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THE USE OF FIBEROPTIC ENDOSCOPY IN ANESTHESIA

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Use of the fiberoptic bronchoscope in anesthesiology has dramatically increased since its introduction in the 1960s. The fiberoptic bronchoscope is now an indispensable tool used in many clinical airway scenarios. It has proven to be especially useful in securing the difficult or compromised airway and managing the double-lumen tube (DLT) in thoracic surgery. In the past, a surgical patient with a recognized difficult airway (e.g., abnormal or difficult anatomy, mass lesions, cervical spine immobility) represented a challenging clinical problem with a limited number of suboptimal solutions. Although this is still a difficult situation, the fiberoptic bronchoscope permits the anesthesiologist to intubate this type of patient, awake or asleep, with considerable ease, patient comfort, and safety.

Fiberoptic bronchoscopes also may be used as a secondary method of intubation in patients with unrecognized difficult airways after the primary method of intubation (usually direct laryngoscopy) has failed. This includes directly intubating the trachea with the fiberoptic bronchoscope, intubating through a laryngeal mask airway, and intubating over a retrograde wire.

The fiberoptic bronchoscope is used in management of the airway in patients undergoing thoracotomy or thoracoscopic surgery. It can be used to place a variety of different endotracheal and endobronchial tubes, correctly position them, and then assist in the diagnosis of intraop-

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erative hypoxemia or hypoventilation. This article describes uses of the fiberoptic bronchoscope especially as they apply to thoracic surgery.

USE OF THE FIBEROPTIC BRONCHOSCOPE IN INTUBATION

Predicting the Difficult Airway

Although the fiberoptic bronchoscope can be used to intubate patients with normal airway anatomy, it is particularly useful in those with abnormal or difficult airways. The anesthesiologist may encounter difficult intubation in patients with congenital anatomic abnormalities or acquired disease processes. Congenital syndromes associated with a potentially difficult intubation include Pierre Robin, Treacher Collins, Goldenhar's, and Down's. Acquired conditions that may predispose a patient to airway difficulty include infectious processes, arthritis, tumors, trauma, obesity, acromegaly, and acute burns.[32]

Several steps in evaluating the airway may assist in predicting potential difficulty and the need for fiberoptic bronchoscopic intubation. First, a careful history may reveal airway difficulties in previous intubation attempts or conditions associated with a difficult intubation. The next step is an objective assessment of the patient's airway. The size of the oral aperture and teeth, the size of the tongue base in relation to other structures (Mallampati class),[33] space for the tongue to be compressed into during laryngoscopy,[34] and neck extension[4] are all important components of the airway examination. Although the sensitivity of these factors to predict difficulty in intubation is high, the specificity is low enough to cause many "easy" airways to be labeled as "difficult."[14] When a difficult airway is anticipated on the basis of either history or physical examination, it is most prudent to secure an airway before the patient is rendered apneic from the induction of general anesthesia. If anesthesia is induced prior to this, a potentially fatal scenario can occur if the anesthesiologist is unable to intubate or ventilate the patient. Several methods are used to secure the airway in an awake patient, including blind nasal, direct laryngoscopic, retrograde wire, and fiberoptic intubation.

Equipment Needed for Fiberoptic Intubation

The equipment needed for fiberoptic bronchoscopy and intubation includes a medical-grade fiberscope, a light source with a backup bulb or twin light source, oxygen and suction supplies, an assortment of endotracheal tubes, and airways that will protect the teeth and direct the bronchoscope toward the larynx.[25]

Currently, the two fiberscopes most commonly used by anesthesiologists for intubating adults are the Olympus LF-1 (4.0 mm diameter, Olympus Corporation, Lake Success, NY) and the Pentax FI-10P (3.5 mm diameter, Pentax Corporation, Englewood, CO). These fiberscopes fit through single-lumen endotracheal tubes as small as 5 mm (internal diameter) and through DLTs as small as 35-F. The 4.9-mm diameter bronchoscopes (i.e., Olympus P20)–fit snugly down a 7.0-mm endotracheal tube or a 39-F DLT. Smaller fiberscopes are also available for pediatric patients. The adult-sized fiberscopes contain light guides, image bundles, directional controls, and one channel (for suction or instillment of oxygen or fluids).[13] Illumination for the fiberscope is provided by either a halogen or xenon light source. The xenon light source provides excellent illumination for video images but is much more expensive. The halogen light source is cheaper and provides adequate illumination for still photographs.[13]

To prepare the equipment for fiberoptic intubation with the patient awake, the fiberscope is connected to the light source, focused, and oriented. Oxygen tubing is attached to the fiberscope and a continuous oxygen source. An appropriate-sized endotracheal tube is lubricated and placed over the fiberscope. This preparation should be carried out before bringing the patient into the operating room.

Preparation of the Patient for Bronchoscopic Intubation

The patient scheduled for fiberoptic bronchoscopy while awake requires a thorough explanation of the procedure as well as pharmacological preparation. Antisialagogues are crucial in minimizing secretions that may obscure the fiberoptic bundles and wash away topical local anesthetic.[37] Glycopyrrolate and atropine are both acceptable choices; however, glycopyrrolate has more antisialagogue effect with less tachycardia. Also, because of its tertiary amine configuration, glycopyrrolate does not cross the blood-brain barrier and is unlikely to contribute to perioperative confusion.

Sedation is the next step in preparing the patient for intubation. The patient should be comfortable and mildly sedated, yet awake and interactive. Sedation helps blunt the stress of an awake intubation without taking away control of the airway. Several different drugs are available to provide sedation, including opioids, benzodiazepines, and other sedatives or hypnotics. Opioids have the advantage of suppressing the cough reflex but may cause severe respiratory depression. Both opioids and benzodiazepines can be reversed pharmacologically if the need should arise. Regardless of the method employed, the goals should be to provide comfort, sedation, and minimization of the cough reflexes without apnea.

Anesthetizing the airway either with topical anesthesia or nerve blocks facilitates smooth intubation of the trachea. Local anesthesia involves nerve blocks of the maxillary (nose) and mandibular (anterior two-thirds of the tongue) branches of the trigeminal nerve, glossopharyngeal nerve (posterior one-third of the tongue, soft palate, oropharynx), and vagus nerves (pharynx and larynx). Detailed descriptions of specific techniques of local anesthesia and nerve blocks are provided elsewhere.[37]

Fiberoptic Bronchoscopy with the Patient Awake

After the patient is sedated and the airway adequately anesthetized, the patient is positioned in the supine position with the endoscopist at his or her head. Difficult fiberoptic visualization of the larynx can sometimes be overcome by placing the patient in the sitting position. For nasal intubations, placement of nasal airways may assist in dilating the nasal mucosa and allow an unimpeded view through the nares and turbinates into the nasopharynx. If a nasal airway is split longitudinally, it can be removed around the bronchoscope to allow the endotracheal tube to be advanced. When oral intubation is performed, an oral airway may help keep the tongue out of the way and guide the fiberscope toward the larynx. The Ovassapian airway is specially designed for this use.[36] The fiberscope should be held with two hands—one hand on the control and viewing end and one holding the tip of the scope pulling it taut. The endoscopist should continuously confirm landmarks as the fiberscope is advanced into the nose or mouth. If orientation or landmarks are lost, the endoscopist should remove the scope and start again. When the vocal cords are visualized, the fiberscope is advanced into the trachea where the cartilaginous tracheal rings and carina are confirmed. With the position of the fiberscope stabilized above the carina, the endotracheal tube is threaded off into the trachea. If difficulty is encountered while advancing the endotracheal tube past the arytenoid cartilages or arytenoepiglottic fold, rotation of the tube counterclockwise to place the bevel posterior or displacement of the tongue and mandible forward with a laryngoscope might overcome this. A smaller endotracheal tube (6.5 to 7.0 mm internal diameter in adults) may also thread into the trachea with greater ease. Accurate placement of the endotracheal tube is confirmed by clinical examination and with sustained end-tidal CO_2.

THORACOTOMY/VATS: ONE-LUNG VENTILATION AND THE USE OF FIBEROPTIC BRONCHOSCOPY

With the introduction and increasing prevalence of video-assisted thoracoscopic surgery (VATS) and the continued use of thoracotomy for thoracic procedures, anesthesiologists should remain up-to-date with various considerations specific to this type of surgery. The preoperative preparation, intraoperative management including single-lung ventilation, and postoperative considerations are discussed herein. Specifically, we focus on one-lung ventilation and the correct use of the fiberoptic bronchoscope as an invaluable tool in endotracheal and bronchial tube placement.

Preoperative Evaluation and Preparation

Patients undergoing thoracic surgery are at high risk for postoperative pulmonary complications (including atelectasis and pneumonia) because of preexisting pulmonary dysfunction, the nature of the procedure itself, and inadequate postoperative pain control.[6, 28] During preoperative evaluation, the anesthesiologist should identify those patients who are particularly susceptible to postoperative complications, optimize their medical management, and consider postoperative care, including pain management and the potential need for postoperative ventilation. Because VATS is a much less invasive procedure than open thoracotomy, initial studies indicate that patients undergoing VATS have reduced postoperative pain requirements, hospitalization, and recovery times.[29] Until larger and more rigorous outcome studies are performed, the conventional preoperative assessment for open thoracotomy should be applied to patients scheduled for VATS.

Detailed reviews of the conventional preoperative preparation and the evaluation of the patient undergoing open thoracotomy are presented elsewhere.[3, 6] A thorough history and physical examination may identify patients who are at high risk for postoperative complications; preoperative prophylactic measures are initiated to decrease the postoperative pulmonary complications.[6] These measures include the cessation of smoking (more than 4 weeks in advance for maximal benefit),[45] chest physiotherapy, preoperative education, and medications. $Beta_2$-adrenergic drugs, such as albuterol, are effective in patients with a reversible brochospastic component documented by pulmonary function tests with brochodilators. Other medications that may be useful include steroids, ipratropium bromide, and theophylline. Patients with pneumonia or acute bronchitis should be treated preoperatively.

Conventional thoracotomy incisions cause intense postoperative pain which may result in pulmonary dysfunction and postoperative morbidity due to decreases in functional residual capacity (FRC) and vital capacity (VC),[31] which return to baseline values usually within 1 to 2 weeks.[1, 12] Patients undergoing VATS have a lower incidence of postoperative pain in comparison with those undergoing a more traditional thoracotomy, most likely due to the less surgically invasive nature of the VATS procedure.[17, 27, 38, 39] Postoperative pain of most patients undergoing VATS can be controlled with nonsteroidal anti-inflammatory drugs (NSAIDs) and mild oral analgesics (e.g., codeine with acetaminophen); however, patients undergoing decortication, pleurodesis, or pleurectomy usually require a stronger postoperative analgesic regimen.[35] Postoperative pain in these cases can be controlled with systemic opioids, such as patient controlled analgesia (PCA) morphine, or epidural analgesia if needed.

Methods of One-Lung Ventilation

Patients undergoing VATS usually require general anesthesia with controlled positive pressure ventilation and deflation of the operative lung (one-lung ventilation). This is especially important during a thoracoscopic procedure in which surgical exposure (visibility and space) is of prime importance. Regional anesthesia for patients undergoing VATS is possible but is not desirable as mediastinal shift and paradoxical respiration occur in the spontaneously breathing patient under regional anesthesia for a thoracic procedure. This movement may interfere with surgical visualization, a problem accentuated by the video monitor magnification. Unlike in an open thoracotomy, it is difficult for the surgeon to pack off a lung or push it aside during a VATS procedure. For this reason, few options are available other than one-lung ventilation when providing anesthesia for VATS.

Several methods can secure one-lung ventilation for patients undergoing VATS. These include use of the double-lumen endotracheal tube (DLT), a single-lumen tube placed in a main stem bronchus or in the trachea with a bronchial blocker, or a single-lumen tube with a built-in bronchial blocker (Univent Tube, Fuji Systems Corporation, Tokyo, Japan). Regardless of which method is used, precise placement of the tube or blocker is extremely important to ensure adequate ventilation of the nonoperative lung and a quiescent operative lung. For VATS, the importance of adequate surgical visibility from one-lung ventilation cannot be overstated. Correct positioning can be challenging because of the short distances from the carina to the right and left upper lobes.[7] Unlike routine endotracheal intubation with a single-lumen tube in which the entire length of the trachea is available for correct tube positioning, one-lung ventilation requires more precision. Previously, DLTs were placed blindly with the position confirmed by auscultation. Currently, the most reliable method of confirming and placing the DLT is with the aid of fiberoptic bronchoscopy.

Aside from its use in VATS, there are other indications for one-lung ventilation.[6] Absolute indications include the need to isolate one lung to prevent interbronchial spread of infection, secretions, and blood and to provide and control positive pressure ventilation, such as in a patient with a bronchopleural fistula or large unilateral bulla. Facilitating surgical exposure is a relative yet extremely important indication for the use of one-lung ventilation. Certain surgical procedures, such as VATS, pneumonectomy, thoracic aortic aneurysm, or upper lobectomy, require a greater amount of surgical exposure than other procedures. Contraindications for utilizing a DLT include anatomical anomalies that may obstruct the path of the endotracheal tube (e.g., tracheal stenosis, tumors, or vascular lesions). The different tools and methods used to establish one-lung ventilation are discussed in the following sections.

Endobronchial Tubes

Single-lumen endotracheal tubes are used to isolate one lung, especially in an emergency situation such as massive hemoptysis. Blindly inserting the endotracheal tube until resistance is felt will usually place the tube in the right main stem bronchus, allowing for one-lung ventilation of the right lung. However, because of the proximity of the right upper lobe bronchus to the carina, ventilation will most likely occur only in the right lower and middle lobes.

To insert the single-lumen endotracheal tube into the left main stem bronchus, one can either blindly intubate the patient with the head turned to the right and the bevel of the endotracheal tube rotated 180 degrees or place the endotracheal tube with the aid of a fiberoptic bronchoscope.[26] In an emergency situation, especially with significant bleeding into the airway, fiberoptic bronchoscopy may not be possible.

Bronchial Blockers

One-lung ventilation in children and small adults (less than 30 to 45 kg) necessitates the use of bronchial blockers because DLTs are too large (smallest size is 28-F).[6, 42] Bronchial blockers also represent an alternative to DLTs in full-size adults, although they are associated with limitations. Bronchial blockers are used in conjunction with a standard single-lumen endotracheal tube. Most commonly, a Fogarty venous occlusion catheter (Edwards Laboratories, Santa Ana, CA) is placed through or alongside the endotracheal tube into the desired main stem bronchus under fiberoptic or rigid bronchoscopic control.[16] For adults, an 8-F catheter is used with either a 14- or 22-F balloon (diameter when deflated). The 14-F balloon has a 10-mL capacity for liquid and 20 mL for air. The 22-F balloon has a 43-mL capacity for liquid and 50 mL for air (from package insert). Smaller catheters are used for children depending on their size. Bending the balloon end of the catheter prior to placement allows the catheter to be directed down the desired main stem bronchus under direct vision. The balloon is inflated under direct visualization, the bronchoscope is removed, and the single-lumen endotracheal tube cuff is inflated. Inoue and colleagues[20] have introduced a single-lumen endotracheal tube (Univent, Fuji Systems Corporation, Tokyo, Japan) that incorporates a bronchial blocker with a low-pressure cuff placed through a small channel in the anterior wall. After endotracheal intubation, the bronchial blocker can be advanced into the right or left main stem bronchus either blindly or with the aid of fiberoptic bronchoscopy. The balloon of the blocker is inflated, and the lung distal to the blocker is isolated. The Univent tube is reported to be as easy to place as DLTs to isolate one lung for surgery, trauma, and bleeding.[15, 21–24] The advantages of the Univent tube or single-lumen endotracheal tube with bronchial blocker include a larger lumen for ventilation (and fiberoptic bronchoscope placement) without an increased external diameer, safe prolonged use if postoperative ventilation is required, and use n a patient with a difficult airway or risk of aspiration.[15]

The presence of a bronchial blocker is also associated with disadvantages. Its use prevents effective suction or lavage of the operative lung distal to the bronchial blocker and the ability to add continuous positive airway pressure (CPAP) or inflate the operative lung intraoperatively.[19] Furthermore, as is true for all methods of lung isolation, there can be a loss of or difficulty with single-lung ventilation if the blocker becomes dislodged or malpositioned. When isolating the right lung, a bronchial blocker may have difficulty staying in position because of the short distance from the carina to the right upper lobe takeoff. One way to overcome this is to place the blocker out the right upper lobe bronchus and to inflate the balloon to obstruct the right main stem bronchus. These potential disadvantages along with the cost of the Univent tube have limited the use and popularity of bronchial blockers in adults undergoing thoracic surgery.

Double-Lumen Endotracheal Tubes

The double-lumen endotracheal tube consists of two tubes (a thoracic and endobronchial tube) of unequal length connected side-to-side with a proximal low-pressure endotracheal and distal low-pressure endobronchial cuff. This design allows ventilation of both lungs through the tracheal lumen when the endobronchial cuff is deflated and one-lung ventilation through the endobronchial lumen when the endobronchial cuff is inflated. Because the DLT permits the anesthesiologist to suction and ventilate the operative lung, if needed, use of the DLT has become the preferred method of separating the lungs when one-lung ventilation is required.[6] DLTs are available in sizes ranging from 28- to 41-F (internal diameters of 4.5 and 6.5 mm, respectively) and as left- or right-sided tubes. Usually, 39- to 41-F DLTs are used for men and 35- to 39-F for women. For a left-sided tube, the longer left endobronchial tube is placed in the left main stem bronchus while the shorter right tracheal tube is in the trachea. The reverse is true for a right-sided DLT. Use of a right-sided DLT for left lung surgery may result in inadequate ventilation to the right upper lobe due to malalignment of the right upper lobe ventilation slot to the opening of the right upper lobe.[6] For this reason, many anesthesiologists prefer to use a left-sided DLT for both right and left lung surgeries.

The DLT is initially inserted with the distal curvature with the blue endobronchial balloon concave upward. After the endobronchial balloon has passed through the vocal cords, the distal concave curvature is turned 90 degrees toward the side of desired endobronchial intubation. The DLT is advanced until resistance is encountered. Intubation with the DLT and confirmation of its position can be performed either blindly or with fiberoptic guidance.

Placement of the Double-Lumen Endotracheal Tube Blind and with Fiberoptic Bronchoscopy

Correct placement of the DLT is an extremely important procedure. When done accurately, it is possible to ventilate selectively or not ventilate an entire lung. When placed incorrectly, the ability to ventilate selectively is obviated, and difficulty in ventilating either lung or the upper lobes may occur. For VATS, the ability to provide one-lung ventilation is important to allow adequate room for visualization of operative structures. Because the operative window is small and visualized through a thoracoscope, malposition of the tube may result in less than optimal operating conditions as well as difficulty in oxygenation or ventilation.

Before the widespread use of fiberoptic bronchoscopy to confirm DLT placement, tube position was confirmed with auscultation after blind insertion. Although confirming tube position with auscultation is still used if a fiberoptic bronchoscope is not available, fiberoptic confirmation of correct placement is rapidly becoming the standard of care in most centers. The technique of auscultatory confirmation is as follows. Once the DLT is placed in the bronchus, both cuffs are inflated, and the chest is auscultated for bilateral breath sounds. Then, in succession, the right and left lumens are clamped while the chest is auscultated for disappearance of breath sounds on the ipsilateral side and continuation of normal breath sounds on the contralateral side. If this does not occur, the DLT is not positioned correctly and must be repositioned. The DLT can be misplaced in one of three positions: in too far on the left side, in too far on the right side, or out too far. Final DLT position is determined using a protocol described by Benumof.[3] This involves auscultating the chest after serially inflating and deflating the bronchial cuff.

Several other problems have been described concerning blind DLT placement with auscultatory confirmation. These include difficult access for repeated auscultation of the chest intraoperatively, inadequate breath sounds in patients with preexisting lung disease, and tube movement during the course of the operation.[3] Difficulty with blind DLT placement was described by Black and Harrison[8] who presented a retrospective series of 78 patients and a prospective series of 59 patients undergoing thoracotomy using a Robertshaw DLT. They reported difficulty in intubating the left main stem bronchus in 22 of 59 patients prospectively and 9 of 78 patients retrospectively. Difficulties in placing the DLT resulted from tracheal bronchial lesions or anatomical variations. Cohen and colleagues[11] described a case in which a patient undergoing resection of a descending thoracic aortic aneurysm was intubated with a DLT. Passage of the DLT was impossible using a blind insertion technique and was eventually achieved using fiberoptic bronchoscopy guidance. This case demonstrates not only the difficulty but the potential danger in blind placement of DLTs.

Several studies investigating DLT positioning have found the auscultatory method to be inaccurate in confirming blind DLT placement.

Smith and co-workers[43] prospectively studied 23 patients undergoing thoracotomy and compared blind placement of the DLT with corresponding bronchoscopic findings. Bronchoscopy revealed inadequate positioning of the DLT in 48% (11) of the patients. In four patients, the bronchial cuff had herniated over the carina, and in six patients, the bronchial cuff could not be visualized. Lewis and co-workers[30] studied 200 thoracic surgical patients requiring DLT placement. The DLTs were placed blindly with position confirmed by auscultation and sequential lumen clamping. After the tube was thought to be in correct position, the cardiothoracic surgeon used a fiberoptic bronchoscope to confirm position and to correct any malpositions. Tube position was incorrect in 37.5% (75 of 200) of the patients despite correct auscultation. Overall, fiberoptic bronchoscopy showed poor tube position in 106 of 200 patients. Malpositions diagnosed by fiberoptic bronchoscopy included obstruction of the respective right or left upper lobe (43 of 106 patients, 40.5%), bronchial balloon above or straddling the carina (38.6%, 41 of 106 patients), and endobronchial tube passed into the wrong main stem (20.6%, 22 of 106 patients).

Placement of the DLT is difficult for several reasons. Due to the anatomy of the trachea, there is little room for error in placing the tube.[7] Furthermore, there may be previously undiagnosed anatomical variations or airway pathology.[2] Benumof and co-workers[7] studied tracheal anatomy in 69 patients, 42 cadavers, and 55 lung casts to define the margin of safety in positioning the DLT. For the left-sided DLT, the margin of safety was defined as the "length of the left main stem bronchus minus the length from the proximal margin of the left cuff to left lumen tip." The margin of safety in positioning left-sided DLTs was 16 to 19 mm. The average margin of safety in positioning right-sided DLTs was 8 mm (Mallinkrodt) and 1 to 4 mm (Rusch). It was concluded that because of the larger margin of safety, left-sided DLTs should be used whenever possible. In addition, fiberoptic bronchoscopy should be used to aid tube placement with either type of tube because of the relatively small distances.

To confirm position or to reposition a DLT, the fiberoptic bronchoscope is placed down the tracheal lumen after tracheal intubation. Usually, a pediatric fiberoptic bronchoscope with an outer diameter of less than 4.5 mm is used and can fit through a DLT as small as 35-F. In positioning a left-sided DLT, the fiberoptic bronchoscope is first placed in the tracheal lumen. The viewer should see the blue endobronchial cuff just below the carina (Fig. 1). With the cuff inflated, the viewer can insert the fiberoptic bronchoscope down the bronchial lumen and should see the left bronchial carina and minimal bronchial lumen narrowing. Because the bronchial orifice does not have a Murphy eye, the opening should be centered in the lumen and not impacting onto the bronchial wall. Again, the position of the endobronchial cuff is of prime importance due to the small margin of safety involved. If the bronchial lumen is inserted too far into the left main stem bronchus, obstruction of the left upper lobe may occur, and the tracheal lumen may even be inserted

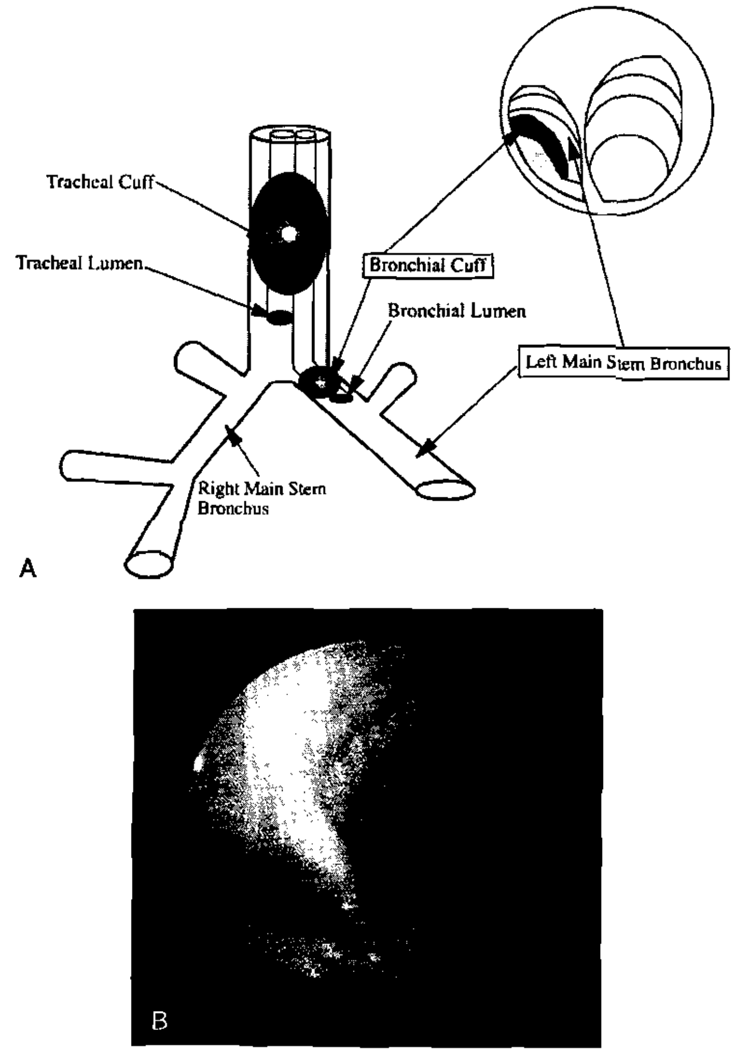


Figure 1. *A* and *B*, Endoscopic view through tracheal lumen. Double lumen tube in proper position. Note bronchial cuff just visible down the left main stem bronchus.

all the way down into the left main stem bronchus (Fig. 2). If the bronchial lumen is not inserted far enough, the bronchial cuff can herniate out of the left main stem bronchus and obstruct the trachea or right main stem bronchus (Figs. 3 and 4). The fiberoptic bronchoscope should be used to recheck the positioning of the DLT after positioning and at anytime throughout the case. Intraoperative confirmation of DLT position can be crucial in diagnosing airway obstruction, hypoxia, or difficulty in ventilation. Unlike the auscultation method, fiberoptic bronchoscopy is easy, fast, convenient, and definitive.

Fiberoptic bronchoscopy is useful not only for confirming the final positioning of a DLT but for initial placement and guidance of the DLT into position.[40, 41] This minimizes the possibility of placing the endotracheal tube into the right main stem bronchus as shown in Figure 5. The DLT is first placed in the trachea either with direct or fiberoptic laryngoscopy.[18] The fiberoptic bronchoscope is then placed through the bronchial lumen to the carina. After the operator gains position perspective (tracheal rings anterior, membranous trachea posterior), the fiberoptic bronchoscope is placed into the left main stem bronchus just proximal to the left upper lobe takeoff. The DLT is advanced over the fiberoptic bronchoscope until it appears through the endoscope. The fiberoptic bronchoscope is removed and reinserted into the tracheal lumen where the endobronchial cuff should just be visible down the left main stem bronchus (see Fig. 1). If the cuff is not visible or has herniated out over the carina, repositioning of the tube with the cuffs deflated is required. The procedure is similar for right-sided tubes. One additional maneuver includes positioning the right upper lobe aperture so that the right upper lobe bronchus is visible within the center of it.

Intubating the bronchus over a fiberoptic bronchoscope provides the advantages of viewing the airway prior to placing the DLT and atraumatically placing the tube with a higher degree of accuracy in certain patients. As reported by Atwell,[2] major tracheobronchial tree anomalies were noted in a series of 1200 consecutive bronchograms, explaining why in some patients blind placement of the DLT was difficult.[8] In one report, difficulty in placing a DLT resulted from a compressing thoracic aneurysm.[11] Careful atraumatic placement of this DLT using a fiberoptic bronchoscope guide was critical in successful positioning.

Complications of Double-Lumen Tubes

The use of DLTs for VATS may be associated with several potential complications, including malpositioning, airway trauma, and hypoxemia.[5, 9, 10, 44] Tube malposition may result in gas trapping during positive pressure ventilation, incomplete isolation of an infected or bleeding lung, poor surgical exposure, or hypoxemia.[9] Because of these potential problems, a fiberoptic bronchoscope should be used to ensure correct positioning after tube placement, after any manipulation of patient position, and as a first step in developing a differential diagnosis for intraop-

(Text continued on page 345)

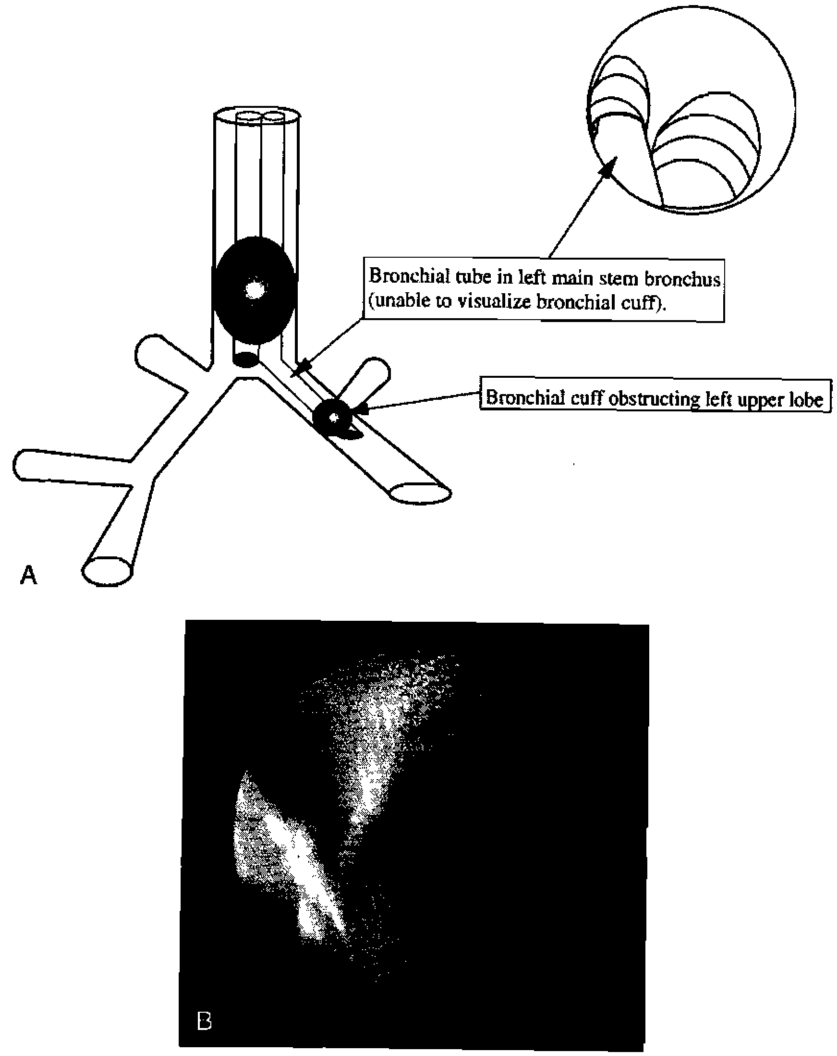
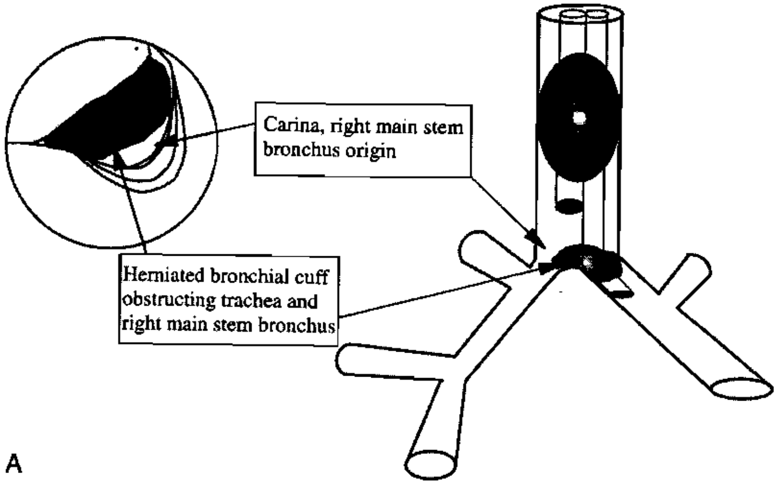


Figure 2. *A* and *B*, Endoscopic view through tracheal lumen. Double-lumen tube in too far. Note inability to visualize bronchial cuff.



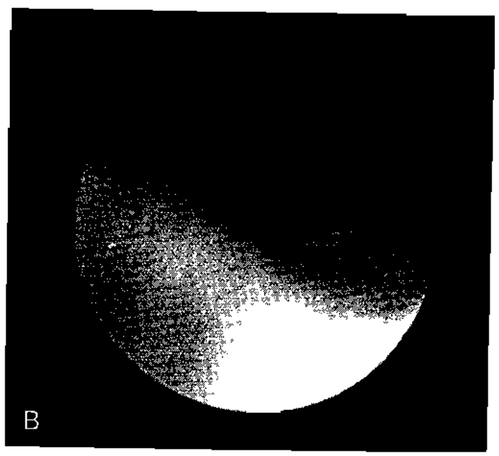
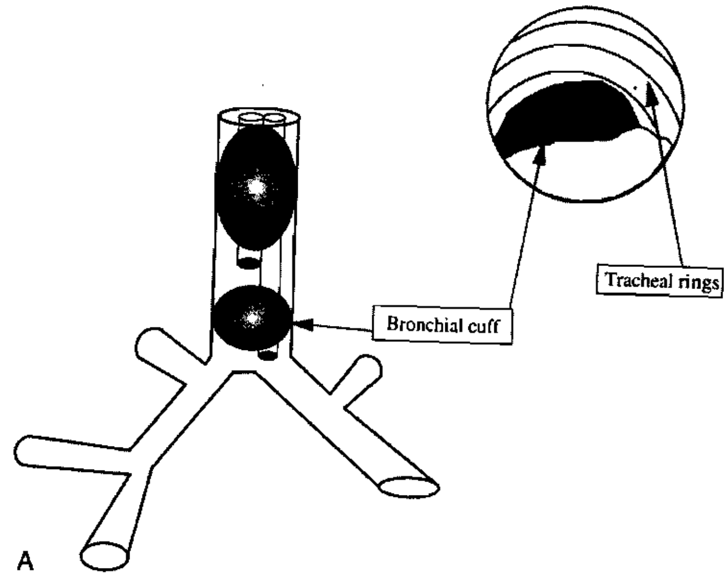


Figure 3. *A* and *B*, Endoscopic view through tracheal lumen. Bronchial cuff has herniated out of the left main stem bronchus and is obstructing the trachea and right main stem bronchus.



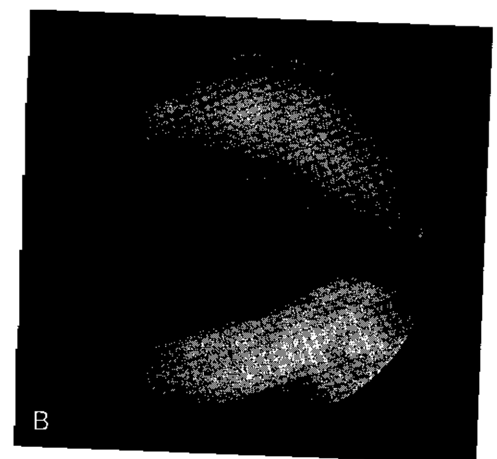


Figure 4. *A* and *B*, Endoscopic view through tracheal lumen. Double-lumen tube is not inserted far enough and the bronchial cuff has obstructed the trachea.

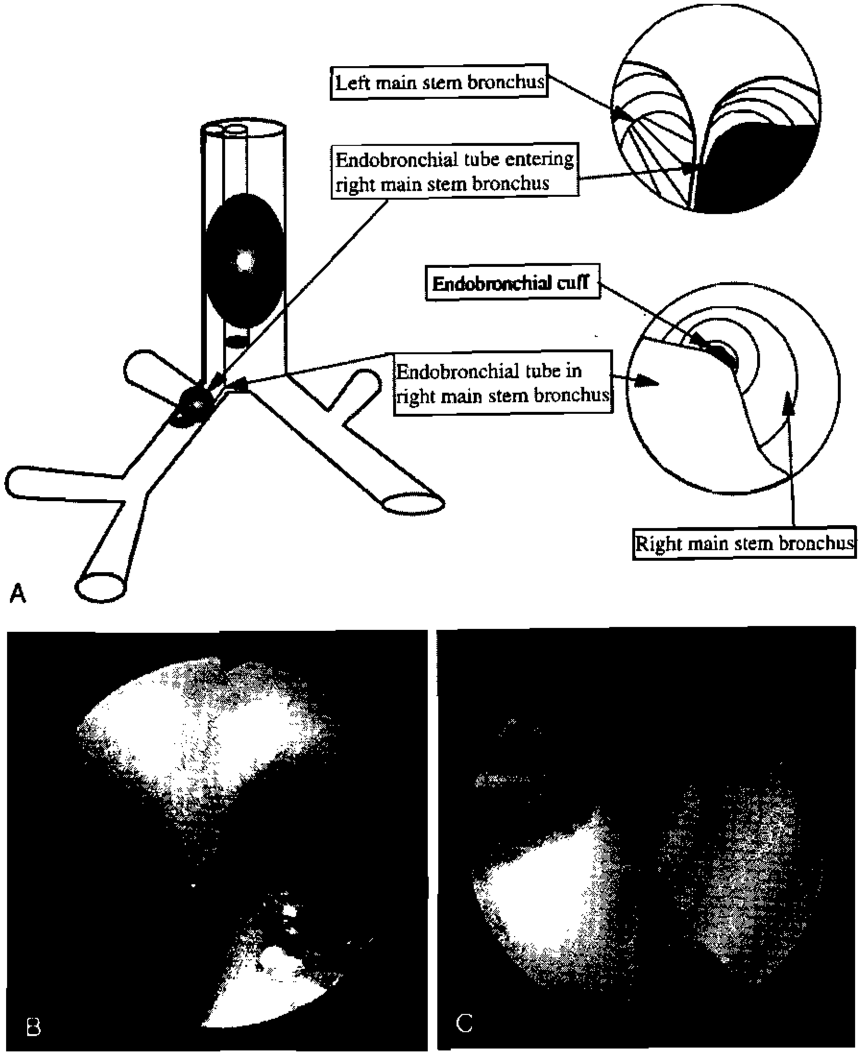


Figure 5. *A–C*, Endoscopic view through tracheal lumen. Double-lumen tube in right main stem bronchus. First view, endobronchial tube entering right main stem bronchus. Second view, endobronchial tube placed past carina into right main stem bronchus.

erative hypoxia. Several tube malpositions with their endoscopic views are described in detail earlier in this article.

Trauma to the airways is a rare complication of DLT placement with the diminished use of stiff red rubber DLTs with high-pressure cuffs.[9] Even so, there have been several case reports of tracheal or bronchial rupture with the use of polyvinyl chloride DLTs equipped with low-pressure cuffs.[10,44] Appropriate cuff inflation, correct tube positioning, and repeated monitoring of cuff pressures with nitrous oxide may help to minimize the possibility of airway injury. One should have a high index of suspicion for airway rupture when confronted with persistent airway leakage, blood in the DLT, or signs of pneumothorax. Bronchoscopy can be performed to assess the airway integrity when airway injury is suspected.

Hypoxemia is a common problem during one-lung ventilation. Contributing factors include tube malposition and the physiologic changes that occur in one-lung ventilation. The anesthetized and ventilated patient in the lateral position has increased blood flow to the dependent underventilated lung. This results in a ventilation/perfusion mismatch that is exacerbated by blood perfusing the collapsed nondependent lung (right-to-left shunt). Hypoxic pulmonary vasoconstriction is the physiologic response to minimize the shunt, but this protective reflex may be rendered ineffective by many drugs and physiologic states.[5] Several maneuvers have been described to maintain oxygenation during one-lung anesthesia, including 100% forced inspiratory oxygen (FiO_2) and CPAP to the nondependent lung.

CONCLUSION

The fiberoptic bronchoscope has many uses in managing the airway of surgical patients. It has revolutionized the anesthesiologist's approach to the difficult airway, providing a relatively simple alternative method for intubation. It has also improved the accuracy and ease of placing endotracheal or endobronchial tubes for one-lung ventilation in thoracic surgical patients. As with any tool, the fiberoptic bronchoscope is useful only in the hands of an operator who is not only technically adept but who has enough background knowledge to understand its benefits and appropriate uses.

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