScope (Glidescope® Go™), pediatric Spectrum blade, and pediatric Gliderite stylet.



Play Video

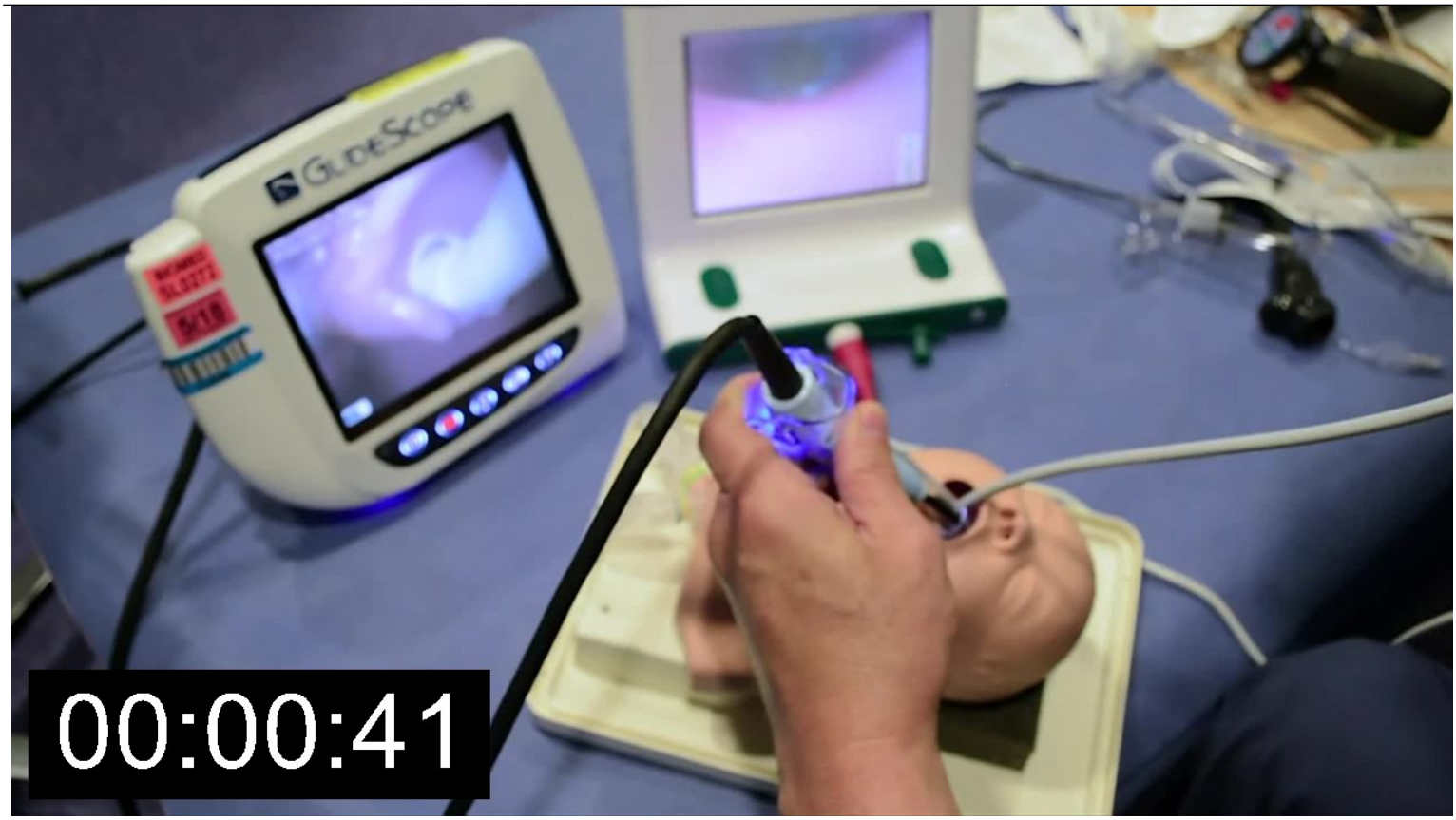
Video 27-07: Video intubation using King Vision channeled blade.

Play Video

Video 27-08: Combined Air-Q ILA and fiberoptic intubation.

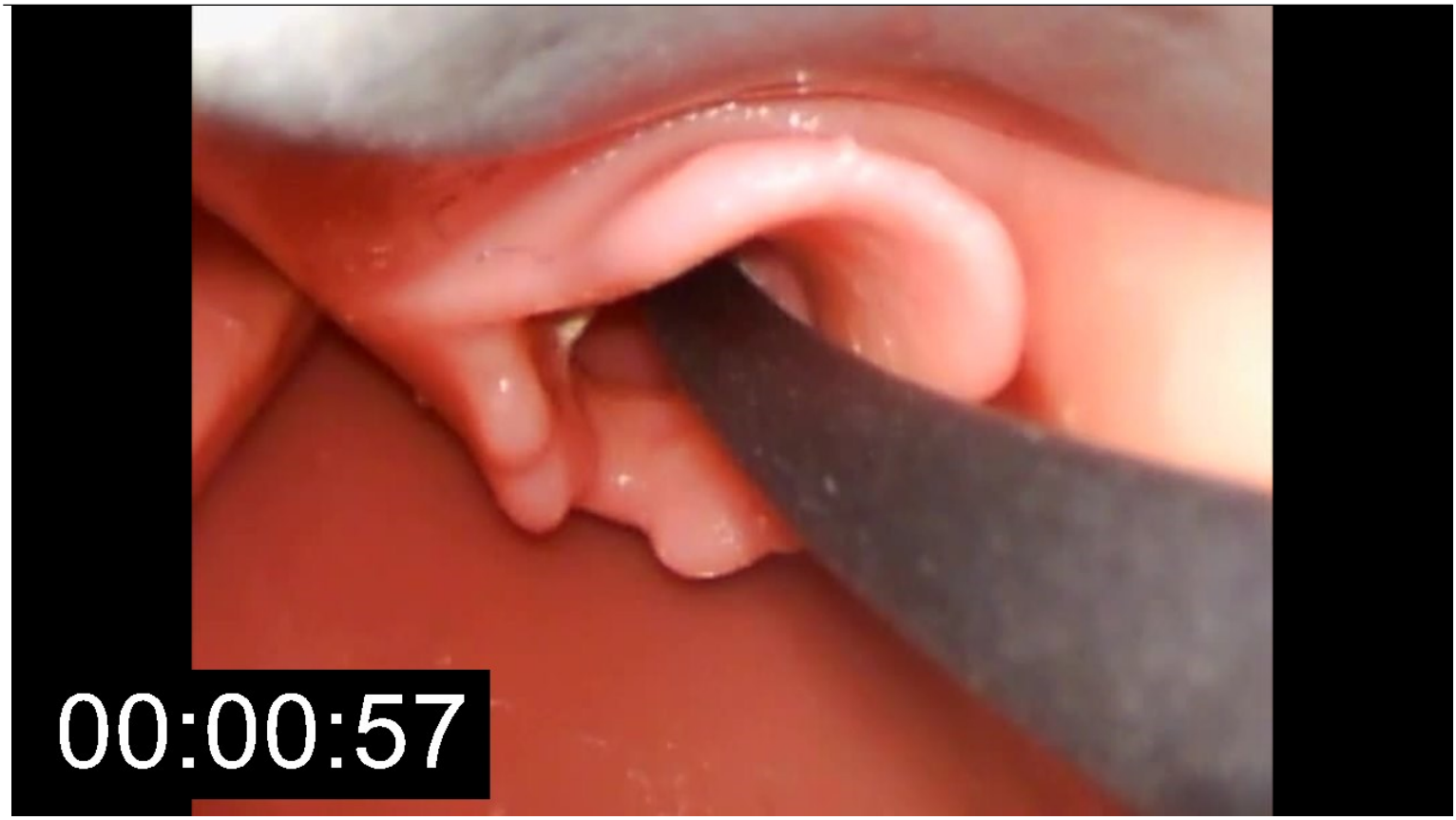
Play Video

Video 27-09: Combined GlideScope and fiberoptic intubation (Ambu aScope digital scope) showing both views.



Play Video

Video 27-10: Combined C-MAC video laryngoscope and fiber-optic intubation (internal C-MAC view only).



Play Video

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