Fiberoptic Intubation: An Overview and Update

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Fiberoptic intubation (FOI) is an effective technique for establishing airway access in patients with both anticipated and unanticipated difficult airways. First described in the late 1960s, this approach can facilitate airway management in a variety of clinical scenarios given proper patient preparation and technique. This paper seeks to review the pertinent technology, clinical techniques, and indications for and complications of its use. The role of FOI in airway management algorithms is discussed. Evidence is presented comparing FOI to other techniques with regard to difficult airway management. In addition, we have reviewed the literature on training processes and skill development in FOI. *Key words: fiberoptic bronchoscope (FOB); fiberoptic intubation (FOI); fiberoptic laryngoscopy; difficult airway; awake intubation.* [Respir Care 2014;59(6):865–880. © 2014 Daedalus Enterprises]

Introduction

The transmission of a visual image through a flexible fiberoptic bundle was first reported in 1954.[1] Over a decade later, an English anesthetist named Peter Murphy used a fiberoptic choledocoscope to aid in the nasal intu-

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bation of a patient with Still's disease.[2] Currently, fiberoptic intubation (FOI) with a flexible fiberoptic bronchoscope has become a mainstay of difficult airway management in awake, sedated, and anesthetized patients; its use is taught at the annual meeting of the American Society of Anesthesiologists (ASA),[3] and its role is recognized in guidelines for management of both anticipated and unanticipated difficult airways.[4-7]

Fiberoptic Technology

The technology of fiberoptics is based on the optical characteristics of very thin (diameter of 8–25 μm) flexible glass fibers that are capable of transmitting light over their length. Insulation of these fibers by a glass layer with a different optical density enables transmission by internal reflection of light. An image is transmitted through the length of the scope by an organized coherent bundle of fibers that have the exact orientation at both ends of the scope. A separate fiberoptic bundle is attached to a light source to provide illumination, and lenses at the tip of the scope and eyepiece provide an image that can be focused by the user. In brief, the fiberoptic bronchoscope consists of an eyepiece atop a control handle with a focusing ring that is attached to a thin flexible fiberscope. A thumb control lever allows the distal tip of the scope to be flexed or extended. A separate port that travels the distance of the scope can be utilized for suction, injection of saline or local anesthetic, oxygen insufflation, or passage of brushes or forceps for diagnostic purposes.

A more recent evolution to the bronchoscope is the addition of a charge-coupled device camera, whereby a captured digital image is then transmitted electronically to an external monitor screen. More recent hybrid technology retains fiberoptic bundles from the distal end of the scope to the handle, where the charge-coupled device camera is located. This configuration allows smaller external diameters of bronchoscopes with larger working channels and enhanced flexibility.

The components of the flexible fiberoptic bronchoscope have been detailed well in prior reviews. Figures 1 and 2 highlight basic components of a flexible bronchoscope. We refer the reader to one such comprehensive book chapter to explore these components in more detail.[8] Rigid or semirigid fiberscopes such as the Bonfils and UpsherScope have also been described in successful management of the difficult airway[9,10] but are not discussed in this review.

Indications

Fiberoptic bronchoscopes are currently used to facilitate endotracheal intubation via either the nasal or oral route, in the positioning of endotracheal and endobronchial tubes and bronchial blocking devices, and in airway examination

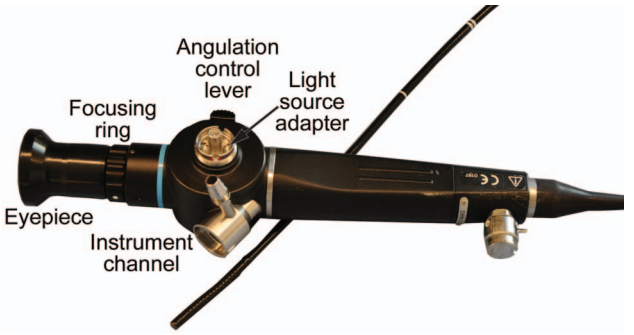

Fig. 1. Flexible bronchoscope (Olympus LF-GP).

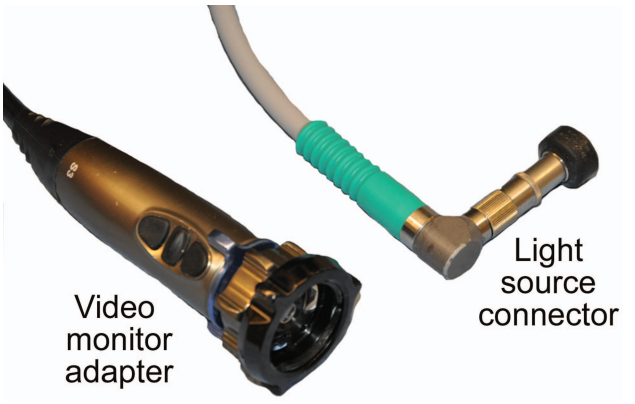

Fig. 2. Additional components of a flexible bronchoscope.

or evaluation. In clinical scenarios in which tracheal intubation is deemed necessary and mask or supraglottic ventilation (eg, via a laryngeal mask airway [LMA]) is unlikely to be successful or poses an aspiration risk, awake FOI is a standard approach. FOI remains the accepted standard in elective airway management of the awake spontaneously breathing patient with an anticipated difficult airway.[11] FOI is ideally suited in such patients because intubation can be performed prior to the induction of general anesthesia with its attendant risks of inadequate ventilation and oxygenation, loss of upper airway patency, and failed intubation. This FOI technique also safeguards against the risk of the cannot intubate/cannot ventilate scenario. Success of the technique, however, presupposes adequate time for preparation in a cooperative patient, a requirement for safe and successful FOI.

Table 1 lists common indications for awake FOI. The need for FOI may be anticipated based on a history of difficult intubation and various anatomic and anthropometric features that may predict difficult laryngoscopy. These include limited mouth opening, limited thyromental distance, reduced neck mobility, inability to prognath, oropharyngeal classification, and obesity.[12] FOI may also be indicated for known or suspected cervical spine instability, anatomic malformations of the mandible or larynx, con-

Table 1. Common Indications for Awake Fiberoptic Intubation

Known difficult intubation
Suspected difficult intubation by direct laryngoscopy (eg, history of difficult intubation, limited mouth opening, decreased thyromental distance)
Unstable cervical spine
Abnormal anatomy
Congenital airway deformities (eg, Pierre Robin syndrome)
Head and neck cancers (eg, supraglottic tumors)
Trauma
Face/neck
Upper airway

genital deformities of the head and neck, and history of head, neck, and spine trauma. If a difficult airway is suspected, the ability to mask ventilate and the need for tracheal intubation should be assessed. Awake intubation is recommended for patients who are at high risk for difficult mask ventilation, particularly those who may be at an elevated risk for aspiration during the airway management process. While difficult airway guidelines are available from a number of specialty societies, these are derived by experts with analysis of limited randomized controlled trials; few recommendations have been validated rigorously. Familiarity, experience, and skill with different approaches, as well as equipment availability, must be considered when applying such guidelines to clinical practice.

During preoperative assessment, a detailed anesthetic history may elicit a history of difficult or unsuccessful attempts by direct laryngoscopy. Prior anesthetic records should be obtained whenever possible. Multiple studies have attempted to identify exam features or to define characteristics that predict difficult intubation. However, the reported usefulness of such predictive tests has been questioned given their low positive predictive value.[13] To complicate matters, the term "difficult intubation" has been variously defined in the literature as limited view on direct laryngoscopy,[12,14] the need for more than one attempt or use of different airway aids,[15,16] and a quantitative score termed the Intubation Difficulty Scale.[17] These approaches limit the means of defining and assessing difficult intubation.

Nonetheless, a recent meta-analysis found that the overall incidence of difficult intubation in subjects without pathologic airway anatomy was 5.8%.[18] The incidence of difficult intubation in select groups such as those with abnormal anatomic features of the head, neck, or airway is difficult to establish given that direct laryngoscopy is less likely to be performed in these patients. However, it is likely to be higher than in those subjects without airway anatomic abnormalities. In an observational study, independent predictors of difficult/impossible mask ventilation and difficult intubation included limited mandibular protrusion, abnormal neck anatomy, sleep apnea or snoring, and body mass index of 30 kg/m^2 or greater.[19] In a follow-up study, this same group reviewed over 50,000 anesthetic records over a 4-year period and demonstrated impossible mask ventilation as an infrequent event (0.15%); of this patient subset, 25% were difficult to intubate.[20] Patients for whom FOI was planned were excluded from data collection and analysis.

FOI is often performed in patients with cervical spine injury or instability. Although there are no outcome data to support a recommendation of FOI over other techniques in such airway management scenarios, surveys of North American anesthesiologists indicate that they prefer to use FOI in patients with cervical spine injury. Interestingly, many also admit limited skills with use of the fiberoptic bronchoscope. In one study of nearly 500 responses from 1,000 active members of the ASA who were surveyed, 78% reported a preference for an awake intubation and use of a bronchoscope in patients with cervical spine injury.[21] A similar survey showed that most respondents favored awake FOI in patients with cervical spine disease (ankylosing spondylitis or rheumatoid arthritis) presenting for elective surgery.[22]

It is important to note that FOI has not been proven superior to other intubation techniques with regard to intubation success rates or clinical outcomes in patients with cervical spine injury, although studies on this subject tend to be limited by their retrospective nature and small sample size.[23] In one retrospective case control study examining 454 subjects with critical cervical spine injuries over an 8 y period, a case group of 165 subjects required intubation within 2 months of injury due to the need for airway protection, respiratory failure, or provision of general anesthesia.[24] Of this subset, all subjects were intubated by an awake technique without the aid of general anesthesia or muscle relaxants: 46% by fiberoptic laryngoscope, 32% by blind nasal intubation, and 22% by direct laryngoscopy. Despite a higher injury severity score in this case group of 165 subjects, there was no difference in neurologic deterioration between this subset and those who were not intubated.

Despite the lack of unequivocal evidence demonstrating improved neurologic outcomes in cervical spine injury patients managed with an awake FOI technique, there are purported advantages. All airway interventions, from mask ventilation to direct or indirect laryngoscopy, result in some degree of neck movement. This movement is typically small, within physiologic ranges, and of unknown clinical importance. If performed, cervical in-line mobilization can protect the cervical spine by diminishing such small movements regardless of airway technique. However, awake FOI techniques in patients with injured cervical spines may have several benefits. First, the head and neck can be maintained in a neutral position during airway management, and neck flexion and extension can be easily limited. A previous study assessed cervical spine motion in

stable cervical spine subjects during intubation with a GlideScope video laryngoscope compared to a flexible fiberoptic bronchoscope.[25] The fiberoptic approach resulted in less cervical movement in the absence of cervical immobilization, a potential advantage not seen in a study comparing a luminous stylet (Trachlight) to FOI in unstable cervical spine subjects with manual in-line stabilization.[26] A second benefit to awake FOI is that protective reflexes can be maintained, thereby reducing the risk of aspiration. Additionally, neurologic assessment can be made after intubation and patient positioning and prior to induction of a general anesthetic.

Fiberoptic bronchoscopy can also be used diagnostically during and/or after FOI to facilitate inspection of the airway for the identification and diagnosis of airway trauma that may co-present in patients with head, neck, and cervical spine injuries. The use of techniques that do not permit visualization of the lower airway in such cases may predispose to incorrect endotracheal tube (ETT) placement via a false lumen or through injured tissue, for example. Such conventional techniques may then lead to severe or catastrophic complications, including massive subcutaneous emphysema and airway loss. Sengupta et al[27] reported a patient with complete tracheal disruption after blunt trauma in which the injury was identified during an awake FOI, facilitating precise ETT placement and positioning. Other reports have described soft tissue swelling and hematoma causing airway obstruction in patients with cervical spine injuries.[28,29] Fiberoptic techniques permit precise evaluation of such pre-existing injury and can be used to facilitate ETT placement beyond the level of injury. For these reasons, FOI in the spontaneously breathing patient has been previously referred to as the method of choice for airway management in patients with airway trauma.[30]

Airway management challenges also exist in patients with head and neck pathologies, a large category including congenital craniofacial defects such as micrognathia, head and neck cancers that may distort airway anatomy, surgical scarring, and radiation fibrosis. Early studies have shown that the difficult airway resulting from head and neck pathology is a significant cause of deaths during general anesthesia.[31] Altered algorithms have been developed for use in this population.[32] Radiographic studies such as computed tomography and magnetic resonance imaging may be particularly useful in airway evaluation of these patients. During preoperative assessment, a history of hoarseness may indicate the location of a mass or progression of disease. Upper airway obstructive symptoms and signs should be elicited. Positional dyspnea, specifically orthopnea, is particularly worrisome. Furthermore, even with successful chemotherapy and radiation treatment in head and neck cancer patients, post-treatment changes can distort the submandibular space and limit neck mobility, rendering laryngoscopy difficult or impossible. In one recent study of 152 difficult airway cases due to head and neck pathology, several factors that predicted airway difficulty were identified.[33] These included cancer diagnosis, history of radiation therapy, and supraglottic/glottic sites. Those subjects with glottic or subglottic lesions required the most intubation attempts. Fiberoptic techniques may be ideally suited for use in this patient subset. In this study, awake FOI was performed successfully in 68 (44.7%) cases.[33] The other most common airway techniques were induction with mask ventilation, followed by direct laryngoscopy (25%) and a dilator cricothyroidotomy technique (28.9%). Awake tracheostomy was performed in 1.3% of subjects.

Fiberoptic Techniques

FOI can be performed nasally or orally in awake patients with topical or regional anesthesia alone, or in sedated or anesthetized patients. The technique is most easily performed with the patient supine or in the seated position. Standard airway and emergency equipment should be available. In circumstances in which mask ventilation may be difficult and risk of airway loss is high, an awake technique is preferred. A nasal approach is particularly useful in patients with a large tongue, limited mouth opening, receding lower jaw, or tracheal deviation or in cases in which an unobstructed surgical field is beneficial (eg, dental surgery). This approach is also anatomically favorable in that the laryngeal opening is more easily seen with the fiberscope as it courses past the nasopharynx with less obstruction by the tongue.[34]

If performed orally, FOI may be facilitated by various intubating airways or supraglottic devices. Such airways or devices allow the user to protect the bronchoscope, maintain a midline position, and displace the tongue more easily. Combination approaches utilizing supraglottic devices are discussed below. There are a variety of oral bite blocks and intubating airways available as well to facilitate oral FOI. Unlike standard oral airways, these devices utilize channels along their sides or top that permit the midline introduction and passage of a bronchoscope and ETT. Proper placement prevents the base of the tongue or the phalange of the airway from protruding into the posterior oropharynx and facilitates easy scope and tube passage to the hypopharynx. One such common airway device, the Ovassapian airway, is illustrated in Figure 3.

Other techniques to facilitate FOI include the jaw thrust, tongue protrusion, positioning the scope in the midline of the pharynx during advancement, and rotating the ETT 90° counterclockwise if resistance is encountered during advancement to facilitate passage through the vocal cords. A laryngoscope blade can be used as an adjuvant to displace the tongue in order to promote bronchoscope and ETT passage. Additionally, specialized face masks are

Fig. 3. Ovassapian airway (Hudson RCI), one of several intubating airways available to facilitate fiberoptic intubation via an oral approach. The tip of the fiberoptic bronchoscope is shown following the plastic airway device, which helps guide the scope to the glottic opening.

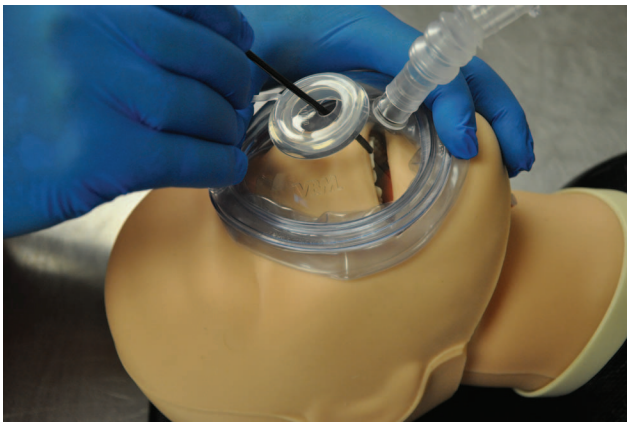

Fig. 4. An endoscopy mask with a specialized central orifice for placement of a fiberoptic bronchoscope. Note the additional (larger) port that can be connected to a circuit for mask ventilation.

available that can deliver oxygen and permit mask ventilation during FOI attempts (Fig. 4).

Patient Position and General Techniques

Awake FOI can be performed with the patient in the seated or supine position. When introducing the scope into the patient's mouth (oral approach), the tip of the scope should be tilted ~45° (upward if intubating from the head of the bed or downward if intubating from the side of the bed or with the patient in a seated position) as shown in Figures 5 and 6. The tip of the scope is then advanced until it is beyond the base of the tongue. A jaw thrust provided by an assistant can aid in bronchoscope passage through

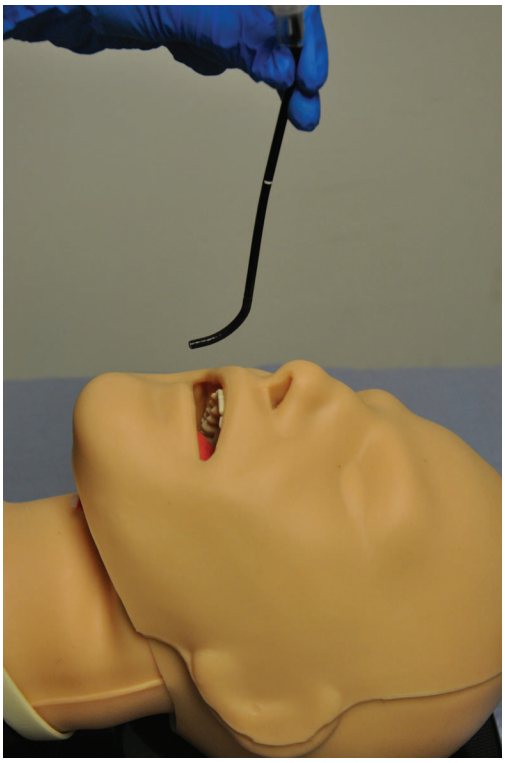

Fig. 5. The fiberoptic scope as introduced for an oral intubation. When introducing the scope from the head of the bed, the tip of the scope is angulated up at an angle of 45°.

the oropharynx. The tip can then be directed to the glottic opening. Fine adjustments with slight motion of the wrist and elevation or depression of the tip using the angulation (thumb) control lever aid in steering the scope toward the vocal cords. Once the scope enters the trachea, it is advanced to the level of the mid-trachea, where a previously loaded ETT is then guided into the trachea. The ETT should be turned gently counterclockwise with retraction and then re-advanced if resistance is encountered during placement. This can decrease the likelihood of laryngeal trauma. Adequate size matching of the ETT on the scope permits less play between the scope and tube and may avoid the tube becoming caught at the level of the epiglottis or on the arytenoid cartilages (Fig. 7). In addition, the greater the gap between the ETT and the bronchoscope, the higher the likelihood of failure of threading the tube.[35] Once the ETT is passed, a bronchoscopic view can verify placement, with optimal tube positioning 2–3 cm above the carina in an adult patient. The scope is then withdrawn as the tube is held in place by hand. Finally, tube placement is checked by end-tidal carbon dioxide and auscultation and subsequently secured and connected to a circuit for ventilation. For a nasal approach (see below), a vasoconstrictor can be applied to the preferred naris to limit or prevent bleeding during intubation. After slow dilation of

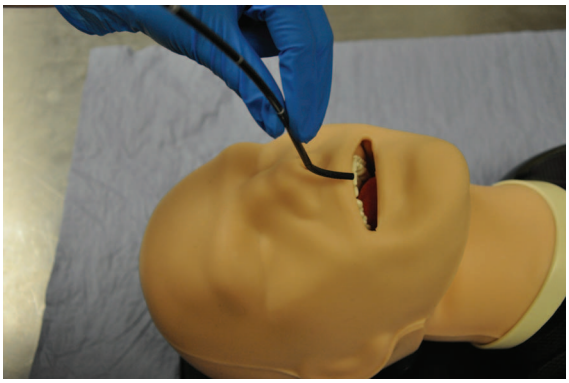

Fig. 6. When performing oral intubation when the patient is seated or from the side of the bed, the tip of the scope is angulated down at an angle of 45°.

Fig. 7. Gap size differences between the fiberoptic bronchoscope and a standard endotracheal tube (ETT) are shown. Poor size matching with a large gap (at left) can result in the leading edge of the ETT contacting and becoming caught on glottic structures as it passes through the cords over the bronchoscope. Smaller gap (at right) reduces the risk of entrapment and trauma to the glottic structures.

the naris with increasingly sized nasopharyngeal airways, a well-lubricated ETT (usually 7.0 mm or smaller) is placed and gently pushed medially and posteriorly ~6–8 cm with the goal of advancing the tube into the posterior oropharynx. If resistance is encountered, caution should be exercised. If this problem occurs with both nares, the bronchoscope should be introduced first to assess for altered anatomy (eg, nasal polyps) and also to direct passage around the turbinates. With a firm jaw thrust by an assistant (alternatively, the tongue can be grasped and pulled forward), the bronchoscope is advanced and directed to the glottic opening for a view of the cords in similar fashion as with the oral approach. Once past the cords, the ETT is advanced to the level of the mid-trachea, and placement is confirmed and finally secured.

Patient Preparation

In preparation for an awake FOI, the patient should be made aware of the steps involved and reassured that patient safety and comfort will be optimized. An antisialagogue is often used to decrease mucus and salivary secretions. Glycopyrrolate is frequently chosen (0.1–0.2 mg intravenously) because of a rapid onset and lack of sedation; however, atropine and scopolamine can also be used. For the nasal approach, the nasal mucosa (V1 and V2 divisions of the trigeminal nerve) must be anesthetized with local anesthetic. Lidocaine is commonly used and is typically applied as a 2% gel or a 5% ointment. Solutions of lidocaine can also be applied on pledgets or soaked cotton swabs and are usually combined with a vasoconstrictor (premixed solution of 0.25% phenylephrine and 3% lidocaine) to limit bleeding by shrinking the nasal mucosal vasculature.

The selected nasal passage is then gently dilated with lubricated nasopharyngeal airways of increasing diameter prior to passing an ETT. For the tongue, oropharynx, and larynx (V3 division of the trigeminal nerve and glossopharyngeal and vagus nerves), topicalization can be achieved by aerosolized, gargled, or nebulized lidocaine. Topical application of lidocaine during awake FOI approaches reportedly results in plasma concentrations well below toxic levels.[36] Other common topical anesthetics such as benzocaine have been shown to cause methemoglobinemia even in therapeutic doses, and Cetacaine (a mixture of benzocaine and tetracaine) has a narrow therapeutic window.

These techniques and considerations for airway topicalization have been described in detail in other reviews.[37] The spray-as-you-go technique utilizes the fiberscope working channel to directly administer local anesthetic to supraglottic and glottic structures during advancement of the instrument. This technique may minimize aspiration risk because airway reflexes are maintained until just before passage of an ETT. Supplemental oxygen can be delivered by nasal cannula to reduce the risk of hypoxia during sedation and intubation.

Regional Anesthesia

Regional airway blocks can be performed in preparation for FOI in lieu of topical anesthetic approaches by the aforementioned methods. These include the glossopharyngeal nerve block, superior laryngeal nerve block, and transtracheal (transcricoid) block. The glossopharyngeal nerve supplies sensory innervation to the posterior third of the tongue, the vallecula, the anterior surface of the epiglottis, the walls of the pharynx, and the tonsils. Blockade of this nerve can be performed using local anesthetic-soaked pledgets held at the base of the tonsillar pillars or by injecting local anesthetic using the mandible and mastoid process as landmarks. The superior laryngeal nerve (branch of the vagus nerve) provides sensory innervation from the base of tongue and posterior surface of the epiglottis to the arytenoids. It can be blocked by injecting local anesthetic using landmarks at the cornu of the hyoid bone. The transtracheal block is performed at the level of the cricothyroid membrane in order to anesthetize the vagus nerve branches that supply sensory innervation to the underside of the epiglottis and trachea.

Details of these blocks are provided in other reviews.[37] They are typically performed based on clinician familiarity and experience as well as patient preference. A distinct advantage of such blocks is a more rapid onset of local anesthetic action and a longer duration of action that may facilitate airway anesthesia with extubation. For instance, the duration of action of plain 1% lidocaine solution used for such specific nerve blocks is ~75 min; it increases to 400 min when 1/200,000 epinephrine is added to the solution.[36] However, complications of airway blocks are not insignificant and include intra-arterial injection, hematoma formation, and tracheal injury. Moreover, Sitzman et al[38] have shown that glossopharyngeal nerve blocks are no more effective than topical application of lidocaine as a route of local anesthetic administration for awake direct laryngoscopy.

Sedation Versus General Anesthesia

Sedative medications and supplemental oxygen are often administered in patients undergoing awake FOI. Goals are to ensure patient comfort and to provide adequate anxiolysis while maintaining a patent airway and ensuring adequate ventilation. In addition, patient responses to fiberoptic scope advancement and tracheal intubation can be blunted. Hypoxemia and aspiration are the most common complications associated with awake FOI.[39] During this technique, benzodiazepines are often combined with opioids to achieve adequate patient comfort and sedation. Midazolam is commonly used because of its rapid onset, short half-life, and ability to provide anterograde amnesia. Opioids such as fentanyl or morphine provide analgesia and can depress laryngeal reflexes. However, they are associated with respiratory depression. In an older study using volunteers, the combination of midazolam and fentanyl for sedation produced apnea in half of the subjects, with nearly all experiencing hypoxemia (oxyhemoglobin saturation $< 90\%$).[40]

More recent case reports,[41,42] case series,[43,44] and randomized studies[45] have reported on dexmedetomidine for conscious sedation during awake FOI and its superior characteristics in this setting. Dexmedetomidine is a selective α_2 adrenergic agonist with sympatholytic, analgesic, and sedative properties that does not cause respiratory depression within recommended dosing ranges (0.2–0.7 μg/kg/h). Although studies are small and limited, it is an alternate and perhaps superior alternative for sedation of patients with difficult airways during FOI attempts. Other studies have reported similar results regarding patient comfort, sedation, and intubating conditions using a combination of midazolam and remifentanil for awake fiberoptic nasotracheal intubation.[46] Still another study of 60 patients undergoing fiberoptic nasotracheal intubation found that remifentanil facilitated better cooperation than propofol in patients and may be safer when spontaneous ventilation is critical.[47]

FOI can also be performed under general anesthesia, often in the spontaneously ventilating patient. There are few studies investigating FOI in spontaneously ventilating anesthetized patients. Propofol and sevoflurane have been compared in this setting with little group differences except that patients receiving propofol had more frequent episodes of hypoxemia.[48] Easy and titratable anesthesia was provided in both groups. Similar findings have been reported in patients with anticipated difficult airways using sevoflurane[49] and propofol[50] with the aid of pressure support ventilation. Another recent randomized study comparing sevoflurane and propofol in patients scheduled for maxillofacial surgery who were difficult to intubate based on predictive criteria reported a high intubation success rate with both.[51] In this study, apnea was limited in both groups by the avoidance of opioids.

One might question whether awake FOI with topical anesthesia solely might be a superior alternative in an effort to reduce the risks of aspiration, airway compromise, inadequate ventilation, hypoxemia, and apnea associated with sedation or general anesthesia. However, there have been some reports of upper airway obstruction using topical anesthesia approaches.[52,53] One study has reported that awake FOI may be uncomfortable in 20% of patients even with premedication and incremental sedation during the procedure with a benzodiazepine.[54] Moreover, even the use of topical anesthesia combined with heavy sedation may be limited or may not prove adequate for some patients, as seen in at least one case series.[55] In select patient groups with difficult airways (children, uncooper-

ative adults, and patients with mental disabilities), general anesthesia (via mask induction or intravenous titration) may be required.

Combined Techniques

The ASA practice guidelines for management of difficult airways were developed in 1991. In 2003, revision of the guidelines included use of the LMA as a rescue device for ventilation and as a conduit for insertion of an ETT, either blindly or guided by a fiberoptic bronchoscope. A variety of supraglottic airway devices are now available; these include the LMA Classic, LMA Unique, LMA ProSeal, and LMA Supreme with slightly different features as well as the intubating LMA (ILMA) Fastrach specifically designed for ETT placement. These supraglottic devices aid in displacing the tongue and epiglottis to allow glottic exposure that may not be achieved with conventional direct laryngoscopy in difficult airways. They also assist in fiberoptic scope advancement since the aperture of a properly placed LMA lies in proximity to the glottis.[56] As Table 2 highlights, ETT size is limited by the size of an LMA conduit. Previous case reports have highlighted the use of different supraglottic devices (Classic,[58,59] ProSeal,[60-62] Supreme,[63] I-Gel,[64] and ILMA[65]) with a fiberoptic bronchoscope to facilitate successful intubation.

Still other devices include rigid indirect laryngoscopes such as the Airtraq, Pentax-AWS, and Bullard laryngoscopes and video laryngoscopes such as the GlideScope. These devices can be used alone or in combination with a fiberoptic bronchoscope to aid in intubation, as has been reported in mannikin studies[66] and case reports[67-69] of difficult airways. A unique advantage of FOI using a video laryngoscope or a rigid/semirigid bronchoscope as an adjuvant is that any ETT maneuvering can be performed under direct vision, thereby limiting or avoiding trauma to the glottic structures. Still other reports have described modified catheter-assisted techniques,[70,71] the use of two bronchoscopes,[72] and even novel devices (LMA CTrach) via fiberoptic bronchoscopy approaches.[73]

Outcomes/Comparison Studies

FOI has a unique role in several clinical scenarios when difficulty with airway management is anticipated. These include intubation via an awake approach in the setting of anticipated airway difficulty, intubation when neck motion is to be avoided, and evaluation of the airway (eg, trauma, inhalational injury). The value of FOI in the management of the difficult airway is well established with a high success rate. In one early study of 423 consecutive fiberoptic nasotracheal intubations spanning nearly 5 years, the success rate for intubation was 98.8%.[74] The majority of intubations were performed by trainees. Ten attempts were aborted because narrow nasal passages did not allow easy passage of a nasotracheal tube or fiberscope. Of the remaining (413) attempts, only 5 were unsuccessful, three of these because of difficulty with advancement of the ETT over the fiberscope. Sequelae were rare; inadequate topical anesthesia led to hyperactive airway reflexes in 4.6% of patients but no permanent injuries. Complications of FOI approaches can be significant but are limited and are discussed below.

Table 2. Laryngeal Mask Airway Size and Endotracheal Tube That Will Fit Through the Device

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

Modified from Reference 57.
LMA = laryngeal mask airway
ETT = endotracheal tube

One of the first studies comparing FOI to another device for the management of the difficult airway (ILMA Fastrach) was performed in patients meeting difficult intubation criteria under general anesthesia.[75] Surprisingly, more adverse events occurred in the fiberoptic group, notably hypoxemia. However, the randomized study found that the two approaches were nearly equivalent and complementary; that is, when one technique failed, the other always succeeded. Failures of the ILMA occurred in patients with head and neck cancers and prior cervical radiation therapy, suggesting that alignment of the ILMA with the glottis aperture may be difficult with these patient features and that FOI may be a better choice.

A similar study compared patients with predicted difficult airways for awake FOI versus ILMA-guided tracheal intubation under general anesthesia.[76] Of note, exclusions included poor mouth opening, cervical spine instability, morbid obesity, and pathologic airway abnormalities. Intubation was successful in all patients in both groups, and those in the ILMA group had higher satisfaction scores by questionnaire. However, a second anesthesiologist was needed in 10% of the patients in the ILMA group for successful intubation. This may reflect more limited experience with the ILMA.

Another study of 54 patients comparing the ILMA and FOI (orotracheal) in awake patients with topical anesthesia demonstrated overall success rates of 84 and 96%, respectively; intubation times were shorter in the ILMA group, and cardiovascular responses were similar.[77] A more recent study comparing FOI to the McGRATH video laryngoscope in awake patients intubated under topical anesthesia and sedation demonstrated no differences in time to

intubation, intubation success on the first attempt, and patient-reported comfort with the procedure.[78]

Complications

There is a paucity of data on the specific incidence and scope of complications attributable to FOI. Potential complications associated with fiberoptic techniques include epistaxis (nasal approach), laryngotracheal trauma, laryngospasm, and aspiration of saliva, blood, or gastric contents. Most studies are in the form of case reports[79-81] or small prospective investigations examining injury.[82] Presumably rare complications include gastric distention and rupture from oxygen insufflation during FOI[79] and the development of subcutaneous emphysema and pneumomediastinum caused by tracheal perforation.[80]

A number of reports have focused on the mechanisms of ETT advancement during FOI because this process can fail or lead to traumatic laryngeal injury.[83] Early reports described failure of ETT passage in up to 1% of attempts related to inability to visualize the larynx, direct a tube toward the larynx, or advance the tube over the fiberoptic bronchoscope.[74] A recent study of 45 patients undergoing clinically indicated (orotracheal) FOI demonstrated that tracheal intubation on the first attempt failed in 53.3% of cases,[82] a rate similar to those reported in other studies.[84,85] Attempts were ultimately successful and were facilitated by ETT maneuvers, notably tube retraction and 90° counterclockwise rotation. Using in vivo endoscopic visualization of the intubation process, this same study also demonstrated that the structure most frequently impinged upon during attempted FOI was the right arytenoid cartilage.

The type, design, and flexibility of the ETT may be an important factor in this regard. For instance, the rate of first successful passage into the trachea during FOI has been reported at 66% with a standard tube, 40% with warmed standard tubes, and 40% with (flexible) wire-reinforced tubes.[85] Three cases of serious laryngeal injury resulting from FOI with standard ETTs have been reported.[81] It has been shown that impingement of the tube on laryngeal structures decreases with use of a modified tip such as a tapered tip[86] or Parker Flex-Tip[87] ETT (Fig. 8). The extent of the gap between the bronchoscope and the tube also seems to be an important determinant in the process of tube placement as it advances over the scope. As highlighted earlier, a large gap can result in contact between the ETT bevel and laryngeal structures, increasing difficulty and the risk of injury.[35] Using a smaller diameter ETT or a larger diameter bronchoscope to minimize this gap is generally recommended.

Training

Difficult airway management is a critical aspect of anesthesiology and critical care practice, and the role of FOI in difficult airway situations is well established. Moreover, skills in FOI are an essential part of anesthesiology training. Arguably, the simulation and practice of crisis management may be as important as technical skill learning with any particular airway technique. Algorithms developed for difficult airway management as well as preplanned strategies may be most useful during such clinical scenarios. These include those developed by national societies as well as institutional algorithms.[88,89]

Fig. 8. A standard cuffed Parker Flex-Tip endotracheal tube. Note the curved tapered distal tip designed to slide past the cords more easily and reduce trauma to glottic structures.

However, instruction and training seem quite variable both in simulated difficult airway scenarios and with specific skill sets such as FOI. Although earlier studies demonstrated improved effectiveness with a stepwise training program (ie, learning fiberoptic techniques in a controlled environment: model or patient with a normal airway) compared to traditional teaching with difficult airway patients,[90] it remains uncertain how best to facilitate skill development or to determine when an acceptable level of expertise is reached. Once learned, the technique can then be incorporated into routine anesthetic practice for continued proficiency. There is evidence that the initial learning curve for fiberoptic laryngoscopy and intubation is steep, and the skill is learned within 10 intubations in patients with normal laryngeal anatomy under general anesthesia.[91] Studies of similar training programs with inexperienced residents have shown that FOI training can be successfully and safely ac-

complished in anesthetized paralyzed (apneic) patients[92] as well as spontaneously breathing anesthetized patients.[93] Others have argued that training devices[94] and models[37] can help novices better appreciate and learn technical skills involved with FOI.

Surveys

A survey of 132 American anesthesiology residency programs (60% response rate) found that only 33% of the programs that responded had a difficult airway rotation, usually with formal instruction prior to the rotation.[95] The fiberoptic bronchoscope and LMA were the most frequently used devices in the rotations, with little emphasis on more invasive techniques. Another survey of American and Canadian programs (60% response rate) reported similar results with both formal and mannikin instruction in combination with formal airway rotations including the use of fiberoptic techniques.[96] Video laryngoscopes were also highly utilized.

Designated airway programs are also prevalent in internal medicine-based critical care fellowship programs,[97] with 58% of United States programs surveyed (66% response rate) reporting a formal rotation and 70% incorporating simulation-based airway education. Fellows were reportedly taught FOI in 64% of programs. However, the average number of FOI procedures performed prior to graduation was estimated at $\leq$ 10 in 65% of trainees. In a survey of Canadian anesthesiologists, respondents (47% response rate) preferred the lighted stylet most often (45%) in a theoretical difficult intubation scenario, with only 26% preferring the fiberoptic bronchoscope.[98] Expectedly, anesthesiologists with experience in a given technique reported more comfort using it in patients.

United States Training

To our awareness, there is no consensus regarding the best approach for teaching FOI. Although the ASA practice guidelines include a number of airway adjuncts, including fiberoptic approaches to the difficult airway, they provide no specific guidelines for teaching these skills. In addition, a universally agreed upon airway management skill set competency level has not been established, although one has been recommended in the Canadian system.[99] Some have suggested that FOI is best accomplished by those clinicians who use it in daily practice.[89]

In the United States, this subject is less well studied. Airway skills seem most often acquired in training programs by way of formal airway management instruction with varied use of simulation, mannikins, and anesthetized patients without predictors for difficult mask ventilation or intubation. Since the implementation of a task force of the Society for Airway Management in 2008 and resurveying of accredited anesthesiology residency programs in the United States, survey data reveal that there has been an increase in implemented specific airway rotations from 27% in 1995[100] to 33% in 2003[95] and to 49% in a more recent 2009 survey.[96] After direct laryngoscopy, the most common techniques for tracheal intubation were fiberoptic bronchoscope and video laryngoscopy. In addition, simulation is now used in 68% of reporting programs compared to just 12% in the aforementioned 2003 survey. Empirical data on trainee performance are needed before evidence-based airway management competency recommendations can be made.

Cadavers

Very limited data exist on the use of cadavers for airway education and management, especially with regard to fiberoptic techniques. Although cadaveric models have been used for teaching of invasive procedures such as surgical cricothyrotomy,[101] their use has been controversial in the United States primarily because of ethical concerns.[102,103] Some authors have suggested, however, that the use of appropriately donated cadavers with educational workshop permission may be a cost-effective method for educating and training anesthesiology residents, especially compared with the high cost of mannikins and simulators.

It has been suggested that cadaveric models may increase the use of invasive airway techniques, including the use of FOI in the management of difficult airway situations.[104] However, residents reported that they were no more confident with FOI after the training in contrast to invasive techniques such as cricothyrotomy, and the authors acknowledged that the use of unpreserved donated cadavers would offer more realistic models for training.

Virtual Simulation and Model Fidelity

Simple models and mannikins have been used successfully to teach FOI skills.[90,105] These may be particularly useful to convey didactic information.[105] The model methodology may improve FOI performance and be more practical than hands-on practice with more traditional training with anesthetized patients. Models may serve as an adjunct to FOI training in this regard by introducing and refining key fiberoptic manipulation skills.

More recently, simulation has been recognized as an effective approach as well.[106] Virtual-type simulators have the ability to imitate a realistic clinical scenario better than many other approaches. In a recent observational study, residents were found to decrease the time required for FOI after using a virtual reality simulator.[107] Other studies have shown that simulator practice can improve psychomotor skills for FOI.[108]

While studies on simulation training for FOI remain quite limited, this training modality arguably has the most

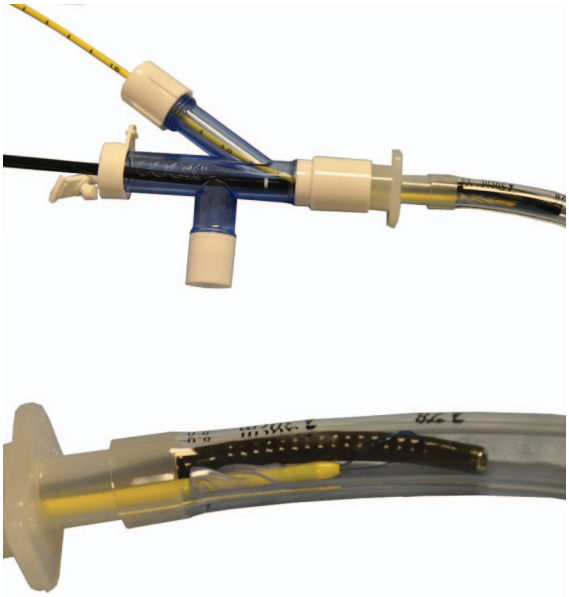

Fig. 9. The Arndt endobronchial blocker, one of the commercially available endobronchial blockers for lung isolation. At top, a fiberoptic scope is shown entering a bronchoscopy port of a multiport airway adapter. The endobronchial blocker (yellow) is passed through the blocker port. The bronchoscope can then be advanced into and through a guide loop (shown at bottom), which can be tightened and couples the endobronchial blocker to the bronchoscope. The bronchoscope is advanced through the endotracheal tube into the lung section to be blocked. The endobronchial balloon is inflated under bronchoscopic vision after the blocker is released from the bronchoscope and its position confirmed.

potential as an adjunct and substitute for clinical practice in FOI training and additionally provides the potential for objective clinical assessment of trainee skill level and progress. Whether practiced using simple models or performed in anesthetized patients, we believe that the use of a video monitor for larger image display may be most effective for the novice or trainee. This enables a more experienced clinician to have the same view as the individual performing the procedure and serves for real-time instruction, guidance, and evaluation.

Additional Uses

In addition to helping in intubation of the difficult airway, fiberoptic bronchoscope techniques are useful in a variety of other settings. They are often needed for airway examination for diagnostic and therapeutic purposes in thoracic surgery. The fiberoptic bronchoscope is the accepted standard for confirming ideal positioning of double-lumen ETTs and has led to an increased margin of safety with positioning of double-lumen tubes compared with auscultation and clamping maneuvers alone.[109] The fiberoptic bronchoscope helps with correct placement of bronchial blockers (Fig. 9)[110] and is essential for correct positioning of single-lumen endobronchial tubes. Such techniques are particularly beneficial in the setting of a difficult airway and the need for lung isolation.[111]

While most of the available literature on the use of FOI in patients with difficult airways relates to predicted or known difficulty associated with visualizing and accessing the glottis and proximal trachea, another category of patients with lower airway abnormalities may also benefit from or require FOI. It is important to remember that FOI remains the only airway management modality available to date that is suitable for facilitating both endotracheal intubation and distal tracheal or endobronchial intubation under direct visualization. Such maneuvers may be critical and lifesaving in patients with tracheobronchial compromise from mediastinal masses or other pathologies. Direct intubation of the distal trachea or even one main bronchus over an intubating bronchoscope may enable the skilled practitioner to bypass a life-threatening lower airway lesion or obstruction. Still other uses include placement of endobronchial stents and exchange of airway guide-wire catheters.[112] Finally, extubation strategies can be accomplished with fiberoptic aid, specifically to assess pharyngeal airway swelling, vocal cord function, and subglottic stenosis by means of adjuvants such as the LMA and airway exchange catheter, as suggested in a recent report.[113]

Summary

Management of the difficult airway is a crucial patient safety issue, and FOI is a well-established and versatile tool for airway management in patients with known or suspected difficult airways or as a rescue technique. The technique may be performed in a variety of settings, including the operating room during anesthetic management, the emergency department, and the ICU. It is a component of difficult airway algorithms and can be used in combination with other airway devices such as the LMA and video laryngoscope to facilitate successful intubation. A variety of clinical approaches are possible and include awake nasal and oral approaches, typically with regional and/or topical local anesthetic techniques with or without sedation. FOI is also possible in the anesthetized patient. Training is aided by models as well as the more recent advent of virtual reality simulation.

REFERENCES

1. Hopkins HH, Kapany NS. A flexible fiberscope, using static scanning. Nature 1954;173(4392):39-41.
2. Murphy P. A fibre-optic endoscope used for nasal intubation. Anaesthesia 1967;22(3):489-491.
3. Gil KS. Fiber-optic intubation: tips from the ASA workshop. Anesthesiology News Guide to Airway Management 2012;38:21-29.
4. Drolet P. Management of the anticipated difficult airway–a systematic approach: continuing professional development. Can J Anesth 2009;56(9):683-701.

5. Apfelbaum JL, Hagberg CA, Caplan RA, Blitt CD, Connis RT, Nickinovich DG, et al. Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. Anesthesiology 2013;118(2):251-270.
6. Heidegger T, Gerig HJ, Henderson JJ. Strategies and algorithms for the management of the difficult airway. Best Pract Res Clin Anaesthesiol 2005;19(4):661-674.
7. Henderson JJ, Popat MT, Latto IP, Pearce AC. Difficult airway society guidelines for management of the unanticipated difficult intubation. Anaesthesia 2004;59(7):675-694.
8. Ovassapian A. Fiberoptic tracheal intubation. In: Fiberoptic airway endoscopy in anesthesia and critical care. New York: Raven Press; 1990:57-79.
9. Halligan M, Charters P. A clinical evaluation of the Bonfils Intubation Fiberscope. Anaesthesia 2003;58(11):1087-1091.
10. Fridrich P, Frass M, Krenn CG, Weinstabl C, Benumof JL, Krafft P. The UpsherScope in routine and difficult airway management: a randomized, controlled clinical trial. Anesth Analg 1997;85(6): 1377-1381.
11. Koerner IP, Brambrink AM. Fiberoptic techniques. Best Pract Res Clin Anaesthesiol 2005;19(4):611-621.
12. el-Ganzouri AR, McCarthy RJ, Tuman KJ, Tanck EN, Ivankovich AD. Preoperative airway assessment: predictive value of a multivariate risk index. Anesth Analg 1996;82(6):1197-1204.
13. Yentis SM. Predicting difficult intubation–worthwhile exercise or pointless ritual? Anaesthesia 2002;57(2):105-109.
14. Nath G, Sekar M. Predicting difficult intubation–a comprehensive scoring system. Anaesthesia Intensive Care 1997;25(5):482-486.
15. Frerk CM. Predicting difficult intubation. Anaesthesia 1991;46(12): 1005-1008.
16. Savva D. Prediction of difficult tracheal intubation. Br J Anaesth 1994;73(2):149-153.
17. Adnet F, Borron SW, Racine SX, Clemessy JL, Fournier JL, Plaisance P, Lapandry C. The intubation difficulty scale (IDS): proposal and elevation of a new score characterizing the complexity of endotracheal intubation. Anesthesiology 1997;87(6):1290-1297.
18. Shiga T, Wajima Z, Inoue T, Sakamoto A. Predicting difficult intubation in apparently normal patients: a meta-analysis of bedside screening test performance. Anesthesiology 2005;103(2):429-437.
19. Kheterpal S, Han R, Tremper KK, Shanks A, Tait AR, O'Reilly M, Ludwig TA. Incidence and predictors of difficult and impossible mask ventilation. Anesthesiology 2006;105(5):885-891.
20. Kheterpal S, Martin L, Shanks AM, Tremper KK. Prediction and outcomes of impossible mask ventilation. Anesthesiology 2009; 110(4):891-897.
21. Rosenblatt WH, Wagner PJ, Ovassapian A, Kain ZN. Practice patterns in managing the difficult airway by anesthesiologists in the United States. Anesth Analg 1998;87(1):153-157.
22. Ezri T, Szmuk P, Warters RD, Katz J, Hagberg CA. Difficult airway management practice patterns among anesthesiologists practicing in the United States: have we made any progress? J Clin Anesth 2003;15(6):418-422.
23. Crosby ET. Airway management in adults after cervical spine trauma. Anesthesiology 2006;104(6):1293-1318.
24. Meschino A, Devitt JH, Koch JP, Szalai JP, Schwartz ML. The safety of awake tracheal intubation in cervical spine injury. Can J Anaesth 1992;39(2):114-117.
25. Wong DM, Prabhu A, Chakraborty S, Tan G, Massicotte EM, Cooper R. Cervical spine motion during flexible bronchoscopy compared with the Lo-Pro GlideScope. Br J Anaesth 2009;102(3):424-430.
26. Houde BJ, Williams SR, Cadrin-Chênevert A, Guilbert F, Drolet P. A comparison of cervical spine motion during orotracheal intubation with the Trachlight or the flexible fiberoptic bronchoscope. Anesth Analg 2009;108(5):1638-1643.
27. Sengupta S, Saikia A, Ramasubban S, Gupta S, Maitra S, Rudra A, Maitra G. Anaesthetic management of a patient with complete tracheal rupture following blunt chest trauma. Ann Card Anaesth 2008; 11(2):123-126.
28. Cleiman P, Nemeth J, Vetere P. A significant cervical spine fracture: think of the airway. J Emerg Med 2012;42(2):e23-e25.
29. Lazott LW, Ponzo JA, Puana RB, Artz KS, Ciceri DP, Culp WC Jr. Severe upper airway obstruction due to delayed retropharyngeal hematoma formation following blunt cervical trauma. BMC Anesthesiol 2007;7:2.
30. Abernathy JH 3rd, Reeves ST. Airway catastrophes. Curr Opin Anaesthesiol 2010;23(1):41-46.
31. Campling EA, Devlin HB, Hoile RW, Lunn JN. The report of the National Confidential Enquiry into Perioperative Deaths 1992/1993. London: National Confidential Enquiry into Perioperative Deaths; 1995. www.ncepod.org.uk/pdf/1992_3/Full Report 1992-1993.pdf. *Accessed May 2, 2014.*
32. Dougherty TB, Clayman GL. Airway management of surgical patients with head and neck malignancies. Anesthesiol Clin North America 1998;16(3):547-562.
33. Iseli TA, Iseli CE, Golden JB, Jones VL, Boudreaux AM, Boyce JR, et al. Outcomes of intubation in difficult airways due to head and neck pathology. Ear Nose Throat J 2012;91(3):E1–E5.
34. Stackhouse RA, Marks JD, Bainton CR. Performing fiberoptic endotracheal intubation: clinical aspects. Int Anesthesiol Clin 1994; 32(4):57-73.
35. Hakala P, Randell T. Comparison between two fiberscopes with different diameter insertion cords for fiberoptic intubation. Anaesthesia 1995;50(8):735-737.
36. Walsh ME, Shorten GD. Preparing to perform an awake fiberoptic intubation. Yale J Biol Med 1998;71(6):537-549.
37. Stackhouse RA. Fiberoptic airway management. Anesthesiol Clin North America 2002;20(4):933-951.
38. Sitzman BT, Rich GF, Rockwell JJ, Leisure GS, Durieux ME, DiFazio CA. Local anesthetic administration for awake direct laryngoscopy: are glossopharyngeal nerve blocks superior? Anesthesiology 1997;86(1):34-40.
39. Ovassapian A. Fiberoptic endoscopy and the difficult airway, 2nd edition. Philadelphia: Lippincott Williams & Wilkins; 1996;61-69.
40. Bailey PL, Pace NL, Ashburn MA, Moll JW, East KA, Stanley TH. Frequent hypoxemia and apnea after sedation with midazolam and fentanyl. Anesthesiology 1990;73(5):826-830.
41. Bergese SD, Khabiri B, Roberts WD, Howie MB, McSweeney TD, Gerhardt MA. Dexmedetomidine for conscious sedation in difficult awake fiberoptic intubation cases. J Clin Anesth 2007;19(2):141-144. Erratum in: J Clin Anesth 2007;19(4):323.
42. Grant SA, Breslin DS, MacLeod DB, Gleason D, Martin G. Dexmedetomidine infusion for sedation during fiberoptic intubation: a report of three cases. J Clin Anesth 2004;16(2):124-126.
43. Avitsian R, Lin J, Lotto M, Ebrahim Z. Dexmedetomidine and awake fiberoptic intubation for possible cervical spine myelopathy: a clinical series. J Neurosurg Anesthesiol 2005;17(2):97-99.
44. Abdelmalak B, Makary L, Hoban J, Doyle DJ. Dexmedetomidine as sole sedative for awake intubation in management of the critical airway. J Clin Anesth 2007;19(5):370-373.
45. Bergese SD, Bender SP, McSweeney TD, Fernandez S, Dzwonczyk R, Sage K. A comparative study of dexmedetomidine with midazolam and midazolam alone for sedation during elective awake fiberoptic intubation. J Clin Anesth 2010;22(1):35-40.
46. Machata AM, Gonano C, Holzer A, Andel D, Spiss CK, Zimpfer M, Illievich UM. Awake nasotracheal fiberoptic intubation: patient comfort, intubating conditions, and hemodynamic stability during

conscious sedation with remifentanil. Anesth Analg 2003;97(3): 904-908.
47. Lallo A, Billard V, Bourgain JL. A comparison of propofol and remifentanil target-controlled infusions to facilitate fiberoptic nasotracheal intubation. Anesth Analg 2009;108(3):852-857.
48. Bonnin M, Therre P, Albuisson E, Beaujard H, Barthelemy I, Mondie JM, Bazin JE. Comparison of a propofol target-controlled infusion and inhalational sevoflurane for fiberoptic intubation under spontaneous ventilation. Acta Anaesth Scand 2007;51(1):54-59.
49. Favier JC, Da Conceiçao M, Genco G, Bidallier I, Fassassi M, Steiner T, Pitti R. [Fiberoptic intubation in adult patients with predictive signs of difficult intubation: inhalational induction using sevoflurane and an endoscopic facial mask]. Ann Fr Anaesth Reanim 2003;22(2):96-102. *Article in French.*
50. Bourgain JL, Billard V, Cros AM. Pressure support ventilation during fiberoptic intubation under propofol anesthesia. Br J Anaesth 2007;98(1):136-140.
51. Péan D, Floch H, Beliard C, Piot B, Testa S, Bazin V, et al. Propofol versus sevoflurane for fiberoptic intubation under spontaneous breathing anesthesia in patients difficult to intubate. Minerva Anestesiol 2010;76(10):780-786.
52. Ho AM, Chung DC, To EW, Karmakar MK. Total airway obstruction during local anesthesia in a non-sedated patient with a compromised airway. Can J Anaesth 2004;51(8):838-841.
53. McGuire G, el-Beheiry H. Complete upper airway obstruction during awake fiberoptic intubation in patients with unstable cervical spine fractures. Can J Anaesth 1999;46(2):176-178.
54. Kundra P, Kutralam S, Ravishankar M. Local anesthesia for awake fiberoptic nasotracheal intubation. Acta Anaesthesiol Scand 2000; 44(5):511-516.
55. Boucek CD, Gunnerson HB, Tullock WC. Percutaneous transtracheal high-frequency jet ventilation as an aid to fiberoptic intubation. Anesthesiology 1987;67(2):247-249.
56. Benumof JL. Use of the laryngeal mask airway to facilitate fiberscope-aided tracheal intubation. Anesth Analg 1992;74(2):313-315.
57. Fulling PD, Roberts JT. Fiberoptic intubation. Int Anesthesiol Clin 2000;38(3):189-217.
58. Berkow LC, Schwartz JM, Kan K, Corridore M, Heitmiller ES. Use of the Laryngeal Mask Airway-Aintree Intubating Catheter-fiberoptic bronchoscope technique for difficult intubation. J Clin Anesth 2011;23(7):534-539.
59. Varghese E, Nagaraj R, Shwethapriya R. Comparison of oral fiberoptic intubation via a modified Guedel airway or a laryngeal mask airway in infants and children. J Anaesthesiol Clin Pharmacol 2013; 29(1):52-55.
60. Xue FS, He N, Xiang PC, Liu JH, Xu XZ. Use of a modified ProSeal laryngeal mask airway to facilitate diagnostic fiberoptic bronchoscopy in anesthetized patients. Can J Anesth 2009;56(7): 547-548.
61. Cranshaw J, Shewry E. Use of ProSeal laryngeal mask airway as a dedicated airway for fibreoptic-guided tracheal intubation. Anaesthesia 2006;61(2):199-201.
62. Yuste JA. Fiberoptic tracheal intubation via modified ProSeal laryngeal mask airway in children. Paediatr Anaesth 2009;19(2):172-174
63. Mathes AM, Wrobel M, Reus E, Rensing H, Grundmann U. Fiberoptic-guided intubation via the laryngeal mask airway Supreme. J Clin Anesth 2008;20(4):322-323.
64. Michalek P, Hodgkinson P, Donaldson W. Fiberoptic intubation through an I-Gel supraglottic airway in two patients with predicted difficult airway and intellectual disability. Anesth Analg 2008; 106(5):1501-1504.
65. Sener EB, Sarihasan B, Ustun E, Kocamanoglu S, Kelsaka E, Tur A. Awake tracheal intubation through the intubating laryngeal mask airway in a patient with halo traction. Can J Anesth 2002;49(6): 610-613.
66. Nishikawa K, Hukuoka E, Kawagishi T, Shimodate Y, Yamakage M. Efficacy of the Airtraq with a fiberoptic bronchoscope compared with that of Airtraq alone for tracheal intubation: a manikin study. J Anesth 2011;25(1):93-97.
67. Yuan YJ, Xue FS, Liao X, Liu JH, Wang Q. Facilitating combined use of an Airtraq optical laryngoscope and a fiberoptic bronchoscope in patients with a difficult airway. Can J Anesth 2011;58(6): 584-585.
68. Vitin AA, Erdman JE. A difficult airway case with GlideScope-assisted fiberoptic intubation. J Clin Anesth 2007;19(7):564-565.
69. Sharma D, Kim LJ, Ghodke B. Successful airway management with combined use of GlideScope videolaryngoscope and fiberoptic bronchoscope in a patient with Cowden syndrome. Anesthesiology 2010; 113(1):253-255.
70. Gosavi KS, Nirkhi AM. Exchange catheter-assisted fiberoptic nasal intubation: a modified technique. Anesth Analg 2011;113(1):205-206.
71. Chu Q, Dou Z, Xie G, Yang A, Zhang W. Combined use of adult fiberoptic bronchoscope and CARTO catheter for tracheal intubation in children with known difficult airway. J Anesth 2011;25(4):531-534.
72. Gorlin A, Susarla SM, Chatburn J, Jiang Y. Use of a second fiberoptic bronchoscope to guide oral fiberoptic intubation in 2 patients with existing vocal cord injury. J Oral Maxillofac Surg 2011;69(2): 546-550.
73. Kristensen MS. The LMA CTrach for awake intubation combines the features of the LMA Fastrach and the fiberoptic bronchoscope, but cannot replace this combination in all patients. Acta Anaesthesiol Scand 2006;50(4):526.
74. Ovassapian A, Yelich SJ, Dykes MH, Brunner EE. Fiberoptic nasotracheal intubation: incidence and causes of failure. Anesth Analg 1983;62(7):692-695.
75. Langeron O, Semjen F, Bourgain JL, Marsac A, Cros AM. Comparison of the intubating laryngeal mask airway with the fiberoptic intubation in anticipated difficult airway management. Anesthesiology 2001;94(6):968-972.
76. Joo HS, Kapoor S, Rose DK, Naik VN. General anesthesia versus awake fiberoptic intubation in patients with difficult airways. Anesth Analg 2001;92(5):1342-1346.
77. Dhar P, Osborn I, Brimacombe J, Meenan M, Linton P. Blind orotracheal intubation with the intubating laryngeal mask versus fiberoptic guided orotracheal intubation with the Ovassapian airway: a pilot study of awake patients. Anaesth Intensive Care 2001; 29(3):252-254.
78. Rosenstock CV, Thøgersen B, Afshari A, Christensen AL, Eriksen C, Gätke MR. Awake fiberoptic or awake video laryngoscopic tracheal intubation in patients with anticipated difficult airway management: a randomized clinical trial. Anesthesiology 2012;116(6): 1210-1216.
79. Hershey MD, Hannenberg AA. Gastric distention and rupture from oxygen insufflation during fiberoptic intubation. Anesthesiology 1996;85(6):1479-1480.
80. Kaneko Y, Nakazawa K, Yokoyama K, Ishikawa S, Uchida T, Takahashi M, et al. Subcutaneous emphysema and pneumomediastinum after translaryngeal intubation: tracheal perforation due to unsuccessful fiberoptic intubation. J Clin Anesth 2006;18(2):135-137.
81. Maktabi MA, Hoffman H, Funk G, From R. Laryngeal trauma during awake fiberoptic intubation. Anesth Analg 2002;95(4):1112-1114.
82. Johnson DM, From AM, Smith RB, From RP, Maktabi MA. Endoscopic study of mechanisms of failure of endotracheal tube advancement into the trachea during awake fiberoptic orotracheal intubation. Anesthesiology 2005;102(5):910-914.
83. Marsh NJ. Easier fiberoptic intubation. Anesthesiology 1992;76(5): 860-861.

84. Brull SJ, Wiklund R, Ferris C, Connelly NR, Ehrenwerth J, Silverman DG. Facilitation of fiberoptic orotracheal intubation with flexible tracheal tube. Anesth Analg 1994;78(4):746-748.
85. Hakala P, Randell T, Valli H. Comparison between tracheal tubes for orotracheal fiberoptic intubation. Br J Anaesth 1999;82(1):135-136.
86. Jones HE, Pearce AC, Moore P. Fibreoptic intubation: influence of tracheal tube tip design. Anaesthesia 1993;48(8):672-674.
87. Kristensen MS. The Parker Flex-Tip tube versus a standard tube for fiberoptic orotracheal intubation: a randomized double-blind study. Anesthesiology 2003;98(2):354-358.
88. Combes X, Le Roux B, Suen P, Dumerat M, Motamed C, Sauvat S, et al. Unanticipated difficult airway in anesthetized patients: prospective validation of a management algorithm. Anesthesiology 2004;100(5):1146-1150.
89. Heidegger T, Gerig HJ, Ulrich B, Kreienbühl G. Validation of a simple algorithm for tracheal intubation: daily practice is the key to success in emergencies–an analysis of 13,248 intubations. Anesth Analg 2001;92(2):517-522.
90. Ovassapian A, Dykes MH, Golmon ME. A training programme for fiberoptic nasotracheal intubation. Use of model and live patients. Anaesthesia 1983;38(8):795-798.
91. Johnson C, Roberts JT. Clinical competence in the performance of fiberoptic laryngoscopy and endotracheal intubation: a study of resident instruction. J Clin Anesth 1989;1(5):344-349.
92. Cole AF, Mallon JS, Rolbin SH, Ananthanarayan C. Fiberoptic intubation using anesthetized, paralyzed, apneic patients. Results of a resident training program. Anesthesiology 1996;84(5):1101-1106.
93. Erb T, Hampl KF, Schürch M, Kern CG, Marsch SC. Teaching the use of fiberoptic intubation in anesthetized, spontaneously breathing patients. Anesth Analg 1999;89(5):1292-1295.
94. Rosenblatt W. The fiberoptic training jig. Anaesthesia 2007;62(2): 201-202.
95. Hagberg CA, Greger J, Chelly JE, Saad-Eddin HE. Instruction of airway management skills during anesthesiology residency training. J Clin Anesth 2003;15(2):149-153.
96. Pott LM, Randel GI, Straker T, Becker KD, Cooper RM. A survey of airway training among U.S. and Canadian anesthesiology residency programs. J Clin Anesth 2011;23(1):15-26.
97. Joffe AM, Liew EC, Olivar H, Dagal AH, Grabinsky A, Hallman M, Treggiari MM. A national survey of airway management training in United States internal medicine-based critical care fellowship programs. Respir Care 2012;57(7):1084-1088.
98. Wong DT, Lai K, Chung FF, Ho RY. Cannot intubate–cannot ventilate and difficult intubation strategies: results of a Canadian national survey. Anesth Analg 2005;100(5):1439-1446.
99. Crosby E, Lane A. Innovations in anesthesia education: the development and implementation of a resident rotation for advanced airway management. Can J Anaesth 2009;56(12):939-959.
100. Koppel JN, Reed AP. Formal instruction in difficult airway management. A survey of anesthesiology programs. Anesthesiology 1995;83(6):1343-1346.
101. Tabas JA, Rosenson J, Price DD, Rohde D, Baird CH, Dhillon N. A comprehensive, unembalmed cadaver-based course in advanced emergency procedures for medical students. Acad Emerg Med 2005; 12(8):782-785.
102. Orlowski JP. Politically correct ethical thinking and intubation practice on cadavers. J Clin Ethics 1994;5(3):256-260.
103. Ardagh M. May we practice endotracheal intubation on the newly dead? J Med Ethics 1997;23(5):289-294.
104. Hatton KW, Price S, Craig L, Grider JS. Educating anesthesiology residents to perform percutaneous cricothyrotomy, retrograde intubation, and fiberoptic bronchoscopy using preserved cadavers. Anesth Analg 2006;103(5):1205-1208.
105. Naik VN, Matsumoto ED, Houston PL, Hamstra SJ, Yeung RY, Mallon JS, Martire TM. Fiberoptic orotracheal intubation on anesthetized patients. Do manipulation skills learned on a simple model transfer into the operating room? Anesthesiology 2001;95(2):343-348.
106. Schaefer JJ. Simulators and difficult airway management skills. Paediatr Anaesth 2004;14(1):28-37.
107. Goldmann K, Steinfeldt T. Acquisition of basic fiberoptic intubation skills with a virtual reality airway simulator. J Clin Anesth 2006;18(3):173-178.
108. Rowe R, Cohen RA. An evaluation of a virtual reality airway simulator. Anesth Analg 2002;95(1):62-66.
109. Klein U, Karzai W, Bloos F, Wohlfarth M, Gottschall R, Fritz H, et al. Role of fiberoptic bronchoscopy in conjunction with the use of double-lumen tubes for thoracic anesthesia: a prospective study. Anesthesiology 1998;88(2):346-350.
110. Campos JH. An update on bronchial blockers during lung separation techniques in adults. Anesth Analg 2003;97(5):1266-1274.
111. Kaza SR, Maddali MM, Albahrani MJ, Vaghari AA. One lung ventilation in a patient with an upper and lower airway abnormality. Indian J Anaesth 2012;56(6):567-569.
112. Campos JH. Update on tracheobronchial anatomy and flexible fiberoptic bronchoscopy in thoracic anesthesia. Curr Opin Anaesthesiol 2009;22(1):4-10.
113. Li Q, Zhou RH, Liu J, Rao L. Strategy for suspected difficult extubation: algorithm and the role of laryngeal mask airway, fiberoptic bronchoscope, and airway exchange catheter. Paediatr Anaesth 2012;22(6):598-600.

Discussion

Berkow: I hear a lot from my residents in my training program, as well as feedback from other anesthesia residency programs, that the experience of FOI [fiberoptic intubation] seems to be decreasing now that we have video laryngoscopes and that a lot of patients who potentially in the past would have been intubated fiberoptically awake are now having video laryngoscopy. And I even see this with my surgical colleagues, who often would ask for awake FOI for their cervical spine patients, now just ask for the GlideScope. So, I'm concerned a lot about that especially in the face of competency and residency program requirements that are changing, and now we are going to be required to monitor milestones and address competency in a more formal fashion. And I don't know how we make sure that our residents get that fiberoptic experience that they need.

Blank: I agree completely. As these alternative technologies continue to evolve, they may ease the clinical chal-

Hurford: One way we've gotten around that in our anesthesiology training program is that our first year residents do a month with our ENT [otolaryngology] colleagues on the airway service. They go to the airway clinic and do a lot of nasopharyngeal examinations. They also go to the OR [operating room]and work with the ENT surgeons. So, I must admit, at the end of that, they probably have a better level of initial competency than many of my attending physicians.

Ramachandran: I'd like to go back to Dr Berkow's comment. I think the challenge with all of these advanced airway techniques is the failure rate. There is no single technique that doesn't have a failure rate that's truly startling if you look at the statistics. A failure rate of 10–15% hasn't really changed for the awake FOI technique. It's scary if that's our final sort of end point for airway management. Granted, the risk of the actual number of cases where you would be in a situation of failed intubation, failed supraglottic airway, and failed fiberoptic is going to be very small. Perhaps the changing technology means that there needs to be a change, a paradigm shift, in what we think is our ultimate best technique. To comment on a point made in an earlier discussion, I'd like to emphasize the point that the best techniques are the ones you know and know well. Those should be your plan A and your plan B. I find that FOI teaching is very biased toward one thing or the other; it's not a wide range of things that we're used to. And what Dr Berkow said is particularly important because many soft indications for awake FOI meant that the art of the fiberoptic was how you got the sedation right; you just don't get that chance anymore. Our residents go to the ENT clinic, but I think oral FOIs are still a huge challenge to train young residents on.

Collins: I am impressed with even the most recent (revised) practice guidelines[1] for management of the difficult airway by one main point. Despite the structured guidelines, in the case of unsuccessful intubation after induction of general anesthesia with adequate face mask ventilation, there are such a variety of options. The airway approach at this point is up to the clinician. In fact, one can try any number of options. I think, practically, the point is really to use what one is good at using in terms of managing the airway based on one's judgment and experience within that clinical situation. I am not aware of resident training requirements for how many successful intubating LMA [laryngeal mask airway] placements are needed before one graduates a program. Or successful light wand attempts, or fiberoptic intubations, etc. I do believe residency programs are graduating residents who are not capable of meeting some or a lot of the proficiency standards for these tools. And perhaps we shouldn't focus on learning them all, but rather on learning a few of them and then learning how to decide which ones are advantageous in different scenarios.

Blank: I think the point in that slide is that the chosen modality is not as important as learning to use it well. This is a point we've heard several times already. I think this is true, and what was demonstrated in one of the studies highlighted that the failure rate was much lower than 10%. Now, this was performed by very experienced anesthesiologists, who have extensive experience with these procedures, and their failure rate was 6/12,000. That is an impressively low failure rate. That clearly is not the case in all the reported studies, but his approach was to simply use 2 modalities instead of 12 or 15 and to be very good at them. I think it's possible to achieve a lower failure rate, but then the other challenge Dr Berkow and Dr Collins pointed out is how do we train our residents to use all of them? We need to establish minimum standards for our training programs. One thing I saw that was disturbing in reviewing this literature was that in internal medicine–based fellowship programs in critical care, approximately two thirds of the graduating fellows had done fewer than 10 FOIs. I don't think any of us really think that competency or expertise can be developed with those kinds of numbers. Certainly not in patients who really need that approach–patients with a difficult airway. I think it is important to train residents to perform flexible fiberoptic intubation and other selected approaches to airway management electively in healthy patients with normal airways, and that's certainly what we try to do. But we don't focus on 12 different modalities.

Berkow: It's interesting that in the most recent survey by Pott[2] that you cited, what's startling is that the survey found that still only 50% of anesthesia residency programs have a formal airway rotation. So, if we don't even have formal airway rotations, I don't know how we can guarantee that our residents get trained on these devices. And I hope that will change now that we'll have to show milestones. We're currently working in our department to make milestones for airway management and airway techniques; it's a big challenge, and in some ways, there are so many different techniques to teach, how do you teach them all within the span of one residency period?

Ramachandran: To follow up on that, in thinking about the hospital model for management of failed airway, Dr Napolitano, could you comment on whether fellows now in surgery or intensive care are required to do a minimum number of emergent tracheostomies?

Napolitano: Yes, that's an interesting question. The Accreditation Council for Graduate Medical Education (ACGME) modified the program requirements for graduate medical education in pulmonary disease and critical care medicine[3] in September 2012

and suggested that pulmonary medicine critical care fellows should have experience in percutaneous tracheostomy. It's always been mandatory for surgical critical care, so it's always been part of the critical care fellowship training for surgery. We were a bit miffed when the guidelines came out for medicine because there were no recommendations of having surgery backup and who's going to train them . . . the exact same issues related to how to become competent in this procedure. But, we recognized it was important, and so we partnered with our pulmonary medicine colleagues, and we taught their attending staff first. They became experienced, and it's just like doing a difficult airway; once you're experienced, then you can teach your trainees. But it's the exact same thing. We have moved now to both bronchoscopy and tracheostomy simulation in order to start to begin to get competency. And of course, the human experience is very valuable.

Blank: Is that simulation on mannikins or cadavers, or both?

Napolitano: Both. And we have, as part of ACLS [Advanced Cardiovascular Life Support], procedure issues that are done but we can teach trach the same time that we teach cricoid. So, it's simple; it's all about doing it the same way every time.

Berkow: There's a relatively new simulator developed by my friend and colleague Dr Paul Baker in New Zealand called the Orsim. He developed an airway simulation program because he really felt that the current simulations that are out there or simulated on a mannikin really didn't accurately reflect an actual FOI in a human being. So, there are efforts underway to make FOI simulation much more useful for anesthesiologists.

Blank: What kind of additions has he added to the experience?

Berkow: It includes a bronchoscope and a laptop with a graphics simulation which looks much more realistic than some of the older ones. It offers multiple airway scenarios and pathologies; plus it's portable, so you can take it with you from place to place.

Durbin: Continuing with changing technology, and being one of the older teachers in the room, new technologies create a significant challenge for academic faculty. I'm happy teaching FOI, but it is more of a challenge for me to teach video laryngoscopy because I haven't actually had enough hands-on experience yet. I've watched 50 or more intubations, I think I know what the residents are doing right and wrong, but the reality is that I don't do many cases myself, and learning to use these devices competently requires hands-on experience. So, as the technology advances and these changes occur, we also need to ask, "what do we do about the person who's in practice now, and how do we get them to adopt new technology and become competent?" This same question needs to be applied to academic faculty. We need a solution for "how to teach the teachers" when new technology is introduced into clinical practice.

REFERENCES

1. Apfelbaum JL, Hagberg CA, Caplan RA, Blitt CD, Connis RT, Nickinovich DG, et al. Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on management of the difficult airway. Anesthesiology 2013;118(2):251-270.
2. Pott LM, Randel GI, Straker T, Becker KD, Cooper RM. A survey of airway training among U.S. and Canadian anesthesiology programs. J Clin Anesth 2011;23(1):15-26.
3. Accreditation Council for Graduate Medical Education (ACGME). ACGME program requirements for graduate medical education in pulmonary disease and critical care medicine (internal medicine). Approved September 2012; effective July 2013. http://www.acgme.org/acgmeweb/Portals/0/PFAssets/2013-PR-FAQ-PIF/156_pulmonary_critical_care_int_med_07132013.pdf. *Accessed March 4, 2014.*