Fiberoptic Intubation

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The notion of indirect laryngoscopy was first noted in the 19th century by a professor of singing in Paris named Garcia. Garcia had used dental mirrors to view and study his vocal cords.[1] Since then, many devices have utilized mirrors to grant an indirect view of the glottic opening. However, the 20th century brought the introduction of fiberoptic technology to view the airway or other desired structures. This chapter will outline the clinical application of the fiberoptic bronchoscope (FOB) for airway management in both awake and anesthetized patients.

■ The Science of "Fiberoptics"

The image obtained through a fiberoptic scope is actually transmitted via a bundle of very thin (less than 25 µm in diameter) glass rods. In comparison, a human hair is around 20 µm in diameter. The fibers, when this small in diameter, become able to transmit light. Total internal reflection is the scientific principle describing how light is carried within the fiber over its length.[2] As light strikes the fiber, insulation called cladding (1-µm thick layer of glass having a different optical density) provides a refractive index less than that of the fiber, which results in the transmission of the image.[3] One fiber alone cannot provide a clear view, so a bundle of coherent fibers are utilized. These bundles of fibers are "coherent" in that the fiber's orientation in the bundle remains constant throughout the course of the scope. The bundle of fibers is delicate and easily damaged, which make gentle handling both during use and cleaning of the instrument essential. Lenses placed in the tip of the fiberoptic scope and in the eyepiece provide a clear image for the user.

■ Elements of the Fiberoptic Scope

As shown in Figures 1 and 2, the fiberscope consists of a control handle with two cords emanating from it. The eye piece, used for viewing the image, is located at the handle. Below the eye piece is a focusing ring that rotates to focus the image. A thumb control lever is used to manipulate (flex-deflex) the distal tip of the fiberoptic laryngoscope via two wires in the fiberoptic bundle. There is a separate port that travels the distance of the scope and emerges at the distal tip. This channel can be used for insufflation of oxygen, injection of saline or local anesthetic, placement of a biopsy wire, or for suction. The insufflation of oxygen can be used to either push secretions away (to improve visualization) or to oxygenate the patient. The instillation of saline can be used to help clear secretions in situations of aspiration or to obtain a sputum/cytology sample. Finally, local anesthetic can be injected through the port for topical anesthesia of the airway.

There are two tubes coming out of the fiberoptic scope's handle. The larger of the two contains the illumination bundle that plugs into the light source. It is composed of noncoherent fiberoptic bundles that relay light to the fiberoptic scope. The other tube is the bundle of fibers that will be used to access the trachea and intubate the trachea. During preparation for the procedure, care should be taken to ensure that the scope is kept

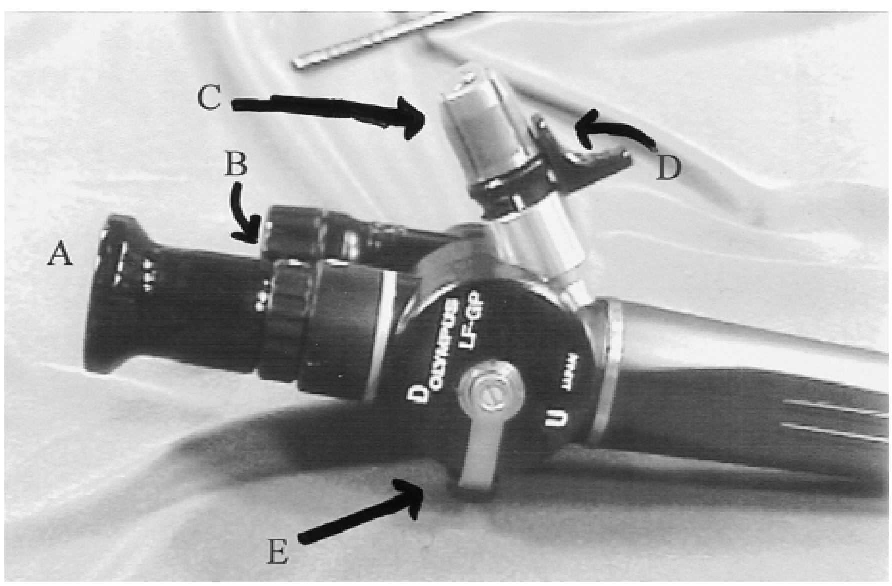

Figure 1. *The fiberoptic scope is displayed with its elements labeled. The features labeled include the (A) eyepiece, (B) focusing ring on the eyepiece, (C) oxygen connector (hidden by channel control valve), (D) channel control valve, and (E) thumb control lever.*

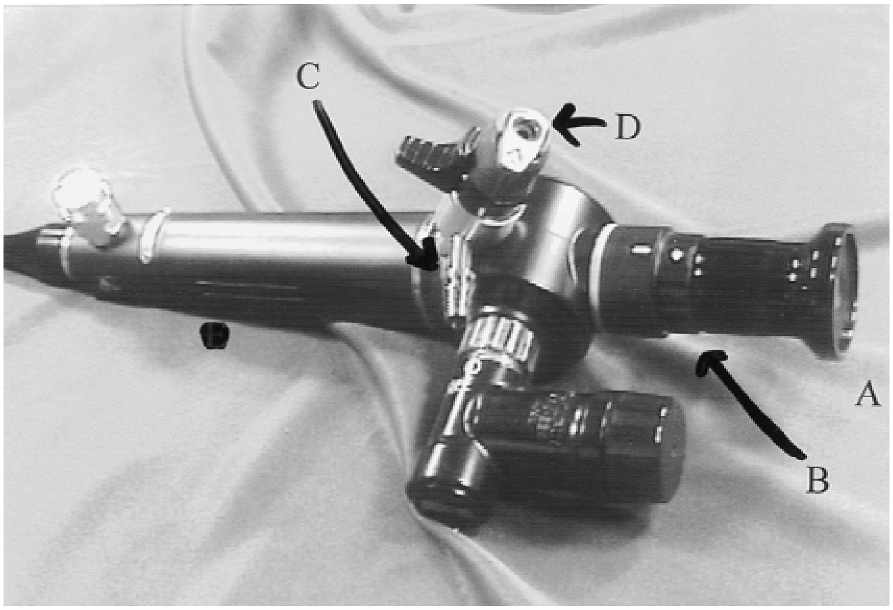

Figure 2. *The fiberoptic scope from another angle with its elements labeled as in Figure 1. The features are the (A) eyepiece, (B) focusing ring, (C) oxygen connector, and (D) channel control valve.*

clean and in its natural shape, avoiding unnecessary bending of the scope that could damage the fragile fiberoptic fibers.

■ Learning Curve of Fiberoptic Intubation

The ability of clinicians to use the FOB is directly proportional to the amount of experience they have using the device. What is the learning curve for fiberoptic intubations? The question has been studied by Johnson and Roberts.[4] Objectives of the study were an intubation time of less than 2 minutes and greater than 90% success on the first attempt. The study demonstrated that the mean number of intubation attempts to accomplish these goals was 10. Erb and colleagues[5] demonstrated that novice endoscopists could be successfully trained on both paryalyzed apneic patients as well as those who were spontaneously breathing.

Clinicians new to the technology should spend time in controlled situations while getting familiar with the FOB. This can be done on mannequins or airway simulators before moving onto patients with normal anatomy. Ovassapian and associates[6] showed that a stepwise learning orientation utilizing simulators provided more success in initial attempts at fiberoptic intubation than traditional teaching methods. In this way, the beginner can grow comfortable and optimistic with its use before utilizing it in the higher stress environment of a difficult airway. Becoming familiar with the orientation and proper manipulation of the FOB is imperative before using the device in a difficult airway patient during adverse conditions.

■ Preparation for Fiberoptic Intubation

When preparing to use the FOB, some basic issues must be addressed. These include the approach to the airway, the position of the patient, the necessary instruments, and the suppression of the patient's airway reflexes.

Approaching the Airway

The majority of fiberoptic intubations will be through the mouth or the nose. While other avenues of controlling the airway exist, we will limit this chapter to discussing the far more common routes of orotracheal and nasotracheal tube placement.

Nasotracheal intubation can be chosen versus the orotracheal route for a variety of reasons. Included among these are keeping the surgical field unobstructed during facial or dental surgery. Plans for prolonged intubation in an awake patient may be an indication, as patients sometimes tolerate this more easily than an orally placed endotracheal tube.[7] Other noted advantages to the approach include a more secure tube, decreased chance of becoming obstructed either by kinking or biting, fewer oral secretions, and the anatomical benefit it confers in placement.[7] The anatomical advantage to the nasotracheal approach is that the scope often faces the glottis as it follows its course from the nasopharynx, which provides an easier view of the laryngeal opening secondary to decreased interference from the tongue.[8] The approach also helps in patients with cervical spine injuries, where the halo or protective collar might make orotracheal intubation more problematic.[9]

Risks of nasal intubation include causing bleeding from nasal mucosa, which can obscure the view of the laryngeal opening (or of any other discernible anatomy) and make intubation attempts more difficult, if not impossible. Also, prolonged nasal intubation has been shown to have a higher incidence of sinusitis versus an oral endotracheal tube.[10,11] Lastly, it is important to keep in mind that the same contraindications exist for the nasotracheal fiberoptic approach as in any other type of nasotracheal intubation.

Positioning

Correct positioning of the patient during fiberoptic intubation will aid the clinician in expeditiously securing the airway. This can save not only time, but minimize the risk of repeated attempts and their possible con-

Table 1. *Elements of Patient Positioning for Fiberoptic Intubation*

Head of the patient
Torso of the patient
Larynx of the patient
Operating room table height

sequences. The different aspects of positioning are listed in Table 1. The first question to answer is how the patient's head will be positioned. Whereas positioning the head for supine direct laryngoscopy involves cervical spine flexion and atlantooccipital joint extension to properly align the oral, pharyngeal, and laryngeal axes, this is not the ideal position for a fiberoptic intubation.[12,13] Instead, cervical and atlantoocipital extension is utilized to lift the epiglottis off of the posterior pharyngeal wall. In displacing the epiglottis, the FOB has a more direct approach to the vocal cords.

Next, the patient's torso must be positioned. For the majority of intubations, the patient will be supine, but there are situations in which the subject may be seated, in the lateral position, or even prone. These different positions will also change the alignment of anesthetist to the patient. Some of the possibilities are listed in Table 2.

With the patient supine, the clinician can either position him or herself at the patient's head or at the side of the bed. For the patient who cannot tolerate being recumbent, a seated upright intubation is sometimes done. In this situation, the clinician would be either sitting or standing on the right-hand side of the patient (Fig. 3). This stance would enable the clinician to use his or her right hand on the control unit with the left hand on the flexible part of the FOB.

The clinician can be seated for the patient in either the lateral decubitus or prone position. These approaches are attempted under special situations or emergent circumstances and are not routinely employed.[14] Whereas having the patient prone has the possibility of making mask ventilation more difficult, it has the benefit of gravity displacing the epiglottis off of the laryngeal opening and making the fiberoptic attempt easier while also making pulmonary aspiration less likely if the patient were to vomit.[15] Standard airway management steps are taken in either event before moving on to fiberoptic intubation.

Table 2. *Listing of Patient Position Relative to Position of the Clinician*

Supine/clinician at head
Supine/clinician at side
Prone/clinician at head
Sitting/clinician in front of patient
Lateral decubitus/clinician at head
Lateral decubitus/clinician at side

Figure 3. *Clinician position for the seated upright patient is shown. When the patient is seated upright, the clinician will usually be on the right-hand side of the patient and facing the patient.*

Optimal bed height in fiberoptic intubations is also different than when doing direct laryngoscopy. While the bed is elevated to approximately the xiphoid process of the clinician during direct laryngoscopy, it is lowered for fiberoptic intubation. By lowering the bed, the clinician is able to maintain the FOB in its extended form during visualization of the laryngeal inlet. The clinician can also stand on a stool to increase his or her height above the patient to facilitate this position. The FOB is kept extended to maintain the orientation of the view at the eyepiece to the tip of the scope (Fig. 4).

Instruments

Preparation for managing an airway includes having the proper equipment available. Table 3 lists the instruments that should be available during fiberoptic intubation. Included in the list are things that are required for routine efforts at intubation. These are essential to have when dealing with a recognized difficult airway as well as when doing elective fiberoptic intubations, as back-up plans include direct laryngoscopy. It is essential to check that the equipment is available and functioning appropriately be-

Figure 4. *Extended fiberoptic scope is shown. When the clinician uses the fiberscope, it should be kept extended so as to keep proper orientation. The fiberscope is typically held with the left hand on the bundle at the 10-cm mark as it is inserted into the mouth.*

fore inducing general anesthesia or beginning to anesthetize the airway for awake intubation.

The FOB should have been cleaned and sterilized since its previous use. The functioning of the thumb control lever should be assessed.

Table 3. *Equipment for Fiberoptic Endotracheal Intubation*

Anesthesia machine/oxygen supply and back up	Suction
Masks for mask ventilation/Ambu bag	Oral/nasal airways
Flexible fiberoptic laryngoscope with light source	Capnograph
Endotracheal tubes with stylets	Laryngeal mask airways
Laryngoscopes (MacIntosh and Miller blades)	Pulse oximeter
Lubricant—silicone, etc	Oxygen supply tubing
Alcohol pad or other defogging device	Syringes and needles
Local anesthetic/vasoconstrictor	Atomizer
Cotton-tipped applicators	Nebulizer set-up
Lightwand	
Retrograde guidewire	Magill forceps

Checking the equipment also includes ensuring that the light source is plugged in and functional. The scope should be defogged by either placing the tip in warm sterile saline or wiping off the tip with an alcohol pad or antifog solution. The scope should be white balanced and focused to ensure that the view is clear. The scope can be focused by adjusting the focusing ring on the handle of the scope while visualizing small writing, like that on an alcohol pad's package. Ensure that silicone, or some other nontoxic substance, is available to lubricate the tip of the FOB. This will make it easier to pass the endotracheal tube off of the scope into the trachea. Lastly, tubing may be attached to suction or an oxygen flow meter (set at 7 L/min) and secured onto the appropriate port on the scope.

Other instruments that should be available during a fiberoptic intubation are oral airways. There are many oral bite blocks available, including the Olympus bite block (Olympus Corporation; Lake Success, NY), Patil airway (Anesthesia Associates; San Marcos, CA), Williams bite block (Anesthesia Associates), and the Ovassapian airway (The Kendall Company, Boston, MA). The airways are used during oral fiberoptic intubation to help with the anatomical obstacles of the tongue and soft tissue as well as to protect the delicate fiberoptic instrument from biting (Figs. 5–7).

If the intubation attempt will include using nerve blocks or vasoconstriction of mucosa, there needs to be further equipment available. This list includes cotton-tipped applicators to apply solutions containing local anesthetic and a vasoconstrictor if spray bottles are not used. Needles, syringes, and local anesthetic also should be present if nerve blocks will be utilized. These will be discussed in greater detail in the next section. Lastly, a collection of drugs used for sedation, amnesia, and analgesia should be available. These types of drugs have been reviewed elsewhere and will not be covered here.

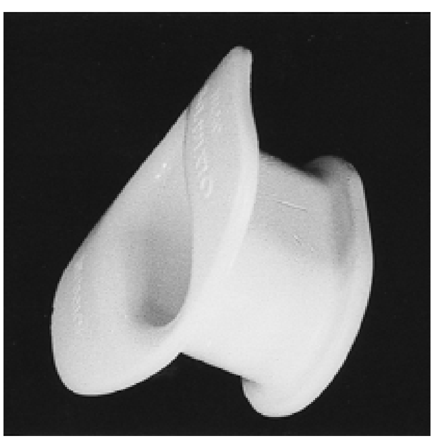

Figure 5. *The Olympus (Olympus Corporation; Lake Success, NY) oral airway is designed as a bite block to protect the delicate fiberoptic bundles from damage.*

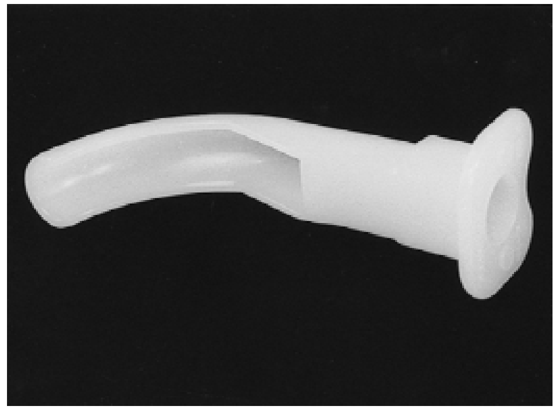

Figure 6. *The Williams (Anesthesia Associates; San Marcos, CA) oral airway is primarily designed to protect the fiberscope from being bitten.*

Reflexes

An awake intubation is more complex than one done under general anesthesia. An awake intubation involves preparing the patient for the experience both mentally and physically. Mentally, a patient must be informed of why and how the intubation attempt will proceed. The second part of mental preparation is the titration of sedation (when appropriate) to a level at which the patient is comfortable but not at risk for hypoxemia, hypercarbia, or losing control of his or her airway. The physical preparation involves blunting a host of airway protective reflexes. Reflex responses to instrumenting the airway are listed in Table 4. Managing these responses is essential to effective awake airway management.

Knowledge of the nerve supply to the nasopharynx, mouth, and airway is of paramount importance to clinicians dealing with awake airway manipulation. The nasal passages transmit sensory impulses via the ophthal-

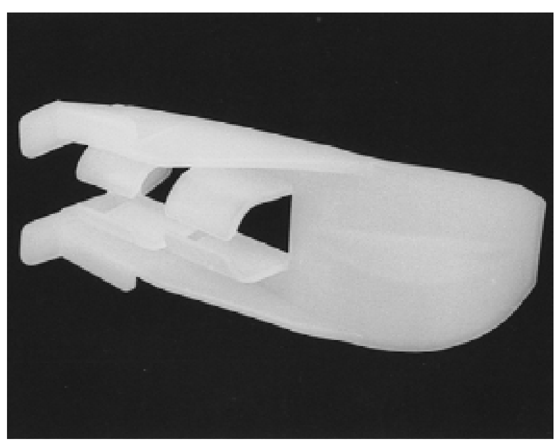

Figure 7. *The Ovassapian (The Kendall Company; Boston, MA) oral airway is designed not only to protect the fiberscope from being bitten, but also to guide the tip of the scope to the glottic opening.*

Table 4. *Airway Reflexes*

Gag	Secretory
Cough	Vomiting
Reflex laryngeal closure	Cardiovascular
Bronchospasm	

mic and maxillary divisions of the fifth cranial nerve (trigeminal).[16] Specific nerves involved include the anterior ethmoid, infraorbital, anterior superior alveolar, olfactory, and sphenopalatine.[17]

The oropharynx's posterior portion is innervated by the glossopharyngeal nerve, while the anterior surface of the tongue has sensation divided between two nerves. A branch of the trigeminal nerve called the lingual nerve covers the anterior two-thirds of the tongue, while the posterior third is covered by branches of the ninth cranial nerve (glossopharyngeal).[16] The pharynx transmits sensory impulses via both the 9th and 10th (glossopharyngeal and vagus) cranial nerves.

Afferent impulses from the base of the tongue, epiglottis, piriform fossa, vallecula, and trachea pass centrally on branches of the 10th cranial nerve (vagus). The superior laryngeal nerve, which is composed of an internal and external branch, innervates the area up to the trachea. The internal branch of the nerve is responsible for sensory impulses, while the external branch supplies motor innervation to the cricothyroid muscle (the only intrinsic muscle of the larynx not innervated by the recurrent laryngeal nerve).[16] The recurrent laryngeal nerve is also a branch of the vagus nerve. It contains both sensory and motor fibers. The sensory component covers the mucous membranes inferior to the vocal cords and in the upper trachea, while its motor function includes innervation of all the laryngeal muscles except the cricothyroid.[16]

Gag Reflex The glossopharyngeal nerve serves as the afferent limb of this response beginning from sensory nerves in the oropharynx. These continue on through the dorsal nucleus of the vagus from which efferent impulses then depart to cause this protective reflex. Blocking this reflex is a priority for a successful awake intubation. When effectively blocked, it will make the patient more cooperative with the intubation attempt.

This reflex can be blocked in multiple fashions. Most often, the oropharyngeal sensory nerves discussed previously are anesthetized by using either topical anesthetic or a direct nerve block. We usually use either benzocaine spray (20%) or atomized lidocaine to block the oropharynx. Other options include using an oral airway coated with 5% lidocaine ointment, administering lidocaine by nebulizer, or having the patient gargle orally administered lidocaine. These topical approaches, while effective for the passage of the fiberoptic laryngoscope, will not block the pressure receptors in the back of the tongue that cause a gag response to direct laryngoscopy.[18] In situations in which direct laryngoscopy is planned, a bilateral block of the lingual branch of the glossopharyngeal nerve is required.[18,19]

Cough Reflex As discussed, the sensory afferents from the larynx and trachea emanate from the internal branch of the superior laryngeal nerve and the recurrent laryngeal nerve. These travel to the nucleus of tractus solitarius and to the dorsal motor nucleus of the vagus where they are relayed back to the recurrent laryngeal nerve and external branch of the superior laryngeal nerve that innervate the muscles of the larynx.

This reflex can be blocked by both direct nerve blocks and topical anesthesia. Nerve blocks of the superior laryngeal nerve and translaryngeal administration of local anesthetic are well detailed in the literature. The superior laryngeal nerve is blocked by administering local anesthetic to the nerve as it penetrates the thyrohyoid membrane between the superior lateral cornu of the thyroid cartilage and the inferior lateral margin of the cornu of the hyoid bone.[20] Translaryngeal anesthesia is given by injecting local anesthetic (typically 4 ml of 4% lidocaine) into the trachea via the cricothyroid membrane. Care needs to be taken when doing the block, as the cough that usually results with administration of the anesthetic (helping the proximal spread of the anesthetic to the vocal cords) can be dangerous if the clinician does not pay careful attention to the needle in the patient's neck.[20]

Topical blunting of this reflex can also be accomplished by directly spraying the vocal cords with local anesthetic. This can be done with an atomizer when direct laryngoscopy is performed over previously anesthetized airways. It also can be instilled via the fiberoptic scope through the port mentioned earlier. Once the vocal cords are visualized, the clinician carefully positions the scope close enough to be able to spray the cords without touching them to avoid causing reflex laryngospasm. An assistant then injects a syringe of local anesthetic through the port of the FOB and onto the vocal cords.

Reflex Laryngeal Closure Laryngospasm is an involuntary closure of the laryngeal opening secondary to muscle spasm. This reflex can be stimulated by irritation of the sensory area innervated by the superior laryngeal nerve (internal branch), which then passes to the central vagal nuclei and back out to the effector muscle groups innervated by the external branch of the superior laryngeal nerve and recurrent laryngeal nerve. These muscle groups act to protect the laryngeal entrance by closing the laryngeal entrance from secretions or foreign body invasion. This reflex can be blunted by both topical anesthesia or direct nerve blocks and careful avoidance of vocal cord irritation—either with the endotracheal tube or fiberoptic scope. Lastly, adequate use of antisialagogues will help to prevent secretions from falling down on the vocal cords and causing the response.

Bronchospasm Reflex Along with the airway-mediated reflexes that serve to protect the airway comes an exaggerated airway reactivity. Increases in bronchial smooth muscle tone with increased mucosal edema and secretions combine to cause the airflow obstruction pattern. Usually manifested in patients with preexisting reactive airway disease, the response presents as increased expiratory airway resistance with either wheezing or diminished breath sounds. These effects can cause significant changes in pulmonary function with decreased arterial oxygen tension, vital capacity, and first-second forced expiratory volume.[21]

There are multiple possible causes of bronchospasm. Inflammatory mediators such as leukotrienes or histamine can cause smooth muscle contraction and up-regulate subendothelial irritant receptors in the tracheobronchial tree. The specialized mechanoreceptors in the tracheobronchial tree, along with laryngeal/pharyngeal receptors, can be stimulated by many factors, including mechanical pressure, liquid, and touch.[15] Nerve fibers from the trachea are propagated via the recurrent laryngeal nerves to the nucleus of the tractus solitarius. From there, interneurons travel to the efferent portion of the reflex located in the ventrolateral medulla, which cholinergically synapse with mucus-secreting cells and bronchial smooth muscle.

The laryngeal and pharyngeal receptors, both possible causes of bronchospasm, have different afferent tracts. The laryngeal response is carried by afferents via the superior laryngeal nerves that, like the afferents from the tracheobronchial tree, also travel to the tractus solitarius. The pharyngeal response is carried via the glossopharyngeal nerves to the tractus solitarius at which point they are carried via interneurons to the ventrolateral medulla. From there, vagal efferents transmit the impulses to the tracheobronchial tree to cause the response in the airway.

Preventing this response combines many of the techniques that have been discussed previously. Primarily, decreasing the irritation of these receptors minimizes the chances of the response. This includes careful manipulation of any devices that are being used to instrument the airway, including the fiberoptic scope and endotracheal tube. Adjuncts to the gentle manipulation of the airway include topical anesthetics, which may be used to block the mechanoreceptors. These methods can include application of sprayed, viscous, aerosolized, or translaryngeal injection of local anesthetic. Other pharmacological methods to prevent the response include the administration of anticholinergics (either by the aerosolized, intravenous, oral, subcutaneous, or intramuscular route) and β_2-adrenergic agonists to help promote bronchodilation and to counteract increased vagal tone.

Secretory Reflex Secretions in the airway of an individual undergoing awake fiberoptic intubation can be detrimental to both the patient and the clinician. The patient feels uncomfortable because of the need to clear his or her throat and cough. Secretions can impact the clinician by obstructing the view of the larynx through the fiberoptic scope, possibly making the patient move or cough, and not allowing applied topical anesthetics to work properly. They decrease the effectiveness of local anesthetics by not allowing the drugs to contact the mucosa, their site of action. Also, secretions can decrease the amount of local anesthetic available to the mucosa by draining the drug away from its site of action.

The three salivary glands (parotid, submandibular, sublingual) of the oropharynx come in pairs, one on either side of the mouth. The largest of the group is the parotid gland. The nerve supply to the gland arises from parasympathetic secretomotor fibers from the inferior salivary nucleus of the glossopharyngeal nerve.[16] These fibers pass to the otic ganglion via the tympanic branch of the glossopharyngeal nerve and the lesser petrosal nerve. The auriculotemporal nerve carries the postganglionic parasympathetic fibers to the gland.

The sublingual (smallest of the three glands) and submandibular gland have similar nerve supplies. The glands receive parasympathetic secretomotor transmission from the superior salivary nucleus of the facial nerve, which then travel to the submandibular ganglion passing with the chorda tympani nerve and lingual nerve. Postganglionic parasympathetic fibers reach the glands via the lingual nerve, while postganglionic sympathetic fibers travel to the glands via nerves around the lingual and facial arteries.[16] Mucous glands located in the larynx, below the vocal cords, and in the trachea are innervated via secretory fibers associated with the recurrent laryngeal nerve.

Antisialagogues are commonly used to decrease this response. The drugs used are glycopyrrolate, atropine, and scopolamine. Their pharmacological properties and differences are shown in Table 5. It is important to give the medication early in the process because the drugs help to stop

Table 5. *Antisialagogues for Fiberoptic Intubation*

Drug	Amine	Intravenous Dose (mg) (for adults)	Side Effects
Glycopyrrolate	4°	0.1–0.2	⇑ HR, urinary retention, ventricular ectopy; ⇓ GI peristalsis
Atropine	3°	0.4	⇑ HR, urinary retention, delirium, ventricular ectopy; ⇓ GI peristalsis
Scopolamine	3°	0.5	⇑ HR, amnesia/sedation, delirium; ⇑ temperature

HR = heart rate; GI = gastrointestinal.

production of secretions but have no effect on the secretions already present. It is important to keep in mind the other actions of the antisialagogues when utilizing them as a premedication. Obviously, tachyarrhythmias are one of the more pertinent effects and need to be kept in mind with patients whose physiology does not tolerate a more rapid heart rate (i.e., patients with coronary artery disease). While tachycardias are more likely to occur after intravenous administration, it does not exclude them from occurring if given via other routes. Scopolamine, while having the beneficial effects of sedation and amnesia, is used less frequently than glycopyrrolate or atropine because of its increased incidence of producing delirium.[20]

Vomiting Reflex The vomiting pathway has multiple possible stimulants and can be one of the more problematic and dangerous of the responses. Stimuli can be carried by afferents of sympathetic or parasympathetic origin. These afferent impulses travel to the vomiting center (dorsal part of lateral reticular formation of medulla), which receives input from the chemotactic trigger zone in the area postrema of the medulla, as well as the gastrointestinal tract, mediastinum, pharynx, and visual center.[15] Efferents from the vomiting center travel in a variety of efferents including the phrenic, vagus, and sympathetic nerves.

Preventing the reflex can be attempted by using topical anesthetics to block oral and pharyngeal stimulation, as has been described previously. Given the multitude of causes for vomiting, however, this does not ensure its prevention. Along with attempts to anesthetize the airway, there are other ways to decrease the likelihood of vomiting or minimize the damage caused by it. Ensuring nothing-by-mouth status when possible is a way to decrease the chance, or at least the volume, of emesis. Also, when present, an orogastric, nasogastric, or gastric feeding tube should be suctioned prior to manipulating the airway. While this does not guarantee the removal of all stomach contents, it does reduce the amount of gastric residual volume.[22]

Pharmacological interventions such as histamine$_2$ blockers and proton pump inhibitors (e.g., omeprazole) to block acid secretion, prokinetics (e.g., metoclopramide) to decrease gastric volume, and nonparticulate antacids (e.g., sodium citrate) to increase the pH of gastric contents can help minimize the damage if aspiration of stomach contents were to occur. We recommend that every patient be evaluated for risk of emesis and that prophylactic measures be taken prior to airway manipulation.

Cardiovascular Reflex Laryngeal and glottic receptors initiate increased sympathetic activity with stimulation of the airway. Stimulation from the upper airway travels via the cranial nerves innervating these areas, which relay impulses to the brain stem. There, the impulses are integrated and translated into efferents that affect cerebral and neuromuscular end-points, as well as the cardiovascular response.[15]

The cardiovascular response can include hypertension, tachycardia, and bradycardia. The vagal afferents from both the superior laryngeal nerve and recurrent laryngeal nerve are important mediators in this reflex. These nerves travel to the ventrolateral medulla and on to higher centers, including cortical, hypothalamic, and brain stem centers, to produce the response. The high vagal tone and overall low amount of sympathetic tone have been used to explain the increased likelihood of airway-mediated bradycardia and sometimes asystole in children.[23] This is why an anticholinergic medication is often recommended as pretreatment before airway manipulation in young patients. However, this does not mean that a bradycardic response should not be expected from older patients, as it has occurred with intubation or suctioning in adults.[24,25]

In general, hypertension and tachycardia are more commonly seen in the adult patients during airway manipulation. These responses are mediated by both direct sympathetic efferent activity as well as indirect release of stress hormones. Stoelting[26] reported that after epiglottic stimulation, systolic and diastolic arterial blood pressures increase within 5 seconds of stimulation and reach a maximum after 45 seconds. This epiglottic response was followed by increased heart rate and further increases in arterial pressure with tracheal intubation. The hypertension and tachycardia seen with stimulation are thought to be attributable mainly to release of norepinephrine and epinephrine.[15]

Attempts at blocking this response focus on either blocking mechanoreceptor stimulation by using local anesthetics or by using pharmacological mediators to affect the afferent or efferent limb of the response. As was mentioned previously, local anesthetics to the upper airway and infraglottically are not foolproof, and so other drug therapies are utilized. Some of the more common adjuncts, which include anesthetics and antihypertensives, are listed in Table 6.

■ Fiberoptic Intubation

We will describe the steps of preparing a patient for an awake fiberoptic intubation and then discuss what changes occur when general anesthesia is used. Indications for awake laryngoscopy and intubation, as listed in Table 7, are uncommon. Therefore, when time allows, there needs to be careful attention paid to educating and instructing the patient in not only what will be done, but why this form of airway management is being chosen. Although awake intubation can be one of the patient's greatest fears, those patients the clinician believes require a fiberoptic intubation will be more understanding, more compliant, and more appreciative of efforts made on their behalf when a proper discussion has taken place.

Table 6. *Pharmacological Agents Used to Block Cardiovascular Responses to Intubation*

Anesthetics
Narcotics
Barbiturates
Hypnotics
Inhalational agents
Local Anesthetics
Topical
Nerve block
Parenteral
Antihypertensives
Peripheral vasodilators
β-Adrenergic blockers
α-Adrenergic blockers
Combination α- and β-adrenergic blockers
Central α-adrenergic blockers
Calcium channel blockers

Nasal Approach

One of the more immediate concerns when approaching intubation nasally is the risk of epistaxis. Epistaxis can occur with passing the endotracheal tube, passing the fiberoptic scope, or placing a suction catheter. Therefore, vasoconstriction of the nasal mucosa needs to be accomplished before instrumenting the nose (either with an awake intubation attempt or after induction of general anesthesia). The fear with bleeding is that it can impair visualization and impede timely efforts to secure the airway, if not make attempts at fiberoptic intubation impossible.

Typically, vasoconstriction of the nose is accomplished with either phenylephrine, oxymetazoline, or cocaine. Cocaine was used more commonly in the past but has gradually lost favor secondary to the possible side effects. When cocaine is used, a 4% cocaine solution is used more frequently than higher concentrations because of the increased incidence of side effects (including increased myocardial oxygen consumption, de-

Table 7. *Common Indications for Awake Fiberoptic Intubation*

Unstable cervical spine
Trauma
Upper airway
Face/neck
History of difficult intubation
Congenital airway abnormalities
Pierre Robin syndrome, Treacher Collins syndrome, etc
Upper airway masses

creased coronary blood flow, and increased coronary artery vasospasm) with the higher concentrations.[27,28] Cocaine can either be sprayed into the nostrils or instilled via cotton-tipped applicators. The use of cocaine-soaked applicators is advocated to decrease the amount of drug reaching the alveoli and possibly the systemic circulation via absorption.[29] When using this approach, the applicators are soaked with cocaine and advanced into the nasopharynx as the patient tolerates.

The combination of phenylephrine and lidocaine can be used in the same fashion as the cocaine-soaked applicators to provide vasoconstriction and decreased sensation to the nasopharynx. We use a premixed solution of phenylephrine 0.25% solution with 3% lidocaine for nasal fiberoptic intubations. This combination is not a controlled substance (versus cocaine) and can be stored routinely in airway carts. It has become our choice for anesthetizing and vasoconstricting the nasal mucosa because of the better side-effect profile, availability, and lack of studies demonstrating a consistent difference between the two options.[30,31]

To vasoconstrict the nasal mucosa before instrumentation in a patient under general anesthesia, we use 0.05% oxymetazoline spray. As a pure α-adrenergic agonist, it provides vasoconstriction of the nasal mucosa without any local anesthetic properties. It has the added advantage of being able to be stocked in airway carts, since it is not a controlled substance. After induction of general anesthesia, the oxymetazoline is sprayed in both nostrils in case attempts made via the first side are unsuccessful. If done while the patient is awake, warn the patient prior to administering the spray about its purpose and the feeling of the solution running down the throat, which will cause no harm. Oxymetazoline has been reported by Katz and coworkers[32] to be more effective than cocaine or lidocaine with epinephrine for prevention of epistaxis with nasotracheal intubation.

Topical Local Anesthetics

After vasoconstricting and anesthetizing the nasopharynx, further sedation is administered while completing anesthesia of the rest of the airway. The choice of local anesthetics for topicalizing the airway includes tetracaine, lidocaine, and benzocaine. The most commonly administered of these is lidocaine. It is chosen for its ease of administration and safety profile compared with the rest of the local anesthetics. Tetracaine is not commonly used for anesthetizing the airway because of the large amounts of the drug required to see a clinical effect and its narrow margin of safety.[20] While benzocaine spray (Hurricaine spray) is kept in our airway cart and the emergency airway bag of our hospital, it, along with prilocaine, can produce methemoglobinemia when given in significant amounts. While they both can provide quick onset of adequate anesthesia, their possible side effects make lidocaine our first choice when anesthetizing the airway.

There are many ways to deliver lidocaine to the airway. One of the easiest methods, which can be done with a patient who is alert, compliant, and has an intact cough reflex, is to simply have the patient swish and gargle 4% lidocaine. Illustration of this is seen in Figure 3 as the clinician administers the 4% lidocaine into the patient's oropharynx. Careful instructions need to be given to the patient before attempting this so that the maximum effect of the local anesthetic can be utilized with minimum side effects. While there has been a study citing an increased risk of nausea and vomiting with this approach, we have not found this to be the case in our experience if the amount of lidocaine swallowed is minimized.[33]

Another method of supplying lidocaine to the airway is with an atomizer. By waiting 3 to 5 minutes between spraying, the airway will become increasingly anesthetized, allowing the clinician to spray lidocaine deeper into the airway. A compliant patient will sometimes allow the use of a laryngoscope blade and application of atomized lidocaine to the vocal cords after proper proximal airway anesthesia has been achieved. The onset time of lidocaine is between 1 and 5 minutes, with duration usually estimated to be around 60 minutes.[20]

Alternatively, the clinician can use nebulized 4% lidocaine to anesthetize the airway. This can be done by running oxygen through a small-volume nebulizer containing 5 to 10 ml of 4% lidocaine. Instructions to the patients are much more simple, since all they are required to do is take deep breaths during the nebulizer treatment. This technique has been reported by Sklar and colleagues[34] and Venus and associates[35] to help prevent the circulatory response to intubating the trachea. The nebulized lidocaine will take 20 minutes or more to effectively anesthetize the airway compared with the shorter times required for orally administered or atomized lidocaine. This increased time requirement must be taken into account when planning the intubation.

There is always the concern of toxicity when giving 4% lidocaine. Vigilance is recommended when calculating the total amount of local anesthetic administered to the patient. Local anesthetics administered into the airway can be absorbed via the mucosa and by absorption from the airways and alveoli. There have been many studies reporting the relative safety of topical lidocaine with doses of 5 to 10 mg/kg and their subsequent benign blood levels.[36–38] Care must still be taken to monitor the amount of drug given, especially when other routes of local anesthetic administration are planned, to ensure that an overdose and systemic side effects are not encountered.

Superior Laryngeal Nerve Block As described previously, the superior laryngeal nerve is a branch of the vagus nerve, which via its internal branch provides sensory innervation from the base of the tongue, epiglottis, piriform fossa, and vallecula. Blunting the sensory aspects of the nerve is the aim of this block. The nerve is targeted as the internal branch crosses the thyrohyoid membrane. Using the thyroid cartilage as a marker, the nerve is reliably blocked.

After discussing the block with the patient, the patient is placed in the supine position. The superior notch of the thyroid cartilage (commonly called the Adam's apple) is located. The hyoid bone is identified cephalad to the thyroid cartilage and is displaced toward the side to be blocked by manipulating it between the index finger and the thumb. After disinfecting the skin with alcohol, a 3-ml syringe filled with 2 ml of 2% lidocaine and fitted with a short 25-gauge needle is advanced until it contacts the greater cornu of the hyoid bone. The needle is then moved caudad off of the greater cornu and, after careful aspiration to check for intravenous or intratracheal placement, the lidocaine is injected. This technique is then repeated on the opposite side. Usual time for onset of the block is 5 to 10 minutes, with duration estimated to be from 4 to 6 hours.[39]

Side effects from the procedure include hematoma because of the proximity of the superior laryngeal artery to the internal branch of the superior laryngeal nerve. This complication usually can be treated with simple compression to the area. The proximity of the artery to the nerve emphasizes the need for careful aspiration before injection, since intravascular placement of the needle is possible. The clinician should also be vigilant to avoid the carotid artery, since intra-arterial injection of small amounts of lidocaine can produce seizures.

Other complications include placement of the needle into the trachea (confirmed by aspiration of air); blockade of the external (motor) branch of the superior laryngeal nerve, possibly causing difficulty with phonation; and needle plugging by cartilage. Contraindications to the block include patient refusal, local infection, or tumor in the area to be blocked.

Translaryngeal Blocks To adequately provide local anesthesia to the laryngotracheal mucosa, the technique of translaryngeal blocks have become popular. Using this block, local anesthetic can be distributed to both branches of the vagus nerve, which supply sensation to the underside of the epiglottis and to the trachea. As discussed earlier in the chapter, these nerves are called the superior laryngeal nerve and the recurrent laryngeal nerve. By instilling local anesthetic distal to the glottic opening, the drug not only acts on the infraglottic mucosa, but is usually spread proximally to the superior laryngeal area by the coughing that accompanies performing the block.

To perform this block, the patient is placed in the supine position, and with the patient's neck extended, the clinician initially identifies thyroid cartilage and then the cricoid bone, which is caudad to the thyroid cartilage. In between these two landmarks, in the midline, is the cricothyroid membrane. After cleaning the area with isopropyl alcohol, the membrane is punctured in the midline with a 22-gauge needle attached to a syringe containing 4 ml of 4% lidocaine. The proper position of the needle is confirmed by aspiration of air. The patient should be reminded that coughing may occur with injection of the local anesthetic. It is imperative to remove the needle quickly after injection to avoid injuring the patient with the needle.

Side effects of the procedure include a 4% incidence of inadequate vocal cord anesthesia.[20] As with other partially effective blocks, it is possible to supplement the anesthesia via another approach, commonly using additional lidocaine to topicalize the cords via an approach discussed earlier. Coughing is expected with the procedure and is not a complication, but it should be kept in mind as a possible contraindication in patients in whom coughing would be detrimental. Other side effects include intravascular placement, hematoma formation, and puncture of soft tissues or the esophagus.

Preparing the Fiberoptic Scope

The clinician should choose which endotracheal tube will be required for the procedure. Typically, a tube that is 0.5 mm (internal diameter) smaller than that used for oral intubation is chosen for nasal intubation. Also, an oral or nasal RAE (Mallinckrodt; St Louis, MO) endotracheal tube is sometimes used to provide a less encumbered field for surgery. Regardless of the tube, the plastic adapter should be taken off to facilitate placement of the tube on the fiberoptic scope. The tip of the fiberoptic scope should be lubricated with silicone solution while keeping the tip of the scope clear. The tip of the endotracheal tube is also lubricated to ease insertion. The tube is advanced up the fiberoptic scope and anchored firmly on the wider proximal portion of the scope to ensure that the tube will not move during the intubation attempt. The clinician should then place the oxygen tubing supplying 7 L/min of flow to the side port of the scope. We use the port for insufflation of oxygen instead of suction in order to "blow" secretions away from the advancing scope. This avoids having inadequately suctioned secretions blur the view through the scope. Complications using oxygen insufflation during fiberoptic intubation have been reported, and we recommend vigilance when using this technique.[40,41]

The body of the fiberoptic scope, with the endotracheal tube in place, is held in the right hand. The thumb is positioned on the control lever responsible for movement of the distal tip of the scope while the index finger is on the button controlling the oxygen supply. The distal end of the scope is held with the left index finger and thumb approximately 8 to 10 cm from the tip. After positioning the scope in the patient's nares, the scope should be advanced under direct visualization.

Manipulating the FOB

The fiberoptic scope may be manipulated in three ways. The scope can be maneuvered with the thumb control lever located on the posterior portion of the handle. This lever, manipulated with the right thumb is used to move the distal end of the fiberscope in a vertical plane. The FOB can be turned on its long axis by rotating the scope as a unit. In other words, the handle of the scope in the right hand and the distal end of the scope in the left hand should be turned as one in order to manipulate the scope. Care should be taken not to turn using only the left hand, as not only will the movement not obtain the desired change of position but it can damage the fiberoptic bundles. Lastly, the scope may be advanced into or withdrawn from the airway. While advancing the fiberoptic scope, always stay in the midline and keep the desired anatomical structures in the center of view. This requires slow, steady movements with the scope. If the orientation of the view is lost, slowly withdraw the fiberoptic scope until the image is restored. Then, after ensuring that the scope is in the midline, and with a clear view, slowly advance in search of desired anatomical landmarks.

Instrumenting the Nose

There are two ways to enter the nasopharynx during fiberoptic intubation. The clinician can either place the lubricated endotracheal tube through the nostril to serve as a guide for the scope or place the scope in first to then serve as a passageway for the endotracheal tube. We will typically place the fiberoptic scope first, as this minimizes the risk of traumatic bleeding obstructing the view of the fiberoptic scope. Placing the scope first also reduces the risk of submucosal tunneling with the more rigid endotracheal tube. Also, there is a chance of not being able to pass the fiberoptic scope through the endotracheal tube once it is bent into position in the nasopharynx.[17] Lastly, there is less time with the larger endotracheal tube in the nasal passages with this technique, which may make an awake intubation more tolerable for the patient.

Some clinicians favor placing the tube first, believing that it guides the fiberoptic scope towards the larynx. A narrowing of the nasopharynx that would not allow the passage of the endotracheal tube would also be discovered before the time and trouble of locating the trachea with the fiberoptic scope were wasted. In this instance, the other nostril could be used, a smaller endotracheal tube selected, or the intubation changed to an oral approach.

The fiberoptic scope should be advanced slowly in deliberate movements to visualize familiar anatomy when it is in the nasopharynx. The first structure typically encountered with this approach is the middle turbinate (Fig. 8). Once this structure is seen, the scope should be advanced in the midline to identify the epiglottis. If the view through the fiberoptic

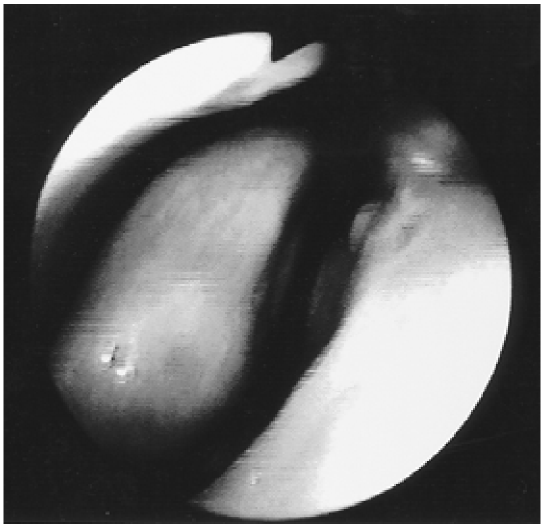

Figure 8. *Picture of the middle turbinate as seen with the fiberoptic scope.*

scope becomes obscured with secretions, brushing the scope against mucosa or insufflating oxygen should clear the picture.

Once the epiglottis is visualized (Fig. 9), the vocal cords are usually in view. If not, advance the scope in the midline directly under the epiglottis to see the laryngeal opening (Fig. 10). When vocal cords are in view, lidocaine may be sprayed through the port of the FOB to anesthetize the area. Careful placement of the scope through the cords is required in spontaneously ventilating patients to minimize irritation and the chance of eliciting the cough reflex or reflex laryngeal closure if the cords are not well anesthetized. Once through the vocal cords, the membranous portion of the trachea along with the characteristic shape of the tracheal rings (Fig. 11) and then the carina (Fig. 12) will be in view.

While the carina is viewed, the clinician slides the previously lubricated endotracheal tube over the fiberoptic scope and into the trachea. Resistance is sometimes met by the bevel of the endotracheal tube prior to entering the trachea. The bevel can be caught at the right arytenoid (usually with the oral approach) or the epiglottis (typically with nasal intubation). This is usually remedied by withdrawing the tube 1 to 3 cm and rotating the tube 90 degrees counterclockwise before gently advancing the tube.[15] Other possible methods of dealing with the problem are to use a smaller endotracheal tube or attempt to slide the tube off of the fiberoptic scope as you are removing the scope from the trachea. The disadvantage of both of those techniques is that some manipulation of the scope is necessary that may require a repeat effort at securing the airway. This becomes more of an issue during a difficult attempt in which issues of sedation, oxygenation, ventilation, and secretions might make repeated efforts more difficult.

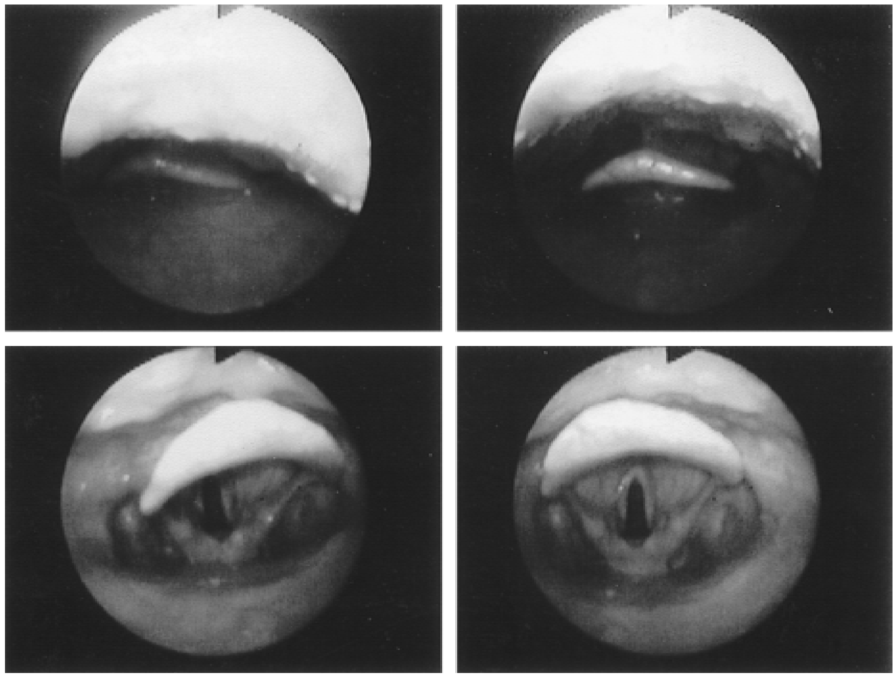

Figure 9. *Picture of the epiglottis coming into view as seen with advancement of the fiberoptic scope.*

Once the tube is in the correct position, care should be taken to keep the tube 4 to 5 cm above the carina. This can be estimated by using the fiberoptic scope as a ruler. When the endotracheal tube is at the carina, the clinician can measure the distance by placing the left index finger and thumb on the scope at the proximal end of the endotracheal tube. Then, while withdrawing the fiberoptic scope from the trachea and while keeping the left fingers on the same location on the scope, the point where the fiberoptic scope enters the distal end of the tube is noted. The distance from the unmoved left fingers on the fiberoptic scope to the proximal end of the endotracheal tube is the distance from the distal end of the tube to the carina.

When the clinician is satisfied with the tube placement, the fiberoptic scope should be carefully removed and placed on a secure airway cart or given to an assistant. The plastic adapter to the tube should be replaced and the proper position of the tube should be checked again by the lack of gastric sounds, bilateral breath sounds, chest excursions, and the presence of end-tidal carbon dioxide. The endotracheal tube cuff should be inflated, the tube properly secured, and the fiberoptic scope returned for proper cleaning and sterilizing for the next use.

Figure 10. *Picture of the vocal cords as seen with the fiberoptic scope.*

Oral Intubation

The preparation of the scope and patient are identical for an awake fiberoptic oral intubation except for the requirement of topicalizing the nasal mucosa. It is important to keep in mind how close the epiglottis is to

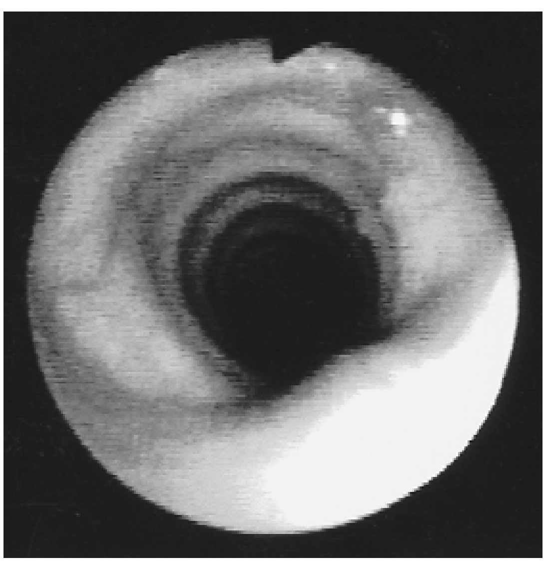

Figure 11. *Picture of the trachea and tracheal rings as seen with the fiberoptic scope.*

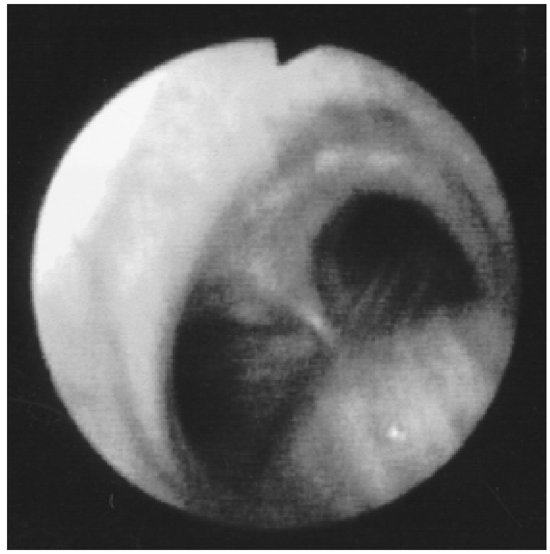

Figure 12. *Picture of the carina as seen with the fiberoptic scope.*

the posterior tongue. Many beginning endoscopists, while making quick and large movements with the FOB, will move by the epiglottis or be off midline and miss airway landmarks. Other points to keep in mind when using this approach is the importance of an oral airway in an awake patient, which will reduce damage to the scope with biting. An aid in awake patients, or those under general anesthesia, is to have an assistant hold the protruded tongue out of the mouth. The tongue can be wrapped with gauze to make this task easier. This increases the distance between the tongue and posterior pharynx and can make the attempt easier.

■ Fiberoptic Intubation under General Anesthesia

While anatomical structures viewed with the FOB will be identical in patients who are awake and under general anesthesia, there has been some question of increased difficulty locating the structures while the patient is under general anesthesia with muscle relaxation. The concern is that the larynx moves to a more anterior position in the patient once anesthesia is induced, making finding the glottic opening more difficult.[42] We have not found this to be an issue when performing or teaching fiberoptic intubations.

The basic set up, as described previously in Table 3, is required. Since the majority of airway reflexes discussed are bypassed with neuromuscular relaxants and general anesthesia, topicalizing the airway becomes less necessary. It is an option, as with any intubation attempt, to use lidocaine topically to decrease the cardiovascular response to placing the endotracheal tube. Other agents such as narcotics, antihypertensives, inhalation agents, induction agents, or intravenous lidocaine can also be used to blunt the response (see Table 6).

While using topical anesthesia in this setting is up to the clinician's discretion, vasoconstriction of the nasal mucosa is still essential when placing the tube nasally. General anesthesia will not decrease the risk of trauma to the mucosa and subsequent epistaxis, which could make the intubation attempt much more difficult.

Common guidelines for inducing general anesthesia should be followed. Induction of anesthesia with standard monitors can proceed as with any other anesthetic. We advocate preoxygenation before inducing anesthesia and continuing to administer 100% oxygen during mask ventilation prior to the intubation attempt to obtain the largest margin of safety during apnea. While remaining on 100% oxygen, an inhalational agent or an intravenous hypnotic can be used for anesthesia during the intubation attempt.

■ Laryngeal Mask Airway and Fiberoptic Intubation

The laryngeal mask airway (LMA) (LMA International, England) developed by Brain has been used successfully to ventilate patients with impossible mask airways[43,44] as well as to secure an airway in a difficult intubation.[45,46] Due to the airway's effectiveness in these situations, it has been incorporated into many clinicians' difficult airway algorithms.[47] The LMA has also been used in troublesome fiberoptic intubation attempts as a guide for the scope, since the aperture of the properly placed LMA rests close to the glottis.[48–50] The size of the endotracheal tube is limited by the size of the LMA in place. A size 5 LMA will accommodate a 7.0-mm endotracheal tube, and a 6.0-mm endotracheal tube will fit through a size

Table 8. *LMA Size and the Size and Type of ETT that Will Fit Through the Device*

LMA Size	ETT International Diameter (mm)
1	3.5 (uncuffed)
2	4.5 (uncuffed)
2.5	5.0 (uncuffed)
3	6.0 (cuffed)
4	6.0 (cuffed)
5	7.0 (cuffed)

LMA = laryngeal mask airway; ETT = endotracheal tube.

3 and 4 LMA. A listing of LMA sizes and the endotracheal tube that can be passed through each are listed in Table 8.[51]

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