Minimally Invasive Thoracic Surgery

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To reduce the risk, trauma, and expense of intrathoracic surgical treatments, minimally invasive procedures performed with the assistance of fiberoptic video technology have been developed for thoracic and bronchial surgeries. The surgical treatment of nearly every intrathoracic condition can benefit from a video-assisted approach performed through a few small incisions. Video-assisted thoracoscopic and rigid-bronchoscopic surgery have improved the results of thoracic procedures by decreasing postoperative pain and speeding the return to normal activity. From January 1992 to February 2000, 185 patients underwent 189 video-assisted thoracoscopic procedures in Ochsner Foundation Hospital for various conditions with good results; only 18 procedures (9.5%) required conversion to open thoracotomy. Video-assisted rigid bronchoscopic surgery has been helpful in managing tracheobronchial conditions and complications following lung transplantation. Ninety-nine patients with bronchial complications following lung transplantation and 20 patients with tracheobronchial conditions not related to transplantation have undergone therapeutic techniques involving video-assisted rigid bronchoscopy.

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Thoracic surgeons strive to provide the best possible treatment with minimal risk, discomfort, and expense, and minimally invasive techniques that reduce risk, trauma, and cost continue to develop and improve. Over the last 10-15 years, wide-exposure, open thoracic surgeries have yielded in part to less invasive procedures due to advances in anesthesia and technology. Thoracoscopic surgery and endoscopic bronchial surgery are two procedural areas that have developed successful, video-assisted, minimally invasive approaches to intrathoracic surgery.

Video-Assisted Thoracoscopic Surgery (VATS)

Thoracoscopy for the treatment of pulmonary tuberculosis was first introduced by Swedish internist Jacobeaus in the early 1900s (1-3). Instruments of the day were primitive and represented modifications of the devices adopted from other surgical specialties (4,5). Early thoracoscopic procedures, limited to diagnostic procedures or management of empyema or effusions, were performed under local anesthesia with the patient spontaneously ventilating or with mask-assisted ventilation and ether drip anesthesia. Exposure and visualization were quite limited. It was not until the introduction of endotracheal intubation and improved anesthetic techniques for cardiopulmonary support that surgeons began to embrace a thoracoscopic approach to diagnosis and treatment of diseases of the chest.

Evaluation of undiagnosed pleural effusions carried out at the Ochsner Clinic in the 1960s by pulmonologist Dr. Hurst Hatch and thoracic surgeon Dr. Paul DeCamp demonstrated thoracoscopy to be a valuable diagnostic tool (6). DeCamp, et al later expanded the use of thoracoscopy to include the evaluation of pneumothorax (7). Despite a growing interest in thoracoscopy, the procedure was generally limited to diagnosis and treatment of pleural diseases and complications of granulomatous disease of the lung. The parallel development of the double lumen endotracheal tube (enabling single lung ventilation) and video-assisted thoracoscopic surgery (VATS) provided both excellent exposure and superior visualization of the thoracic cavity. A variety of diagnostic and therapeutic procedures can now be performed using this minimally invasive VATS approach without requiring open thoracotomy.

Requirements for VATS

Proper patient selection is imperative for a successful VATS procedure (8). The patient's general physical condition and size, the location of the lesion, as well as the complexity of the procedure are important considerations. Large lesions or those in proximity to vital neural or vascular structures may be better approached by standard thoracotomy. The patient must be able to tolerate single contralateral lung ventilation and maintain adequate oxygenation and systemic blood pressure. Patients with a single lung or severely impaired lung function are poor VATS candidates. Previous thoracic surgical procedures, such as thoracotomy or pleurodesis, may be contraindications to VATS. Proper consent includes the possibility of conversion to open thoracotomy in the event of a complication or the inability to accomplish the procedure thoracoscopically. VATS procedures must be performed by a trained and experienced surgeon capable of managing emergent thoracic surgical complications (9,10).

Anesthetic and Surgical Technique

Thoracoscopic procedures are performed in an operating room with the patient under general, double-lumen, endotracheal anesthesia and in a standard thoracotomy position. Proper position and function of the endotracheal tube is important during a VATS procedure and is confirmed by auscultation and fiberoptic bronchoscopy. Arterial oxygen saturations and systemic blood pressure are monitored closely. Anesthetic agents that delay immediate postoperative extubation are avoided.

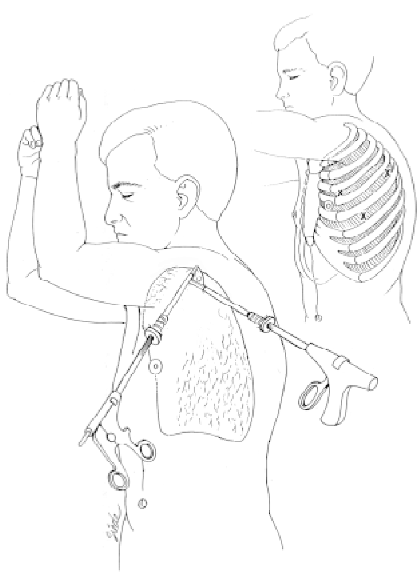

Figure 1. Thoracoscopic approach for VATS lung biopsy.

VATS is performed through one or more 1-2 cm intercostal incisions positioned to most efficiently accomplish the desired procedure. Thoracoport devices, placed into the incisions to maintain patency, are used to introduce and direct the video camera and instruments used for visualization, aspiration, retraction, biopsy, stapling, or cauterization (Figure 1). At the completion of the procedure, tube thoracostomy drainage is accomplished through one incision while the other incisions are closed and the patient is extubated immediately, unless continued ventilation is indicated.

Table 1. Video-assisted thoracoscopic procedures at Ochsner Clinic, January 1992 – February 2000.

Pulmonary	
Evaluation of effusion	59
Diagnostic lung biopsy	
Interstitial lung disease	44
Tumor or metastases	23
Pulmonary wedge resection	13
Treatment of pneumothorax/bullae	16
Pulmonary decortication	2
Repair of bronchopulmonary fistula	3
Esophageal	
Heller esophagomyotomy	5
Mediastinal	
Pericardiectomy	1
Resection of mediastinal tumor	1
Autonomic	
Thoracodorsal sympathectomy	18
Thoracic splanchnicectomy	4

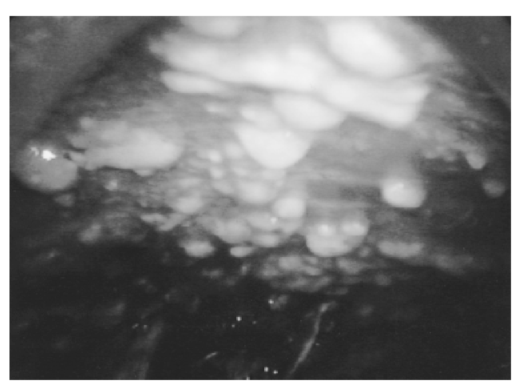

Figure 2. Multiple parietal pleural implants representing metastatic carcinoma noted on VATS evaluation of a recurrent pleural effusion.

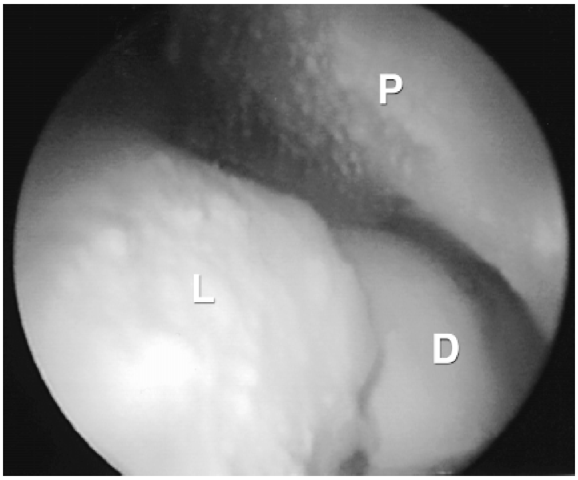

Figure 3. Appearance of talc coated lung (L), diaphragm (D) and parietal pleura (P) surfaces after thoracoscopic pleurodesis for malignant effusion.

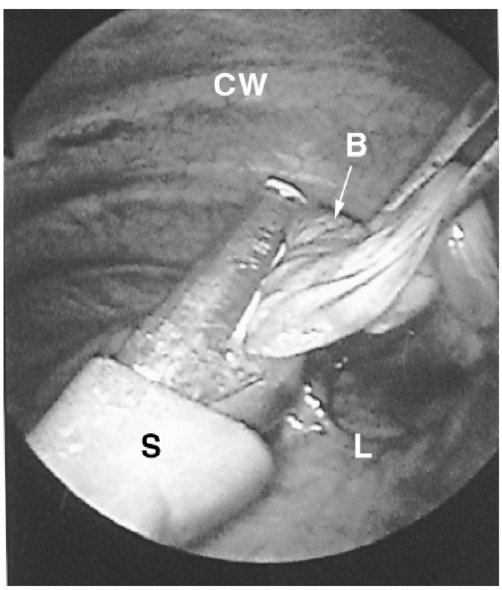

Figure 4. Thoracoscopic resection of a large solitary pulmonary bulla (B) which was the source of a persistent pneumothorax. CW= Chest Wall, L= Lung, S= Stapler.

Table 2. Autonomic disorders treated by video-assisted thoracoscopic surgery at Ochsner from January 1992 – February 2000.

Disorder	Number
Reflex sympathetic dystrophy	5
Hyperhidrosis	6
Causalgia	4
Raynaud's phenomenon	3
Chronic pancreatic pain	4

Ochsner Video-Assisted Thoracoscopic Experience

From January 1992 to February 2000, 189 VATS procedures were performed by a staff of nine surgeons on 185 patients (100 males and 85 females; average age at the time of the procedure was 57.2 years, range 17-85 years). The results of this series through December 1997, comprising the first 148 patients, were previously reported (11). The variety of VATS procedures performed is shown in Table 1. The most common indication (n=59) was the evaluation of undiagnosed pleural effusions (Figure 2). Malignant pleural effusions found during VATS were managed with mechanical, chemical, or talc (Figure 3) pleurodesis, alone or in combination, which resolved symptomatic recurrence of the effusion in 85-90% of patients. Diagnostic lung biopsies for interstitial lung disease or pulmonary malignancies were performed in 67 patients. Management of pneumothorax and bullous lung disease (Figure 4) comprised 8.5% of our cases. In our series, 18 VATS procedures (9.5%) required conversion to open thoracotomy. Common indications for conversion were lack of exposure due to adhesions or dense fibrothorax requiring pulmonary decortication (n=10). Unacceptable postoperative pulmonary air leaks were observed in four patients (n=4), necessitating open repair. The failure to localize deep parenchymal lung lesions (n=2), inability to collapse the ipsilateral lung (n=1), and troublesome bleeding (n=1) completed the causes for conversion.

The VATS approach for managing a variety of autonomic nervous system disorders of the upper extremities and splanchnic plexus comprised a significant and interesting group of patients. As shown in Table 2, 22 procedures (11.6%) were performed for the management of autonomic disorders of the thoracic sympathetic nervous system in 19 patients (7 women and 12 men; age range 17-68 years; mean length of stay 3 days, range 2-7 days). The results of thoracoscopic sympathectomy were excellent in those patients with hyperhidrosis and reflex sympathetic dystrophy, but varied in patients with causalgia and Raynaud's phenomenon (12). A transient Horner's Syndrome was observed in two patients. Four patients who underwent splanchnicectomy for severe chronic pancreatic pain failed to receive long-term pain relief; however, successful splanchnicectomy results have been reported by others (13).

Richardson and Bowen have reported the endoscopic management of achalasia in 21 patients at the Ochsner Clinic, five of whom (four men and one woman) underwent VATS Heller esophageal myotomy (14). Except for conversion to open thoracotomy in one patient, no operative or postoperative complications were observed and long-term relief from dysphagia and heartburn was good.

A VATS approach to pericardial disease has been limited in our experience but was successful in managing coronary artery insufficiency in one patient who had dynamic obstruction of the left anterior descending coronary artery due to herniation of the heart through a congenital pericardial defect (15).

While we are currently in the process of defining the capabilities and limitations of VATS, essentially every thoracic surgical condition other than some open heart and thoracic aortic operations have been successfully accomplished with the assistance of a VATS approach. Experience demonstrates that many conditions can be addressed with a VATS approach including lobectomy, pneumonectomy, and esophagectomy (16-23). Our next challenge is to determine which VATS procedures should be performed based on clinical outcomes and overall cost (24-27).

Video-Assisted Endobronchial Surgery

It was rigid bronchoscopy that first provided direct access to the tracheobronchial tree. With the adaptation of new technologic advances, endoscopic evaluation and management of disorders of the trachea and bronchi have come full circle enabling surgeons and pulmonologists to perform a wide range of minimally invasive endobronchial procedures. Simple diagnostic and therapeutic procedures such as biopsy and foreign body or tumor removal were possible with rigid bronchoscopy performed under general anesthesia. The subsequent development of fiberoptic technology and refinements in instrumentation made it possible to evaluate the tracheobronchial tree with the flexible fiberoptic bronchoscope, thus alleviating the requirement for general anesthesia. However, therapeutic limitations existed with flexible fiberoptic bronchoscopy in the management of large airway maladies, including tumor or foreign body obstruction, tracheoesophageal fistula, bronchopleural fistula, and anastomotic stricture or dehiscence. An ingenious combination of the "older" rigid bronchoscope, modified to incorporate "newer" fiberoptic lenses, video cameras, and television monitors broadened the

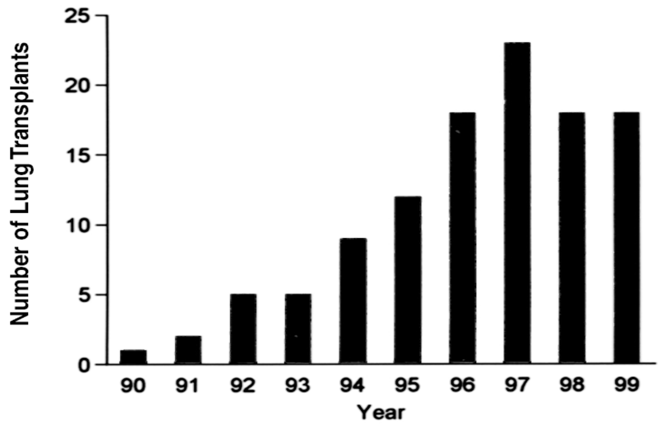

Figure 5. Volume of the Ochsner lung transplantation program over the first decade.

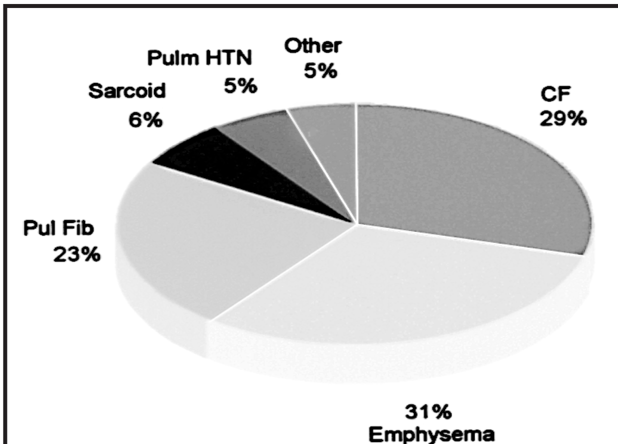

Figure 6. Indications for Lung Transplantation at Ochsner. CF = cystic fibrosis; Pul Fib = pulmonary fibrosis; Pulm HTN = pulmonary hypertension.

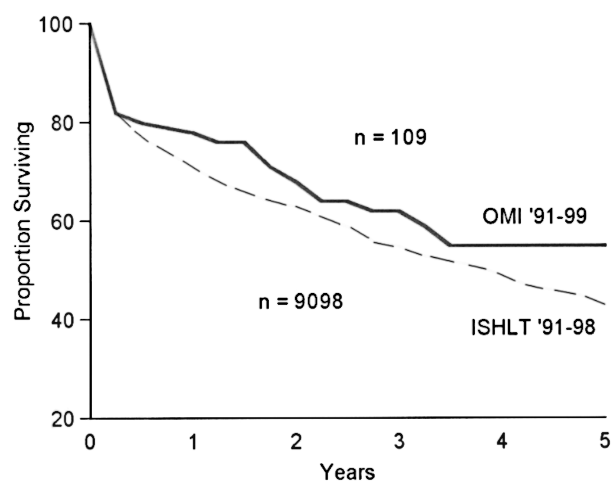

Figure 7. Lung Survival Comparison between Ochsner Medical Institutions (OMI) and the International Society for Heart and Lung Transplantation (ISHLT).

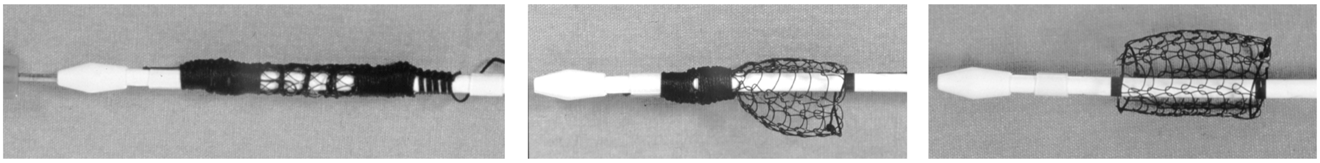

Figure 8. Demonstration of deployment of the Ultraflex (Boston Scientific, Natick, MA) endobronchial stent.

horizon of minimally invasive endobronchial surgery. This concomitant development of instrumentation and devices, keeping pace with advances in endoscopy, has made it possible to treat many conditions that could formerly be managed only by open surgical operations.

Ochsner Video-Assisted Rigid Bronchoscopic Surgical Experience

Although rigid bronchoscopy was performed at Ochsner for decades, its limited application has yielded to the less invasive yet superior visualization of flexible fiberoptic bronchoscopy. A resurgence of rigid bronchoscopy occurred in the early 1990s when fiberoptic lenses and video camera assistance were adapted to the rigid bronchoscope. Our experience in video-assisted rigid bronchoscopic surgery is derived from two sources: bronchial complications following lung transplantation and tracheobronchial conditions that are not transplant related.

Video-Assisted Rigid Bronchoscopy for Complications Following Lung Transplantation

The Ochsner lung transplant program has grown progressively in its first decade (Figure 5). While emphysema remains the major indication for lung transplantation in most U.S. programs, cystic fibrosis is the most common indication at Ochsner (31%), followed closely by emphysema (30%) and idiopathic pulmonary fibrosis (23%) (Figure 6). Overall survival has been excellent and comparable to that reported internationally (Figure 7).

Chronic rejection (obliterative bronchiolitis) and infection are the major causes of death after lung transplantation; however, airway complications are common and may result in significant morbidity and mortality (28, 29). In an effort to evaluate our experience with the management of surgical airway complications (SACs) following lung transplantation, we retrospectively reviewed 115 lung transplant cases performed in 112 patients at Ochsner Foundation Hospital between November 1990 and March 2000. Excluded from the analysis were 13 patients who died within 2 weeks of transplantation (none of whom had SACs) and three patients who underwent pulmonary retransplantation. With these exceptions the study group included 99 patients (with a total of 156 airways at risk) comprised of 42 with single lung transplants and 57 with bilateral sequential lung transplants. Significant SACs requiring endobronchial or open surgical management occurred in 32 airways at risk (20.5%), an incidence that is disconcerting but similar to that reported by others (30). The mean interval to development of SAC was 54.9 days (± 34.4 days SD).

The most common (n=28) indication for intervention was airway compromise due to bronchial anastomotic stenosis or distal airway bronchomalacia. These complications were addressed by dilation alone (n=8) and with endobronchial stenting (n=20)

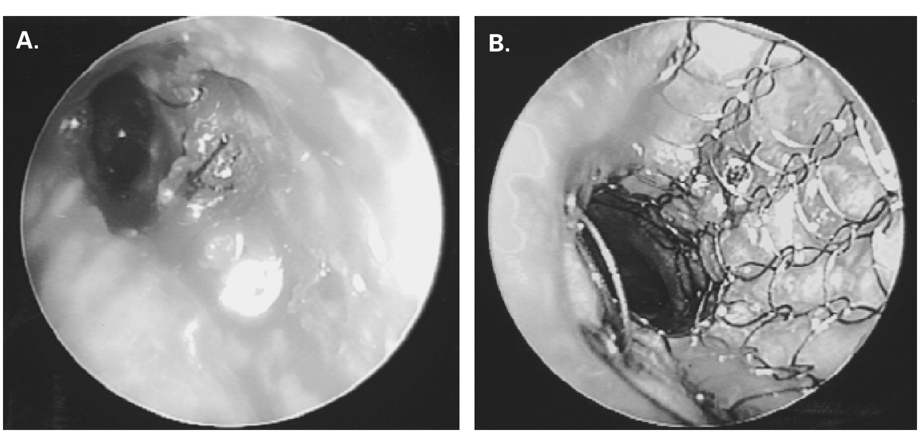

Figure 9.
A. Left bronchial anastomotic stenosis following bilateral sequential lung transplantation.
B. Endobronchial stent deployed to relieve bronchial stenosis.

Table 3. Nontransplant-related indications for video-assisted endobronchial surgery at Ochsner (May 1994 – March 2000).

Tumor (7)	
Bronchogenic	5
Metastatic	2
Stenosis (4)	
Tracheal	
Post traumatic	1
Post resectional/irradiation	1
Bronchial	
Web	1
Wegner's Granulomatosis	1
Fistula (6)	
Bronchopleural	4
Tracheoesophageal	1
Gastrotracheal	1
Foreign Body (3)	
Hematoma	1
Tooth	1
Metal/Suture	1

using a variety of silastic and self-expanding metallic endobronchial stents. Graded balloon dilation of the bronchial stenosis served to open the airway and assist in the sizing of the airway for stent selection. Stent deployment was accomplished under direct endoscopic visualization in each of our patients. The newer self-expanding stents were positioned through the Dumon-Harrell rigid bronchoscope with the assistance of a silastic carrier (Figure 8). After the stenosis was dilated and stented, stent position and distal airway patency was assured by endoscopic evaluation (Figure 9). Some airways required repeated dilations and stent revisions. Bronchial anastomotic dehiscence was observed in three airways, which were successfully managed by open surgical suture repair and vascularized intercostal muscle pedicle wrap (*n*=2) or pneumonectomy (*n*=1). Two-year survival following surgical management of bronchial dehiscence was 100% in our patients. Significant bronchial angulation in an additional airway was corrected by reoperation and bronchial revision.

Variables such as recipient's age, sex, race, and organ ischemic time had no influence on the development of SACs; however, SACs occurred in 23.5% (16/68) of airways at risk in patients with suppurative lung disease (cystic fibrosis 31, brochiectasis 3), compared with 19.6% (9/46) of airways at risk in the nonsuppurative group. Additionally, left bronchial complications were more common than right in both single and bilateral sequential lung transplants. Anastomotic technique also appeared to influence the incidence of SACs, which developed in 21.4% (22/103) of anastomoses performed by an interrupted telescoping suture technique and in only 18.9% (10/53) performed by a continuous end-to-end technique. Early detection and management resulted in similar 1- and 3-year survival in patients with or without SACs. We are currently evaluating these differences in hope of reducing SAC incidence in the future.

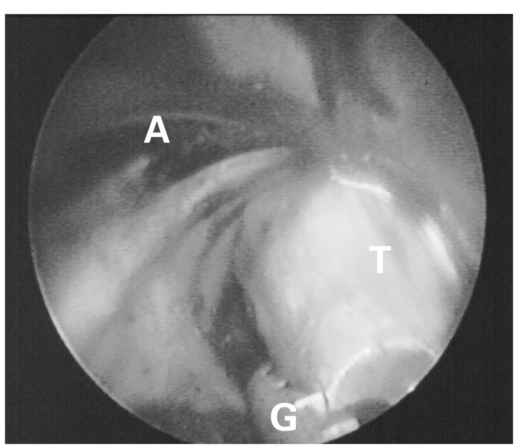

Figure 10 a. Tooth foreign body lodged in right upper lobe bronchus resulting in airway obstruction and recurrent pneumonia. Tooth removed with video-assisted rigid bronchoscopy. A= airway, G= grasper, T= tooth.

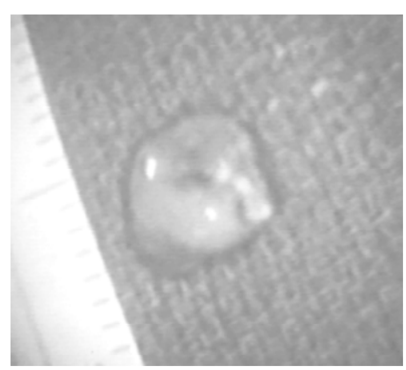

Figure 10 b. Extracted tooth fragment.

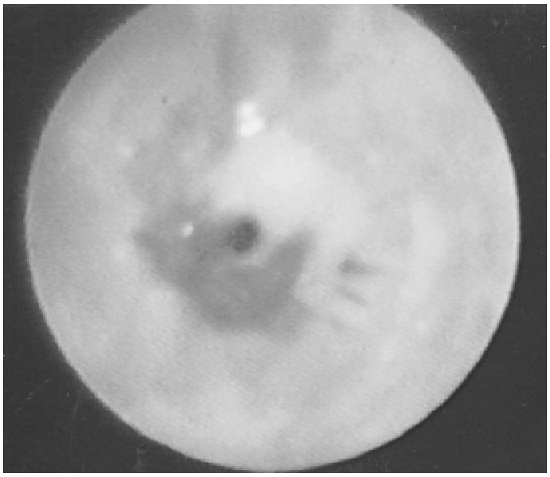

Figure 11 a. Tracheal stenosis at the site of a healed traumatic bronchopleural fistula.

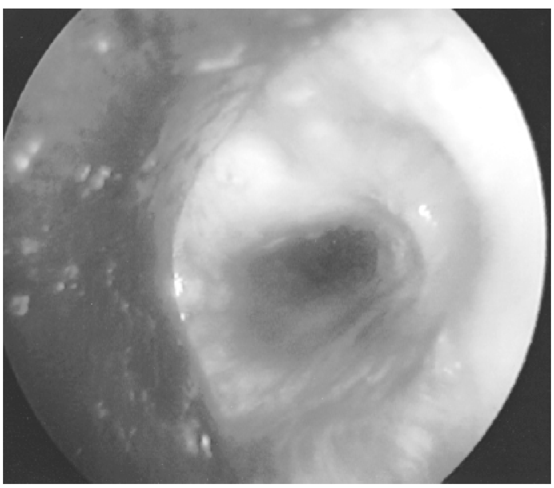

Figure 11 b. Balloon dilation and silastic endotracheal stent placement.

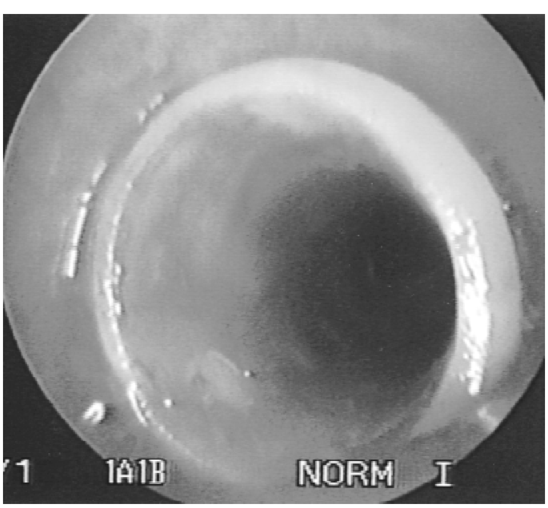

Figure 11 c. Patent airway.

<u>Video-Assisted Rigid Bronchoscopy for Nontransplant-Related Complications</u>

Tracheobronchial conditions that were unrelated to pulmonary transplantation comprised the remainder of our experience with video-assisted endobronchial surgery. Between May 1994 and March 2000, 28 endobronchial procedures utilizing video-assisted rigid bronchoscopy were performed in 20 patients (11 males and 9 females) ranging from 32-76 years of age (mean 59.2 years). Indications for surgery are shown in Table 3. The procedures consisted of resection/débridement (n=9), balloon dilatation (n=5), stent placement (n=5), fibrin glue sealant of fistula (n=5), and foreign body removal (n=4). Sixteen patients required only one intervention, three patients required two, and one patient underwent six interventions.

Rigid bronchoscopy is particularly applicable to foreign body removal, especially when the object is large and beyond the scope of fiberoptic bronchoscopy (Figure 10). Débridement of a tumor may be accomplished mechanically or with the assistance of electrocautery or even a laser. Dilatation and stent placement for benign or malignant airway obstruction has been successfully accomplished with the rigid bronchoscope (Figure 11). The management of small bronchopleural fistulae following pneumonectomy, utilizing the combination of the endobronchial application of fibrin glue sealant to the fistulous opening and adequate thoracic drainage, has obviated the need for reoperative thoracotomy in a few patients. As no mortality or procedural-related complications developed in these patients, video-assisted endobronchial surgery has proved an attractive alternative for selected conditions that are managed currently by palliation alone or by open surgical procedures (31-33).

Conclusion

Many surgical operations are now performed successfully, economically, and with minimal patient trauma through video-assisted thoracoscopic and endobronchial surgeries. Surgeons have begun to better define which minimally invasive thoracic surgical operations are effective and in which patients they are indicated. Patient acceptance has been excellent due to less morbidity and earlier resumption of activity. Continued evaluation of our results with these advanced technologies will help us provide the best possible care for our patients.

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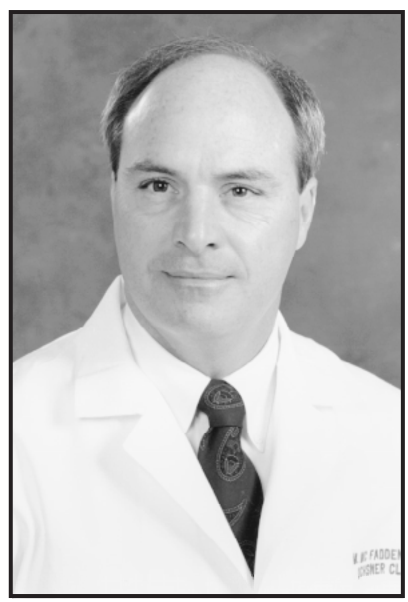

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