# Miller Airway Management

Airway Management

## STRUCTURE AND FUNCTION OF THE UPPER AIRWAYS

### *Nose*

The normal airway begins functionally at the nares. As air passes through the nose, the important functions of warming and humidification occur. The nose is the primary pathway for normal breathing unless obstruction by polyps or upper respiratory infection is present. During quiet breathing the resistance to air flow through the nasal passages accounts for nearly two-thirds of the total airway resistance. 1 The resistance through the nose is nearly twice that associated with mouth breathing. This explains why mouth breathing is utilized when high flow rates are necessary as with exercise.

The sensory innervation of the nasal mucosa arises from two divisions of the trigeminal nerve. The anterior ethmoidal nerve supplies the anterior septum and lateral wall whereas the posterior areas are innervated by nasopalatine nerves from the sphenopalatine ganglion. Local anesthesia can be produced by blocking anterior ethmoidal and maxillary nerves bilaterally; however, simple topical anesthesia is usually quite effective.

### *Pharynx*

The pharyngeal airway extends from the posterior aspect of the nose down to the cricoid cartilage, where the passage continues as the esophagus. An upper area, the nasopharynx, is separated from the lower oropharynx by the tissue of the soft palate. The principal impediments to air passage through the nasopharynx are the prominent tonsillar lymphoid structures. The tongue is the principal source of oropharyngeal obstruction, usually because of decreased tone of the genioglossus muscle. The latter contracts to move the tongue forward during inspiration and thus acts as a pharyngeal dilator.

### *Larynx*

The larynx, which lies at the level of the third through sixth cervical vertebrae, serves as the organ of phonation and as a valve to protect the lower airways from the contents of the alimentary tract. The structure consists of muscles, ligaments, and a framework of cartilages. These include the thyroid, cricoid, arytenoids, corniculates, and the epiglottis. The latter, a fibrous cartilage, has a mucous membrane covering that reflects as the glossoepiglottic fold onto the pharyngeal surface of the tongue. On either side of this fold are depressions called valleculae. These areas provide the site for placement of the curved MacIntosh laryngoscope blade. The epiglottis projects into the pharynx and overhangs the laryngeal inlet. However, it is not absolutely essential for sealing off the airway during swallowing. 2

The laryngeal cavity extends from the epiglottis to the lower level of the cricoid cartilage. The inlet is formed by the epiglottis, which joins to the apex of the arytenoid cartilages on each side by the aryepiglottic folds. Inside the laryngeal cavity one first encounters the vestibular folds, which are narrow bands of fibrous tissue on each side. These extend from the anterolateral surface of each arytenoid to the angle of the thyroid where the latter attaches to the epiglottis. These folds are referred to as the false vocal cords and are separated from the true vocal cords by the laryngeal sinus or ventricle. The true vocal cords are pale white ligamentous structures that attach to the angles of the thyroid anteriorly and to the arytenoids posteriorly. The triangular fissure between these vocal cords is termed the glottic opening, which represents the narrowest segment of the laryngeal opening in adults. In young children (<10 years old), the narrowest segment lies just below the cords at the level of the cricoid ring. The mean length of the relaxed open glottis is about 23 mm in males and 17 mm in females. The glottic width is 6 to 9 mm but can be stretched to 12 mm. Thus, the cross-sectional area of the relaxed glottis may be 60 to 100 $mm^2$ .

The scope of this chapter does not permit a detailed description of the actions of the laryngeal muscles; however, these muscles may be classified into three basic groups relative to their actions on the cords: (1) abductors, (2) adductors, and (3) regulators of tension. The entire motor innervation to these muscles as well as the sensory supply to the larynx is supplied by two branches of the vagus nerve: the superior and recurrent laryngeal nerves. This motor and sensory innervation is summarized in Table 39–1

### *Trachea*

The trachea is a tubular structure that begins opposite the sixth cervical vertebra at the level of the thyroid cartilage. It is flattened posteriorly and supported along its 10- to 15-cm length by 16 to 20 horseshoe-shaped cartilaginous rings until bifurcating into right and left main bronchi at the level of the fifth thoracic vertebra. The cross-sectional area of the trachea is considerably larger than that of the glottis and may be more than 150 $mm^2$ and as high as 300 $mm^2$ .

There are a number of receptors in the trachea that are sensitive to mechanical and chemical stimuli. Slowly adapting stretch receptors are located in the trachealis muscle of the posterior tracheal wall. These are involved in regulating the rate and depth of breathing, but they also produce dilation of upper airways and the bronchi by decreasing vagal efferent activity. Other rapidly adapting irritant receptors lie all around the tracheal circumference. These are usually considered to be cough receptors, although their other reflex actions consist of bronchoconstriction. Studies of topical anesthesia in dogs suggest that the latter receptors are more readily blocked by local anesthetics than are the slowly adapting stretch receptors. 2

*Upper Airway Obstruction*

Airway obstruction may be total or partial. Total obstruction is characterized by the lack of any air movement or breath sounds. Confronted with ineffective breathing efforts, it is important that inexperienced persons not interpret any retractive movements of the rib cage and the diaphragmatic tugging motions as respiration. Actual air movement must be perceived by feeling with the hand or placing the ear over the mouth. Recognition of obstruction depends on close observation and a high index of suspicion.

The patient with partial obstruction exhibits diminished tidal exchange that is associated with retraction of the upper chest and accompanied by a snoring sound if the obstruction is nasopharyngeal or inspiratory stridor if obstruction is near the area of the larynx. If inspiratory efforts are severe, the upper airway may undergo a dynamic inspiratory compression because of the marked pressure gradient in the upper airway.

Treatment of upper airway obstruction depends for the most part on whether it is due to soft tissue obstruction, tumor, foreign body, or laryngospasm. Most often, upper airway obstruction is due to reduction of the space between the pharyngeal wall and the base of the tongue by relaxation of the tongue and jaw. The same obstruction may occur with foreign bodies or even dentures. In the absence of a foreign body, air flow may be restored by preventing the mandible from falling back. Forward motion is applied by placing the forefinger and second finger behind the angle of the mandible. The patient's neck can also be slightly extended to provide an optimal airway. The resultant changes in head position have been shown to modify upper airway resistance significantly. 3

Oropharyngeal obstruction can also be overcome to some extent by increased oropharyngeal pressure from manual inflations with a breathing bag. One of the major concerns with such manual inflation of the lungs without tracheal intubation is the potential for gastric insufflation with high inflation pressures. The relationship between pressure and gas entry into the stomach has been examined in unconscious paralyzed patients. 4 The authors reported that gastric inflation rarely occurred when pressures less than 15 to 20 cm $H_2O$ were utilized. In general such pressures were associated with tidal volumes well in excess of 1 L.

One of the primary skills required of anesthesiologists is the ability to correct upper airway obstruction in the unconscious or anesthetized patient. This obstruction is commonly attributed to occlusion of the pharynx by the tongue, which falls back. Correction of such a problem would be expected by insertion of devices termed oropharyngeal or nasopharyngeal airways (insertion is described later in the chapter). The nasopharyngeal airway is a soft rubber tube that is less traumatic and better tolerated in lighter stages of anesthesia or unconsciousness. The airway itself extends sufficiently into the pharynx to pass behind the base of the tongue. In situations in which the nares do not permit passage, bleeding occurs, or obstruction is not received, an oropharyngeal airway may be used. The latter is designed for insertion along the tongue until teeth or gums prevent further passage. The placement of these devices that provide an artificial passage behind the tongue does not in many cases provide unobstructed airflow. This suggests that the tongue is not the principal cause of upper airway obstruction in the anesthetized patient.

This is further borne out by daily experience of the frequent need to utilize head tilt and maintain head extension, even in patients with an oral airway in place. It is difficult to understand how this means of establishing airway patency produces any forward pull on the tongue. Observations in anesthetized patients indicate that this maneuver actually elevates the hyoid bone and epiglottis and appears to relieve the major cause of upper airway obstruction. 5 The angle of the extension or retroflexion required to achieve airway patency was reduced as the occiput was elevated. The latter to some extent pushes the mandible forward. Further support of the mandible may be provided by forward traction or pressing forward at the mandibular angles. When these simple maneuvers and the use of artificial airways do not provide adequate relief of upper airway obstruction, the insertion of an endotracheal tube to bypass the upper airway must be contemplated.

*Physiology of Airway Protection*

The pharynx, epiglottis, and vocal cords play a role in protecting the lower airway from aspiration of foreign bodies and secretions. Although the epiglottis covers the laryngeal inlet, it is not absolutely essential for airway protection. Most vital in this protective function is the glottic closure reflex, which produces protective laryngeal closure during deglutition. The physiologic exaggeration of this reflex, laryngospasm, is counterproductive to respiration. Laryngospasm consists of prolonged intense glottic closure in response to direct glottic or supraglottic stimulation from inhaled agents, secretions, or foreign bodies. Stimulation from the periosteum or celiac plexus or dilation of the rectum may also precipitate the problem on a reflex basis.

Varying degrees of laryngospasm produce sounds that range from a high-pitched squeaky sound to total absence of sound. The latter indicates complete closure of the cords and must be diagnosed and treated immediately. Treatment of severe spasm may require use of muscle relaxants such as succinylcholine. However, forward displacement of the mandible together with oxygen administered by a mask under pressure is often effective. Strong intermittent pressure applied manually to a bag full of oxygen can force gas effectively through the upper airway and the adducted cords. The traditional concerns about limiting airway pressure to avoid pulmonary barotrauma are not important in this case. However, the stomach contour should be watched closely should an inordinate amount of air be forced into the esophagus. In many cases when laryngospasm is less severe, slight amounts of positive pressure alleviate the difficulty. In any case, one should certainly utilize these simple maneuvers before resorting to tracheal intubation.

An indispensable mechanism for expelling secretions and foreign bodies from the lower respiratory tract is the act of coughing. The major stages of a cough are characterized by three events. First, there is a deep inspiration to attain a high lung volume, which allows attainment of maximum expiratory flow rates. Second, a tight closure of glottis occurs along with contraction of the expiratory muscles. Intrapleural pressure rises to above 100 cm $H_2O$ such that during the third, or expiratory phase, a sudden expulsion of air occurs as the glottis opens. Glottic opening at the onset of the phase is associated with oscillation of tissue and gas that results in the characteristic noise of a cough.

Various physiologic aspects of cough have been observed with radiologic and endoscopic techniques. None is more important than the dramatic narrowing of the airway lumen. The physiologic significance of this reduced airway caliber is the fact that the decreased cross-sectional area increases linear velocity of gas flow and improves cough effectiveness. Various estimates suggest that this dynamic compression decreases the cross-sectional area of the trachea and main bronchi to about 40 percent of their caliber during normal breathing and thus increases linear velocity two and a half times. 6

Neuromuscular weakness may decrease cough flow rates by limiting the inspired volume prior to cough if inspiratory muscles are weakened. Expiratory weakness, on the other hand, does not appreciably diminish flow rates. 7 The major effect appears to be a reduction in cough-induced dynamic airway compression, which results in decreased linear velocity of flow.

Glottic closure is the one phase of cough that differentiates it from other forced expiratory maneuvers and that allows for greater development of pressures. Closure of the glottis is not crucial, however, to the development of high pressures and flow rates of a normal cough. This is well illustrated in tracheotomized and intubated patients. The presence of the endotracheal tube, for example, does not lessen the build-up of peak pressure during coughing. However, by preventing normal glottic closure, the tube allows flow to begin as soon as pressure begins to increase, and, in most cases, the tube allows flow to continue between cough bursts. 8 The normal timing of pressure and flow is altered such that cough resembles a normal forced expiration. Also, because the tube is noncollapsible, it does not permit the high velocities through the tracheal segment that it occupies. Secretions therefore are likely to accumulate in the area at the end of the tube unless subsequent coughs are begun from high lung volumes to allow high flow rates to be achieved.

## EVALUATION OF THE AIRWAY

*History*

A documented history of difficulties with general anesthesia or, more specifically, mask ventilation or endotracheal intubation should immediately arouse concern regarding a patient's airway, and the information should not be lightly dismissed. If one encounters a difficult airway, it is important to specifically inform the patient of the problems encountered so that this information can be transmitted to the next anesthesia caregiver. Until a searchable national database is available, the patient can be provided with a form letter providing information on the airway problem. 9 Even a brief note on the back of a business card provides a handy mobile source of information to future caregivers: e.g., "difficult mask ventilation and intubation." The best means of communication may be the use of a MedicAlert bracelet labeled "difficult airway/intubation." 10 The MedicAlert System can be reached at 1–800–344–3226. Previous anesthesia records are extremely useful, especially when the problem is clearly defined. Remember also that some diseases, such as rheumatoid arthritis and morbid obesity, may have progressed in the interim and now may present a more difficult airway than suggested by the previous anesthetic record.

Many congenital syndromes that involve the airway may make mask ventilation or endotracheal intubation difficult. Several excellent sources provide an extensive listing of these. 11 It may be prudent to keep one of these lists in a readily available place. The more common congenital syndromes and their airway implications are listed in Table 39–2 .

TABLE 39–2. Selected Congenital Syndromes Associated With Difficult Endotracheal Intubation

Other diseases of infectious, traumatic, neoplastic, or inflammatory cause may also profoundly affect airway management. Table 39–3 lists many that should be considered while eliciting a patient history.

*Physical Examination*

The patient must be initially subjected to simple inspection from front and side to identify obvious problems such as massive obesity, cervical collars or traction devices, external trauma, or any indications of respiratory difficulty such as stridor. The presence of ear and hand anomalies often suggests the presence of a difficult airway. Nostril size and patency are essential to establish before considering nasal intubation. A large beard may make physical examination, mask ventilation, and direct laryngoscopy more difficult. Consideration to trimming or removing the beard should be made when the airway is judged difficult or when the surgery prevents circumferential securement of the tracheal tube (e.g., cervical or intracranial surgery).

Edentulous patients are seldom difficult to intubate unless other associated problems are severe. Protuberant upper incisors, on the other hand, can make laryngoscopy difficult and expose the teeth to damage. Isolated loose teeth are particularly prone to damage. These should be noted as well as the location of crowns, bridges, braces, and other significant dental work. Bridges and dentures should be removed if possible unless dentures significantly improve mask fit. Very loose teeth are best removed prior to laryngoscopy to avoid aspiration of a tooth. Most important, patients should be warned of likely damage to teeth both in person and in the preoperative note.

Mouth opening, which is largely a function of the temporomandibular joint, is of prime importance to allow the insertion of a laryngoscope blade and subsequent glottic visualization. 12 Adults should be able to open their mouths so that there is a 30- to 40-mm distance between upper and lower incisors (about two large fingerbreadths). 13 A problem with mouth opening should not be underestimated as it can make visualization of any laryngeal structures impossible. It may be risky to assume that limited mouth opening is due to spasm that will reverse after neuromuscular blockade. Conversely, in some patients able to open the mouth widely in the awake state, adequate mouth opening in the anesthetized state was only possible when th(e mandible was pulled forward. 14 Previous transtemporal neurosurgery may produce severe limitation in mouth opening that was not present during the original anesthetic. 15

The oral cavity examination is aimed at identifying a long narrow mouth with a high arched palate that is associated with difficult intubation. A large tongue in relation to oral cavity size may make laryngoscopy more difficult. Mallampati et al 16 emphasized the importance of the base of the tongue in determining the difficulty of laryngoscopy. If the faucial pillars (palatoglossal and palatopharyngeal arches) and uvula cannot be seen in a seated, vocalizing patient with the tongue protruding (Figs. 39–1, 39–2), then visualization of the glottis is likely to be more difficult than in patients in whom these structures are readily visible. An increase in Mallampati score may be noted during pregnancy and correlates with the slightly higher rate of difficult laryngoscopy in this population.

*Further Evaluation*

If there is suspicion of undetected disease, such as an airway tumor or if the impact of such a tumor or an infection on airway management is not clear, consultation should be obtained for indirect or fiberoptic laryngoscopy. 29 These may be the only methods to detect occult but life-threatening problems such as lingual tonsillar hyperplasia. 30 Serious doubt about an airway may justify the presence of an otolaryngologist during induction to establish an airway surgically, if necessary.

The chest x-ray may reveal problems undetected by the history and physical examination. Lateral and anteroposterior cervical spine films should be obtained if the bony spine or joints may be a source of difficulty or if there is suspected encroachment on the airway. CT scanning has been employed to evaluate the involvement of the trachea, bronchi, and cardiovascular structures in mediastinal tumors. 31, 32 Other means of airway assessment with magnetic resonance imaging have been reported. 33 However, flow-volume loops provide detection and assessment of the physiologic importance of such obstructive lesions, be they extra- or intrathoracic.

## MASK: VENTILATION EQUIPMENT AND TECHNIQUE

Anesthesia face masks of rubber or plastic are employed to administer oxygen and anesthetic gases as well as to ventilate the nonintubated patient. Masks come in a large variety of shapes, but the anatomic mask is most commonly used in adults. 34 Adult masks come in small, medium, and large sizes (#3, 4, and 5). Most adults can be ventilated with a small or medium mask, but the occasional patient with a long or wide face or large nose will need a large mask. Children‘s masks come in newborn, infant, and children sizes. In addition to the anatomic mask, the relatively flat Rendell-Baker-Soucek mask is often used as it conforms to the child‘s flatter face and has minimal dead space. Transparent masks are being used more often for adults as well as for children. They are less frightening than a black opaque mask, and the patient can be better observed for cyanosis and vomiting.

The mask is held with one hand as shown in Figure 39–4 . The fingers should be kept on the bone rather than soft tissues because the latter can cause discomfort in the awake patient and can cause airway obstruction if such pressure sufficiently raises the base of the tongue. Ventilation with a mask requires a tight fit that involves downward displacement of the mask with the thumb and first finger and upward displacement of the mandible with the other three fingers. Mandibular displacement along with upper cervical extension and chin lift all tend to pull the tongue and soft tissues up off the posterior pharyngeal wall and relieve the upper airway obstruction that occurs in the anesthetized or unconscious patient (Fig. 39–5). This may require holding the mask with two hands and vigorously pulling the mandible upward ("jaw thrust") (Fig. 39–6). A two-handed mask grip will require an assistant to provide manual ventilation. If no such help is available, the anesthesia ventilator can be used to supply positive-pressure breaths. If necessary, the anesthetist‘s chin can exert downward pressure on the elbow connector to achieve a tight mask fit. Alternatively, the second person can provide jaw thrust while the first seals the mask and ventilates by anesthesia bag. 35

FIGURE 39–4 Technique for holding the mask with one hand. An effort should be made to avoid excessive pressure on the soft tissues of the neck.

FIGURE 39–5 (A) The normal airway. The tongue and other soft tissue are forward, allowing an unobstructed air passage. (B) Obstructed airway. The tongue and epiglottis fall back to the posterior pharyngeal wall, occluding the airway. (From Dorsch and Dorsch34 )

FIGURE 39–6 Technique for holding the mask with two hands.

As noted in the previous section, mask ventilation may be extremely difficult for patients with problems such as obesity, tumors, infections, and inflammatory disorders. The pediatric patient usually presents less of a problem than the adult as the pediatric airway can usually be managed by mask ventilation unless laryngospasm ensues. Providing a leak-free seal with the mask may be particularly difficult in the older, edentulous patient, and this may be helped by leaving dentures in place, using packing, or employing a mask strap or assistant to pull up the sagging cheeks. In addition to the inability to ventilate, other serious problems with mask ventilation include pulmonary aspiration and pressure damage to the eyes.

When airway integrity cannot be maintained with manipulation of the mask, mandible, or neck, a mechanical airway may restore airway patency. Both oral and nasal airways serve to separate the tongue from the posterior pharyngeal wall (Figs. 39–7, 39–8). The rigid oral airway may provoke a gag reflex or be followed by cough, vomiting, laryngospasm, or even bronchospasm if the patient is not adequately anesthetized. The airway may be inserted right side up or upside down and then rotated 180 degrees into the position of function. In either case, trauma to the teeth must be avoided as well as a misplacement in which the airway (especially if too short) pushes the tongue back into the pharynx and actually increases airway obstruction. After intubation, an airway is often inserted to prevent the patient from biting down on the tube. However, it is advisable to avoid the use of oral airways in prone cases that require extensive neck flexion as severe swelling of the tongue may result. 36 A 4 ¥ 4-inch piece of gauze can be placed between the teeth to avoid active or passive biting with occlusion of the airway. Oral airways are generally made of plastic and in adults range in size from 80 to 90 to 100 mm (#3, 4, and 5, respectively). Children's airways range from 50 to 60 to 70 mm (#0, 1 and 2, respectively), with special small airways (#00, 000) for premature and newborn babies.

FIGURE 39–7 Oropharyngeal airway in place. The airway follows the curvature of the tongue, pulling it and the epiglottis away from the posterior pharyngeal wall and providing a channel for air passage. (From Dorsch and Dorsch34 )

FIGURE 39–8 The nasopharyngeal airway in place. The airway passes through the nose and ends at a point just above the epiglottis. (From Dorsch and Dorsch34 )

Soft nasal airways are useful in patients who are not deeply anesthetized because such airways tend to provoke less of a gag reflex. Relative contraindications to such airways include coagulopathy, basilar skull fracture, and nasal infections or deformities. If possible, vasoconstriction with phenylephrine nose drops (and topical anesthesia with lidocaine if the patient is awake) should precede any nasal instrumentation. However, in the acute situation, the lubricating qualities of lidocaine ointment may suffice. The tip of the airway should be inserted perpendicularly to the face and not upwards toward the cribriform plate. It has been suggested that the length of the airway should be roughly the distance from the tip of the nose to the meatus of the ear. 34 Adult nasal airways are measured in French numbers, which relate to their outer diameter and hence reflect circumferences that range in size from 28, 30, and 32 to 34. If the nasal airway does not have a sizable flange at the nasal end, the placement of a safety pin (taped to the face) in the airway tip will prevent loss of the nasal airway into the patient's lower airway. Both adequately large oral and nasal airways should be employed together if mask ventilation cannot be otherwise accomplished. 35

## LARYNGEAL MASK AIRWAY

The laryngeal mask airway (LMA) is an ingenious supraglottic airway device that is designed to provide and maintain a seal around the laryngeal inlet for spontaneous ventilation and allow controlled ventilation at modest levels (up to 15 cm $H_2O$) of positive pressure. 37 This device is currently available in seven sizes for neonates, infants, young children, older children, and small, normal, and large adults (Fig. 39–9). After establishing an adequate depth of anesthesia and lubrication of the cuff, the appropriately sized LMA is inserted into the mouth, with the aperture facing the base of the tongue and the cuff tip pressed against the posterior pharyngeal wall. While the standard method involves total cuff deflation, other clinicians prefer to insert the LMA with the cuff partially inflated. An excellent instruction manual is available from the manufacturer (Gensia Automedics Inc, 9360 Towne Centre Drive, San Diego, Calif 92121). The requirement for adequate anesthesia makes the LMA generally unsuitable for use in the conscious emergency room patient. The index finger of the dominant hand is used to guide the LMA into the hypopharynx until resistance is felt, and the cuff is inflated with the appropriate volume of air (Fig. 39–10). The resistance indicates that the cuff tip has reached the upper esophageal sphincter (Fig. 39–11). A bite block, usually a folded 4 ¥ 4- inch gauze, is inserted in the mouth to protect the LMA before both gauze and LMA are secured with tape. It is important to check by capnography as well as by auscultation and visualization of air movement that the cuff is correctly positioned and has not produced obstruction from downward displacement of the epiglottis. Because of the limited ability of the LMA to seal off the laryngeal inlet, the elective use of the device is contraindicated in any of the conditions associated with an increased risk for aspiration. 38 In patients without these predisposing factors, the risk for pharyngeal regurgitation appears to be low. 39

FIGURE 39–9 Range of patient laryngeal mask airway sizes. From upper left to lower right: Size 1: neonates/infants up to 5 kg (4); Size 1.5: infants 5–10 kg (7); Size 2: infants/children 10–20 kg (10); Size 2.5: children 20–30 kg (14); Size 3: children/small adults over 30 kg (20); Size 4: normal and large adults (30);

Size 5: large adults (40). Maximum cuff inflation volumes in mL are given in parentheses for each size LMA. (Gensia Automedics, San Diego, Calif)

FIGURE 39–10 Insertion of the LMA. (A) The tip of the cuff is pressed upward against the hard palate by the index finger while the middle finger opens the mouth. (B) The LMA is pressed backward in a smooth movement; note that the nondominant hand is used to extend the head. (C) The LMA is advanced until a definite resistance is felt. (D) Before the index finger is removed, the nondominant hand presses down on the LMA to prevent dislodgement during removal of the index finger; the cuff is subsequently inflated; an outward movement of the tube is often noted during this inflation. (Gensia Automedics, San Diego, Calif)

FIGURE 39–11 The laryngeal mask in position. (From Brain37 )

The LMA may be used as a substitute for the classic mask airway to eliminate the presence of a relatively large mask and practitioner's hand that may interfere with surgical access. 40 A new, flexible LMA (LMA-Flexible, Gensia Medtronics) may allow for easier connection at any angle from the mouth while resisting kinking and displacement. The LMA may be inserted to establish an emergency airway in awkward settings for intubation such as the lateral or prone positions. The device may also be employed to establish an airway in the patient in whom either mask ventilation or tracheal intubation is difficult. 38 This role is discussed in a later section of this chapter. In addition, the LMA may be used to provide a conduit to facilitate fiberoptic, gum bougie–guided or blind oral tracheal intubation (Fig. 39–12). The size of the LMA dictates the size of endotracheal tubes that can be employed; cuffed 6.0 mm internal diameter (ID) for the size 3 and 4 and 7.0 mm ID for the recently introduced size 5 42 Problems include inadequate endotracheal tube length as dictated by the presence of the LMA, limitation on endotracheal tube size, and inability to remove the LMA without risking extubation. 43 The use of the fiberoptic scope to assist in placing a gum elastic bougie rather than direct placement of the endotracheal tube is one possible approach to this situation. Benumof 43 has suggested a number of alternative solutions to the LMA/ fiberoptic intubation dilemma. A laryngeal mask specifically designed to facilitate tracheal intubation is now available (LMA-Fastrach, Gensia Automedics, San Diego, Calif.)

FIGURE 39–12 The use of the LMA as a conduit for fiberoptic intubation. (A) After loading an appropriately sized endotracheal tube, the fiberoptic scope is placed through the LMA into the glottis. (B) The endotracheal tube is threaded into the trachea. (C) The fiberoptic scope is removed. (Gensia Medtronics, San Diego, Calif)

With increasing use, problems have been reported with the LMA; they include pulmonary aspiration, laryngospasm, need for neck extension in the patient with cervical spine disorder, and failure to function properly in the presence of local pharyngeal or laryngeal disease. 41, 44, 45 In patients with diminished pulmonary compliance or increased airway resistance, adequate ventilation may not be possible because of the high inflation pressures required and the resultant leaks. The overall role of the LMA in clinical anesthesia would appear to lie somewhat between that of the face mask and that of the endotracheal tube as it provides more airway security (when properly positioned) than the former but not the reliable airway protection and maintenance of the latter. The LMA can be used to access the glottis for intubation as described; this is likely to become a more common use as the LMA becomes more generally available and clinicians gain experience with it. More important, it has become a nearly essential back-up airway device to provide emergency ventilation when conventional mask ventilation and intubation attempts fail.

## THE COMBITUBE

The Combitube (Sheridan Catheter, Argyle, NY) is another supraglottic airway device that can provide an emergency airway when conventional means are not effective or possible. The Combitube has two lumens so that it can function appropriately whether placed in the trachea or, much more commonly, in the esophagus (Fig. 39–13). It also possesses an esophageal balloon to provide for protection from aspiration, which may represent an advantage over the LMA in obstetric anesthesia. The Combitube has been used successfully in cardiopulmonary resuscitation and probably presents a lower risk of esophageal rupture than the older esophageal obturator airway. 46 Care must also be taken to avoid excessively deep placement in the esophagus, which obstructs the glottic openings. 47 The Combitube is contraindicated for patients less than 5 feet tall and those with intact gag, esophageal disease, or caustic ingestion. A redesigned Combitube with a larger pharyngeal orifice has been found effective in providing a conduit for tracheal suctioning, fiberoptic bronchoscopy, and the use of a guide wire for tube exchange. 48 The practicing clinician can probably anticipate continued modifications in the present supraglottic devices as well as the introduction of new modalities to maintain and protect the airway without tracheal intubation.

*Equipment*

In addition to endotracheal tubes and laryngoscopes, other essential items include an oxygen source, bag and mask, airways, stylet, lubricant, tape, and reliable suction. Other devices that may be utilized in special situations are also discussed.

*Endotracheal Tubes*

The endotracheal tube that is most commonly utilized in current practice is a polyvinylchloride tube that has a low-pressure, high-volume cuff. This type of tube is illustrated in Figure 39–14 . Clinical use of the tube is generally dictated by the internal diameter that limits air flow. The external diameter of the tube depends on the internal diameter and on the thickness of the tube's wall, which varies among manufacturers. In adults, external diameter is limited at the level of the glottic aperture, whereas in children the subglottic (cricoid cartilage) area is the limiting factor in external diameter. Tubes are manufactured in 0.5 mm ID increments from 2.5 to 9.0 mm (Table 39–5). French size reflects the circumference, the product of external diameter and ?, and is therefore higher for thicker-walled tubes than for thinner-walled tubes with the same ID. The table also gives recommended distance of insertion for the tube tip to be placed in the midtrachea. This distance must be evaluated in each individual patient. A small percentage of patients will require a shorter or longer distance of insertion, depending on the highly variable tracheal length.

TABLE 39–5. Endotracheal Tube Size and Position Based on Patient Age

FIGURE 39–14 Various types of endotracheal tubes. (A) An armored or anode tube with a built-in spiral wire to minimize the opportunity of collapse or kinking. (B–D) Tubes made of smooth plastic and recommended for single use. Tube B is uncuffed and is a size appropriate for a child. Tubes C and D are appropriate for adult patients. Tube C is equipped with a built-in high-pressure low-residual-volume cuff. Tube D is constructed to incorporate a low-pressure high-residual-volume cuff. Numbers and letters visible on tubes B, C, and D denote tube diameter, length from tracheal end, and confirmation that the tubes have been tested for tissue compatibility (I.T. or Z-79).

The tube material itself is stamped Z-79 (Committee Z-79 on Anesthesia Equipment of the USA Standards Institute) or IT (implantation tested), indicating that the tube is free of toxic or irritant properties so far as testing can indicate. A line of x-ray opaque material is manufactured into the wall of the tube to aid in placement. Most tubes have a hole cut in the wall opposite to the bevel. This hole is known as the Murphy eye and is designed to allow gas passage if the bevel lumen is occluded. The tube is manufactured to be sterile, and most present-day tubes are disposable. It is wise to check the free flow of air through the tube as part of the pre-case checkout. The interface between the plastic tube and 15 mm connector should be tightened snugly.

The cuffs of present-day plastic tubes are so-called high-volume, low-pressure cuffs. These compliant cuffs are designed to accommodate a relatively large volume of inflation before pressure rises. High pressure in the cuff lumen is transmitted to the tracheal mucosa where it can cause ischemic injury. This is generally not an important issue during an anesthetic and is addressed further in the section on complications of intubation. Before the use of the tube, the cuff should be inflated to check for symmetry and leaks. The syringe must be removed from the one-way valve to test the sealing function of the valve. After insertion, the cuff should be inflated so that there is no air leak on positive-pressure inspiration. This will allow for reasonable airway protection from aspiration without excessive lateral wall pressure. Cuff pressures that afford good (but not perfect) protection (20–25 mm Hg) are just below the perfusion pressure of the tracheal mucosa (25–35 mm Hg). 49, 50 During the case, nitrous oxide may diffuse into the cuff and increase its pressure. 51 With high-volume cuffs and cases of reasonable duration (<24 hours), this is probably not an important issue as even high-pressure cuffs are acceptable for such cases. Although the tension of the pilot balloon is not an exact indication of pressure, a small amount of gas can be released from the cuff in this setting if the balloon becomes very tense, and the clinician is concerned about mucosal ischemia. Alternatively, nitrous oxide can be avoided or even used in the clinical concentration to inflate the cuff. Uncuffed endotracheal tubes have generally been used in children younger than age 8 years. The narrow subglottic area is believed to limit the use of cuffed tubes in these young children. An uncuffed tube is shown in Figure 39–14 . Endotracheal tube leak pressure is a clinically useful way to fit to confirm proper selection of uncuffed tube size in children. 52 Leak should occur at 15 to 20 cm H2 O pressure. The use of cuffed tubes in neonates, infants, and children has undergone renewed scrutiny and has the advantages of reducing waste gas exposure, allowing for lower fresh gas flows, and avoiding repeat laryngoscopy without an increased incidence of croup. 53 These authors used a new formula (cuffed endotracheal tube internal diameter = age/4 + 3) to successfully predict the required cuffed tube size in 99 percent of 488 children younger than 8 years of age.

The top tube shown in Figure 39–14 is reinforced with a spiral wire to reduce kinking or collapse. These tubes are known as armored, anode, spiral embedded, or reinforced tubes, among other names. 34 They are useful when an endotracheal tube is placed in a tracheostomy or laryngectomy stoma to provide an airway. They may also be used in head and neck or neurosurgical procedures when kinking of the tube is a strong possibility. However, care must then be taken to avoid an excessive degree of neck flexion by overenthusiastic surgeons as increased peak airway pressures during positioning will not be available as a monitor for excessive flexion or head turning. The RAE tube is made in oral and nasal versions and is bent to keep the tube out of the respective surgical fields (Fig. 39–15). It may be somewhat difficult to secure the tube tip at an appropriate tracheal level if the patient has an unusually long or short lip to midtracheal distance. The Endotrol tracheal tube (Mallinckrodt Critical Care, Glens Falls, NY) has a mechanism that allows for anterior tip displacement when an operator end loop is pulled. This is particularly useful when a nasally placed tube repeatedly enters the esophagus, and cervical movement is contraindicated. Further information on the equipment employed in airway management can be found in the monograph by Dorsch and Dorsch. 34
FIGURE 39–15 Preformed RAE endotracheal tubes: bottom, oral; top, nasal.

*Tube Size Versus Age and Sex*

In adult males, an 8.0 mm ID endotracheal tube is appropriate, whereas in adult females a 7.0 mm endotracheal tube is usually suitable. Given the variation between individuals, a tube of 1 mm ID size smaller or larger may be best for an individual patient. In general, the larynx is smaller in women, and it is the glottic aperture that limits the size of endotracheal tubes in adults. As noted, uncuffed tubes have traditionally been used in young children. The sizes of uncuffed endotracheal tubes for use in children is given in Table 39–5 . Tubes of 0.5 mm ID smaller and larger sizes must be immediately available. Tube size on children can be estimated from the formula (16+ age) ÷ 4, but variation between individuals requires the availability of multiple tube sizes. If there is a suspicion of laryngeal or tracheal disease in any age group, smaller tubes should be available. A small tube (such as 6 mm ID in adults) may facilitate an otherwise difficult intubation.

*Laryngoscopes*

The standard rigid laryngoscope consists of a detachable blade with removable bulb that connects to a battery-containing handle. Each of the standard blades has a flange for displacing the tongue to the side and an open side for visualization of the larynx (Fig. 39–16). Sizes range from 0 (Miller) to 1 (MacIntosh), which are the smallest blades, to 4 (Miller or MacIntosh), which are the largest. The No. 3 blades are most frequently employed for adult use, with the No. 4 blades reserved for unusual or difficult patients. The smaller blades are used in pediatric patients.
FIGURE 39–16 Examples of the most frequently used detachable laryngoscope blades, which can be used interchangeably on the same handle. The uppermost blade is the straight or Jackson-Wisconsin design. The middle blade incorporates a curved distal tip (Miller). The lowermost blade is the curved or MacIntosh blade. All three blades are available in lengths appropriate for neonates and adults.

The curved blade introduced by MacIntosh is probably most popular for adult use. 54 The commonly used straight blades are the Miller, which has a curved tip, and the Wisconsin blade (and its modified forms) which has a straight tip. 55 Although straight blades may be advantageous in young children, the choice of blade in older children and adults is really a matter of familiarity and taste. The practitioner should be trained in the use of curved and straight blades, because when laryngoscopy is difficult with one type of blade, use of the other type may permit adequate laryngeal visualization. For example, the straight blade may be advantageous when mouth opening is vertically limited or the larynx is anterior. It has been reported that less force and head extension is required with the Miller blade. 56 The curved blade may be advantageous when mouth opening is horizontally limited or when more room is needed to perform the instrumentation desired (e.g., use of Magill forceps, changing tubes, intubation with esophageal obturator in place). Many other types of blades have been designed but their use is too limited to warrant additional discussion.

*Other Equipment for Routine Use*

A stylet is a rigid implement usually made of a flexible metal, which is inserted into the endotracheal tube in order to maintain a chosen shape. This will facilitate intubation when the glottis is visualized, but the tube tip cannot be directed through the glottis or when glottic visualization is minimal or absent and a semiblind or blind technique is required. The usual shape used is that of a hockey stick, but more of a curve may be required for blind or difficult intubations. A stylet is used during rapid sequence intubations or whenever the hemodynamically stressful time of laryngoscopy is best minimized (e.g., cardiac anesthesia or neuroanesthesia). The stylet should be lightly lubricated to facilitate removal and advanced into the tube without its tip protruding past the end of the tube. The stylet should be removed as the endotracheal tube tip enters the larynx to avoid undue trauma.

The Eschmann introducer (Connell Neurosurgical, Exton, Pa) is a 60-cm stylet-like device that is 5 mm in external diameter and has a 35-degree bend 2.5 cm from the end that is inserted into the trachea. Its structure is designed to provide a combination of stiffness and flexibility. It is more commonly known as the gum elastic bougie although it is neither gum, elastic, nor bougie. It is an extremely useful instrument when laryngoscopic view is poor or the tube cannot be otherwise guided into the glottis. It is also useful in limiting the degree of necessary neck movement during intubation with potential cervical spine injuries and to lessen the risk of dental damage. 57 The bent tip is directed blindly or under reduced vision into the glottic inlet and passed about 30 cm into the trachea (the "bougie" has distance markings). Tracheal entry is marked by the sensation of clicking over the tracheal cartilages as well as the hold-up by the reduction in luminal size near the carina. 58 While keeping the laryngoscope in place, the endotracheal tube is slid over the bougie into the trachea—a 90-degree counterclockwise turn facilitates glottic passage by presenting the bevel posteriorly. A smaller tube may also be required for passage. The bougie can also be used as tube changer, although it is a bit short for this purpose. It is reasonable to practice use of the bougie in a simulated difficult laryngoscopy in which a good glottic view is progressively reduced by lessening the force on the laryngoscope. This device is an indispensable part of practice in the United Kingdom and clearly allows for a significant number of direct laryngoscopic intubations that cannot be otherwise accomplished. It is a relatively expensive piece of equipment, and care must be taken that it is not inadvertently thrown out in the course of a difficult airway situation.

Some clinicians lubricate the tip of the endotracheal tube with local anesthetic ointment. This is not necessary, and the ointment may actually increase the incidence of sore throat. 59 Furthermore, the greasy ointment may interfere with handling of the endotracheal tube. The ointment is useful for placing nasal instruments (airways, endotracheal tubes, nasogastric tubes) with oral airways and for lubricating the stylet. Some kind of adhesive tape is necessary for securing the tube after placement. Taping methods that avoid splitting the tape and that include additional reinforcing segments over the tape applied directly to the tube are most effective in preventing dislodgement. 60 Particular care in securing the tracheal tube is indicated for surgical positions in which later access is difficult (e.g., prone neurosurgical patient in head pins with table turned away from the anesthesiologist), when dislodgement is likely (e.g., cleft palate repair), and when intubation is difficult. Cloth (twill) tape is useful in trauma where blood makes adhesive tape less effective and in patients with heavy beards. It cannot be overemphasized that oxygen, bag and mask, and suction should be available for all but the most emergent intubations. An additional oxygen source connected to a manual ventilation bag should be available in the operating room to back-up and supplement the oxygen supply available from the anesthesia machine.

*Techniques*

In every case, the anesthesiologist must attempt to determine whether mask ventilation and intubation will be possible if the patient is anesthetized and paralyzed. The usual intubation sequence includes the administration of a rapidly acting induction agent (e.g., thiopental), the demonstration of adequate mask ventilation, and the administration of a rapidly acting neuromuscular blocking agent (e.g., succinylcholine). The introduction of sevoflurane has made inhalational induction and intubation a reasonable alternative for selected adults as well as children. 61 Preoxygenation of such routine patients is optional but strongly recommended as it provides an added margin of safety. Preoxygenation is essential when a "rapid-sequence" intubation is chosen because of a "full-stomach" situation or other propensity to aspiration (e.g., esophageal disease). In this situation, the neuromuscular blocker is administered with the induction agent, cricoid pressure (Sellick maneuver) is applied, and mask ventilation is not provided unless unsuccessful intubation necessitates it. 62

Before routine or rapid-sequence intravenous induction, the clinician must determine whether this is the best and safest way to intubate the patient. This determination is aided by the history and physical examination, as noted previously in this chapter, in conjunction with a knowledge of those factors and syndromes that affect the airway. The critical point in the decision tree is the administration of muscle relaxants: the clinician must decide whether difficulties in ventilation are due to factors that will be improved by the advent of paralysis or if the patient should be awakened and intubated with a conscious technique. If there is sufficient doubt before induction with regard to the patient's airway, a conscious intubation with sedation and topicalization is indicated. Other clinical factors may influence the decision, including hemodynamic instability and severe intestinal obstruction, for example. In children, such an awake intubation is not generally possible except in newborns. However, a mask airway can usually be maintained in most difficult pediatric intubations.

*Endotracheal Intubation During Anesthesia*

Once the decision has been made that the patient can be safely anesthetized for intubation, a variety of methods can be used to achieve acceptable intubating conditions.

Anesthetics and Muscle Relaxants

For intravenous induction, a rapidly acting anesthetic is first administered (Ch. 12). This is usually thiopental or propofol, but induction drugs include other rapidly acting barbiturates (methohexital, thiamylal), ketamine, benzodiazepines, narcotics (large doses if given alone), and etomidate. The details of the pharmacology of these drugs are described in the chapters on narcotics and nonnarcotic intravenous anesthetic agents. The choice of drug depends mainly on the status of the cardiovascular system but is also influenced by central nervous system effects, effects on bronchomotor tone, presence of an allergy, pharmacokinetic differences, side effects, and the experience of the clinician. Intubation may be accomplished with intravenous or inhalational anesthetics without relaxant, but this approach also possesses difficulties such as the potential for laryngospasm and a lesser degree of muscle relaxation to improve laryngoscopic conditions. In practice, the majority of clinicians employ muscle relaxants to facilitate intubation.

The most commonly employed relaxant for intubation is succinylcholine, but the nondepolarizing relaxants in appropriate doses may be used as well. The popularity of succinylcholine has been questioned, mainly in reference to its association with masseter spasm and malignant hyperthermia. Succinylcholine may also produce the severe side effect of hyperkalemia after burns, neurologic injury, and trauma as well as increases in intraocular and intracranial pressure. The great advantage of succinylcholine is that it produces excellent intubating conditions usually within a minute, or slightly longer if pretreatment with a small (about 1/10 intubating dose) amount of nondepolarizing relaxant is employed to diminish fasciculations and postoperative throat and skeletal muscle soreness. 63 However, others believe that with this pretreatment the quality of intubating conditions is worsened. In sensitive individuals, frightening paralysis and even aspiration may occur. The rapid onset of adequate paralysis for intubation can now be duplicated with rocuronium. 64 However, succinylcholine maintains the advantage of rapid offset of action by ester hydrolysis. If the airway cannot be secured, the patient's own ventilation and airway maintenance will return much more quickly than with any of the currently available nondepolarizing relaxants. Succinylcholine is still the only relaxant with a duration of action (assuming normal pseudocholinesterase activity) that may provide for the resumption of spontaneous ventilation within a time sufficiently short that cerebral integrity can be maintained in the properly preoxygenated patient. When a muscle relaxant is to be employed in a difficult or potentially difficult airway, succinylcholine appears to be the relaxant of choice unless there are contradictions to its use, such as a risk of hyperkalemia.

The use of nondepolarizing relaxants for intubation has increased with the availability of short-acting compounds such as rocuronium. Atracurium, vecuronium and cisatracurium are alternatives that are not quite as rapid in onset as is rocuronium. 64 The effects of these agents can generally be reversed in a shorter time than those of the older, nondepolarizing relaxants. Intubating doses of curare, metocurine, and pancuronium may result in histamine release or undesirable autonomic effects. However, the pancuronium-induced tachycardia that is disadvantageous with certain cardiac disorders may be advantageous in children, with bradycardia, or in massive trauma. In addition, an intubating dose of pancuronium may be cost-effective when relaxation will be required for several hours after intubation.

Nasal Versus Oral Route

In the operating room, nasal intubation is performed when surgery in the oral cavity or on the mandible is facilitated by an unobstructed view. If the mouth is to be wired or banded shut after surgery, a nasal tube must be used. Contraindications to nasal intubation include coagulopathy, severe intranasal disorder, basilar skull fracture, and presence of a cerebrospinal fluid leak. There is at least one report of an endotracheal tube entering the cranium through a nasal fracture. 65 If an oral tube is surgically unacceptable, and nasal intubation is contraindicated, the anesthesiologist must discuss the relative risks of tracheostomy and oral and nasal intubation in that patient with the surgeon to arrive at an acceptable compromise.

Nasal intubation is also used in the operating room in difficult airway situations. These include blind or fiberoptic intubation in the topicalized, sedated patient. Nasal intubation may be chosen because direct laryngoscopy is impossible; it may be quicker and more comfortable than oral intubation in the topicalized, sedated patient. Details on nasal intubations follow in the appropriate sections. Nasal intubation (unlike oral intubation) may produce a bacteremia, and appropriate endocarditis prophylaxis should therefore precede it. 66, 67

Oral Endotracheal Intubation

This is the usual method of intubation in the operating room. In adults, a rapidly acting anesthetic is usually given intravenously, mask ventilation is ensured, and a muscle relaxant is administered to facilitate laryngoscopy. In children, mask, rectal, and intramuscular inductions are frequently employed. Intubation may be performed with anesthesia and no relaxant, but a deep level of anesthesia must be achieved to avoid unforgiving reflexes such as laryngospasm. Unless there is a contraindication, the head is maintained in the classic “sniffing position” to align the oral, pharyngeal, and laryngeal axes (see Fig. 39–3). In adults, a small foam pillow or several folded sheets are often employed to maintain flexion in the lower cervical spine. The Popitz “sniffing position” pillow is an excellent way to establish a satisfactory position for both mask ventilation and endotracheal intubation in the adult patient (Fig. 39–17). It is important to use a head support that, unlike a big, soft pillow, does not allow the head to sink down into it. The laryngoscope is held in the left hand while the fingers of the right hand are used to gently open the mouth. The clinician should wear gloves because of the likely entry of fingers into the patient‘s mouth. The laryngoscope blade is gently inserted into the right side of the patient‘s mouth to avoid the incisor teeth and to enable the flange of the blade to keep the tongue to the left. Pressure on the teeth, gums, or lips is avoided. A mouth piece or maxillary teeth protector may be employed to lessen the likelihood of injury to those teeth. A full-fingered grip on the laryngoscope handle rather than a two-fingered hold at the junction of the handle and blade may provide a mechanical advantage that helps in difficult adult exposures.
FIGURE 39–3 Schematic diagram demonstrating head position for endotracheal intubation. (A) Successful direct laryngoscopy for exposure of the glottic opening requires alignment of the oral, pharyngeal, and laryngeal axes. (B) Elevation of the head about 10 cm with pads below to occiput with the shoulders remaining on the table aligns the laryngeal and pharyngeal axes. (C) Subsequent head extension at the atlanto-occipital joint serves to create the shortest distance and most nearly straight line from the incisor teeth to glottic opening.
FIGURE 39–17 A volunteer positioned on the Popitz pillow demonstrating cervical flexion and a small degree of atlanto-occipital extension (Dermacare, Louisville, Ky). The flexion serves to align the laryngeal and pharyngeal axes. Further extension of the head results in the true “sniffing” position.

After visualization of the epiglottis, the curved blade (e.g., MacIntosh) is inserted into the vallecula (the space between the tongue and epiglottis), and the laryngoscope is pulled forward and upward (Fig. 39–18) to expose the glottis. It is important to recognize structures sequentially as the blade is inserted and not just to insert deeply, pull, and hope for the best. The endotracheal tube is inserted into the right side of the mouth and inserted between the open vocal cords under direct vision (Fig. 39–19). An assistant may help by pulling the right side of the mouth open to improve vision (especially with the Miller blade). Difficulties in visualization may be due to head position, a blade that is too far advanced or not far enough advanced, or a reluctance on the part of the novice laryngoscopist to apply adequate (but gentle) upward force.
FIGURE 39–18 Schematic diagram depicting proper position of the laryngoscope blade during direct laryngoscopy for exposure of the glottic opening. (A) The distal end of the curved blade is advanced into the space between the base of the tongue and pharyngeal surface of the epiglottis (vallecula). (B) The distal end of the straight blade (Jackson-Wisconsin or Miller) is advanced beneath the laryngeal surface of the epiglottis. Regardless of blade design, forward and upward movement exerted along the axis of the laryngoscope blade (arrows) serves to elevate the epiglottis and expose the glottic opening.

FIGURE 39–19 Schematic view of glottic opening during direct laryngoscopy when the epiglottis is elevated with a curved or straight laryngoscope blade. The glottic opening is recognized by its triangular shape and the pale white vocal cords. (From Stoelting RK and Miller RD: Basics of Anesthesia, 3rd ed. New York, Churchill Livingstone, 1994)

A straight blade is used in somewhat similar fashion except that it is usually advanced beyond the epiglottis, so that the epiglottis is included in the structures lifted up by the blade (see Fig. 39–18). Gentle dorsad pressure on the cricoid or thyroid cartilage may bring a nonvisualized larynx into view. The BURP maneuver, which includes backward, upward, and right lateral displacement of the thyroid cartilage, has been shown to be effective in improving the grade of glottic exposure. 68 As noted, the choice of blade is a matter of the clinician's preference. It is not established that one or the other blade causes less of a stimulus to airway reflexes and cardiovascular response. It is traditional but in no way mandatory for the novice to start with a curved blade. Because the peculiar anatomy of an individual patient may allow successful laryngoscopy with one blade but not the other, skill should be developed in the use of both blade types. Turning the head to the left and inserting a straight blade lateral to the molars may improve visualization on occasion by displacing the tongue and affording a more direct line of sight to the larynx. A common cause of inadequate visualization is insufficient flexion of the lower cervical spine that can be augmented while mask ventilation is continued.

In adult males, the tube is generally inserted to about 23 cm at the lips to position the tube, with the tip an appropriate 4 cm above the carina. For adult females, the distance is about 21 cm. Tubes inserted too far will cause endobronchial (usually right) intubation whereas tubes that are not in far enough may be difficult to seal because of cuff protrusion through the larynx and will be more at risk for accidental extubation (Fig. 39–20). Exact placement of the tube requires a fiberoptic bronchoscope, but this is not usually necessary. Endobronchial intubation is easier to remedy than accidental extubation. In children, the distance (cm) at the lips can be estimated from the formula: 12 + (age/2). In this age of laparoscopic surgery, be aware that abdominal insufflation can shift the carina cephalad and convert an acceptable location to an endobronchial one. 69

FIGURE 39–20 Diagrammatic representation of key distances relating to endotracheal tube position (From Stone and Bogdonoff171 )

A rapid-sequence induction is employed when the patient is at particular risk for aspiration and there is reasonable certainty that intubation should not be difficult (Table 39–6). If there is sufficient doubt about the ability to intubate the patient in this setting, an intubation in the conscious patient with judicious use of topical anesthesia with or without sedation should be strongly considered. Before a rapid-sequence induction, the patient is preoxygenated. Although healthy lungs may be largely denitrogenated with four vital capacity breaths, the longer time constants of diseased or aged lungs require a longer period of preoxygenation to ensure adequate nitrogen washout. 70 End-tidal nitrogen concentration, if available, can be used to assess nitrogen washout more precisely if a tight mask seal can be established. When time is critical, as in emergency cesarean section, four vital capacity breaths are adequate. 71 After preoxygenation, an intravenous anesthetic and muscle relaxant are administered together. It is the authors' practice to locate the cricoid cartilage in the conscious patient but not apply pressure until the patient is unconscious. This is because the proper amount of cricoid pressure is very uncomfortable in the awake patient, may provoke vomiting and obstruct the airway, is less likely to be effective in the patient before paralysis inhibits active vomiting, and has been shown to lower esophageal sphincter tone. 72 The downward force on the cricoid cartilage required to occlude the esophagus appears to be approximately 30 to 40 N, about the force of an 8- to 9-lb weight. 73 This may prevent regurgitation if applied properly, and because the force of vomiting is blunted by the muscle relaxant, the force should greatly decrease the risk of aspiration. 74 Interestingly, there have been no studies proving that cricoid pressure is truly beneficial. 73 Incorrectly applied pressure will not protect the patient from aspiration because only the cricoid forms a complete ring that will occlude the esophagus. 75 When intubation is difficult, cephalad (in conjunction with dorsal) cricoid pressure may aid visualization. 76 Laryngoscopy and intubation in this setting are generally performed without any preceding manual ventilation, if possible. If intubation is not possible, mask ventilation should be provided while cricoid pressure continues. It is critical that the cricoid pressure be applied correctly so that it does not actually impede visualization of the glottis or passage of the tube. If glottic visualization or endotracheal tube passage is impaired, pressure may need to be let up or entirely released to see if it is contributing to the problem. In addition to preventing regurgitation, cricoid pressure decreases the flow of gas to the stomach, minimizing gastric distention that can impede ventilation as well as predisposing to regurgitation. Pretreatment with an anticholinergic is recommended to minimize secretions that may impair visualization during a rapid-sequence intubation. Pharmacologic approaches to the patient at risk from aspiration are discussed in Chapters 12 and 57 .

TABLE 39–6. Patients at Risk of Aspiration of Gastric Contents

*Special Considerations*

Laryngoscopy and intubation are powerful noxious stimuli, and the response may have deleterious respiratory, neurologic, or cardiovascular effects. Furthermore, deeper levels of anesthesia are required to blunt the response to laryngoscopy and intubation than the response to surgical incision. 77, 78 When planning the anesthetic induction, these effects must be blunted to whatever degree is possible, especially if the patient falls into a high-risk population (e.g., with coronary artery disease, asthma, elevated intracranial pressure, cerebral aneurysm, and so on).

Nasal Endotracheal Intubation

When nasal intubation is chosen solely for purposes of surgical convenience, anesthesia may be induced before intubation. A vasoconstrictor should be applied before nasal instrumentation. Cocaine (4% up to 1.5 mg/kg) can be used but phenylephrine (¼–1% nose drops) is more readily available and less toxic. After anesthesia is induced and mask ventilation is established, the endotracheal tube is introduced into the nose in a plane that is roughly perpendicular to the face. The patient may be allowed to breathe spontaneously to facilitate blind intubation. In this case, the tube is inserted until maximum breath sounds are heard (usually about 14–16 cm in adults), implying that the tube tip is just above the glottis. The tube is then inserted into the glottis during inspiration. Some clinicians choose to administer $CO_2$ or doxapram to induce hyperpnea and facilitate intubation during spontaneous ventilation, but this is not commonly done currently. Because entry into the glottis is not seen directly, it is essential to have capnographic or bronchoscopic confirmation of endotracheal placement because, at times, all the indirect signs of intubation may be misleading. Anesthetized blind nasal intubation may also be attempted in the apneic, paralyzed patient, but in this case there are no spontaneous breath sounds to aid placement, which is guided by external observation for tip location in the neck.

If the tube does not enter the glottis, the patient‘s head may be extended, flexed, or turned to guide the tip (if not contraindicated by spinal bony disease). If the tube tip is felt anteriorly, flexion may help; if the tip is felt beside the larynx (in the pyriform sinus), turning the tube tip away from that side may help. Most of the time, the tube enters the esophagus, and extension of the head will help. If the trachea cannot be blindly intubated, the patient can be intubated with guidance under direct vision (after appropriate mask ventilation). In this situation, a curved laryngoscope blade appears to provide the greatest amount of space for maneuvering. The tube is inserted into the nose, and direct laryngoscopy is performed in the usual fashion. Under such direct vision, the laryngoscopist may be able to direct the tip into the glottis. If not, Magill forceps may be used to carefully grasp the tube while avoiding trauma to the cuff. The tube can then be directed into the glottis, often with the help of an assistant who can push on the nasal end of the tube. If the glottis cannot be visualized by direct laryngoscopy, the Magill forceps can still be used to attempt to guide the tip blindly into the area of the glottis. Excessive force on the tube should be avoided as delicate laryngeal structures can be damaged or false passages created.

An anterior curve in the endotracheal tube may help in blind nasotracheal intubation. This can be accomplished by putting a stylet in the tube (removed before use) with the desired C-shape or by placing the tube tip in the 15-mm connector to form a circle. The time that the tube holds the curve can be lengthened by placing the curved tube in a refrigerator or freezer for some time before the case. An Endotrol endotracheal tube, which has an operator-end loop that directs the tube tip anteriorly when pulled, may be used. Another technique that utilizes cuff inflation has been described to further aid blind intubation. 79 Breath sounds must be audible, so breathing must be spontaneous. When breath sounds are of maximal intensity, the endotracheal tube cuff is inflated with 15 mL of air, which tends to direct the tip anteriorly. The air is released from the cuff as the tube is passed (2 cm) through the glottis to avoid damage to the cords. The use of a stylet has also been suggested in difficult nasal intubations. 80 After the endotracheal tube is placed so that its tip should be just above the glottis, a stylet in a C-shape is carefully inserted into the endotracheal tube. The tube is then slid off the stylet, which directs it more anteriorly and (ideally) into the glottis.

When Intubation Fails

Every practitioner, no matter how skilled, will encounter patients who are unexpectedly difficult to intubate. The induction of anesthesia should be approached with this possibility in mind so that a clear plan of action can be pursued. The prevalence of difficult laryngoscopy appears to be approximately 1 to 4 percent and is higher in the obstetric than the nonobstetric population. 23 The degree of glottic exposure as described by Cormack and Lehane allows interobserver comparison of the difficulty of laryngoscopy (Fig. 39–21). Patients of grade 4 difficulty and many patients of grade 3 view are likely to present difficulties and may even be impossible to intubate. In addition to difficult visualization, other pathologies, including epiglottitis, laryngeal or tracheal stenosis, and luminal tumors, may make translaryngeal passage of the endotracheal tube difficult.
FIGURE 39–21 Grades of difficulty in laryngoscopy ranging from grade 1, no difficulty; grade 2, only posterior extremity of glottis visible; grade 3, only epiglottis seen; grade 4, no recognizable structures. (From Cormack RS, Lehane J: Difficult tracheal intubation in obstetrics. Anaesthesia 39:1105, 1984)

When an initial attempt at intubation fails, mask ventilation should be resumed while the situation is reassessed. As long as mask ventilation can be maintained, the problem is not emergent. Cricoid pressure should be maintained when a full stomach is suspected. Head position and laryngoscopy technique need to be reexamined. The laryngoscopist may wish to exchange a curved for a straight blade (or vice versa). A longer MacIntosh blade (#4) can be useful in this situation. The Miller No. 4 blade is wider but not much longer than the No. 3 model. This width may help keep the tongue out of the visual field and provide a more effective fulcrum for displacement of the tongue muscle. If repeated laryngoscopy by an experienced practitioner is unsuccessful, a decision-branch point is reached if short-acting drugs (thiopental, inhalational anesthetic, succinylcholine) have been used: the patient may be allowed to awaken for an attempt at intubation with topical anesthesia, or the case may even be postponed if nonemergent. If long-acting drugs have been used (high-dose narcotic, nondepolarizing relaxant), mask ventilation must obviously be maintained until reversal is possible. A task force of the American Society of Anesthesiologists has developed an algorithm for the difficult airway, which is a useful guide in this setting (Fig. 39–22). Benumof has incorporated previously approved ideas and concepts into one flow diagram that some readers may find preferable (Fig. 39–23). He has defined a best attempt at laryngoscopy as being performed by a laryngoscopist with at least 3 years‘ experience, optimal positioning, use of external laryngeal manipulation, and change of blade type and length one time each. 35 As he also points out, a difficult laryngoscopy will likely be readily apparent to a skilled practitioner on the first attempt.
FIGURE 39–22 Difficult airway algorithm developed by ASA Task Force on Guidelines for Difficult Airway Management (Modified from American Society of Anesthesiologists Task Force on Management of the Difficult Airway: Practice guidelines for the management of the difficult airway. Anesthesiology 78:597, 1993)
FIGURE 39–23 Single-flow diagram version of the ASA Difficult Airway Algorithm. +Always consider calling for help (e.g., technical, medical, surgical) when difficulty with mask ventilation and/or tracheal intubation is encountered. ++Consider the need to preserve spontaneous ventilation. *Nonsurgical tracheal intubation choices consist of laryngoscopy with a rigid laryngoscope blade (many types), blind orotracheal or nasotracheal intubation, fiberoptic/stylet technique, retrograde technique, illuminating stylet, rigid bronchoscope, and percutaneous dilational treacheal entry. See Benumof38 for a complete discussion of these TI choices. (Modified from Benumof43 )

If intubation cannot be accomplished, and the decision has been made to keep the patient anesthetized for intubation (or long-acting drugs have been used), a variety of other techniques can be utilized. First, help should be obtained, if possible. The assistant may provide laryngeal displacement such as a BURP maneuver, which is likely to improve glottic exposure. The assistant also provides a fresh pair of hands for mask ventilation and laryngoscopy and an objective viewpoint in what may be a rapidly deteriorating situation. An anticholinergic should be administered to reduce the secretions that often accumulate in this situation. If the arytenoids or epiglottis can be visualized, the gum elastic bougie represents an effective approach to intubation. 81 Currently, this is the next approach to this situation at the authors‘ institution. The elastic gum bougie is less effective in grade 4 views, but an attempt at entering the glottis can still be made. If a skilled bronchoscopist is available and mask ventilation is possible, fiberoptic bronchoscopy is probably best attempted immediately, before the field is obscured with blood and edema. However, this is not an ideal setting for the novice bronchoscopist. Other options include blind nasotracheal intubation or blind orotracheal intubation employing direct laryngoscopy with a curved blade and an endotracheal tube directed anteriorly with a stylet. The use of a lighted stylet or retrograde intubation may be appropriate and are described later. The use of the LMA as a conduit for blind, bougie-guided, or fiberoptic intubation has been discussed. 43 Selected cases can proceed with an LMA or Combitube as airways. An LMA can also be inserted simply to facilitate ventilation until the effects of relaxants and other agents wear off. Other clinicians have suggested the Bullard laryngoscope (Circon ACMI, Stamford, Conn) or the Augustine introducer (Augustine Medical, Eden Prairie, Minn). 82, 83 If multiple attempts fail and the case is not of an emergent nature, it is best to simply ventilate the patient until drugs can be reversed, because edema and blood may produce serious airway obstruction, preventing even mask ventilation. A patient for elective surgery who experiences intermittent laryngospasm and serious dysrhythmias is also a poor candidate for continued attempts at intubation.

When Mask Ventilation and Intubation Are Impossible

The patient who is truly impossible to mask-ventilate (two-handed mask ventilation with oral and nasal airways, complete forward mandibular dislocation, and bag ventilation by an assistant) or intubate presents a brain- and life-threatening emergency that has been estimated to occur 1 in 10,000 anesthetics. 84 As in so many instances in medicine, the best treatment is prevention: the clinician must always carefully evaluate the airway to determine the safest plan for intubation and extubation. 85 In the patient who has been thoroughly denitrogenated, there should be sufficient time to institute one of the following interventions before serious oxygen desaturation and consequent hemodynamic deterioration occur. In reality, one is often dealing with a severely hypoxic patient who has suffered or is near to cardiac arrest. It is critical to institute one of the following interventions *before* irreversible cardiac arrest or brain damage has occurred. If only short-acting drugs have been used (succinylcholine, thiopental, lidocaine, etc.) and the patient has been adequately preoxygenated, adequate spontaneous ventilation may resume before further intervention is required.

The LMA has become the next intervention in this situation; the Combitube is a reasonable alternative, particularly if aspiration is a major concern (Fig. 39–24). If one of these supraglottic devices does not produce adequate gas exchange quickly, transtracheal jet ventilation (TTJV) should be instituted. In TTJV, a 14- or 16-g cannula is inserted through the cricothyroid membrane and attached to a high-pressure oxygen source via a low-compliance circuit (Fig. 39–25). The review of Benumof and Scheller 84 demonstrates that TTJV can provide adequate ventilation as well as oxygenation and serves as a valuable source for those planning to assemble an acceptable TTJV system. Perhaps the most readily available (and least expensive) system employs the fresh gas outlet and oxygen flush valve of the anesthesia machine as the high pressure oxygen source. A 5-mm ID endotracheal tube adapter attached to oxygen supply tubing is inserted into the fresh gas outlet. A three-way stopcock (of large bore, if possible) is attached to the other end of the tubing and then connected to the translaryngeal cannula (Fig. 39–26). The three-way stopcock may help in preventing excessive pressure build-up by releasing the aperture to air between jet inspirations. A much less effective but more readily available system includes use of the standard anesthesia circuit or a self-inflating reservoir bag attached to the translaryngeal cannula (via a 3-mm ID endotracheal tube adapter placed directly into the cannula or an 8-mm ID endotracheal tube adapter placed into the wide end of a 3-mL plungerless syringe, then connected to the cannula). 84 Successful TTJV should be followed up with provision of a definitive airway by tracheostomy, endotracheal intubation, or wake-up and resumption of the normal airway. The most serious complications of TTJV involve some form of hyperinflation due to inadequate venting of inspired gases in the presence of complete or nearly complete upper airway obstruction. This may result in barotrauma and/or diminished cardiac output in the context of an immediately life-threatening problem.
FIGURE 39–24 Role of the LMA in the ASA Difficult Airway Algorithm. (Modified from Benumof43 )
FIGURE 39–25 Anatomy of the cricothyroid membrane (Courtesy of Cook Critical Care, Bloomington, In.)
FIGURE 39–26 Transtracheal jet ventilation apparatus assembled from components generally available in the operating room (5.0-mm ID endotracheal tube adapter, oxygen tubing, three-way stopcock). The connections can be banded for further security.

Although a classic tracheostomy can, in general, not be performed quickly enough in the “cannot ventilate/intubate” situation, cricothyroidotomy can be employed to insert a small endotracheal or tracheostomy tube. A surgical blade (such as #11) on a handle and a Kelly clamp for spreading the incision are required. Kits with all the required materials are commercially available (Melker emergency cricothyrotomy catheter set, Cook Critical Care, Bloomington, Ind). Although an experienced surgeon is the best choice to perform a cricothyroidotomy, the anesthesiologist must be prepared to do so if TTJV is unavailable or unsuccessful. Neither therapy, however, will relieve obstruction that occurs below the first few tracheal rings. Complications of cricothyroidotomy include misplaced tubes early and hoarseness and subglottic stenosis as later problems. 86

Difficult-Airway Cart

The ASA Task Force on Difficult Airway Management has made the reasonable suggestion that a portable storage unit for a variety of intubation aids be readily available. Suggested equipment for this is listed in Table 39–7 . The bronchoscope cart itself is a practical choice for storage of these additional devices, which may be needed urgently on rare occasions.

TABLE 39–7. Suggested Contents of the Portable Storage Unit for Difficult Airway Management

*Conscious ("Awake") Intubation*

While emergency nonanesthetized intubations outside the operating room may be performed with minimal topical anesthesia and no sedation, the term "awake" intubation applied to nonanesthetized intubations in the operating room is usually something of a misnomer. After appropriate sedation, topical anesthesia, and nerve blocks, such intubations can be performed with minimal discomfort in the conscious patient. Conscious intubation is performed when the clinician believes that it is the safest way to insert an endotracheal tube. Indications include a history of difficult intubation, findings on history or physical examination that can make intubation difficult, and severe risk for aspiration or hemodynamic instability. The reasons for conscious intubation should be explained to the patient as time allows and documented in the chart. The primary consideration of safety should be emphasized. At times, surgeons (and other physicians) may be unhappy about their patients being subjected to such procedures because of unwarranted fear of patient discomfort and the time required. If the anesthesiologist has concluded that such intubation is indicated, the demands of such individuals must not take precedence over patient safety. The reasons for conscious intubation should be emphasized to the surgeon as well as to the patient because airway disaster, poor outcome, and litigation may follow airway mismanagement. In the American Society of Anesthesiologists' closed claims study, adverse respiratory events including inadequate ventilation, esophageal intubation, and difficult tracheal intubation form the largest single class of injury. 87, 88

Drugs for Sedation

Narcotic analgesics are the key to facilitating conscious intubation. They afford mild sedation, analgesia, and reduction of airway reactivity that may result in cough and bronchospasm. Any narcotic may be used, but the overall characteristics of fentanyl have made it the most useful in such procedures. A lag in onset (hysteresis) of about 5 minutes for the full effect of fentanyl should be kept in mind as incremental doses of the drug are administered. 89 Dose requirements also vary greatly between individuals (25–500 ?g), and thus the drug should be administered slowly in small increments. The effect (or lack thereof) may not be apparent until the laryngoscope is inserted. Perhaps the greatest advantage of narcotics, especially fentanyl, is the ease of reversibility by naloxone should an undesired degree of respiratory depression result. Such patients may simply need to be reminded to breathe in order to ventilate adequately. If awake intubation is being performed because of a severe risk of aspiration, narcotics (and other intravenous sedatives) must be used sparingly.

In order to afford more sedation than a moderate dose of narcotics provides, a second drug is usually given. Droperidol (Inapsine) is a butyrophenone that supplies adequate sedation without adding to narcotic-induced respiratory depression. 90 The drug is contraindicated in patients with Parkinson's disease because it blocks dopamine receptors and may produce a dystonic reaction. Doses of 1.25–5.0 mg intravenously are usually adequate, although doses up to 10 mg can be used. The latter doses may be associated with bizarre side effects such as akathisia and dysphoria and a prolonged state of sedation (up to 24 hours). To maximize patient comfort, it is best to administer a small dose of fentanyl before droperidol is given.

Other clinicians prefer to add a benzodiazepine to the narcotic effect. Midazolam (Versed), diazepam (Valium), or lorazepam (Ativan) may all be used, but midazolam is probably the most popular at present because of its relatively rapid onset and offset of action as well as the production of anterograde amnesia. The benzodiazepines should be administered slowly in small doses because their effect on consciousness, respiration, and cardiovascular status in individuals is unpredictable. Even 0.5 mg may produce adequate amnesia in some adults. Unlike droperidol, benzodiazepines result in increased respiratory depression in the presence of narcotics, which is usually manifest by apneic spells. 91 Flumazenil, a specific reversal agent, is now available clinically. The principal disadvantage of using benzodiazepines may be the profound decreased level of consciousness that results in loss of verbal contact with the patient, who in such situations must be able to respond to commands, especially to breathe. In the frail elderly patient, intravenous diphenhydramine (Benadryl) in doses of 12.5 mg may provide good supplemental sedation to narcotics without excessive respiratory depression or adverse mental effects.

*Anticholinergics/Topical Anesthesia*

Before any anticipated difficult intubation, a dose of anticholinergic, such as glycopyrrolate (Robinul) 0.2 mg intravenously, is strongly advised. If bronchospasm is anticipated, larger doses (0.4–1.0 mg IV) are recommended to blunt the response to airway instrumentation. Besides improving visualization during laryngoscopy by reducing secretions, topical solutions of local anesthetics will be less diluted and less likely to be washed off the desired site of application. The use of anticholinergics is reasonable for general anesthesia in any smoker, for surgical positions in which suctioning will be difficult, for surgical positions in which secretions could loosen securing tape and predispose to tube dislodgement, and for surgery that involves the airway. For patients in whom succinylcholine is contraindicated, the decreased production of secretions occurring after prophylactic anticholinergics may lessen the chance of severe postextubation laryngospasm, which is especially difficult to treat without succinylcholine.

Anesthesia of the nares and nasopharynx should be accompanied by vasoconstriction to widen the available passage and decrease bleeding. Cocaine (4%) may be used up to 1.5 mg/kg. It is far more convenient and reasonably effective to use a lidocaine/phenylephrine combination. The phenylephrine may be applied first as 1/4 to 1 percent nose drops or the solutions may be mixed and applied together (4 percent lidocaine and 1 percent phenylephrine in a 3:1 combination to yield a 3 percent lidocaine/0.25 percent phenylephrine solution). 92 To anesthetize the sensitive nasopharynx, the solution may be instilled through a 16- or 18-gauge plastic catheter inserted deeply into the nose or on long cotton-tipped applicators that are slowly inserted until they reach the posterior wall of the nasopharynx. If three such applicators can be inserted, a 7.0-mm ID endotracheal tube will usually pass through that nostril. The applicators can be gently moved anteriorly and posteriorly to contact the entire mucosa, and additional solution can be dripped in along the wooden sticks as necessary. The total dose of lidocaine should be carefully controlled to avoid toxicity, particularly if additional lidocaine application is planned. Other practitioners topicalize the nares using progressively larger-sized soft nasal airways coated with 2 percent lidocaine ointment. Finally, the nasal endotracheal tube can be coated with 2 percent lidocaine ointment to facilitate passage and give further analgesia.

The tongue and oropharynx can be anesthetized with 10 percent lidocaine spray, which is placed progressively further into the pharynx using the laryngoscope blade or a tongue depressor to keep the tongue out of the way. The cooperative patient can also gargle and expectorate viscous lidocaine to produce topical anesthesia of the tongue and pharynx. Once there is sufficient topicalization to allow the insertion of an oral airway, the long applicator adaptor for 10 percent lidocaine spray can be blindly placed through the airway to spray local anesthetic directly onto the supraglottic and glottic structures. Nebulization of 5 mL of 4 percent lidocaine can also be employed. 93

The larynx can be sprayed with additional lidocaine directly onto the visualized glottis. If a laryngotracheal applicator (LTA) kit is to be used, it can be inserted with some holes below the vocal cords and some above. This will anesthetize the supraglottic area (including epiglottis) as well as the trachea when the lidocaine is injected. The LTA kit has also been used as an intubation guide with the applicator inserted through the Murphy eye and the endotracheal tube oriented with the concavity to the left. 94 The trachea can also be anesthetized with a transtracheal (or more correctly, translaryngeal) application of 2 to 3 mL of 2 percent lidocaine. A 23-gauge needle is inserted perpendicularly through the cricothyroid membrane in the midline, air is aspirated to ascertain the location of the needle tip, the lidocaine is quickly injected, and the needle is removed (see Fig. 39–25). This may cause vigorous coughing in some patients, but coughing provides excellent spread of the anesthetic in the larynx below the vocal cords. Other practitioners insert a 14-gauge or 16-gauge intravenous catheter through the cricoid membrane and remove the metal inner cannula before injecting local anesthesia. The catheter can be left in place to provide TTJV or access for retrograde intubation. The topicalization produced in the larynx and trachea is suitable for the use of the elastic gum bougie as well as a direct attempt at intubation. Contraindications to such injections include coagulopathy and local disorders such as tumor masses.

The use of topical anesthesia of the airway in the presence of a full stomach should be approached with common sense. The nose, tongue, and oropharynx can be safely anesthetized, but similar anesthesia in the larynx and trachea may diminish airway protection to unacceptable levels. When the cords are visualized, some clinicians may choose to spray the laryngotracheal structures with an LTA kit and then immediately follow with insertion of the tube. Others believe that even such a brief period of susceptibility to aspiration is unacceptable.

*Nerve Blocks*

The glossopharyngeal block blocks the sensory input from the areas of the posterior tongue innervated by that cranial nerve (Ch. 43). A 22-gauge spinal needle is used to inject 5 mL of 1 percent lidocaine with epinephrine into the area where the base of the tongue apposes the palatoglossal fold (Fig. 39–27). The needle should be aspirated to avoid intravascular injections. The block is acceptable with a full stomach and does not appear to affect airway integrity when performed bilaterally. The block is intended to provide more comfortable laryngoscopy with lower doses of injective drugs. However, a study reported that viscous lidocaine swish and gargle folowed by spray application of 10 percent lidocaine is as effective as glossopharyngeal block without producing the prolonged local discomfort seen in some individuals after the block. 95

FIGURE 39–27 Area of needle insertion for glossopharyngeal block. (Courtesy of Andrew Woods, M.D., and Christopher Lander, M.D.)

The superior laryngeal nerve innervates the epiglottis, aryepiglottic folds, and the laryngeal structures down to the false cords. The superior laryngeal nerve (SLN) may be blocked by an external approach using a 23-gauge needle and 3-mL syringe to inject 2 to 3 mL of 1 percent lidocaine between the greater cornu of the hyoid bone and the thyroid cartilage. This block is contraindicated by coagulopathy, a local pathologic problem, or full stomach. The SLN may also be blocked by the application (for about a minute per side) of lidocaine-soaked gauze pads with Krause forceps held in the pyriform fossa. This latter technique is frequently performed by otolaryngologists prior to laryngoscopy.

Choice of Technique

The choice of technique for conscious intubation depends on preference for oral or nasal tube placement, experience, and availability of equipment. If one technique fails, another is usually tried. All anesthesiologists should develop skill with conscious oral intubation with direct laryngoscopy. Blind nasal intubation that avoids the discomfort of laryngoscopy is equally important to learn. If fiberoptic bronchoscopy is an option, it should be performed reasonably early in the sequence because blood, secretions, and edema can make its use extremely difficult.

*Conscious Oral Intubation with Direct Laryngoscopy*

Preparation for conscious oral intubation involves use of the drying agents, sedation, topical anesthesia, and/or nerve blocks previously discussed. Topical application of anesthesia to oropharynx and tongue without glossopharyngeal nerve blocks may allow for laryngoscopic visualization and further anesthesia of the glottis and the trachea via an LTA kit or similar device. The laryngoscope must be inserted gently but with firm manipulation when required. The requirement for sedation, topicalization, and nerve blocks varies greatly among patients so that care must be taken to avoid excessive doses while providing acceptable comfort levels. The use of the elastic gum bougie may improve comfort by reducing the force required to produce acceptable glottic exposure. Superior laryngeal blocks and transtracheal anesthesia are not generally used if there is a concern for aspiration of gastric contents.

To supplement the commonly used laryngoscope blades, a variety of ingenious blades have been devised to cope with the difficult intubation. In addition to a variety of shapes, mirrors (Siker blade) and prisms (Huffman, Bellhouse) have been adapted for looking literally “around the corner.” 96, 97 The Howland lock fits between the blade and handle, changing the angle of their relationship. In very obese patients, the laryngoscope may need to be inserted by turning the handle to the right, inserting the blade and then attaching the handle, or by using a short laryngoscope handle. 98 While some clinicians take an “awake look” and then anesthetize the patient for intubation, visualization of the glottis in the conscious patient does not guarantee similar visualization after anesthesia and/or paralysis as muscle relaxation causes the larynx to shift anteriorly. 99

*Conscious Oral Intubation with Indirect Laryngoscopy*

Unlike the flexible fiberoptics to be discussed, a rigid stylet fiberoptic laryngoscope is available for oral intubation only. The device is used to locate the glottis, but the stylet tip does not actually enter the larynx. 34 The Bullard laryngoscope, an instrument for indirect laryngoscopy, is inserted much like a routine laryngoscope. The handle is then rotated from horizontal to vertical as the blade slides around the tongue. The endotracheal tube may be passed from the intubating attachment of the laryngoscope, or a tube containing a stylet in the shape of the laryngoscope may be used. 83

*Blind Oral Intubation*

When there is minimal visualization of laryngeal structures during direct laryngoscopy, a blind or semiblind technique for intubation may be attempted in the conscious or anesthetized patient. A MacIntosh blade is helpful to pull up the tongue and thereby open up and maintain the airway. An endotracheal tube with a curved stylet is then guided in the presumed direction of the glottis where the tube is then slid off, ideally, into the trachea. Spontaneous ventilation is helpful as breath sounds will guide the way to the larynx. After a blind intubation, confirmation of endotracheal intubation with capnometry and/or bronchoscopy is advisable. The use of the elastic gum bougie has already been discussed. 100 In order to change the direction of the tube tip, stylets with a tip-moving device have been designed 101 (Flexguide, Scientific Sales International, Kalamazoo, Mich). The Magill forceps may also be used to guide the tube tip in the desired direction. Even the clinician‘s fingers may be used in a blind, tactile technique. The first and second fingers of the nondominant hand are placed on either side of the tip of the epiglottis to guide the tube. The patient must be cooperative lest the anesthetist risk getting bitten. The Augustine guide includes a curved positioning blade with a guide channel that fits in the vallecula. The tip is then moved anteriorly to expose the vocal cords, and an endotracheal tube is slid over a flexible stylet that has been passed into the trachea after confirmation of easy air aspiration. 82

Stylets with lights at the tip (“lightwand” stylet) are advantageous in that the stylet tip can be guided by observation of the light‘s movement under the skin (Flexilum, Concept Corp., Clearwater Fla; Tubestat, Xomed-treace, Jacksonville, Fla). These are useful when mouth opening or neck movement is limited. The room must usually be quite dark to see the light adequately. When the tube tip is correctly positioned just above the vocal cords in the midline, a distinct glow is seen in the anterior neck, and the tube is slid off into the trachea. 102, 103 To avoid the reported complication of disruption of the light bulb, the stylet should be well lubricated, removed gently, used a single time, and not used nasally (unless manufactured for nasal use). 104 A new lightwand device (Trachlight, Laerdal Medical, Armonk, NY) has been studied and has the potential advantages of a brighter light source and a flexible wand to facilitate tracheal entry. 105

*Nasal Intubation in a Conscious Patient*

Conscious nasal intubation is useful for urgent intubations outside the operating room when mouth opening or neck movement is limited or prohibited and whenever a nasal endotracheal tube is required but anesthesia and/or paralysis are thought to be too risky. Topical anesthesia of the nose and oropharynx as described is important as well as an appropriate amount of sedation. The supraglottic area can be anesthetized with superior laryngeal blocks or local anesthetic sprayed through the tube during its passage. Translaryngeal anesthesia is especially useful for blind, conscious nasal intubation. The lubricated, curved endotracheal tube is inserted perpendicularly into the nose and gently passed into the hypopharynx. If breath sounds disappear, the tube has passed into the esophagus or a pyriform sinus and must be withdrawn above the level of the glottis. A variety of devices have been employed to amplify the breath sounds, but the ear over the end of the tube is usually adequate. On occasion, vomiting or bronchial secretions will make this unpleasant. Capnography may be used to assist in the process of placement in addition to confirmation of proper position. 106 The tube is passed into the larynx during inspiration, which tends to be deepest immediately following a cough. Some clinicians ask the patient to “pant” to maintain an open glottis with plenty of air movement. The section on anesthetized nasal intubation describes several techniques for facilitating passage of the recalcitrant endotracheal tube. If the mouth can be opened, direct laryngoscopy and Magill forceps can be used to guide the tube into the glottis. If direct laryngoscopy is necessary, further airway anesthesia, heavier sedation, or glossopharyngeal blocks are likely to be required.

*Retrograde Endotracheal Intubation*

Retrograde intubation involves passage of a wire or plastic stylet through the cricothyroid membrane that is then coughed out of the larynx and into the oropharynx by the patient. This may be done in the anesthetized or conscious patient. In the conscious patient, it should be preceded by transtracheal topicalization. In adults, this can be done with a “long-arm CVP” catheter or epidural catheter passed through the accompanying needle. In children, a 20-gauge IV catheter with a .021-inch “J” wire is appropriate. 107 A J-wire technique can also be used in adults. 108 A kit with a J-wire is available that can be used to insert endotracheal tubes as small as 4 mm ID (Fig. 39–28, Cook Critical Care, Bloomington, Ind). If a nasal tube is desired and the wire or catheter comes out of the mouth, the tip can be secured to a nasally passed catheter and then pulled up and out through the nose. The endotracheal tube is then inserted into the larynx over the wire which is held with mild tension. The tip of the tube may catch on the anterior commissure and therefore not pass. Turning the tube, loosening the wire, or threading the tube onto the wire via the Murphy eye (rather than the bevel tip) may facilitate passage. The use of a catheter rather than a wire as a guide (as in the Cook kit) is very helpful in allowing tube passage. The wire can also be threaded up the suction port of a fiberoptic bronchoscope that serves as a stylet with visual capabilities. 28 Details on retrograde intubation technique can be found in Benumof‘s monograph on airway management. 109
FIGURE 39–28 Retrograde intubation with the Cook Retrograde Intubation Set. (A) After placement of an 18-gauge sheath needle into the larynx, the J end of the wire guide is inserted in a cephalad direction until it exits the mouth or nose. (B) An 11.0 French Teflon catheter is threaded down over the guide wire until it contacts the laryngeal access site. The guide wire is removed from above. (C) After advancing the Teflon catheter 2 to 3 cm, the endotracheal tube is advanced into the trachea while maintaining constant control of the catheter. (Courtesy of Cook Critical Care, Bloomington, Ind.)

*Fiberoptic Bronchoscopy*

Fiberoptic bronchoscopy is a technique that may be utilized for all of the difficult airway situations previously described in this chapter. In addition, the scope may be used to evaluate possible obstruction of the endotracheal tube, to rule out esophageal intubation, check for endobronchial intubation, and ensure the correct placement of double-lumen endobronchial tubes. Much like that of the traditional laryngoscope, skillful use requires practice in situations that are neither urgent nor extremely difficult. This may initially include practice on a teaching mannequin if possible. Even in experienced hands, successful intubation with the fiberoptic scope usually requires several minutes and therefore another technique should be used if an airway must be established rapidly in the face of severe hypoxia. On the other hand, when use of the bronchoscope is anticipated for the more elective management of a difficult airway, the bronchoscope should be employed first before airway visualization is obscured with blood, secretions, and edema. Pathologic processes such as tumors, infection, and edema that diminish the space between the anterior and posterior pharyngeal wall may make passage of the bronchoscope difficult.

The bronchoscope itself contains thin glass fibers that transmit reflected light along their length. The fiber size (5–25?m diameter) is chosen for flexibility, strength, and light transmission. In addition to the image-transmitting bundle of fibers, there is another light fiber bundle that transmits the light from a powerful source. The instruments also include wire controls for changing angulation of the tip and a port for suction or injection of local anesthetics and oxygen. The bronchoscope is a relatively delicate instrument and must always be handled with care. Because replacement or repairs are very expensive, the scope should be turned only as a unit and not twisted upon its shaft. The monograph by Ovassapian 110 supplies details concerning care and cleaning of the instrument and has many photographs and illustrations of great utility to the bronchoscopist.

If oral intubation is planned, an endoscopic oral airway or bite block is best used to protect the bronchoscope. The oral airway also has the advantage of preventing dorsal displacement of the tongue, keeps the instrument in the midline, and guides the bronchoscope past the epiglottis into the larynx. Such devices include the Patil-Syracuse airway, Williams airway intubator, and the Ovassapian intubating airway. 110, 111 If an anesthetized intubation is planned, a mask with a sealing endoscopy port can be used to maintain anesthesia with spontaneous or controlled ventilation during the bronchoscopy.

Before any fiberoptic procedure, a dose of anticholinergic is strongly recommended to prevent secretions from obscuring the view in the upper airway. The light source should be checked and the bronchoscope prefocused on printed material. The tip of the bronchoscope should be defogged with commercial solution or warm soapy water. The bronchoscope is lightly lubricated along its entire length with a water-soluble agent

(K-Y jelly or eye lubricant) to facilitate passage through the endotracheal tube. A patent suction port is important and a syringe of 10 mL of 1 percent lidocaine solution can be attached for further topical spray through the bronchoscope. If oxygen insufflation is desired, an appropriate source adaptable to the bronchoscope port should be available, which is useful in keeping secretions off the tip and diminishing fogging as well as providing a source of 100 percent oxygen. However, it also poses the potential for marked gastric insufflation before the trachea is entered and for barotrauma, after tracheal entry.

The bronchoscopist must decide whether the intubation will be nasal or oral and conscious or anesthetized. Nasal intubation has the advantage that the fiberoptic scope is usually positioned to directly visualize the glottis and is therefore technically easier. During conscious, sedated nasal intubation, there is less interference by the tongue. An intubating airway is not required, but a standard airway may be used to keep the tongue off the posterior pharyngeal wall during anesthetized intubations. Some clinicians use a soft nasal airway that has been split lengthwise to introduce the bronchoscope. The previously discussed contraindications to nasal intubation apply. If there is doubt about the ability to maintain the mask airway, intubation should proceed with conscious sedation only. The patient can be anesthetized for fiberoptic intubation if the mask airway can be maintained but intubation is difficult. Such anesthetized intubations are usually more difficult because of the development of upper airway obstruction.

Sedation and topical anesthesia of the airway have been previously addressed in this chapter. In the conscious, sedated patient, superior laryngeal blocks and translaryngeal anesthesia may be applied. Alternatively, the supraglottic, glottic, and tracheal areas may be topicalized with 1 percent lidocaine sprayed through the injection port.

For conscious, sedated nasal insertion, the patient's nares and nasopharynx must be anesthetized and vasoconstricted as previously described. The endotracheal tube or split nasal airway is inserted into the posterior nasopharynx and the fiberoptic bronchoscope passed through it. In the vast majority of cases, the glottis can then be seen with minimal tip manipulation. Note that the appearance of the glottis is quite different during fiberoptic bronchoscopy than the stretched appearance the laryngoscopist expects during classic rigid laryngoscopy. 110 The endotracheal tube can be inserted into the nose under bronchoscopic guidance if there is concern about a foreign body or if the tube will enter the nares but not pass into the oropharynx. A useful alternative method is to blindly insert the endotracheal tube until breath sounds are heard maximally, as in blind nasotracheal intubation. This usually results in an easily-visualized glottis that is quite close to the bronchoscope tip. On occasion, a deviated septum will cause compression of the endotracheal tube and difficult passage of the bronchoscope.

Oral, sedated fiberoptic intubation is somewhat more difficult than nasal intubation because the epiglottis becomes a greater obstacle and the tube tip is not usually directed towards the glottis. An intubating oral airway, or at least a bite block, is inserted after topicalization of the posterior tongue, soft palate, and lateral oropharyngeal areas. This can be accomplished with 10 percent lidocaine spray, nebulization of 4 percent lidocaine, or gargling with about 30 mL of viscous lidocaine. The endotracheal tube is inserted about 8 to 10 cm into the airway and the bronchoscope passed through the tube. If the posterior pharyngeal wall is encountered (usually a pink blur), the tip of the bronchoscope is turned down to visualize the glottis. Otherwise the posterior tongue, epiglottis, and glottis are visualized in proper sequence. If the epiglottis obstructs vision, the bronchoscope must be manipulated under the epiglottis to see the vocal cords. An Endotrol tube may be helpful in guiding the bronchoscope tip to the position required to visualize the glottis. The view may also be improved by having the patient protrude his tongue or gently pulling the tongue anteriorly with a piece of gauze wrapped around the tongue.

Fiberoptic intubation in the anesthetized patient may be performed with spontaneous or controlled ventilation with a standard or Patil endoscopic mask. Other clinicians use some form of insufflation to provide oxygen without a mask. Spontaneous ventilation has the obvious advantage of avoiding apnea while bronchoscopy takes place. However, a diminished anesthetic level may occur resulting in cough, vomiting, laryngospasm, and bronchospasm. The patient must be ventilated by mask with 100 percent $O_2$ between intubation attempts. During bronchoscopy, $O_2$ may be administered through the injection port, but insufflation will require an additional source of oxygen. The endoscope mask has a sealing port that allows for the continuous use of a sealed mask airway during bronchoscopy. If a specialized mask is unavailable, a substitute may be constructed by placing the endotracheal tube cuff into the mask inlet to form a seal and then placing a fiberoptic swivel connector on the endotracheal tube to allow simultaneous bronchoscopy and mask ventilation via the anesthesia circuit. 112 For any fiberoptic anesthetized intubation, an assistant is required to hold the endoscopic mask, maintain the airway, deliver equipment and sometimes help stabilize the endotracheal tube while the bronchoscope is inserted.

If nasal, anesthetized intubation is planned, vasoconstriction of the nares and nasopharynx is again necessary. The actual technique of bronchoscopy is as previously described but may be somewhat more difficult due to soft tissue upper airway obstruction caused by anesthesia and/or paralysis. Pulling the tongue anteriorly as previously described may aid visualization of the glottis. Anesthetized, oral intubation is probably the most difficult of the four possible techniques.

The bronchoscopist may choose to stand at the head or the side of the table. If the patient cannot lie flat, standing at the side is essential, but standing on the side of the bed makes the procedure less awkward. The sitting position may facilitate visualization by gravity drainage of secretions and by pulling the scope tip towards the larynx. Keys to successful intubation include control of secretions, bronchoscopic intervention before extensive bleeding and edema have occurred, adequate topical anesthesia and sedation, proper defogging of the lens, and aligning the scope in the midline. Occasionally the bronchoscope will enter the trachea easily, but the endotracheal tube cannot be advanced over it. This is usually due to the bevel catching on the right arytenoid (oral) or epiglottis (nasal) depending on the approach. 113  This may respond to turning the tube 90 degrees counterclockwise, and then 180 degrees if necessary. Careful laryngeal and neck manipulation may also help. If a small (4-mm) bronchoscope has been used, the substitution of a larger (6-mm) instrument may prove helpful. Alternatively, a smaller endotracheal tube may be necessary. The use of an anode or flexible reinforced tube has been reported to be advantageous. 114  Sometimes, sliding the tube in as the bronchoscope is withdrawn will work. Excessive force should be avoided to minimize laryngeal trauma as well as trauma to the delicate fibers at the tip of the scope.

Bronchoscopy is difficult in the presence of bleeding or airway edema. Severe edema or anatomic airway distortion will occasionally necessitate another approach to airway management if surgery must be performed. The presence of a large epiglottis flopping against the posterior pharyngeal wall can occasionally be an insurmountable problem. 115  If the location of the bronchoscope tip is uncertain, the bronchoscope has usually entered a pyriform fossa that may resemble the glottis in this situation. 116  When direct visualization cannot be accomplished, the room lights can be dimmed and the strong light at the bronchoscope tip observed and manipulated into the midline much like a lightwand stylet. 117

Finally, removal of the bronchoscope may be difficult. At this time it is essential that the tip manipulation lever is in the unlocked, neutral position. The bronchoscope should not be removed with undue force because the fibers may be damaged, the patient injured, or the endotracheal tube displaced. This is most likely to occur with a poorly lubricated bronchoscope used in a relatively small bore tube. It may also be due to pinching of the tube in a tight nasal passage or an errant tip that has gone out through the Murphy eye. In this situation, bronchoscope and tube may have to be removed as a unit and the procedure begun again.

## PEDIATRIC AIRWAY MANAGEMENT

This subject is covered in more detail in textbooks on pediatric anesthesia and is discussed only in general terms here (Ch. 59).

After about age 8 years, airway differences between adults and children mainly reflect size differences. The newborn has the most dramatically different anatomy from the adult that persists during the first year of life and then slowly evolves to the adult form. Differences include a large head that tends to flex the short neck and obstruct the airway and a disproportionately large tongue that may cause airway obstruction and more difficult laryngoscopy. The larynx is more cephalad in infants because the cricoid cartilage is opposite the fourth cervical vertebra (rather than the sixth in adults). The epiglottis is longer, stiffer and lies more horizontally than in adults. As noted, the cricoid cartilage is the narrowest point of the airway until about age 8. The shorter trachea also leaves less margin for error in placement of the endotracheal tube. Finally, the angles of the main bronchi take-off points make left-sided endobronchial intubation as likely as right-sided.

The sizes and insertion lengths of uncuffed endotracheal tubes for children are shown in Table 39–5 . Tubes should pass easily and allow for leak at inflation pressures of 15 to 20 cm $H_2O$. As noted, the use of cuffed tubes for children of all ages has become common practice as has the use of appropriately sized LMAs (see Fig. 39–9). 53  Awake intubation may be performed in newborns up to about 4 weeks of age. Oxygen, atropine, and topicalization of the tongue with lidocaine jelly on a finger are followed by laryngoscopy with a straight blade and thin-handled laryngoscope. Hyoid pressure with the little finger may aid visualization. Older or more vigorous children will require anesthesia for intubation under most circumstances. Sevoflurane has rapidly become the mask induction agent of choice for most circumstances. COMPLICATIONS OF SHORT-TERM INTUBATION

*Laryngoscopy*

When the laryngoscope is used improperly, when laryngoscopy is particularly difficult, or when there is dental/periodontal disease, teeth may be injured. If a tooth is chipped or partially broken, the fragment should be located but cannot be re-affixed to the natural tooth. If an entire tooth is dislodged, the tooth should be carefully handled without touching the root. Dental consultation should be obtained to re-affix the tooth in its socket. If such consultation is not available, the tooth can be placed in saline or milk until dental expertise can be obtained. If fragments or whole teeth cannot be located, chest and abdominal x-rays should be done for localization.

The laryngoscope can also injure the soft tissues, usually the lips or gums, but any area of contact can be injured. These injuries are more likely to occur when intubation is difficult and the finer points of technique are sacrificed to expedite intubation. The details of the injury should be well documented in the anesthetic record and chart and the patient informed of the injury.

When laryngoscopy is performed under inadequate anesthesia, coughing, laryngospasm, bronchospasm, and vomiting (with the possibility of aspiration) may occur. Cough should be especially avoided in the settings of an open-eye injury, increased intracranial pressure, or an intracranial vascular anomaly. Laryngospasm should be treated with oxygen, jaw thrust, and gentle mask pressure but may require muscle relaxants to avoid a period of severe desaturation. If cervical spine disease is present due to traumatic, congenital, inflammatory, or neoplastic disease, the spinal cord can be injured during neck movement. 118 Eye trauma may occur due to accidental injury with an instrument or by the laryngoscopist.
*Laryngoscopy and Intubation*

Hypoxemia and hypercarbia are potential complications of laryngoscopies and intubations that are not successful in a reasonable amount of time. Careful evaluation of the airway will screen out most patients who cannot be adequately ventilated by mask or intubated. The pulse oximeter is essential for detecting desaturation during this time. If neither mask ventilation nor intubation can be accomplished, the insertion of a supraglottic airway device such as the LMA or Combitube should be performed with TTJV or a surgical airway reserved for when less invasive maneuvers are unsuccessful.

There is an increased risk of aspiration in the patient with a full stomach and a difficult airway, but aspiration can also occur in the properly fasting patient who does not present special difficulties. Rapid sequence induction and conscious intubation have been described as means of protecting the patient from aspiration. Aspiration remains a concern but a much lesser one in the patient with a properly placed, cuffed endotracheal tube.

Cardiovascular responses to laryngoscopy include hypertension, tachycardia, and dysrhythmias. In children, bradycardia may occur, but hypoxemia must always be considered as the primary cause. In healthy patients these responses are generally well tolerated; however, in patients with limited coronary or myocardial reserve, myocardial ischemia or failure may follow. The patient with a vascular lesion at risk such as an intracranial vascular anomaly or trauma of the thoracic aorta may also suffer serious sequelae. The clinician must be careful so as not to overtreat these responses and create more difficulties than the responses themselves. Because the MAC for endotracheal intubation is about 30 percent higher than MAC for surgical incision, a relatively deep level of anesthesia must be established. Because deep anesthesia may not be tolerated by many patients, drugs that tend to block the response to airway instrumentation or antihypertensives may be used. Narcotics are one option as an adjunct. Fentanyl has been best studied and requires doses of at least 3 to 4 ?g/kg to be effective. 119 Alfentanil has a more rapid onset of action and is effective for this purpose, and remifentanil is also likely to be similarly effective. 120 In addition to its local anesthetic actions, lidocaine reduces anesthetic requirements by 30 percent with a 1.5 mg/kg IV bolus that is minimally depressive to the cardiovascular system. 121 Intravenous lidocaine may be used to supplement the narcotic effect on hemodynamics. 122 Other studies have called the effectiveness of lidocaine in this setting into doubt. 123 Topical anesthesia with lidocaine has been a less effective method for blunting hemodynamic responses because laryngoscopy precedes intratracheal administration of lidocaine.

Transtracheal anesthesia avoids laryngoscopy but is stimulating in its own right. Glossopharyngeal and superior laryngeal nerve blocks may also be effective methods to blunt adverse hemodynamic responses. A variety of antihypertensive agents have also been used to diminish the blood pressure and heart rate responses to intubation. These include ?-adrenergic blockers, phentolamine, nitroprusside, clonidine, captopril, nitroglycerin, and hydralazine, 124, 125, 126, 127, 128 but their relative efficacy is not established. However, one study reported that a 150 mg esmolol bolus was superior to IV high-dose lidocaine or low-dose fentanyl in preventing the tachycardia associated with intubation. 129 All three treatments provided equivalent blunting of blood pressure increases. In treated (with drugs other than beta blockers) hypertensive adult patients, a single 100-mg intravenous bolus of esmolol given before laryngoscopy appears to control heart rate and blood pressure without excessive hypotension. 130 Dysrhythmias during or immediately following laryngoscopy and intubation generally resolve with adequate ventilation, and establishment of adequate anesthetic depth.

The respiratory response of laryngospasm has been described. In predisposed individuals, laryngoscopy alone may also cause bronchospasm. In healthy volunteers, intubation results in an increase in airway resistance that is greater than the resistance of breathing through the tube held externally. This doubling of the expected resistance even in topically anesthetized airways represents reflex bronchoconstriction to the mechanical irritation of the tube. 131 Bronchospasm may be especially severe in the lightly anesthetized patient with reactive airways. Propofol may be the intravenous induction agent of choice in patients prone to bronchospasm. 132 Clinically, it appears that bronchospasm is blunted by the prior administration of anticholinergics, steroid, inhaled ?2 -agonists, lidocaine (topical, nerve block, intravenous), and narcotics. 133 After intubation, deepening anesthesia with intravenous or inhaled agents and the administration of inhaled or IV beta agonists will help treat the bronchospasm. Muscle relaxants may improve ventilation, and in extreme situations, a small amount of positive end-expiratory pressure may improve oxygenation when it is unsatisfactory on 100 percent oxygen. 134 With the tube *in situ,* it is important to ensure that the audible wheezing is not due to some form of mechanical obstruction of the tube: kinking, clot, mucus, active biting or passive mouth closure, foreign body, cuff-overinflation, bevel against tracheal wall, or endobronchial intubation. Other less likely problems such as tension pneumothorax, a nasogastric tube in the trachea, heart failure, or the negative pressure of a descending ventilator bellows must also be eliminated before definitively treating wheezing as bronchospasm. Visual inspection, passage of a suction catheter (or preferably, a fiberoptic bronchoscope) along with cuff deflation and 90 degree rotation of the tube will rule out several of these possibilities.

The patient with elevated intracranial pressure (ICP) who has minimal reserve in intracranial compliance is actually at risk for brain-stem herniation and sudden death during laryngoscopy and intubation. Instrumentation of the airway may result in a sudden increase in cerebral blood flow due to increases in cerebral metabolic activity and systemic cardiovascular effects. The normal autoregulation mechanism may not be effective because of disease or because its upper pressure limit (normally, mean arterial pressure 150 mm Hg) may be exceeded. Coughing or bucking will decrease venous return from the head and may increase ICP as well. Induction drugs that result in cerebral vasoconstriction are most useful. In practice, this has included thiopental and lidocaine, although etomidate and propofol can also be considered. 135, 136, 137 Narcotics are somewhat useful, although they do not have a great direct effect on central brain function. 138 On the other hand, ketamine is best avoided. Adjunctive measures may include voluntary and/or mask hyperventilation, mannitol, steroids, and establishment of ICP monitoring before laryngoscopy and intubation. 36

*Intubation*

In addition to failed intubation, a most feared complication of intubation is esophageal intubation. 139 Although this occurs most frequently in the setting of inexperience, it can happen to experienced practitioners. Unfortunately, except for direct visualization of the tube passing through the cords, fiberoptic confirmation of placement, and presence and persistence of appropriate levels of end-tidal carbon dioxide levels, the usual clinical means for determining endotracheal placement of the tube may not always be reliable. These include presence of bilateral breath sounds, chest movement, exhaled tidal volumes, tube condensation, epigastric auscultation, reservoir bag filling and compliance, and chest radiography. 140 Routine monitoring of end-tidal CO2 is helpful in the definitive determination of tube placement when visualization is impossible and fiberoptic equipment is not available. A colorimetric single-use carbon dioxide detector (FEF end-tidal carbon dioxide detector, Fenem, New York, NY) may be employed when capnometry is unavailable. 141 The esophageal detector device (EDD) employs a self-inflating bulb that is connected to the endotracheal tube and can be carried in a mobile airway case when capnography is not available. The principle of use is that the esophagus will collapse when the subatmospheric pressure is applied, and therefore, the bulb should stay collapsed if esophageal intubation has occurred. This is in contrast to the more rigid trachea that allows for free aspiration of gas and reinflation of the bulb. The EDD was initially reported to be quite effective, but subsequent studies have noted problems in the obese and in the parturient. 142, 143 This device may have a place in intubations when capnography is not available but independent confirmation is encouraged. A new device that differentiates tracheal from esophageal intubation by recognition of differences in resonating frequency (sonomatic confirmation of tracheal intubation) appears to be no more effective than the simpler, cheaper, bulb device. 144

The endotracheal tube (and/or stylet) may also cause mechanical damage to the pharynx, esophagus, larynx, and trachea. This may involve blunt injury, dissection, or perforation. The delicate structures of the larynx (vocal cord, arytenoids) are especially susceptible. Infections and/or barotrauma may follow these types of injuries. Acute injury to the trachea is associated with use of a stiff protruding stylet and previous pathology such as trauma. Gentle, careful manipulation of the airway and proper use of a stylet that is removed after the glottis is entered should help avoid most of these types of injury.

Endobronchial intubation is most common when there is the least distance for the tube tip to be placed properly above the carina yet below the vocal cords as in small children. Guidelines for placement distance have been discussed (see Table 39–5). In patients older than 1 year of age, right-sided endobronchial intubation will be far more common. Hypoxemia, bronchospasm, atelectasis, and coughing may result. Auscultation and observation of the chest may suggest the diagnosis, but the tube may have to be pulled back a small distance to finalize it. Fiberoptic bronchoscopy is the optimal diagnostic tool. The clinician must be extremely careful when withdrawing the tube in awkward positions or in the difficult airway. Note also that properly placed tubes may change their position during head movement, abdominal insufflation, or repositioning of the patient. 69, 145, 146 Inadvertent extubation may occur during repositioning and surgical manipulation and may even result from head movement and coughing in small children, such that continued vigilance is essential.

TABLE 39–5. Endotracheal Tube Size and Position Based on Patient Age

In addition to bronchospasm, the endotracheal tube has several other effects on pulmonary mechanics. 147 The tube acts a fixed resistor that substitutes for the normal upper airway resistance. The cross-sectional area of an 8.0-mm ID tube (50 mm2 ) is not remarkably less than the mean cross-sectional area of the glottis (narrowest part of the adult airway) during quiet breathing. Thus, the use of 8.0-mm tubes in men or 7.0-mm tubes in women whose glottic aperture is smaller does not impose an undue increase in resistance. Anatomic dead space is reduced by intubation, however. In adults, functional residual capacity is not altered by the presence of an endotracheal tube. 131

Several complications are peculiar to nasal intubation. Epistaxis may occur even when vasoconstriction, a lubricated tube, and careful manipulation are employed. The inflated cuff may tamponade the hemorrhage if correctly positioned. Patients with pharmacologic or spontaneous coagulopathies judged to be significant by the clinician should not be intubated nasally. Severe hemorrhage may result requiring simple tamponade with devices that include the balloons of Foley catheters and require expert consultation with otolaryngologists. The stream of blood pouring down the pharynx may also make subsequent oral intubation extremely difficult.

The nasal or nasopharyngeal mucosa may be damaged and false passages created. Tracheal or esophageal trauma can lead to the serious complications or pneumothorax and infection, respectively. 148, 149 Adenoids, polyps, and foreign bodies may be displaced, causing bleeding and even airway obstruction. Nasal instrumentation in these situations should be done under direct vision if possible. The problems of bacteremia and basilar skull fracture have been mentioned previously. In the former, endocarditis prophylaxis is indicated. 66, 67 In the latter, intubation is contraindicated for fear of entering the cranium or introducing CNS infection. Nasal necrosis is more likely a complication of chronic intubation but may occur perioperatively, especially with the use of nasal RAE tubes. 150 Ulceration of the inferior turbinate has also been described. 151 Sinusitis and otitis are two more common sequelae of longer-term nasotracheal intubation. 152, 153

## EXTUBATION

Extubation of the trachea may be performed while the patient is deeply anesthetized or is nearly fully awake. "Deep" or more precisely, anesthetized extubation, is performed after muscle relaxants have been fully reversed and the patient is maintaining an acceptable respiratory rate and depth. A difficult mask airway, difficult intubation, risk of aspiration, or surgery that may produce airway edema or maintenance problems are contraindications to such extubation. Adequate recovery of the ability to maintain and protect the airway must be demonstrated after the use of neuromuscular relaxants. 154 It is important to remember that adequate ventilation through an endotracheal tube does not guarantee the muscle strength to maintain the airway. Sustained tetanus using a nerve stimulator is very painful in the conscious patient, but sustained (5 sec) head lift is an excellent way to assess clinically adequate reversal. If head lift is contraindicated or painful, leg lift or sustained tongue protrusion can be similarly assessed. As the anesthetic level diminishes, the patient is suctioned, and the tube is removed after a positive pressure breath has been given with the anesthesia bag to allow subsequent expulsion or secretions out of the glottis. Advantages include reduced coughing on the endotracheal tube that may lessen laryngotracheal trauma and cause less adverse effects. However, the airway must be scrupulously maintained because obstruction and aspiration remain possibilities. Furthermore, as the patient awakens, laryngospasm and cough may occur anyway. Because there is no way to entirely avoid such coughing after an anesthetic, many authors regard "deep" extubations merely as premature extubations. The perspective appears valid because present anesthetic practice seldom utilizes techniques of truly "deep" anesthesia.

When such extubations in the anesthetized state are contraindicated, awake extubation is essential. The patient is not extubated until judged ready to maintain and protect the airway. The patient who is unresponsive to verbal stimuli, has deviation of the eyes, or is breath-holding is not ready for extubation and is prone to laryngospasm, which is most likely to occur when patients are extubated in between awake and anesthetized states. Coughing and bucking probably indicate the ability to protect the airway, but the timing of awake extubation remains a matter of clinical judgment. Lidocaine (1–1.5mg/kg IV) or a small dose of narcotic may help smooth out awake extubation at the cost of prolonging the process of awakening. After extubation, the patient may be maintained in the supine or lateral position. After anesthetized extubation, oral or nasal airways are usually left in place until the patient can no longer tolerate them. Vigilance should not be relaxed at this time.

Difficult removal is usually the result of leaving the endotracheal tube cuff inflated. If the cuff will not deflate because of obstruction in the tubing, it can be punctured by a needle placed through the cricothyroid membrane after the cuff is raised to this level. More serious and somewhat unusual causes of difficult extubation include fixation of the endotracheal tube or pilot tube by a Kirschner (K) wire used in head and neck surgery or a suture placed from the pulmonary artery through the trachea into the endotracheal tube. A tangled nasogastric tube, swollen or tense vocal cords, or a "barb" accidentally cut on the endotracheal tube can all interfere with extubation. 155 The nature of the surgical procedure must be kept in mind when a tube will not come out after cuff deflation or rupture so as to avoid trauma from vigorous extubation attempts. Direct or fiberoptic examination may be required.

Special care must be taken in a variety of potential high-risk extubations when the ability to immediately reestablish the airway is questionable. 156 The endotracheal tube may be removed while leaving a device such as a tube changer, nasogastric tube, or bronchoscope within the trachea so that the airway can be immediately reestablished if necessary. 157 A variety of tube changer devices are available and may also be employed with jet ventilation (Cook Airway Exchange Catheter, Cook Critical Care, Bloomington, In; Sheridan TTX tracheal tube exchanger, Sheridan Catheter Corp, Argyle, NY; and Endotracheal ventilation catheter, CardioMed Supplies, Gormley, Ontario, Canada). Note that the presence of such a device does *not* guarantee that the tracheal tube can be replaced. Also note that supraglottic devices such as the LMA may or may not be successful in establishing an airway as the pathology may be at the supraglottic level or below. The presence of an individual who can establish a surgical airway (along with the necessary equipment) may be reasonable in selected instances of anticipated difficult extubation, particularly if there is no leak when the endotracheal tube cuff is let down. 158

*Complications of Extubation*

Airway obstruction, laryngospasm, and aspiration are complications that have been previously discussed. Note that after intubations lasting 8 hours or more, airway protection may be impaired for 4 to 8 hours. 159 Sore throat is a complication of anesthesia that may have pharyngeal, laryngeal and/or tracheal sources and may occur in the absence of endotracheal intubation. 160 Factors that may affect the incidence of sore throat include area of cuff-trachea contact (tracheitis), use of lidocaine ointment and size of the endotracheal tube (laryngitis), and the use of succinylcholine (pharyngitis). Cuffs with a longer cuff-trachea interface appear to cause a higher incidence of sore throat. 161 The incidence of sore throat may also be related to intracuff pressures. 162 As previously noted, lidocaine ointment has a questionable effect on the incidence of sore throat. The higher incidence of sore throat in women is probably related to the tube size/laryngeal size relationship. One study demonstrated that tube size is related to the incidence and severity of sore throat in both sexes. 163 This study did not find that the use of succinylcholine was related to sore throat but other workers have reported succinylcholine to be a contributing factor and that nondepolarizing pretreatment reduced the incidence somewhat (from 68 to 45%). 63 The mechanism for succinylcholine-related sore throat is postulated to be myalgias due to fasciculation of peripharyngeal muscles. Sore throat is a minor side effect that should resolve within 72 hours and should not be a factor in determining whether endotracheal intubation is required. It may also occur with the use of an LMA. Hoarseness is another minor side effect correlated with endotracheal tube size and should be investigated if persistent.

Laryngeal edema is most commonly symptomatic in children because their small airway size is more severely reduced by edema; i.e. edema producing only hoarseness in an adult may cause a significant reduction in laryngeal cross-sectional area in a small child. Subglottic edema is particularly more common in children as the nonexpandable cricoid cartilage is the narrowest part of the pediatric airway. Edema may also be uvular, supraglottic, retroarytenoid, or at the level of the vocal cords. The precise diagnosis may be made with fiberoptic laryngoscopy, but this is not usually necessary. Stridor is produced by the extrathoracic obstruction that produces mainly inspiratory wheezing. Diminished stridor may represent total airway obstruction, and movement of air must be repeatedly confirmed. The contributing factors to the production of laryngeal edema are somewhat controversial but include too large a tube, trauma from laryngoscopy and/or intubation, excessive neck manipulation during intubation and surgery, excessive coughing or bucking on the tube, and present or recent upper respiratory infection. The prophylactic use of steroids before extubation to reduce edema is an unproven but frequently utilized treatment if the likelihood of postextubation stridor is suspected. Treatment includes warmed, humidified oxygen, nebulized racemic epinephrine (.25–1mL), and IV dexa-methasone (.5 mg/kg up to 10 mg). If obstruction is severe and persistent, reintubation must be considered.

Vocal cord paralysis may be due to surgical injury of the recurrent laryngeal nerve or from the endotracheal tube cuff. 164 Vocal cord edema occurring in the presence of a paralyzed cord may precipitate complete airway obstruction as can bilateral cord paralysis. It may be prudent to pursue preoperative otolaryngologic evaluation of the hoarse patient for elective surgery so that important pathology is detected and so that subsequent vocal problems are not entirely attributed to the anesthesiologist. The arytenoid cartilage may be dislocated by the laryngoscope blade and result in a weak voice after extubation that may require surgical correction. 165, 166 Other complications include ulcerations or granulomas of the vocal cords that may result in persistent hoarseness. 167 More serious complications resulting in laryngeal or tracheal stenosis are extremely rare sequelae of short-term perioperative intubation. 168

*General Recommendations*

1.
Preoxygenate all patients (including children) to whatever extent possible. This provides a buffer to tolerate an inability to ventilate or intubate for several additional minutes.
2.
Evaluate every airway carefully from the standpoint of history, physical examination, and other indicated investigations. Keep in mind that several small abnormalities may add up to a difficult airway.
3.
Approach every patient with the possibility that mask ventilation and/or endotracheal intubation may not be possible. Have a back-up plan formulated before the problem occurs. A transtracheal jet ventilation system cannot be assembled from scratch when the oxygen saturation is falling. Make sure that whatever might be needed is available.
4.
Whenever possible, provide mask ventilation before administering any muscle relaxant, especially nondepolarizers. Unless succinylcholine is contraindicated, consider its use when the airway looks potentially difficult and anesthetized intubation is selected. The short-action (as opposed to any currently available nondepolarizing relaxant) of succinylcholine can be life-saving and brain-saving in the “can‘t

mask/can‘t intubate” situation. However, the duration of a dose of succinylcholine may be longer than the duration of a brain tissue oxygen level compatible with full recovery. 175

5.

Gain confidence and skill with a variety of approaches to conscious intubation so that it can be applied properly when needed. Don‘t let less cognizant individuals (surgeons, nurses, etc.) unduly influence your decision to employ conscious intubation. The airway is your responsibility, and you, the patient, and the patients‘ loved ones suffer the consequences of misjudgments.