Video-Assisted Thoracic Surgery (VATS)

Todd L. Demmy, M.D.
University of Missouri-Columbia
Ellis Fischel Cancer Center
Columbia, Missouri, U.S.A.

LANDES BIOSCIENCE
GEORGETOWN, TEXAS
U.S.A.

VADEMECUM
Video-Assisted Thoracic Surgery (VATS)
LANDES BIOSCIENCE
Georgetown, Texas U.S.A.

Please address all inquiries to the Publisher:
Landes Bioscience, 810 S. Church Street, Georgetown, Texas, U.S.A. 78626
Phone: 512/ 863 7762; FAX: 512/ 863 0081

ISBN: 1-57059-632-8

Library of Congress Cataloging-in-Publication Data

Video-assisted thoracic surgery (VATS) / [edited by] Demmy, Todd L.
p.;cm.--(Vademecum)
Includes bibliographical references and index.
ISBN 1-57059-632-8 (spiral)
1. Chest--Endoscopic surgery. 2. Thoracoscopy. I.Title:VATS. II. Demmy, Todd L. III. Series.
[DNLM: 1. Thoracic Surgery, Video-Assisted. WF 980 v652 2001]
RD536.V53 2001
617.5′4059--dc21 00-065534

Chapter 1

Overview and General Considerations for Video-Assisted Thoracic Surgery

Todd L. Demmy

History and Definitions

The contemporary practice of thoracoscopy has, like most endeavors in medicine, a rich history in the development of both its practice and supporting technology. While this handbook focuses largely on the key elements of its practice, a brief review of the landmarks leading to the development of the present use of Video-Assisted Thoracic Surgery (VATS) seems appropriate.

In 1806, the cystoscope was invented, later the instrument first used for thoracoscopy. During the 1800s knowledge was gained about the treatment of thoracic diseases like collapse therapy for tuberculosis and the cystoscope was refined by the inclusion of the electric light bulb. It was not until 1910 that Jacobeus first used this device for the thoracoscopic treatment of complications related to tuberculosis and later went on to describe diagnostic thoracoscopy for other diseases.[1] The potential for complications related to thoracoscopy at that time caused leading thoracic surgeons to discourage its use by nonsurgeons, commentary echoed more recently during its resurgence.

The 1970s heralded a renewal of interest in this methodology that occurred with the refinement of bronchoscope technology. A decade later, the first international symposium about thoracoscopy was held and the mediastinoscope had emerged as a popular tool for this practice because of its shorter length and accompanying useful instruments.[1] In the late 1980s laparoscopy evolved from a largely gynecological discipline to the preferred method by which cholecystectomies and other general surgical operations were accomplished. This revolution took a while to start but exploded in popularity and soon there were multiple video systems in every operating room. Thoracic surgeons began to borrow these tools and applied them to simple diagnostic and therapeutic procedures. In 1990, the term VATS was coined to differentiate it from the older direct viewing technology that limited the involvement of first assistants. The eponym was also invented to incorporate the word “Surgery” to emphasize the need for those who practice it to have sufficient skill to handle the operations and any resulting complications using traditional open techniques. In the past decade VATS has become the standard of care for many operations like lung and pleural biopsy. It has also been tried for more complex procedures with variable success and resulting refinement of the indications for its application. The “Learn

ing Curve" was driven by increased operator experience but perhaps more by constantly upgrading video and instrument technology.[2] Each upgrade allowed surgeons to perform these operations with viewing and manipulation like open chest operations. Presently there are ongoing advances in robotic technology that may allow operations of increasing complexity to be performed with diminishing invasiveness.

Anatomy and Exposures

Typical Setup

Many thoracic problems can be handled through the following approach. However, this represents only a guideline which is frequently altered in varying degrees depending on the anatomic needs of the patients or their diseases. Port placement is essentially equivalent to exposure, one of the guiding principles of any surgical discipline.

Port Placement

The ports sites are chosen by two key questions: "Will the placement allow the instruments, including the camera, to be used optimally" and "If needed, can they be incorporated into a larger incision later to reduce the amount of chest wall trauma?"

Decisions related to these questions are based on the manipulation needs of the particular operation as well as anatomical variations found by preoperative imaging studies. I believe that most thoracoscopic cases require the presence of chest CT scans in the operating room for optimal planning and safety. Occasionally a chest roentgenogram may be sufficient for planning; however, the palpation component of VATS exploration is limited leading to reliance on CT imaging or similar technology to detect deep visceral abnormalities.

Ports are generally placed in the middle, anterior, and posterior axillary lines (Fig. 1.1). The middle is usually placed through the seventh or eighth intercostal space although the skin incision can be one or two cm lower than the rib in thin patients. This is to allow for a sufficient subcutaneous tunnel to prevent postoperative air ingress around the chest tube that is usually placed through this port at the completion of the operation. The finding of resonance by percussion of the chest wall over the planned site may help guide the surgeon in safe placement. This is particularly true for patients with obesity, phrenic paresis, or other diseases where diaphragm is more superior. Similarly, it is important to enter the intercostal space carefully, preferably by gentle spreading with a blunt instrument. Digital exploration should precede port insertion to confirm safe entry and sufficient depth to allow port placement.

The anterior and posterior ports are usually placed near their respective axillary lines. Planning for a possible thoracotomy, the incisions are made so that they can be connected later if necessary. Since these incisions will be closed at the completion of the operation, there is no advantage to creating a 'tunnel'. Safety of thoracic penetration and port placement is guided by viewing these moves internally through the camera that has been placed through the middle port. This typical three port arrangement provides a 'Baseball Diamond' arrangement where the anterior and posterior ports represent 1st and 3rd base and are used for the manipulating instruments. Similarly 2nd base represents the target area and is viewed from 'Home Plate' (the middle camera port, Fig. 1.2).

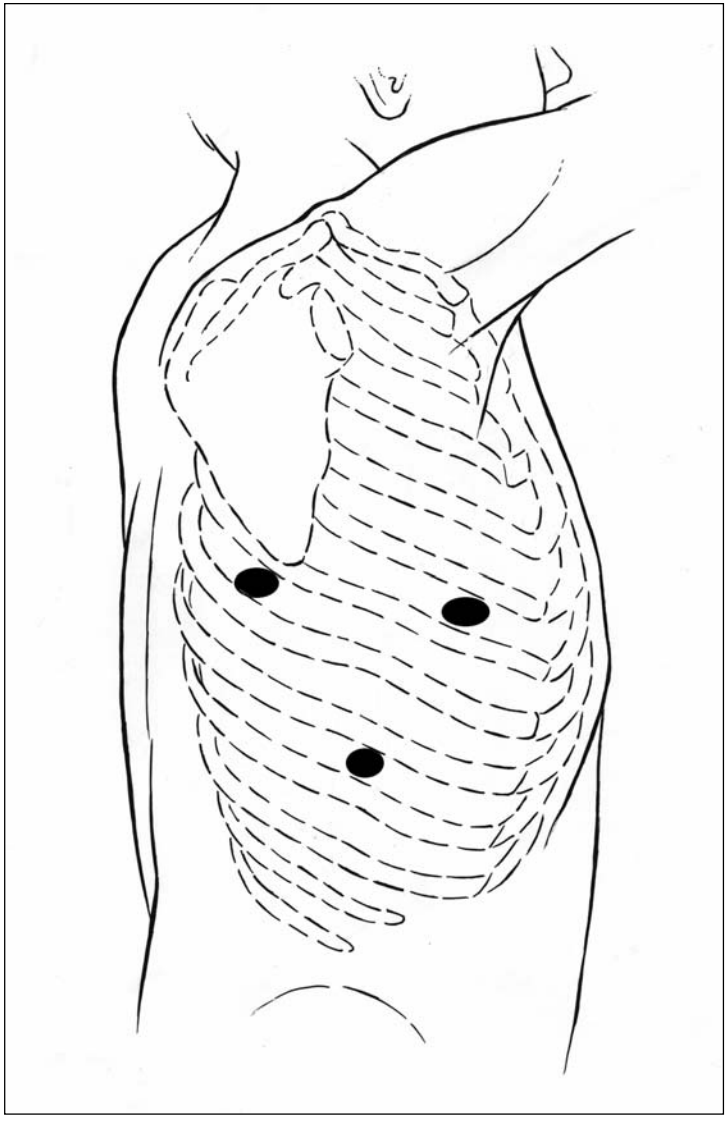


Fig 1.1. Diagram showing typical placement location for three ports that will serve for many diagnostic or therapeutic thoracoscopy cases. The patient is shown in the left lateral decubitus position with the bed flexed to open the intercostal spaces wider. The inferior (camera) port is in the 7th or 8th intercostal space in the mid-axillary line. The superior (instrument) ports are in the 5th and 6th intercostal spaces near the anterior and posterior axillary lines.

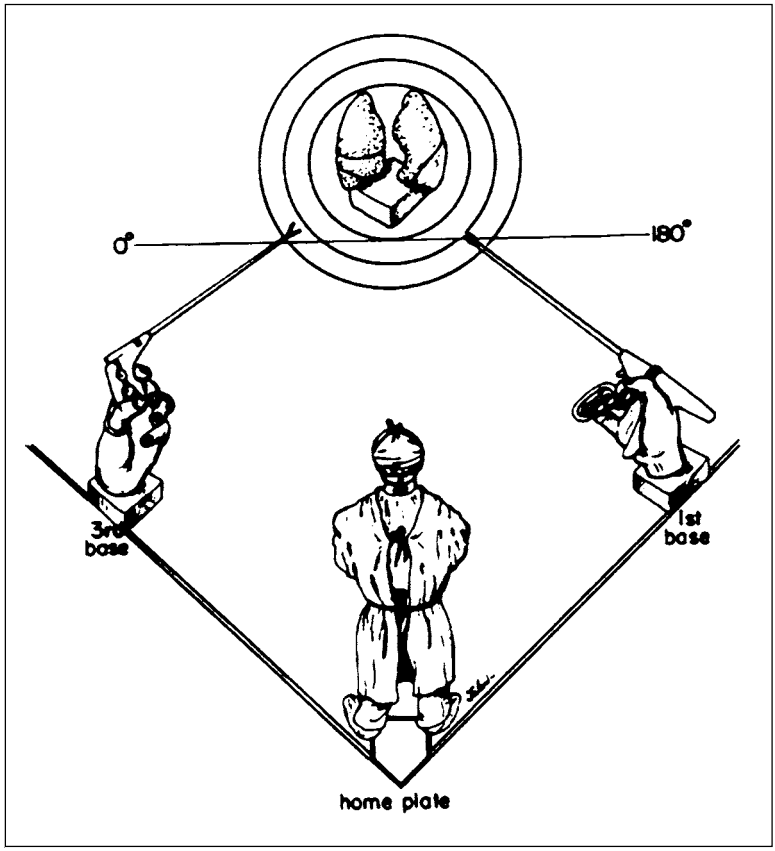


Fig 1.2. Diagram showing the baseball diamond concept for setting up VATS operations. The surgeon's view (camera) is from home plate while the target is at 2nd base being dissected by instruments inserted through ports at 1st and 3rd bases. (Reproduced with permission from Annals of Thoracic Surgery).

Port Hardware

The use of ports in patients whose pneumothorax is created by opposite lung ventilation is optional. A camera port is necessary to prevent smearing of the telescope lens during insertion unless one can clean the lens intracorporeally. Reusable ports are available to reduce cost. Using a camera port that is larger than the telescope allows for air ingress when suction is used. I frequently place reusable ports through the working sites then remove them to dilate the tracts. This allows for easier insertion of the standard instruments.

Use of Insufflation

Many VATS surgeons rely on pulmonary elastic recoil to achieve collapse for the operation. This requires selective ventilation of the opposite lung which may be less desirable to some surgeons. An alternative method is to insufflate CO2 in a manner similar to laparoscopy. Although the possible adverse hemodynamic effects of this are debated, careful use of this technique seems safe.[3]

General Techniques

Exposure of the operative field requires use of patient positioning and various tools that will be described later. Traditional laparoscopic instruments are useful but frequently standard instruments are even more helpful. Because of their larger size, the standard graspers (like Babcock forceps) may manipulate the bulky lung better and tissue scissors cut better than laparoscopic instruments. In general, three ports can be used to accomplish most operations. However, one should not hesitate to add more ports if needed. Five millimeter ports allow passage of useful laparoscopic instruments and cause little additional morbidity. While the chest wall rigidity provides a working space without the need of gas insufflation, it is also a hindrance when straight instruments can't achieve enough angulation with respect to the chest wall to reach the desired target area. This problem is addressed by swapping existing ports (cameras and/or instruments), adding new ports, or selecting a tool that is angled or has the capability to articulate in some way. Much of the art of VATS relates to predicting and correcting exposure problems that exist because of this chest wall limitation. Difficulty with visualization can usually be corrected by using a thirty degree telescope or a flexible thoracoscope. If one chooses to modify (e.g., bend) an existing tool for VATS, care is needed to prevent unexpected problems like cautery current leakage, breakage within the thoracic cavity with foreign body, etc. In thin patients, a standard extension tip for the cautery can be used provided one avoids induction heating or current loss in the chest wall. This is also a useful tool to attain hemostasis at the port sites by placing the tip within the port, withdrawing the port back just outside the rib and thusly exposing just the deep port tissues for cautery. Also standard suction will evacuate intrathoracic clot and fluid but there needs to be another port or open space around the sucker to prevent re-expansion of the lung and possible harmful negative barotrauma. A standard pool sucker provides venting and good drainage of large effusions.

The following sections will describe various techniques to achieve exposure for specific areas in the chest.

Chest Wall and Parietal Pleura

Most of the internal chest wall is visible because the parietal pleural lines most of its surface. The internal surface of ribs can be seen from the first rib to rib eight anteriorly, ten laterally, and twelve posteriorly. Since chest wall tumors are generally biopsied superficially and are resected through extensive incisions, VATS has limited value other than its occasional usefulness in diagnosing visceral invasion and marking internally the tumor extension for planning margins for chest wall resection.

Pleural diseases, however, are ideal problems for the diagnostic and frequently the therapeutic capabilities of VATS. The typical setup described above (Fig 1.1) will suffice for generalized disease. When a specific target in the pleural cavity is

desired, it is important to be sure that a straight biopsy forceps will reach the target by appropriate placement of the anterior or posterior port. Otherwise, creating a new port to accomplish this angle will be needed.

Anterior mediastinal Compartment

The anterior mediastinal compartment is generally approached for biopsy of masses not expected to be appropriate for resection. Also the incidence of malignancy in this compartment is higher. VATS for thymectomy has had limited popularity because of difficulties with exposure and concerns regarding adequacy of resection. The placement of ports for access to this region are shifted anteriorly and superiorly (Fig. 1.3). Unlike standard positioning, extension of the arm allows greater access to the axillary region and modified decubitus with a posterior tilt allows the lung to fall away posteriorly. Frequently the left side is selected for this exposure. Care is taken to avoid injury to the phrenic nerve that courses lateral to the superior vena cava on the right and innominate vein, pulmonary artery, lateral thymus and superior pericardium on the left.

Middle Mediastinal (Visceral) Compartment

Resection of benign cysts and drainage of the pericardium are popular operations for this compartment. The optimal approach is determined largely by the preoperative CT scan by judging which pleural space has most exposure to the target lesion. Great vessel operations are rarely appropriate other than inspection during exploration. The esophagus is accessed best through the right chest where its dissection is relatively easy using the typical setup. The lung is retracted anteriorly and the esophagus is visible from near the thoracic inlet to near the inferior pulmonary ligament with minimal dissection. The distal esophagus can be exposed through the left chest using inferiorly based retraction ports for the diaphragm as well as others for the lung. An endoscope within its lumen can increase its visibility between it and related pericardium, aorta, and vertebral body. The pericardium is easily seen in both thoracic cavities. Some surgeons prefer to create a pericardial window by VATS. The left approach may be better because of reduced likelihood of cardiac herniation. While the posterior port may provide retraction of the lung, an extra anterior port may aid dissection by allowing grasping of the pericardium for safe entry. The trachea is accessed through the right chest and is found anterior to the esophagus above the level of the azygous vein. The subcarinal region is explored by dissection beneath the azygous vein.

Posterior Mediastinal Compartment

Most of the VATS interest in the posterior compartment will be related to disorders of the nervous system and spine and can be explored with minor modifications to the typical setup. The sympathetic chain is visible as a fine line in the posterior-superior region of each chest near the costovertebral junction. An extra port for retraction or grasping may be necessary to hold the lung out of the way while this region is dissected. The vagal fibers including the recurrent nerves can be found near the esophagus in each chest. Nerve neoplasms like schwannomas are usually resectable by VATS even if posterior neurosurgical intravertebral release of a dumbbell tumor is required first. Lymphatic tributaries including the thoracic duct are infrequently

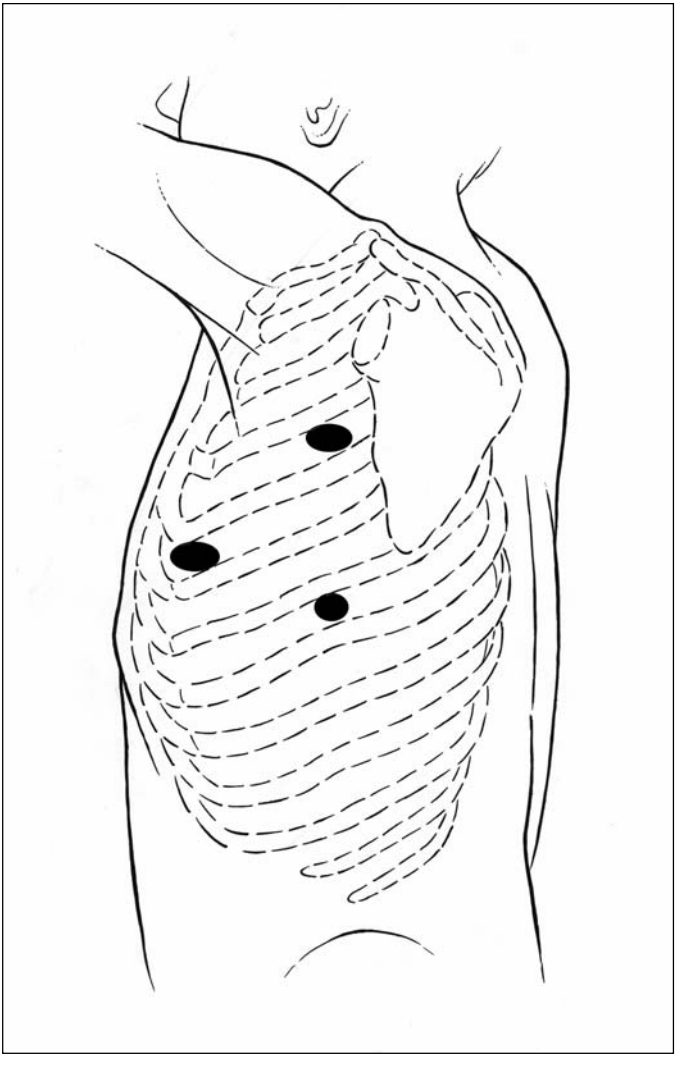


Fig 1.3. Diagram showing how ports can be moved to optimize the concept shown in Figure 1.2. In this case the patient is in the right lateral decubitus position and the target area is the anterior mediastinum. The camera port is positioned more superiorly (6th intercostal space) while the working ports are positioned anterosuperiorly in the 4th and 3rd interspaces.

identified. They are usually found near the esophagus, esophageal hiatus, and trachea particularly when olive oil or similar lipid meal are used for enhanced visualization.

Lung and Visceral Pleurae

The approach to the lung and investing pleurae is dependent on whether the operation requires a random or specific target area. The typical setup described above is fairly versatile and random biopsies from any lobe are quite easy with this approach. The inferior acute margins of any lobe are relatively easy to biopsy because it is easy to pull these areas into the stapling devices. Alternatively, the bulky, central regions of the upper lobe are typically the hardest areas to access. When the intent is to excise specific nodules, then care is needed for port selection. A more anterior and apical placement of one of the ports may be helpful for deep, superior nodules. A straight atraumatic clamp may be useful to help gather tissue into the jaws of the stapler to prevent lung injury.[4] When the tumor size or its depth exceed 4 cm excision may be complicated and require laser excision or open thoracotomy for success.[5] Another option could be to perform a core needle biopsy and if positive for lung cancer, perform a minimally invasive lobectomy. This procedure may be easier or safer to perform than excision of a difficult deep nodule. Also all specimens should be withdrawn through the chest wall in a specimen extraction sac to prevent seeding of the chest wall.

Diaphragm

The diaphragm is easily visible through the thoracoscope. Inspection of this organ is straight-forward and is done typically to inspect for metastases and occasionally for injury from penetrating trauma. Care should be taken to avoid biopsy of the diaphragm as it is relatively easy to lacerate; however intracorporeal suture repair can be performed should this complication occur. The typical port arrangement may be used, although a 30° or flexible scope may be useful. Also the diaphragm may be seen better from above by placing the camera port high above the anterior and posterior ports. This along with separate diaphragmatic retraction ports is used to approach to the esophageal hiatus.

General Indications and Contraindications

The indications for VATS will be covered in detail in the subsequent Chapters; however, review of the general application of thoracoscopic surgery is warranted.

Diagnostic Evaluation

The relatively low morbidity of VATS has made earlier invasive testing more popular for difficult to diagnose pleural disorders. Essentially any suspicious pleural mass or cryptogenic exudative effusion are appropriately evaluated by VATS although the diagnostic yield on the latter may be disappointing. Pulmonary nodules, particularly those in the peripheral lung fields, and any undiagnosed interstitial lung disease are appropriate for this technology. Common mediastinal masses appropriate for biopsy include lymphomas and carcinomas that appear unresectable by CT planning. Diseases commonly diagnosed but not treated by VATS are listed in Table 1.1.

Table 1.1. Diseases diagnosed by VATS

Benign Pleural	Inflammation Infection Autoimmune/Rheumatologic Fibrous plaques Benign Mesothelioma Foreign body
Malignant Pleural	Metastatic Carcinoma Mesothelioma Thymoma
Benign Lung	Interstitial lung disease Usual Interstitial Pneumonitis Desquamative Interstitial Pneumonitis Lymphoid pneumonia Idiopathic pulmonary fibrosis Sarcoid Bronchiolitis Obliterans Organizing Pneumonitis (BOOP) Infectious Tuberculosis, typical and atypical Fungal Viral Benign Nodules Wegener's Granulomatosis Castlemann's disease Pulmonary Blebs and Bullae
Malignant Lung	Bronchogenic carcinoma Metastatic carcinoma or sarcoma
Other Viscera	Lymphoma Cysts Bronchogenic Enteric Pericardial Idiopathic Neurogenic tumors Teratoma

Therapeutic Interventions

Diseases appropriately diagnosed and treated by VATS can also be categorized by their organ type. Pleurodesis is usually performed by mechanical abrasion for benign problems like recurrent pneumothoraces or insufflated sclerosants like talc for malignant disease. Benign lung nodules are treated optimally by VATS but malignant nodules are also appropriately resected without formal lobectomy in patients with impaired lungs or who have metastatic disease. The safety and value of VATS for other oncologic work is still under study.

Mediastinal conditions treated by VATS include drainage with resection of cysts and resection of benign solid tumors like schwannomas. The pericardium can be drained or opened for minor cardiac interventions like placement of pacemaker leads. Esophageal diseases treated by VATS include myotomy, reflux disease, and simple cyst or benign tumor excision.

Vascular diseases have not yet been treated by VATS routinely except for ductus ligation. A list of operations performed by VATS and their indications is presented in Table 1.2.

Contraindications to VATS

The most agreed upon absolute contraindication to VATS is the inability to create a working space with which to perform the operation. This is most commonly the result of pleural fusion from adhesions or the inability of the patient to tolerate single lung ventilation. Other contraindications are more relative and stem from concerns of possible dangerous or inadequate surgery. Examples of dangerous operations are those that risk of tumor dissemination, inadequate tumor staging, or sudden life threatening complications like hemorrhage not controllable safely by a minimally invasive maneuvers. Inadequate operations may occur when the exposure or minimally invasive tools used to accomplish VATS are inferior to open operations. An example of this could be a densely adherent decortication rind that would be more completely removed using an open incision. Most of the relative contraindications can be avoided by careful planning using the working diagnosis and preoperative imaging as guides. Table 1.3 lists situations where VATS could be contraindicated.

Preoperative Preparation

The evaluation of the potential VATS patient needs to be performed by a surgeon who is well versed in general thoracic surgical principles and can discuss the VATS procedure in the context of the standard open operation. Generally the assessment of risks is discussed and is similar to counseling for open thoracic operations. The surgeon should encourage smoking reduction or cessation if possible. Abrupt withdrawal of smoking may increase the complication rate for two or more weeks after complete cessation.[6] Whether the patient can tolerate single lung ventilation is of primary concern. As thoracic imaging improves, the problem of indeterminate contralateral lesions is becoming more common. When this is an issue, generally the indeterminate lesion requires biopsy and this may be best accomplished in a staged fashion if the pulmonary reserve is too poor to tolerate violation of both pleural cavities at the same operation. Pulmonary function tests should be obtained before diagnostic procedures including VATS that could diminish respiratory performance by pain or a procedural complication. This is especially true if a formal pulmonary resection may be required. Although preoperative pulmonary evaluation is beyond the scope of this Chapter, common values that predict complications are listed in Table 1.4. Cardiac diagnostic evaluations may be necessary for patients with unstable angina or impaired ventricular function, although many times a relatively stable function history and an ECG without signs of a recent myocardial infarction is all that is necessary to perform VATS safely. An echocardiogram may be useful to determine left ventricular function. Patients with stable angina, satisfactory ventricular

Table 1.2. Diseases treated by VATS

Benign Pleural	Foreign body Refractory effusion	*Extraction Pleurodesis
Malignant Pleural	Metastatic Carcinoma Mesothelioma Thymoma	*Pleurodesis (generally chemical, like talc).
Benign Lung	Pneumothoraces (recurrent) COPD Giant Bullae	Stapling Blebs Pleurodesis (generally mechanical) Lung reduction Bullae excision
Malignant Lung	Bronchogenic carcinoma Metastatic carcinoma or sarcoma	Wedge resection of primary Metastasectomy Lobectomy or pneumonectomy
Other Viscera	Cysts Bronchogenic Enteric Pericardial Idiopathic Neurogenic tumors Teratoma Thymic Hyperplasia (Myasthenia gravis) Thymoma	Resection
	Esophageal achalasia and other motility disorders	Myotomy
	Hyperhidrosis, Reynauds syndrome, other sympathetic disorders	Sympathectomy

*Widely accepted indications for VATS

Table 1.3. Absolute and relative contraindications to VATS

Absolute Contraindications
Inability to create a pleural space because of pleural symphysis
Lack of physiologic reserve to tolerate lung collapse
Relative Contraindications
Severe adhesions
Marginal physiologic reserve
Difficulty achieving single lung ventilation
Likely complications because of difficulty achieving operation by VATS (large malignant tumor, dense pleural rind, etc.).
Small working area because of high diaphragm (obesity, phrenic paresis, etc)

Table 1.4. Common values that predict severe complications following pulmonary resection

Predicted Postoperative FEV1 < 800 cc
MVV < 50% Predicted
DLCO < 40% Predicted
Preoperative VO2 max < 15 ml/kg/min
pCO2 > 50

function and evidence of a thoracic malignancy may not benefit from extensive cardiac evaluations or interventions. This is because typical poor long term survival associated with chest neoplasms may not be enhanced by coronary revascularization or other operations. Also there is usually some urgency in beginning cancer therapy, and the risk/benefit ratio to this concern should be considered before initiating any diagnostic or therapeutic process that may delay therapy.

Consent for VATS, to be informed, should have the patient understand clearly any added risk there may be in the performance of the operation by minimally invasive means. The patient or their representative should understand the relative risk of conversion to standard open techniques and whether this conversion would result in problems in excess of having the operation performed in the standard way initially. In most cases, and particularly when the risk of conversion is high, it is useful for the consent form to reflect the title and/or description of the open operation. Since VATS technology tends to influence the patient toward the lure of less operative trauma and an earlier return to their previous lifestyle, it is important that the physician offset this bias when appropriate and document the same.

Antibiotic prophylaxis for VATS cases should be performed using the same guidelines as for open operations. In general, there is little justification for the use of antibiotics beyond 24 hours following a clean operation even if the chest tube remains for a prolonged time.

Many patients who require VATS surgery may be receiving chronic steroid therapy for their obstructive pulmonary disease or other conditions. While VATS may cause less tissue trauma stress than typical open operations, generally bolus doses of steroids (e.g., 100 mg of intravenous solumedrol) are still recommended because of the blunted adrenal response.

Operating Room Organization and Planning

The best ergonomic response to the disruption of traditional operating room management that occurs from the intrusion of VATS technology requires consideration of the following issues: placement of the surgeon, scrub nurse, assistant(s) and anesthesiologist; video monitor placements; x-ray view box placement; potential need to convert to an open operation; need for unusual instruments (imaging, laser, etc.) that are occasionally useful for VATS; the need for bronchoscopy to reposition double lumen or other airway control tube; the use of an insufflator; and special patient positioning. One possible setup is depicted schematically in Figure 1.4. In general the scrub nurse can stand on the right side of the patient. While the surgeon typically stands on the side facing the patient's back, this may be less convenient

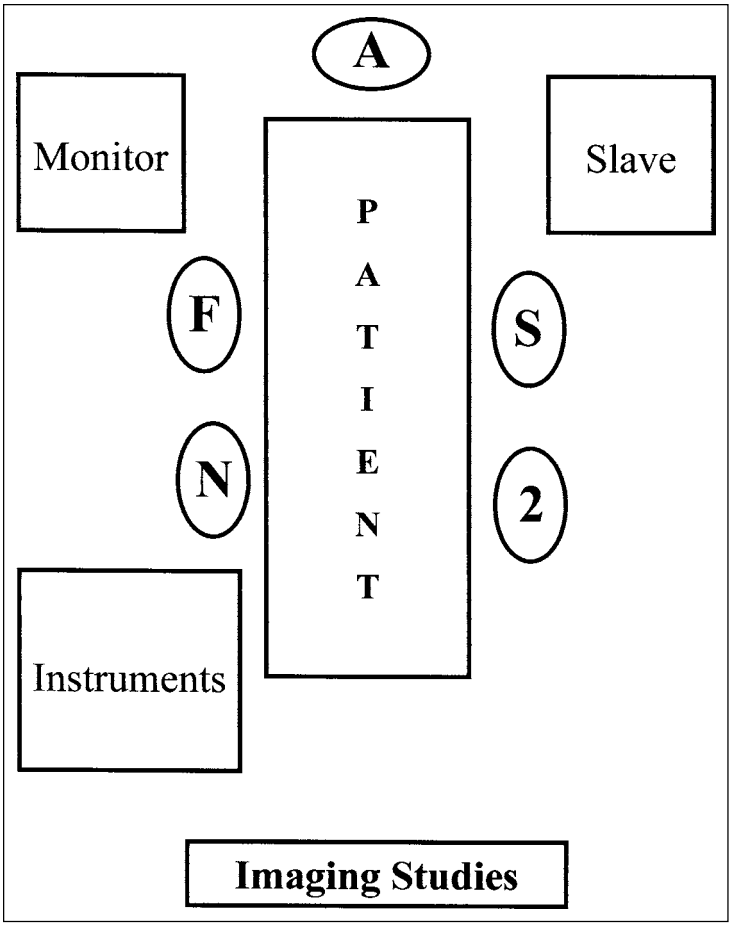


Fig 1.4. Schematic diagram showing one way to arrange operating room for thoracoscopy. The master monitor and slave are positioned toward the head of the table for the Surgeon (S) and First assistant (F) to view the operation comfortably without obstruction of view. The scrub nurse or technician (N) can then have access to instruments in the usual fashion while the second assistant (2) manipulates the camera to the surgeon's needs. The CT scans or other imaging studies are positioned behind the anesthesiologist (A) or at the foot of the bed as in this case.

than the anterior side of the patient for certain VATS cases. Examples are situations where it is easier to apply stapler loads from the anterior side of the table or, in the case of VATS lobectomy, when the access thoracotomy is positioned more anteriorly and viewed easier from that side of the table. Monitors can be placed at the head of the table, but usually a master and slave are positioned on each side of the table

parallel with the table and shifted so that both surgeons have an unobstructed view. Usually shifting monitors toward the head of the bed is most effective. The patient's arm can be positioned more extended if access to the axilla is necessary, as in an anterior mediastinal operation.

Anesthesia

Most thoracoscopy is performed under general anesthesia with positive pressure ventilation; however for patients who can tolerate single lung ventilation, and procedures that require minimal manipulation of the thoracic viscera, the operation can be performed with local anesthesia with intravenous sedation. Generally this is performed by creating a thoracostomy using a generous amount of subcutaneous one-half to one percent lidocaine infiltrated into the skin, subcutaneous tissue, intercostal region and pleura. By allowing air ingress through this hole, the lung collapses by its own recoil. Through this site a telescope is placed and through a separate small incision, instruments can be manipulated. Afterward a chest tube is placed through the camera hole and connected to a closed drainage system to re-expand the lung. Generally, patients need to have substantial ventilatory reserve because ventilation in the other lung may be hampered by dependent position, sedation, and unfavorable mediastinal shift.

A more versatile method requires general anesthesia and selective pulmonary ventilation. A bronchus blocker may be used to collapse the desired side. It is easier to place a 10 mm Fogarty occlusion catheter immediately before placing the standard endotracheal tube because it is sometimes difficult to place the catheter into the trachea beside the large tube. The blocker is directed towards the desired side by placing a bend in the wire stylet. A flexible bronchoscope placed through a swivel adapter is used to position the blocker in the mainstem bronchus so that all lobar branches on the desired side are occluded by injecting 3-10 ml of air into the balloon at end-expiration. It is important to save the wire stylet so that the blocker can be repositioned later if desired. It is possible to place the blocker through the endotracheal tube; however one usually has to modify the swivel adapter to fit snugly around the catheter once it is in position and usually the patient cannot be ventilated while both the bronchoscope and catheter are in the same channel. In this author's experience, the bronchus blocker is disadvantageous when pulmonary reserve is limited, when emphysema lengthens the time for absorptive atelectasis to collapse the lung, and when the airway anatomy makes stable position of the blocker unlikely (such as a proximal right upper lobe bronchus). Some commercially available tubes have a built-in bronchial blocker.

A double lumen endotracheal tube allows control of both airways including low pressure expansion of the operative side to improve oxygenation if necessary. This tube requires bronchoscopic confirmation using a pediatric or intubating bronchoscope. The instances where a right sided bronchial double lumen tube is preferred are rare. This is because of problems controlling the right upper lobe bronchus consistently with the right sided tubes. The dual lumen tubes that have a left bronchial catheter and tracheal opening are more predictable. The most common sources of malpositions are incorrect depths and right mainstem placements. For many patients, the fused portion of the catheter rises only 1-3 cm beyond the teeth after positioned. The tube can be confirmed to be in excellent position by bronchoscopic

inspection of the bronchial tube with a small rim of blue bronchial cuff in the orifice of the left mainstem bronchus. This inspection is carried out through the tracheal lumen where the wide right mainstem opening and right upper lobe bronchus are viewed easily. The proper position should also be confirmed after turning the patient as the tube tends to pull out somewhat in the decubitus position. If it becomes difficult to position the catheter through the tracheal lumen, the double lumen tube can be pulled back so that the bronchial tube is well above the carina. Then the bronchoscope can be passed through the bronchial lumen, the scope advanced in the left mainstem bronchus, and then the double lumen tube advanced over the bronchoscope into the distal left mainstem bronchus. Sometimes the bronchial tube will still not advance into the left bronchus, and a blocker or other means of airway control is needed.

A small endotracheal tube can also be used for single lung ventilation by advancing it into the appropriate bronchus. Typically, the tube will advance into the right mainstem naturally but the right upper lobe is easily occluded. The lung can also be collapsed by CO2 insufflation by using a pressure of 5-10 cm water. Rarely the lungs may be collapsed using cardiopulmonary bypass for very unusual indications. The surgeon should be skilled to assist with the placement of these tubes and may need to break scrub during the operation to assist with recontrol of the airway if needed. To the extent that VATS cannot be performed without this control, cooperation is needed between the anesthesiologist and surgeon to achieve a minimally invasive operation.

A variety of intraoperative anesthetic regimens are appropriate, although care is needed to avoid long acting agents because of the rapid closing times for these cases. Pain control postoperatively is aided by the use of intercostal nerve blockade. This can be accomplished quite effectively by using one-quarter percent bupivicaine introduced by passing a 21 gauge needle from the skin to just tent the parietal pleura guided by internal visualization. The wheal is observed as it extends throughout the interspace. Thoracic epidural anesthesia is usually not needed. A chest tube that allows intermittent infusion of bupivicaine (e.g. a "James" or Axiom™ intrapleural anesthesia catheter) also helps relieve postoperative pain. Bupivicaine 30 ml of one-quarter percent solution every six hours with the chest tube on water seal for 20 minutes beginning just before infusion is useful.

Intraoperative Preparation

Monitoring

For low risk patients in whom a only a diagnostic or limited therapeutic procedure is planned, intraoperative monitoring can be minimized. The basic elements are vital signs, ECG monitoring, reliable peripheral venous access and pulse oximetry. As the severity of patients' comorbidities increase or if preparation for a longer or more invasive operation is needed then some combination of the following are useful: bladder catheterization, arterial catheterization, central venous or pulmonary arterial catheterization, core temperature monitoring and surface warming.

Positioning

Patients are positioned in the lateral decubitus position with the bed flexed to open the intercostal spaces. A roll is placed just below the axilla. A deflatable bean

bag inferior to the dependent arm, three inch thick cloth tape over the hip or similar positioning devices are useful to maintain the position. The ipsilateral arm can be placed in a padded articulating table piece. Access to the anterior mediastinum may be enhanced by placing the patient in a modified posterolateral position with the arm abducted and extended (airplane position) to allow access to more of the axilla. Similarly, the table can be tilted to allow the lung to flop away or the bed placed in reverse Trendelenburg to drop the diaphragm to improve exposure.

Conduct of the Operation for Surgeon and Assistants

While it is customary for the surgeon to stand on the posterior side of the patient in open procedures, the need to work through ports may change that depending on the location of the area in the chest where exposure is desired. The surgeon may be positioned better toward the side of the table opposite the pathology. For operations where an access thoracotomy is useful, standing closer to that wound is optimal. The first assistant generally stands on the side opposite the surgeon. The second assistant functions as the cameraperson below both the surgeon and first assistant and opposite of the scrub technician.

The surgeon may need to manipulate the camera frequently for exposure. A self retaining holder for the camera may be useful, particularly if staffing for a second assistant is limited. High torque, intercostal neuralgia producing, angulations for the cameras or instruments through the chest wall should be avoided by backing the thoracoports up out of the chest wall onto the instruments to create more room within the space. If this is unsuccessful, use of an articulating or bendable instrument may be helpful. Using a flexible thoracoscope or a 30° rigid scope should also allow less torque.

Using a fog elimination compound and prewarming the scope will reduce the steaming of the camera lens. Keeping the lens clean may be difficult because of pesky oozing of bleed from the camera port site down to the tip of the scope. Removing the scope can be avoided by stuffing the corner of a gauze laparotomy sponge into the port site before inserting the thoracoport, irrigating the lens intracorporeally, and by using a lens irrigation system that is built into a flexible thoracoscope.

Moving the instruments by visual cues can be one of the most vexing tasks facing the novice endoscopic surgeon and assistants. Many times the actions are reversed from the image seen on the screen. The best way to avoid this problem is for the surgeon and assistants to pretend that the chest wall is invisible and move the instruments based on their knowledge of patients' internal anatomy. Instead of attempting to compensate for diverse possibilities of movement caused by changing forced camera perspectives, the TV screen defines the problem whose solution requires a motion driven by the knowledge of internal anatomy and the present position of the surgeon's instruments. While this may seem to be a minor point, I have found that this minor change in thinking about the movement problems in VATS has greatly reduced the frustration levels in trainees.

Standardizing instructions to the camera person is helpful but self adjustment of the camera position is usually optimal for complex cases. For instance, right and left "panning" commands are used to direct camera movement in the sagittal plane, up and down "tilting" commands are used for coronal movements and in and out "Zoom-

ing" commands are used to magnify or widen the field of view. These commands can be performed by an operating room robot.

Common operative techniques in thoracic surgery include visceral retraction which is usually done by an assistant using a fan-type retractor placed out of the visual field. Suction requires allowing air ingress by venting through another port. Fine dissection is enhanced by the surgeon using two instruments, one in the nondominant hand to retract and the other in the dominant hand to cut or cauterize.

Equipment

There are many options available when selecting equipment for VATS. Because a pressure seal is not needed, many standard instruments can be inserted into the surgical ports and maintain the tactile performance with which the surgeon is familiar. Generally, instruments that surgeons like to use in open cases should be tried with VATS (Fig. 1.5). Care should be taken with instruments like peanut dissectors and other items that could be lost in the wound. In the case of the peanut dissector, a suture can be attached to allow retrieval. When standard instruments are not practical, there are many laparoscopic tools that are used appropriately in the chest without investing in specific thoracoscopic instruments. Most video systems are useful in both cavities.

Thoracoscopic instruments do not require pressure seal designs requiring insertion through straight ports. Consequently, they can be designed with curves to reach areas otherwise difficult to reach with straight instruments. Some tools are designed for specific thoracoscopic tasks like grasping pulmonary nodules or insufflating talc.

Video Systems

Video systems should be able to cast sufficient light to illuminate the thoracic cavity, even when darkened by hemorrhage. Color and resolution has been optimized by 3 chip cameras and more recently by direct video chips within the cavity on the ends of flexible scopes. While the flexible scopes have cast less light and flickered in earlier models, this problem has been improved. Other systems have used dual cameras to provide three dimensional viewing by the use of separate screens for each eye mounted into helmets or by gating the images using synchronized polarized lens in special eyewear. The video system ideally should be able to produce a hardcopy of images viewed and preferably have videotape output as well. Unfortunately, the medical video industry has not established a standard for image storage and management. Some companies have based their systems on proprietary software to discourage conversion to different systems. Fortunately, lower cost options for this problem are emerging.

Straight telescopes at 0 and 30° can accomplish most views needed in VATS. Unfortunately there is some degradation in image by attaching a camera to a telescope rather than using an intracorporeal video chip. Also, intracorporeal lens washing systems are more convenient in some of the flexible systems. Examples of Video systems companies are given in Appendix I.

Ports

Ports are disposable or reusable, and generic or designed specifically for VATS surgery. Some were designed to be flexible to allow the insertion of instruments that have a curved shape. Most operations can be performed with two ports designed

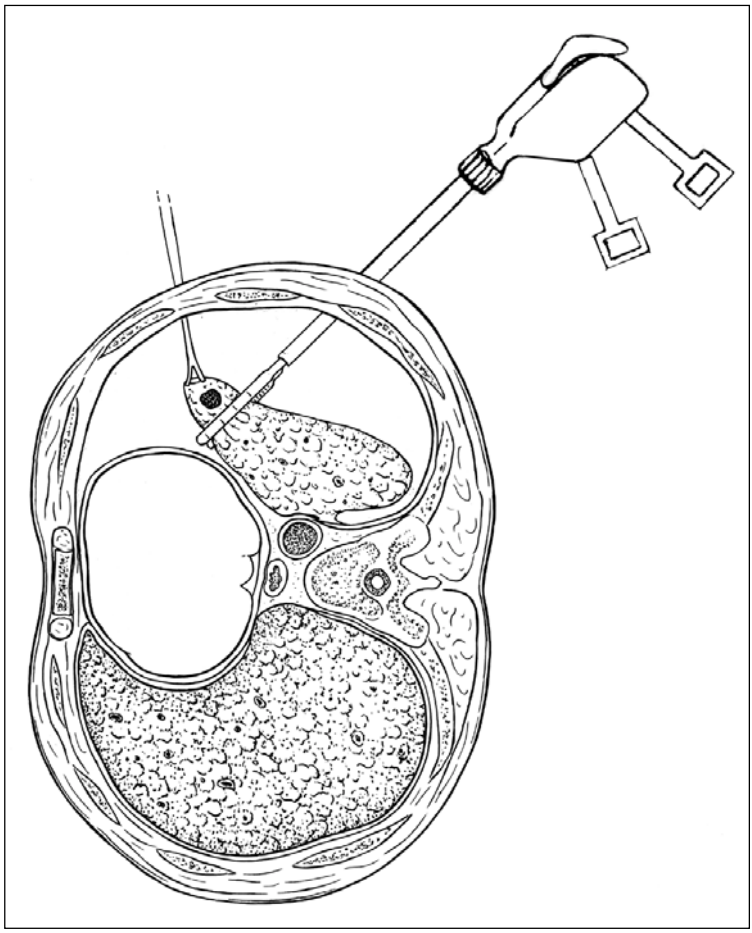


Fig 1.5. Sagittal diagram of relatively simple thoracoscopic left lingular nodule excision. The lung is being grasped with a standard Babcock clamp. The endoscopic 30mm linear cutter is applied beneath the nodule.

to accommodate 10 mm telescopes or graspers. One slightly larger to allow insertion of a standard twelve mm stapler may be substituted if needed. Five mm ports are useful for small instruments and 15 mm ports are needed for some very large stapler instruments.

Nondisposable Instruments

Common standard and laparoscopic instruments useful for VATS and their indications are listed in Table 1.5. Many of these instruments are also available in a

semi-disposable format or have removable tips such as scissors to maximize sharpness. Similarly, disposable instruments are listed in Table 1.6.

Many times, tools that are useful for other operations can be applied to VATS to improve efficiency. For instance, I have found that a straight vascular clamp (Fig 1.6) can be useful to gather in and compress lung tissue so that a deeper purchase can be made with the endoscopic stapler. [4]

Cautery

Cautery should be available in a hand controlled device as well as a wire to connect to various instruments that is controlled by foot. Care should be taken when applying cautery through an uninsulated port. This is because burns can occur by current leakage through insulation that is worn or damaged by bending the instruments. Also there can be heat production by inductive coupling through the skin by undamaged instruments. There are some instrument systems that have built in shielding to prevent grounding of the current other than at the desired site. The harmonic scalpel uses ultrasound to denature protein and seal vessels and has become a popular alternative to cautery for some endoscopic procedures.

Uncommonly Needed Equipment

The YAG/KTP and other lasers have occasional uses in thoracoscopic operations. They can be used for ablation of the parietal pleura for pleurodesis but other methods are simpler, less traumatic, and probably more effective. The laser can be used to shrink blebs in the context of lung reduction as well as seal lung parenchyma as part of a deep lung nodule excision. In general, these uses are second in line to stapler and other sealant technology. The argon beam coagulator can be used in the chest for ablation of pleura and hemostasis but its advantages over less expensive cautery are limited. Topical ultrasound has not yet reached much popularity in the chest although some investigators have used it to find pulmonary nodules in atelectatic lung. Cryoablation and photodynamic therapy have had only investigational usage with VATS.

Postoperative Management

As opposed to open thoracic operations, pain is generally less severe and seems to be related to the thoracic catheter used. Generally pain can be controlled by Schedule III narcotics and prudent use of NSAIDs. Occasionally, patients with more pain will require potent narcotics or the use of a patient controlled analgesia pump. An epidural anesthetic is needed rarely. Many times the pain can be relieved best by planning for early removal of the thoracic catheter. Use of a chest tube that allows intermittent infusion of local anesthetics is another effective way to limit narcotic usage. For adult patients, 30 cc of 1/4% bupivicaine can be given every 6 hours through the local anesthesia infusion port of these chest tubes. The chest tube is removed from suction just before infusion. Suction is restarted 20 minutes later. If no air leak is seen on evening rounds the day of surgery, the chest tube may be placed on water seal and discontinued the following morning. For patients who have pulmonary biopsies, 60% should be candidates for discharge on postoperative day one and 30% on postoperative day two. The benefits of postoperative chest roentgenograms in asymptomatic patients is controversial because of relatively low

Table 1.5. Reusable Instruments Appropriate for VATS

Standard Instruments	**VATS Indications**
Babcock, Small Pennington Clamp	Grasping lung
Standard Right Angle Clamp	Fine dissection
Large (Herrington) Right Angle Clamp	Dissection, Passing guide catheters Grasper for tonsil sponge or cautery scratch pad for mechanical pleurodesis
Sponge Stick Forceps	Grasping viscera
Cautery with tip extension	Cautery, Dissector
Pool suction tip	Evacuating irrigation or effusion
Standard Yankauer Suction tip	Discrete suction
Long knife handle	Dividing bronchus on linear stapler
Straight vascular or bowel clamp	Compressing bulky lung to allow insertion of endoscopic stapler
Kelly clamp with peanut dissector	Dissecting pulmonary hilum
Vein retractor	Exposure beneath azygous vein
Metzenbaum scissors	Completing division across staple line not achieved by endoscopic GIA stapler
Endoscopic instruments	**Indications**
Maryland or similar dissector	Fine dissection
Reusable fan retractor	Retract lung or diaphragm
Scissors	Dissect tissue
Knot pusher	Internal suture placement
Needle driver	Intracorporeal suturing
Babcock	Grasping of viscera
Standard laparoscopic grasper	Fine dissection
Hook and spatula cautery	Divide adhesions, hemostasis
Suction / Irrigator	Cleaning field
Talc insufflator	Applying poudrage
Endoscopic clip appliers	Hemostasis

Table 1.6. Disposable instruments appropriate for VATS

Disposable Instruments	VATS Indications
Fan retractor	Lung and Diaphragm Retraction
Ligating loop	Hemostasis
Extraction sacs, Free or loaded on expanding ring	Extraction of tissue to prevent chest wall seeding
Clip Appliers	Hemostasis
Scissors	Fine dissection
Peanut dissector	Blunt dissection
Graspers	Dissection
Cautery scratch pad	Mechanical pleurodesis
Velcro strips (Strip-Ts™)	Securing cables to drapes
Fog reduction (FRED™)	Reducing lens condensation
Talc	Pleurodesis
Endoscopic Staplers	Vascular, Bronchus, and lung division
Articulating Stapler	Vascular, Bronchus, and lung division
30mm linear stapler - 4.8mm load	Bronchus division
Special chest tubes (silicone, James tube™)	Reducing chest tube contribution to pain.
Red rubber catheters	To pass the anvil of the staplers.
Sputum trap	To sample pleural fluid and other aspirates.

yield; however, we prefer a postoperative film and at least one before discharge, particularly if the patient is to travel a long distance.

Activity should be encouraged with ambulation the day of surgery. If the air leak is mild, the chest tube may be placed on water seal for ambulation; otherwise, the drainage system can have extra suction tubing added to extend the tether from the wall. Pulmonary toilet is essential including incentive spirometry and frequent cough and deep breathing. Preferably these exercises should be taught preoperatively. The patient can usually be discharged with Schedule III narcotics or less. There are no lifting restrictions and the patient can return to work within one to four weeks depending on the extent of the operation. Prophylactic postoperative antibiotics are not used for clean or clean-contaminated cases over 24 hours following surgery. If a pleurodesis procedure was performed, the chest tube is left in place until drainage is less than 150 ml in 24 hours.

Management of Common Complications

The most common complication following VATS surgery is prolonged air leak. This complication is more common in patients with emphysema particularly those who have upper lobe wedge resections for inflammatory nodules. It is best to treat these before leaving the operating room. The extent of leak and location can be determined by filling the chest with irrigation or irrigating over the area of suspected leak. The area may then be stapled, possibly using pericardium or PTFE inserts on the stapler to buttress the areas of leak. These staple line reinforcements should be used preemptively for nodule excision when air leak seems likely. Work is under way to create a biologic glue that is photochemically activated to seal leaks.

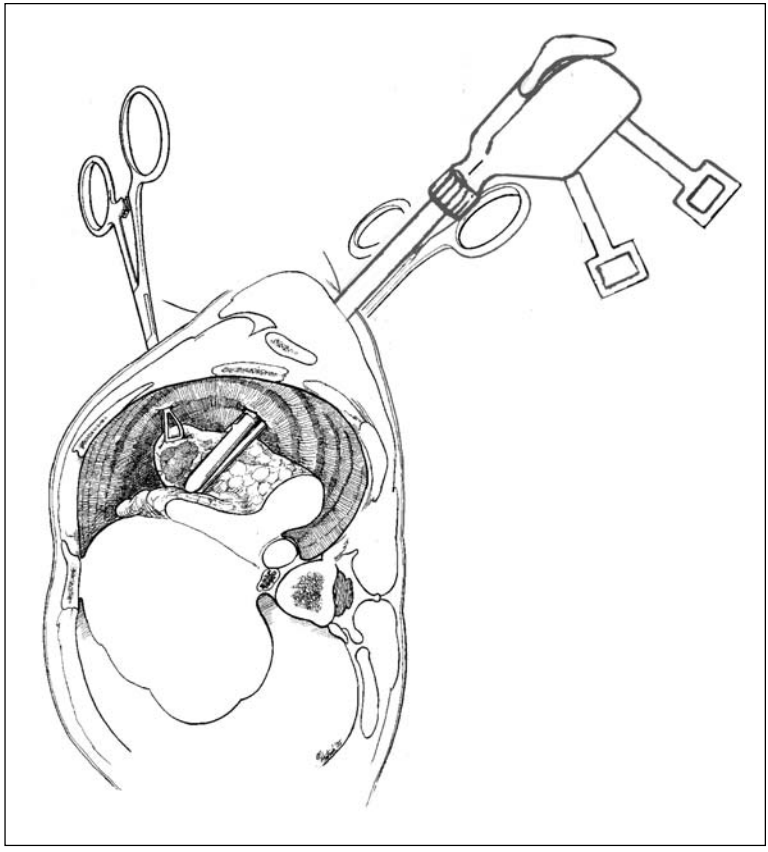


Fig 1.6. Sagittal diagram showing one method to handle a nodule that is deep within the lung parenchyma. If the available staple does not open very wide or if the lung is stiff, the anvil might damage the lung while the stapler is being positioned. Compressing the tissue with another instrument placed through the same port site may prevent this complication. Here a straight vascular clamp was used to compress the tissue. The stapler then finds its way to its full tissue depth. The vascular clamp is removed and the stapler can then be moved farther away from the target before closing and firing. Reproduced with permission from Missouri Medicine 1996; 2:86-87. © 1996 Missouri State Medical Association.

Other operative interventions that may be indicated are division of the inferior pulmonary ligament to allow apical pleural coaptation, suturing with monofilament absorbable suture, and mechanical pleurodesis. Occasionally, when air leaks are moderate, difficult to fix by VATS, and the morbidity of a thoracotomy seems prohibitive, the operation is terminated with the expectation that the air leak will

decrease when positive pressure ventilation ceases. It is important to avoid or use the least effective suction on the chest tube system to avoid accelerating the air leak. Other postoperative manipulations that may be effective are withdrawal of chest tubes so that the holes are not over the areas of leak, chemical (non-talc) pleurodeses, and discharges with Heimlich valves to allow the leaks to seal in the outpatient setting.

The prevention of atelectasis, pneumonia, and the need for prolonged ventilatory support is accomplished by using techniques of pulmonary toilet and early ambulation common to most surgical disciplines. These complications are predictable for patients with a lot of pulmonary risk factors (See preoperative preparation section). It is hoped that the reduced chest wall trauma of VATS will allow better ventilation and fewer such complications. Similarly, infectious complications of wound infection/empyema and cardiac complications like myocardial infarction are also predictable and perhaps easier to manage.

Chylothorax if minor can be treated by bowel rest and hyperalimentation. As a postoperative complication, it is usually caused by dissection in the posterior aspect of the visceral mediastinal compartment. The leak should be sealed surgically after failure of conservative management or immediately if associated with esophageal cancer or other severe nutritional problem. The use of a olive oil or creme meal two hours before surgery is helpful to identify the leak. Mechanical pleurodesis may also be necessary.

Intraoperative hemorrhage is usually controllable without the need for thoracotomy. If severe, compression of the bleeding area by sponge stick tamponade or similar instrument minimizes bleeding until a rapid thoracotomy can be made. Sometimes thoracotomy can be avoided if the bleeding is self limited or can be controlled by ligation of a noncritical vessel. For instance, dissection behind the azygous vein can lead to considerable bleeding which can be controlled by dividing the azygous vein with a vascular endoscopic linear cutter. This also serves to improve exposure for the dissection. Care should be taken to avoid the use of clips or other hemostatic methods in a panic which could lead to further hemorrhage. Intercostal vessels should be controlled with a clip as cautery may not be permanent. Thrombostatic materials like Surgicel™ should be used and many times venous bleeding can be controlled with these substances plus patience. VATS pericardial window may lead to delayed postoperative bleeding from the pericardial edges.

Trocar injuries are uncommon but potentially serious. They occur most often by rapid pleural entry without bracing the instrument or predicting the proximity of underlying viscera. If the lung has been deflated before pleural entry or if the diaphragm rides high because the patient is obese or has a phrenic nerve problem, then the diaphragm or pericardium can be penetrated easily. An anterior and inferior left port wound puncture can damage the heart easily as well. Cardiac wounds require early recognition and thoracotomy. Frequently the liver or spleen is injured as well as the diaphragm but may not require repair. Generally, a small thoracotomy made by extending the port wound allows enough exposure to deal with the diaphragm tear and underlying viscerae. Diaphragmatic penetration can occur easily during attempts to biopsy pleural metastases. This complication can usually be treated by intracorporeal suture repair. Esophageal injury is uncommon but can occur with a

minimally invasive myotomy. It may be controlled best with open methods to ensure good coverage of the injury by a pleural flap or other method.

Arrhythmias are usually managed intraoperatively by ceasing the inciting factor (like retraction of the pericardium) then by typical ACLS treatment algorithms if they persist. Postoperative atrial fibrillation correlates with the extent of pulmonary dysfunction and the amount of operative trauma. Hypercarbia or pneumothorax related hemodynamic compromise caused by positive pressure thoracoscopy is treated by reducing pressure or converting to a single lung ventilation technique.

Care is needed to avoid losing specimens and small objects used for creating pleurodesis or dissection. This is avoided by using a tether for any potentially dislodgeable object. Most objects can be found in the chest by VATS provided they are recognized as missing.

References

1. Dieter RS. The History of Thoracoscopy. In: Dieter RA, ed. Thoracoscopy for Surgeons: Diagnostic and Therapeutic. New York: Igaku-Shoin; 1995: 1-10.
2. Demmy TL, Curtis JJ, Boley TM et al. Diagnostic and therapeutic thoracoscopy-lessons from the learning curve. Am J Surg 1993; 166:696-700.
3. Krasna MJ, McLaughlin JS. Efficacy and safety of thoracoscopy for diagnosis and treatment of intrathoracic disease: The University of Maryland experience. Surgical Laparoscopy & Endoscopy 1994; 4:182-8.
4. Demmy TL, Nielson D, Curtis JJ. Improved method for deep thoracoscopic lung nodule excision. Mo Med 1996; 93:86-7.
5. Demmy TL, Wagner-Mann CC, James MA et al. Feasibility of mathematical models to predict success in video-assisted thoracic surgery lung nodule excision. Am J Surg 1997; 174:20-3.
6. Bluman LG, Mosca L, Newman N et al. Preoperative smoking habits and postoperative pulmonary complications. Chest 1998; 113:883-9.

Pleural Disease

Ben D. Davis, Michael T. Jaklitsch, David J. Sugarbaker

Pneumothorax

Primary Spontaneous Pneumothorax

Primary spontaneous pneumothorax occurs when a subpleural bleb in otherwise apparently normal lung tissue ruptures and releases air into the pleural space. The etiology is unclear although evidence suggests that an imbalance between elastase and α-1 antitrypsin results in bleb and bullae formation.[1,2] There is a predilection for males to be affected, typically young, lean, smoking adults. Annual age-adjusted incidence is 7.4/100,00 among males and 1.2/100,00 among females.[3] Ninety-five percent of blebs occur in the lung apices; 5% are found at the margins of lower lobes.

The pneumothorax causes collapse of the lung parenchyma resulting in reduced compliance and ventilatory volumes. Patients commonly experience ipsilateral chest pain and acute dyspnea although this may resolve within 24 hours despite the persistence of the pneumothorax. Physical examination commonly reveals tachycardia. Less commonly, decreased breath sounds are detected along with a decrease in tactile fremitus and egophony. These latter findings are generally associated only with moderately large pneumothoraces. Diagnosis is established by plain chest roentgenogram, although chest CT scan can aid in the detection of blebs.

For a first, uncomplicated episode of spontaneous pneumothorax preferred treatment options include observation, aspiration or closed tube thoracostomy. The treatment of choice for pneumothoraces less than 20% of the volume of the hemithorax in young, healthy adults is observation. Without further leak causing more collapse by repeat chest roentgenogram 4-6 hours later, the pneumothorax will be reabsorbed at a rate of 1-2% per day. Aspiration of pleural-trapped air or closed tube thoracostomy to re-expand lung is best for patients with larger pneumothoraces. Most patients do not have active air leaks and achieve good apposition of lung and chest wall.

Complications of spontaneous pneumothorax develop in 3-20% of patients and include tension pneumothorax, persistent air leak or recurrent pneumothorax.

Schramel and colleagues reviewed 11 studies from 1963-1995, involving 1242 patients with primary spontaneous pneumothorax treated with bed rest and needle aspiration or closed tube drainage found a 30% recurrence rate.[1] Of patients with recurrent pneumothorax after initial spontaneous pneumothorax, 72% will develop a subsequent pneumothorax within a 2-year period. [4]

Recurrent spontaneous pneumothorax or persistent air leaks at initial presentation are indications for operative treatment. In addition, patients in certain occupations with excessive pressure changes (pilots and divers) or those likely to be remote from medical care are operative candidates after a single spontaneous pneumothorax to prevent a potentially life-threatening recurrence.

Axillary thoracotomy or VATS blebectomy is performed commonly under general anesthesia with single-lung ventilation; the use of local anesthesia with sedation has also been reported.[5] Because patients are usually young and otherwise healthy, they tolerate general anesthesia well, and the complication rate is correspondingly low. Surgical excision of the culprit bleb is achieved easily by either axillary thoracotomy or VATS bullectomy.[6] Operative goals are the surgical extirpation of the blebs and mechanical pleurodesis to fuse the lung and chest wall. Pleurodesis limits the magnitude of pneumothorax should a bleb rupture later. Pleural symphysis is achieved by chemical pleurodesis*, mechanical abrasion and parietal pleurectomy. Abrasion and/or pleurectomy yield better results than chemical agents although the debate over optimal pleurodesis therapy continues.

Nezu and colleagues reported a mean operative time of 63 ± 20 minutes.[5] Bronchoscopy performed before surgery excludes an endobronchial obstruction or infections that increase airway pressure thereby rupturing blebs. Hospital morbidity ranges from 6-11% from prolonged air leaks, atelectasis, incomplete re-expansion of the lung, bleeding or Horner's syndrome.[5,7] Long-term results are good. Bertrand and colleges reported a 5.3% recurrent pneumothorax rate at 42 months when mechanical pleurodesis was added to the treatment regime.[7]

To summarize: The first episode of spontaneous pneumothorax is treated by observation, aspiration or closed thoracostomy tube drainage. The second episode is treated with blebectomy and pleurodesis. Those in high-risk occupations should undergo blebectomy and pleurodesis after the first episode.

Secondary Spontaneous Pneumothorax

Secondary spontaneous pneumothorax arises in the setting of underlying lung disease. Even small pneumothoraces can dramatically compromise patients with baseline poor respiratory function. The most common underlying disease is chronic obstructive pulmonary disease (Table 2.1).[8] Cystic fibrosis and interstitial lung disease are other common causes. Annual age-adjusted incidence is 6.3/100,000 among males and 2.0/100,000 among females.[3]

Pneumothorax occurs when distal air spaces hyperextend from proximal airway obstruction. When alveolar pressure exceeds interstitial pressure sufficiently, air ruptures into the interstitial space. This air can dissect to the hilum causing pneumomediastinum or with rupture of the visceral pleura a pneumothorax. Necrotizing pneumonia destroys lung parenchyma. Resultant broaching of the visceral pleura results in pneumothorax.

Patients present with sudden onset of dyspnea, cough and chest pain. The intensity of the symptoms depends upon underlying lung function and magnitude of the pneumothorax. Diagnosis is established by chest roentgenogram best seen with an

---

* Chemical pleurodesis to treat pneumothorax has included talc. See study under heading of pleural metastasis.

Table 2.1. Etiology of secondary spontaneous pneumothorax

Bullous disease, including COPD
Cystic fibrosis
Spontaneous rupture of the esophagus
Marfan's syndrome
Eosinophilic granuloma
Pneumocystis carinii, especially in patients with AIDS
Metastatic cancer, especially sarcoma
Pneumonia with lung abscess
Catamenial
Asthma, secondary to mucous plugging
Lung cancer
Lymphangioleiomyomatosis

AIDS: acquired immunodeficiency syndrome
COPD: chronic obstructive pulmonary disease
From: [8]Fry WA, Paape K. Pneumothorax, in Shields TW, LoCicero J, Ponn RB (eds): General Thoracic Surgery, ed 5, Philadelphia: Lippincott Williams & Wilkins, 2000.

upright posteroanterior view. Progression to a tension pneumothorax causes distended neck veins, contralateral tracheal deviation, hyper-resonant ipsilateral sounds to chest percussion, hypotension and tachycardia. Tension pneumothorax remains a clinical diagnosis requiring emergent needle decompression or chest tube placement without awaiting a chest x-ray.

Most patients can be treated initially with aspiration or closed tube thoracostomy drainage. Lung re-expansion may take longer and air leaks persist longer than primary spontaneous pneumothorax.[9,10] Observation without evacuation of the pneumothorax is usually not possible because these patients usually are very symptomatic. While 61-70% of leaks resolve by day 7 of tube drainage, further drainage is unlikely to improve success.[9,10] Indications for operative treatment include persistent air leak, recurrent pneumothorax, pneumothorax after pneumonectomy or intolerance of the prolonged effects of pneumothorax not relieved with more conservative approaches.

VATS is commonly performed under general anesthesia with split-lung ventilation. Objectives for surgical treatment, including VATS, are bullectomy followed by mechanical pleurodesis or parietal pleurectomy to reduce risk of recurrence. The bullae excision removes the cause of the pneumothorax while the pleural symphysis prevents future complete pneumothorax. Aggressive pleurodesis methods should be avoided in chronic obstructive pulmonary disease patients suitable for lung transplantation to reduce graft implantation complications.

The goal of treatment is restoration of lung function and the prevention of life threatening recurrences. Various options exists to achieve pleural symphysis including talc poudrage, pleural abrasion or parietal pleurectomy. Chemical pleurodesis can be achieved through agents instilled through chest tubes. Treatment of underlying disease is dictated by etiology. The patient's baseline pulmonary function from lung pathology is often suboptimal in this patient population and may represent a relative contraindication to split-lung ventilation therefore axillary thoracotomy may

have an advantage over VATS. Recurrence rates are similar to those following surgery for primary spontaneous pneumothorax.

Pleural Effusion

Pleuroscopy is one of the simplest and most common uses of VATS. It is combined with directed biopsy in the diagnosis of pleural disease, effusion, and some mediastinal diseases. In addition to diagnostic benefits, it allows therapeutic intervention by breaking-up loculations for drainage of empyema and other effusions.

Under normal conditions, estimated pleural fluid turnover is 0.15 ml/kg/hr.[11] Net pressure differences are the driving force for flux of fluid from the parietal pleura into the pleural space. Fluid dwell time is relatively short. Although forces would favor absorption of fluid by the visceral pleura, most fluid is reabsorbed by the parietal pleura lymphatics because the visceral pleural is relatively incapable of absorbing fluid proteins. Little fluid is resident in the pleural space at any given time under normal circumstances. Pleural homeostasis is a function of fluid viscosity, pleural thickness and lymphatic distribution throughout the parietal pleura. Mechanisms for fluid accumulation are increased hydrostatic pressure, decreased plasma oncotic pressure, increased capillary permeability, disturbed lymphatic drainage, pleural thickening, increased peritoneal-pleural movement and increased intrathoracic negative pressure.[11,12]

The differential diagnosis of pleural effusion is lengthy and is roughly categorized by transudative or exudative etiologies (Table 2.2).[13] Increased hydrostatic pressure or decreased oncotic pressure results in transudative effusions while derangement in vessel permeability results in exudation.

Patient presentation ranges from asymptomatic to significantly dyspneic and is tempered by the underlying etiology of the effusion. Cough and chest pains are also common presenting symptoms. Chest pain may range from a dull, nonspecific ache and sensation of heaviness or pressure to a sharp, pleuritic pain. Physical examination may reveal decreased breath sounds and dullness to percussion and decreased tactile fremitus over the effusion. Initial diagnosis is made by plain chest roentgenogram, chest CT scan or ultrasonography. Lateral decubitus plain films can differentiate significant pleural effusions from parenchymal opacities. Diagnostic thoracenteses limit the differential diagnoses to transudative or exudative etiologies. Any of the fluid ratios below classify the effusion as exudative:[3]

pleural fluid protein/serum protein	> 0.5;
pleural fluid LDH/serum LDH	> 0.6;
or pleural fluid LDH/serum LDH upper limit normal	> 0.66.

In addition to pleural fluid protein and LDH measurement, pleural fluid should be collected for measurement of pH, glucose, amylase, differential cell count, Gram's stain, acid fast bacillus and culture (anaerobic, aerobic, *Mycobacteria* and fungal). (Table 2.3) Pleural fluid cytology is useful to confirm a suspected malignant pleural effusion.

If the diagnosis remains elusive after attempts at diagnosis with thoracentesis or needle biopsy, directed pleural biopsy utilizing the thoracoscope is useful. Diagnostic thoracoscopy is commonly used in the setting of pleural effusion of unknown etiology and frequently follows unfruitful attempts at diagnosis with thoracentesis

Table 2.2. Etiology of pleural effusions

- Transudative Effusion
  - Congestive heart failure
  - Cirrhosis
  - Nephrotic syndrome
  - Hypoalbuminemia
  - Fluid overload
  - Pulmonary embolism
  - Lobar collapse
  - Meigs' syndrome
- Exudative Effusions
  - Malignant
    - Bronchogenic carcinoma
    - Metastatic carcinoma
    - Lymphoma
    - Mesothelioma
    - Pleural adenocarcinoma
  - Infectious
    - Bacterial/parapneumonic
    - Empyema
    - Tuberculosis
    - Fungal
    - Viral
    - Parasitic
  - Collagen-vascular disease-related
    - Rheumatoid arthritis
    - Wegener's granulomatosis
    - Systemic lupus erythematosus
    - Churg-Strauss syndrome
  - Abdominal/Gastrointestinal disease-related
    - Esophageal perforation
    - Subphrenic abscess
    - Pancreatitis/pancreatic pseudocyst
    - Meigs' syndrome
  - Others
    - Chylothorax
    - Uremia
    - Sarcoidosis
    - Postcoronary artery bypass grafting
    - Postradiation therapy
    - Trauma
    - Dressler's syndrome
    - Pulmonary embolism with infarction
    - Asbestosis-related

Printed with permission from ref. 13:Lukanich JM, Grondin SC, Sugarbaker DJ. Chest wall and pleural, in Townsend et al (eds): Sabiston's Textbook of Surgery, Philadelphia: WB Saunders, 2000.

Table 2.3. Pleural fluid analysis factors for pleural effusion of unknown etiology

Protein
LDH
Glucose
Amylase
Differential cell count
Gram's stain
Acid fast bacillus
Culture
anaerobic
aerobic
mycobacteria
fungal

LDH: lactic dehydrogenase

and final needle biopsy. The majority of these effusions are from malignancy. Pleural cytology is a useful diagnostic tool, but achieves a diagnostic accuracy of only 47-60% in malignant effusions. Similarly, needle biopsy achieves 59% accuracy. Repeat cytology or needle biopsy does not improve the yield greatly.[14] The sensitivity of malignancy diagnosis by thoracoscopy after failure of pleural cytology and needle biopsy is 87%.[14]

Most procedures are performed under general anesthesia with split-lung ventilation that may be problematic with concomitant patient comorbidities. Alternatively, draining large effusions may relieve significant ipsilateral atelectasis. Single-lumen endotracheal intubation with brief periods of apnea frequently allows successful pleuroscopy, biopsy, and talc poudrage. Lung deflation is frequently easier in these cases than full lung re-inflation. Regional and even local anesthesia with sedation have also provided good diagnostic and therapeutic yield.

We confirmed a definitive etiology in all of our 196 patients who underwent VATS for evaluation and treatment of symptomatic pleural diseases. Half the cases were malignant.[6] Complications are rare and include bleeding, lung trauma from instrument placement and infection.

Pleural Metastases

Most cancers can metastasize to the pleura so malignant effusions are common oncologic problems. Hausheer and Yarbro found most malignant effusions were from carcinomas of the lung (35%), breast (23%) or lymphoma (10%).[15]

Histopathologic confirmation of malignancy in suspected malignant effusion or pleural-based tumor is achieved by cytological examination of thoracentesis or percutaneous needle biopsy specimens. Thoracentesis provides symptomatic relief with complete drainage of the effusion, but the diagnostic yield of cytology is only 60-80%. CT directed percutaneous biopsy accuracy of pleural masses improves as radiographic resolution advances; however, not all pleural masses can be sampled like this, and the tumor must be large enough for targeting by biopsy instruments. VATS offers a comprehensive pleural surface exploration, directed biopsy of metastases at all pleural locations, and tissue of sufficient size and depth for definitive diagnosis.

Simultaneous pleurodesis is appropriate treatment of symptomatic malignant effusion that often accompanies pleural-based metastases. Thoracentesis provides acute resolution of symptoms but fluid reaccumulation can be rapid with 98% recurrence by 30 days.[16] Talc pleurodesis successfully prevents malignant effusion recurrence in up to 94% of patients.[17]

A review by Kennedy and Sahn of 22 studies of talc pleurodesis for the treatment of pneumothorax (including 17 which used talc poudrage as the method of talc application) noted that the effect of the dose of talc on success could not be determined, but that the quantity of talc used range between 2 and 10 gm.[18] In 31 studies reviewed in which talc pleurodesis was used in the treatment of pleural effusion (including 19 which used talc poudrage), the quantity of talc used ranged from 1-14 gm; similar rates of success were noted if < 5 gm was used compared to > 5 gm. A 2-5 gm quantity is commonly recommended.

Local treatment does not alter systemic disease progression but does provide symptomatic relief and improved quality of life. Possible complications are hemothorax, fluid loculation, empyema and failure to achieve pleural symphysis with resultant fluid reaccumulation.

Empyema

Empyema is a progressive, exudative effusion that develops into a pyogenic, suppurative process. It may result from direct extension of infective agents from the lung parenchyma or bronchial tree, ruptured intrathoracic abscess, mediastinal sources (esophageal perforation), hematologic spread or contamination resulting from surgery or trauma. Common causative organisms are *Streptococcus* and *Pneumococcus pneumoniae*. More recently gram-negative bacteria and fungi have become more common.

Successful treatment decisions are based on the phase of empyema organization. Stage I disease is an exudative phase comprised of fluid with low viscosity treated by closed tube thoracostomy drainage and antibiotics. When the empyema progresses to the fibrinopurulent phase (stage II), pus and fibrin loculate the fluid with deposition of a fibrin peel on the visceral pleural surface. The fibrin peel causes restriction of full lung expansion. Closed tube thoracostomy treatment is ineffective at this stage; treatment is best performed by VATS drainage and pleural debridement. Loculations can be located and broken down easily. Stage III marks the deposition of collagen fibers by fibroblasts and the thickening of the pleural peel, further restricting lung mechanics. Decortication is required at this stage by an open thoracotomy technique.

Clinical staging of empyema is challenging. Physical examination and laboratory analyses of pleural fluid contribute little. Chest CT scans frequently provide insufficient information and ultrasonography while helpful, remains operator dependent.[19] Chest CT defines the presence of a pleural rind and locates empyema cavities. With chronic empyema, chest roentgenogram demonstrates opacification of the involved hemithorax with evidence of thickened pleura.

Intrapleural fibrinolytic agents allow nonoperative empyema therapy for empyemas unresponsive to more conservative therapy. Fibrinolytic therapy decreases empyema viscosity and dissolves fibrin-produced loculations and early peel. This therapy fails with more advanced disease.[20] Therefore, fibrinolytic therapy's role in the treat-

ment of empyema remains ill defined. Fibrinolytic therapy may be tried in undrained empyema prior to use of VATS.

The goals of VATS treatment include the removal of pus, disruption of loculations, control of local infection with adequate drainage, full lung expansion, and prevention of complications.

A flexible bronchoscopic evaluation follows anesthesia induction. Obstructing endobronchial lesions are sought that could prevent full lung re-expansion after pleural debridement. Bronchoalveolar lavage fluid (BAL) of abnormal lung segments provides valuable bacteriologic cultures.

Pleural fluid for Gram's stain, aerobic, anaerobic and fungal cultures should be obtained in addition to appropriate testing for *Mycobacterium*. Patients are treated with empiric, broad-spectrum antibiotics until culture results allow for a more focused antimicrobial selection.

VATS conversion rates range from 0-40% depending on the accuracy of preoperative staging.[19] Prolonged air leak, which can usually be treated by conservative measures, and pneumonia are typical complications. Extensive division of pleural symphysis and decortication increases the risk of parenchymal injury with subsequent air leak. Without full lung re-expansion and obliteration of pleural space, prolonged air leak and persistent infection are likely. Mortality rates range from 0-13%.[19]

Aggressive postoperative pulmonary therapy and increased activity benefit patients. Long-term outcomes of patients treated by VATS are encouraging. In a prospective series of empyema treated by VATS, Cassina and colleagues reported no empyema relapse, normal pulmonary function tests, and normal exercise capacity in 86% of patients at a mean 20.1 months after hospital discharge. [19] Patients with abnormal PFTs demonstrated moderate obstruction and restriction without exercise capacity impairment.

Chylothorax

Accumulation of lymph in the thoracic space is termed chylothorax. The characteristic milky-white pleural fluid contains high concentrations of triglycerides, chylomicrons and lymphocytes. In malnourished patients, however, the fluid may be nearly clear. The fluid accumulation is more common on the left if injury to the thoracic duct occurs above the T5-T6 level where the thoracic duct crosses midline from the right. Injury below this level usually results in fluid accumulation in the right hemithorax. Fluid losses can be large (> 3 L/day).

Chylothoraces are iatrogenic (postsurgical and due to catherization), congenital, traumatic (blunt and penetrating), infectious, and neoplastic (50% are secondary to lymphoma). Another 15% are idiopathic. A spontaneous chylothorax is associated with mediastinal lymphoma in half of the cases. Presenting symptoms occur over days and the compressive effect of the fluid on lung parenchyma results in dyspnea. Chyle is relatively nonirritating so there is no peel formation or lung trapping.

Initial management of chylothorax involves diagnosis and conservative management consisting of closed tube thoracostomy drainage and supportive measures. Nutritional support may include enteral medium chain triglycerides, which are absorbed directly into the venous system bypassing the thoracic duct, or parental nutrition with gastrointestinal rest. Chylothorax from lymphoma is often responsive

to radiotherapy, but if resistant to chemotherapy or radiotherapy is treated successfully with thoracoscopic talc pleurodesis.[21]

Chylous effusions unresponsive to 1-2 weeks of conservative therapy warrant surgical intervention. VATS allows conventional intrathoracic repairs with the benefits of minimal access surgery. Graham and colleagues applied VATS to treat chylothorax using combinations of thoracic duct clipping, chemical pleurodesis and fibrin glue for patients ages 7 months to 82 years.[22]

Treatment goals are improved respiratory function as the mass effect of pleural fluid accumulation is relieved and prevention of drainage loss of fats, proteins, and fat-soluble vitamins. Stemming of lymphocytic losses maintains immunologic function.

Graham and colleagues reported no procedure-related morbidity or mortality in their series.[22] For those patients who received chest tube drainage after VATS treatment (patients with pleuroperitoneal shunts did not receive tube thoracostomy drainage), the average time to chest tube removal after VATS treatment of chylothorax was 6.6 days. All chylous effusions had resolved by 12 days and the average length of hospital stay after VATS treatment was 8.9 days.

Spontaneous Hemothorax

Blood in the pleural space is defined as hemothorax although a quantitative distinction between a bloody pleural effusion and hemothorax is not defined. In addition to hemothorax as a result of trauma (discussed elsewhere), spontaneous hemothorax has a number of etiologic causes (Table 2.4) including pulmonary parenchymal, pleural, and neoplastic pathologies, coagulation disorders, or intra-abdominal pathology causing transdiaphragmatic bleeding.[23] Hemothorax can be indistinguishable from pleural effusion radiographically.

If the fluid collection does not become infected, spontaneous absorption occurs in most patients. If necessary, the initial drainage treatment is thoracentesis or closed tube thoracostomy. Deposition of fibrin on the pleural surface occurs within days of hemorrhage and is made worse if the hemothorax becomes infected. Deposition on a lung partially collapsed by an undrained hemothorax results in the fibrin's organization, development into an inelastic membrane and pulmonary trapping. Physiologic impairment of gas exchange results and pulmonary mechanics alterations cause shunting and restriction. Decortication is then required to restore full pulmonary expansion.

Management of spontaneous hemothorax starts with hemodynamic support, fluid resuscitation and stabilization. Drainage of fluid accumulations of sufficient size is performed by closed tube thoracostomy. Open thoracotomy is the best option when initial blood drainage by thoracostomy exceeds 1000 cc, there is ongoing drainage of 200 cc/hr or more in 8 hours or >100 cc/hr for 24 hours. If closed tube thoracostomy does not drain the clotted blood within 5-7 days, VATS should be considered for its full evacuation before a dense fibrous peel develops. Open thoracotomy and decortication is required once a dense peel develops.

The treatment goal is to provide symptomatic relief and to salvage lung function by removing loculated fluid collections and removing adhesions that prevent full lung expansion. Any fibrinous peel responsible for lung collapse must be removed (decorticated). The hemithorax is inspected carefully for sources of bleeding.

Table 2.4. Etiology of spontaneous hemothorax

Pulmonary Pathology	
	Bullous emphysema
	Necrotizing infections
	Pulmonary embolus with infarction
	Tuberculosis
	Arteriovenous malformation
	Hereditary hemorrhagic telangiectasia
Pleural Pathology	
	Torn pleural adhesions secondary to spontaneous pneumothorax
	Neoplasms
	Endometriosis
Pulmonary Neoplasms	
	Primary
	Metastases
	a. Melanoma
	b. Trophoblastic tumors
Blood Dyscrasias	
	Thrombocytopenia
	Hemophilia
	Complication of systemic anticoagulation
	von Willebrand's disease
Abdominal Pathology	
	Pancreatic pseudocyst
	Splenic artery aneurysm
	Hemoperitoneum
Thoracic Pathology	
	Ruptured thoracic aortic aneurysm

Printed with permission from ref. 23. DeMeester TR, Lafontaine E. The Pleura. In: Sabiston DC, Spencer FC eds. Surgery of the Chest, Ed 5. Philapdelphia: W.B. Saunders Company 1990.

Suspicious lesions are sampled. Arteriovenous malformations, located below the visceral pleura, are ligated or excised as appropriate.

Landreneau and colleagues reported 100% success in VATS drainage and pleural debridement of spontaneous hemothorax in their 23 patients. [24] No complications occurred but there was 1 death unrelated to the hemothorax. Chest tubes were removed after a mean of 2.8 ± 0.5 days, and a mean hospital stay was 4.3 ± 1.9 days.

Patient selection impacts conversion rates. Those patients with a firm, fibrous peel will likely require conversion to thoracotomy for successful operative intervention. However, little is lost if the surgeon commences with VATS expecting simple pleural debridement but then performs a thoracotomy for severe lung entrapment.

Malignant Pleural Mesothelioma

Malignant pleural mesothelioma is an aggressive, locally progressive thoracic malignancy. Aggressive multimodality treatment at an early stage of disease results in improved survival. Malignant mesothelioma originates from mesothelial cells of the pleura. Three histological types have been identified: epithelial, sarcomatous and mixed. About 2000-3000 cases are diagnosed annually in the United States.

The disease is associated with asbestos exposure usually 20-30 years before development of disease. Debate continues over the association between Simian Virus 40 (SV 40), a contaminant of early poliovirus vaccines (1955-1963), and mesothelioma.

At presentation, most patients have pleural effusions. Dyspnea occurs from the effusion or by lung restriction from tumor encasement. Pain from chest wall invasion is common in locally advanced disease. Constitutional symptoms such as weight loss, anorexia, night sweats and fatigue are reported frequently.

Early chest roentgenographic findings range from effusions to slight pleural thickening that are subtle. Chest CT scan and magnetic resonance imaging (MRI) are effective in determining the presence of advanced disease and predicting mediastinal or transdiaphragmatic invasion. The role of positron emission tomography (PET) in staging is undefined at this point.

Cytological examination of pleural fluid has a diagnostic sensitivity of 32%; negative studies lack mesothelioma cells in a number sufficient for diagnosis.[25] Cytogenetic analyses can improve diagnostic sensitivity to 56%. These analyses inspect chromosomal rearrangements or deletions to characterize tumors like the epithelial subtype. Percutaneous pleural biopsy usually provides insufficient tissue for pathologic diagnosis. Until cytological examination can provide reliable diagnosis for this disease, ample thoracoscopic biopsy tissue remains the cornerstone of diagnostic evaluation. Positive cytologic results should also be confirmed by pleural biopsy. The thoracoscope port sites should be excised at the time of definitive mesothelioma resection to minimize recurrent disease. Thus, number and placement of port sites should be planned with this in mind.

The median time to diagnosis from the onset of symptoms is 8 weeks (average 17.9 weeks), and patients with a negative cytology result wait 12 weeks before definitive diagnosis.[25] Median survival with supportive care ranges between 4-12 months. Treatment in a multimodality setting using extrapleural pneumonectomy followed by adjuvant chemoradiotherapy achieved median survival of 19 months and a perioperative mortality rate of 3.8%.[26]

The role of VATS in the management of malignant pleural mesothelioma is confined to the diagnosis of the disease.

Operations

Blebectomy and Bullectomy (Fig. 2.1)[27]

Patient Position: - lateral decubitus with ipsilateral arm at right angle to the torso rather than the typical swimmer's position to open the axilla.

Ports: Ten-millimeter thoracoscopes should generally be placed anterior in the midaxillary line because the rib interspaces become progressively wider as the ribs approach the line of the costal angle. Five-millimeter thoracoscopes, however, can easily be placed between the ribs posterior to the midaxillary line and may give the same visualization of posterior blebs as an axillary incision.

Camera port	fifth to seventh intercostal space midaxillary line
Posterior instrument port	third to fourth intercostal space, placed just lateral to the scapula.

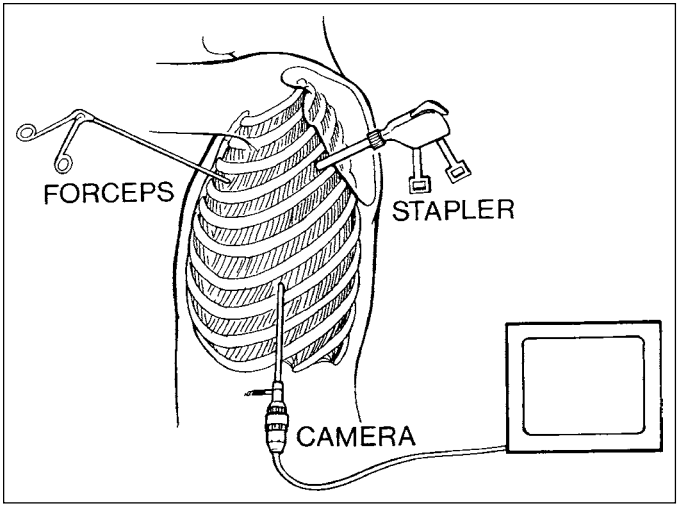


Fig. 2.1. Port placement for blebectomy.[27]

Anterior instrument port third to fourth intercostal space, placed in the axilla.

OR Set-Up

Basic VATS set-up

Endoscopic linear stapler

Technique

Bronchoscopy is performed before VATS to exclude endobronchial obstruction or purulence causes for localized increased airway pressures with bleb rupture.

Blebectomy

The surface of the lung is carefully inspected and subpleural blebs identified. Because the superior segmental surface of the lower lobes can be a source of blebs as well, a careful inspection of the entire visceral pleural is required.

Previous bleb ruptures frequently result in adhesions between pleural surfaces. These should be taken down cautiously with scissors or cautery while providing traction by grasping the lung. Alternatively, the adhesions are left intact, since they provide useful counter traction. In these cases, the lung is undercut with the stapler, and then the adhesions are lysed.

A forcep from behind rolls down the apex of the lung and delivers it to the jaws of the stapler usually passed through the anterior port. The bleb is then amputated at its base by several stapler firings.

The stapler is passed more easily from anterior ports than posterior. This is because of increased interspace width anterior to the posterior axillary line.

If resection of the superior segment of the lower lobe is required, a fourth port placed in the anterior axillary line facilitates proper placement of grasping forceps to manipulate the bleb within the stapler jaws.

Giant Bulla

Resection is similar to blebectomy. The lesion is identified and any adhesions are taken down with sharp dissection. The bullae is deliberately opened by cautery or scissors and allowed to deflate. An endoscopic lung clamp is used to grasp the bulla and is then rotated repeatedly as if winding a clock. This action collapses the bulla onto itself and the demarcation between bulla and normal lung parenchyma is revealed. Small ventilated breaths to the ipsilateral lung can also highlight this transition zone. The endoscopic linear cutter stapler is then used to amputate the base of the bulla (Fig. 2.2).[27]

After completion of the bleb resection, pleurodesis is performed to decrease risk of recurrent pneumothorax.

Pleurodesis (Mechanical and Chemical) and Parietal Pleurectomy

Pleural symphysis is used to obliterate the potential space between pleural surfaces to prevent recurrent pneumothorax or reaccumulation of effusion. This is accomplished by inducing an inflammatory reaction between the visceral and parietal surfaces with a chemical agent, mechanical abrasion or by stripping the parietal pleura which results in fusion of the visceral surface to the denuded thoracic wall. This technique is usually performed at the conclusion of bleb resection for spontaneous pneumothorax, evacuation of a pleural effusion and pleural biopsies.

VATS Procedure

Existing port sites can often be used to achieve satisfactory results.

Mechanical Pleurodesis

Mechanical pleurodesis is accomplished easily by vigorously abrading the parietal pleural surface with tightly rolled gauze between ringed forceps or a Bovie scratch pad that is passed through an accessory port. The entire parietal surface is scarified in this manner (Fig. 2.3).[27]

Chemical Pleurodesis

Alternatively, chemical irritation of the pleural surfaces can be achieved with talc poudrage. Talc available for pleurodesis is asbestos-free (USP standard), but is not sterile. Several techniques for sterilization are available.[26]

Talc is insufflated into the chest so that complete dispersion throughout the hemithorax is accomplished. This is typically accomplished with an atomizer. Alternatively, talc can be blown into the chest from a LUKI tube (Sherwood Medical Company, St. Louis, MO) in front of a 6 L/min oxygen flow rate.

Parietal Pleurectomy

An alternative to chemical and mechanical pleurodesis is parietal pleurectomy. The parietal pleura can be lifted from the rib cage by infusing saline in subpleural space, then grasped and bluntly dissected with an endoforceps. Alternatively, the

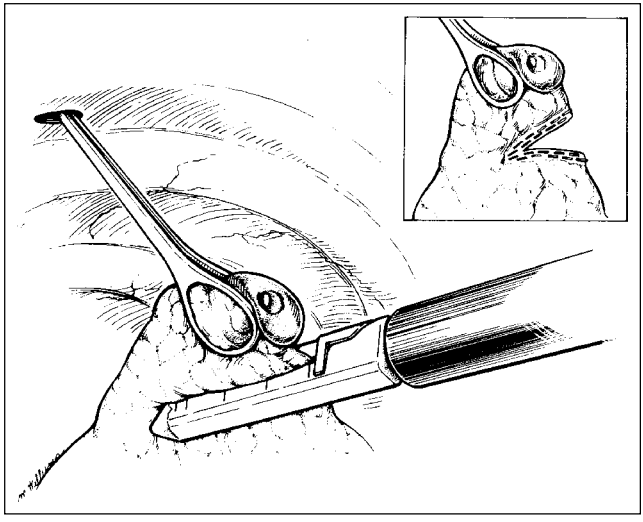


Fig. 2.2. Apical bullectomy is initiated using a ring forceps and an endoscopic stapler.[27]

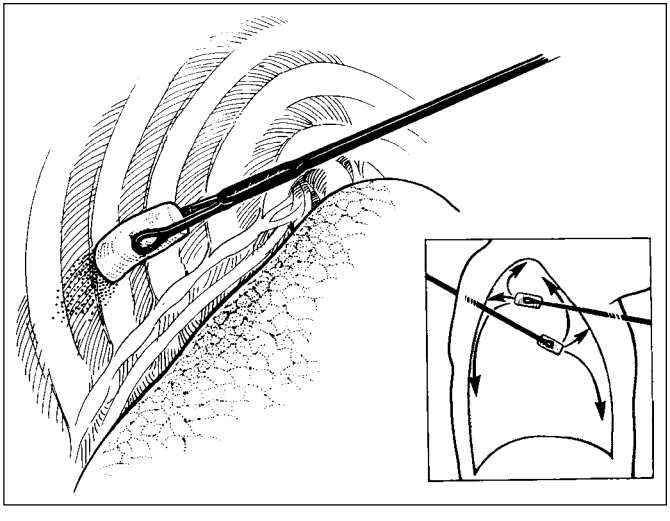


Fig. 2.3. Method of mechanical pleurodesis.[27]

pleurectomy is started at the upper edge of the two instrument ports and dissected bluntly to the apex of the hemithorax. An extrapleural plane is begun with cautery and the parietal pleural stripping is completed with blunt dissection in the area the surgeon wishes potential space obliteration to occur.

Accessory ports are removed under direct thoracoscopic guidance and the sites inspected for hemostasis. A single chest tube is placed to the apex of the hemithorax. The lung is inflated under direct vision by the scope to verify complete inflation, locate additional blebs, and insure proper placement of the chest tube to the apex of the hemithorax. An inflated lung can displace a tube 2-3 cm caudally. If not corrected, this will frequently lead to a loculated pneumothorax at the apex and thwart the pleurodesis. The sites are closed in two layers with an absorbable suture. A chest tube replaces the camera port and is secured with a suture. The chest tube can usually be removed within 24 hours.

Pleuroscopy and Biopsy

Patient Position:	full lateral decubitus position
Ports:	
Camera	sixth to eighth intercostal space anterior axillary line
Accessory ports	Anywhere (Fig. 2.4) [27]

OR Set-Up

Basic VATS or Carlen's cervical mediastinoscopy.

Anesthetic/Airway Management

After verification of proper placement of the double-lumen endotracheal tube, the patient is positioned in the full lateral decubitus position, offering exposure to the hemithorax of interest (operative side up). The limb of the endotracheal tube to the operative side is suctioned to augment rapid atelectasis. This method provides quick lung collapse to provide operative space without the deleterious effect of sudden hemodynamic embarrassment from lung compression using compressed gas.

Technique

An initial 2 cm incision in the seventh intercostal space (top of the sixth rib) is made in the midaxillary line. This location offers maximal exposure and facilitates removal of the port incision during a larger future extirpation in the case of mesothelioma. Muscle fibers are carefully spread perpendicular to their course until the superficial surface of the sixth rib is encountered. Electrocautery is used to divide the intercostal muscles from their insertion on the top of the sixth rib for a 2 cm course. The pleura is identified next and is opened sharply under direct vision. The atelectatic lung should fall away from the lateral chest wall once the pneumothorax is created. A finger is then used bluntly to gently dissect any adherent lung away from the pleural incision. A 12 mm port can then be placed safely through the incision and into the thoracic cavity. The camera is then introduced into the chest.

Before accessory ports are placed, a thorough, systematic exploration of the chest is performed. Beginning at the apex, lung and parietal surface are examined with the dome of the lung depressed by the thoracoscope. The examination then proceeds sequentially along the posterior thorax with the lung pushed anteriorly, along the anterior thorax with the lung pushed posteriorly and then along the hilum of the

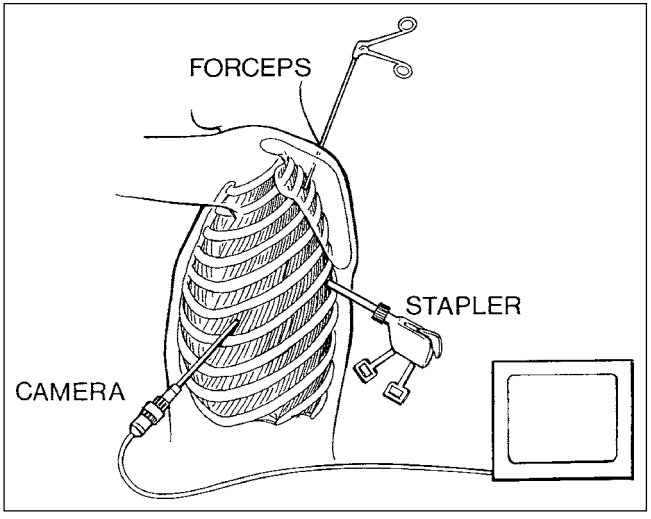


Fig. 2.4. Port placement for pleuroscopy.[27]

lung and into the major lung fissures. Fibrinous loculations can frequently be broken up with the thoracoscope during these maneuvers. Occasionally, an accessory port may be necessary to provide access for instruments to retract the lung.

Accessory port placement is variable. Site selection should be based upon principles of triangulation to allow sufficient tension and countertension to be applied to areas undergoing biopsy. Placement of additional ports is done under thoracoscopic guidance to avoid injury to lung parenchyma.

For lesions of the posterior mediastinal surface or the lateral margin of the anterior chest wall, a 1.5 cm incision is made in the seventh intercostal space in the posterior axillary line beneath the tip of the scapula. A 5 mm camera is superior to a 10 mm camera posterior to the posterior axillary line due to the narrowed rib interspace.

For lesions of the anterior mediastinal surface or the lateral margin of the posterior chest wall, accessory port placement should be in the anterior axillary line.

A grasper is passed through the accessory ports. It can retract the lung providing exposure to the paraesophageal and hilar areas. Biopsies can be performed with standard biopsy forceps passed parallel to the camera through the camera port or through an accessory port. Bleeding from biopsy sites is controlled with cautery or hemoclips.

At the conclusion of the procedure, the ports are removed while dual lung ventilation is restored. Accessory ports are removed first and the sites inspected with the thoracoscope for bleeding. The accessory port incisions are closed in two layers with absorbable suture; the superficial fascia is approximated and the skin is approximated with a subcuticular stitch.

The camera is placed in the last remaining accessory port, and a chest tube is placed under thoracoscopic guidance through the initial camera port and secured.

This tube is generally removed when pleural drainage has subsided to an acceptable level and there is no sign of air leak. If these criteria are met, this tube can be removed in the recovery room.

Decortication

Patient Position Full lateral position with the patient prepped and draped for open thoracotomy.

Ports

Preoperative radiographic studies should provide locations for optimal port site placements. The chest CT scan provides detailed information including fluid loculation status and presence of a visceral peel that may indicate need for extensive decortication. Three to four ports are usually required, and placement should be tailored to the location of the pathology. Triangulation of the target area will provide optimal thoracoscopic visualization.

Technique

The camera port is placed first and is positioned at a vantage point that will afford maximum visibility. This typically is in the seventh intercostal space in the mid-axillary line. This position gives the surgeon the broadest view of the hemithorax; additionally, it is near the lung base, which is commonly the site of involvement. Two additional working ports are then placed directly over the involved area in such a way that these ports center on the area of interest. At least one of these ports should also be close enough to any identified lesions to allow direct digital palpation of the pathologic process, which is part of the intraoperative assessment.

Carefully entering the pleural space in the area of maximal fluid collection, evacuating fluid and then exploring the cavity by digital palpation allows placement of the initial port site with minimal lung parenchymal injury. Loose adhesions can be bluntly taken down by this maneuver. After adequate space for the thoracoscope has been achieved, the camera is introduced without traumatizing lung parenchyma. Additional ports or working incisions are then created under direct vision.

Samples of pleural fluid are sent for Gram's stain and culture. Consideration should be given for additional fluid sample collection for fungal and *Mycobacterium* culture, cytology, and chemistry analysis depending on the differential diagnosis under consideration. If etiology is in question, multiple pleural biopsies should be obtained to improve diagnostic yield.

The thoracic cavity is evacuated of fluid and debris using a suction catheter placed through a working port or with ringed forceps. A 32 or 36 French chest tube can serve as a large-bore suction catheter.

Adhesions are taken down with blunt dissection using the camera or sharply with thoracoscopic instruments. This procedure defines areas of thicker adhesions that require more involved adhesiolysis or areas of a fibrin peel causing lung restriction. Large areas of pleural symphysis need not be taken down if they do not impede adequate evacuation of fluid or impinge on full lung re-expansion.

If significant fibrous peel is present resulting in a trapped lung, conversion to a thoracotomy with decortication may achieve an improved outcome. Similarly, if significant pleural symphysis impairs adequate débridement, conversion to a mini-thoracotomy or full thoracotomy is required to achieve operative goals.

The fibrous peel is completely stripped away from the lung using a combination of blunt and sharp dissection employing thoracoscopic forceps and scissors. The parietal and visceral pleura typically needs to be removed in the involved area. This decortication can be bloody depending upon the amount of inflammation present. A thoracoscopic sponge forceps may be used to tamponade bleeding sites by gentle, direct compression until the lung can be re-expanded. Bleeding usually ceases when the lung is allowed to fully re-expand.

At the conclusion of the adhesiolysis and debridement, the lung should be re-expanded under visualization to confirm that full lung re-expansion has occurred.

Visceral pleurectomy will often result in an air leak after the lung is re-inflated. Good apposition of the lung with the chest wall provides for rent healing over time with cessation of the air leak. Deeper parenchymal rents may need their edges opposed with an endoscopic stapler or interlocking suture. Care must be taken with this, however, because the parenchyma is often delicate and friable and will not hold staples or suture well. The patient may be best served by 12-24 hours of positive pressure ventilation postoperatively to help the lung adhere to the chest wall or placement of additional chest tubes to allow higher negative pressure generation within the chest. Generally, two chest tubes are placed through existing port sites, secured, and connected to –20 cmH_20 suction.

Thoracic Duct Ligation

Patient Position lateral decubitus

Ports:

Camera	sixth intercostal space anterior axillary line
Posterior	fourth intercostal space mid or posterior axillary line
Access	optional anterior working port if needed

OR Set-Up

Basic VATS
endoscopic clip applier

Technique

After visualization of the pleural surfaces and drainage of the chylous effusion, adhesiolysis is performed as necessary. As needed, the inferior pulmonary ligament is taken down to provide greater access to the thoracic duct superior to the diaphragm as it courses between the aorta and azygous vein. A right-angled dissector is used to dissect the entire fat pad between the aorta and azygous vein. This fat pad is ligated by endoscopic suture, clip or fibrin glue. Pleurodesis is a good adjunct to reduce the risk of recurrence chylothorax.

Enteral cream, olive oil, or ice cream taken by the patient 1 hour before the VATS procedure can aid in the visualization of the thoracic duct and the site of leakage.

References

1. Schramel FMNH, Postmus PE, Vanderschueren RGJRA. Current aspects of spontaneous pneumothorax. Eur Respir J 2000; 10:1372-1379.
2. Fukuda Y, Haraguchi S, Tanaka S et al. Pathogenesis of blebs and bullae of patients with spontaneous pneumothorax: Ultrastructural and immunohistochemical studies. Am J Respir Crit Care Med 1994; 149(Suppl):1022.

3. Melton LJ, Hepper NG, Offord KP. Incidence of spontaneous pneumothorax in Olmsted County, Minnesota: 1950 to 1974. Am Rev Respir Dis 1979; 120:1379-1382.
4. Lippert HL, Lund O, Blegvad S et al. Independent risk factors for cumulative recurrence rate after first spontaneous pneumothorax. Eur Respir J 1991; 4:324-331.
5. Nezu K, Kushibe K, Tojo T et al. Thoracoscopic wedge resection of blebs under local anesthesia with sedation for treatment of spontaneous pneumothorax. Chest 1997; 111:230-235.
6. DeCamp MM, Jaklitsch MT, Mentzer SJ et al. The safety and versatility of video-thoracoscopy; a prospective analysis of 895 consecutive cases. J Am Coll Surg 1995; 181:113-120.
7. Bertrand PC, Regnard J, Spaggiari L et al. Immediate and long-term results after surgical treatment of primary spontaneous pneumothorax by VATS. Ann Thorac Surg 1996; 61:1641-1645.
8. Fry WA, Paape K. Pneumothorax. In: Shields TW, LoCicero J, Ponn RB, eds. General Thoracic Surgery. Philadelphia: Lippincott Williams & Wilkins, 2000.
9. Schoenenberger RA, Haefeli WE, Weiss P et al. Timing of invasive procedures in therapy for primary and secondary spontaneous pneumothorax. Arch Surg 1991; 126:764-766.
10. Sahn SA, Heffner JE. Spontaneous pneumothorax. N Engl J Med 2000; 342(12):868-874.
11. Miserocchi G. Physiology and pathophysiolgy of pleural fluid turnover. Eur Respir J 1997; 10:219-225.
12. Sahn SA. The pathophysiology of pleural effusions. Annu Rev Med 1990; 41:7-13.
13. Lukanich JM, Grondin SC, Sugarbaker DJ. Chest wall and pleura. In: Townsend CM, Beauchamp RD, Evers BM et al, editors. Sabiston's Textbook of Surgery: The Biological Basis of Modern Surgical Practice. Philadelphia: W.B. Saunders Company, 2000.
14. Boutin C, Viallat JR, Cargnino O et al. Thoracoscopy in malignant pleural effusions. Am Rev Respir Dis 1981; 124:588-592.
15. Hausheer FH, Yarbro JW. Diagnosis and treatment of malignant pleural effusion. Semin Oncol 1985; 12:54-75.
16. Anderson CB, Philpott GW, Ferguson TB. The treatment of malignant plerual effusions. Cancer 1974; 33:916-922.
17. Yim AP, Chung SS, Lee TW et al. Thoracoscopic management of malignant pleural effusions. Chest 1996; 109:1234-1238.
18. Kennedy L, Vaughan LM, Steed LL et al. Sterilization of talc for pleurodesis: Available techniques, efficacy, and cost analysis. Chest 1995; 107:1032-1034.
19. Cassina PC, Hauser M, Hillejan L et al. Video-assisted thoracoscopy in the treatment of pleural empyema: stage-based management and outcome. J Thorac Cardiovasc Surg 1999; 117:234-238.
20. Temes RT, Follis F, Kessler RM et al. Intrapleural fibrinolytics in management of empyema thoracis. Chest 1996; 110:102-106.
21. Mares DC, Mathur PN. Medical thoracoscopic talc pleurodesis for chylothorax due to lymphoma: A case series. Chest 1998; 114:731-735.
22. Graham DD, McGahren ED, Tribble CG et al. Use of video-assisted thoracic surgery in the treatment of chylothorax. Ann Thorac Surg 1994; 57:1507-1512.
23. DeMeester TR, Lafontaine E. The pleura. In: Sabiston DC, Spencer FC, editors. Surgery Of The Chest. Philadelphia: W.B. Saunders, 1990.
24. Landreneau RJ, Keenan RJ, Hazelrigg SR et al. Thoracoscopy for empyema and hemothorax. Chest 1996; 109:18-24.

25. Renshaw AA, Dean BR, Antman KH et al. The role of cytologic evaluation of pleural fluid in the diagnosis of malignant mesothelioma. Chest 1997; 111:106-109.
26. Sugarbaker DJ, Flores RM, Jaklitsch MT et al. Resection margins, extrapleural nodal status, and cell type determine postoperative long-term survival in trimodality therapy of malignant pleural mesothelioma: results in 183 patients. J Thorac Cardiovasc Surg 1999; 117:54-65.
27. Jaklitsch MT, Harpole DH, Jr., Roberts JR, Sugarbaker DJ. Video-assisted techniques in thoracic surgery. In: Loughlin KR, Brooks DC (eds): Principles of Endosurgery. Cambridge: Blackwell Scientific Publishers, Inc. 1995.

VATS in Diffuse Lung Disease

Chong-Hee Lim, Malcolm M. DeCamp Jr.

Introduction

Videothoracoscopy (or video-assisted thoracic surgery, VATS) is a versatile technique for the diagnoses of various diffuse parenchymal lung diseases. By providing access to all areas of the thorax, VATS allows sampling of discrete nodular or infiltrative lesions in any lung segment and provides tissue sufficient for exhaustive histologic and microbiologic analyses. It is particularly useful for classifying interstitial lung disease where tissue samples from bronchoscopic or percutaneous needle biopsies are insufficient size for histologic architectural detail.

More recently, VATS techniques allow therapeutic interventions for selected patients suffering from obstructive lung disease. Giant bullae are resected readily with a thoracoscopic approach restoring favorable ventilation/perfusion matching and relieving dyspnea. Similar physiologic improvement for diffuse forms of emphysema through lung volume reduction surgery (LVRS) is under active study throughout the world. VATS may offer a unique advantage for this high-risk population in whom less surgical trauma typically allows earlier mobilization and decreased postoperative morbidity.

In this Chapter, we will review the evolution of VATS in the management of patients with obstructive lung disease, interstitial lung disease and complex or refractory infectious pulmonary diseases. Intraoperative as well as perioperative principles are emphasized.

Bullous Lung Disease

Bullae are air filled spaces within the lung parenchyma resulting from the progressive destruction of alveolar tissue. Typically they have relatively thick fibrous walls, grow progressively larger, and are poorly ventilated and malperfused. These lesions crowd out more functional lung parenchyma, impair airflow, compress pulmonary arterial flow to normal lung thereby creating more physiologic deadspace. The resulting ventilation-perfusion mismatch causes dyspnea. Bullae progression may be from continued destruction of lung tissue and preferential inflation of the bullous lesion according to Laplace's law.[1] A giant bulla is defined as one which occupies more than one third of the chest cavity.

Clinical Presentation

Patients with bullae that appear relatively large on a standard chest radiograph may be well compensated and asymptomatic. As the bulla enlarges, dyspnea is usu-

ally the chief symptom and the main indication for surgical intervention. Relative indications for bullectomy are recurrent or persistent pneumothorax, radiologic evidence of size progression and significant compression of normal lung,. Resection of an asymptomatic bulla produces little clinical improvement.[2,3] These lesions are followed with serial chest radiographs.

Imaging

The simple chest radiograph provides much of the necessary information including size, number, location and degree of compression of the remaining lung. Comparisons with old films determine progression.[4] Computed tomography (CT) provides excellent visualization of the anatomy and delineates further the extent of regional lung compression. CT differentiates pneumothoraces from giant bullae and provides information of the underlying lung parenchyma with greater sensitivity. High resolution, spiral CT scanning with intravenous contrast has largely replaced pulmonary arteriography in the evaluation of symptomatic giant bullae. CT scans are essential before surgical intervention to identify targets for resection, their relationship to the pleural edges and fissures and the location and depth of the transition between bullous tissue and more normal lung.[5]

Video-Assisted Bullectomy

The goal of the operation is to resect the bullous, nonfunctional lung and to leave as much normal lung as possible. Conventional operations involve a standard posterolateral thoracotomy, opening of the bulla, oversewing of the bronchial opening and folding in of the edges of the bulla which are then stapled at the base of the lesion with exogenous buttressing materials to minimize postoperative airleak.

Wakabayashi described the use of the laser in the thoracoscopic management of bullous lung disease.[6] The major morbidity was prolonged airleak in 11 of 17 patients as well as a prohibitively high incidence of delayed pneumothoraces. The advent of better designed endostaplers with provision for matched sized buttressing materials (bovine pericardium, collagen or PTFE) avoids the technical shortcomings of laser-ablation of bullae and yields results equivalent to those achieved with conventional, open techniques.[7,8]

Technique

The operation is performed under general anesthesia with selective single lung ventilation. The patient is positioned in the lateral position with the upper arm fixed to an ether screen and abducted so that the axilla is exposed (Fig. 3.1). This provides access to the apex of the lung through an axillary thoracotomy when required. The camera port is placed in the mid-axillary line in the seventh interspace. The pleural space should be entered bluntly and finger dissection used to confirm the lack of visceral to parietal adhesions at the camera site. After introducing the camera, the entire lung is inspected. The second port is placed anteriorly in the third or fourth intercostal space lateral to the breast tissue and pectoralis muscle. The third port is positioned posteriorly near the scapular tip in the fourth, fifth or sixth interspace depending on the size and location of the bulla. At each port site, the pleural space is entered under camera guidance. The margins of the bulla are inspected carefully identifying the transition to normal lung. Where the base of the bulla is wide, the cyst is opened along its long axis and the excess wall is excised with

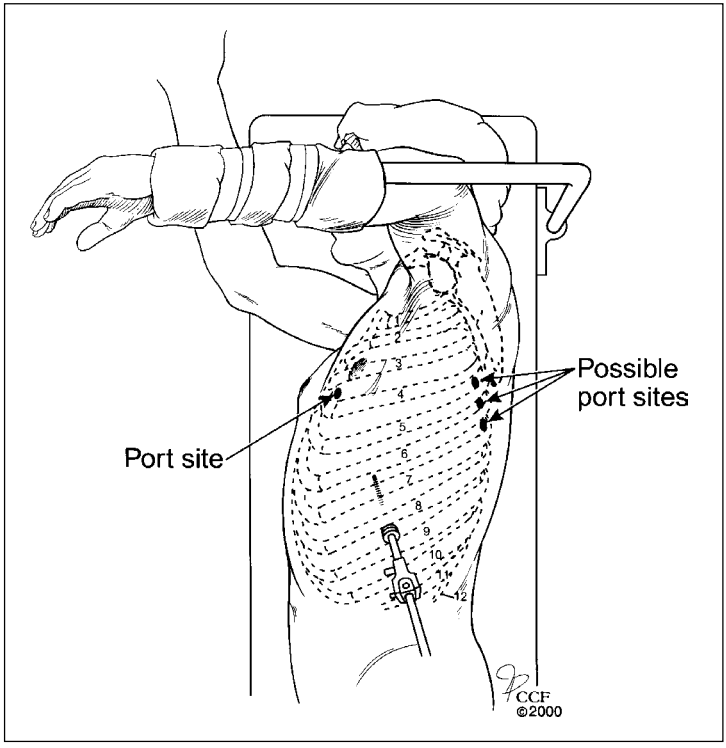


Fig. 3.1. Suggested positioning of the patient for unilateral video-assisted thoracic surgery. The position is useful for giant bullectomy, unilateral LVRS and lung biopsy. Note how the operative-side arm is abducted and secured to the ether screen providing axillary access should a utility thoracotomy be required. Suggested port sites (arrows) as well as the camera location are indicated.

endoscissors. The bronchial opening is usually small and can be approximated with a single application of the endostapler. The remaining walls of the bulla are opposed and stapled serially with buttressing materials along the entire margin. The staple lines are carefully fashioned and intersect to minimize airleak. In cases where the bulla has a narrow base, it is opened and deflated at its apex with endoscissors. The apex is held with a grasping forceps and twisted along its axis. The transition from the thin-walled bulla to the thicker normal lung tissue is obvious. The buttressed endostapler is applied at this level excising the lesion.

Mechanical pleurodesis is recommended as a routine adjunct to giant bullectomy. This is best achieved with abrasion of parietal pleura using a coarse sponge, a dental pledget or kittner. Where there is an anticipated space problem, an apical pleural tent may be performed to assist with visceral to parietal pleural apposition. This can be initiated from the anterior instrument port where the parietal pleura is stripped from the chest wall with an Endokittner™. The subpleural injection of saline may

facilitate the creation of the tent. The pleural tent is allowed to fall towards the apex of the lung.

Two 28F chest tubes are then placed (under a tent if present) usually through the camera and the anterior ports. Both tubes are directed to the apex of the pleural space. Minimal suction, 0-10 cm water, is applied. Chest radiographs are obtained in the immediate postoperative period and tubes are removed in the usual fashion when drainage and air leaks stop. In case of prolonged air leaks, Heimlich valves may be used to shorten the hospital stay.

For bilateral giant bullous disease we prefer staging the operations to minimize morbidity as well as to allow the ipsilateral lung to reexpand completely, optimizing the patient's functional status before attacking the contralateral lesion.

Thorascopic Lung Volume Reduction Surgery in Emphysema

Emphysema is defined anatomically by permanent destructive enlargement of airspaces distal to the terminal bronchioles. The disease results in loss of elastic recoil, limits expiratory airflow and results in hyperinflation. Severe emphysema limits the patient's exercise capacity due to abnormal pulmonary mechanics.[9] Medical therapy centers on bronchodilators, steroids, use of supplemental oxygen, and pulmonary rehabilitation. In the most advanced forms of emphysema, any improvement in symptoms offered by maximal medical therapy is limited.

Lung volume reduction surgery (LVRS) is a relatively new procedure offered for selected patients with severe emphysema. It is based physiologically on the same principles as giant bullectomy. The goal of LVRS is to resect the most diseased portions of lung, restore the elastic recoil of the remaining lung and improve respiratory mechanics. By re-establishing the normal diaphragmatic configuration, the patient is literally able to 'take a deep breath.' By improving elastic recoil, the patient is better able to expire.

While the concept was introduced first by Otto Brantigan in 1961, no consistent objective improvements, significant morbidity (protracted air leaks) and high mortality (> 20%) led to the abandonment of the procedure.[10] In 1995 Cooper and colleagues reintroduced LVRS, via a median sternotomy for bilateral pleural access.[11] They demonstrated significant objective improvements in pulmonary function and respiratory mechanics in a highly selected group of end stage emphysema patients. Interest in LVRS for diffuse emphysema then surged.

Common issues raised regarding the procedure are the optimal methods for excision, type of access incision and unilateral versus bilateral LVRS. There are acceptable criteria for performing unilateral LVRS.[12,13]

1. unilateral disease
2. pleurodesis
3. previous thoracotomy
4. hemodynamic instability with one lung ventilation
5. contralateral lung transplantation
6. massive air leak after first unilateral LVRS

McKenna and associates demonstrated the benefit of a bilateral operation over the unilateral approach in terms of improvements in FEV1, overall decrease in O2 usage and a lower 1-year mortality.[13] In a separate study, better overall survival was

observed at two years in the bilateral group.[14] Morbidity and mortality in bilateral surgery was not increased compared to unilateral LVRS.

Though Cooper et al used a median sternotomy in their series, the VATS approach gained popularity and bilateral simultaneous or staged procedures showed similar improvements in functional as well as objective data.[11,15,16] Higher mortality occurred in the sternotomy group especially in older patients. In contrast, two large studies (150+ patients) from McKenna using VATS approach or Cooper using median sternotomy demonstrated a similar 50% improvement in FEV1 with low, acceptable and similar mechanisms of mortality and morbidity in both groups.[17,18] Currently a bilateral approach to LVRS is accepted as the procedure of choice.

In the recently instituted prospective, randomized nation wide trial (National Emphysema Treatment Trial–NETT), patient outcomes after bilateral LVRS performed using VATS or median sternotomy will be compared to those achieved with maximal medical therapy. The trial is a coordinated effort between the National Institutes of Health and the Health Care Finance Administration/Medicare to evaluate the safety, efficacy, survival benefit and cost efficiency of the new surgical procedure as compared to best medical therapy.[19]

Patient Selection

Patients eligible for LVRS should demonstrate moderate to severe symptoms from emphysema with pulmonary function tests showing FEV1 of less than 35% and hyperinflation (TLC > 120%, RV > 200%) despite adequate medical therapy. Typical chest radiograph features of emphysematous hyperinflation are flat diaphragms and increased A-P and lateral diameters. Chest CT scans show emphysematous lung destruction, ideally in a mixed pattern with areas of better preserved lung and other regions of resectable, more diseased lung. A quantitative perfusion scan demonstrates the areas of poor perfusion which correspond to targets for resection. All patients are assessed psychologically and should be highly motivated. They are required to undergo 6-8 weeks of cardiopulmonary rehabilitation. Smoking cessation for at least 6 months is mandatory. Steroid therapy is tailored to a low dose (< 20 mg prednisone/day) prior to the operation. Coronary artery disease is assessed for women older than 55 years and men older than 50 years using history, electrocardiography, stress echocardiography, stress thallium imaging and right and left heart catheterization. Exclusion criteria are PaCO2 > 55 mmHg, DLCO < 20% predicted, pulmonary nodule requiring further evaluation, significant bronchiectasis, neoplastic disease with life expectancy less than two years, psychiatric disturbances, significant coronary artery disease and pulmonary hypertension (mean of > 30 mmHg or PA systolic > 45 mmHg).[18,20]

Anesthesia and Postoperative Management

After placement of a thoracic epidural catheter for postoperative analgesia, the patient is intubated with a left-sided double lumen endotracheal tube. The placement is confirmed with a pediatric bronchoscope. This enables the resection of the collapsed lung with ventilation of the opposite side. Perioperative antibiotics are used for 24-48 hours. Inhalation agents are discontinued before wound closure begins to allow sufficient time to excrete volatile agents given ventilatory limitations. Intravenous anesthesia is used at the conclusion of the case until the patient is eucapneic thus facilitating prompt extubation.

Surgical Technique

The patient is positioned supine with the arms extended above the head. The shoulder and arms are protected with foam paddings. Three blanket rolls are placed under the patient in the form of the letter "I" with one across the shoulder, one across the hips, and one occupying a middle, vertical position (Fig. 3.2). The patient is secured to the surgical table with wide tape adding security when the table is rotated laterally. The lumen of the split endotracheal tube supplying the initial operative side is clamped while positioning the patient. This allows sufficient time for lung deflation from absorption atelectasis. The skin is prepped from the neck to the umbilicus and as far lateral as possible. The special position allows a more posterior placement of the last working port. The camera port is placed in the anterior axillary line in the seventh intercostal space. Care has to be taken on entry into the pleural space with open technique to prevent lung injury and to perfect hemostasis. A 10 mm 30° video thorascope is introduced and the pleural space is inspected. The second and third ports are then placed under endoscopic guidance anteriorly along the submammary line in the midclavicular line and posteriorly in front of or just inferior to the scapular tip (Fig. 3.3). Adhesions are divided with electrocautery.

Emphysematous lung traps air and remains inflated despite clamping of the endotracheal tube. This and prior radiological imaging data identify the targets for resection. The diseased lung is grasped with a ring forceps and we use the ELC (60, 45, 30 mm)—Auto suture stapling device. Resection begins by excising tissue over the surface of the most diseased lung, usually in the upper lobe. The staple line is buttressed with bovine pericardium or PTFE. The staple lines are continued carefully such that the margins overlap, helping seal potential air leaks.[21] Strict care has to be taken to grasp only lung that is to be resected. The excised lung should form a gentle curve. This shape allows easy apposition of the remaining lung to the parietal pleura, reducing potential space problems. In general, about 30% of the volume of each lung is removed. For lower lobe emphysema the camera port may be switched to the anterior position. The inferior ligament is released when space problems are likely and this also facilitates lower lobe stapling. The specimen is placed in an endosac or other bag retrieval device and extracted through the largest port. This lowers the risk of port site contamination from incidental cancer in the resected lung.

After ensuring hemostasis at the port sites and along each staple line, two thoracostomy tubes are placed under direct visualization. Both are directed to the apex for upper lobe resections while for LVRS involving lower lobe targets, one tube should be directed to the base. The lung is re-expanded slowly. The tubes are secured and the last wound is closed in an airtight fashion. The patient is rotated to the opposite side and the procedure is repeated. [22]

Postoperative Care

At the end of the operation the patient is ventilated to eucapnea then weaned off the ventilator and extubated, preferably in the operating room. Inhalation anesthetics are discontinued as early as is feasible during the procedure with intravenous and epidural anesthetics as the preferred agents. As all these patients have ventilatory limitation, a protracted emergence results when volatile agents are used until final wound closure. We transfer all LVRS patients to the cardiothoracic intensive care unit for ventilatory observation. The chest tubes are placed to water seal. Low suction

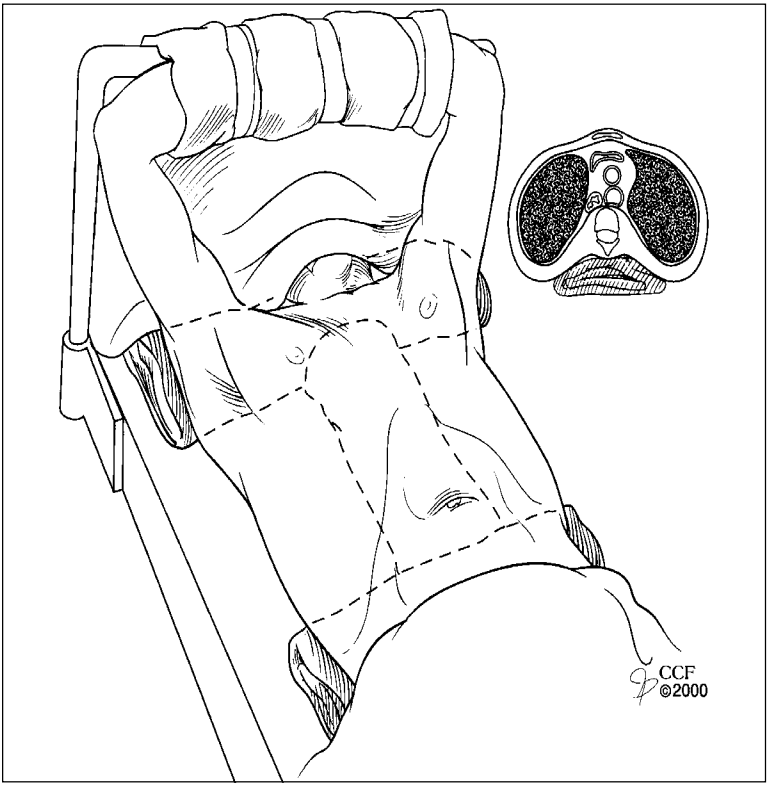


Fig. 3.2. Suggested position of the patient for bilateral video-assisted lung volume reduction surgery. The patient is elevated from the table by blanket rolls under the shoulders and hips and along the spine. The arms are padded and secured above the head providing posterior axillary access.

is applied where there is a space problem or progressive subcutaneous emphysema. Aggressive chest physiotherapy and early mobilization are crucial. Adequate pain relief is provided with thoracic epidural anesthesia or patient controlled analgesic pumps. Chest tubes are removed using the usual criteria for lung resection. If prolonged airleaks are encountered, pleural sclerosants are tried and/or a Heimlich valve is placed to promote early hospital discharge.[23]

Results

Most reported series show mean improvements in FEV1 of 50% in the early postoperative period (6 weeks to 6 months). Two large studies utilizing stapled resection[17,18] that compared median sternotomy with VATS showed similar improvements. Stammberger et al performed VATS LVRS on 143 patients. Improvements in FEV1 were 43% at the time of discharge.[24] These improvements were sustained and the gain remained statistically significant one year later. Residual volume (RV)

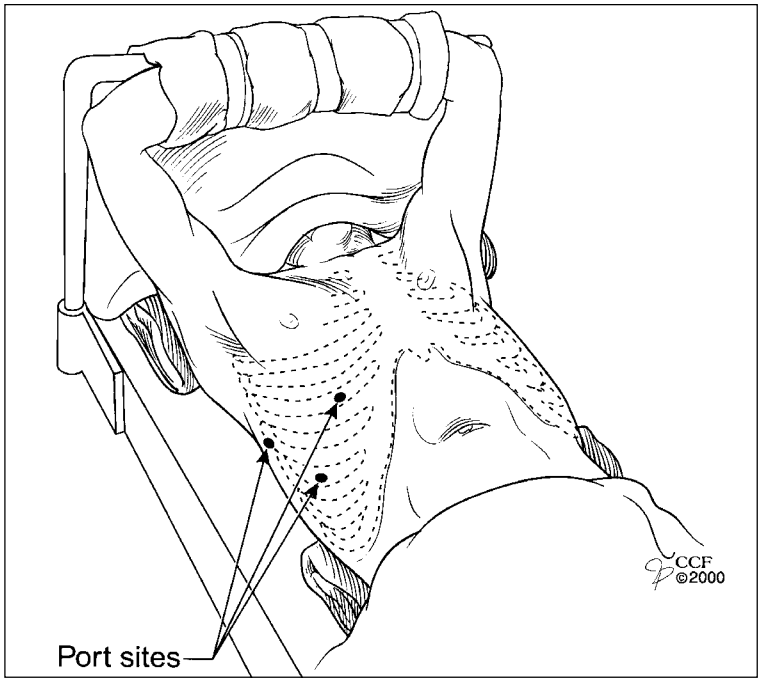


Fig. 3.3. Standard port position for approaching the right lung during bilateral VATS LVRS. Left sided port positions will be the mirror image (not shown).

and the ratio of residual volume to total lung capacity (TLC) were reduced significantly in the early postoperative period documenting an actual reduction in overall lung volume. RV and TLC slowly begin to rise at the end of one year but the decrease in ratio was preserved. Symptomatic improvements were dramatic—in many patients as early as a few days after surgery. Exercise capacity as shown by 6 minute walk test improved between 28-59%.[15,24,25]

Several questions regarding the utility of LVRS as appropriate therapy for emphysema remain unanswered. Patients with heterogenous emphysema profit most from LVRS. This was initially a key selection criteria in many series. It is possible that a similar benefit may be achieved in homogenous emphysema from improvements in pulmonary mechanics, improvement in expiratory airflow and enhanced elastic recoil.

Long-term follow-up is required to define the durability of the operation. Whether LVRS extends survival in patients with severe emphysema is unknown. Perhaps more importantly, a careful analysis of the impact of LVRS on exercise capacity and quality of life will more appropriately define the utility of this intervention. Once completed, the NETT trial should definitively answer these controversial questions regarding lung volume reduction and help clinicians refine patient selection criteria.[19]

Thorascopic Lung Biopsy for Interstitial Lung Disease

Interstitial lung disease (ILD) represents a heterogeneous group of lung conditions of both known or unknown etiologies. When presenting to the surgeon, patients with ILD are usually symptomatic with progressive dyspnea and a dry, nonproductive cough. Spirometry demonstrates a restrictive defect with diminished lung compliance and a loss of diffusing capacity. Patients become hypoxic initially manifest by desaturation with exercise and eventually require supplemental oxygen continuously. Peripheral, patchy pulmonary infiltrates are often visible on chest radiographs. Two clinical scenarios typify the disease symptomatology. The first is a slow progression of dyspnea and hypoxia with diminished exercise tolerance accompanied by increasing radiographic abnormality. The other is characterized by fulminant respiratory failure and rapid deterioration of the patient leading rapidly to the need for mechanical ventilation.

Initial investigations of patients with ILD involve routine sputum cultures and cytology. This is time consuming and the diagnostic yield is low. Bronchoscopy and lavage increase the yield especially in cases with infective causes and the yield may be improved further with transbronchial biopsies. Diagnostic yield from transbronchial biopsies have been reported to be between 37.7-59%.[26,27] Surgical biopsies are superior in terms of diagnostic yield and allow both pathologic and microbiologic assessment. A discrete diagnosis is defined in greater than 90% of cases in most reported series.[26-28]

The clinical value of a discrete diagnosis in ILD and thus the lung biopsy itself has been controversial. The positive impact of an accurate diagnosis that changes therapy on the clinical outcome is uncertain. In two series, change in therapy did not improve survival.[29,30] In Warner's series the hospital mortality was 30% and the overall one-year survival was only 9%.[30] In contrast, a more recent report, Temes et al demonstrated significant beneficial therapeutic changes were made in 61% of the patients.[31] Overall operative mortality rates were 27% in their series. The major risk factor for perioperative death was the urgency of the operation which relates to the clinical state of the patient at the time of surgery. Patients undergoing elective evaluation for ILD had low operative mortality and morbidity and benefited most from therapy targeted toward the pathology defined by the biopsy. Among the patients who had emergency lung biopsy, the operative mortality was 54% and therapeutic benefit was achieved in only 7% of them. In this group there was no significant difference in survival benefit between those who received therapeutic changes and those who did not. In the subgroup of critically ill patients already on mechanical support, lung biopsy is usually a last resort in the face of end stage respiratory failure and eminent death. A favorable response is difficult to anticipate and underscores the need to consider biopsy earlier in the course of disease.[32]

Imaging

The most common radiographic abnormality in ILD is the presence of bilateral reticular or linear infiltrates often favoring the lower lobes. Late changes may show coarser infiltrates with honeycombing. A ground glass appearance if seen suggests a component of alveolitis. A high resolution CT (HRCT) scan provides detailed images of the parenchyma localizing areas of active interstitial disease, honeycombed regions indicative of end-staged fibrosis, as well as unsuspected nodules and cysts. Areas of ground glass attenuation are more obvious on HRCT than standard CT or plain

radiographs. The HRCT provides the surgeon target areas for appropriate biopsy. However, in a diffuse disease process, identification of a discrete target may not be necessary.[31]

Surgical Technique

The goal of surgical lung biopsy is to obtain an adequate stapled wedge of lung parenchyma. The wedge of lung sent must be representative of the disease process and several biopsies may be necessary to show a gradient of lung parenchymal injury. In the elective situation, a wedge biopsy of each lobe is optimal. As most interstitial disease processes tend to affect lower lobes, single biopsies of the lower lobe usually show extensive damage of the lung (diffuse alveolar damage or endstage fibrosis/honeycomb change). This is the final, common pathway for acute and chronic lung injury respectively. Such single region biopsies should be avoided as little useful clinical information is gained. Though several reports have shown the adequacy of lingular and middle lobe biopsies, at least two wedges of different parts of the lung is preferable in order to demonstrate the spectrum of disease.[33,34]

The technique of lung biopsy in interstitial lung disease is closely linked to the urgency of the procedure. Open techniques are preferred in an ill patient on a ventilator where the risks of increased operative time, single lung ventilation and reintubation with double lumen endotracheal tube are substantial.[31] When the clinical situation permits, elective thoracoscopic techniques should be used. VATS lung biopsies are performed in a full lateral position with double lumen intubation and single lung ventilation (Fig. 3.1). A bronchial blocker can be used especially on the left side where the bronchus is longer which facilitates easy placement and makes migration less likely. Many patients who require supplemental oxygen tolerate single lung ventilation surprisingly well. In case of hypoxia occurring during the procedure, brief intermittent ventilation of the deflated lung or low levels (5 cm water) of continuous positive airway pressure (CPAP) will suffice to allow completion of the procedure.

Three access ports are used. The camera port is placed first in the seventh interspace in the mid axillary line. The lung is inspected and targets for biopsy identified. The edge of the middle lobe along the fissure, the upper lobe along the fissures, the lateral edge of the lower lobe or the superior segment of the lower lobe are the preferred sites. The other ports are placed in the submammary space between the anterior axillary and the midclavicular lines and in the sixth interspace in the midscapular line (Fig. 3.1). They provide access for a lung grasping clamp and endoscopic stapling device. All specimens should be extracted with an impenetrable bag to prevent contamination of the pleura and chest wall. A single chest tube is placed in the posterior gutter directed to the apex. The rest of the ports are closed in layers, with subcuticular skin closure.

The evaluation of specimens are dependent on the immunocompetency of the patient. Frozen section provides important information as to adequacy of the biopsy and may direct further investigations including immunoperoxidase or fungal staining, flow cytometry or electron microscopy. Granulomatous diseases (infective and noninfective) are readily identified on frozen section allowing fresh tissue to be appropriately cultured. Fungal forms (hyphae or buds) or viral inclusion bodies may be identified. In the immunocompromised patient, tissue is also sent for bacterial,

fungal, acid fast bacilli stains and cultures, viral isolation and cultures, PCP stains and occasionally for parasitic cultures.

The need to convert to open minithoracotomy is rare, ranging from 0 to 5.3%.[35,36] This is usually related to inadequate atelectasis, intolerance to single lung ventilation, pleural adhesions or iatrogenic lung injury.[37]

Comparisons have been made between open techniques versus VATS in lung biopsies. The main advantage of VATS is the excellent visualization of nearly the entire lung surface and with some retraction almost any portion of lung can be approached and sampled if necessary. This is of importance where the disease process is nonuniform and biopsies of normal and abnormal lung are desired.[32] Other perceived advantages are shorter hospitalization, decreased operative morbidity and postoperative pain. With the use of smaller sized ports (5 mm) and a single larger port for the endostapler, this advantage can be maximized. In the long term (beyond 3 months), there appear to be no difference in postoperative neuralgia and muscle function between open thoracotomy and VATS.[38]

Role of VATS In Pulmonary Infection

Pulmonary infections are classified broadly into community acquired, nosocomial, aspiration pneumonia and pneumonia in an immunocompromised patient. Thoracic surgeons are involved in the management of all forms of pulmonary infections and often help secure a discrete diagnosis when infection persists despite standard or empiric medical therapy or when there is rapid respiratory deterioration.

Symptoms of pulmonary infection include fever, chills, pleuritic chest pain, and cough with purulent sputum. Constitutional symptoms such headache, nausea, myalgia, arthralgia, and anorexia may predominate. Presentation may vary depending on the patient age, prior antibiotic therapy, and comorbid conditions such as diabetes, chronic renal failure, steroid dependence or other immunosuppressed states.

Identification of the etiologic infectious agent simplifies and optimizes the management of pulmonary infection. While most lung infections are diagnosed clinically, radiologically and with appropriate cultures obtained noninvasively, invasive measures may be required. A variety of invasive methods of obtaining specimens or tissue for culture are available to the pulmonologist. These include bronchoalveolar lavage (BAL), transbronchial biopsy (Tbbx) and transthoracic needle aspiration. These methods provide a high yield for specific diseases. In patients with AIDS with suspected *Pneumocystis carinii*, a 95% diagnostic yield is expected from bronchoalveolar lavage and as such these patients rarely need lung biopsies. In a series reviewed by Murray et al, BAL was accurate in diagnosis of Mycobacterium avium, CMV, Legionella, and active fungal disease in 82 to 95% of cases.[39]

Transbronchial biopsy is complimentary to BAL. Technically more demanding, Tbbx requires a skilled bronchoscopist. Biplane fluoroscopy is useful in localizing the tip of the biopsy forceps in reference to the lesion. The diagnostic accuracy is dependent on the technical expertise of the bronchoscopist, the amount of tissue, its handling and the experience of the pathologist. Average diagnostic yield for microbial agents in immunocompromised patients is 29% in reported series.[40-42] As expected the diagnostic yield is greater with diffuse infiltrates compared to localized lesions. Infectious agents most commonly detected are *Pneumocystis carinii*, Legionella, CMV, Nocardia, mycobacteria and fungi. The small amount of sample and considerable

crush artifact are the main limitations of Tbbx. Complications include pneumothorax (8%) and hemoptysis (7%). Contraindications for this procedure include a known or suspected bleeding diathesis and pulmonary hypertension both associated with significant risks of fatal hemorrhage. Positive pressure ventilation is a relative contraindication with a higher risk of biopsy-induced pneumothorax.

Transthoracic needle aspiration provides another means of obtaining tissue. Tissue samples are small and subject to crush artifact. Its diagnostic yield averages approximately 60-80% in immunocompromised patients and about 40% in patients with diffuse pulmonary infiltrates. Major complications include pneumothorax and bleeding in 20-60% of patients.[43] The risk of mortality associated with these complications largely influenced internists to abandon this procedure for open lung biopsy which provides a greater diagnostic yield with a similar or lower complication rate.

Surgical lung biopsy provides the most optimal specimens of diseased lung for histopathologic examination and microbiologic study. It provides sufficient lung tissue for diagnosis and allows sampling of different sites. In the immunocompromised host, the need to exclude noninfectious causes of diffuse lung infiltrates (e.g., drug induced pneumonitis, lymphocytic interstitial pneumonia, Kaposi sarcoma) makes surgical lung biopsy particularly useful. The diagnostic yield for infectious agents from surgical lung biopsy varies from 34-91%.[44] Reviewing several series, the average overall yield as 69%.[45]

Surgical lung biopsy via a thoracotomy is the procedure of choice for the patient on a ventilator requiring high levels of positive airway pressure and/or a high level of inspired oxygen. These patients are unable to tolerate single lung ventilation and even the change of endotracheal tube to a double lumen tube or the placement of a blocker may be hazardous. Most elective and semiurgent lung biopsies can be done via the VATS technique which provides results equivalent to thoracotomy in terms of tissue sampling. With video assistance the entire lateral surface of the lung can be visualized and allows the surgeon to perform biopsies of diseased and nondiseased areas.

Indications for VATS in the assessment pulmonary infection include:

1. Presence of diffuse or focal pulmonary infiltrates
2. Peripheral nodule/nodules
3. Ability to tolerate single lung ventilation
4. Associated pleural effusion

Technique

VATS lung biopsy is performed under general anesthesia with selective bronchial intubation and single lung ventilation. The patient is placed in the lateral position with the ipsilateral arm abducted and fixed to the ether screen such that the axilla is exposed to allow placement of a port or minithoracotomy if required (Fig. 3.1). Care is taken to avoid neural injury to the arm by avoiding undo tension on the brachial plexus in the axilla and with appropriate padding around the elbow. The operating table is flexed at the hip, widening the intercostal spaces and deflecting the hips away from the operative field. The camera port (10 mm) is placed in the seventh space in the midaxillary line. The pleural space is then inspected and any significant effusion is collected for culture to evaluate for coexistent empyema. The second and third ports (5 mm or 10 mm) are placed under thoracoscopic guidance

in positions similar to those used for VATS biopsy for ILD (Fig. 3.1). In a patient with a diffuse lung process, wedge biopsies are taken with the use of the endostapler, from the edges of the affected lobe as well as areas which are relatively uninvolved. All specimens are retrieved in bags to protect against port site contamination. Fresh tissue should be submitted immediately for culture with meticulous sterile technique, with a matching sample evaluated by frozen section for histopathology. Where there is a nodular lesion seen on chest radiograph and defined by CT scan, one port is placed perpendicularly over it such that the surgeon's index finger can be introduced to palpate the lesion. Localizing the lesion by tactile sense guarantees a definitive biopsy. Wedge excision of the lesion is taken with a margin of normal lung.

To reduce the risk of postoperative neuralgia, there should minimal manipulation of the access port sites. Improved videoscopic equipment including smaller cameras and ports (5 mm) may be used. Only one chest tube is necessary and is placed through the original camera port site. It can be removed on the next postoperative day.

Handling of Specimens

It is imperative that the specimens be handled carefully such that crush artifact is minimized. With the use of stapling devices to perform wedge biopsies instead of punch biopsies utilizing cupped biopsy forceps, this problem is reduced considerably.[46] Tissue specimens are sent for histopathological examination including hematoxylin and eosin stain, Ziehl-Nielsen stain, KOH preparations, methenamine stain—(for *Pneumocystis carinii*), and Gram's stain. Frozen sections are performed where early and urgent diagnoses are required to help focus therapy. Tissue specimens are divided with sterile technique in the operating room and may be submitted for aerobic and anaerobic culture, mycobacteria and fungal culture, Legionella, mycoplasma, *Pneumocystis carinii*, nocardia, and CMV isolation and/or staining. This panel of studies is tailored to each patient based on the specific clinical scenario and the immune status of the host.

References

1. Morgan MD, Edwards CW, Morris J et al. Origin and behavior of emphysematous bullae. Thorax 1989; 44:533-8.
2. Wesley JR, Macleod WM, Mullard KS. Evaluation and surgery of bullous emphysema. J Thorac Cardiovasc Surg 1972; 63:945-5.
3. Iwa T, Watanabe Y, Fukatani G. Simultaneous bilateral operations for bullous emphysema by median sternotomy. J Thorac Cardiovasc Surg 1981; 81:732-7.
4. Gaensler EA, Jederline PJ, FitzGerald MX. Patient work-up for bullectomy. J Thorac Imaging 1986; 1:75-93.
5. Morgan MD, Denison DM, Strickland B. Value of computed tomography for selecting patients with lung disease for surgery. Thorax 1986; 41:855-62.
6. Wakabayashi A. Thoracoscopic technique for management of giant bullous lung disease. Ann Thorac Surg 1993; 56:708-12.
7. Yim AP, Ho JK. Video assisted thoracoscopic staple resection of a giant bulla. Aust N Z J Surg 1996; 66:495-7.
8. Tsuchida M, Nakayama K, Shinonaga M et al. Video-assisted thoracic surgery for thoracoscopic resection of giant bulla. Surg Today 1996; 26:349-52.
9. Gallagher CG. Exercise limitation and clinical exercise testing in chronic obstructive pulmonary disease. Clin Chest Med 1994;15:305-26.

10. Brantigan DC, Kress MB, Mueller EA. The surgical approach to pulmonary emphysema. Dis Chest 1961; 39:485-501.
11. Cooper JD, Trulock EP, Triantafillou AN et al. Bilateral pneumectomy (volume reduction) for chronic obstructive pulmonary disease. J Thorac Cardiovasc Surg 1995;109:106-16.
12. Fischel RJ, McKenna RJ, Jr. Video-assisted thoracic surgery for lung volume reduction surgery. Chest Surg Clin N Am 1998; 8:789-807.
13. McKenna RJ Jr, Brenner M, Fischel RJ et al. Should lung volume reduction for emphysema be unilateral or bilateral? J Thorac Cardiovasc Surg 1996;112:1331-8.
14. Serna DL, Brenner M, Osann KE et al. Survival after unilateral versus bilateral lung volume reduction surgery for emphysema. J Thorac Cardiovasc Surg 1999;118:1101-9.
15. Kotloff RM, Tino G, Bavaria JE et al. Bilateral lung volume reduction surgery for advanced emphysema. A comparison of median sternotomy and thoracoscopic approaches. Chest 1996;1106:1399-406.
16. Wisser W, Tschernko E, Senbaklavaci O et al. Functional improvement after volume reduction: Sternotomy versus videoendoscopic approach. Ann Thorac Surg 1997; 63:822-7.
17. McKenna, RJ Jr, Brenner M, Fischel RJ et al. Patient selection criteria for lung volume reduction surgery. J Thorac Cardiovasc Surg 1997;114:957-64.
18. Cooper JD, Patterson GA. Lung-volume reduction surgery for severe emphysema. Chest Surg Clin N Am 1995; 5:815-31.
19. The National Emphysema Treatment Trial Research Group. Rationale and design of the National Emphysema Treatment Trial (NETT): A prospective randomized trial of lung volume reduction surgery. J Thorac Cardiovasc Surg 1999; 118:518-528.
20. Yusen RD, Lefrak SS. Evaluation of patients with emphysema for lung volume reduction surgery. Washington University Emphysema Surgery Group. Semin Thorac Cardiovasc Surg 1996; 8:83-93.
21. Cooper JD. Technique to reduce air leaks after resection of emphysematous lung. Ann Thorac Surg 1994; 57:1038-9.
22. Vigneswaran WT, Podbielski FJ, Halldorsson A et al. Single-stage, bilateral, video-assisted thoracoscopic lung volume reduction surgery for end-stage emphysema. World J Surg 1998; 22:799-802.
23. McKenna RJ Jr, Fischel RJ, Brenner M et al. Use of Heimlich valve to shorten hospital stay after lung reduction surgery for emphysema. Ann Thorac Surg 1996; 61:1115-7.
24. Stammberger U, Bloch KE, Thurnheer R et al. Exercise performance and gas exchange after bilateral video-assisted thoracoscopic lung volume reduction for severe emphysema. Eur Respir J 1998;12:785-92.
25. Miller JI Jr, Lee RB, Mansour KA. Lung volume reduction surgery: Lessons learned. Ann Thorac Surg 1996; 61:1464-8.
26. Wall CP, Gaensler EA, Carrington CB et al. Comparison of transbronchial and open biopsies in chronic inflitrative lung diseases. Am. Rev. Respir. Dis. 1981; 123:280-5.
27. Burt ME, Flye MW, Webber BL et al. Prospective evaluation of aspiration needle, cutting needle, transbronchial, and open lung biopsy in patients with pulmonary infiltrates. Ann Thorac Surg 1981; 32:146-53.
28. Gaensler EA, Carrington CB. Open biopsy for chronic diffuse infiltrative lung disease: Clinical, roentgenographic, and physiological correlations in 502 patients. Ann Thor Surg 1980; 30:411-26.

29. Thomas JH, Farek PE, Hermreck AS et al. Diagnostic value of open lung biopsy in immunocompromised patients. Ann J Surg 1987; 154:692-5.
30. Warner DO, Warner MA, Divertie MB. Open lung biopsy in patients with diffuse pulmonary infiltrates and acute respiratory failure. Ann Rev Respir Dis 1988; 137:90-4.
31. Temes RT, Joste NE, Qualls CR et al. Lung biopsy: Is it necessary? J Thorac Cardiovasc Surg 1999; 118:1097-100.
32. Ferson PF, Landreneau RJ. Thoracoscopic lung biopsy or open lung biopsy for interstitial lung disease. Chest Surg Clin N Am 1998; 8:749-62.
33. Miller RR, Nelems B, Muller NL et al. Lingular and right middle lobe biopsy in the assessment of diffuse lung disease. Ann Thorac Surg 1987; 44:269-73.
34. Wetstein L. Sensitivity and specificity of lingular segmental biopsies of the lung. Chest 1986; 90:383-6.
35. Bensard DD, McIntyre RC Jr, Waring BJ, Simon JS. Comparison of video thoracoscopic lung biopsy to open lung biopsy in the diagnosis of interstitial lung disease. Chest 1993; 103:765-70.
36. Krasna MJ, White CS, Aisner SC et al. The role of thoracoscopy in the diagnosis of interstitial lung disease. Ann Thorac Surg 1995; 59:348-51.
37. Zegdi R, Azorin J, Tremblay B et al. Videothoracoscopic lung biopsy in diffuse infiltrative lung diseases: A 5-year surgical experience. Ann Thorac Surg 1998; 66:1170-3.
38. Landreneau RJ, Mack MJ, Hazelrigg SR et al. Prevalence of chronic pain after pulmonary resection by thoracotomy of video-assisted thoracic surgery. J Thorac Cardiovasc Surg 1994; 107:1079-85.
39. Murray JF, Felton CP, Garay SM et al. Pulmonary complications of the acquired immunodeficiency: A report of a National Heart, Lung and Blood Institute workshop. N Engl J Med 1984; 310:1682-8.
40. Nishio JN, Lynch JP 3d. Fiberoptic bronchoscopy in the immunocompromised host: the significance of a "nonspecific" transbronchial biopsy. Am Rev Respir Dis 1980; 121:307-12.
41. Poe RH, Utell MJ, Israel RH et al. Sensitivity and specificity of the nonspecific transbronchial lung biopsy. Am Rev Respir Dis 1979; 119:25-31.
42. Shelhamer JH, Toews GB, Masur H et al. NIH conference. Respiratory disease in the immunosuppressed patient. Ann Intern Med 1992; 117:415-31.
43. Herman PG. Needle biopsy of the lung. Ann Thorac Surg 1978; 26:395-6.
44. Bartlett JG. Invasive diagnostic techniques in pulmonary infections. In: Pennington JE, ed. Respiratory Infections—Diagnosis and Management, 3rd edition New York: Raven Press 1994:73-99.
45. Matthay RA, Moritz ED. Invasive procedures for diagnosing pulmonary infection. A critical review. Clin Chest Med 1981; 2:3-18.
46. Swartz MN. Approach to the patient with pulmonary infections. In: Fishman AP, ed. Fishman's Pulmonary Disease and Disorders. 3rd edition. New York: McGraw-Hill 1997:1905-37.

Pulmonary Nodules and Masses

Joshua R. Sonett

Thoracoscopy has gained its widest acceptance and most common utility to date in the diagnosis of pleural diseases and in the evaluation of the indeterminate pulmonary nodule. Although the algorithm for the evaluation of pulmonary nodules is commonly debated, it is now well accepted that the use of thoracoscopy is an essential element in the final diagnosis in many of these lesions. Since there are over 150,000 thousand patients diagnosed annually with solitary lesions, the currently practicing thoracic surgeon must consider the thoracoscopic resection of pulmonary nodules as an essential and critical technique in the care and evaluation of their patients.[1]

The Solitary Nodule

The work up and evaluation of solitary pulmonary nodules must be individualized for patients characteristics and their particular radiological findings. Thus no one algorithm can completely guide the work up of these patients. To avoid the potential error of missing a malignant lesion, the basic tenet of our group's approach is to consider each lesion as malignant until proven to be benign. At the same time we try to minimize operative procedures in patients with benign disease.

As always, the evaluation of a patient begins with a careful history and physical exam. In this respect, the evaluation of a new solitary lesion in a 70 year old smoker proceeds differently than a 30 year old nonsmoker with a recent upper respiratory tract infection. Additionally, the use of thoracoscopy in the diagnosis depends on the location that determines depth of the lesion, and the resultant ease and morbidity of a thoracoscopic resection. These patients usually present after a chest radiograph and CT scan has identified a new lesion, but before a biopsy has identified the lesion as benign or malignant. Since most central lesions are diagnosed by bronchoscopy, the patients evaluated by the thoracic surgeon require triage to percutaneous CT biopsy, thoracoscopic wedge resection, or possibly positron emission topography (PET) scan. In general, lobectomy (thoracoscopic or open) should be performed only after confirmation of malignancy.

Imaging Considerations: Noninvasive Evaluation

In an ideal world, the preoperative diagnosis of benign versus malignant disease could be attained by totally noninvasive techniques. High Resolution CT scans (HRCT) and PET offer hope in this area, but will always fall short of definitive

tissue diagnoses. However, selective use of these modalities may continue to decrease the need for invasive procedures in benign disease.

At present, the CT scan is the primary imaging modality for the solitary pulmonary nodule, and may soon become the standard screening tool rather than chest radiograph.[2] Lesions evaluated by conventional CT scans display certain characteristics suggestive of benign versus malignant disease like fat and calcium distribution consistent with hamartoma, vascular markings of AVM or sequestration.[3] The sensitivity of and specificity of CT scans improve when oral or intravenous contrast is used. Enhancement of a nodule to >25 Hounsfield units (HU) is strongly suggestive of malignancy, while lesions that measure <15 HU are more likely to be benign.[4] This technique is an improvement over standard CT scans but is difficult to reproduce at all centers, and may still leave the patient with a nodule that has a 10-20% chance of malignancy.

Positron Emission Tomography (PET) scan is the newest modality to offer hopes of noninvasive diagnosis. PET scan using an analogue of glucose to measure functional metabolic activity of a lesion and may differentiate benign from malignant lesions that are > 1cm. An overall sensitivity, specificity, and accuracy of 96%, 88%, and 94% respectively may be attained in the detection of malignancy.[5] Although very promising, the technique still needs further widespread validation. It will continue to leave patients with a "nonmalignant" reading with a 10-15% chance of malignancy. Although a 90% chance of not having a malignancy is appealing, that degree of uncertainty in an individual patient may still be unacceptable or at a minimum repeated CT scans are required to exclude growth of the lesion. Hence, a biopsy is required for safety.

Percutaneous Biopsy versus Thoracoscopic Resection: The Solitary Lesion

The use of percutaneous needle biopsy to identify malignant disease is well documented; however, the ability of percutaneous biopsy to prove benign disease is limited achieving definitive diagnoses of benign disease in only about 20% of patients.[6] The other 80% have either malignant or indeterminate diagnoses that require nodule excision for a definitive pathologic diagnosis and/or potential curative resection. Thus in candidates for definitive resection, the preoperative diagnosis of malignant disease by percutaneous biopsy may not alter the course of their treatment, so one may proceed directly to thoracoscopy.

The superiority of VATS over open thoracotomy in the resection of peripheral nodules was shown by its significantly less acute pain and fewer hospital days.[7] VATS wedge resection may be performed with a less than 1% rate of mortality or significant morbidity. Conversion to open thoracotomy now approaches just 1% and is usually necessitated by the inability to locate a nodule.[8] The only significant contraindication to thoracoscopic resection is a previous thoracotomy with evidence of pleural symphysis, yet this is not absolute given reports of successful repeat thoracoscopy.[9]

Thoracoscopy may yield evolving and unique benefits in the overall treatment of lung cancer. At initial thoracoscopy, as many as 5% of operative candidates will be found to have occult malignant effusions or other signs of metastatic disease.[10] Additionally, the routine use of operative thoracoscopy enables the surgeon to consider

more complex operations like VATS Lobectomy. Thus the use of thoracoscopic resection of the indeterminate nodule allows definitive diagnosis, detection of occult advanced disease, and smaller operative approaches for definitive resections. The combined attributes of this technique may justify the expense of thoracoscopic instruments and operative time. Also, early definitive diagnosis in patients with benign disease avoids costly repetitive radiological surveillance.

Multiple and Bilateral Pulmonary Lesions/ Metastatic Disease

Multiple and bilateral pulmonary lesions often represent metastases. Evaluations are directed initially at finding active sources of the metastatic disease, or documenting previously treated cancers that may have metastasized. The next question is whether the pulmonary lesions are resectable with curative intent or for diagnosis alone. If the patient has a known treated primary malignancy with no evidence of recurrence outside of the chest, then pulmonary metastases should be evaluated for curative resection. If a patient can have all metastatic lesions completely resected, a large amount of historical data supports aggressive resection of single or multiple lesions. Pulmonary metastasectomy has been validated for many nonhematologic malignancies and has an overall 5, 10, and 15 year survival after complete metastasectomy of 36%, 26%, and 22% respectively.

The use of thoracoscopy in the diagnosis of pulmonary metastases is well accepted, and widely practiced; however the therapeutic use of VATS in pulmonary metastasectomy remains controversial. Opponents of VATS argue that lack of manual palpation of the lung will leave metastatic deposits missed by noninvasive techniques within the parenchyma adversely affecting the therapeutic effect of pulmonary metastasectomy. Data cited to support this argument were not derived from current spiral CT scanning technology that can detect nodules as small as 3 mm.[11] Additionally, this argument against the use of VATS must, by logical extension, favor mandatory bilateral-manual exploration for all patients undergoing therapeutic metastasectomy. In lieu of definitive data to support either approach, the thoracic surgical community should prospectively test and validate all new techniques and technologies before widespread implementation or disparagement.[12]

Other Masses: AVMs and Sequestration

Despite the deficiencies of noninvasive testing, probable benign diagnoses may be made for some lesions. Some of these are sequestration, A-V malformations, aspergilloma, and other cavitary-inflammatory lesions that may have unique CT scan characteristics. Although benign, their resection may prevent infectious and hemorrhagic complications. The feeding vessels of vascular malformations may be clearly identified on CT scan; however confirmation of the malformations may be advisable before thoracoscopic removal. Early resection of cavitary lesions is especially important in immunocompromised patients with HIV or posttransplant immunosuppression. Minimally invasive resection of these masses may be ideally suited to VATS as a large wedge resection, or VATS lobectomy if necessary. When approaching a probable sequestration, preoperative angiography may enhance the diagnosis and identify anomalous vessels that require ligation with vascular staples.

Operations: Wedge Resection

The operative techniques for simple wedge excision have been well described and reflect the common use of this important technique. However, technical modifications and port placement decisions must be individualized for each patient based on the location of each nodule. As with most thoracoscopic procedures, the patient will be intubated with a double lumen tube and positioned in the lateral decubitus position. An electric operating room table is used for easy anterior and posterior rotation as well as trendelenburg and reverse trendelenburg positions in order to enable gravity to help manipulate and visualize the lung. Television monitors should be placed at the head of the bed (and the foot if there are any lesions near the diaphragm that may require visualization in a caudal direction). Such placement avoids mirror imaging. Equipment for CO2 insufflation should be available to help collapse the lung or invert the diaphragm. If CO2 insufflation is used, continuous arterial monitoring ensures that there is no component of tamponade. Intrapleural pressure should be limited to 10-12 mmHg.

Specific Instruments and Disposables

Routinely we start each case with an operating scope that has a 5 mm access channel. 5 mm instruments (45 cm long), are used through the access channel. This initial manipulation of the lung may localize the lesion and enable more accurate port placement. A 45 cm long scissors with bovie electraucautery used through the operating scope allows adhesions to be released from the chest wall so that additional ports can be placed safely. After the lung is partially compressed, a long blunt working port probe gently sweeps and deforms the lung to looking and "feeling" for the lesion. A curved and straight Masher (Pilling-Weck) is extremely helpful to localize a lesion and compress the lung in order to allow safe stapling and adequate parenchymal margin. These instruments, designed for thoracoscopy, have long 8 mm manipulating jaws that gently compress long segments of lung. In order to staple deeper, thicker segments of lung, the EZ 45™ stapler (Ethicon), has a wide and long opening aperture, and should be available in the operating room.

In general all operating ports should be placed as anterior as possible, and port placement posterior to the scapula tip should be avoided. This takes advantage of wide rib interspaces and decreases the chance of chronic intercostal nerve pain. Although the port placement should be individualized for the location of each lesion, a general port configuration is recognized. For simple wedge resection of a nodule, we utilize a pie or pizza slice configuration (Fig. 4.1). In this configuration the camera and stapler are oriented in an almost parallel line of visualization with the lesion, facilitating intraoperative manipulation and avoiding the difficulty of mirror imaging. For many lesions, the manipulating port situated above the target can be either a 5 mm trocar for thoracoscopic instruments or a 5 mm incision with direct placement of a standard sponge forceps. For areas identified using the operating scope, a 5 mm camera is placed in the most inferior position, and the most anterior 10 mm port is used for the stapler. Thus the case proceeds with two 5 mm ports and instruments and only one 10 mm port. Utilizing this general configuration, specific port placement can be planned as directed by the location of the lesion. Different configurations for superior, middle, and lower lobe problems are depicted in Figures 4.2, 4.3, and 4.4.

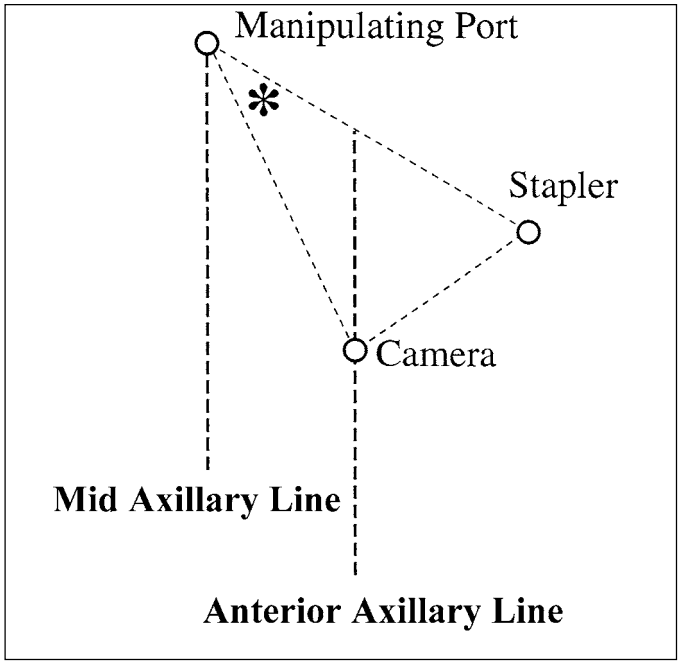


Fig. 4.1. Pie configuration for VATS resection of nodules. All ports as anterior as possible.

Lesion localization and resection are guided by the CT scan and by intraoperative "palpation" (using thoracoscopic instruments). Careful evaluation of the CT scan with special attention to lesion lobar position and its proximity to a fissure allows focussed palpation of the lung. I find it helpful to draw a point on the chest wall over my estimate of the lesion's location. The three port "pie" placement can then be approximated around that point. Using the scapula tip as a reference on the CT scan (internal to external reference point), the specific location is predicted by measuring the parenchymal lesion on CT to the palpable fixed reference point of the scapula tip. After the mass is located a resection line is planned, palpated, and compressed, using an atraumatic thoracoscopic instrument (Pilling-Weck Masher). If a safe resection margin can be attained, the EZ-45 stapler may then be used to resect the lesion. As the staples are applied, the instrument placed through the manipulating port gently lifts the stapled lung tissue, to expose the apex of the staple line. It is important not to directly squeeze, grasp, or manipulate the lesion. The stapled specimen is then placed in a protective bag and removed from the chest. **All thoracoscopy tissue samples should be removed in a protected bag, even if the lesion is probably benign; this prevents the possible contamination of the chest wall.**

Table 4.1. Pulmonary nodulectomy setup

General Operative Procedure	VATS Lung nodule Resection
Preoperative preparation	May need CT needle localization
Anesthetic concerns	Double lumen Endotracheal Tube
Other endoscopic equipment needed	Intubating Bronchoscope
Patient positioning Patient monitoring Catheters	Lateral Decubitus Arterial line if lobectomy possible Bladder catheter if lobectomy Possible
Video system needed	0 and 30 degree Telescope Operating scope
Special Supplies Nondisposable Disposable instruments*	 Curved and Straight Masher Grasping forceps, Pilling Weck Ports, US Surgical Thoracoport™
Specimen extraction sac • Endo GIA-30™, 3.5 mm; EZ-45™-Multiple reloads • YAG laser for Deep Nodule.	
Instruments needed to open chest	Thoracotomy tray Small Finechetto
Postoperative Care	Special silicone chest tube if VATS

Localization Considerations

With experience and patience, most peripheral nodules are identified with standard thoracoscopic techniques. For lesions not initially seen on the pleural surface, methodical palpation of the lung is warranted. This is done by slowly "sweeping" over the lung parenchyma with a long straight instrument. Small nodules can be felt or seen in this manner, as the mass will "pop out" from under the instrument. For lesions that are small and several centimeters below the visceral pleura, direct palpation is difficult or ineffective. In this case, preoperative percutaneous localization or a large wedge resection or segmentectomy of the region suspected by CT scan are options. I personally dislike 'blind' resections, as the lung is distorted more by blind resection. If the lesion is not in the specimen, direct manual palpation of the lung becomes necessary.

To avoid this intraoperative dilemma, percutanous localization can be performed with CT scan. Wire localization, combined with methylene blue injection, are performed immediately preoperatively and are well-described.[13] Since percutaneous wire localization may cause a pneumothorax, it should take place immediately before the OR start time. The small amount of methylene blue injected into the region of the

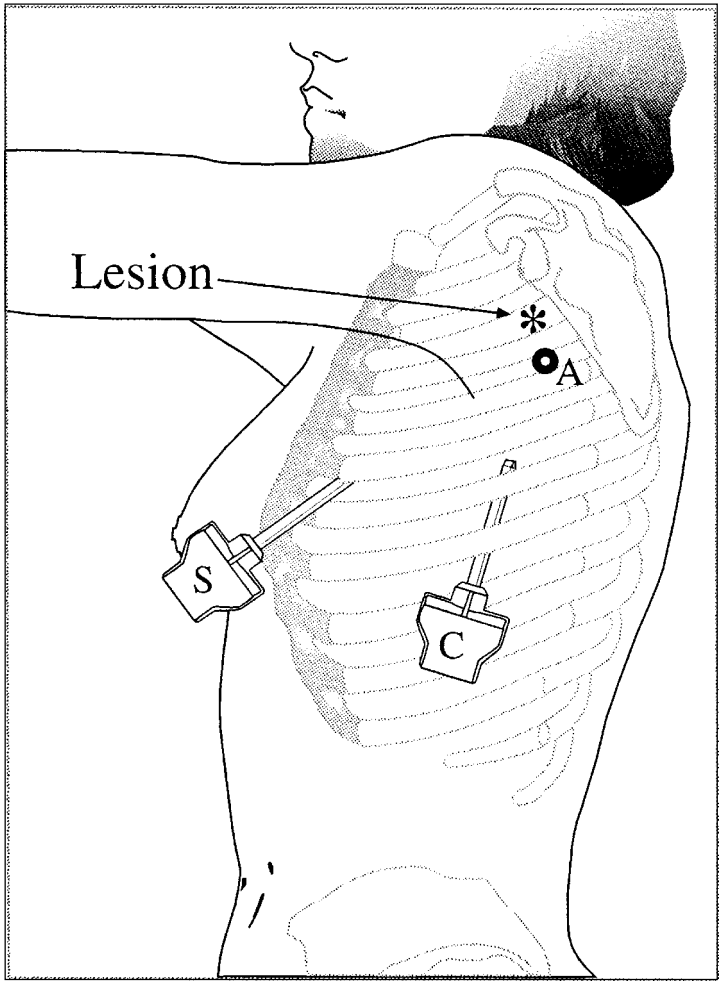


Fig. 4.2. Port placement for upper posterior segment lesion of lung.

lesion is extremely helpful as the needle localization wire may become dislodged with induction of single lung anesthesia and induced lung collapse. Several investigators described the use of intraoperative ultrasound to locate parenchymal lesions. This technique appears labor intensive, but exciting, and needs validation at other institutions.[14]

To date, surgeons rely primarily on their personal experience to preoperatively assess the feasibility of completing a safe VATS nodulectomy. Mathematical equations, based on exact preoperative CT scan measurements, as developed by Demmy et al may make preoperative assessment of patients more

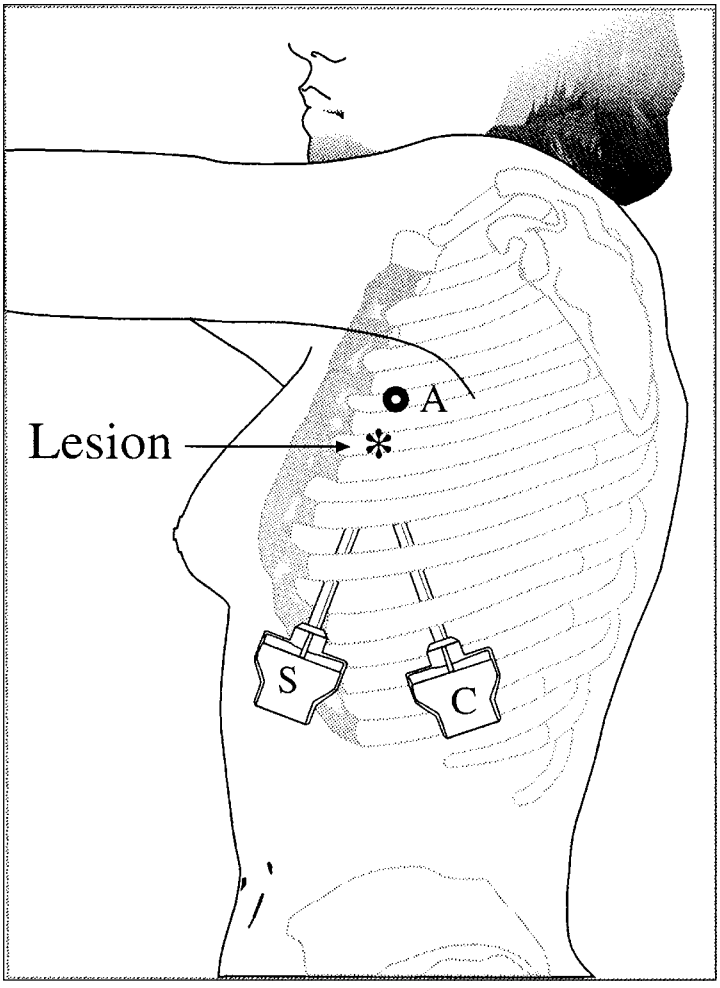


Fig. 4.3. Port placement for anterior lesion of the upper lobe .

objective and transferable.[15] **Of utmost importance is the concept that it is unacceptable to leave the operating room without removing the lesion that warranted thoracoscopy.** If the lesion can not be located thoracoscopically, open palpation of the lung should be performed. This should be considered an expectation rather than a complication.

Modification for Deep Nodules

Wedge resections of deep nodules are very challenging procedures by open thoracotomy and are especially difficult thoracoscopically. Three approaches to these

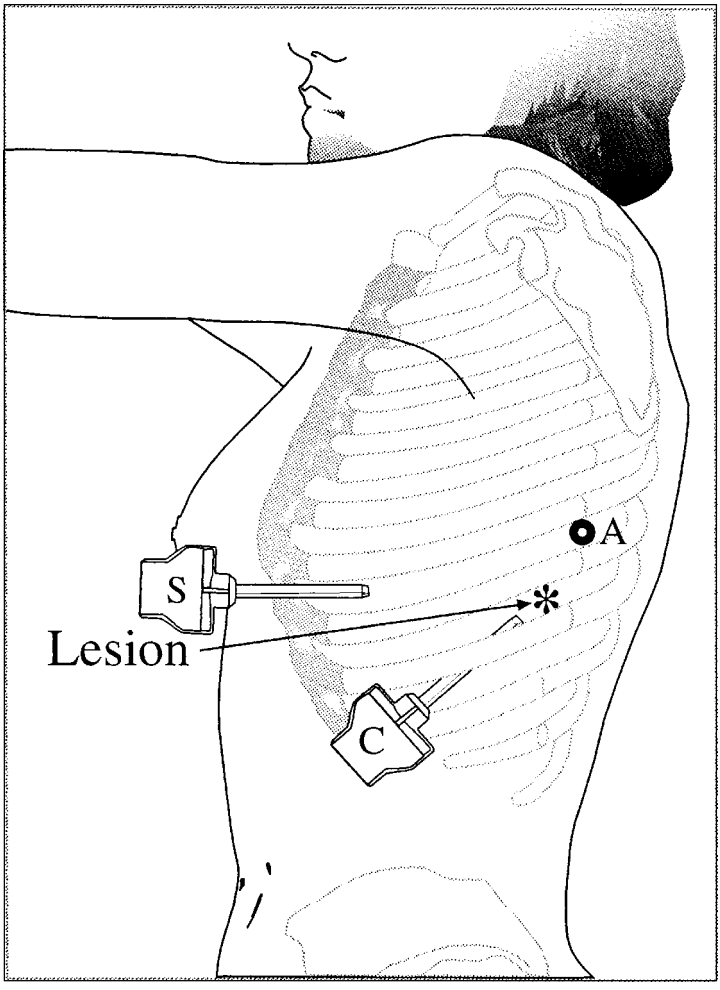


Fig. 4.4. Port placement for lower lobe posterior location of lung lesion.

lesions are large segmental resection, deep stapled nodulectomy, and cautery/laser assisted nodulectomy. Stapled segmentectomy is simpler, avoids difficult intraoperative localization, but may result in the resection of a large amount of normal lung parenchyma. Lesions situated in the anterior segments of the upper lobes, lingula, or superior segment of the lower lobes may be best approached with this technique. The 45mm endoscopic linear cutter with a large square jaw aperture facilitates this larger resection into deeper lung parenchyma.

Deep stapled nodulectomy is a technique to bi-valve the lung parenchyma to reach a more centrally located lesion. This technique may preserve lung tissue, but is

more challenging to locate the lesion and to perform the stapling. Finally, lesions distant from fissures are sometimes unresectable with simple stapling techniques, and may not be amenable to a segmentectomy (i.e., lesions located in on the lateral and basal segments.) For these nodules, YAG laser or electro cautery is used to encircle the lesions which are then stapled at the base.[16] In this technique, the lesion is "excavated" circumferentially creating a type of crater. As the base of the lesion is thinned out, a stapler can be applied. To help decrease the postoperative air leak, the resection bed is filled with fibrin sealant thoracoscopically.

Incisional Biopsies

The need to perform an incisional lung biopsy is now relatively uncommon because of advanced interventional techniques. A lesion for incisional biopsy is generally pleural based, but of such depth and extension that complete removal requires full anatomic resection. In such a case, a thoracoscopic wedge resection is not be possible. Diagnosis by percutaneous true cut needle biopsy under CT guidance, should be attempted first because even lymphoma can be diagnosed and subtyped by this technique. However, if percutaneous methods fail, an incisional biopsy can be performed easily under thoracoscopic guidance. In this case, the initial trocar site is placed and thoracoscopy is performed to localize the lesion. A 12 mm access incision is created to insert a long handled knife or other biopsy tool. A third port may be added to support the lung or tamponade bleeding from the incisional biopsy. Bleeding is cauterized easily using a standard bovie with a long extension. As always in thoracoscopy, the specimen should be removed from the chest in a protected fashion.

Complications of VATS Nodulectomy

As expected with all surgical procedures, complications occur occasionally. The complications result from intraoperative technical problems or more likely to the patients overall poor condition.

Complications may result from stapling devices that are routinely used in both open and thoracoscopic procedures. Properly loaded staplers rarely miss-fire; however poor technique in reloading stapling devices easily causes staple line failures. Significant bleeding may occur quickly if the unstapled cut lung opens. Control of the bleeding is accomplished quickly and efficiently by regrasping the cut end of the lung parenchyma with either a sponge stick (without a sponge), or a Landreneau Masher (previously described). A new staple line can then be applied. Lung tissue that is very edematous may not hold staples. In this case, an open procedure may control air leaks or bleeding better. Seeding of the chest wall with tumor, a previously described complication of VATS, should not occur with the use of protected bags to remove all specimens. Excess force on the bag during extraction can rupture the bag. Other complications can occur with VATS as with open procedures, but significant morbidity can be avoided simply by converting the VATS procedure to an open thoracotomy if complications, or inadequate resection margins occur. All individuals involved should expect conversion to standard open techniques if minimally invasive techniques fail or become cumbersome. Conversion to an open procedure should always be discussed with the patient preoperatively, and should not be considered a complication, but rather an expectation if difficulties arise.

Summary

The use of thoracoscopy in thoracic surgery may now be considered a standard technique for all practicing thoracic surgeons. Peripheral, indeterminate pulmonary nodules are resected routinely, and patients may be discharged from the hospital in less than 24 hours. The role and demand for VATS may dramatically increase as spiral CT scanning is incorporated into lung cancer screening.

References

1. Hazelrigg SR, Magee MJ, Cetindag IB. Video-assisted thoracic surgery for diagnosis of the solitary lung nodule. Chest Surg Clin N Am 1998; Nv:8(4)763-774.
2. Henschke CI, Yankelevitz DF. Screening for lung cancer. JThoracicImaging 2000; 15(1):21-27.
3. Erasmus JJ, Connolly JE, McAdams HP et al. Solitary pulmonary nodules: Part I. Morphologic evaluation for differentiation of benign and malignant lesions. Radiographics 2000; 20(1):43-58.
4. Erasmus JJ, McAdams HP, Connolly JE. Part II. Evaluation of the indeterminate nodule. Radiographics 2000; 20(1):59-66.
5. Patz EF Jr. Imaging in Lung cancer. Semin Oncol 1999; 26(5 suppl 15):21-26.
6. Mitruka S, Landreneau RJ, Mack MJ et al. Diagnosing the indeterminate pulmonary nodule: percutaneous biopsy versus thoracoscopy. Surgery 1995; 118(4):676-684.
7. Mack MJ; Hazelrigg SR, Landreneau RJ et al. Thoracoscopy for the diagnosis of the indeterminate solitary pulmonary nodule. Ann Thorac Surg 1993; 56(4):825-830.
8. Swanson SJ, Jaklitsch MT, Mentzer SJ et al. Management of the solitary pulmonary nodule: role of thoracoscopy in diagnosis and therapy. Chest 1999; 116(6Suppl):523s-524s.
9. Yim AP, Liu HP, Hazelrigg SR et al. Thoracoscopic operations on reoperated chests. Ann Thorac Surg 1998; 65(2):328-330.
10. Sonett JR, Krasna MJ. Thoracoscopic staging for intrathoracic malignancy. In: Minimal Access Cardiothoracic Surgery. Yim AP, Hazelrigg S, Izzat MB et al, eds. Philadelphia: WB Saunders 2000:183-93.
11. Sonett JR. Video-assisted thoracoscopic surgery for the therapeutic resection of pulmonary metastases: biologic and historical justification for VATS and the need for a multi-institutional randomized study of VATS versus open resection. Eur JCTSurg 1999; 15:1-4.
12. Sonett JR. VATS and Thoracic Oncology: Anathema or Opportunity. Ann Thorac Surg, 1999; 68:795-796.
13. Plunkett MB, Ferson PF, Keenan RJ, Landreneau RJ. Computed tomography-guided wire localization of pulmonary lesions before thoracoscopic resection: results in 101 cases. J Thorac Imaging 1999; 14(2):90-8.
14. Santambrogio R, Montosi M, Bianchi P et al. Intraoperative ultrasound during thoracoscopic procedures for solitary pulmonary nodules. Ann Thorac Surg 1999; 68(1):218-222.
15. Demmy TL, Wagner-Mann CC, James MA. Feasibility of mathematical models to predict success in video-assisted thoracic surgery lung nodule excision. Am J Surg 1997; 174(1)20-23.
16. Landreneau RJ, Keenan RJ, Hazelrigg SR et al. Vats wedge resection of the lung using neodymium:yttrium-aluminum garnet laser. Ann Thorac Surg 1993; 56(3):758-761.

Lung Cancer: Diagnosis and Treatment

David P. Mason, Scott J. Swanson

Introduction

Lung cancer is the leading cause of cancer death in the United States and is the most common thoracic malignancy. Furthermore, the number of reported cases of lung cancer increased markedly over the last 50 years. Unfortunately, lung cancer continues to carry a poor prognosis with less than 15% overall survival at 5 years for all stages combined. Thoracoscopic surgery is being used increasingly for the primary treatment of lung cancer over the last decade although this technique is not new. Hans Christian Jacobaeus first used thoracoscopy to lyse adhesions between the lung and the chest wall in 1910,[1] but the use of thoracoscopy remained limited to simple pleural procedures because of the limited viewing field of the early, rudimentary equipment. There has been a resurgence of interest in endoscopic surgery recently given the improved technology of video-endoscopic equipment with increased camera resolution. The successful use of laparoscopy by gynecologists and general surgeons has led the way. Video-endoscopic imaging allows wide viewing of the pleural space. This permits the active involvement of assistants who can see the surgical field on video monitors and participate in the operation. Thus, more complex thoracic procedures can now be performed that were previously possible only with a thoracotomy. Video-assisted thoracic surgery (VATS) has been used to manage a wide variety of lung cancer problems in both diagnosis and treatment. However, its exact role in each area remains to be defined and will continue to evolve.

Diagnosis

Lung cancer typically causes subtle, nonspecific symptoms or is entirely asymptomatic. This accounts for the late presentation of most lung cancers and the advanced stage at diagnosis. When picked up as an incidental finding on a diagnostic study for an unrelated problem, the stage and prognosis may be more favorable. Surgical resection holds the only possibility for cure, but approximately 65-80% of patients with nonsmall cell lung cancer (NSCLC) are unresectable at the time of presentation.[2] Greater than 50% of lung cancers are metastatic at the time of presentation, contributing to the dismal overall prognosis. Clearly, an efficient and cost-effective screening method is critical to early lung cancer detection and improved outcome. Effective methods for this have proven elusive.

Chest Radiography (CXR) and Computed Tomography (CT)

The chest radiograph (CXR) is a commonly used method to screen for lung cancer, but its efficacy as a widespread screening tool is controversial. Consensus conferences in the 1970s suggested no benefit with its use. Recently, this has been challenged. Most early stage lung cancer patients have small solitary pulmonary nodule detected by CXR.[3] Asymptomatic patients with disease identified initially by CXR tend to have early disease and, therefore, are more likely to be cured by resection.[4] Thus, the work-up for the evaluation of lung cancer generally begins with a CXR. However, the radiographic detection of lung cancer by CXR is impaired when there is a small lesion superimposed on other thoracic structures. The "error" rate for missed early lung cancers by CXR is between 20% and 50%.[5] A chest computed tomogram (CT) for screening may impact favorably on this, and trials are being carried out currently. While the CXR may estimate the tumor size or chest wall invasion in peripheral lesions, CT is better in predicting the size of central tumors or the presence of lymph node involvement.

Bronchoscopy

Bronchogenic carcinoma is the most common cancer affecting men and women in the United States.[6] Fiberoptic bronchoscopy is often used in the initial evaluation of lung tumors to confirm the diagnosis of cancer, determine the tumor's specific histology and identify an endobronchial component to define stage and resectability. While fiberoptic bronchoscopy has a high diagnostic yield in the presence of clinical signs of endobronchial disease such as hemoptysis or radiographic signs such as lobar atelectasis, its diagnostic yield is much lower if no indicators are present. This is particularly true in the setting of a peripheral pulmonary nodule or mass.[7,8] In one study, fiberoptic bronchoscopy provided a histologic diagnosis in only 18% of peripheral pulmonary nodules smaller than 6 cm.[9]

A chest CT is obtained in most patients with a suspicious pulmonary nodule. CT has proven sensitive in evaluating the proximal bronchi for the presence of neoplasms and may obviate the need for bronchoscopy in this setting.[10] The necessity for bronchoscopy in the preoperative evaluation of a pulmonary nodule is even less certain because bronchoscopy is almost always performed by the thoracic surgeon in the operating room prior to definitive surgical resection. Intraoperative bronchoscopy is done to exclude proximal endobronchial invasion that might preclude resection.

CT-Guided Needle Biopsy

A new solitary pulmonary nodule in a patient over 35 years of age is considered malignant until proven otherwise. The most appropriate management strategy for small (less than 3 cm in diameter) peripheral lung nodules has been debated. Many physicians use percutaneous needle biopsy as the initial diagnostic maneuver for these lesions. Although 80% of these lesions will have positive cytology using CT-guided needle biopsy, the false-negative rate approaches 60% when the cytologic findings are nonspecific and benign.[11] This high false-negative rate is unacceptable because treatment of a small, peripheral malignancy might be delayed. Consequently, percutaneous biopsy obviates the need for an operation in only 10% of surgical candidates.[12] The reason for this is lesions proven malignant by percuta-

neous needle biopsy, require surgical management as do indeterminately benign masses to exclude the possibility of a false-negative biopsy. CT-guided needle biopsy may also add unnecessary cost and morbidity to the work-up. Instead, we consider VATS excisional biopsy to be the initial diagnostic approach to the peripheral, small, indeterminate pulmonary nodule in most patients who can tolerate surgical resection.[11] Using this algorithm exploratory thoracotomy is avoided if the lesion proves to be benign or metastatic.[13] Completion lobectomy is performed for malignant lesions.

Pathology

The World Health Organization Histologic Classification of Lung Tumors separates primary lung tumors into usual and rare tumors. Lung cancer is divided broadly into NSCLC and small cell lung cancer (SCLC) varieties. Adenocarcinoma has recently surpassed squamous cell carcinoma and is increasing in frequency now the most common type of NSCLC (Table 5.1).[14] Small cell cancers are generally not amenable to surgical therapy so, the remainder of this Chapter will address the surgical management of NSCLC.

Staging

The purpose of staging NSCLC is to determine a patient's prognosis and to direct therapy. The prognosis for a potentially resectable NSCLC is directly related to its pathologic stage at presentation,[15] and surgical resection remains the mainstay of cure. The stage of the tumor (Table 5.2)[15] is based in part on the presence or absence of metastases to the hilar and mediastinal lymph nodes in addition to the size and location of the tumor. Therefore, it is critical to accurately evaluate both the tumor and the various lymph node stations to optimally manage the patient with NSCLC. There are numerous methods used to stage NSCLC; some are noninvasive and some invasive. The optimal staging method continues to be debated, particularly as new and improved technology becomes available. We shall review some of these modalities.

Noninvasive Modalities of Staging

Chest CT

CT scan of the chest and upper abdomen has proven essential in the evaluation of thoracic malignancies and has become the standard diagnostic procedure following CXR in the evaluation of lung cancer. CT is helpful in staging disease by evaluating tumor extension, and diagnosing mediastinal lymph node involvement, vascular encasement, and vertebral body invasion. The use of CT scans to diagnose and stage metastatic mediastinal involvement is controversial and used in differing capacities by thoracic oncologists. Studies have shown that a lymph node less than 1 cm in size visualized by CT is unlikely to be malignant.[16] Using this cutoff, some investigators have taken hilar lymph nodes greater than 1.0 cm in the shortest axis to be diagnostic of clinical metastatic nodal involvement.[17] Nevertheless, CT of the chest has been reported to have a sensitivity and specificity of only 60-70% in identifying mediastinal lymph node metastases and to have lower accuracy in evaluating squamous cell carcinomas, central tumors and lower left-sided tumors.[18,19] CT is best in evaluating the superior mediastinal nodes and less accurate in identifying inferior

Table 5.1. Types of bronchogenic carcinoma

Nonsmall cell lung cancer	
Adenocarcinoma	40%
Squamous cell carcinoma	25%
Other	10%
Small cell lung carcinoma	25%

Table 5.2. TNM descriptors

Primary Tumor (T)

- TX Primary tumor cannot be assessed or tumor proven by the presence of malignant cells in sputum or bronchial washings but not visualized by imaging or bronchoscopy.
- T0 No evidence of primary tumor.
- Tis Carcinoma in situ.
- T1 Tumor ≤ 3 cm in greatest dimension, surrounded by lung or visceral pleura, without bronchoscopic evidence of invasion more proximal than the lobar bronchus* (i.e., not in the main bronchus).
- T2 Tumor with any of the following features of size or extent:
  size: > 3 cm
  Involves main bronchus. ≥ 2cm distal to the carina
  Invades the visceral pleura
  Associated with atelectasis or obstructive pneumonitis that extends to the hilar region but does not involve the entire lung.
- T3 Tumor of any size that directly invades any of the following: chest wall (including superior sulcus tumors), diaphragm, mediastinal pleura, parietal pericardium; or tumor in the main bronchus <2 cm distal to the carina, but without involvement of the carina; or associated atelectasis or obstructive pneumonitis of the entire lung.
- T4 Tumor of any size that invades any of the following: mediastinum, heart, great vessels, trachea, esophagus, vertebral body, carina; or tumor with a malignant pleural or pericardial effusion,† or with satellite tumor nodule(s) within the ipsilateral primary tumor lobe of the lung.

Regional Lymph Nodes (N)

- NX Regional lymph nodes cannot be assessed
- N0 No regional lymph node metastasis
- N1 Metastasis to ipsilateral peribronchial and/or ipsilateral hilar lymph nodes, and intrapulmonary nodes involved by direct extension of the primary tumor.
- N2 Metastasis to ipsilateral mediastinal and/ or subcarinal lymph node(s).
- N3 Metastasis to contralateral mediastinal, contralateral hilar, ipsilateral or contralateral scalene, or supraclavicular lymph node(s).

Distant Metastasis (M)

- MX Presence of distant metastasis cannot be assessed
- M0 No distant metastasis
- M1 Distant metastasis present+

Stage Grouping—TNM subsets++	
Stage 0	Carcinoma in situ
Stage IA	T1N0M0
Stage IB	T2N0M0
Stage IIA	T1N1M0
Stage IIB	T2N1M0
	T3N0M0
Stage IIIA	T3N1M0
	T1N2M0
	T2N2M0
	T3N2M0
Stage IIIB	T4N0M0
	T4N1M0
	T4N2M0
	T1N3M0
	T2N3M0
	T3N3M0
	T3N4M0
Stage IV	Any T, Any N, M1

* The uncommon superficial tumor of any size with its invasive component limited to the bronchial wall, which may extend proximal to the main bronchus, is also classified T1.
† Most pleural effusions associated with lung cancer are due to tumor. However, there are a few patients in whom multiple cytopathologic examinations of pleural fluid show no tumor. In these cases, the fluid is nonbloody and is not an exudate. When these elements and clinical judgment dictate that the effusion is not related to the tumor, the effusion should be excluded as a staging element and in the patient's disease should be staged T1, T2, or T3. Pericardial effusion is classified according to the same rules.
+Separate metastatic tumor nodule(s) in the ipsilateral nonprimary-tumor lobe(s) of the lung also are grouped as M1.
++ Staging is not relevant for occult carcinoma, designated TXN0M0.
Reprinted with permission. [15]

mediastinal nodes such as paraesophageal (Level 8) and pulmonary ligament (Level 9) nodes. In addition, chest wall and mediastinal invasion is not accurately demonstrated by CT.[20] Therefore, it is our policy to perform routine mediastinoscopy on all patients except those with small peripheral tumors (T_1, nonadenocarcinoma) with nodes less than 1 cm in diameter seen on CT scan in whom we feel the risk of mediastinal involvement to be low.[21] In addition, we do not defer surgical resection based on CT findings of adenopathy, but pathologically confirm these findings with a tissue diagnosis obtained by mediastinoscopy. Magnetic resonance imaging (MRI) of the chest appears to offer no benefit over CT for the imaging and staging of bronchogenic carcinoma. The sensitivity of CT and MRI in the evaluation of T status and N status appear to be virtually identical with the exception of the better MRI evaluation of vascular or neural invasion for superior sulcus tumors.[22]

CT and MRI of the Head

The brain is a common site for the metastatic spread of lung cancer. Brain metastases occur at presentation in 12-18% of patients and generally contraindicate primary lung tumor resection.[23] However, isolated brain metastasectomy with

resection of lung cancer without lymph node metastases may have a prolonged associated survival.

CT scan with intravenous dye injection accurately detects metastatic tumors.[24] Although controversial, head CT is valued in the preoperative staging of NSCLC patients including those free of neurologic symptoms.[25,26] Because of evidence that contrast-enhanced MRI has a higher sensitivity than CT it may detect smaller lesions earlier.[27] Such detection would prevent unneccessary lung resection or might identify candidates for open resection of an isolated brain metastasis or for stereotactic radiosurgery.[27] More studies are needed to determine whether the extra cost and increased patient inconvenience of contrast-enhanced MRI is warranted. In general, we perform a routine preoperative head CT on all lung cancer patients.

Bone Scan

The exclusion of bone metastases is important in the initial staging of NSCLC. The sensitivity is as high as 100% with a specificity of approximately 50%. Studies have shown that clinical indicators such as chest or skeletal pain, bone tenderness on physical exam, elevated serum alkaline phosphatase and serum calcium are almost always present in patients with bony metastases that are later confirmed with radioisotope bone scanning and biopsy.[28]

PET Scan

Positron electron tomography (PET), in existence for 30 years, and has recently been used in the evaluation of lung cancer. Malignant cells have increased rates of metabolism and proliferation; metabolic products of radioisotopes remain trapped within cells and emit positrons detectable by a PET camera. [^{18}F]fluorodeoxyglucose (FDG) is the most common molecule used in the evaluation of lung cancer. The theoretical advantage of PET scanning over other imaging modalities is that it provides a noninvasive, functional study able to distinguish benign from malignant tumors and the presence or absence of metastases. Preliminary PET lung cancer studies are encouraging. The sensitivity and specificity of FDG-PET in evaluating an unknown lung opacity discovered on CXR or CT for malignancy was 100% and 89%, respectively.[29] Another group reported a sensitivity of 95% and specificity of 81%.[30]

While FDG-PET has great potential, its present role in the lung cancer evaluation algorithm remains unclear. PET is expensive ($2,000-$3,000 per scan), not available at all institutions, and not uniformly reimbursed by medical insurance. It is unlikely that PET will replace CT that has greater accuracy in determining anatomic relationships and establishing local invasion; however, CT scan used in conjunction with PET scan may be optimal. PET scanning may decrease the need for mediastinoscopy if capable of accurately excluding mediastinal lymph node metastases. The sensitivity and specificity of PET scanning has not been compared to mediastinoscopy in a prospective, randomized fashion; mediastinoscopy, however, was necessary for pathologic confirmation of PET accuracy in almost all studies.

Invasive Techniques

Precise information regarding nodal status provides the most reliable information regarding prognosis and also enables optimal preresectional treatment. Histologic confirmation of no metastatic nodal disease can be obtained before surgical

resection using mediastinoscopy or VATS. Dissection and nodal sampling at the time of resection is performed as well.

Mediastinoscopy

Mediastinoscopy can access metastatic mediastinal nodes (N2 and N3) that generally contraindicate surgical resection as a single modality for cure. We perform mediastinoscopy on all patients who have mediastinal nodes greater than 10 mm in transverse diameter found on staging chest CT. Also, we perform mediastinoscopy on all other patients unless the lung lesion is 3 cm or smaller, peripheral and known to be squamous cell histology. There are several surgical techniques to stage lung cancer. Cervical mediastinoscopy remains the primary method and gives access to the superior, paratracheal mediastinal nodes (Stations 2 and 4) as well as the anterior subcarinal nodes (Station 7). A left-sided VATS approach or anterior mediastinoscopy (Chamberlain procedure) is useful to assess adenopathy difficult or impossible to access by cervical mediastinoscopy typically located in the aorticopulmonary window, anterior mediastinum and posterior subcarinal space.[13,31]

Thoracoscopic (VATS) Staging.

Depending on the indications, we employ VATS staging techniques in differing capacities. Left upper lobe bronchogenic carcinomas tend to metastasize to the subaortic (AP window) nodes [Station 5] before the paratracheal nodes and, for this we use either a left-sided VATS approach or a left anterior mediastinotomy. VATS permits better visualization of the para-aortic nodes (Level 6), paraesophageal nodes (Level 8), and inferior pulmonary ligament nodes (Level 9). In addition to evaluating N2 disease, we also use VATS to evaluate the relationship of a tumor to vascular, neural and bony structures. This information is critical to staging and assessing resectability and previously necessitated an exploratory thoracotomy. Any pleural effusion associated with a tumor is also assessed using VATS.

Operative Technique

To approach the AP window using thoracoscopy, the camera port is placed in the seventh intercostal space (ICS), midaxillary line.[32] The two accessory ports are placed in line with the planned thoracotomy incision which will be made if the nodule proves to be malignant and the mediastinal nodes prove to be free of metastatic disease. One port is placed in the anterior axillary line, the other below the tip of the scapula (Fig. 5.1). The lung is retracted inferiorly and the mediastinal pleura is opened along the inferior margin of the aortic arch (Fig. 5.2A). The subaortic nodes are retracted out from the mediastinum with grasping forceps, and a hemoclip applied to the base of the vascular pedicle. The pedicle is amputated and the node sent to the pathology laboratory (Fig. 5.2B). Inferior pulmonary ligament nodes are sampled easily using VATS. We divide the inferior pulmonary ligament with electrocautery and sample the nodal basin by grasping the nodes and amputating them using electrocautery. The pleural space is carefully evaluated to detect occult pleural seeding.

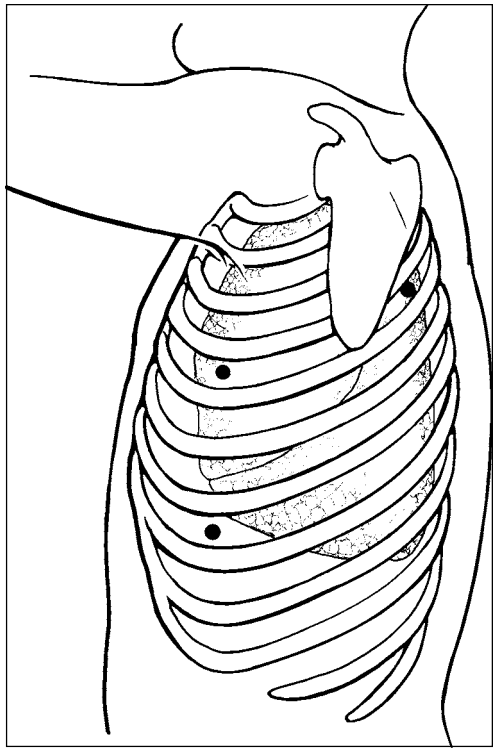


Fig. 5.1. Port placement for left VATS aortopulmonary lymph node biopsy. Camera is placed in the seventh intercostal space in anterior axillary line and fifth intercostal space below tip of the scapula.

Lung Cancer Management

Definitive management of lung cancer for cure necessitates anatomical resection of the entire involved lobe with hilar lymph node dissection in the patient who has cardiopulmonary reserve to tolerate the resection. Until recently, this necessitated thoracotomy. Recently, several investigators have explored the utility of VATS approaches to anatomic lobectomy to manage small, peripheral, clinical stage I NSCLC.[33-37] However, the definition of what constitutes a VATS lobectomy is inexact. Poorly controlled variables include the size of the incision for the port sites, the use of a utility thoracotomy, the use of rib resection and rib spreading, the amount of the dissection of hilar structures, and whether or not a lymph node dissection is performed. The variability has made comparison of outcomes for VATS lobectomy difficult. It remains unproven whether VATS lobectomy yields equivalent outcomes in regards to cancer therapy, and we still use open thoracotomy and lobectomy as our standard approach to lung cancer. The completeness of lymph node retrieval, the adequacy of surgical resection and the possibility of port-site seeding are controversial topics regarding the oncologic validity of VATS lobectomy. When the proper technique is used, port-site seeding does not appear to be a problem.[38]

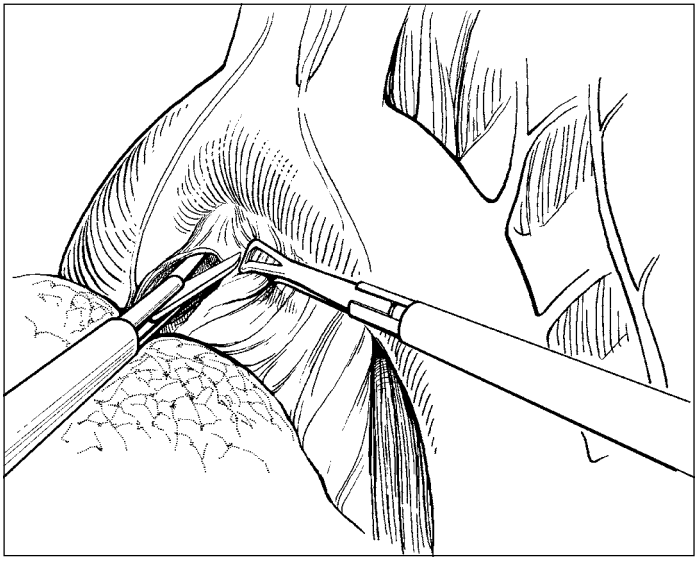


Fig. 5.2. (A) Thoracoscopic scissors are used to open the mediastinal pleura over the aortopulmonary window.

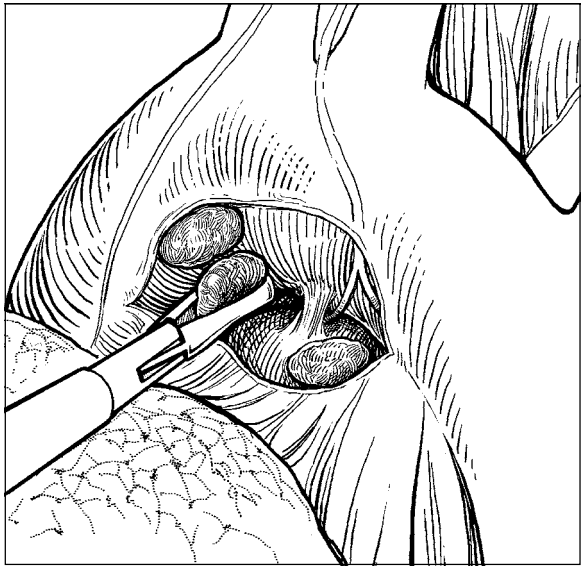


Fig. 5.2. (B) The vascular pedicle has been clipped. Thoracoscopic grasping forceps are now used to remove aortopulmonary lymph nodes.

In experienced hands, lymph node retrieval is not compromised by VATS lobectomy, nor is overall or disease-free survival.[39] However, a prospective, randomized trial comparing VATS to standard lobectomy has not yet been performed.

We have attempted to standardize our approach to VATS lobectomy. To gain maximal patient benefit and to optimize patient outcome, we believe that VATS lobectomy should include anatomic lobar resection with standard hilar lymph node sampling but without the use of a rib retractor and rib spreading. We perform standard mediastinal node sampling using cervical mediastinoscopy and a left-sided VATS approach when indicated. We attempt to sample at least two nodal stations of the ipsilateral mediastinum. For right-sided dissection, these stations are 2,4,7,8,9, and left-sided sampling should also include stations 5 and 6. Presently a national intergroup study is underway to assess the feasibility of a VATS lobectomy for solitary, peripheral, < 3.0 cm lung lesions with suspected or histologically documented NSCLC.* This protocol does not permit any rib spreading and utilizes an access or utility incision 8 cm or less to remove the specimen and aid in the hilar dissection (Fig. 5.3). Lobectomy is performed with removal of the entire anatomic pulmonary lobe with standard nodal dissection or sampling similar to what is done during a traditional lobectomy. Our standard hilar dissection includes the individual isolation and division of the lobar vein, artery and bronchus. Three port incisions are allowed including the access incision. All nodules and lobes are placed in an extraction sac prior to removal (Fig. 5.4) from the thoracic cavity to prevent port-site seeding.[38]

VATS Approach to the Right Upper Lobe (Fig. 5.5)

Positioning left lateral decubitus.

Ports

Camera	7th ICS in the posterior axillary line.
Posterior	4th ICS posterior to tip of the scapula.
Access incision	4th ICS in anterior axillary line.

Surgical Technique

We begin by using the ringed retractor in the posterior port to retract the lung posteriorly. We then dissect the anterior hilum through the anterior access incision. Next, minor fissure is divided between the right upper lobe and right middle lobe using an endoscopic 30mm linear cutter stapler. We divide the superior pulmonary vein using the standard dissection technique, a right angle and the endovascular stapler. To facilitate and safely divide the vascular structures, we attach one anvil of the stapler to an 8 mm red rubber catheter. This catheter serves to dilate the passage around the vessel and assure that the stapler will fit comfortably since the proximal end of the catheter is flared (Fig. 5.6). Next, we dissect out and divide the truncus anterior branch of the right pulmonary artery and the posterior recurrent branch of the pulmonary artery using the endovascular 30 mm stapler (Fig. 5.7).[40] We then open the posterior hilum and identify the right mainstem bronchus. We complete

---

* Swanson SJ CALGB Protocol 39802, Video-assisted lobectomy: For peripheral (≤ 3 cm) N0 nonsmall cell lung cancer: a phase II feasibility study, 1998

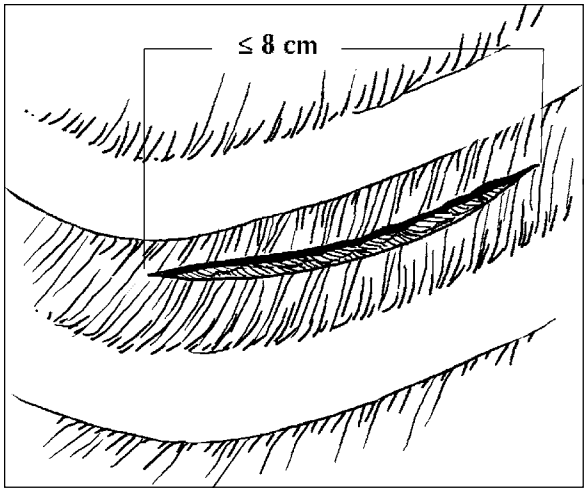


Fig. 5.3. The 8 cm or less access incision is made to aid in the hilar dissection and to remove the specimen.

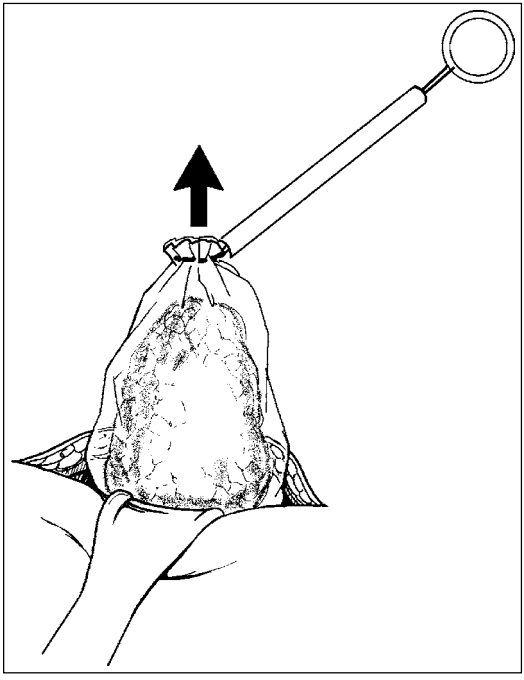


Fig. 5.4. Specimen in sac ready for removal through the access incision. Sacking is done to prevent port site seeding.

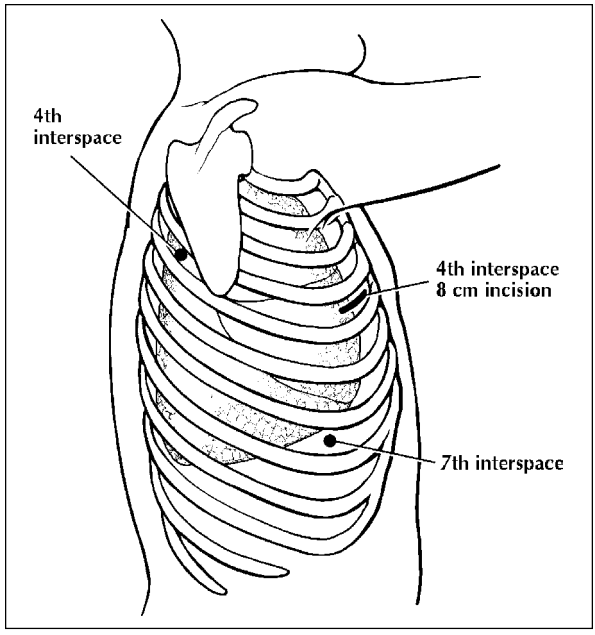


Fig. 5.5. The three thoracoscopic port incisions for dissection of the right upper lobe. The access incision is in the fourth intercostal space, anterior axillary line, and is 8 cm or less. The camera port is in the seventh space, the posterior port in the fourth.

the fissure posteriorly between the right upper lobe and the superior segment of the right lower lobe. We dissect the right upper lobe bronchus free and retract the lobe anteriorly from the anterior access incision using the thoracoscopic ring forceps. We then divide the right upper lobe bronchus using the endoscopic 30mm linear cutter that we bring in through the posterior port to free the lobe completely (Fig. 5.8). Now that the lobe is free of all surrounding structures, we place it in a thoracoscopic bag and extract it via the access incision.

VATS Approach to the Right Middle Lobe (Fig. 5.9)

Positioning	left lateral decubitus.
Ports	
Camera	7th ICS in the posterior axillary line.
Posterior	6th ICS below tip of the scapula.
Access incision	4th ICS in anterior axillary line.

Surgical Technique

We begin by creating the minor fissure between the right upper lobe and the right middle lobe and by dissecting out the anterior hilum via the access incision. We identify the vein draining the right middle lobe and divide it using the endovascular stapler passed through the access incision. Using the access incision,

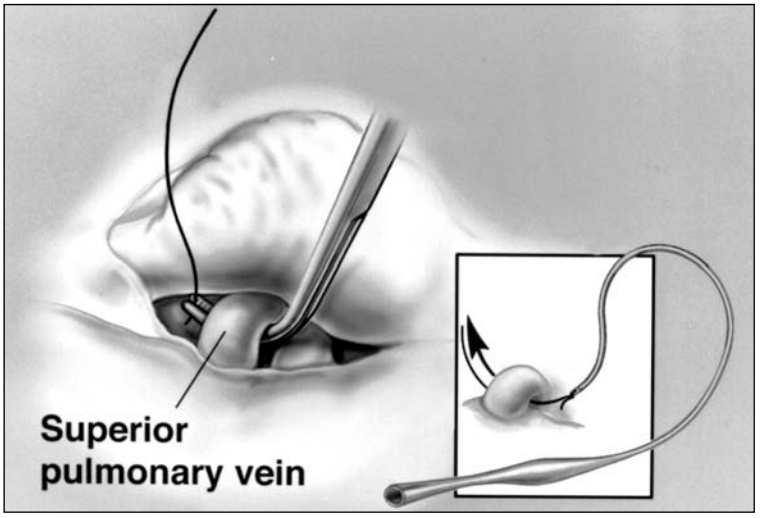


Fig. 5.6. The guidance catheter is being placed under the superior pulmonary vein to facilitate safe thoracoscopic stapling of the vessel. To allow safe placement of the stapler, one jaw of the endoscopic stapler fits into the end of the pliable, plastic, self-dilating catheter.[40]

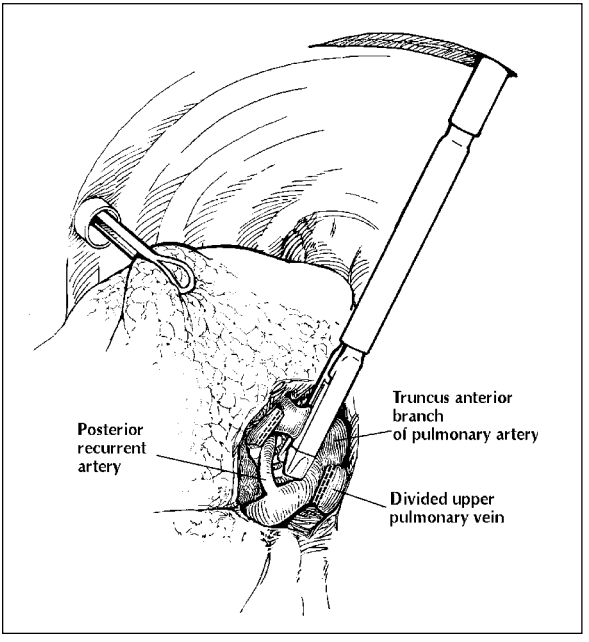


Fig. 5.7. Through the posterior port, the ringed forceps retract the upper lobe. The truncus anterior branch of the right pulmonary artery is divided using the endostapler through the access incision.

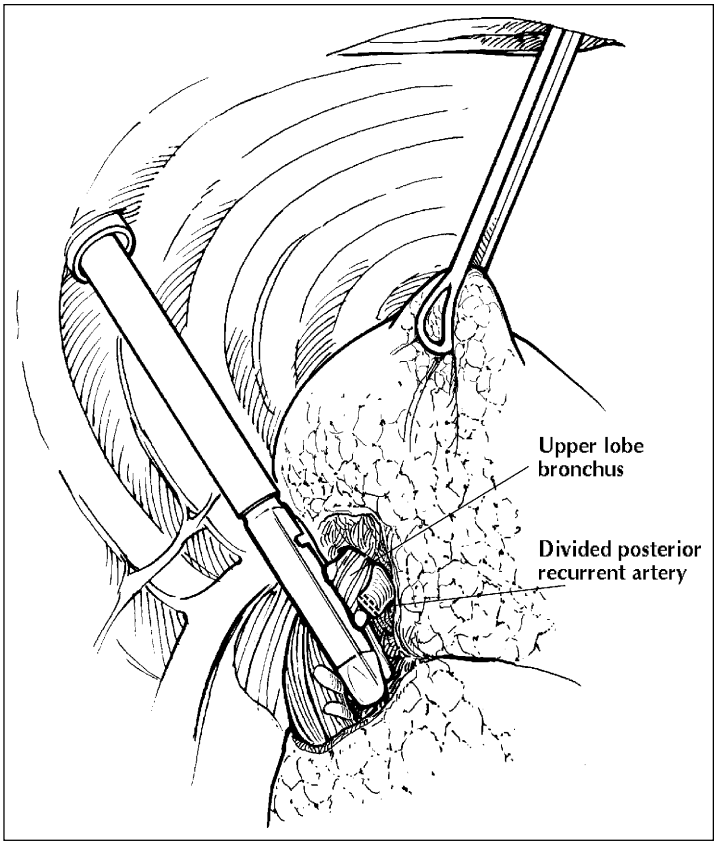


Fig. 5.8. Through the access port, the ringed forceps retract the right upper lobe anteriorly. Through the posterior port, the endoscopic 30mm linear cutter divides the upper lobe bronchus.

we next identify and dissect free the bronchus to the middle lobe which lies posterior and slightly inferior to the vein. We retract the middle lobe posteriorly with the ringed forceps placed through the posterior access port . We then divide the middle lobe bronchus with an endoscopic 30mm linear cutter placed through the access incision (Fig. 5.10). Next, we dissect free the artery to the middle lobe. This artery lies posterior and slightly superior to the bronchus. We retract the middle lobe posteriorly via the posterior port using the ringed forceps and then divide the artery with the 30 mm endovascular stapler introduced through the access incision (Fig. 5.11). We next complete the fissure between the right middle and right lower lobes using the endoscopic 30 mm linear cutter, freeing the lobe. We place it into an extraction bag and remove it through the access incision.

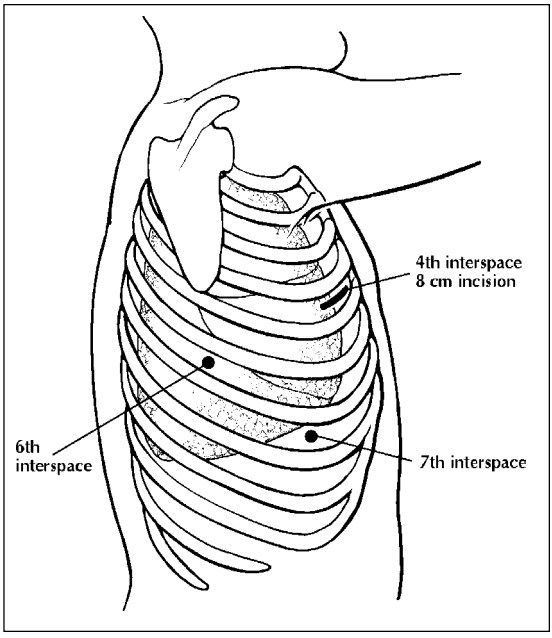


Fig. 5.9. The three port incisions for dissection of the right middle lobe. The access incision (8 cm or less) is in the fourth intercostal space, anterior axillary line. The camera port is in the seventh intercostal space, posterior axillary line, and the posterior port is in the sixth space.

VATS Approach to the Right Lower Lobe (Fig. 5.12)

Positioning left lateral decubitus.

Ports

Camera	7th ICS in the posterior axillary line.
Posterior	6th ICS below tip of the scapula.
Access incision	5th ICS in anterior axillary line.

Surgical Technique

We begin by dividing the inferior pulmonary ligament using the cautery with an extended tip through the posterior port. We then retract the lower lobe anteriorly through the access incision using the ringed retractor and open the anterior hilum via the access incision. We identify the inferior pulmonary vein next and divide it using the endovascular 30 mm stapler placed through the access port (Fig. 5.13). By a combination of blunt and sharp dissection we free the pulmonary artery in the fissure using the access incision and the posterior port. We retract the lower lobe posteriorly and divide the pulmonary artery with an access incision placed endovascular 30 mm stapler (Fig. 5.14). Depending on the angle, we place the endovascular stapler through the posterior incision with particular care to avoid

Fig. 5.10. The middle lobe is retracted by the ringed forceps through the posterior port. The middle lobe pulmonary vein has been divided. Through the access port, the middle lobe bronchus is about to be divided (broken line) by the endoscopic 30mm linear cutter.

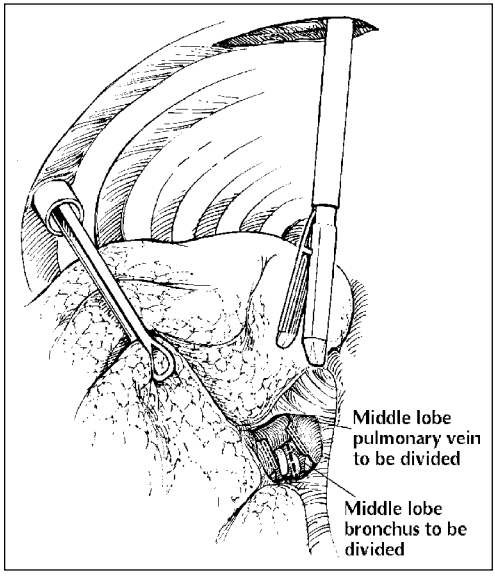
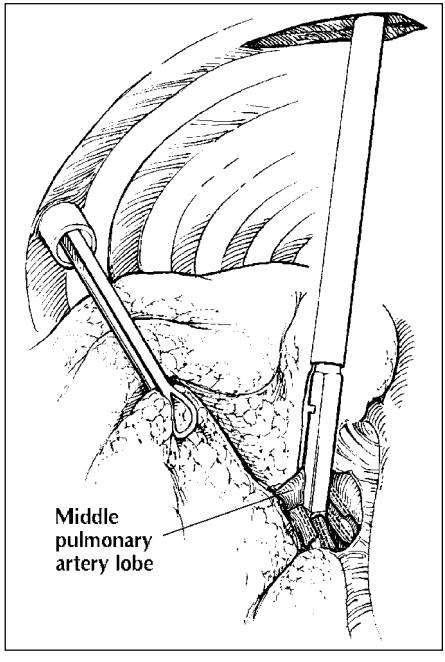


Fig. 5.11. Through the posterior port, the ringed forceps retract the right middle lobe. Through the access port, the middle lobe pulmonary artery is stapled and divided with the endovascular stapler.



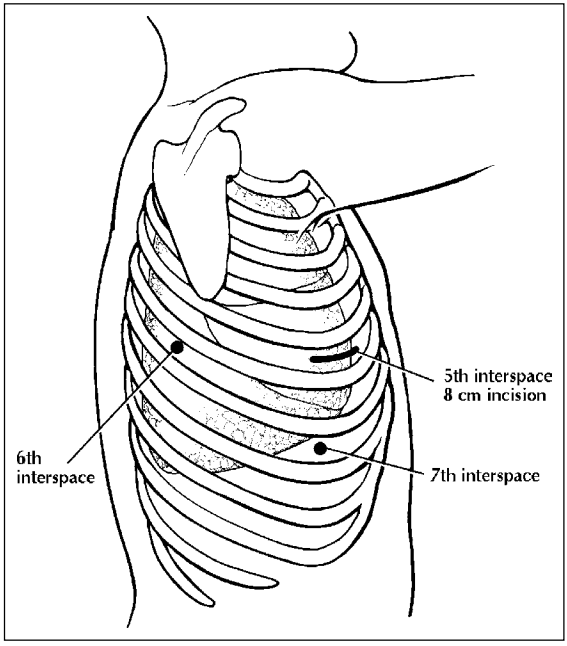


Fig. 5.12. The three port incisions for dissection of the right lower lobe. The access incision (8 cm or less) is in the fifth intercostal space, anterior axillary line; the camera port in the seventh space, posterior axillary line, and the posterior port in the sixth intercostal space.

injuring the middle lobe artery. If the right middle lobe pulmonary artery is too close we divide the lower lobe's superior segmental artery and basilar artery separately. Using the posterior port we open the posterior hilum and create the fissure between the superior segment of the lower lobe and posterior upper lobe using the endoscopic linear cutter. We retract the lower lobe anteriorly by the anterior access port and isolate and divide the right lower lobe bronchus using the endoscopic 30mm linear cutter stapler introduced through the posterior port (Fig. 5.15). If the middle lobe bronchus is very close to the right lower lobe bronchus, we staple and divide the superior segmental bronchus and the basilar bronchus separately. Now that the lobe is free of all surrounding attachments, we place it in an extraction sac and remove it using the access incision.

VATS Approach to the Left Upper Lobe (Fig. 5.16)

Positioning right lateral decubitus.

Ports

Camera	7th ICS in the posterior axillary line.
Posterior	4th ICS posterior to tip of the scapula.
Access incision	4th ICS in anterior axillary line

Fig. 5.13. Through the posterior port, the ringed forceps retract the lower lobe. The endovascular 30-mm stapler comes through the access port ready to divide the lower pulmonary vein.

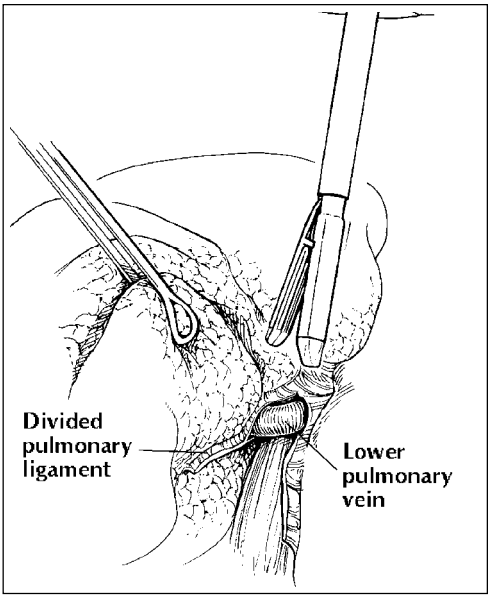
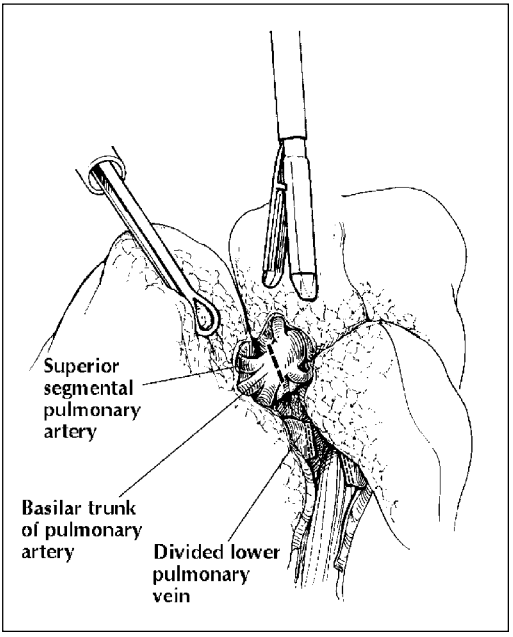


Fig. 5.14. Through the posterior port, the ringed forceps retracts the lower lobe. Through the access port, the endovascular stapler is ready to divide the pulmonary artery (broken line) to the lower lobe.



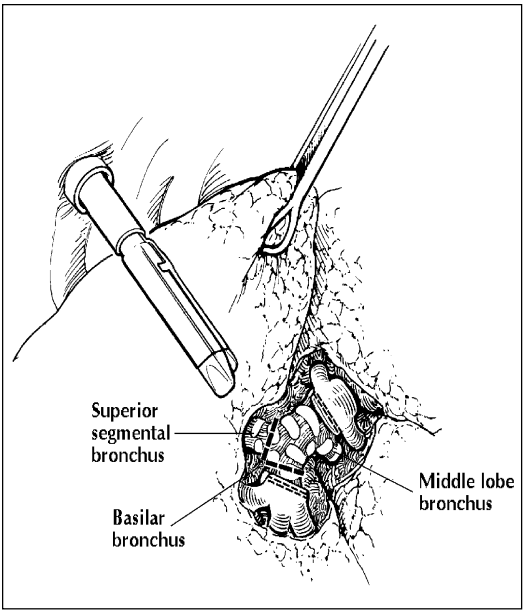


Fig. 5.15. Through the access port, the ringed forceps retracts the lower lobe. Through the posterior port, the endovascular stapler is positioned to divide the right lower lobe bronchus. The broken lines show an alternate method of bronchial division where the superior and basilar segments are divided separately if the middle lobe branch is too close to the lower lobe takeoff.

Surgical Technique

We begin by opening the anterior hilum using the access incision and dissecting the superior pulmonary vein free. We retract the upper lobe using a posterior port placed ringed forceps and divide the vein with an endovascular 30 mm stapler traversing the access incision (Fig. 5.17). Next, we create the posterior fissure between the superior segment of the lower lobe and the upper lobe using a posterior port endo-linear cutter. With the posterior port we open the posterior hilum and free the pulmonary artery as it courses posteriorly between the upper and lower lobe. We then divide the anterior pulmonary artery with an access incision placed endovascular 30 mm stapler. The posterior arterial branches and the branches to the lingula are divided with a posterior port endovascular 30 mm stapler (Fig. 5.18). We dissect the anterior hilum further using the access incision and complete the fissure between the lingula and the lower lobe using the endo-linear cutter. We dissect the left upper lobe bronchus free using the posterior port and divide it through the same port using the endolinear 30mm cutter (Fig. 5.19). Now freed of its surrounding attachments, we place the lobe in an extraction sac and remove it through the access incision.

VATS Approach to the Left Lower Lobe (Fig. 5.20)

Positioning right lateral decubitus.

Ports

Camera	7th ICS in the posterior axillary line.
Posterior	4th ICS posterior to tip of the scapula.
Access incision	5th ICS in anterior axillary line.

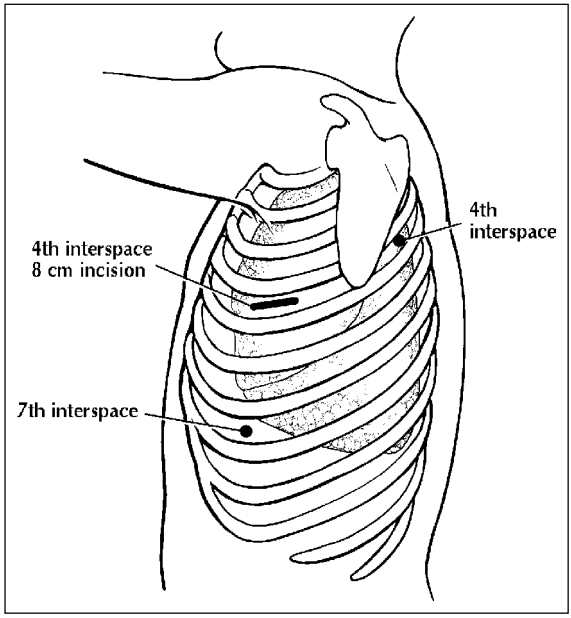
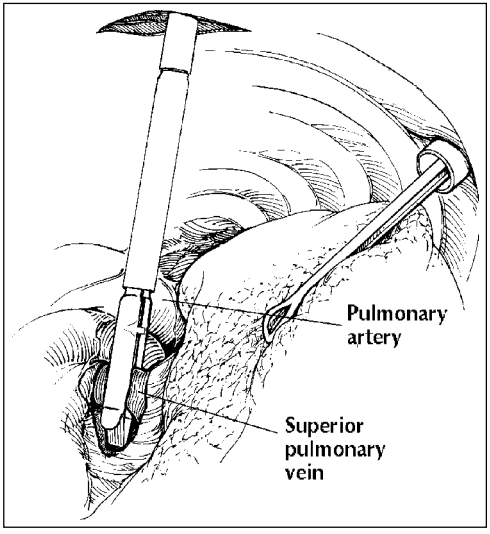


Fig. 5.16. The three port incisions for resection of the left upper lobe. The 8-cm or less access incision is in the fourth intercostal space. The camera port is in the seventh space; the posterior port in the fourth.

Fig. 5.17. Through the posterior port, the ringed forceps retracts the upper lobe. On the left, through the access port, the endovascular stapler divides the superior pulmonary vein.



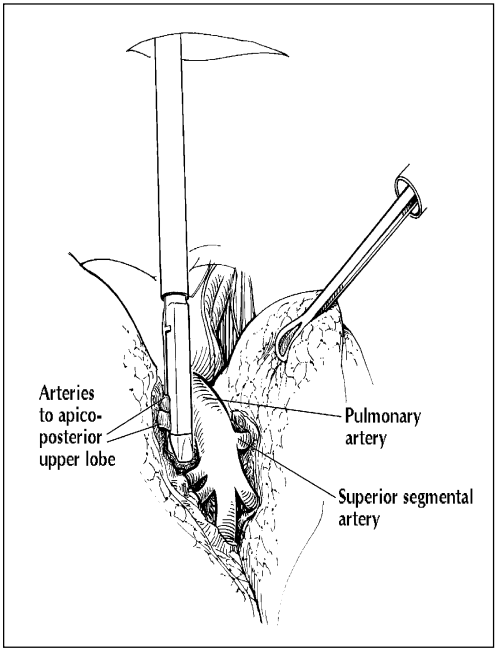


Fig. 5.18. Through the posterior port, the ringed forceps retracts the lower lobe. Through the access incision, the endovascular 30-mm stapler divides the posterior arterial branches and the branches to the lingula.

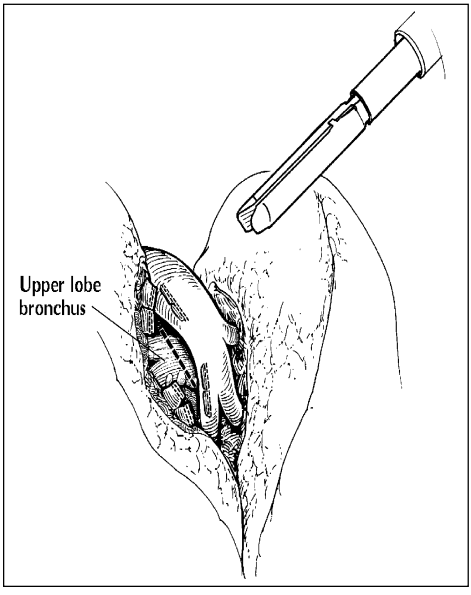


Fig. 5.19. Through the posterior port, The endoscopic linear cutter is ready to staple and divide the upper lobe bronchus (broken line).

Surgical Technique

We divide the inferior pulmonary ligament through the posterior port incision using an extended tip electrocautery while applying anterior traction to the lower lobe with the access incision ringed forceps. We then dissect free the anterior hilum using the access incision and identify the inferior pulmonary vein. We create the anterior fissure between the lingula and lower lobe using an endolinear 30mm cutter that traverses the access incision. We then retract the lower lobe posteriorly through the posterior port and divide the inferior pulmonary vein using the endo-linear cutter placed through the access incision (Fig. 5.21). We next create the posterior fissure between the superior segment of the lower lobe and the upper lobe using a posterior port endoscopic linear stapler port. We then dissect the pulmonary artery in the fissure with a combination of sharp and blunt dissection using the access incision and the posterior port. We divide the superior segmental artery and the basilar pulmonary arteries using the endovascular stapler with serial firings through the posterior port. We next dissect free the posterior hilum through the posterior port while applying traction anteriorly with the ring access incision retractor. We then identify and dissect the lower lobe bronchus free. We retract the upper lobe gently using the access incision and divide the lower lobe bronchus using the endo-linear cutter introduced through the posterior port (Fig. 5.22). Once the lobe is free of all surrounding attachments, we place it in a specimen extraction bag and remove it through the access incision.

Stage Specific Therapy

Stage I and II

The standard therapy for Stage I and II lung cancer is surgical excision, and a thoracotomy with lobectomy remains a standard of care. However, for small peripheral lesions with no evidence of involved nodes, VATS lobectomy is possible in experienced hands. Standardizing our protocol to produce a consistent "VATS lobectomy" allows better outcome comparisons. We do not attempt to resect T3 lesions using VATS. We do, however, use VATS to determine resectability and spare a patient an unnecessary thoracotomy. Adjuvant therapy is not proven for Stage I and II lung cancers. However, given the significant failure rate for large tumors (Stage 1B), there is currently a Cancer and Leukemia Group B (CALGB) protocol to examine the effect of postoperative chemotherapy (carboplatin/paclitaxel) in this setting (CALGB 9633)*.

Stage I Tumors in Compromised Patients

VATS wedge resections of small, peripheral, Stage I lung cancers are appropriate for in patients who are extremely compromised. Wedge resections are planned to obtain clear surgical margins around the tumor. Standard staging must be performed using methods previously described with mediastinal and hilar nodes sampled for accurate stage comparisons. "Compromise" resections using segmentectomies or

* Strauss GM. CALGB 9633. A phase III study of adjuvant chemotherapy after resection for patients with T2N0 stage I nonsmall cell carcinoma of the lung. 1996.

† Shennib H. CALGB 9335. Video-assisted wedge resection (VAR) and radiotherapy for high risk T1 nonsmall cell lung cancer: A phase II study. 1994.

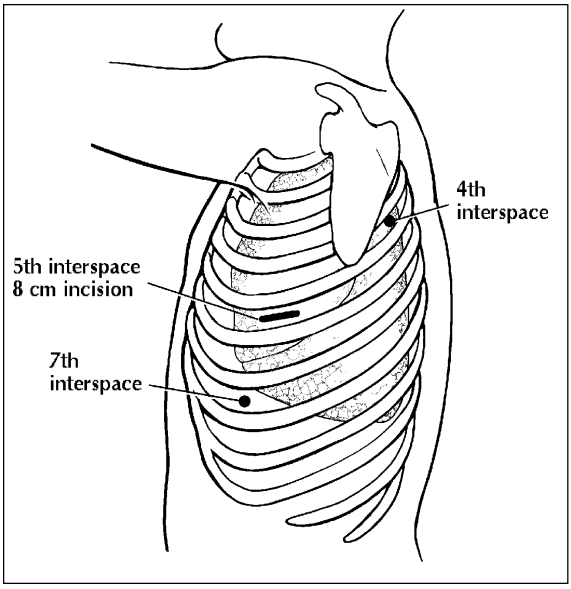


Fig. 5.20. The three port incisions for resection of the left lower lobe. The 8-cm or less access incision is in the fifth intercostal space. The camera port is in the seventh space; the posterior port in the fourth.

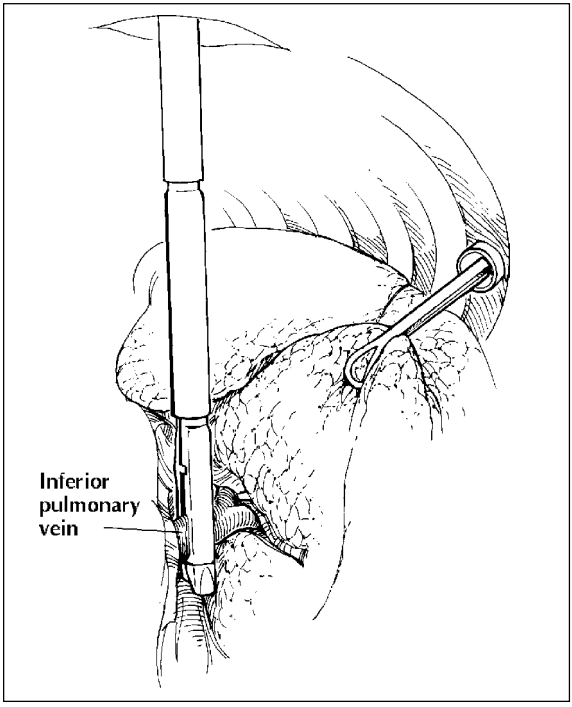


Fig. 5.21. Through the posterior port, the ringed forceps puts traction on the lower lobe. Through the access port, the endovascular 30-mm stapler is positioned to staple and divide the inferior pulmonary vein.

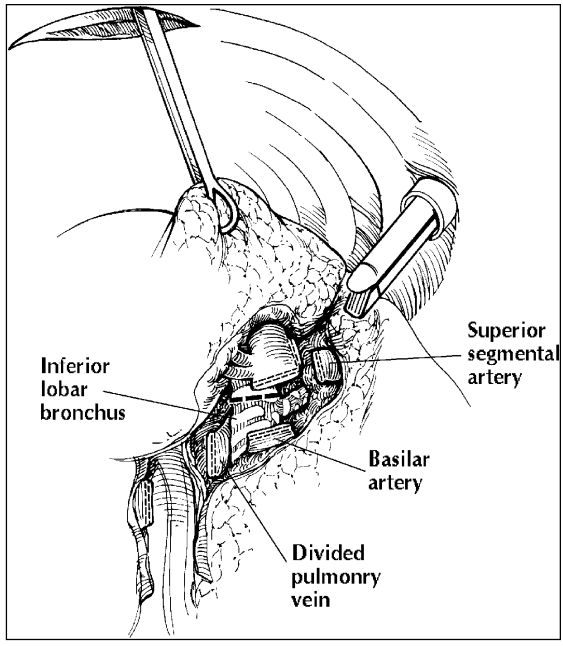


Fig. 5.22. Through the access port, the ringed forceps retracts the upper lobe. Through the posterior port, the endoscopic 30mm linear cutter is ready to divide the lower lobe bronchus (heavy broken line).

wedge excisions produced 1- and 5-year actuarial survivals in patients comparable to lobectomies in similarly matched cases.[41,42] However, the risk of local recurrence appears to be increased using segmental resections as opposed to lobectomy,[43] and, therefore, we continue to recommend lobectomy for all patients who can tolerate this operation. The results of CALGB 9335†, (a study of the feasibility of wedge resection and postoperative radiation therapy in high-risk patients) show that this is a safe approach.

Stage III

The prognosis for patients with Stage III disease is significantly worse than for those with Stage I and II disease. Stage IIIA disease encompasses locally advanced disease (T3N1M0) that remains confined to the hemithorax without mediastinal node involvement as well as tumors with metastases to the ipsilateral mediastinal nodes (T[1-3] N2M0). Metastatic N2 nodes discovered during preoperative staging yield a significantly worse prognosis than positive N2 nodes discovered in specimens from the definitive resection. Preoperatively established metastatic N2 nodes generally preclude lobectomy unless the patient is enrolled in an investigational protocol.

Numerous studies have evaluated both adjuvant and neoadjuvant therapies for metastatic and locally advanced NSCLC using combination chemotherapy. Preop-

---

* Jalkitsch MT CALGB 39803 Pre-resectional minimally invasive surgical restaging of stage III (mediastinal node positive) nonsmall cell lung cancer. 1998.

erative chemotherapy provided a survival benefit in some studies of patients with Stage IIIA lung cancer.[44-47] Several new anticancer drugs undergoing phase II trials appear promising for the treatment of locoregionally advanced lung cancer. At present, we enroll patients with Stage IIIA cancer in protocols for neoadjuvant therapy. A future investigation is of whether patients should be restaged by repeat mediastinoscopy or thoracoscopy to determine response to chemotherapy and radiation before surgical resection (CALGB 39803).* Persistent N2 disease following induction therapy is a poor prognostic sign where surgical resection of the primary tumor provides little benefit.[47-49] Patients with postoperatively determined Stage IIIA disease should probably receive a regimen of chemotherapy with or without radiotherapy in a protocol setting.

Radiation therapy has been used extensively to provide long-term local control of Stage IIB and Stage III NSCLC, but, the results have been disappointing. Approximately one-third of patients irradiated for unresectable disease have local recurrence and another one-third have both local and distant disease recurrence.[50,51] There are protocols in place for neoadjuvant treatment of Stage IIIB NSCLC, and there are some encouraging studies in small numbers of patients with T4N0 tumors that suggest surgical resection may improve survival. At this time, we do not recommend surgery for Stage IIIB NSCLC except in a protocol setting. Trimodality therapy has been attempted with encouraging results for IIIA and IIIB disease with 26% combined overall survival at 3 years with no significant differences in outcome between patients with IIIA and IIIB disease.[48] The role of VATS in the management of advanced stages of lung cancer at this time remains restricted to the management of malignant pleural effusions.[52]

Stage IV

The prognosis for metastatic NSCLC is dismal. There are a number of chemotherapeutic regimens in use and under investigation that appear to improve symptoms, quality of life, and perhaps median survival. Cure, however, is not presently considered possible. The one exception may be in the setting of isolated cranial metastases. With no mediastinal metastases and controllable lung primary and the cranial disease, survival may be prolonged with surgical resection.[53]

Conclusions

Surgery is important in the management of lung cancer. VATS usage is increasing in frequency and has expanding indications. It has proven to be a versatile tool that aids in accurate staging, decreases the number of exploratory thoracotomies, decreases the length of a patient's hospital stay, and has less postoperative pain than thoracotomy.[54] VATS lobectomy is feasible for the management of peripheral Stage I lung cancers; however, prospective, randomized comparisons of VATS lobectomy against standard lobectomy are necessary to establish VATS lobectomy as a standard therapy. Evolving technologies such as computer driven instruments, tactile feedback, three-dimensional imaging, intraoperative ultrasound, and nuclear scintigraphy are being developed that may improve the ease and versatility of VATS.[55] VATS will continue to play an important role in the future of thoracic surgery.

References

1. Jacobaeus H. The practical importance of thoracoscopy in surgery of the chest. Surg Gynecol Obstet 1922; 34:289-296.
2. Webb R, Gatsonis C, Zehrhouni E. CT and MR imaging in the staging of nonsmall cell bronchogenic carcinoma: report of the Radiologic Diagnostic Oncology Group. Radiology 1991; 178:705-713.
3. Swett H, Nagel J, Sostman H. Imaging methods in primary lung carcinoma. Clin Chest Med 1982; 3:331-51.
4. Fontana R, Sanderson D. Screening for lung cancer: A progress report. Lung Cancer, Current Statistics and Prospects for the Future. 1986; Austin, Texas, University of Texas Press:51.
5. Guiss L, Kuenstler. A retrospective review of survey photofluorograms of persons with lung cancer. Cancer 1960; 13:91-95.
6. Greenlee RT MT, Bolden S, Wingo PH. Cancer Statistics 2000. Cancer J. Clin. 2000; 50:7-33.
7. Goldberg S, Walkenstein M, Steinbach A. The role of staging bronchoscopy in the preoperative assessment of the solitary pulmonary nodule. Chest 1993; 104:94-97.
8. Aristizabal J, Young K, Nath H. Can chest CT decrease the use of preoperative bronchoscopy in the evaluation of suspected bronchogenic carcinoma. Chest 1998; 113:1244-49.
9. Torrington KG, Kern JD. The utility of fiberoptic bronchoscopy in the evaluation of the solitary pulmonary nodule. Chest 1993; 104:1021-1024.
10. Mayr B, Ingrisch H, Haussinger K, Huber RM, Sunder-Plassman L. Tumors of the bronchi: role of evaluation with CT. 1989; 172:647-652.
11. Landreneau R, Mack M, Dowling R et al. The role of thoracoscopy in lung cancer management. Chest 1998; 113:6S-12S.
12. Mitruka S, Landreneau R, Mack M. Diagnosing the indeterminate pulmonary nodule: percutaneous biopsy versus thoracoscopy. Surgery 1995; 118:676-684.
13. Landreneau R, Hazelriggg S, Mack M. Thoracoscopic mediastinal lymph node sampling: a useful approach to mediastinal lymph node stations inaccessible to cervical mediastinoscopy. J Thorac Cardiovasc Surg 1993; 106:554-558.
14. Anderson B, Burt M. Chest wall neoplasms and their management. Ann Thorac Surg 1994; 58:1774-1781.
15. Mountain C. Revisions in the International System for staging lung cancer. Chest 1997; 111:1710-1717.
16. Gross D, Glazer G, Orringer M. Bronchogenic carcinoma metastatic to normal-sized lymph nodes: Frequency and significance. Radiology 1988; 166:71.
17. Aronchick J. CT of mediastinal lymph nodes in patients with nonsmall cell lung carcinoma. Radiol Clin North Am 1990; 28:573-581.
18. Dillemans B, Deneffe G, Verschakelen J, Decramer M. Value of computed tomography and mediastinoscopy in preoperative evaluation of mediastinal nodes in nonsmall cell lung cancer. A study of 569 patients. Eur J Cardiothorac Surg 1994; 8:37-42.
19. Gdeddo A, Van Schil P, Corthouts B, Van Mieghem F, Van Meerbeeck J, Van Marck E. Prospective evaluation of computed tomography and mediastinoscopy in mediastinal lymph node staging. Eur Respir J 1997; 10:1547-51.
20. Glazer G. Radiologic staging of lung cancer using CT and MRI. Chest 1990; 96:44S-475.
21. Sugarbaker DJ, Strauss GM. Advances in surgical staging and therapy of nonsmall-cell lung cancer. Semin Oncol 1993; 20:163-172.

22. Manfredi R, Pirronti T, Bonomo L, Marano P. Accuracy of computed tomography and magnetic resonance imaging in staging bronchogenic carcinoma. MAGMA 1996; 4:257-262.
23. Mintz B, Tuhrim S, Alexander S. Intracranial metastases in the initial staging of bronchogenic carcinoma. Chest 1984; 86:850-853.
24. Hooper R, Tenholder M, Underwood G. Computed tomographic scanning of the brain in initial staging of bronchogenic carcinoma. Chest 1984; 85:774-776.
25. Salbeck R, Grau H, Artmann H. Cerebral tumor staging in patients with bronchial carcinoma by computed tomography. Cancer 1990; 66:2007-2011.
26. Kormas P, Bradshaw J, Jeyasingham K. Preoperative computed tomography of the brain in nonsmall cell bronchogenic carcinoma. Thorax 1992; 47:106-108.
27. Yokoi K, Kamiya N, Matsuguma H, Machida S, Hirose T, Tominaga K. Detection of brain metastasis in potentially operable nonsmall cell lung cancer: a comparison of CT and MRI. 1999; 115:714-719.
28. Michel F, Soler M, Imhof E, Perruchoud A. Initial staging of nonsmall cell lung cancer: value of routine radioisotope bone scanning. Thorax 1991; 46:469-473.
29. Patz E, Lowe V, Hoffman J. Focal pulmonary abnormalities: evaluation with F-18 fluorodeoxyglucose PET scanning. Radiology 1993; 188:487-490.
30. Lowe V, Fletcher J, Gobar L. Prospective investigation of positron emission tomography in lung nodules. J Clin Oncol 1998; 16:1075-1084.
31. Hazelrigg S, Mack M, Landreneau R. Video-assisted thoracic surgery for mediastinal disease. Chest Surg Clin North Am 1993; 3:249-261.
32. Jaklitsch MT, Harpole DH, Jr., Roberts RJ, Sugarbaker DJ. Video Assisted Techniques in Thoracic Surgery. In: Lokughlin KR, Brooks DC, eds. Principles of Endosurgery. Cambridge, Massachusetts: Blackwell Science, 1996.
33. Kirby T, Mack M, Landreneau R. Initial experience with video-assisted thoracoscopic lobectomy. Ann Thorac Surg 1993; 56:1248-1253.
34. Roviaro G, Rebuffat C, Varoli F. Video-endoscopic pulmonary lobectomy for lung cancer. Surg Laparosc Endosc 1992; 2:244-247.
35. Walker W, Carnochan F, Pugh G. Thoracoscopic pulmonary lobectomy: Early operative experience and preliminary clinical results. J Thorac Cardiovasc Surg 1993; 106:1111-1117.
36. McKenna R. Lobectomy by video-assisted thoracic surgery with mediastinal node sampling for lung cancer. J Thorac Cardiovasc Surg 1994; 107:879-882.
37. Iwasaki S, Shirakusa T, Yoshinaga Y, Okabayashi K, Shiraishi T. Is video-assisted thoracoscopic surgery suitable for resection of primary lung cancer. Thorac Cardiovasc Surgeon 1997; 45:13-15.
38. Swanson SJ, Jaklitsch MT, Mentzer SJ et al. Induction chemotherapy, surgical resection and radiotherapy in patients with malignant pleural effusion, mediastinoscopy negative (stage IIIB) nonsmall cell lung cancer. Prog Am Assoc Thorac Surg 1998:146-147.
39. McKenna R, Wolf R, Brenner M, Fischel R, Wurnig P. Is lobectomy by video-assisted thoracic surgery an adequate cancer operation? Ann Thorac Surg 1998; 66:1903-1908.
40. Garcia JP, Richards WG, Sugarbaker DJ. Surgical treatment of malignant mesothelioma. In: Kaiser LK, Kron IL, Spray TL, eds. Mastery of Cardiothoracic Surgery. Philadelphia: Lippincott-Raven, 1997.
41. Landreneau R, Sugarbaker D, Mack M. Wedge resection versus lobectomy for stage I (T1N0M0) nonsmall-cell lung cancer. J Thorac Cardiovasc Surg 1997; 113:691-698.

42. Shennib H, Landreneau R, Mack M. Video-assisted thoracoscopic wedge resection of T1 lung cancer in high risk patients. Ann Surg 1993; 218:555-560.
43. Ginsberg R, Rubenstein L. Randomized trial of lobectomy versus limited resection for T1N0 nonsmall cell lung cancer. Ann Thorac Surg 1995; 60:615-623.
44. Roth J, Fossella F, Komaki R. A randomized trial comparing perioperative chemotherapy and surgery with surgery alone in resectable stage IIIA nonsmall cell lung cancer. J Natl Cancer Inst 1994; 86:673-680.
45. Rossell R, Genez-Codina J, Camps C. A randomized trial comparing preoperative chemotherapy plus surgery with surgery alone in patients with nonsmall cell lung cancer. N Engl J Med 1994; 330:153-158.
46. Saijo N. New chemotherapeutic agents for the treatment of nonsmall cell lung cancer: the Japanese experience. Chest 1998; 113S:17S-23S.
47. Sugarbaker D, Herndon J, Kohman L, Krasna M, Green M. Results of Cancer and Leukemia Group B protocol 8935: a multi-institutional phase II trimodality trial for stage IIIA (N2) nonsmall-cell lung cancer. J Thorac Cardiovasc Surg 1995; 109:473-485.
48. Albain K, Rusch V, Crowley J et al. Concurrent cisplatin/etoposide plus chest radiotherapy followed by surgery for stages IIIA (N2) and IIIB nonsmall cell lung cancer: mature resuls of southwest oncology group Phase II Study 8805. J Clin Oncol 1995; 13:1880-1892.
49. Lau DH, Crowley JJ, Gandara DR et al. Southwest Oncology Group phase II trial of concurrent carboplatin, etoposide, and radiation for poor-risk stage III nonsmall-cell lung cancer. J Clin Oncol 1998; 16:3078-3081.
50. Cox J, Azarinia N, Byhardt R. N2 nonsmall cell carcinoma of the lung: prospective trends of radiation therapy with total doses 60Gy by the Radiation Therapy Oncology Group. Int J Radiat Oncol Biol Phys 1991; 20:7-12.
51. Dillman R, Seagren S, Propert K. A randomized trial of induction chemotherapy plus high-dose radiation versus radiation alone in stage III nonsmall cell lung cancer. N Engl J Med 1990; 323:940-945.
52. Hartman D, Gaither J, Kesler K. Comparison of insufflated talc under thoracoscopic guidance with standard tetracycline and bleomycin pleurodesis for control of malignant pleural effusions. J Thorac Cardiovasc Surg 1993; 105:743-748.
53. Harpole D, Amos A, Alexander E et al. Stage of the primary is important when treating isolated brain metastases from lung cancer. Prog Proc Am Soc Clin Oncol 1996.
54. Giudicelli R, Thomas P, Lonjon R et al. Video-assisted minithoracotomy versus muscle-sparing thoracotomy for performing lobectomy. Ann Thorac Surg 1994; 58:718.
55. Mason DP, Swanson SJ. VATS The Future. In: DiFalco G, ed. Videothorascopic Surgery (Atlante Chirurgico di Videotoracoscopia). Milan: Masson S.p.A., 1999:205-211.

Esophageal Cancer Diagnosis and Treatment

David P. Mason, Scott J. Swanson

Introduction

Esophageal cancer accounts for approximately 1% of all cancers in the United States. It is becoming more common with a doubling in the incidence of adenocarcinoma and a stabile incidence of squamous cell carcinoma.[1-3] Unfortunately, survival is poor regardless of treatment modality with an overall 5-year survival of about 5-10%.[2] Video-assisted thoracic surgery (VATS) has become an important tool in the management of esophageal cancer. It has increased the accuracy of preoperative staging which is critical in the management of esophageal cancer, particularly given some promising early results of neoadjuvant therapy. In addition, resectability can be determined using minimally invasive techniques. Definitive thoracoscopically assisted esophagectomy has been performed although an advantage for this approach has not been demonstrated. Open esophagectomy using standard techniques remains the standard of care for resectable esophageal cancer.

Diagnosis

The clinical presentation of esophageal cancer is often subtle so patients often present with advanced largely incurable cancer. The most common presenting symptom is dysphagia that generally begins with solid foods and advances to dysphagia for all foods. Dysphagia usually occurs when the tumor encroaches upon 60-80% of the esophageal circumference. Weight loss is also common, but cachexia is rare for esophageal cancer. Persistent chest pain or pain unrelated to meals is an ominous sign that suggests mediastinal penetration. At presentation, esophageal cancer is locally unresectable or metastatic in every other patient. Barium esophagram is usually the initial study to evaluate patients with dysphagia. The cervical esophagus as well as the stomach and duodenum must be studied. A single contrast study is highly sensitive for identifying structural abnormalities such as masses, ulcers and strictures and can determine the length, circumferential involvement and degree of obstruction from esophageal tumors.[4] Double-contrast studies allow even better examination of the mucosa to evaluate potential early lesions although upper endoscopy is more sensitive. Upper endoscopy is critical to the diagnosis and evaluation of esophageal cancer because it gives a visual map of the extent of the lesion as well as a tissue diagnosis by biopsy. Biopsies for early, subtle lesions can directed by toluidine blue or Lugol's iodine stain to localize malignancy.[5]

Multiple biopsies should be obtained to increase the detection rate. Overall accuracy using upper endoscopy with biopsy should be greater than 90%.

Staging

Accurate staging is required to validate and compare results, direct new treatments and to advise patients of prognosis. The staging system for esophageal cancer is based on depth of wall penetration by tumor and regional lymph node involvement . It appears to be most predictive of long-term survival (See below). Neoadjuvant therapies for esophageal cancer appear to hold promise and rely on accurate staging to allow valid comparison of the different therapeutic plans. VATS is ideally suited to providing these data. See Table 6.1.

Noninvasive Modalities

Radiographic staging is generally inadequate to stage esophageal cancer. Plain chest radiograph rarely demonstrates mediastinal invasion, airway involvement, or other staging findings. Upper GI contrast studies identify lesions well, but cannot evaluate depth of tumor invasion or presence of lymph node involvement.

Computed Tomography and MRI

Computed tomography (CT) scan is used widely to evaluate esophageal cancer and is usually the first study obtained after making a diagnosis of this disease. It determines the extent of local tumor invasion, the presence of enlarged local lymph nodes that would suggest tumor involvement (N1 disease), and the presence of metastatic disease. However, CT has its limitations evaluating each of these aspects of the tumor. It is too insensitive to detect invasion of the esophageal layers and therefore cannot distinguish T1 from T2 tumors.[7] In addition, the accuracy of CT scan in determining local invasion (T4) is in the range of 54-90%.[8,9] Therefore, CT is not particularly useful in evaluating T stage. CT scan can suggest the extent of the primary tumor that is radiologically characterized by asymmetric thickening of the esophagus. Nevertheless, it is inaccurate in determining the true cranial and caudal extent of disease because it does not have the sensitivity to demonstrate submucosal infiltration.

The use of CT scan to evaluate local nodal disease is also problematic. Studies have shown low specificity with high false-positives for N1 disease when CT scan has been used to stage regional nodes, and the accuracy of CT scan in evaluating regional lymph node status is less than 69%.[10,11] We use CT scan of the chest and abdomen as a preliminary but not a definitive staging tool. CT scan is highly accurate in detecting distant metastastic disease of the lungs and abdomen including disease in the liver, adrenals glands, and nonperigastric nodes. Metastases in these locations can be detected with a rate of 80% sensitivity and 98% specificity, therefore making CT a good tool to identify metastatic disease (stage IV). If needed, confirmation is provided by CT-guided needle biopsy.

MRI was studied as a noninvasive staging tool for esophageal cancer. While better in distinguishing tumor abutment from invasion of surrounding structures, the diagnostic accuracy of MRI in regards to assessing regional nodes is virtually identical to CT scan.[12] Therefore, MRI adds little the staging of esophageal cancer and is used rarely over CT given its discomfort to the patient due to its longer imaging times and added cost.

Table 6.1. TNM Staging System for Esophageal CA.

Primary Tumor (T)
TX: Primary tumor cannot be assessed
T0 : No evidence of primary tumor
Tis: Carcinoma in situ
T1: Tumor invades lamina propria or submucosa
T2: Tumor invades muscularis propria
T3: Tumor invades adventitia
T4: Tumor invades adjacent structures

Regional lymph nodes (N)
NX: Regional lymph nodes cannot be assessed
N0: No regional lymph node metastasis
N1: Regional lymph node metastasis

Distant Metastasis
MX : Distant metastasis cannot be assessed
M0: No distant metastasis
M1: Distant metastasis
Tumors of the lower thoracic esophagus:
M1a Metastasis in celiac lymph nodes
M1b Other distant metastasis
Tumors of the midthoracic esophagus:
M1a Not applicable
M1b Nonregional lymph nodes and/or other distant metastasis
Tumors of the upper thoracic esophagus:
M1a Metastasis in cervical nodes
M1b Other distant metastasis

Stage Grouping of Carcinoma of the Esophagus—TNM subsets
Stage 0 (TisN0M0)
Stage I (T1N0MO)
Stage IIA (T2N0MO) (T3N0M0)
Stage IIB (T1N1M0) (T2N1M0)
Stage III (T3N1M0) (T4 any N,M0)
Stage IV (any T, any N, M1)
Stage IVA (any T, any N, M1a)
Stage IVB (any T, any N, m1b)

Reprinted with permission from ref. 6

Endoesophageal Ultrasound

Endoesophageal Ultrasound (EUS) is highly accurate and vastly superior to CT scan in defining the depth of tumor penetration in the wall of the esophagus (T stage) and regional lymph node stage (N stage).[13] It's close-proximity images of the esophageal wall and adjacent structures are generated by an ultrasonic transducer that is inserted endoscopically. It images the GI tract as a five-layered structure and these layers correspond to mural histology. Therefore, EUS is an ideal method for evaluating T status which is classified according to depth of tumor invasion. It is accurate in evaluating both early stage disease as well as more advanced and unresectable disease.[14]

Using EUS, it can be difficult to differentiate between mucosal and submucosal disease in early esophageal cancer (T1). Endoscopic evaluation of lymph node status is more accurate than using CT, but it is not yet possible to clearly differentiate malignant from benign lymph nodes. However, EUS does provide more information than CT such as border characteristics of the node and central echogenicity that suggests whether the node is malignant or benign; a directed biopsy can then be performed.[15] EUS should be used as an adjunct and not a substitute to CT scan. Its accuracy of locoregional staging combines with accurate CT identification of metastatic disease. Techniques of fine needle aspiration of lymph nodes during EUS may improve diagnosis of nodal involvement significantly.

Positron Emission Tomography

Positron emission tomography (PET) is an imaging technique that discloses tumors based on their increased metabolic demands. Tumors are imaged through increased uptake of the positron-emitting tracer ^{18}F-fluorodeoxyglucose (FDG), and the differential distribution of FDG helps distinguish benign from malignant tissue. There have been several studies evaluating the sensitivity and specificity of PET scanning to stage lung cancer and yet its use in preoperative esophageal staging, although promising, is largely confined to case reports.[16-18] PET may come to replace the bone scan and CT scan as a single noninvasive test to evaluate esophageal cancer primary, regional and metastatic disease.

Invasive Techniques

Bronchoscopy

We perform routine flexible and/or rigid bronchoscopy on all patients with carcinoma of the upper and middle esophagus to assess cord mobility as well as any invasion into the membranous trachea or main stem bronchus. Any suspicious regions characterized by erythema or edema are biopsied and samples are sent for pathologic evaluation.

Mediastinoscopy

Mediastinoscopy has been the classic approach to sample regional thoracic nodes for the metastatic spread of esophageal cancer. Aorticopulmonary nodes and left para-aortic lymph nodes are difficult to sample using this technique, but can be evaluated using an anterior mediastinotomy (Chamberlain procedure). Mediastinoscopy combined with minilaparotomy was described by Murray et al to stage lymph node metastases prior to esophageal cancer resection.[19] With our increased VATS experience, we now use thoracoscopy combined with laparoscopy as a preresectional lymph node staging approach for esophageal cancer. While there is no consensus on the role of surgical staging in esophageal cancer, a multi-institutional pilot study from the Cancer and Leukemia Group B showed 90% accuracy for thoracoscopic and laparoscopic lymph node staging.[20] We believe that surgical-pathologic staging of patients with esophageal cancer should form the basis for the institution of therapy and the uniform evaluation of outcomes of new protocols.

Minimally Invasive Surgical Staging

Right-Sided Thoracoscopy

We routinely use right-sided thoracoscopy to stage esophageal cancer because it allows us access to the thoracic esophagus while avoiding the aorta. If preoperative studies suggest abnormal left-sided mediastinal nodes, then we use left-sided thoracoscopy to evaluate the aortico-pulmonary window nodes, left peri-esophageal nodes and the distal esophagus. Thoracoscopy allows us to accurately visualize the depth of wall invasion by the tumor and any spread to contiguous structures. In addition, regional lymph nodes are identified and sampled for histologic studies.

Technique

Thoracoscopy

We begin the operation with esophagogastroduodenoscopy (EGD) to evaluate the tumor directly. After careful flexible tracheobronchoscopy through a single-lumen tube to rule out direct tumor invasion, we proceed to double-lumen endotracheal intubation. We then place the patient in the left lateral decubitus position and proceed to single left-lung ventilation. We place our camera port in the seventh interspace in the midaxillary line with the addition of one port in the fourth or fifth intercostal space at the midaxillary line and a third port in the eighth intercostal space posteriorly (Fig. 6.1).

To start, we carefully inspect the hemithorax and open the mediastinal pleura along the length of the esophagus using the electrocautery. If necessary, we divide the azygous vein using the endoscopic vascular stapler to aid in dissecting the esophagus and evaluating the regional nodes. We sample all node levels regardless of whether or not they appear normal including levels 2R, 4R, 3, 10R, 7, 8, and 9.

After concluding our evaluation of the right chest, we close and leave a single chest tube in the inferior (camera) port incision. The tube can be removed on postoperative day number one (Figs. 6.2 and 6.3).

Laparoscopy or Minilaparotomy

After thoracoscopy, we place the patient supine and perform either staging laparoscopy or minilaparotomy. Under direct vision, we place a camera port in the umbilical region and a dissecting port in the upper midline and left upper quadrant. A port for the liver retractor is placed below the right subcostal margin (Fig. 6.4). We then inspect the upper abdomen including the liver, gastrohepatic ligament, subdiaphragmatic region and stomach. We use laparoscopic retractors to look under the liver, inspect the caudate lobe as well as look at the pouch of Douglas for any evidence of metastatic disease involvement. We divide the gastrohepatic ligament and biopsy the perigastric and celiac nodes as well as any abnormally appearing portal nodes (Figs. 6.5 and 6.6). Finally, we place a central venous infusion port and feeding jejunostomy tube in any patient with positive nodal disease and requiring neoadjuvant therapy.

Surgery—Technical Descriptions

There are several techniques that have been described for total esophagectomy. These techniques include the transhiatal, Ivor Lewis, tri-incisional (modified

Fig. 6.1. Port placement for minimally invasive esophageal staging. The camera is placed in the seventh intercostal space in the midaxillary line. The working ports are placed in the fifth intercostal space in the midaxillary line and the eighth intercostal space posteriorly.

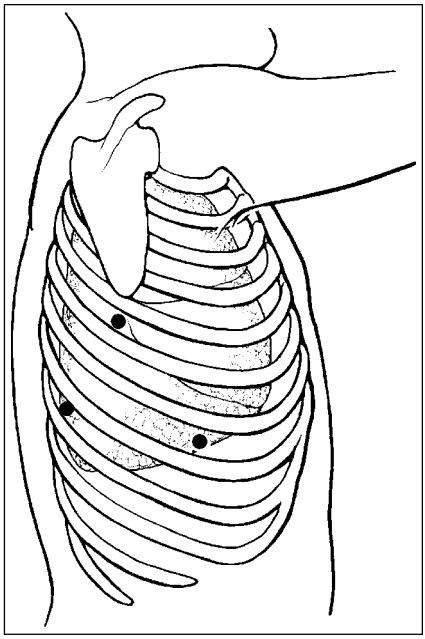
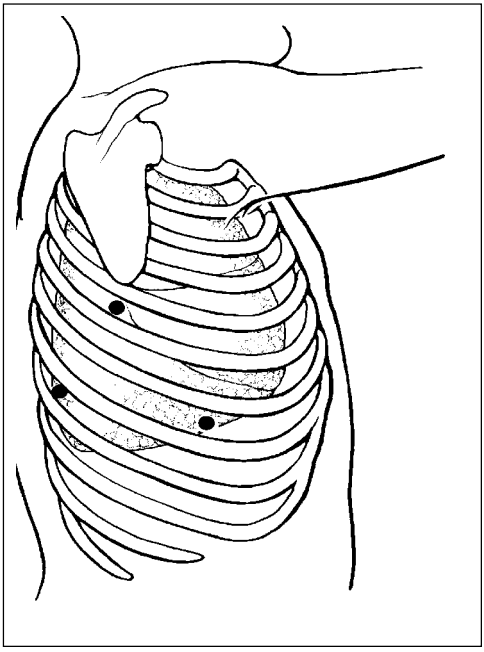


Fig. 6.2. Thoracoscopic view of periesophageal lymph node dissection.



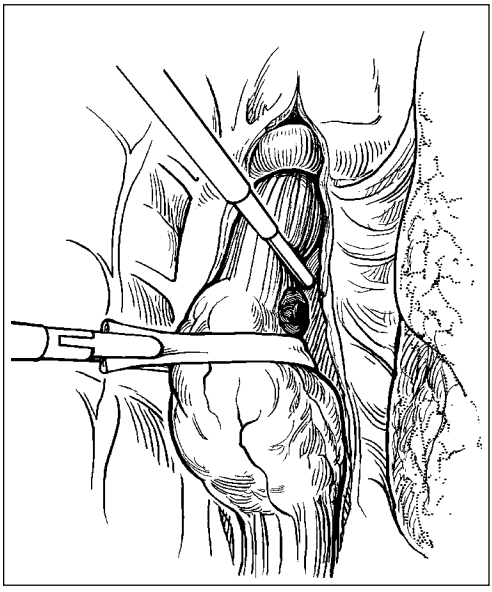


Fig. 6.3. The esophagus and tumor being gently retracted with a quarter-inch Penrose to expose posterior periesophageal lymph nodes.

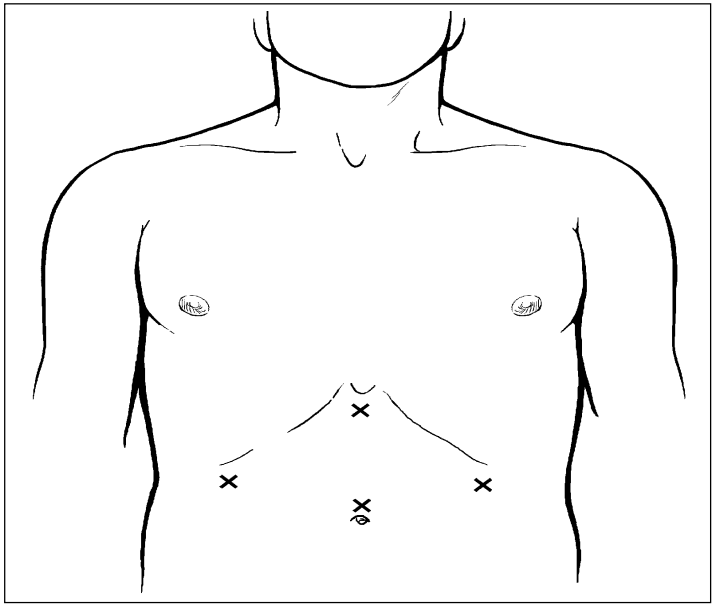


Fig. 6.4. Port placement for laparoscopic evaluation of the abdomen for staging esophageal cancer.

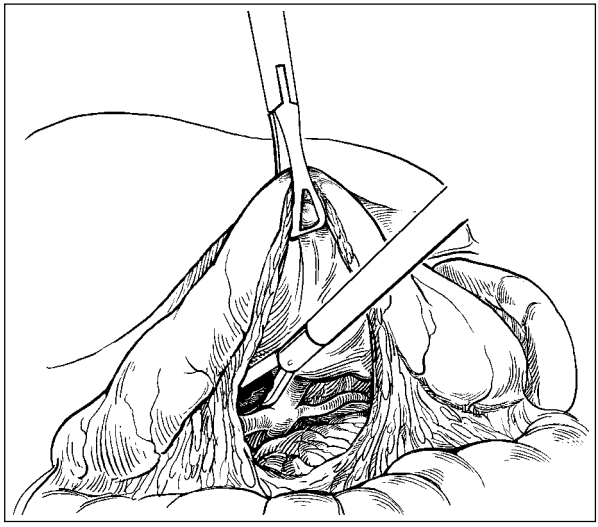


Fig. 6.5. Laparoscopic view of celiac lymph nodes being biopsied to stage esophageal cancer.

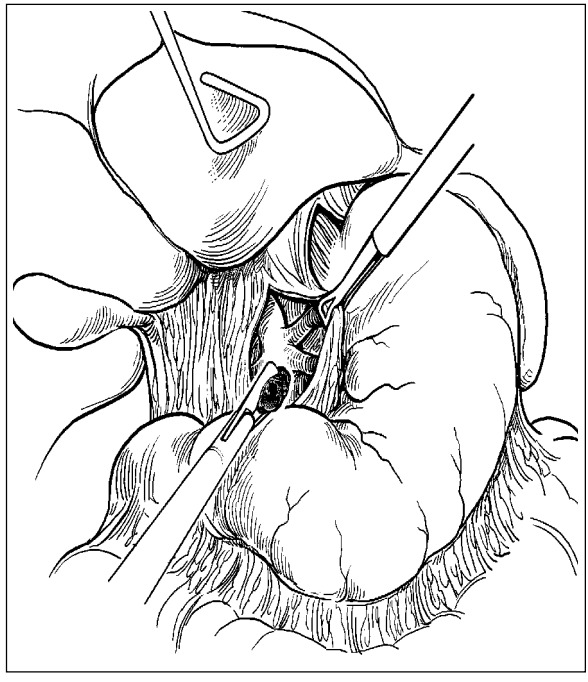


Fig. 6.6. Perigastric artery lymph node being biopsied using laparoscopic approach.

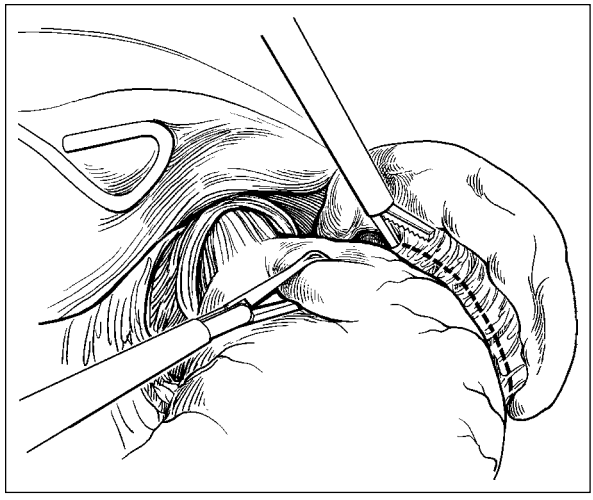


Fig. 6.7. Division of short gastric vessels.

Fig. 6.8. Division of gastrocolic omentum with preservation of right gastroepiploic artery.

McKeown) Brigham, and left thoracoabdominal with radical en bloc resection, and total thoracoscopic or thoracoscopically assisted esophagectomy. The operative approach must consider the location of the tumor in the esophagus (upper, middle or lower) and the type of conduit used for reconstruction (stomach, small bowel or colon) as well as the placement of the reconstruction (subcutaneous, substernal or posterior mediastinum).

Transhiatal

Transhiatal esophagectomy without thoracotomy in which the thoracic esophagus is removed by dissection through the esophageal hiatus, as reported in 1978,[21] has been popularized by Orringer. His group has reported excellent results for esophagectomy for both benign disease as well as cancer, the most recent report being a 20-year case series of 1085 patients.[22] They are able to perform the procedure in almost 99% of the patients and use stomach as the esophageal substitute in 96%. Their hospital mortality rate is 4% with a low complication rate and good late functional results. They have used the technique in upper, middle and lower third esophageal cancers although the majority of their case series were for lower third and/or cardia cancers. For the patients with carcinoma, they report 2-year survival as 47% and 5-year survival as 23%. These results compare favorably to other techniques for esophageal resection for cancer but there are no prospective, randomized studies making this comparison directly. This technique provides limited exposure to resect thoracic lymph nodes.

Ivor-Lewis

The Ivor Lewis procedure was described in 1945[23] for surgical treatment of the carcinoma of the middle third of the esophagus. This was performed in two stages with the first stage being an abdominal exploration with feeding jejunostomy placement followed several weeks later by a right thoracotomy and thoracic esophageal resection. Stomach was used as the conduit and an esophagogastric anastomosis was created at the apex of the chest. It is still used today commonly as a one-stage technique by many surgeons. It involves a left upper paramedian or midline abdominal incision for mobilization of the stomach with division of the left gastric artery, left gastroepiploic artery and short gastric vessels. This is followed by a right thoracotomy through the sixth rib with mobilization and resection of the thoracic esophagus, pulling up the gastric conduit into the chest and performing either a hand-sewn, or stapled esophagogastric anastomosis. This approach limits the proximal resection and places the anastomosis in the chest.

Tri-Incisional Brigham (Modified Mckeown) Approach

The Brigham and Women's Hospital approach to esophagectomy is a modification of the original Ivor-Lewis technique and is a variation of the technique described by McKeown.[24] We begin the procedure with the patient in the left lateral decubitus position and perform a limited right posterolateral thoracotomy by dividing the latissimus muscle as caudally as possible, sparing the serratus and reflecting it medially and entering the chest through the fifth interspace. In addition, we "shingle" the posterior sixth rib to aid in exposure. We next retract the lung anteromedially and incise the mediastinal pleura along its posterior aspect to expose the esophagus. We begin mobilization of the esophagus above the tumor in a region free of disease in

order to visualize the tumor and the surrounding structure. We then continue dissection toward the apex of the chest. We use a Penrose drain to encircle the esophagus above the tumor and use counter traction, blunt finger dissection and electrocautery to develop the tracheoesophageal plane up to and above the thoracic inlet. We divide the azygous vein with an endoscopic vascular stapler and divide the perforating branches between the aorta and esophagus with clips or electrocautery. After knotting the Penrose drain, we pass it up through the thoracic inlet and leave it lying beneath the left omohyoid muscle where it will be retrieved during the neck dissection. The Penrose helps identify the surgical dissection plane and avoid nerve injury. We then pack the apex of the chest to tamponade any bleeding.

We next turn attention to the tumor and distal esophageal dissection and place a second Penrose drain distal to the tumor to aid in mobilization which we achieve using electrocautery. We dissect down to the diaphragm and take a rim of diaphragmatic hiatus in the region surrounding the specimen. We then enter the peritoneum posteriorly and push the Penrose down around the gastroesophageal junction below the diaphragm and prophylactically ligate the thoracic duct using a 0-silk ligature.

At this point, we place the patient flat and make our second incision which is an upper midline laparotomy. We expose the Penrose drain at the gastroesophageal junction and begin mobilization of the greater curvature at the superior aspect near the hiatus. We divide the short gastric vessels between the stomach and the spleen and identify the transition between the left and right gastroepiploic arteries and continue our mobilization at least 2 cm lateral and inferior to the right gastroepiploic arcade (Figs. 6.7, 6.8). We next reflect the stomach superiorly and to the right to expose the left gastric artery and coronary vein which are ligated and divided using an endovascular stapler near their origin. We resect all lymph nodes in the celiac region and lesser and greater omentum with the specimen. We then perform a Kocher maneuver to mobilize the duodenum and perform a pyloromyotomy or Heineke-Mikulicz pyloroplasty with a single layer 3-0 silk closure.

After mobilization of the stomach, we proceed to our third incision which is a left cervical incision along the anterior border of the sternocleidomastoid muscle. We reflect the sternocleidomastoid laterally and dissect bluntly in this plane using a finger deep to the omohyoid muscle until we encounter the Penrose drain that we left positioned during the thoracic dissection. We ligate the middle thyroid vein and divide the omohyoid muscle and gently pull up on the Penrose drain to retract the cervical esophagus laterally. The nasogastric tube is then pulled into the pharynx and the esophagus divided using a linear cutter. We place a heavy silk suture through the proximal end of the divided esophagus in order to keep access to the posterior mediastinum and remove the specimen through the abdominal incision.

We next form our conduit using a linear cutting linear cutter starting at the top on the fundus and continuing along the lesser curve to just above the vagel aracade (crows foot). To produce wide tumor margins and a conduit the size of the normal esophagus, we staple along the stomach in a fashion that produces a narrow conduit. We then place an arthroscopy camera bag over the conduit and tie the proximal end to a 30 ml Foley catheter. The catheter is then tied to the heavy silk that was left from the neck incision through the posterior mediastinum, and we use this to deliver the gastric conduit into the cervical wound. We orient the stomach conduit with the staple line to the patient's right and make a gastrotomy on the posterior wall. We

then perform an end-esophagus-to-side-gastric hand-sewn anastomosis using a single layer, interrupted technique with nonabsorbable sutures. Alternatively, we use a linear cutter 75 mm stapler and linear 30 mm stapler to perform a side-to-side, functional end-to-end anastomosis. Finally, we close the neck over a Jackson-Pratt drain which is positioned inferiorly along side the gastric conduit and which exits from a separate stab incision above the clavicle. This drain is typically removed postoperative day 5 after performing a swallow using diatrizoate meglumine diatrizoate sodium (Gastrografin, Bracco Diagnostics, Princeton, NJ) to confirm that the cervical anastomosis does not have a leak.

Left Thoracoabdominal Approach

There are advocates of the left-sided transthoracic approach with radical en-bloc esophagectomy. Proponents believe that this approach has a beneficial effect on cure rate, even in cases of lymph node involvement.[25] This approach is used for tumors below the carina. A left thoracoabdominal incision is made and the diaphragm is opened at its periphery to give wide exposure to the chest and abdomen. A wide peritumoral dissection is carried out and careful lymphadenectomy performed around the celiac axis and superior mesenteric artery. In the cases of tumors of the gastroesophageal junction, the entire left upper abdominal quadrant down to the renal artery is cleared of tissue. The posterior mediastinum is also cleared of nodes including the subcarinal, aortopulmonary window nodes and the thoracic duct. For tumors of the upper half of the esophagus, a right-sided approach is used, and the nodes around the recurrent laryngeal nerve and brachiocephalic trunk carefully cleared. A gastric tube reconstruction is used with resection of the lesser curvature.[26]

Thoracoscopic Esophagectomy

As technology and techniques in minimally invasive surgery improve, these have been applied to the management of esophageal cancer. While there have been several series reported of VATS esophagectomy, none have achieved totally endoscopic esophagectomy, but have combined a conventional laparotomy and transhiatal esophagectomy with VATS dissection of the thoracic esophagus. There have been no benefits demonstrated for this technique over standard procedures. At the most recent Society of Thoracic Surgeons meeting in January 2000, a group from Pittsburgh presented a series of thoracoscopic/laparoscopic/ left neck esophagectomies. They showed that it was feasible, but noted longer intraoperative times and more complications.[27] With improvement in technology, this technique may prove useful. Whether it is an improvement over the current technique remains to be seen.

Adjuvant and Neoadjuvant Therapy

The diagnosis of carcinoma of the esophagus is typically made late accounting for a high rate of T3 or T4 tumors and N-positive lesions. These tumors have a poor prognosis, and cure with surgery alone is uncommon. Therefore, development of adjuvant and neoadjuvant therapies is being examined to determine whether such a multimodality strategy will have a favorable impact.

Radiation Therapy

Radiation therapy has been used preoperatively, intraoperatively and postoperatively as well as for the definitive management of esophageal cancer.

Preoperative Radiotherapy

A variety of radiotherapy doses and fraction sizes have been used to manage patients prior to resection, predominantly patients with squamous cell cancer. While some studies have shown a complete pathologic response in as many as 15-25% of the patients treated, preoperative radiation therapy has not been demonstrated to significantly improve survival in patients with esophageal cancer and cannot be recommended alone as a neoadjuvant therapy.[28]

Postoperative Radiotherapy

Prospective, randomized studies have been performed comparing radiation therapy or observation following surgery, again primarily in squamous cell esophageal cancer. No survival advantage has been demonstrated on patient outcome in these studies, and, therefore, postoperative radiotherapy cannot be recommended for patients with resectable squamous cell cancer.[29,30] Radiotherapy may diminish the chances of local recurrence in those patients who have residual mediastinal disease following resection.

Definitive Radiotherapy and Intraoperative Brachytherapy

Curative radiotherapy without concurrent chemotherapy is not effective therapy for esophageal carcinoma.[31,32] Intraoperative radiotherapy has been used in pilot studies, but its role in the treatment of esophageal cancer remains to be defined.

Chemotherapy

Single Agents

Approximately seven agents have been identified with activity against esophageal cancer in phase II clinical trials. Most of the drugs were evaluated in patients with metastatic squamous cell carcinoma.[33] These drugs have a 20% or greater response rate and include fluorouracil, mitomycin, cisplatin, bleomycin, methotrexate, mitoguazone, vindesine. Currently, new agents being evaluated are paclitaxel, vinorelbine and the cisplatin analogue lobaplantin, but their efficacy remains to be demonstrated. Chemotherapy alone as preoperative therapy for patients with localized esophageal cancer has not been shown to improve overall survival nor has postoperative chemotherapy.[34]

Combination Therapy

The combination of fluorouracil and cisplatin is standard therapy for patients with advanced cancer of the esophagus. There is an approximately 50% overall response rate for localized disease and 35% response rate for metastatic disease.[35] Studies are underway evaluating the combination of paclitaxel, fluorouracil and cisplatin.

Multimodality Therapy

Effective locoregional control and the prevention of metastasis is critical to improving outcome in patients with resectable esophageal cancer and is the primary focus in the treatment of esophageal cancer today. Multimodality therapy focuses on this issue. Presently, multimodality regimens consist of preoperative chemoradiation utilizing cisplatin and fluorouracil.[36,37] Results have been mixed with

some significant treatment related morbidity and mortality but also good pathologic response and median survival. A study reported in the New England Journal of Medicine by Walsh and colleagues from Ireland showed a significant benefit to induction chemoradiotherapy followed by surgery versus surgery alone.[38] There are criticisms of this study particularly with regard to the equality of the two treatment groups and the poor overall survival with surgery alone (median 8 mo). Further follow-up and more studies will be necessary to establish the efficacy of preoperative chemoradiotherapy and to evaluate new drugs and combined regimens.

Other Treatment Options

Photodynamic therapy (PDT)

PDT is the application of an agent that is selectively taken up by tumor cells and activated to kill those cells by light energy delivered by via laser. This therapy appears to have use in opening up an esophagus obstructed by tumor and is being looked at as a curative treatment for T1 lesions or high grade Barrett's dysplasia. The data are very preliminary and await careful study.

Stents

To palliate an obstructed esophagus, flexible stents have been developed which can be delivered via a flexible endoscope. They appear superior to the more traditional Celestin tubes that had a high rate of failure. These stents have a role for patients who are not amenable to other more curative therapies and have significant dysphagia.

Conclusion

Esophageal cancer continues to present a tremendous challenge in diagnosis and management. The development of new technology and surgical techniques promises to improve the accuracy of staging and reduce its morbidity as well as play a significant role in the definitive management of the disease. A team effort with a focus on multimodality therapy will be needed to significantly increase the cure rate for this disease.

References

1. Wang HH, Antonioli DA, Goldman H. Comparative features of esophageal and gastric adenocarcinomas: Recent changes in type and frequency. Hum Pathol 1986; 17:482-487.
2. Parker SL, Tong T, Bolden S. Cancer statistics, 1996. CA Cancer J Clin 1996; 65:5-27.
3. Blot WJ, Devesa SS, Kneller RW et al. Rising incidence of adenocarcinoma of the esophagus and gastric cardia. JAMA 1991; 265:1287-1289.
4. Reeders JW, Bartelsman JF. Radiologic diagnosis and preoperative staging of oesophageal malignancies. Endoscopy 1993; 25:10-27.
5. Canto MI. Vital staining and Barrett's esophagus. Gastrointest Endosc 1999; 49(3 part 2):S12-S16.
6. American Joint Committee on Cancer Staging Manual. In: Fleming ID, Cooper JS, Henson DE et al, eds. Philadelphia: Lippincott-Raven, 1997.
7. Botet JF, Lightdale CJ, Zauber AG et al. Preoperative staging of esophageal cancer: comparison of endoscopic US and dynamic CT. Radiology 1991; 181:419-425.

8. Sondenaa K, Skaane P, Nygaard K et al. Value of computed tomography in preoperative evaluation of resectability and staging of oesophageal carcinoma. Eur J Surg 1992; 158:537-540.
9. Consigliere D, Chua CL, Hui F. Computed tomography for oesophageal carcinoma: its value to the surgeon. J R Coll Surg Edinb 1992; 37:113-117.
10. Lefor AT, Merino MM, Steinberg SM et al. Computerized tomographic prediction of extraluminal spread and prognostic implications of lesion width in esophageal carcinoma. Cancer 1988; 62:1287-1292.
11. Lea JW, Prager RI, Bender HWJ. The questionable role of computed tomography in preoperative staging of esophageal carcinoma. Ann Thorac Surg 1984; 38:479-481.
12. Maas R, Nicholas V, Grimm H. MRI of esophageal carcinoma with ECG gating at 1.5 Tesla. In: Ferguson MN, Little AG, Skinner DB, eds. Diseases Of The Esophagus. Mount Kisko, NY: Futura Publishing Company, 1990:145-155.
13. Van Dam J. Endosonographic evaluation of the patient with esophageal cancer. Chest 1997; 112(4 Suppl):184S-190S.
14. Chak A, Canto M, Gerdes H et al. Prognosis of esophageal cancers preoperatively staged to be locally invasive (T4) by endoscopic ultrasound (EUS): A multicenter retrospective cohort study. Gastrointest Endosc 1995; 42:501-506.
15. Grimm H, Hamper K, Binmoeller KF et al. Enlarged lymph nodes: malignant or not? Endoscopy 1992; 24(Suppl 1):320-323.
16. Lowe VJ, Naunheim KS. Positron emission tomography in lung cancer. Ann Thorac Surg 1998; 65:1821-1829.
17. Lowe VJ, Fletcher JW, Gobar L et al. Prospective investigation of positron emission tomography in lung nodules. J Clin Oncol 1998; 16:1075-1084.
18. Luketich JD, Schauer P, Urso K et al. Future directions in esophageal cancer. Chest 1998; 113(1 Suppl):120S-122S.
19. Murray GF, Wilcox BR, Starek PIK. The assessment of operability of esophageal carcinoma. Ann Thorac Surg 1977; 23:393-399.
20. Krasna MJ, Reed CE, Jaklitsch MT et al. Thoracoscopic staging for esophageal cancer: A prospective, multi-institutional trial. Ann Thorac Surg 1995; 60:1337-1340.
21. Orringer MB, Sloan H. Esophagectomy without thoracotomy. J Thorac Cardiovasc Surg 1978; 76:643-654.
22. Orringer MD, Marsall B, Iannettoni MD. Transhiatal esophagectomy: clinical experience and refinements. Ann Surg 1999; 230:392-403.
23. Lewis I. The treatment of carcinoma of the esophagus: With special reference to a new operation for growths of the middle third. Br J Surg 1945; 34:18-31.
24. McKeown KC. Total three-stage oesophagectomy for cancer of the oesophagus. Br J Surg 1976; 63:259-262.
25. Skinner DB. En bloc resection for neoplasms of the esophagus and cardia. J Thorac Cardiovasc Surg 1983; 85:59-71.
26. Lerut T. Esophageal surgery at the end of the millennium. J Thorac Cardiovasc Surg 1998; 116:1-20.
27. Peracchia A, Rosati R, Fumagalli U et al. Thoracoscopic esophagectomy: are there benefits? Semin Surg Oncol 1997; 13:259-262.
28. Diehl LF. Radiation and chemotherapy in the treatment of esophageal cancer. Gastroenterol Clin North Am 1991; 20:765-774.
29. Teniere P, Hay JM, Fingerhut A et al. Postoperative radiation therapy does not increase survival after curative resection for squamous cell carcinoma of the middle and lower esophagus as shown by a multicenter controlled trial. French University Association for Surgical Resection. Surg Gynecol Obstet 1991; 173:123-130.

30. Fok M, Sham JST, Choy D et al. Postoperative radiotherapy for carcinoma of the esophagus: a prospective randomized controlled trial. Surgery 1993; 113:138-147.
31. Smalley SR, Gunderson LL, Reddy EK et al. Radiotherapy alone in esophageal carcinoma: Current management and future directions of adjuvant, curative, and palliative approaches. Semin Oncol 1994; 21:467-473.
32. Herskovic A, Martz K, al-Sarraf M et al. Combined chemotherapy and radiotherapy compared with radiotherapy alone in patients with cancer of the esophagus. N Engl J Med 1992; 326:1593-1598.
33. Wittes RE, Adrianza ME, Parsons R. Compilation of phase II results with single antineoplastic agents. Cancer Treat Rep 1985; 4:91-130.
34. Kielsen DP, Ginsberg R, Pajak TF et al. Chemotherapy followed by surgery compared with surgery alone for localized esophageal cancer. N Engl J Med 1998; 339:1979-1984.
35. Ajani JA. Contributions of chemotherapy in the treatment of carcinoma of the esophagus: results and commentary. Semin Oncol 1994; 21:474-482.
36. Forastiere AA, Orringer MB, Perez-Tamayo C et al. Concurrent chemotherapy and radiation therapy followed by transhiatal esophagectomy for local-regional cancer of the esophagus. J Clin Oncol 1990; 8:119-127.
37. Bates BA, Detterbeck FC, Bernard SA. Concurrent radiation therapy and chemotherapy followed by esophagectomy for localized esophageal carcinoma. J Clin Oncol 1996; 14:156-163.
38. Walsh TN, Noonan N, Hollywood D et al. A comparison of multimodal therapy and surgery for esophageal adenocarcinoma. N Engl J Med 1996; 335:462-467.

Minimally Invasive Esophagectomy

Todd L. Demmy

Minimally invasive esophagectomy is a technically demanding operation that has been performed selectively at several centers. Many experts in thoracoscopy, like those who authored the preceding Chapter, use thoracoscopy primarily as a staging tool or to facilitate the thoracic dissection. Nevertheless, there are several reasonable arguments for presenting the technique of the full endoscopic operation in this brief Chapter.

Given the rapid evolution of the surgical techniques and instrumentation, larger operations like this should become even more feasible. The necessity of an extensive abdominal lymph node dissection particularly for patients with severe dysplasia or early stage proximal malignancies, is uncertain. Many thoracic surgeons consider esophagectomy to be a largely palliative operation—so minimizing operative trauma and hastening convalescence is desirable. This is further supported by the fact that many patients are frail from nutritional depletion, comorbid conditions, or preoperative chemoradiotherapy. The latter, while controversial regarding its salutary effects on survival, produces a pathologic complete response in 10-20% of cases raising the question whether resection improves results. The application of minimally invasive esophagectomy for patients who are good operative risks should be done in an investigational setting. Groups unlikely to benefit from an extensive regional dissection would make good candidates.

However, there are clinical situations in which application of this new technology could be considered as an ethically acceptable operation outside of a clinical trial. Patient frailty, refusal of a standard method and other unusual factors are examples in which a surgeon with excellent laparoscopic skills could offer a VATS esophagectomy provided there is appropriate informed consent regarding the uncertainties involved.

Ideally, the patient should have favorable anatomy and could tolerate a prolonged anesthetic.

Indications, Perioperative Management and Postoperative Care

These issues were described well in the preceding Chapter and will not be repeated here.

Surgical Technique

Methods to dissect the intrathoracic esophagus were discussed in the preceding Chapter and can be used as an alternative. I will concentrate on the intraabdominal portion of the operation and for simplicity will focus on a technique described by Nguyen, et al , who offered this operation to patients with Barrett's esophagus with high grade dysplasia.[1] Other small series of patients undergoing similar operations have been reported and can be instructive.

Thoracic Dissection

After esophagoscopy and, if appropriate, bronchoscopy, patients are positioned in the left lateral decubitus position and selective ventilation of the left lung is begun. Two 5 mm and two 10 mm ports are placed as indicated in Figure 7.1. Alternatively, I like to dissect the esophagus through a posterior access thoracotomy less than 8 cm in length without rib spreading and use only an inferior camera port and an anterior port for other instruments. A heavy suture placed through the central tendon of the diaphragm and brought out inferiorly aids exposure of the distal esophagus. If desired, an additional inferior port to place a fan or similar retractor for the diaphragm can be used.

The esophagus is exposed by opening the pleural over it or each side where the tumor is nearby. The inferior pulmonary ligament is divided by cautery while the azygous vein is divided using an endoscopic vascular stapler. The esophagus is encircled using a 1/4-1/2" penrose drain or a semi-circular laparoscopic esophageal retractor (Snowden-Pencer). The penrose is useful because the ends can be joined and the drain left in the inferior cervical paravertebral-esophageal space for later retrieval from the neck. Lymph nodes are sampled as described previously. Surgeons who find the transhiatal method tedious for dissecting tumors or postirradiation adhesions away from the membranous airway will appreciate the visualization afforded by this method. Dissection proceeds to the thoracic apex and a plane is developed between the esophagus and cervical spine for placement of the penrose drain. Tissue compression and lung reinflation holds the drain in place. Dissection proceeds distally to the diaphragmatic reflection nearing the esophagogastric junction. The port sites or access thoracotomy are closed and a chest tube inserted through an inferior lateral 10 mm port site. This drains fluid or gas lost from the pneumoperitoneum needed later.

Laparoscopic Technique

This portion of the operation begins like many laparoscopic antireflux operations. The patient is placed in the supine position and the stomach and bladder should be decompressed by catheters by this point. Placing the legs in lithotomy position is used by some surgeons to increase surgeon position options. Five ports are placed in the anterior abdominal wall. A periumbilical or lower quadrant port is used for the camera. A right upper quadrant port allows placement of a fan or self retaining retractor to provide upward displacement of the left lobe of the liver. A ultrasonic dissection shears divides the short gastric vessels to mobilize the fundus. The dissection proceeds down the greater curvature and the gastrocolic omentum is divided without disturbing the arcade of the right gastroepiploic artery. This allows elevation of the greater curvature with identification of the left gastric artery and

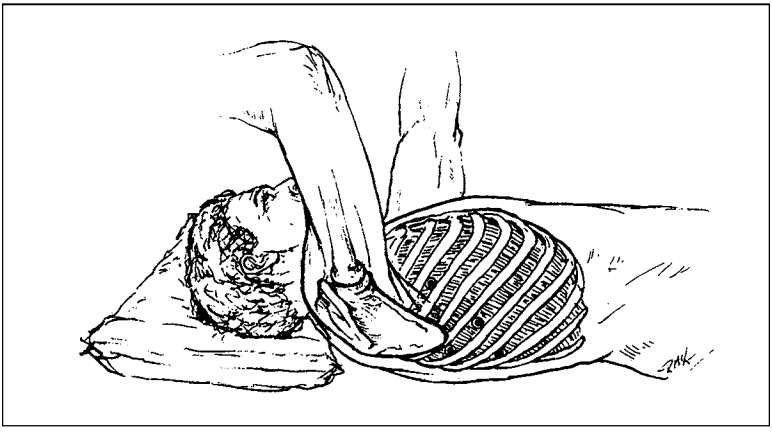


Fig. 7.1. Diagram of port placement for video-assisted esophagectomy. Reproduced with permission from Surgery 2000; Vol. 127(3):281-290.

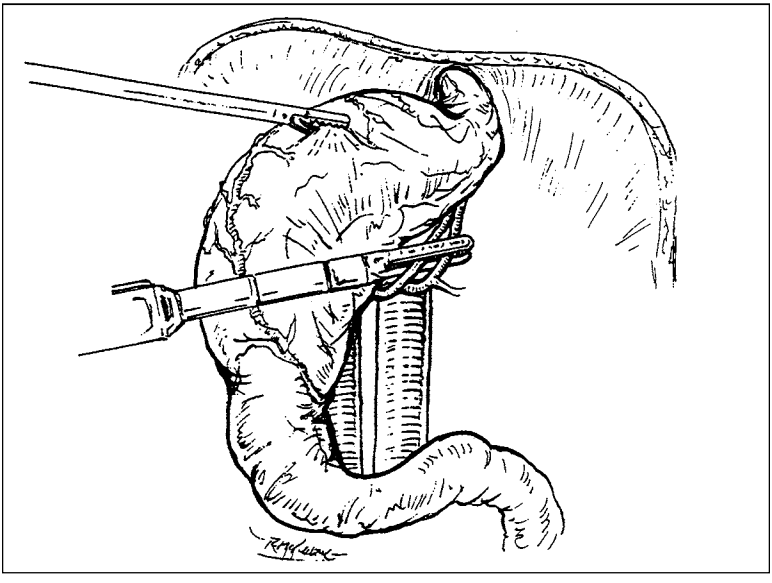


Fig. 7.2. Division of left gastric vessels using an endoscopic stapler.Reproduced with permission from Surgery 2000; Vol. 127(3):281-290.

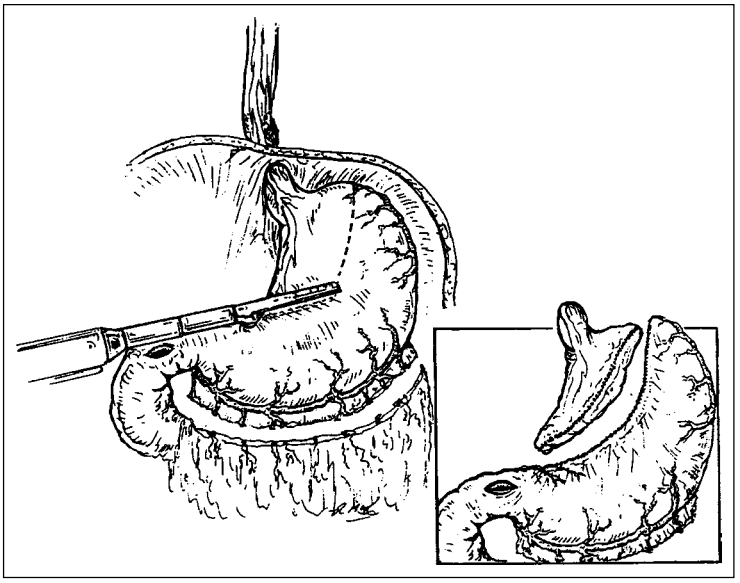


Fig. 7.3. Division of stomach below esophagogastric junction. Reproduced with permission from Surgery 2000; Vol. 127(3):281-290.

vein. These are dissected and then divided using an endoscopic vascular stapler (See Fig. 7.2). This leaves division of the remaining hepatogastric omentum without damaging the right gastric artery as the final step to free the gastric graft. A pyloromyotomy is performed and a pyloroplasty can be added if the mucosa is damaged. The pyloroplasty is performed using a single layer of simple sutures with intracorporeal knot tying techniques.

Next, using several fires of an endoscopic stapler capable of compressing the stomach, the stomach is divided starting perpendicular to the lessor curvature and then angulating toward the fundus to leave the apex of the fundus for maximal length of the graft (Fig. 7.3). The gastric remnant is then sutured to the fundus and all remaining peritoneal and other attachment between the esophagus and hiatus are divided to join the previous thoracic dissection (Fig. 7.4).

A limited, low cervical incision anterior to the sternocleidomastoid muscle provides sufficient exposure to complete the operation. The strap muscles are divided as necessary and the penrose drain is retrieved from the esophagovertebral plane. Care is taken to avoid injury to the recurrent laryngeal nerve while completing the remaining dissection bluntly. The middle thyroid vein may require division.

The anastomosis is constructed using the original interrupted Gambee suturing techniques with OOO silk sutures or by using a hybrid technique using a 30 mm endoscopic stapler and sutures as recently described by Orringer.

References

1. Nguyen NT, Schauer P, Luketich JD. Minimally invasive esophagectomy for Barrett's esophagus with high-grade dysplasia. Surgery 2000; 127: 284-90.

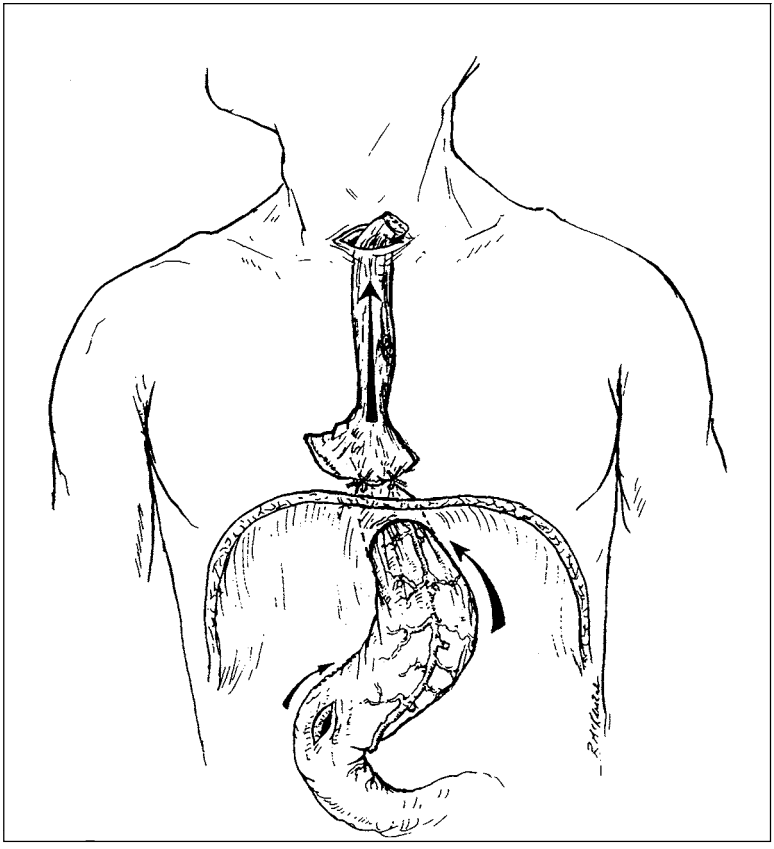


Fig. 7.4. Delivery of gastric fundus into neck wound. Reproduced with permission from Surgery 2000; Vol. 127(3):281-290.

Thoracoscopy for Trauma

Oliver A. R. Binns, David R. Jones

Background and Indications

Thoracic injuries are seen in 30-40% of patients requiring hospitalization following traumatic injury.[1] Thoracic trauma is directly responsible for 25% of trauma deaths and contributes to death in an additional 25% of cases.[2] Many late deaths also occur from the complications of thoracic trauma. Despite the high incidence of thoracic trauma, the majority of injuries are managed by observation with or without closed-tube thoracostomy. In fact, less than 15% of traumatic thoracic injuries require operative intervention. A minority of these patients will require an urgent thoracotomy for massive hemorrhage, tracheal or bronchial injury, or management of other life-threatening injuries. In the majority of patients who present with subacute thoracic injuries, video-assisted thoracic surgery (VATS) is being used increasingly to diagnose and treat these injuries.

VATS has evolved from its initial diagnostic use to a therapeutic modality. As the use of VATS continues to expand in thoracic surgery, its role in the management of the trauma patient is also growing.[3] With the advent of simplified thoracoscopic techniques and improved technology, VATS is proving to be an important advancement in the assessment and management of patients with thoracic injuries.

The first use of thoracoscopy in the management of penetrating thoracic injuries was reported by Castello-Branco in 1946.[4] Since then, several series and case reports have attempted to define the role of VATS and its indications in the realm of thoracic trauma.[5,6] Currently accepted indications for VATS in the setting of trauma include persistent hemothorax despite tube thoracostomy, diagnosis and repair of diaphragmatic injuries, recurrent pneumothorax or ongoing air leak, posttraumatic empyema, evaluation and treatment of ongoing hemorrhage in a hemodynamically stable patient, and diagnosis of intrapericardial or other mediastinal injuries. VATS is also useful in the evaluation of the stable patient with penetrating thoracoabdominal trauma and may obviate the need for exploratory laparotomy. It is important to emphasize that VATS has no role in the management of unstable patients or those with clear indications for emergent or urgent thoracotomy.

Basic Considerations for VATS in the Trauma Patient

General Assessment

The successful management of the acutely injured trauma patient begins with an accurate primary survey with special attention to the patient's airway, respiratory

status, and circulation. A secondary assessment is then completed to further define the location and extent of injuries. Stabilizing concurrent resuscitation proceeds according to specific patient needs. One can then consider which diagnostic or therapeutic modalities are best suited for patients and their associated injuries.

The trauma patient has unique differences compared to other patients who undergo VATS procedures. These differences are the multidisciplinary team approach to the trauma patient with multiple injuries and the coordination of the patient's care in an urgent, timely manner. When evaluating the trauma patient one must assess the patient's ability to tolerate selective lung ventilation if considering a VATS procedure. In the trauma setting, preoperative pulmonary function function tests are not performed commonly in contrast to more elective VATS procedures. Thus, it is the clinical and radiographic assessment that determines whether the patient is a good candidate for a VATS procedure. Examples of important preoperative considerations in the trauma patient are: Does the patient have a significant contralateral pulmonary contusion with resultant shunting and hypoxia? Could there be an occult tracheobronchial injury that may become evident with selective lung ventilation? Are there other identified or as yet unrecognized injuries that could result in instability during the procedure? Does the patient have a blunt cardiac injury? These problems can make trauma a difficult setting in which to perform VATS; however, with careful patient selection and appropriate planning, VATS can be successful.

Anesthetic Considerations

We prefer a double-lumen endotracheal tube to allow selective ventilation of the contralateral lung in order to facilitate visualization and use of instrumentation in the involved hemithorax. The potential for aggravation of a cervical spine injury during intubation of the trauma patient must always be kept in mind. Double-lumen tube placement in patients with cervical spine injuries and cervical collars can be difficult, but it is by no means a contraindication. For patients with an existing tracheostomy, we prefer a bronchial blocker that causes resorptive atelectasis of the ipsilateral lung.

Continuous pulse oximetry and ECG monitoring are performed. In addition, end-tidal CO_2 monitoring to assess the adequacy of ventilation and invasive arterial pressure monitoring are frequently used. More invasive monitoring is rarely needed and is used only as clinically indicated. During the operation the patient should constantly be reassessed for hemodynamic changes during single lung ventilation and the surgeon should be prepared to convert to an open procedure if needed.

Patient Positioning

Positioning of the trauma patient presents special considerations. Airway management and attention to endotracheal tube position during patient positioning needs vigilant, frequent reassessment. Associated traumatic injuries must be noted and protected appropriately. Injuries seen frequently in conjunction with chest trauma include vertebral and extremity fractures. Neurosurgical or orthopedic specialists may provide useful assistance in positioning the patient.

We favor a lateral decubitus position for virtually all VATS procedures. In addition, the patient is in the correct position should a thoracotomy be needed. Flexible bronchoscopy should then be used to confirm appropriate positioning of the endo-

tracheal tube after the patient has been positioned. Many patients will already have a chest tube in place and this tube is removed before application of the prep-solution and draping. One must ensure patency and necessary suction of the pleurovac system prior to draping in patients with a contralateral tube thoracostomy. Attention to this detail can avoid the development of a contralateral pneumothorax with impaired ventilation during the procedure.

VATS Set-up

The table set-up for VATS in the trauma patient includes all necessary VATS instrumentation and appropriate "open" instruments as well. Preoperative communication between the surgeon and the operating room nurses regarding the patient positioning, planned approach, and the necessary instrumentation will help obviate delays in the case and educate the surgical team. The video towers are positioned as noted in Chapter 1 except in cases of suspected diaphragmatic injury where I prefer to have the operating surgeon's tower at the foot of the bed.

Diagnostic VATS in the Trauma Patient

Once the patient is correctly positioned, prepped and draped, and selective lung ventilation instituted and tolerated, the actual VATS exploration of the chest can begin. Using selective lung ventilation, we have found no need to perform CO_2 insufflation. Irrespective of the primary indication for the procedure, the entire hemithorax is carefully inspected for occult injuries. Exploration of the pleural cavity includes an inspection of the pericardium, the pulmonary hilum, and the posterior mediastinum. The presence of hematoma formation, significant contusion, the presence of chyle, or a bulging pericardium all necessitate further exploration. In addition, the aorta, esophageal recess, and diaphragm should be examined carefully. Finally, the chest wall, including the internal mammary and intercostal vessels as well as the entire lung parenchymal surface needs to be visualized.

Specific Traumatic Injuries

Hemothorax

Thoracic surgeons are frequently involved in the evaluation of trauma patients with hemothoraces. VATS can be used to evaluate ongoing hemorrhage with hemodynamic stability or to evacuate an existing hematoma. Most trauma centers proceed with surgical intervention if chest tube output continues at a rate of 150-250 mls/hr for 2-4 hours or is greater than 1500 mls in 24 hours. VATS is an ideal modality in these patients to allow earlier diagnosis and control of hemorrhage while potentially avoiding a thoracotomy.

In 36 hemodynamically stable patients with hemothoraces following penetrating trauma, VATS altered the management in 30% of cases.[5] In 97% of patients undergoing VATS, the injuries were identified including the sites of ongoing bleeding. In another small series of penetrating trauma, five patients had their source of bleeding identified as an intercostal artery and the bleeding was successfully controlled in three of the patients using VATS techniques. In the other two patients the required thoracotomy was facilitated by localization of the injury by VATS.[6]

In addition to controlling hemorrhage, VATS also provides a means to evacuate clotted hemothoraces that have failed to respond to tube thoracostomy. Computed

tomography (CT) can be helpful in the evaluation of persistent hemothoraces or those with delayed presentation. CT often determines the degree of clot organization and differentiates between intrapleural and parenchymal disease processes. The ultimate fate of blood within the pleural space is variable and its mere presence does not always result in organization. Of those patients with hemothoraces treated without thoracotomy approximately 2-3% will develop an empyema or require a delayed thoracotomy for a retained hemothorax. If untreated, some patients will develop a fibrothorax with parenchymal entrapment and functional loss. The role of fibrinolytic agents as an adjunct to tube thoracostomy has been shown to be beneficial in our experience. Despite their use, however, certain patients will need surgical intervention.

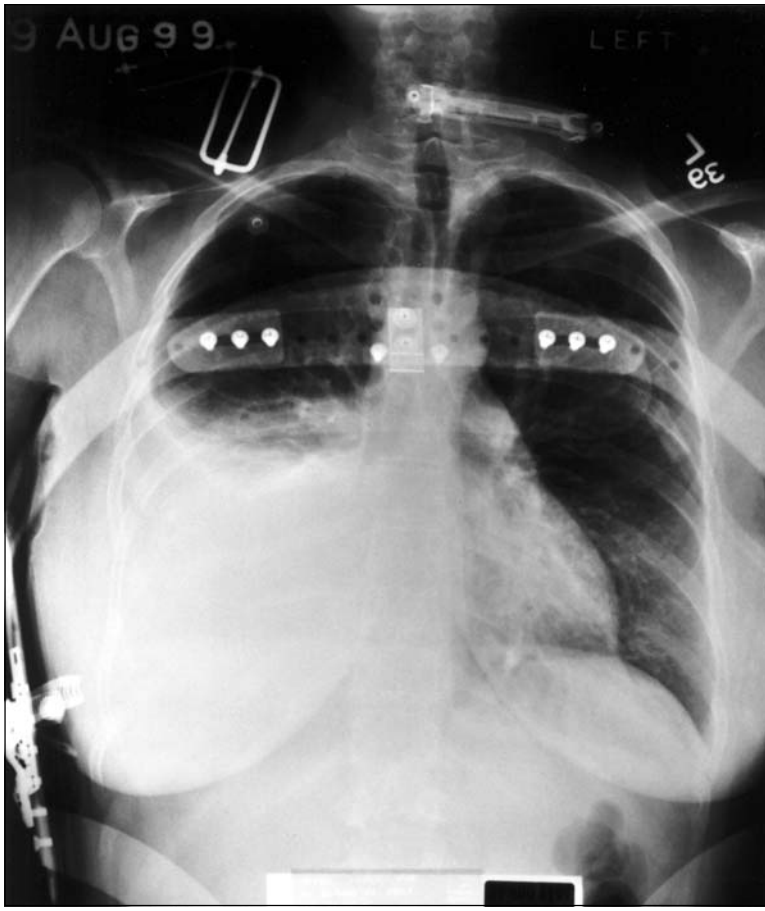
Appropriate, early VATS, as supported by our clinical experience and other authors,[7] is very useful in selected patients. An 89% success rate for evacuating clotted hemothoraces with VATS has been reported, and the authors noted that the evacuation was technically easier within the first 10 days following injury.[6] Occasionally we are confronted with a delayed presentation of posttraumatic hemothorax. In our experience, even a delayed presentation of a traumatic hemothorax does not categorically preclude VATS evacuation (see Figs. 8.1-8.3) and therefore VATS should be attempted as the initial procedure.

Operative Strategies for Hemothorax

The surgical approach to a traumatic hemothorax should allow a thorough evaluation of the hemithorax keeping in mind the potential need for a formal thoracotomy.

After induction of anesthesia and placement of a double-lumen endotracheal tube, the patient is placed in full posterolateral thoracotomy position. Review of preoperative roentgenographic studies, including CT scans, may aid in trocar placement. Aspiration using a large gauge needle can also confirm the location of a fluid collection and the appropriate interspace for port placement. Digital examination of the pleural space is recommended prior to introduction of VATS instrumentation. A recent closed-tube thoracostomy wound is often used for placement of the initial port and introduction of the thoracoscope. We commonly use the 30° and 45° scopes to enhance our visualization, especially in areas such as the costophrenic recesses. In cases of simple, unilocular fluid collections two ports usually provide adequate visualization and working space for lysis of adhesions and evacuation of fluid collections. Use of an operating thoracoscope provides an additional working port. We favor placing additional ports in the line of a potential posterolateral thoracotomy and/or future chest tube sites. However, location of pathology, adequate visualization, and necessary exposure should ultimately guide trocar location.

Thorough exploration of the hemithorax is performed initially. All adhesions necessary to adequately visualize the chest cavity are taken down using a combination of sharp dissection and electrocautery. This allows all pleura surfaces to be inspected and enhances postoperative lung expansion and drainage of the pleural space. Large caliber suction and irrigation devices are very helpful in removing larger blood clots. Sites of ongoing hemorrhage amenable to VATS control include intercostal arteries and veins, the internal thoracic artery and veins, and lung parenchymal lacerations. After identifying the source of bleeding it can frequently be controlled with electrocautery or application of endoclips. Direct suture ligation or oversewing



Figs. 8.1a and 8.1b. PA and lateral chest x-ray demonstrating delayed presentation of a right hemothorax after blunt thoracic trauma with thoracic spine injury and chest wall flail segment.

of bleeding vessels is occasionally necessary. Difficult to control hemorrhage from an intercostal artery can be addressed using a Keith needle to completely encircle the rib and associated intercostal bundle. The suture can then be tied outside the chest over a bolster on the skin. This technique does, however, predispose the patient to postoperative neuralgia in the distribution to the involved intercostal nerve. More significant injuries may require thoracotomy.

If no sources of ongoing hemorrhage are identified after systematic inspection of the hemithorax, the procedure may be terminated. However, in cases of delayed presentation, the presence of a fibrous peel overlying the lung parenchyma will require

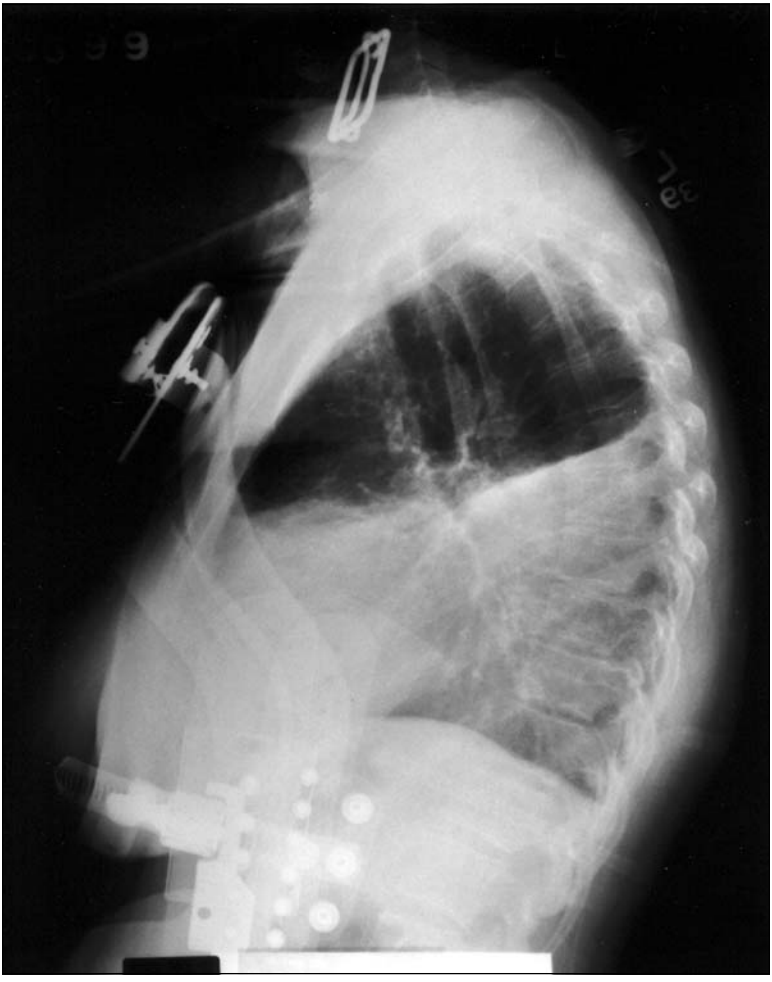


Fig. 8.1b.

further intervention. VATS decortication can usually be performed at this time. After completing the decortication, reinflation of the lung is performed under direct vision to confirm the adequacy of re-expansion. If VATS techniques fail to provide adequate lung re-expansion, conversion to a limited thoracotomy may be needed. If open thoracotomy is necessary, leaving VATS equipment on the operative field is appropriate to aid in visualization if needed.

At the completion of the procedure the chest is irrigated with antibiotic solution and chest tube drains are inserted under direct vision for optimal placement. Trocar

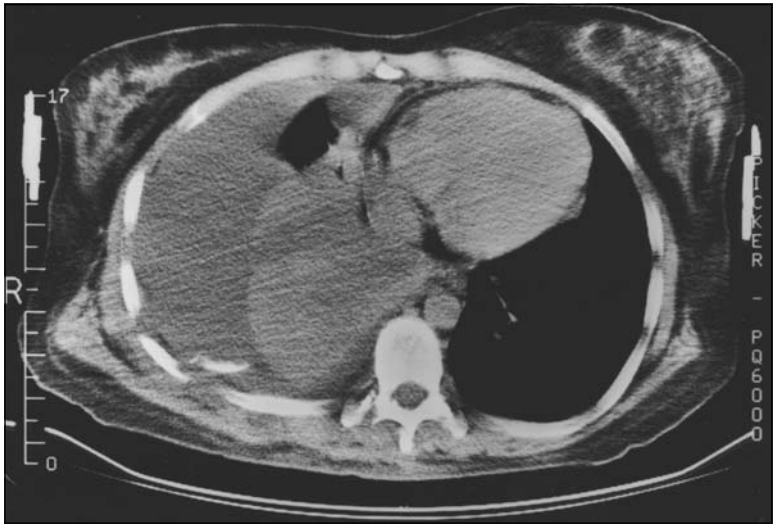


Fig. 8.2. CT scan of the above patient showing no evidence of loculations. Despite delayed presentation on postinjury day 12, the collection could easily have been evacuated using thoracoscopy techniques. A thoracotomy was performed, however, to facilitate stabilization of the chest wall defect.

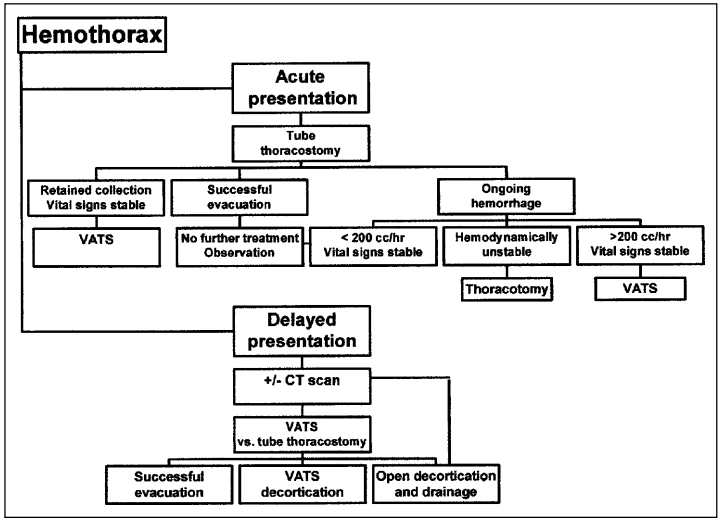


Fig. 8.3. Algorithm for the management of traumatic hemothorax

incisions are commonly used for chest tube insertion thus avoiding additional wounds. Typically two pleural drainage catheters are used and placed to -20 cm H_2O suction.

Diaphragmatic Injury

Currently employed diagnostic tests for detecting traumatic diaphragmatic injuries are notoriously insensitive. Physical exam, plain radiography, CT, and diagnostic peritoneal lavage all have an unacceptable false negative rate for diagnosis. Diagnostic peritoneal lavage has a false negative rate of 24% with blunt diaphragmatic rupture.[8] In 234 trauma patients evaluated prospectively, physical exam and chest radiographic findings missed the diagnosis of diaphragmatic hernia in 5 of 14 patients.[9]

Penetrating injuries are more common than blunt and often result in small defects that are undetectable by noninvasive modalities. Feliciano et al report a 33% rate of missed diaphragmatic injury at the time of laparotomy in patients presenting with delayed diagnosis of injuries to the diaphragm after penetrating trauma.[10] Due to the peritoneal-pleural pressure gradient these defects may not close spontaneously and are prone to herniation. With time these defects can enlarge thus predisposing the patient to the late complications of diaphragmatic hernia and associated sequelae. Thoracoscopy provides a minimally-invasive method for evaluating the entire surface of the hemidiaphragm in patients in whom there is a high index of suspicion for a diaphragmatic injury.

Several small series documented the benefit of VATS in evaluating the diaphragm after thoracoabdominal injuries. Smith et al conducted a prospective trial of VATS in 24 patients with chest trauma, 10 of whom diaphragmatic injury was suspected based on an abnormal chest radiograph (2 patients) or proximity of penetrating injury (8 patients).[6] Diaphragmatic injury was confirmed in five patients and excluded in four. The examination was incomplete in one patient due to intolerance of single lung ventilation. Successful repair in four patients with small (< 4 cm) lacerations was accomplished with VATS. One patient with a large defect secondary to blunt disruption required a laparotomy to repair the injury. Finally, in the setting of thoracoabdominal injuries with evidence of intrathoracic penetration, a negative VATS diaphragmatic evaluation may obviate the need for laparotomy.

Operative Strategies for Diaphragm Injuries

Patients considered for a VATS approach to diagnose and potentially treat posttraumatic diaphragm injuries need to have completed a secondary and commonly a tertiary trauma assessment. The majority of patients undergo selective lung ventilation utilizing a double-lumen endotracheal tube or a bronchial blocker. Other techniques of selective ventilation are described in Chapter 1. We always perform this procedure under a general anesthetic. All patients should have an orogastric or nasogastric tube inserted as well a Foley catheter. This is because these patients may require concomitant laparoscopy at which time both the bladder and stomach should be decompressed prior to inserting the laparoscope.

The patients are positioned in a modified lateral decubitus position with flexion of the operating table to open the intercostal spaces. This modified posterolateral position permits the patient to be in an approximately 60° thoracotomy position. This positioning allows the surgeon to insert the laparoscope should this be necessary

in order to better identify the diaphragm injury and/or remove any abdominal viscera, including omentum, which may have herniated through the defect. Accordingly, a patient is prepped and draped widely to include the abdomen and chest.

After instituting selective lung ventilation the initial port-site is generally in the anterior axillary line in the third or fourth intercostal space. This port-site is not tunneled and allows the operator to visualize the entire diaphragm from well above the suspected injury. Exploratory thoracoscopy is then performed to look at other potential areas of injury in the thorax. A second port-site is inserted in the seventh intercostal space in the posterior axillary line. This facilitates the division of the inferior pulmonary ligament, which I perform in all cases of suspected diaphragm injury. A 5 mm trocar can be inserted anteriorly and the endo-grasper used to grasp the lung and retract it while the inferior pulmonary ligament is divided. Once the inferior pulmonary ligament is taken down the patient may be placed in a moderately steep Trendelenburg position in order to allow the lung to fall away from the diaphragm and facilitate its exposure. A nondisposable retracting fan is inserted through a second five-millimeter port in order to retract the lung and/or the diaphragm.

The entire surface of the diaphragm is inspected including the posterior sulcus and lateral costophrenic angle. Complete visualization of the entire diaphragm is facilitated by using a 30° scope, which we use in all cases of thoracic trauma. One needs to avoid grasping the diaphragm too vigorously, as it is prone to injury. In planning repair of identified injuries, one needs to be aware of the phrenic nerve innervation to the diaphragm. The right phrenic nerve is directly lateral to the vena cava and divides into an anterior and posterior branch. The anterior trunk gives off an anterolateral branch and a medial or sternal branch. The posterior trunk gives rise to a posterolateral or pleural branch. The left phrenic nerve usually separates into two trunks before penetrating the diaphragm just anterior to the central tendon on the anterior aspect near the pericardium. A working knowledge of the phrenic nerve anatomy allows the surgeon to plan his repair for the identified injuries.

Diaphragm injuries may be stellate tears, simple linear lacerations, or larger injuries with abdominal viscera and/or omentum protruding through the defect. Exposure of the area of interest is greatly enhanced by using the endo-fan to aid in retracting the diaphragm. Linear lacerations of the diaphragm that are ≤ 5 cm can be closed with simple interrupted nonabsorbable sutures tied extracorporally. This may require insertion of another 5 mm port in order to tie these knots. Larger diaphragmatic injuries or complex stellate lacerations may require a limited thoracotomy to definitively effect a tight closure. Endo-staplers have been used to repair diaphragmatic injuries, but were not used in our experience.

Large diaphragmatic defects diagnosed months to years posttrauma frequently will require synthetic material (Gortex or proline mesh) in order to close them. In this circumstance, I favor a combined thoracoscopic and laparoscopic approach. The laparoscope and one or two abdominal instruments can greatly facilitate and expedite exposure and closure of the defect. Placement of the patch is performed using VATS to affix the patch to the diaphragm with simple interrupted nonabsorbable sutures. Upon completion of diaphragm repair, a single chest tube is left in the pleural space and the port sites are closed in the usual fashion.

Persistent Pneumothorax

Experience using VATS techniques to diagnose and treat persistent posttraumatic pneumothorax is limited. This is related, in part, to the low incidence of this thoracic complication because of the success of closed tube thoracostomy. A persistent posttraumatic pneumothorax with an ongoing air-leak and failure of the lung to re-expand mandates an aggressive evaluation for a major airway injury. Flexible and/or rigid bronchoscopy should be performed before open operative intervention.

Occasionally puncture injuries, parenchymal lacerations, or disruption of preexisting blebs will result in a persistent air-leak despite adequate positioning of chest tubes. VATS provides a minimally invasive means to identify and treat the injury. In one series of 11 patients, 10 had VATS pulmonary resections for identifiable sources of ongoing air-leak with a 100% success rate.[11] Nine of eleven patients were discharged from the hospital within 72 hours postprocedure and all chest tubes were removed within 48 hours after the procedure.

We use 48-72 hours of conventional intrapleural suction for a persistent posttraumatic air-leak as our indication to consider the use of VATS in the stable trauma patient. In difficult cases of persistent posttraumatic pneumothorax we have used VATS and pleurodesis to seal ongoing air-leaks and provide early hospital discharge. Alternatively, a parietal pleural flap can be created to cover larger, raw parenchymal surfaces not appropriate for staple closure. The resulting pleural flap is then stapled to the surrounding normal lung tissue. These patients should be extubated as soon after the procedure (preferably in the operating room) as possible to avoid aggravation of the injury with positive-pressure ventilation.

Other Indications

There are other indications for the use of VATS procedures in the trauma patient although most are anecdotal or were performed only sparingly. VATS has been used to facilitate the removal of foreign bodies, evaluate the esophagus status-postpenetrating trauma, diagnose and repair traumatic thoracic duct injuries, and to evaluate the pericardium for rupture and associated cardiac herniation. As the surgeon and his team gain experience with the use of VATS techniques in thoracic surgery, there will be a natural evolution toward using VATS for more complicated indications in the trauma patient.

References

1. Carrilio EH, Heniford BT, Etoch SW et al. Video-assisted thoracic surgery in trauma patients. J Am Coll Surg 1997; 184:316-324.
2. Pickard LR, Mattox KL. Thoracic trauma and indications for thoracotomy. In: Mattox KL, Moore EE, and Feliciano DV eds. Trauma. Norwalk: Appleton and Lange 1988: 315-320.
3. Graeber GM, Jones DR. The role of thoracoscopy in thoracic trauma. Ann Thorac Surg 1993; 56:646-648.
4. Castello-Branco JM. Thoracoscopy as a method of exploration in penetrating injuries: a preliminary report. Dis Chest 1946; 12:330-335.
5. Jones JW, Kitahama A, Webb WR et al. Emergency thoracoscopy: A logical approach to chest trauma management. J Trauma 1981; 21:280-284.
6. Smith RS, Fry WR, Tsoi EKM et al. Preliminary report on videothoracoscopy in

the evaluation and treatment of thoracic injury. Am J Surg 1993; 166:690-695.
7. Landreneau RJ, Keenan RJ, Hazelrigg SR et al. Thoracoscopy for empyema and hemothorax. Chest 1996; 109(1):18-24.
8. Freeman T, Fischer RP. The inadequacy of peritoneal lavage in diagnosing acute diaphragmatic rupture. J Trauma 1976; 16:538-542.
9. Hirshberg A, Thomson SR, Bade PG et al. Pitfalls in the management of penetrating chest trauma. Am J Surg 1989; 157(4):372-375.
10. Feliciano DV, Cruse PA, Mattox KL et al. Delayed diagnosis of injuries to the diaphragm after penetrating wounds. J Trauma 1988; 28:1135-1144.
11. Carrillo EH, Schmacht DC, Gable DR et al. Thoracoscopy in the management of posttraumatic persistent pneumothorax. J Am Coll Surg 1998; 108(6):636-640.

Thoracoscopic Management of Benign Esophageal Disease

Stephen R. Hazelrigg

The esophagus represents the tubular structure which peristalses the bolus of oral intake to the stomach for digestion. Benign abnormalities that result in symptoms can be varied but most prominently include the inflammatory changes that result from gastroesophageal reflux, dysmotility that delays or impairs the transit of the food bolus, and benign cysts and tumors which must be distinguished from malignant masses and may produce obstructive symptoms. This Chapter will cover these topics with special attention to the thoracoscopic role in surgical correction of these abnormalities.

Gastroesophageal Reflux Disease (GERD)

It has been estimated that indigestion or heartburn is experienced by 50% of the population at least once a month and 1 of every 10 Americans experience heartburn even more frequently.[1-2] For years GERD has been underestimated in both its incidence and in its proclivity to alter lifestyle.

Esophagitis typically is the result of the prolonged acid exposure in the distal esophagus. Any anatomic or physiologic condition which enhances reflux, such as gastric outlet obstruction, gastric stasis, hiatal hernia, or absence of an adequate lower esophageal sphincter will promote GERD and esophagitis. Likewise, a poor clearance mechanism such as is seen in motility disorders will result in prolonged acid exposure and worsened esophagitis. Although acid is the most frequent problem, bile has been demonstrated to be quite toxic to the esophageal mucosa and has been suggested as a possible factor in stimulating dysplastic changes. Severe reflux may produce intense inflammatory changes that result in bleeding or ulcer creation. Long term injury similarly may result in stricture formation.[2]

There is an extensive array of medical options for the management of GERD which includes diet modification, antacids, prokinetic agents, histamine blocking agents and proton pump inhibitors. The latter group of medications has been particularly effective, especially in the short term, at providing symptomatic relief.

Indications for surgical therapy are strictures, bleeding and ulceration from esophagitis, and failure of medical therapy. Failure of medical therapy has many different definitions. Obvious failure is recurrent or persistent esophagitis on proton pump inhibitors for four to six weeks. In many cases, surgical therapy may be chosen in younger patients as opposed to lifelong medical therapy.

Surgical Therapy For GERD

Numerous antireflux surgical procedures have been reported in the literature. Broadly, these may be grouped into complete 360º wraps such as the Nissen Fundoplication and partial wraps such as the Toupet. Partial wraps are used in patients with distal esophageal motility problems to avoid relative obstructions complete wraps may cause.[3] These procedures have been described extensively and are typically performed from the abdomen.[4-9] The following discussion will be on antireflux procedures performed thoracoscopically through the chest, i.e., Belsey Mark IV.

Belsey Mark IV Antireflux Procedure

Because the abdominal antireflux procedures have been successful and technically reproducible there has been only a handful of reports of thoracic antireflux procedures. This approach may be applicable:

1. When it is desired to avoid an abdominal procedure, i.e., prior upper abdominal surgery.
2. When combined with dysmotility procedure, i.e., myotomy for achalasia or diffuse esophageal spasm.
3. Large paraesophageal hernia.
4. Coexistent epiphrenic diverticulum.

Technique

A double lumen endotracheal tube is used and single lung ventilation is instituted. The patient is positioned in the full lateral position as for a thoracotomy with the left side up. Typically, four thoracoscopic ports are required; one for retraction of the diaphragm, one for the camera and two working ports. Occasionally, a fifth port site is required for lung retraction. Typically, we have not used true trocars but instead worked directly through the small incisions. We do use a 10 mm trocar which is nondisposable for the thoracoscope to prevent smudging of the lens during its introduction.

The viewing monitor is positioned at the foot of the patient and ports are selected such that instruments point more toward that direction. Typically, one port is placed low (seventh or eighth intercostal space) which will be used to retract the diaphragm. Two ports are placed in the fifth intercostal space; one in approximately the posterior and anterior axillary lines. These are used for instruments and the final port is placed in the mid-axillary line fourth intercostal space for the camera site. The steps are:

1. Diaphragm retraction with a fan retractor or similar device.
2. Division of inferior pulmonary ligament with electrocautery.
3. Opening of mediastinal pleura over esophagus.
4. Mobilization of esophagus and passing penrose drain or umbilical tape around it. Typically, these loops are brought out through out trocar sites to allow optimal retraction and suspension of the esophagus.
5. Left and right crural limbs of the esophageal hiatus are identified and dissected.
6. The phrenoesophageal ligament is incised and the gastric fundus pulled up into the chest. Often several short gastric arteries are divided with the harmonic scalpel (Ethicon, Cincinnati, OH, USA) or clips.

7. Performance of the Belsey Mark IV fundoplication with two rows of pledgeted 2-0 nonabsorbable suture. These stitches are placed just as for an open Belsey Mark IV. Three stitches are placed in each row to form a 270° wrap and the second row includes diaphragm (Fig. 9.1).
8. The crurae are approximated with simple nonabsorbable 2-0 stitches.

For postoperative management, I prefer a 28 F chest tube for 24 hours, an intercostal nerve block with one-fourth percent marcaine intraoperatively at each trocar site, and no nasogastric tube. Liquids ingestion is permitted the first postoperative morning and the diet advanced as tolerated. Most patients are discharged by postoperative day two.

Results

There are few reports of thoracoscopic antireflux procedures. Yang et al reported three thoracoscopic Belsey fundoplications performed for GERD with good results.[10] Champion et al reported 17 similar procedures with two late strictures, one esophageal leak, and one recurrence of reflux.[11]

Nguyen et al reported 15 thoracoscopic Belsey operations in 1997. Several of these patients had these procedures combined with myotomies for motor disorders.[12] Excellent to good results were found in 73% of cases at a mean follow-up of 19 months. This was compared to an 85-90% success rate reported with the "open" Belsey. They concluded by noting that they favored the laparoscopic antireflux procedures.

The thoracoscopic Belsey appears to be technically feasible but, at least based on the limited early reports, does not seem to have any clear advantage over the laparoscopic procedures in most cases.

Esophageal Dysmotility

Motility disorders are characterized by abnormal peristalsis or abnormal esophageal sphincter function. The primary motility disorders include achalasia, diffuse esophageal spasm (DES) and high amplitude peristalic contractions (nutcracker esophagus). Other motility problems include cricopharyngeal abnormalities and nonspecific esophageal disorders of the body and lower esophagus.

In this Chapter a brief description of the pathophysiologic and manometric findings are discussed with an emphasis on treatment, in particular the role of Video-Assisted Thoracic Surgery (VATS).

Achalasia: This disorder has an incidence of approximately 0.5/100,000 population in North America. Symptoms often are subtle initially, but progressively become dominated by dysphagia followed by regurgitation and aspiration. Achalasia is characterized by poor esophageal motility and failure of sphincter relaxation. This produces the classic radiographic finding of the "bird beak" deformity on barium contrast esophagrams. Esophageal dilatation increases with the duration of the disease, eventually resulting in a sigmoid shaped esophagus if left untreated. The definitive diagnosis of achalasia is made with manometry which demonstrates absent distal esophageal contraction and failure of sphincter relaxation.

Achalasia develops as a result of degeneration of the myenteric plexus of the lower esophagus. The denervation of the inhibitory nerves cause incomplete relaxation of the sphincter and increased resting pressure. Treatment for achalasia has

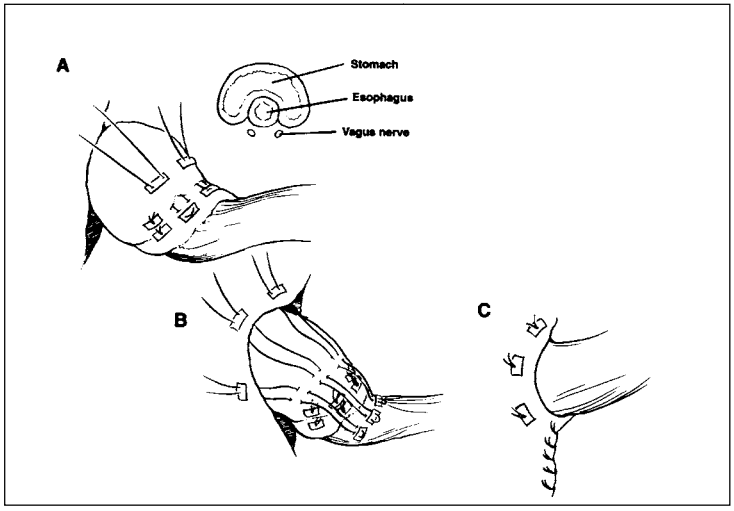


Fig. 9.1. Placement of stitches for Belsey Mark IV antireflux procedure.

required pharmacologic agents, pneumatic dilatation or surgery. The best method of treatment has been a topic of much debate for many years.

Pharmacologic agents that are used for this disease include smooth muscle relaxants. Isosorbide dinitrate and nifedipine provide some success in the early stages of achalasia. Unfortunately, clinical improvement has been unpredictable and usually transitory. Medication side effects are common and on the whole pharmacologic therapy is selected for patients with early achalasia or other conditions that prohibit surgery or dilatation.

Pneumatic dilatation has been used for decades. Most recently a balloon is positioned across the GE junction and rapidly inflated to produce disruption of the LES musculature. Currently, 75% of patients attain an improvement in symptoms but many ultimately need subsequent dilatations.[13] Complications that are reported with dilation include perforation (< 5%), development of reflux symptoms (10%), and failure to control symptoms requiring operative therapy (10-15%). The advantages of dilatation are lower costs compared with surgery and a rapid return to activity. Results with this modality are very operator dependent and this fact should be considered when deciding between dilatation or surgical therapy.

Surgical therapy for this disease is an esophageal myotomy (Heller Myotomy). The thoracoscopic details are discussed later; however, the goal is to divide the muscles of the sphincter enabling the food bolus to pass easily. Open surgical treatment has traditionally reported greater than 90% success with a mortality rate of less than 1%.

Myotomy can be performed by a thoracic or abdominal route. The abdominal route limits the proximal length of the myotomy and always disrupts the GE junction and hence an antireflux procedure is usually added.[14] There is much debate regarding the benefit of a long myotomy in achalasia and this question remains to be

answered adequately. There is evidence supporting a long myotomy for those with vigorous achalasia because better pain relief is achieved.

The transthoracic approach for a long myotomy generally causes less disruption of the GE junction; consequently, many feel that an antireflux procedure is not required. Both thoracoscopic and laparoscopic approaches have been reported with and without antireflux procedures. In general, the results have been good and mimic the results in open surgery. Hospital stays are short and recovery time is reduced. The early learning curve complications have led to a few reports of perforations and incomplete myotomies. Long term results are lacking, but optimism remains that these minimally invasive routes are real advantageous. This may sway decision making toward surgery as an effective low morbidity alternative to balloon or medical therapy.[15-16]

End stage, severe achalasia may require resection and reconstruction. Esophagectomy with gastric pull-up is the most frequent procedure. Limited resection and jejunal interposition is performed occasionally.

Diffuse Esophageal Spasm (DES)

This disorder is characterized by the symptoms of chest pain and dysphagia. The diagnosis of DES is based upon manometric evidence of simultaneous distal esophageal constriction occurring after more than 30% of wet swallows. The lower esophageal sphincter is normal. Prolonged or repetitive esophageal contractions are frequent. The cause and incidence of DES are not known but microscopy of the esophageal wall reveals muscle hypertrophy. It has been postulated that DES may result from abnormal vagal sensory nerves (while achalasia involves failed vagal motor pathways).

Successful treatment of DES with calcium channel blockers and nitrates results are inconsistent. As with achalasia, the medications produce frequent side effects. Medical therapy and supportive care are the first line of treatment, but surgery has been utilized in some cases. A long myotomy from aortic arch to LES results in improved symptoms in 75% of patients.[17]

High Amplitude Peristalic Contractions (Nutcracker Esophagus)

The cause of this disorder is not known; however, it is associated with gastroesophageal reflux. The dominant complaint is chest pain and the diagnosis is made by finding normal peristalsis but high distal esophageal pressures. The mean contraction amplitude in the distal esophagus exceeds 200 mm Hg. Contraction duration may also be prolonged, often lasting 5-10 seconds. Treatment for this includes calcium channel blockers and nitrates which have a fairly high rate of response but may exacerbate GERD.[18] Esophageal myotomy was employed successfully in a small group of patients that failed medical therapy. Shimi et al reports that thoracoscopic long myotomy for this disorder succeeded in three patients.[19-20]

Cricoesophageal Disorder

Discoordination between the inferior pharyngeal constrictor and the cricopharyngeus muscles leads to excess pressure on the bare mucosa in the triangle between them resulting in the diverticulum (Zenkers Diverticulum). The dominant symptom is dysphagia and some patients aspirate the contents in the diverticulum. Demonstrating the pouch on barium contrast studies confirms the diagnosis.

Treatment of this disorder is cricopharyngeal myotomy with diverticulectomy or diverticulopexy if the diverticulum is large. The cricopharyngeus muscle is divided

5 cm longitudinally. Small pouches require no additional treatment, but large ones are usually excised over a large bougie. Alternatively, the pouch may be suspended superiorly so that food will drain by gravity. Results of this standard operation are very good in 85-90% of patients. Endoscopic approaches have been described. The Dohlman procedure is the division of the common wall between the esophagus and diverticulum (which includes the cricopharyngeus muscle) with laser or electrocautery. Overall success of this method is about 60% but some salivary fistulas occur.[20]

A small series of procedures performed orally using a special speculum has been described with excellent results.[21] A standard thoracoscopic stapler (i.e., EndoGIA™) was used to divide the common wall (Fig. 9.2). This procedure has the appeal of no incisions and simultaneous myotomy. No long term results were reported.

Epiphrenic Diverticulum

The etiology of this disorder is similar to the Zenkers diverticulum in that failure of relaxation of the LES results in a diverticulum. The diverticulum develops in the distal esophagus where pressures are highest. Typical symptoms are dysphagia, regurgitation, and pain. A barium contrast study confirms the diagnosis. Treatment requires a distal myotomy usually 180º opposite the neck of the diverticulum. The pouch is resected over a bougie and the muscle layers are closed over the mucosa suture line.

Esophageal Myotomy: Thoracoscopic

Patients are placed under general anesthesiasia and a double lumen endotracheal tube is used such that single lung ventilation is instituted. The patient is positioned as for a left thoracotomy in the full lateral decubitus position. The video monitors are moved to the patient's foot to aid in orientation. It has been valuable to place an endoscope in the esophagus for several reasons. The indwelling endoscope allows one to visualize the mucosa internally to ensure that it is intact and that the myotomy is complete. Once can observe the esophagogastric junction enlarge as the myotomy proceeds onto the stomach (Fig. 9.3).

Five trocars are typically used, although the procedure may be performed with four. One trocar site is placed in the eighth or ninth intercostal space at the midaxillary line through which is placed a fan retractor to displace the diaphragm. The remaining trocars are placed as shown. Always place trocars anterior to the posterior axillary line to minimize the risk of intercostal nerve injury. All instruments are directed toward the foot of the patient to minimize "mirror imaging." The lung frequently needs to be retracted early in the procedure but after complete atelectasis this is no longer required. We usually place a ring forceps in the lower lobe to retract it. The steps for myotomy are identical to those done in an open myotomy and are:

1. The inferior pulmonary ligament is divided with cautery from the inferior margin to the inferior pulmonary vein.
2. The pleura is opened, the esophagus is exposed and the vagal nerves are identified and preserved. We no longer encircle the esophagus, but may use an endoscopic babcock clamp to manipulate it.
3. Using endoscopic scissors, the muscular layers are incised to the mucosa. The magnification of the scope actually helps and cautery may be used to keep the field dry. The indwelling endoscope is also valuable at this time

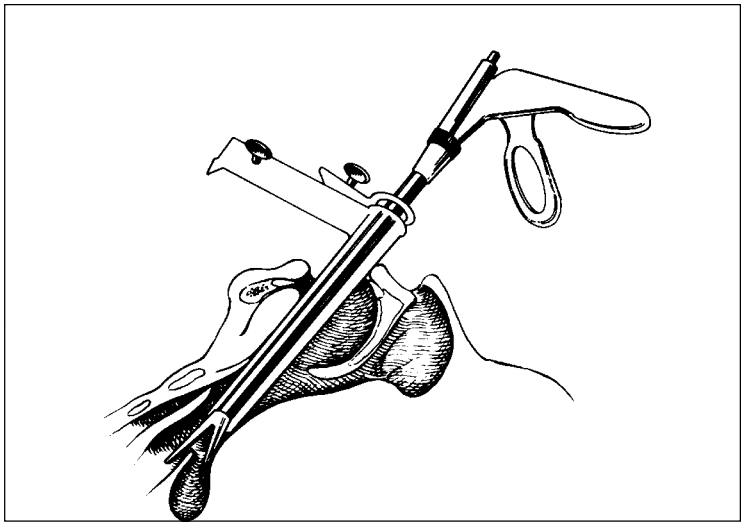


Fig. 9.2. Transoral resection of Zenker's diverticulum using endoscopic linear cutter.

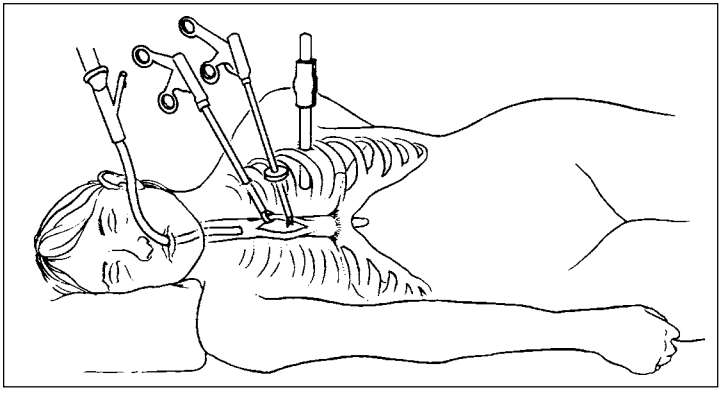


Fig. 9.3. Esophageal myotomy in progress with indwelling endoscope.

because one can see when the appropriate layer has been entered. We avoid cautery near the mucosa to prevent thermal injury and delayed leakage.

4. The myotomy is extended from the inferior pulmonary vein to 1 cm onto the stomach (Fig. 9.4).
5. A modified Belsey antireflux procedure may be added if there is concern about GERD.

Our results with thoracoscopic myotomy are excellent. It is tolerated well, diet is begun on the first postoperative day and most patients are sent home on the second postoperative day. Long term results are still pending, but we have observed no long term problems with many of our patients followed now over five years. The issue of adding an antireflux procedure is controversial. Significant reflux has been reported in 10-15% after open myotomy. Pellegrini reported a 90% freedom from GERD symptoms in 24 patients treated thoracoscopically, but 24 hour pH studies did show a higher incidence of reflux.[16] The thoracoscopic approach should produce minimal disruption of the phrenoesophageal ligament and hence reduced risk for GERD. Conversely, myotomy performed laparoscopically should have a concomitant antireflux procedure.

Resection of Benign Esophageal Tumors

There have been several esophageal leiomyomas resections using thoracoscopic techniques. Leiomyomas are the most frequent benign tumor of the esophagus and are resected because of symptoms (dysphagia or pain) or suspicion of malignancy. Most are localized, but leiomyomas encircling the esophagus have been described which makes resection more challenging (Fig. 9.5). Thoracoscopic resection is appealing for these benign tumors to avoid the morbidity of open thoracotomy. Several reports have demonstrated success in enucleating these extramucosal tumors. The smaller the size, the easier is their technical resection. However, there is one report of an 11 cm leiomyoma resected thoracoscopically. All reports cited short hospital stay, minimal pain, and rapid return to activity.

Most resections are performed through the right chest using a double lumen tube to discontinue ventilation of the right lung. For distal tumors, a left chest approach can be used. If the leiomyoma is in the distal one-third of the esophagus, as 56% are, we position the video monitors at the foot. If the tumor is in the upper two-thirds then we position the monitors at the head. We always try to have all working instruments moving in the same general direction as the camera. Typically, we require four trocar sites for resection of the leiomyoma. One port is used for lung retraction (ring forceps), one for the camera, and two for instruments. The location of the ports depends upon the tumor location. We try to keep all ports anterior to the posterior axillary line. The steps for resection are:

1. The mediastinal pleura and muscular layers are opened longitudinally over the tumor with endoscopic scissors.
2. Typically, we place a large (i.e., 2-0) traction suture in the tumor for the purpose of manipulation.
3. Blunt dissection is used to tease the tumor off the mucosa. This is usually straightforward unless the tumor is very large or transmucosal biopsies have been done.
4. The tumor is extracted in a retrieval bag. At times, a trocar site will require enlargement. Rib spreading is avoided (Fig. 9.6).
5. The muscular layers of the esophagus are usually reapproximated with simple sutures of 2-0 prolene or silk.

We find the indwelling endoscope helpful for this procedure as described in the esophageal myotomy section. At completion, we insufflate air into the esophagus while observing the area under water for any bubbles with the thoracoscope.

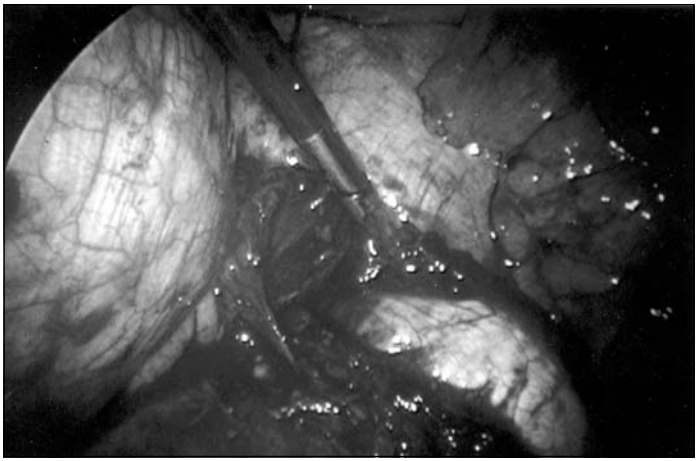


Fig. 9.4. Operative photograph with esophageal myotomy in progress.

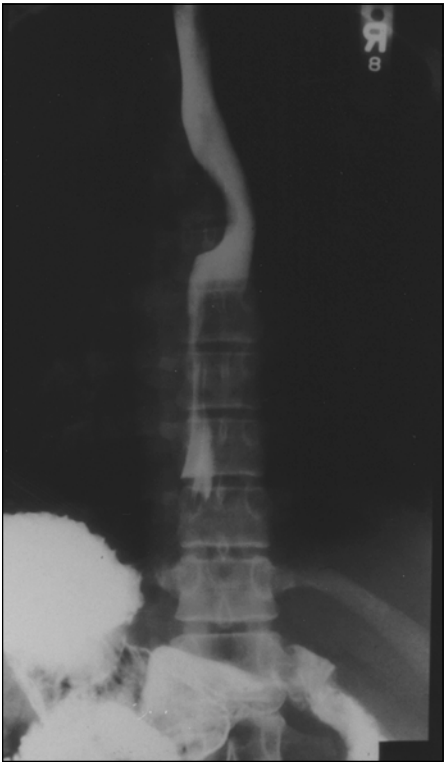


Fig. 9.5. Barium swallows with leiomyoma producing esophageal defect.

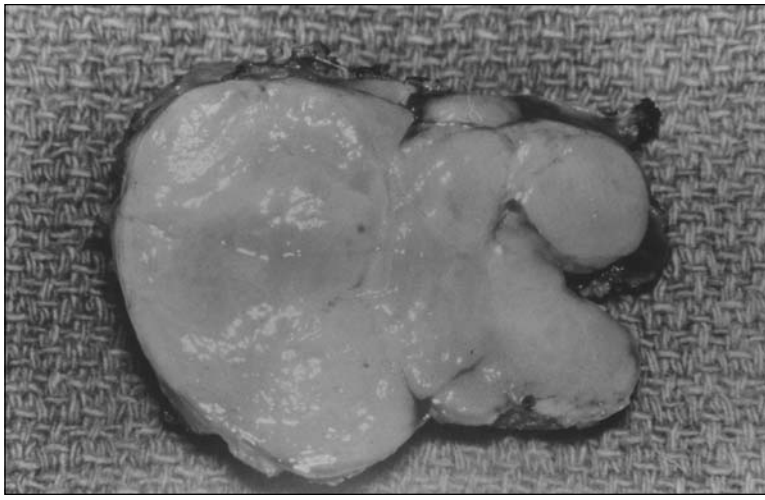


Fig. 9.6. Thoracoscopically resected leiomyoma.

Most thoracoscopic resections of leiomyomas require operation times of one and one-half to three hours and hospital stays of two days. Results have been uniformly excellent.[22-26]

Esophageal (Enteric) Cysts

These are often difficult to differentiate from bronchogenic cysts. Enteric cysts are usually within the walls of the esophagus and rarely have communication with the true lumen. When excision is recommended, a thoracoscopic approach is warranted. Resection is performed for symptoms or suspicion of malignancy. When cysts are firmly adherent to vital structures, they may be left in place in those areas and the mucosa cauterized. We have reported success with resection of nine mediastinal cysts which averaged 4.2 cm in size. A two day average postoperative hospital stay was required.[27] The technical aspects of resection mimic that of leiomyomas resection.

Conclusion

Minimally invasive approaches to esophageal disorders have become common. Most antireflux procedures are now done laparoscopically with good results. However, there remains a role for the thoracic approach. Benign tumors, cysts and motility disorders are much less common than GERD but are excellent indications for thoracoscopy and to date have produced good results. Attention to port placement that minimizes nerve injury has resulted in excellent postoperative pain control. With experience, VATS has steadily enlarged its role in esophageal surgery and the expectation is for this trend to continue.

References

1. Gallup Organization National Survey. Heartburn across America. Princeton: The Gallup Organization Inc. 1988.
2. Landreneau RJ, Wiechmann RJ, Hazelrigg SR et al. Success of laparoscopic fundoplication for gastroesophageal reflux disease. Ann Thorac Surg 1998; 66:1886-1893.
3. Rydberg L, Ruth M, Abrahamsson H et al. Tailoring antireflux surgery: A randomized clinical trial. World J Surg 1999;23:612-618.
4. Coosemans W, DeLeyn P, Deneffe G et al. Laparoscopic antireflux surgery and the thoracic surgeon: what now? Eur J Cardiothorac Surg 1997;12:683-688.
5. Peracchia A, Rosati R, Bona S et al. Laparoscopic treatment of functional diseases of the esophagus. Int Surg 1995;80:336-340.
6. Dallemagne B, Weerts JM, Jeahes C et al. Results of laparoscopic nissen fundoplication. Hepatogastroenterology 1998;45:1338-1343.
7. Laine S, Rantala A, Gullichsen R et al. Laparoscopic vs conventional Nissen fundoplication. Surg Endosc 1997;11:441-444.
8. Wu JS, Dunnegan DL, Luttmann DR et al. The influence of surgical technique on clinical outcome of laparoscopic Nissen fundoplication. Surg Endosc 1996;10:1164-1170.
9. Deschamps C, Allen MS, Trastek VF et al. Early experience and learning curve associated with laparoscopic Nissen fundoplication. J Thorac Cardiovasc Surg 1998;115:281-285.
10. Yang HK, Del Guercio LRM, Steichen FM. Thoracoscopic Belsey-Mark IV fundoplication. Surg Rounds 1995;18:277-291.
11. Champion JK, McKernan JB. Thoracoscopic Belsey for complicated gastroesophageal reflux disease[Abstract]. Minimally Invasive Thoracic Surgery Interest Group (First International Symposium. Boston) 1996:26.
12. Nguyen NT, Schauer PR, Hutson W et al. Preliminary results of thoracoscopic Belsey Mark IV antireflux procedure. Surg Laparosc Endosc 1998;8:185-188.
13. Csendes A, Braghetto I, Henriquez A et al. Late results of a prospective randomised study comparing forceful dilatation and oesophagomyotomy in patients with achalasia. Gut 1989;30:299-304.
14. Hunter JG, Trus TL, Branum GD et al. Laparoscopic Heller myotomy and fundoplication for achalasia. Ann Surg 1997;225:655-665.
15. Monson JRT, Darzi A, Guillou PJ. Thoracoscopic Heller's cardiomyotomy: A new approach for achalasia. Surg Laparosc Endosc 1994;4:6-8.
16. Pellegrini CA, Leichter R, Patti M et al. Thoracoscopic esophageal myotomy in the treatment of achalasia. Ann Thorac Surg 1993;56:680-682.
17. Little AG, Chen WH, Ferguson MK et al. Physiologic evaluation of esophageal function in patients with achalasia and diffuse esophageal spasm. Ann Surg 1986;203:500-504.
18. Cattau EL, Castell DO, Johnson DA et al. Diltiazem therapy for symptoms associated with nutcracker esophagus. Am J Gastroenterol 1991;86:272-276.
19. Shimi S, Nathanson LK, Cuschieri A. Laparoscopic cardiomyotomy for achalasia. J R Coll Surg Edinb 1991;36:152-154.
20. Shimi SM, Nathanson LK, Cuschieri A. Thoracoscopic long oesophageal myotomy for nutcracker oesophagus: initial experience of a new surgical approach. Br J Surg 1992; 79:533-536.
21. Collard JM, Otte JB, Kestens PJ. Endoscopic stapling technique of esophagodiverticulostomy for Zenker's diverticulum. Ann Thorac Surg 1993; 56:573-576.

22. Hazelrigg SR, Gordon P, Boley TM. Video-assisted thoracic surgery in esophageal disease. In: Dieter, ed. Thoracoscopy for Surgeons: Diagnostic and Therapeutic. New York, NY: Igaku-Shoin Medical Publishers, Inc. 1994:133-147.
23. Tamura K, Takamori S, Tayama K et al. Thoracoscopic resection of a giant leiomyoma of the esophagus with a mediastinal outgrowth. Ann Thorac Cardiovasc Surg 1998; 4:351-353.
24. Everitt NJ, Glinatsis M, McMahon MJ. Thoracoscopic enucleation of leiomyoma of the oesophagus. Br J Surg 1992; 79:643.
25. Bardini R, Segalin A, Ruol A et al. Videothoracoscopic enucleation of esophageal leiomyoma. Ann Thorac Surg 1992; 54:576-577.
26. Gamliel Z, Krasna MJ. The role of video-assisted thoracic surgery in esophageal disease. Chest Surg Clin N Am 1998; 8:853-869.
27. Hazelrigg SR, Landreneau RJ, Mack MJ et al. Thoracoscopic resection of mediastinal cysts. Ann Thorac Surg 1993; 56:659-660.

Mediastinal VATS

Todd L. Demmy

Surgery in the mediastinum began a decade before the introduction of thoracoscopy. Because of the vital nature of many of the organs in this area of the body, many open techniques remain the safest means to accomplish exposure and surgical therapy. However, VATS is appropriate for diagnosis and occasionally the treatment of some of these disorders.

General Mediastinal Anatomy

The mediastinum occupies the central portion of the chest and while most agree about its general borders (thoracic inlet, diaphragm, and pleurae), there are several ways to divide this area. For the purposes of this Chapter, I will use the simple divisions described by Shields, i.e., the Anterosuperior, Visceral (Middle) and Paravertebral (Posterior) compartments.[1] These are shown by Figure 10.1 and are relatively easy to remember. In brief, the Anterior compartment contains the structures anterior and superior to the pericardium. This area is seen well on a lateral chest roentgenogram as the lucent area behind the superior sternum. It contains the thymus or thymic remnant, lymph nodes and fat. The visceral compartment contains the great vessels, central airways, lymphatics and lymph nodes, pericardium, and heart. This compartment also includes the esophagus and aorta that are arbitrarily assigned to the posterior compartment in other systems. The paravertebral compartment contains the nerves and autonomic ganglia. Specific VATS exposures for each will be explained in their respective categories.

General Diagnostic Interventions and Preparation

Symptoms and Physical Signs

Two-thirds of patients who present of symptoms will have malignant mediastinal masses whereas the asymptomatic patient has a 75% chance of having a benign mediastinal tumor.[2] Mediastinal masses often cause symptoms by direct compression of mediastinal structures and can cause various airway or swallowing symptoms. Symptoms may therefore predict the involved compartment and, therefore, the likely cell type. Certain compartments are more likely to have malignant cell types and therefore sources for more complaints. Physical finding are likewise uncommon unless the tumor is malignant. Of course, a rapid tempo in the onset of certain symptoms suggests malignancy.

Signs of mediastinal masses are those of airway compression like stridor or vascular compression like superior vena cava (SVC) syndrome. A more complete list of common symptoms and signs and related diagnoses can be found in Table 10.1.

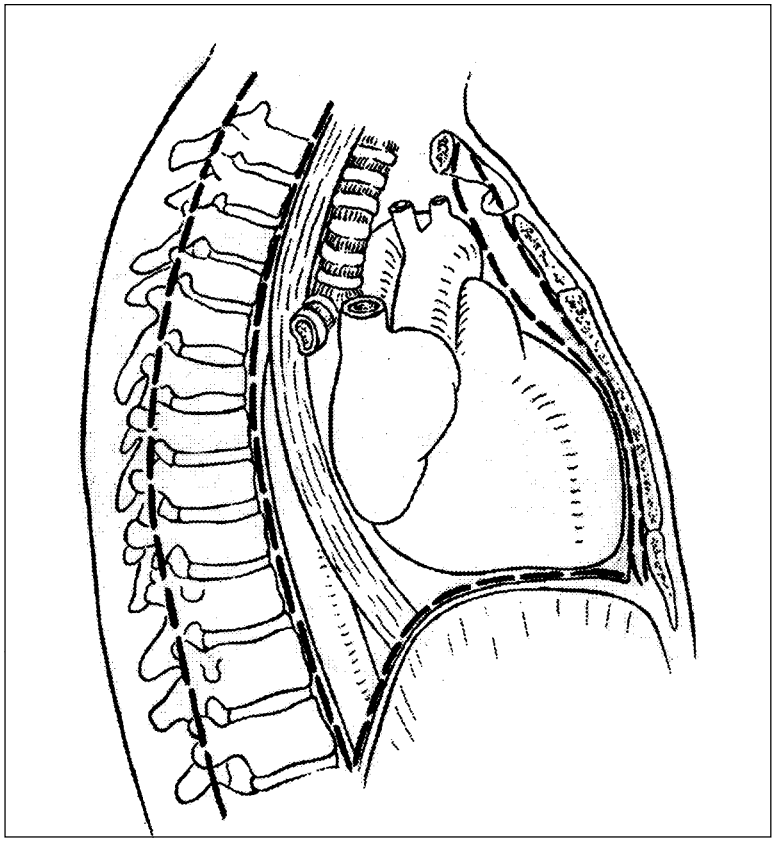


Fig. 10.1. Diagram of the chest demonstrating the mediastinal compartments: Anterosuperior, Visceral (Middle) and Paravertebral (Posterior) compartments are demonstrated by dashed lines.

Laboratory Tests

Laboratory tests for patients with asymptomatic mediastinal masses are unlikely to be of high yield. One exception may be tests for germ cell markers in patients with suspected germ cell tumors, e.g., β-human chorionic gonadotrophin (β-HCG), α-fetoprotein (AFP), and placental alkaline phophatase.[3] Otherwise, symptoms of endocrine overactivity will likely lead to the appropriate assay for the suspected abnormal hormone or its metabolite. Some of the serologic hematologic and chemistry tests to aid in the confirmation of mediastinal tumor diagnoses are included in Table 10.1 as well.

Table 10.1. Mediastinal considerations by compartment

Compartment and Common Symptoms or Signs	Typical Tumors	Additional Symptoms and Signs	Laboratory Tests	Invasive Tests
Anterior	Thymoma	Fatigue and Weakness Pallor	ACH Antibody EMG Hemogram	*FNA
Dyspnea, Stridor Dysphagia	Germ Cell	SVC-S	AFP, β-HCG	*FNA
	Lymphoma	SVC-S, Fever, Sweats	Flow cytometry on specimen	Mediastinoscopy
	Goiter	Thyromegaly	I^{131} scan	Mediastinotomy
Middle	Lymphoma	SVC-S, Fever, Sweats	Flow cytometry on specimen	Mediastinoscopy Mediastinotomy *FNA
Dyspnea, Stridor, Dysphagia	Cyst	Pain	Culture of cyst Barium Swallow	*FNA Bronchoscopy Esophagoscopy
	Inflammatory mass	SVC-S, Fever, Sweats Pain	Fungal serologies Skin tests	Bronchoscopy
Posterior	Schwannoma, neurofibroma	None to moderate pain	MRI, spinal	
	MNST	Pain	MRI	*FNA
	Neuroblastoma	Horner's syndrome, pain, dyspnea, diarrhea, flushing, neurologic deficits	MRI Plasma catecholamines HVA, VMA levels	*FNA

*The utility of Fine Needle Aspiration (FNA) for some of these diagnoses is controversial. Considerable variations in the use of this diagnostic technique exists between institutions.
ACH- Acetylcholinesterase antibody; AFP- alpha fetoprotein; β-HCG- beta human chorionic gonadotrophin; EMG- electromyography; MSNT- malignant nerve sheath tumor; MRI- magnetic resonance imaging; SVCS- superior vena caval syndrome

Radiologic Investigations

Roentgenographic imaging is essential in the diagnosis and treatment planning of patients with mediastinal tumors. While the chest roentgenogram may be the first test to disclose the presence of a mediastinal tumor, the CT scan provides vital information on tumor size, consistency, vital organ relations and possible sites of invasion. In general, the CT scan provides most of the information needed by the thoracic surgeon to confirm the appropriateness and safety to attempt a VATS approach to a mediastinal tumor. For instance, evidence of unfavorable anatomy could lead to an open approach rather than VATS while evidence of unresectability or a nonsurgically treated neoplasm may warrant VATS to secure a diagnosis only.

The preoperative chest CT scan should be viewed with the followed questions related to VATS planning in mind: Is the tumor cystic or solid? Is the goal diagnosis only, or therapeutic excision as well? If the tumor turns out to be malignant, will a VATS approach compromise oncologic principles? If the tumor is solid, will it be extractable through access incisions to make VATS worthwhile? What will be the optimal port placement to accomplish the planned dissection? What organs, particularly vascular, are related to the mass that may cause trouble?

MRI is occasionally useful to exclude vascular invasion of some tumors or intraspinal extension of neurogenic tumors. Transcutaneous or transesophageal ultrasound may help characterize cysts. Angiography, radioisotope scans, and PET scanning are sometimes useful to localize metabolically active tumors for directed excision or biopsy. Occult metastatic lymph nodes (fluorodeoxyglucose positron emission tomography, FDG-PET), pheochromocytomas (metaiodobenzylguanidine, MIBG), and ectopic parathyroid glands (Technetium) are such examples.

Other Invasive Testing

It is important to consider methods for the diagnoses of mediastinal masses that are even less invasive than VATS. These are best for diagnoses treated without surgical intervention, e.g., lymphoma. On the other hand, some working diagnoses like thymoma are difficult to confirm histologically using fine-needle aspiration and are often appropriately resected before confirmation. Mediastinoscopy, bronchoscopy, anterior mediastinotomy, CT, ultrasound, transesophageal ultrasound, or fluoroscopic directed biopsy techniques are such examples that can be useful depending on the anticipated histology and location of the mediastinal tumor.

Anterior Compartment Masses

Differential Diagnoses

The most likely diagnoses for each mediastinal compartment along with the imaging appearances form the basis for most surgical decision making. The anterior mediastinal mass is most likely to be related to one of the four "Ts". These are Thymoma, Teratoma (and other germ cell tumors), Thyroid, and "Terrible" (or T/B cell) Lymphoma. Less common diagnoses are lymphangioma, lipoma, fibroma, fibrosarcoma, thymic cysts, and parathyroid adenomas.[1]

Thymomas are the most common primary tumor of the anterior mediastinum occur in middle-aged patients, and are associated with myasthenia gravis(MG) as well as other parathymic disorders like hypogammaglobulinemia and red cell aplasia.

Because 30-50% of thymoma patients have MG, a serum anticholinesterase antibody is indicated. Alternatively 15% of patients with MG will have a thymoma.[2] Also, about one-third are invasive and all have the potential to seed the pleural space with drop metastases. This combined with the relatively low morbidity of a median sternotomy for removal has limited the popularity of VATS for this disorder. Teratomas comprise about two-thirds of mediastinal germ cell tumor and the remainder are seminomatous and nonseminomatous types. Lymphomas are classified as Hodgkin's (HD) and Non-Hodgkin's (NHL) types and can appear in a variety of forms from discrete tumors to indistinct tumors that invade various mediastinal structures. The nodular sclerosing variety of HD and the large B-cell and lymphoblastic varieties of NHL seem to favor the thymus/anterior mediastinum.[4] Mediastinal goiter represents 10% of mediastinal masses resected in some series but is more common clinically because many are diagnosed and observed unless large and symptomatic.

Symptoms and Physical Findings

Because of relatively higher proportion of malignant tumors in the anterior mediastinum, it follows that this compartment would be associated with more symptoms. Dyspnea, dysphagia and superior vena cava syndrome can occur by invasion or posterior compression by these tumors. Chest pain, cough, and hoarseness (either from edema or recurrent nerve paresis) are more subtle symptoms. Skeletal weakness may be a manifestation of MG for patients with thymoma and may be reversed briefly with edrophonium chloride (Tensilon). Also, "B" symptoms like fever, chills and night sweats occur in 30% of lymphoma patients but could also be caused by infections or toxic goiter.[4]

Also, other endocrine manifestations of unusual masses in this region include symptoms and signs of hypertension (pheochromocytoma) and hypercalcemia (parathyroid adenoma). Physical exam should focus on extrathoracic lymph node enlargement, jugular venous distension, stridor, hoarseness, vocal cord paresis and gonadal examination.

Laboratory Studies

Besides the anticholinesterase antibody noted above, a complete blood count is needed with a presumed diagnosis of thymoma and other hematologic tumors. A thyroid panel is useful for goiter and other endocrine related tests include adrenal corticotrophic hormone (Cushing), catecholamine assays like urine metanephrines (Pheochromocytoma), 5-hydroxyindoleacetic acid (carcinoid), and calcium (hyperparathyroidism). β-HCG and AFP are useful for germ cell tumors with the latter not being elevated for seminomas.[5]

Radiologic Investigations

The chest roentgenogram is likely to show widening of the superior mediastinum on AP and opacification on the lateral. On computed tomography, thymomas and malignant nonseminomatous germ cell tumors have a more heterogeneous appearance as they become larger because of necrosis, hemorrhage, and cyst formation. Lymphomas may show enlargement in regional or distant lymph node groups and like seminoma are more homogeneous. Teratomas may show cystic areas combined with areas of bone or tooth formation. Mediastinal goiter is heterogeneous and often can be followed into the lower neck.

Special radiologic tests to localize or assess mediastinal masses include I^{131} (Thyroid), Technetium (parathyroid), and MRI (Thymus, parathyroid, and any tumor with possible vascular invasion).

Other Invasive Testing

Traditional cervical mediastinoscopy does not access the anterosuperior mediastinum well although placement of the mediastinoscope through a more anterior plane (extended mediastinoscopy) or a different incision may be possible.[6] Anterior mediastinotomy (Chamberlain) may also be useful. The cell types of tumors found in this region do not lend themselves to pathologic diagnoses without substantial quantities of tissue making percutaneous or transtracheal biopsy methods less useful. Some centers report diagnosis of lymphoma by FNA but others recommend 1 cm of tissue properly processed for optimal diagnoses.[3,7] Biopsy of suspicious extrathoracic lymph nodes is an alternative method.

Planning–VATS Versus Open

The proportion of malignant tumors in the anterior mediastinum makes VATS appropriate for diagnosis when resection is unnecessary such as with lymphoma. However, one needs to pause when considering this for resectable malignant or locally aggressive tumors. This is because of concern of inadequate oncologic control. Depending on the malignancy, VATS for definitive therapy should be considered investigational unless the patient is at prohibitive risk for more invasive techniques. For instance, pleural seeding by a thymoma has been reported by other biopsy methods. Therefore VATS thymus resections have largely been limited to the resection of residual thymus for MG and for smaller, encapsulated, noninvasive thymomas. Mediastinal goiter, although not an oncologic risk, can usually be extracted through a neck incision. Thymic cysts, teratomas, and other clinically benign tumors may be optimal for VATS given their relations to other vital mediastinal structures.

Special Operative Concerns

The preoperative preparation of a patient with MG goes beyond the scope of this Chapter; however, the patients usually have been optimized medically and had their cholinergic medications held briefly so as not to interfere with the anesthetic management. Muscle relaxants are not used for these patients. Similarly, if the patient had a toxic goiter or other active endocrine tumor, then medical optimization should precede surgery.

Large anterior mediastinal masses that cause dyspnea or positional preferences for the patient are at increased risk of airway loss during the induction of general anesthesia. Evidence of airway compression on computed tomography, even in relatively asymptomatic patients, should warn the surgeon of this potential catastrophic complication. If the operation is for diagnosis only, an alternative means to biopsy the mass should be considered. Otherwise, the induction should be slow and allow for placement of a small endotracheal tube past the obstruction if necessary. Inspection for vocal cord paresis should be considered when appropriate.

The surgical instruments needed to perform the operation through a traditional open approach should be immediately available in the event of conversion to complete

the operation or control a complication like hemorrhage. For general operating room preparation and anesthetic considerations refer to Chapter 1.

Typical Operations of the Anterior Mediastinum

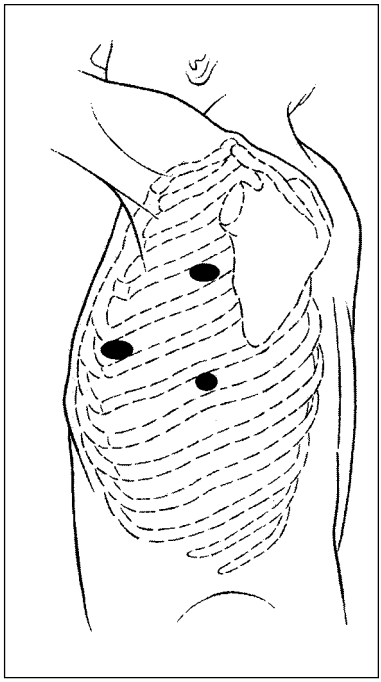
Biopsy of an Anterior Mediastinal Mass (Typical Posterolateral Positioning)

After the preoperative planning and anesthetic concerns listed above, the CT scan is reviewed once again to determine whether the right or left pleural space is better exposed to the mass in question. If the mass is bulging toward the lung, then the patient may be placed in the posterolateral decubitus position with the ipsilateral side up. When there is no obvious advantage based on the imaging, the left side affords clear visualization of the anatomy in this region. On the other hand, if some dissection of the anterior mediastinal contents is anticipated, then a modified posterolateral approach as described below in the thymectomy section is appropriate. The superior base of the typical inverted triangular arrangement of ports is made more anteriorly and the viewing port more anterior and superiorly, (Fig 10.2). The working port sites are selected and made using internal guidance by the telescope. The bed is rolled and placed in reversed Trendlenberg to facilitate the lung falling away from the target region. A fan retractor or lung grasper typically inserted through the posterior working port moves the lung inferiorly and posteriorly to fully expose the anterior mediastinum. Then a large endoscopic biopsy forceps (a mediastinoscope type is frequently handy) can be inserted though the anteriosuperior working port and multiple sections taken and classified as adequate for diagnosis by frozen section or imprint cytology. In areas where the vascular anatomy is uncertain, no blood return by mediastinoscope needle aspiration in the area of planned biopsy is useful. Cautery should be used with care given the proximate location of the phrenic nerve and therefore a small piece of methylcellulose or similar thrombostatic agent can be applied for hemostasis. A specimen extraction sac should be used to remove large pieces of malignant tissue that could potentially seed the chest wall.

Operative Procedure VATS Mediastinal Biopsy

Preoperative preparation	Routine CT Scan of chest in room
Anesthetic concerns	Double Lumen Endotracheal Tube or Bronchus Blocker Difficult airway cart if airway compression External warmer if thoracotomy likely
Other endoscopic equipment needed	Intubating Bronchoscope Possible Mediastinoscopy tray
Patient positioning	Lateral Decubitus, possibly modified
Patient monitoring	Routine. Arterial line if airway compression
Catheters	Bladder catheter if thoracotomy likely
Video system needed	0 and 30 degree Telescope or Flexible thoracoscope

Fig. 10.2. Diagram showing patient in the right lateral decubitus position and the target area is the anterior mediastinum. The camera port is positioned more superiorly (6th intercostal space) while the working ports are positioned anterosuperiorly in the 4th and 3rd interspaces.



Reusable tools	Endoscopic biopsy forceps, large Mediastinoscope aspirator Endoscopic dissector Long, narrow jaw Babcock clamps Hook cautery Cautery extension piece
Ports	Nondisposable metal, 2 x 10 mm,1 x 12 mm
Disposable instruments	Specimen extraction sac* Endoscopic clip appliers* Endo-retract™*
Chest tube	Intrapleural anesthesia, 32 F or Silicon, 28F
Port closing sutures	Standard
Instruments needed to open chest	Thoracotomy tray*
Postoperative Care	General recovery. ICU if airway compression
Special Exceptions	None.

*Confirm before opening.

Resection of the Thymus or other Anterior Mediastinal Mass

If the mass is small, subpleural and encapsulated, it can be resected using the above outlined methods. However, instead of an incisional biopsy, the uninvolved pleurae over or around the mass is incised sharply and reflected. The mass is distracted to allow division of any attachment using cautery or endoscopic clips. If cyst rupture occurs, the mass' contents are aspirated to prevent spillage. The tumor is placed in an extraction sac and the operation is completed the same.

When a complete thymectomy or intermediate size mass excision is contemplated, then special positioning and exposure techniques become more useful. A modified decubitus position is popular with the back at 30-45° to the plane of the table and the patient's arm suspended over the head by a special table piece (Fig. 10.3). The operation can be performed using a total thoracoscopic port technique or by employing a submammary access thoracotomy.

In addition, further exposure of this "tight" spaced region can be created by creating a low cervical incision for the purpose of inserting the claw of an internal mammary or similar self retaining retractor beneath the superior manubrium. Anterior retraction can then be applied to enhance exposure. Also this cervical incision can also be used to help mobilize the superior poles of the thymus and prevent inefficient dissection deep in a 'hole'. Using this approach, the inverted triangle of ports can be made even more superior and anterior so that the camera is in approximately the 5-6th interspace and the anterior working port is parasternal. The lung no longer requires retraction because the patient's position allows it to fall away naturally.[8]

The dissection of the left lobe can be performed from inferior to superior by using a grasper in the lateral port and a dissector through the medial port. Endoclips are used to divide the thymus from the innominate vein. Once the left lobe is removed, the right lobe is grasped at its inferior pole, pulled toward the left, and dissected in a similar fashion. Avoiding cautery near the pericardium helps prevent arrhythmias and trauma that could cause delayed pericardial effusions.

Use of the access thoracotomy with a cervical incision allows for the upper portion of cervical thymectomy to be performed as well as a more complete inferior thymic resection than might occur by cervical thymectomy alone.[9] The cervical component can be performed first and then delivered below the innominate vein for completion of the lower component through the access thoracotomy using the above noted dissection methods.

Operative Procedure VATS Thymectomy

Preoperative preparation	Discontinue mestinon CT Scan of chest in room
Anesthetic concerns	Double Lumen Endotracheal Tube or Bronchus Blocker Avoid muscle relaxants External warmer
Other endoscopic equipment needed	Intubating Bronchoscope Possible Mediastinoscopy tray
Patient positioning	Modified Lateral Decubitus "Trapeze" for arm positioning

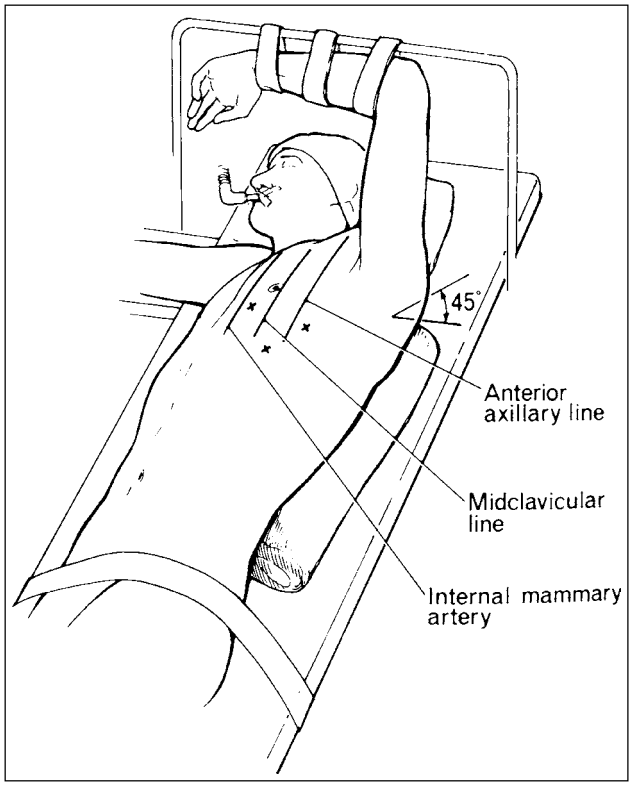


Fig. 10.3. Patient positioning for resection of an anterior mediastinal mass or thymectomy. Reproduced by permission from the Society of Thoracic Surgeons. Annals of Thoracic Surgery.

Patient monitoring	Routine.
Catheters	Bladder catheter.
Video system needed	0 and 30 degree Telescope or Flexible thoracoscope
Reusable tools	Endoscopic dissector Endoscopic grasper Self retaining (Weitlaner) retractors Long, narrow jaw Babcock clamps Pediatric rib spreader Internal mammary retractor Hook cautery Cautery extension piece

Ports	Nondisposable metal, 2 x 10mm, 1 x 12 mm
Disposable instruments	Specimen extraction sac* Endoscopic clip appliers* Endo-retract*
Chest tube	Silicon, 28F
Port closing sutures	Standard
Access thoracotomy sutures	Standard
Instruments needed to open chest	Thoracotomy tray*
Postoperative Care	General recovery. ICU if airway compression or severe myasthenia gravis
Special Exceptions	None.

*Confirm before opening.

Middle (Visceral) Compartment Masses

Differential Diagnoses

The most common tumors of the middle mediastinum are lymphomas and cysts. Lymphomas are classified as Hodgkin (HD) and non-Hodgkin(NHL) varieties and are discussed in the Anterior Compartment section. The NHL type has more of a predilection for the middle compartment.[4]

The common cystic tumors are bronchial, pericardial or esophageal in origin although the exact origin of some defy histologic categorization. More unusual cysts are mesothelial, neuroenteric, and thoracic duct varieties. Uncommon benign solid masses in this region are granulomas, hamartomas, and paragangliomas. Malignant pheochromocytomas and nerve sheath tumors can arise from neural tissue in the middle compartment but these are unusual.

Symptoms and Physical Findings

Patients who present with NHL typically have constitutional symptoms or extrathoracic lymphadenopathy. The foregut cysts typically cause symptoms of airway or esophageal obstruction previously mentioned; however many are discovered incidentally on screening radiologic examinations. Two-thirds of the asymptomatic cysts go on to cause problems and are best treated when discovered.[4] This is because the cysts tend to enlarge over time by internal secretions, bleeding or infection. Pericardial cysts are rarely symptomatic and are usually observed safely.

Those patients with inflammatory granulomatous disease of the mediastinum may have had pneumonia or flu-like respiratory complaints in the past. They may also develop constriction of the superior vena cava or aerodigestive tract from fibrosing mediastinitis. Rarely, inflammatory cysts can occur and cause symptoms like

hoarseness from recurrent nerve paresis. Benign solid neoplasms can also cause symptoms by enlargement or by endocrine effects (e.g., pheochromocytoma).

Laboratory Studies

Unless the patient has unusual or endocrine related symptoms, routine preoperative tests are all that are necessary for preparation of patients with masses in this compartment. While some inflammatory cysts (like histoplasmosis) may have positive skin tests or serologic findings, the endemic nature of these infections in many regions reduces the diagnostic value of those tests. Pathologic tissue obtained from lymphomas are often best preserved in special nonformalin fixatives for special stains and cell culture media for flow cytometry and to help with classification. Also, cysts and inflammatory masses should be cultured.

Radiologic Investigations

About three-fourths of patients with newly diagnosed HD have mediastinal widening on chest roentgenograms and computed tomographic scans. [4] As opposed to anterior mediastinal HD, NHL is not as apparent radiologically–less than half of the patients will have an abnormal chest roentgenogram. The CT scan will often show the lymph node enlargement that was overshadowed by normal mediastinal structures on the routine CXR. The CT will also show unusual lymphoma extensions to pericardium, pleural and other thoracic structures.

Cyst locations and their relations to the mediastinal viscera provided by computed tomography and occasionally magnetic resonance imaging can provide useful diagnostic information. The cysts are usually round, thin-walled, and homogenous in appearance. Most bronchogenic cysts arise near the trachea or major bronchi. Neuroenteric cysts occur proximally, separate from the esophagus, toward the right, have associated vertebral abnormalities and often require MRI to rule out spinal extension. Enterogenous cysts are similar to bronchogenic radiographically except that they tend to be more posterior and near the esophagus. Esophageal duplication cysts occur toward the distal right esophagus and are intimately related with the esophagus.[10] Pericardial cysts are very thin and occur three times more commonly on the right pericardial phrenic angle than the left.[11]

Other Invasive Testing

Biopsies of extrathoracic lymph nodes are usually less invasive than intrathoracic biopsies in suspected lymphoma patients. However, fine needle or core biopsies may be insufficient. While bronchoscopy and mediastinoscopy may be able to drain some cysts, this provides symptomatic, not definitive therapy.

Planning–VATS Versus Open

In comparison to anterior mediastinal masses, most middle mediastinal masses may be approached by VATS techniques appropriately. This is because the outcome of lymphoma is unlikely to change by transpleural biopsy. Cysts are usually benign and generally very accessible. The less common solid malignant tumors should be resected by VATS as part of an investigation or because patient factors make it the safest option. Inflammatory masses may be approached by VATS but if solid, there are typically many adhesions that may make the operation risky or tedious.

Special Operative Concerns

For patients with symptoms or signs of airway compression, the concerns listed in the previous section should be reviewed. These patients should also be prepared to undergo thoracotomy by elective conversion to complete the operation or urgently to treat a serious complication. Also, those patients with cystic lesions should have a sputum trap attached to the suction to allow sampling of the fluid for culture and occasionally for other analyses if the cyst ruptures during removal.

Typical Operations of the Middle (Visceral) Mediastinum

Biopsy of a Middle Mediastinal Mass

The technique for biopsy of masses in this region is similar to that noted in the previous section although the exposure tends to be better. A standard three port technique described in Chapter 1 is useful for most middle masses. Selection of retraction and dissection ports will differ whether the mass is anterior, posterior, or inferior to the hilum of the lung. Additional ports may be necessary for retraction of the diaphragm, esophagus, azygous vein, or pulmonary hilar structures. Remembering to tilt the operating room table to a favorable position that allows the diaphragm or lung to fall away favorably is also useful. Frequently, division of the inferior pulmonary ligament and pleurae anterior to the vertebral body or around the hilum is useful for exposure.

Excision of a Mediastinal Cyst

The standard three port location is useful for most mediastinal cysts. However, because of their potential diverse locations, it is important to consider modifications of these positions based on the preoperative imaging. Also, one should not hesitate to place additional ports to improve the safety and tempo of the operation. The nature of most mediastinal cysts is that they are thin-walled and under some tension because of the pressure of their contents. Consequently, they are likely to leak or rupture during dissection. This is often favorable because the deflated cyst wall is easier to manipulate and remove. It also give the surgeon the ability to look inside the cyst if necessary. When the cyst is infected or likely to be so, partial controlled drainage may be preferred to the risk of rupture and spillage.

Once the cyst is identified, the pleura near it is divided and reflected to find the plane between the cyst wall and its related structures. Dissection proceeds with one instrument either pushing the cyst wall away or pulling it away by clamping the wall of the cyst. Adhesions are divided by cautery and endoclips where necessary.

Depending on the wall thickness and tension, rupture may occur where the cyst is grasped. A large bore suction should be available for placement though one thoracostomy (while inward venting occurs though another port) to handle a sudden rupture. A sputum trap or culture media should be available. Controlled drainage is accomplished by spinal needle aspiration or mediastinoscopy aspirator to relieve the pressure. Then the needle hole is occluded by the retraction clamp to prevent further leakage.

The cyst should be placed in an extraction sac for removal once it is freed. The bed of dissection is inspected and cautery or topical hemostatic agents are used judiciously. Occasionally the wall of the cyst is amalgamated to a vital structure. In

this case, all cyst wall safely removable is excised and epithelial lining of the cyst is destroyed by cautery, chemical, or other ablative maneuver. Routine chest drainage is used postoperatively.

Operative Procedure VATS Mediastinal Cyst Excision

Preoperative preparation	CT Scan of chest in room
Anesthetic concerns	Double Lumen Endotracheal Tube or Bronchus Blocker External warmer optional
Other endoscopic equipment needed	Intubating Bronchoscope
Patient positioning	Lateral Decubitus
Patient monitoring	Routine
Catheters	Bladder catheter optional
Video system needed	0 and 30 degree Telescope or Flexible thoracoscope
Reusable tools	Endoscopic dissector Endoscopic grasper Long, narrow jaw Babcock clamps Hook cautery Yankauer suction Cautery extension piece
Ports	Nondisposable metal, 2 x 10mm, 1 x 12 mm
Disposable instruments	Specimen extraction sac* Endoscopic clip appliers* Endo-retract™* Sputum trap* Culture media* Spinal needle (18 or 20 gauge)
Chest tube	Intrapleural anesthesia catheter or Silicon, 28F
Port closing sutures	Standard
Instruments needed to open chest	Thoracotomy tray*
Postoperative Care	General recovery.
Special Exceptions	None.

*Confirm before opening.

Posterior (Paravertebral) Compartment Masses

Differential Diagnoses

The paravertebral compartment is the natural location of nerve related neoplasms. Schwannomas and neurofibromas are the most common mediastinal neurogenic tumors and occur equally in both sexes, typically in midlife.[4] Multiple neurogenic tumors or a single plexus of these tumors can be pathognomonic for the disease neurofibromatosis. About a third of patients with this disease have paravertebral neurofibromas which occur at a younger age and have a greater risk of malignant transformation.[4,12] It is rare for a preexisting schwannoma to undergo malignant change.

Less common tumors in this region include malignant tumors of nerve sheath origin also called malignant schwannomas or malignant neuroblastomas. As noted above, these tumors occur half the time in patients with neurofibromatosis but can also present after radiation exposure or sporadically. Tumors can also arise from the sympathetic ganglia. Ganglioneuromas occur in children or young adults and are composed of mature ganglion cells that are curable by resection. Ganglioneuroblastoma and neuroblastoma, on the other hand, affects children typically less than 10 years with subjects less than age two having a better prognosis.[12] Rarely this region may have lateral thoracic meningoceles, paragangliomas, fibromas, and lymphoma tumors. The lateral meningocele represents a common cause of posterior mediastinal mass in patients with neurofibromatosis.[4]

Symptoms and Physical Findings

Most of the common benign neurogenic tumors are asymptomatic unless the tumor is large enough to compress surrounding tissue or extends within the spinal foraminae. Malignant nerve sheath tumors, however, present with pain commonly which may have been present for months. The neuroblastoma tumors may have extensive spread within the chest or distant metastases which cause symptoms like Horner's syndrome, respiratory distress and neurologic deficits. These tumors may also produce catecholamines or intestinal vasoactive peptides that cause diarrhea and flushing.

Laboratory Studies

Benign neurogenic tumors require only routine laboratory tests before planned excision. Neuroblastomas, as noted above, can lead to elevation of plasma catecholamines or urinary catecholamine products (homovanillic or vanillylmandelic acids) that can be used to monitor recurrence.

Radiologic Investigations

Common benign neurogenic tumors (e.g., schwannomas) are found in the paraspinous tissues and by computed tomography are round with distinct margins but occasionally are lobulated. They typically span only 1-3 interspaces although they can get quite large. Calcification of these tumors is rare. Half will show pressure effects on surrounding structures like benign erosion and about 10% will extend into the spinal canal creating the so-called dumbbell tumor.[4] This intraspinal extension is shown best by MRI, a usual preoperative test for patients suspected of having this tumor. The MRI may show communication of cerebrospinal fluid between the

spinal canal and a lateral thoracic meningocele as well as the vertebral abnormalities associated with this disorder. The malignant nerve sheath tumors have similar locations and shapes but are larger (> 5 cm), more irregular, and can contain areas of necrosis, calcification, or local invasion.[13]

The sympathetic chain tumors tend to be oblong and run along the anterolateral aspect of the spine. Ganglioneuromas create benign erosions, are either homogenous or heterogeneous, and occasionally calcify with a stippled pattern. MRI also shows intraspinal extension. The malignant counterparts show more calcification and evidence of invasion. Because of its catecholamine production, MIBG scanning can be useful.[4]

Other Invasive Testing

The benign posterior mediastinal tumors are usually diagnosed with a reasonable degree of certainty based on the clinical presentation and radiologic imaging features. CT directed biopsies are not indicated. Patients with advanced malignant neurogenic tumors that are unresectable or require multimodality therapy may require open or directed biopsy.

Planning–VATS Versus Open

Benign neurogenic tumors that appear resectable by preoperative imaging may be approached quite satisfactorily by VATS techniques which are considered a standard therapy in many centers. This can also include the patients who require laminectomy to free the intraforaminal portion of a dumbbell tumor. Patients with single tumors less than 4 cm and few tumor related chest wall deformities are ideal. Multiple level tumors including those that form a plexus that can extend below the diaphragm are undesirable for this approach.

The more that the chest wall requires operative trauma to complete the operation, the less VATS techniques are relevant. Malignant neurogenic tumors are generally approached by open techniques unless in investigational settings or highly selected patients at too high risk for thoracotomy.

Special Operative Concerns

Because of intercostal arterial bleeding, hemorrhage during the resection of posterior mediastinal tumors is occasionally persistent enough to require conversion to open thoracotomy.

This problem is less frequent with better operator experience and better methods for VATS hemostasis. Also, it is important to have the preoperative imaging studies in the operating room that usually includes an MRI to exclude spinal involvement by these tumors.

Typical Operation of the Posterior (Paravertebral) Mediastinum

Resection of a Benign Neurogenic Tumor

The standard three port technique is useful for many patients with posterior mediastinal tumors although moving the ports might be useful for tumors at the apex of the chest or near the diaphragm. Apical tumor resections might be easier with the port triad shifted more anteriorly and one to two interspaces superiorly.

Low tumors may require arranging the ports in an inverted fashion with the camera superior as is required by a distal esophageal VATS procedure. Rolling the patient anteriorly serves to move the lung out of the field and a reversed Trendelenberg position can drop the diaphragm somewhat away from inferiorly based tumors (although extra ports to retract the diaphragm may be necessary). If a fan retractor is needed to hold the lung away, a fourth (5 mm) port is added to aid dissection, Figure 10.4. The resection is begun by cauterizing the pleural circumferentially around the tumor and reflecting it slightly to define the plane between the mass and the chest wall. Many times, division of the nerve root from which the tumor arises is necessary early to continue to allow rotation of the tumor out of its bed by continued sharp and dull dissection. Finally the other side of the nerve origin is divided and the mass is removed in a specimen extraction sac. Bleeding from intercostal vessels can be troublesome because of difficulty with exposure with the space confined by the bone structures. Venous oozing is controlled by topically agents like methylcellulose but care is needed to avoid packing materials like Gelfoam™ that can creep into the spine and cause cord compression. Arterial bleeding can be controlled by cautery, endoscopic clips, sutures, and other creative or newer means of hemostasis. A limited thoracotomy could also be useful in aiding hemostasis but patience is usually all that is needed. If the patient requires neurosurgical treatment of the spinal side of a dumbbell tumor, this is performed prior to the VATS component to prevent avulsion injury and intraspinal hemorrhage.

Operative Procedure VATS Neurogenic Tumor Excision

Preoperative preparation	CT Scan of chest in room MRI of Chest in room
Anesthetic concerns	Double Lumen Endotracheal Tube or Bronchus Blocker External warmer optional
Other endoscopic equipment needed	Intubating Bronchoscope
Patient positioning	Lateral Decubitus (Possibly prone if neurosurgery is needed first)
Patient monitoring	Routine.
Catheters	Bladder catheter.
Video system needed	0 and 30 degree Telescope or Flexible thoracoscope
Reusable tools	Endoscopic dissector Endoscopic grasper Long, narrow jaw Babcock clamps Hook cautery Yankauer suction Cautery extension piece

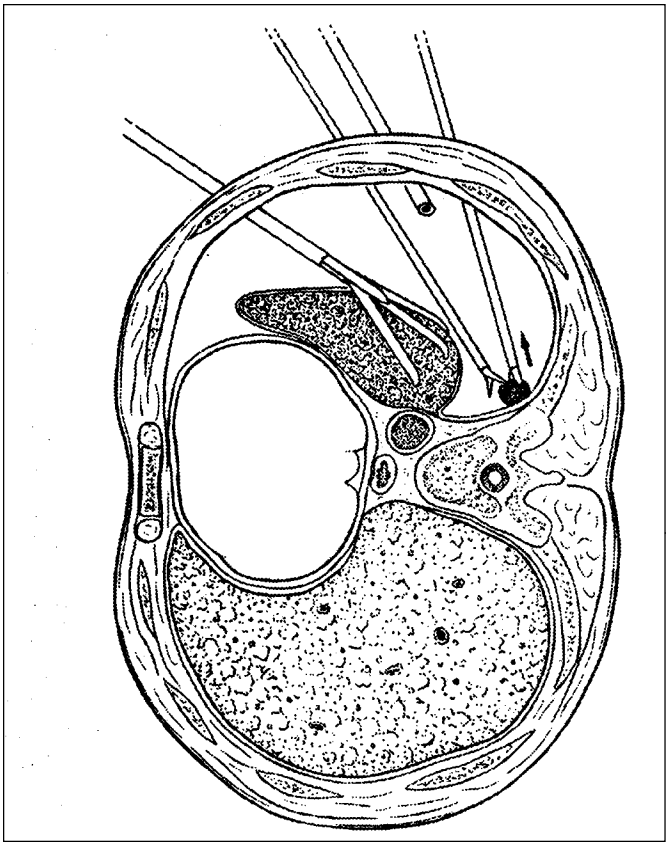


Fig. 10.4. Sagittal diagram showing resection of a posterior mediastinal tumor. Retraction of the lung is helped by tilting the table anteriorly.

Ports	Nondisposable metal, 2 x 10mm, 1 x 12 mm Disposable 5 mm port*
Disposable instruments	Specimen extraction sac* Endoscopic clip appliers* Endo-retract™*
Chest tube	Intrapleural anesthesia catheter or Silicon, 28F
Port closing sutures	Standard
Instruments needed to open chest	Thoracotomy tray*

Postoperative Care	General recovery.
Special Exceptions	Topical hemostatic agent*. May require laminectomy first (10%).

*Confirm before opening.

Results of VATS for Mediastinal Tumor Excision

The uncommon nature of mediastinal tumors has limited the study of VATS for this problem. Most of the published experience has come from busy centers of VATS surgery or cooperative group efforts. A recent experience from seven centers collected 48 patients with an average age of 41 years.[14] Twenty-two of the cases were asymptomatic and 92% of the remaining symptomatic patients had resolution or improvement of their complaints. In this series, 5 of 48 were from the anterior compartment and the remainder were roughly distributed between the middle and posterior compartments. The diagnoses were typical for the compartments described above and the tumors averaged 5.2 cm. Twelve of the lesions were biopsied without excision and the rest were excised completely. Fifteen of the cases were cysts and 10 were malignant (8 biopsy only).

In this series the operations were briefer for the posterior compartment (93 min) as opposed to the middle (170 min) or the anterior (195 min). This was probably because of the greater simplicity and better exposure of the pathology treated surgically in the posterior compartment. Only six of the cases required conversion to open operations because of bleeding, large size, impaired exposure or rib attachments and none of these cases had morbidity beyond that expected of a thoracotomy. The patients who did not require conversion stayed 3.2 days as opposed to 5.5 for the thoracotomy group and chest tube duration was shorter as well. There were no postoperative deaths or major complications but there were 7 minor complications that included air leak, ileus, superficial wound infection, severe pain, pneumothorax, pleural effusion, and transient Horner's syndrome. Eighty percent of patients reported returning to full preoperative activity by 4 weeks. During the relatively brief followup of this study there was one asymptomatic cyst recurrence and one local liposarcoma recurrence.

The avoidance of malignancy in this series (4 benign:1 malignant) is noteworthy when compared to the 3:2 ratio of open series of mediastinal tumors. Also, the anterior compartment comprised 10% of the cases in this VATS series compared to 50-60% in reviews of open series. The reasons for that are noted above in the anterior mediastinal tumor section. It was the opinion of this group that VATS, when applied carefully, was safe for excision of benign mediastinal tumors and investigational for resection of malignant tumors. Biopsy of neoplasms may be appropriate and even desirable by VATS (because of better exposure than other methods) if pleural contamination is not an issue such as in lymphoma or if already metastatic elsewhere.

Summary

VATS can be applied safely to certain cases of mediastinal tumors. The decision to treat a mediastinal tumor by VATS is predicated on whether it is possible

to perform exposure and dissection that achieve principles basic to an open operation. This requires planning by considering tumor location, proper port placement, and the amount of operator VATS experience with dissection in the region of the tumor. There should be good judgement by having a low threshold to add ports, access incisions or standard thoracotomy to improve exposure. This is especially important when there is excessive risk for hemorrhage or tumor dissemination.

Thin walled cysts and small solid masses are appropriate for VATS resection particularly when they appear low risk because of known benign histologic characteristics, slow growth, encapsulation, posterior compartment location, and lack of invasion or neovascularity by imaging or thoracoscopic inspection. While neoplasm biopsy can be appropriate, the oncologic validity of VATS resection of malignant mediastinal disease is unknown and should be tested in an investigational setting before being applied to patients who can tolerate standard exposure techniques.

References

1. Shields TW. Primary tumors and cyst of the mediastinum. In: Shields TW, ed. General Thoracic Surgery. Third ed. Philadelphia: Lea & Febiger 1989:1096-1123.
2. Strollo DC, Rosado de Christenson ML, Jett JR. Primary mediastinal tumors. Part 1: Tumors of the anterior mediastinum. Chest 1997; 112:511-22.
3. Kohman LJ. Approach to the diagnosis and staging of mediastinal masses. Chest 1993; 103:328S-30S.
4. Strollo DC, Rosado-de-Christenson ML, Jett JR. Primary mediastinal tumors: Part II. Tumors of the middle and posterior mediastinum. Chest 1997; 112:1344-57.
5. Davis RD Jr, Oldham HN Jr, Sabiston DC Jr. Primary cysts and neoplasms of the mediastinum: Recent changes in clinical presentation, methods of diagnosis, management, and results. Ann Thorac Surg 1987; 44:229-37.
6. Lopez L, Varela A, Freixinet J et al. Extended cervical mediastinoscopy: Prospective study of fifty cases. Ann Thorac Surg 1994; 57:555-7.
7. Goldberg M, Burkes RL. Current management of mediastinal tumors. Oncology (Huntingt) 1994; 8:99-110.
8. Sugarbaker DJ. Thoracoscopy in the management of anterior mediastinal masses. Ann Thorac Surg 1993; 56:653-6.
9. Kaiser LR. Thoracoscopic resection of mediastinal tumors and the thymus. Chest Surgery Clinics of North America 1996; 6:41-52.
10. Reed JC, Sobonya RE. Morphologic analysis of foregut cysts in the thorax. Am J Roentgenol Radium Ther Nucl Med 1974; 120:851-60.
11. Feigin DS, Fenoglio JJ, McAllister HA et al. Pericardial cysts. A radiologic-pathologic correlation and review. Radiology 1977; 125:15-20.
12. Shields TW, Reynolds M. Neurogenic tumors of the thorax. Surg Clin North Am 1988; 68:645-68.
13. Kumar AJ, Kuhajda FP, Martinez CR et al. Computed tomography of extracranial nerve sheath tumors with pathological correlation. J Comput Assist Tomogr 1983; 7:857-65.
14. Demmy TL, Krasna MJ, Detterbeck FC et al. Multicenter VATS experience with mediastinal tumors. Ann Thorac Surg 1998; 66:187-92.

Thoracoscopic Neurologic Surgery and Thoracoscopic Access for Spinal Surgery

Mark J. Krasna, Xiaolong Jiao

Indications for Neurologic Surgery

Thoracoscopic neurologic operations are typically upper or lower sympathectomies. The most common indication for upper thoracic sympathectomy is either palmar or axillary hyperhidrosis. Raynaud's syndrome and Buerger's disease in the upper extremities are also indications for upper thoracic sympathectomy. Other vascular disorders that warrant this operation are reflex sympathetic dystrophy, critical digital ischemia with ulceration, and rest pain despite thorough medical treatment. However, for these indications, the salutary effect of thoracic sympathectomy may be short-term.[1] Thus, only patients who have severe disease and failure of medical therapy should be operated upon.

The main indication for lower thoracic sympathectomy is intractable upper abdominal pain for patients suffering from chronic pancreatitis or upper abdominal malignancy. When physical treatments are unsuccessful, surgery is indicated. Transthoracic division of the splanchnic nerves with vagotomy for the treatment of chronic pancreatitis was first reported in 1947 by Rienhoff and colleagues.[2] Thoracoscopic splanchnicectomy is a recently described approach that combines the benefits of a visually controlled division of the splanchnic nerves with the low morbidity and reduced patient discomfort associated with minimal access techniques. Some authors recommend bilateral splanchnicectomy, while others suggest that left splanchnicectomy can produce equally effective pain relief. The addition of vagotomy during a left splanchnicectomy may limit recurrent episodes of pain in alcoholic pancreatitis by reducing acid stimulation of pancreatic secretions.

Results

Results of Thoracoscopic Neurologic Surgery

For a patient with hyperhidrosis, the desired effect of dry hands is immediate. In most large series, approximately 95% of cases are successful achieving low long-term recurrence rates. Patient satisfaction is usually excellent. The side effect of the procedure is compensatory sweating on the back and around the lower abdomen and inner thigh. Theoretically, this compensatory sweating could happen to every patient but is reported in about 37-75%. The degree of compensatory sweating differs from patient to patient. Serious compensatory sweating is uncommon. Among our initial series of 26 patients, we found only one patient with serious compensatory sweating.[3]

It is difficult to compare between reports because of no clear definitions on the issues of hyperhidrosis, compensatory sweating, and subjective outcome endpoints like success rate or overall satisfaction rate. We recommend scoring systems with subjective and objective descriptions and tests to quantitate sweating before and after operation to evaluate treatment effectiveness[4] (Tables 11.1 and 11.2). Other possible morbidities are pneumothorax, bleeding, allodynia, and Horner's syndrome. Allodynia is a kind of dysesthesia, manifesting as an irritable and sometimes painful reaction to a non-noxious stimulus to normal skin. It is usually seen around the arms. Allodynia may be caused by an accidental intercostal nerve injury.

Sympathectomy as an indication for patients with Raynaud's disease is a controversial issue. Patients with mild Raynaud's disease usually have a good early response but nearly all eventually relapse, whereas patients with severe Raynaud's syndrome, trophic changes and ulceration rarely achieve even a temporary response.

Results of Lower Thoracic Sympathetic Nerve Resection/ Splanchnicectomy

The reported results of splanchnicectomy in splanchnic pain control are encouraging. The effect of pain relief is usually achieved immediately after surgery. Complete pain relief is reported in 60-100% of patients. However, there are no large series reports, and the long-term results are not available since many of the patients are at the end stage of malignancy. Further prospective studies are needed to evaluate the role of splanchnicectomy as pain control for patients with chronic pain caused by benign or malignant diseases originating from the pancreatic region. Serious complications are rare. Some slight gastrointestinal side effects like diarrhea and constipation may occur. Delayed gastric emptying is common if bilateral truncal vagotomy is added to the procedure.

Thoracic Outlet Syndrome

Thoracic outlet syndrome (TOS) involves compression of the subclavian vessels or the brachial plexus, or both, by the first rib and adjacent structures at the superior aperture of the chest. The most common symptoms are neurologic and are related to compression of the brachial plexus in the distribution of the ulnar nerve. Patients with neurologic or vascular symptoms can be treated successfully by resecting the first rib, usually through a transaxillary approach. Advantages of the open transaxillary approach are that it can be accomplished without major muscle division, without brachial plexus retraction, and with an acceptable cosmetic result. The disadvantages of this open approach include limited visualization of the important structures at the thoracic inlet and possibility of injury to the intercostobrachialis cutaneous nerve. A thoracoscopic approach can provide excellent visualization of the thoracic outlet. With the endoscopic drill and, more recently, a thoracoscopic rib cutter, a total thoracoscopic rib resection can be performed.

The most successful approach for first rib resection reported is the transaxillary approach, initially described by Atkins, reported by Roos, and popularized by Urschel. By completely resecting the first rib, Urschel reported 85% good results in properly selected patients. Diagnostic evaluation includes history, physical examination, chest radiograph, cervical spine films, electromyogram, and ulnar nerve conduction velocities studies. A complete neurologic workup in most patients is required. Once

Table 11.1. Severity of hyperhidrosis scoring system

	Grade 0	Grade 1	Grade 2	Grade 3
Dampness	"None or slight"	"Damp"	"Wet"	"Dripping"
Quality of life	Normal	Annoyance	Debilitating	Social phobic
Blot test	–	+	++	+++

Table 11.2. Severity of compensatory hyperhidrosis

	Grade 0	Grade 1	Grade 2	Grade 3
Location	Any site	Plantar	Trunk	Facial
Dampness	None or slight	"Damp"	"Wet"	"Dripping"
Quality of life	Normal	Annoyance	Debilitating	Social phobic

other diagnoses are excluded and medical therapy options are exhausted, surgical therapy is entertained.

The thoracoscopic approach to first rib resection was described by Ohtsuka.[5] Endoscopic instruments, including endoscopic elevators, curettes, and rongeurs (Sofamor Danek, Nashville, TN), were fashioned from regular orthopedic tools by extension and modification to pass through 10 mm endoscopic ports.

The endoscopic rib cutter can be used to transect the first rib instead of the drill. It adds safety to the division maneuver and is relatively easy to use compared to the drill. It also enabled this procedure to be performed totally thoracoscopically.

A harmonic scalpel (Ethicon Endosurgery, Inc., Cincinnati, OH) operates with ultrasonic energy, produces less smoke and heat than electrocautery, and facilitates endoscopic dissection of the first rib.

Results

The initial results from some small series are encouraging. Pain and numbness can be relieved after surgery. Blood loss was minimal, operation time was less than 100 minutes with experience and hospital stay was reduced to one day. However, this procedure requires significant thoracoscopic experience with operator carefully avoiding possible vascular injuries.

Thoracoscopic Spine Surgery

Thoracoscopy offers a new approach to spine surgery. Nearly all procedures on the thoracic spine previously approached by thoracotomy are appropriate for thoracoscopic spine surgery. The main indications are idiopathic scoliosis deformities, kyphotic deformities, neuromuscular deformities accompanied by at-risk pulmonary status, and discectomy or corpectomy. Relative contraindications are inability to tolerate single-lung ventilation, severe or acute respiratory insufficiency, high airway pressures with positive pressure ventilation, pleural symphysis, empyema, and previous thoracotomy.

The mean operative time is about 2.5 hours and the average chest tube duration is around 1.5 days. Blood loss varies according to different procedures performed. The anterior thoracic releases for deformity has a mean intraoperative blood loss of about 100 cc. Thoracic discectomy and spinal canal decompression has a mean

blood loss of 400 cc. The most extensive procedures was anterior thoracic corpectomies with bleeding from raw cancellous bone surfaces and epidural vessels, and the mean blood loss is over 1000 cc.

Complications of thoracoscopic spine surgery: The most common complications of thoracoscopic spine surgery are transient intercostal neuralgia and atelectasis.[6]

Operations

Thoracoscopic Sympathectomy

Anesthetic concerns	Double lumen endotracheal tube is preferred
Other endoscopic equipment needed	Intubating bronchoscope, 0° operating thoracoscope, long hook-cautery
Patient positioning	Lateral decubitus for unilateral or semi-sitting position (semi-Fowler's position) for bilateral simultaneous sympathectomy.
Video system needed	Standard 1/3 chip camera with monitor on either side of patient's head.
Ports	1 reusable or disposable
Disposable instruments	None
Instruments needed to open chest	Thoracotomy tray (in room unopened)
Postoperative care	No chest tube is needed unless chest x-ray film shows residual pneumothorax.
Special Exceptions	None

Surgical Technique

General anesthesia is used in all patients utilizing one lung ventilation with a double lumen endobronchial tube. CO_2 insufflation is used to aid lung collapse. In our initial experience, the patient was placed in the lateral decubitus position and three ports were used to gain intrathoracic access. Recently, we prefer to use a semi-Fowler's position with patient's arms abducted and a roll behind the shoulders (Fig. 11.1). This position improves access to the upper sympathetic chain since with gravity the lung naturally falls downwards and away from the upper posterior chest wall. Only one 10mm port with an operative-thoracoscope is utilized for access to the chest. The sympathetic chain is easily identified under the parietal pleura, running vertically over the necks of the ribs in the upper costo-vertebral region (Fig. 11.2).

Generally, we use a hook cautery to divide the sympathetic chain. The transected ends of the sympathetic chain are separated as far as possible and electrocauterized to prevent regrowth of the nerve and recurrence. Special care is taken to make sure

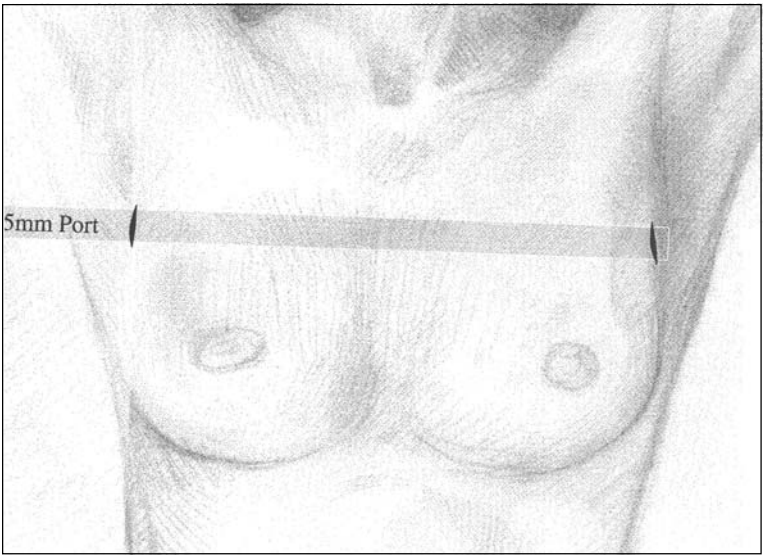


Fig. 11.1. Semi-Fowler's position for simultaneously bilateral sympathectomy.

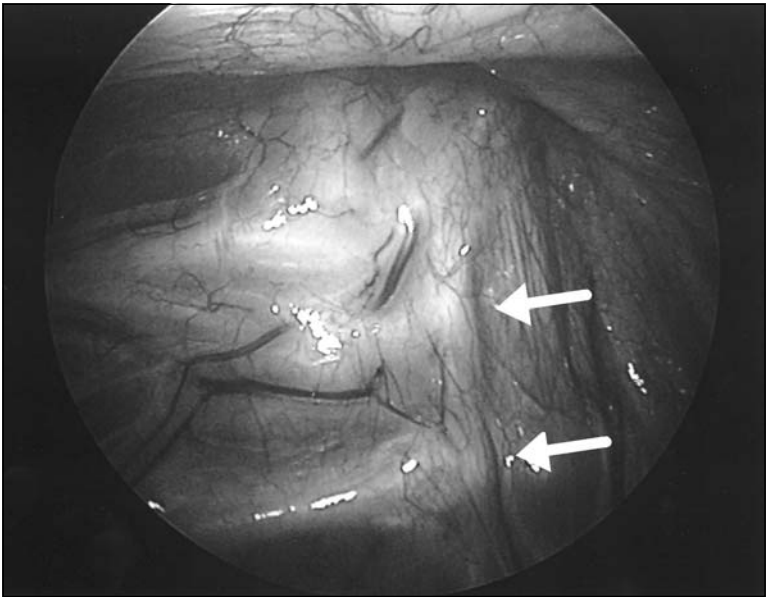


Fig. 11.2. Sympathetic chain.

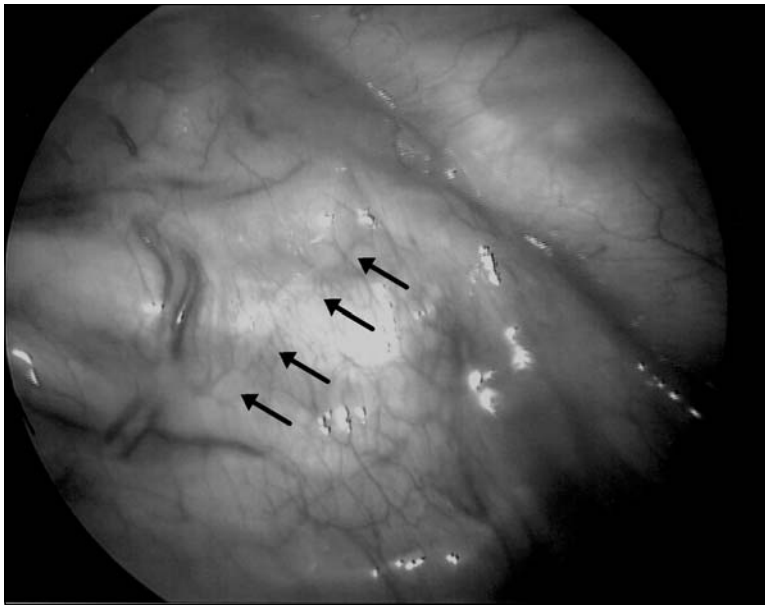


Fig. 11.3. Aberrant nerve bundle of Kuntz.

that complete ablation of ganglia and severance of the sympathetic chain is achieved. If an aberrant nerve bundle of Kuntz is identified (generally at the T2 level), it too is severed (Fig 11.3). For patients with hyperhidrosis, level T2,3 or T2-5 were divided depending on the severity of the lower extremity sweating. One should be careful not to divide the sympathetic chain above the level of the second rib for the treatment of palmar and plantar hyperhidrosis, since it increases the risk of Horner's Syndrome, and contributes little benefit. For reflex sympathetic dystrophy, we usually approached T1-3. Before closing the skin, a small chest tube is left in the chest and the subcutaneous tissue is closed with 3-0 Vicryl. After ventilating the patient with both lungs using positive pressure ventilation, the tube is removed from the chest quickly at positive pressure to avoid a residual pneumothorax, and then a final subcuticular suture is placed. Hence, no thoracic drain is needed. Local analgesia is achieved with a 10 cc 0.5% marcaine nerve block. A chest radiograph is obtained immediately after the operation in the operating room to ensure complete lung expansion.

Lower Thoracic Sympathectomy/Splanchnicectomy

General requirement: same as that for upper thoracic sympathectomy

Surgical technique: The left-sided procedure should be considered first, because the organs that cause pain are located in the left upper abdomen in many cases, and the left-sided intervention alone may be adequate.[7] We employ right-sided inter-

ventions only when the left-sided procedures are insufficient while others use simultaneous bilateral procedures for some patients.

The patient is placed in the full lateral position. General anesthesia with one-lung ventilation is needed. Insufflation with CO2 is generally used. The advantage of using general anesthesia with one-lung ventilation and resection of the nerve fiber is that it is a currently available technique and its efficiency as already been evaluated. Also, full-lung collapse provides a excellent visualization of the lower thoracic cavity. We usually divide the branches of the sympathetic chain at the level of T4 to T10. Separation and cautery ablation of the fiber may be sufficient, although the nerve resection method is a better evaluated procedure. The greater, lesser and least splanchnic nerves can be visualized clearly and transected distant to the takeoff from the main sympathetic chain (Fig 11.4).

Thoracoscopic Resection of the First Rib for Thoracic Outlet Syndrome

Special instruments: endoscopic drill or endoscopic rib cutter, endoscopic orthopedic rongeurs.

The room setup: Both surgeons position themselves on the anterior side of the patient, who is placed in the lateral position after induction of general anesthesia with a double-lumen tube. Three 10-mm thoracic ports are used for the operation. The higher ports, in the anterior third and lateral fifth intercostal spaces, are for the working instruments, and a lower port on the lateral wall in the sixth intercostal space is used for a rigid 30-degree scope.

Initially, the parietal pleura as well as intercostal muscles are sharply dissected from the costal edge of the first rib using the harmonic scalpel or electrocautery. The subclavian vein, artery, and brachial plexus, lying from anterior to posterior and draped over of the first rib, are bluntly freed using an endoscopic Cobb elevator and endoscopic curettes. Next, cautious dissection with a spinous process elevator frees the ribs circumferentially. An endoscopic drill is then used to divide the rib. The vessels and nerve are protected from the revolving drill by placing an endoscopic elevator behind the rib. The powdered tissue is evacuated by suction. Recently, an endoscopic rib cutter has replaced the drill. The endoscopic rib cutter is employed to divide the first rib both anteriorly and posteriorly in its midportion. The divided rib is then removed through one of the port incisions. Endoscopic orthopedic rongeurs are then used to trim the resected ends of the rib back to the transverse process posteriorly and anteriorly to the manubrium. Final assessment should include palpation of the transverse process posteriorly, as well as the costochondral junction anteriorly. This allows complete excision of the first rib.

Thoracoscopic Spine Surgery

Team coordination: The ability to perform thoracoscopic spinal surgery revolves around a team of surgeons (access surgeon and spinal surgeon), anesthesiologist, nurses, and surgical technicians. The access surgeon, usually a thoracic surgeon, is responsible for handling the thoracoscope and providing visualization and illumination of the endothoracic anatomy. The spinal surgeon generally performs the corrective procedure. Some surgeons prefer to work on the same side of the table, usually facing the patient, who is in the lateral decubitus position (Fig. 11.5). Others prefer

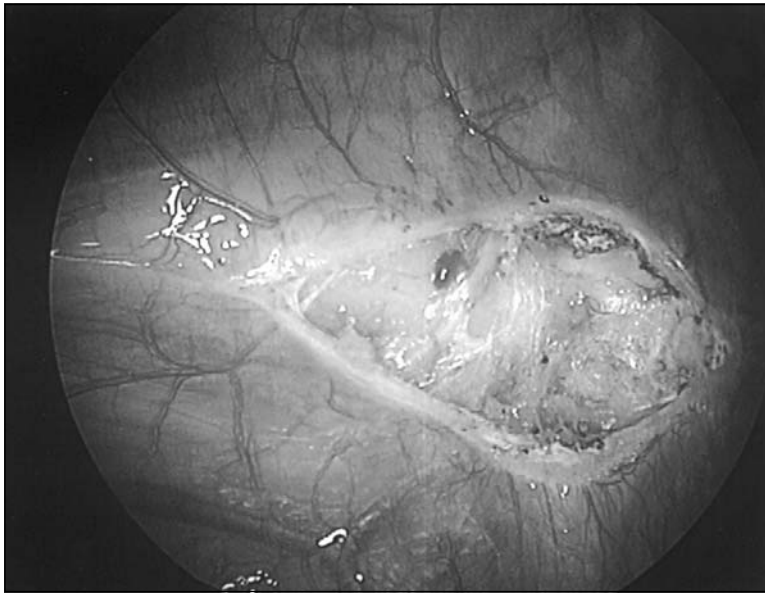


Fig. 11.4. Splanchnic nerve.

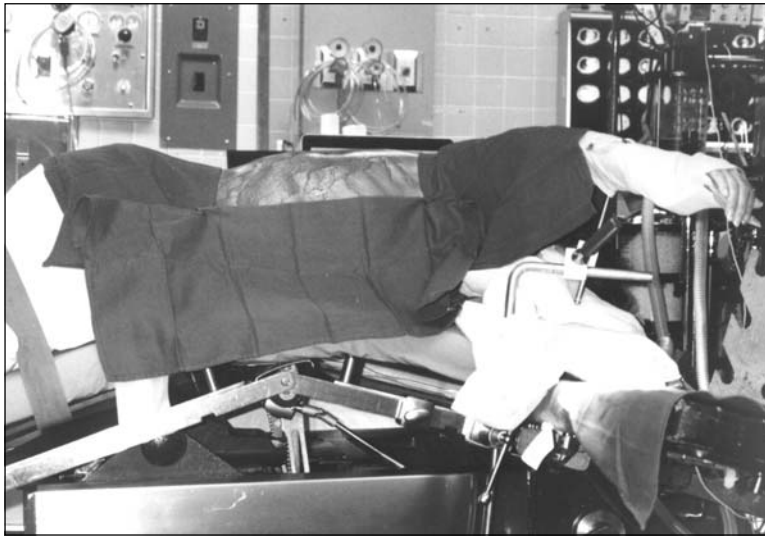


Fig. 11.5. Conventional setup for thoracoscopic spine surgery.

to work opposite each other, viewing the intrathoracic contents by placing monitors directly across from them and usually looking over the associate's shoulder. We generally stand with both thoracic and orthopedic surgeon on the same side facing the monitor that is behind the patient. The endoscopic hardware includes various angled thoracoscopes capable of magnifying up to 15 times, as well as specialized thoracospinal instruments (e.g., Rongeurs, curettes, periosteal elevators, electrocautery, harmonic scalpel, and suction irrigation devices).

Thoracoscopic spine exposure procedure: General anesthesia is administered via a double-lumen tube or bronchial blocker. The patient is turned to the lateral decubitus position. The anesthesiologist should observe deflation of the lung before draping is carried out, and 10 minutes are allowed to achieve complete resorption atelectasis. Routine intraoperative monitoring for thoracic procedures (i.e., arterial pressure line, pulse oximeter, and end-tidal carbon dioxide measurement) is initiated. Because the majority of thoracic spinal deformities appear on the right side, the patient is usually placed in the left lateral decubitus position with a kidney rest support.

Although not sterilely draped, the arm is hyperflexed at the shoulder to allow the placement of portals high into the axilla. The Mayo stand is situated so that electrocautery, suction, and light source are fully accessible. The topographic anatomy, specifically the scapular borders, the 12th rib, and the iliac crest, are identified and outlined with a water marker. Although four to five ports are often necessary, we recently have progressed to two or three 5-10 mm trocars for all operations. The first port is most frequently placed in the T6 or T7 interspace in the anterior axillary line. Entry at this level usually avoids the diaphragm. The incision is made over the top of the rib to avoid the intercostal vessels. A 10 mm trocar is used, through which a 10 mm, 30°, angled rigid telescope is placed. The 30° scope allows direct vision into the intervertebral disk spaces, without either impeding the surgical instrumentation or obscuring the operative field. Recently, we have been using a 30° 5 mm scope with two 10 mm trocars for instruments. A panoramic assessment and evaluation of the intrathoracic space should be performed to determine spine anatomy and port site locations that allow a direct approach to the intervertebral disks (Fig. 11.6). The ports should be as far apart as possible.

Once the spinal anatomy has been identified, it is important to select the levels to perform annulotomy and discectomy. The ribs are counted by palpation with a blunt grasping instrument. The superior intercostal vein usually empties into the azygos circulation at or about the T3 or T4 interspace. If there is a question of the specific level, a spinal needle is inserted into an intervertebral disk and a radiograph is taken. The vertebral column is approached through the parietal pleura. The intervertebral disk is identified by the mounds observed on the spinal column and the vertebral bodies by the valleys. The segmental vessels are noted to nest in the valleys directly overlying the bodies. Controversy has arisen as to whether the segmental vessels should be transligated to allow better exposure or whether they should be preserved. Transligation of the segmental vessels appears to be fairly safe according to a recent report of 6000 cross-ligations of the segmental vessels in 1197 cases which did not demonstrate a neuropathic consequence.[8] We generally do this only for corpectomies but avoid ligation when doing standard discectomies for kyphotic deformities.

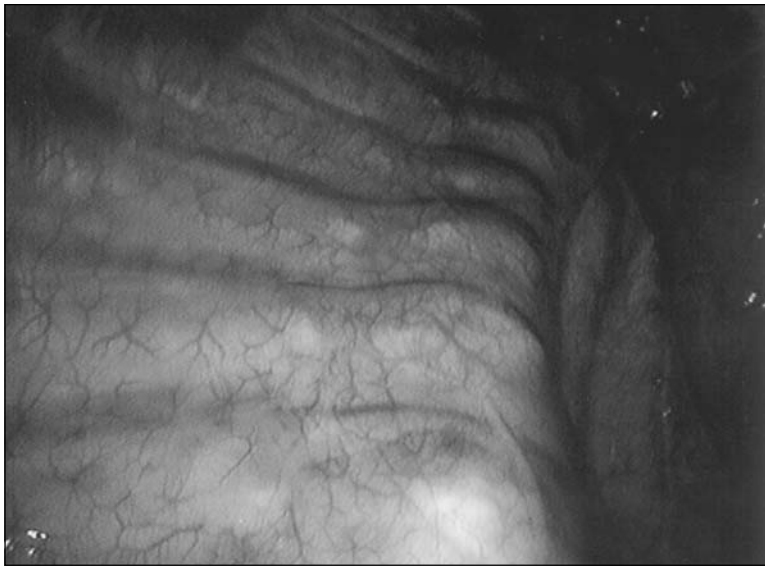


Fig. 11.6. Vertebral body exposure for the thoracoscopic spine surgery.

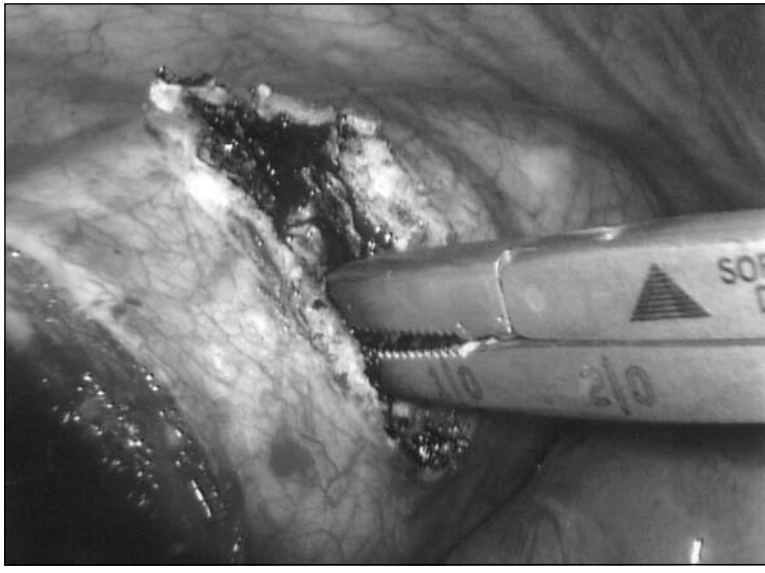


Fig. 11.7. Thoracoscopic rongeur removing disc.

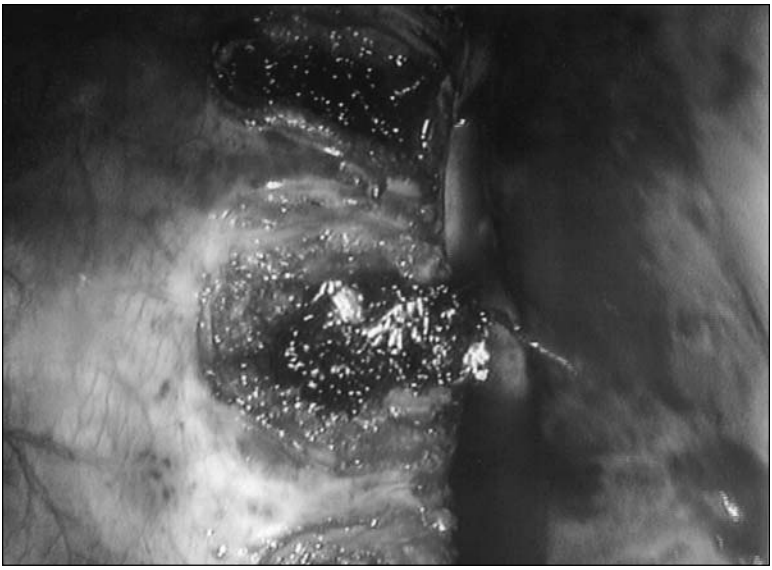


Fig. 11.8. Completed disectomies with topical thrombostatic material applied.

Once the pleura has been completely dissected, the spinal surgeon may proceed directly to excision of the annulus at the level of the intervertebral disk. The disc is incised using electrocautery via a "spatula" probe (Figs. 11.7, 11.8). The disc material is then removed using a curette and thoracoscopic rongeur. So far, we performed 16 cases of thoracoscopic spinal surgery. The diagnoses were scoliosis (11 patients), kyphosis (3 patients), spinal deformity (1 patient), and rib osteomyelitis (1 patient). Fifteen had thoracoscopic spinal discectomy, and one had rib resection. There was one conversion to thoracotomy because of bleeding. Transfusions were needed in 5 patients. One patient developed atelectasis postoperatively. No other complications occurred and there was no mortality.

References

1. Lau H, Cheng SW: Burger's disease in Hong Kong: A review of 89 cases. Aust NZ J Surg 1997; 67:264-269.
2. Rienhoff WF, Baxter BM. Pancreolithiasis and chronic pancreatitis: Preliminary report of a case of apparently successful treatment by transthoracic sympathectomy and vagotomy. JAMA 1947; 134:20-1.
3. Krasna MJ, Jiao X, Sonett J et al. Thoracoscopic sympathectomy. Surg Laparosc Endosc Percutan Tech. 2000; In press.
4. Krasna MJ, Demmy TL, McKenna RJ et al. Thoracoscopic sympathectomy: The U.S. experience. Eur J Surg 1998; Suppl 580:19-21.
5. Ohtsuka T, Wolf RK, Dunsker SB. Port-access first-rib resection. Surg Endosc 1999; 13:940-2.
6. McAfee PC, Regan JR, Zdeblick T et al. The incidence of complications in endoscopic anterior thoracolumbar spinal reconstructive surgery: A prospective

multicenter study comprising the first 100 consecutive cases. Spine 1995; 20:1624-1632.
7. Noppen M, Meysman M, D'Haese J et al. Thoracoscopic splanchnicolysis for the relief of chronic pancreatitis pain; experience of a group of pneumonologists. Chest 1998; 113:528-531.
8. Winter RB, Lonstein JE, Denis F et al. The risk of paraplegia secondary to segmental vessel ligation: An analysis of 1197 consecutive anterior operations. Orthop Trans 1995-1996; 19:616.

Suggested Reading

1. Krasna MJ, Mack MJ. Atlas of thoracoscopic surgery. Quality Medical Publishing, Inc 1994.
2. Yim AP, Hazelrigg SR, Izzat MB et al eds. Minimal Access Cardiothoracic Surgery. W.B. Saunders Company 2000.
3. Regan JJ, McAffe PC, Mack MJ. Atlas of endoscopic spine surgery. Quality Medical Publishing, Inc 1995.

Pediatric Thoracoscopy

Bradley M. Rodgers

Thoracoscopy has been applied to various thoracic disorders in children with increasing frequency since its first description in 1976. The technique was proposed initially as a method of rapidly obtaining lung biopsy specimens under local anesthesia. The specific diagnosis of interstitial pneumonitis in that era was difficult and many children were referred for open lung biopsy. The general trend was to refer these children very late in the course of their disease, when empiric therapy had failed, and the morbidity and the mortality of an open thoracotomy for biopsy in these children was significant. We were anxious to develop a technique which was truly "minimally invasive" and yet as accurate as open lung biopsy and which we hoped would stimulate earlier referral of these patients for a tissue diagnosis. The majority of the procedures during that era were performed without endotracheal intubation, using intravenous sedation and intercostal block. As we became more familiar with the technique it was clear that it had considerably more utility than simple lung biopsy. With rapidly expanding interest in laparoscopic techniques and the development of better endoscopic instrumentation, interest in pediatric thoracoscopy became wide-spread. Today it can be considered as truly the "gold standard" for several endothoracic procedures, virtually eliminating the need for open thoracotomy (Table 12.1). Many innovative procedures have been described and thoracoscopy appears to be at least equivalent to open thoracotomy in its ability to manage many thoracic disorders in children.

The most common indications for thoracoscopy in pediatric surgical practice today are pleural debridement for empyema, biopsy of mediastinal malignancies, lung biopsy for diffuse or localized infiltrates, resection of pulmonary nodules, resection of mediastinal cysts and tumors and treatment of pneumothorax. This Chapter will discuss the technical details of these procedures as well as a few innovative techniques potentially useful in pediatric patients.

General Considerations

The techniques for thoracoscopy in pediatric patients are very similar to those described in adult patients, with one very important exception. The smaller physical size of many of the pediatric patients significantly limits the working space within the chest and hampers the ability to use some thoracoscopic instruments. Some procedures, readily accomplished in adolescents or adults are difficult or as yet impossible in small infants, making an open procedure preferable. With the thoracic space limitations, thoughtful port placement in children becomes even more critical than in adult patients. Careful review of preoperative imaging studies is essential to envision the most efficacious port location. Considering the ability to

Table 12.1. Pediatric thoracoscopy indications

A.	Best Technique
	Mediastinal Biopsy
	Pleural Debridement–Empyema
	Pleurodesis–Pneumothorax
	Lung Biopsy (Selected Patients)
	Resection Mediastinal Cysts
	Thoracic Sympathectomy
B.	Accepted Technique
	Ligation–PDA
	Anterior Spine Exposure
	Resection Mediastinal tumor
	Esophagomyotomy
	Diaphragm Plication
	Trauma
C.	"Experimental" Technique
	Closure Diaphragmatic Hernia
	Lobectomy
	Repair Esophageal Atresia

access the lesion, a sufficient angle between the ports allows the most efficient use of the instruments.

Selecting various anesthetic options is important in pediatric patients. Many procedures are performed successfully using intravenous sedation and intercostal block techniques. We currently prefer these regional blocks for quick, simple procedures like talc pleurodesis in older children. These blocks are particularly useful for children with very large mediastinal malignancies causing tracheal compression. These patients risk of airway obstruction with general anesthesia. Multiple biopsies of these large lesions are obtained rapidly by thoracoscopy performed with intercostal block. General anesthesia with endotracheal intubation is useful for lung biopsy in patients with diffuse interstitial processes. A relatively light level of anesthesia avoids the need for selective or positive pressure ventilation, thereby allowing the lung to collapse. To accomplish this, we often combine general anesthesia with infiltration of the trocar tracts with local anesthesia. Spontaneous ventilation is critical for children with localized pulmonary infiltrates. These areas are usually identified by regional atelectasis and color changes on the visceral pleura. These areas are difficult to identify after complete collapse of the lung. For procedures that require mediastinal dissection or considerable manipulation of the lung we prefer general anesthesia with unilateral ventilation. Pediatric unilateral ventilation is achieved by various techniques like contralateral mainstem intubation, bronchial blockers with endotracheal intubation, or a dual lumen endobronchial tube. The endobronchial tube requires a relatively large airway uncommon in children younger than 12 years.

Performance of thoracoscopy in children requires access to a broad array of telescopes and instruments. Primarily, we use 5 mm or 10 mm telescopes and 5 mm instruments. Recently developed precision 3 mm telescopes and instruments have prompted some of these procedures in small children. The endo-GIA™ stapling device requires a 12 mm trocar and 5 cm of intrathoracic space in order to open its jaws. This limits the use of this instrument to larger patients, generally over the age

of 5 or 6 years. Unfortunately, the better lung retracting instruments are 10mm or more in diameter and also require 4-5 cm of intrathoracic space to deploy. These tools are of limited value so we generally use blunt dissecting instruments to retract the lung in smaller patients. Because of difficulty accessing the pleural space for 10 mm telescopes and instruments in small patients, we routinely employ the expandable Step™ cannula for thoracoscopy trocars. This cannula has an expandable sheath which fits snugly over a Verhees needle. The needle-sheath assembly is placed into the pleural space immediately over the top of the appropriate rib. The Verhees is removed from the sheath and a rigid expander is passed to dilate the sheath to a 5,10 or 12 mm diameter. This method avoids shearing injuries to the intercostal bundle and allows 10mm telescope in quite small patients.

Specific Procedures

Pleural Debridement for Empyema

Parapneumonic empyema develops relatively frequently in children following bacterial pneumonia.

Usually these empyemas will respond to antibiotics and thoracentesis or tube thoracostomy, but occasionally they progress to the fibrinopurulent stage with multiple loculations. Traditionally, these patients have required an open pleural debridement and, occasionally, pleurectomy. After the initial report of Bainbridge demonstrating the use of thoracoscopy for treatment of empyema in adults, we began to use a modification of this technique for children. If all of the infected fluid cannot be evacuated from the pleural space by thoracentesis or tube thoracostomy, the patient is offered thoracoscopic pleural debridement. We prefer to perform this procedure within 7 days of the onset of the empyema to avoid the problems associated with the organizing phase of this disease. Preoperative transthoracic ultrasound or CT scan imaging demonstrates the location of the fluid locules. No special laboratory studies are necessary.

Thorough debridement of the pleural space requires lung considerable manipulation so we preferred general anesthesia with unilateral ventilation. Preoperatively, our radiologist marks the chest wall over the largest loculation of pleural fluid identified by transthoracic ultrasound. The patient is positioned in a full lateral position. Initially, a 10mm trocar is placed directly into the largest fluid locule and suction is used to evacuate this area. A Leukin's trap is connected to the suction if fluid culture is needed. A 10mm telescope inserted into this locule is used to bluntly dissect and loosen pleural adhesions. After clearing a large enough intrathoracic area, a 5 mm trocar is inserted into an adjacent interspace, posterior to the initial trocar (Fig. 12.1). A suction/irrigation instrument is used through this trocar to disrupt the loculations of fluid and evacuate the pleural space. We divide denser adhesions with electrocautery instruments passed through the posterior trocar. To free the anterior surface of the lung and debride the anterior pleural space, a 5 mm telescope can be placed in the posterior trocar with suction instruments or cautery traversing the initial 10 mm trocar. If needed, a third trocar located anteriorly permits complete evacuation of the pleural space. Thick pleural debris is evacuated using either the 5 mm Prestige grasping instrument or the 10 mm "Jaws" forceps. With a combination of manual debridement, and forceful irrigation and suction most debris is removed from the

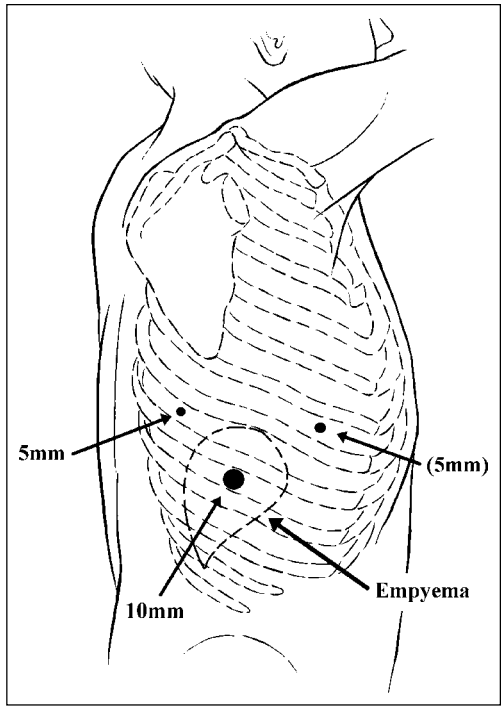


Fig. 12.1. Diagram showing approach for posterior-inferior empyema. The telescope is inserted into the largest fluid loculation. Suction irrigators are used through the 5mm ports (the anterior 5mm port may be optional).

pleural space. Complete removal of the pleural debris is difficult and unnecessary, but all individual locules of fluid must be disrupted to eliminate the empyema successfully. At the completion of the procedure a small epidural catheter is placed through the posterior trocar and guided into the paravertebral gutter with either a forceps or the telescope. This catheter is used for installation of Urokinase if moderate pleural debris remains after the debridement. A 20-26 French chest tube is inserted through the telescope trocar tract and other port sites are closed with subcuticular sutures.

Postoperatively, appropriate intravenous antibiotics are continued. If Urokinase therapy is required 250,000-500,000 units are mixed with 60cc of sterile saline and instilled through the pleural catheter. The chest tube is then clamped for 30 minutes while the patient is rotated to various positions to distribute the enzyme throughout the pleural space. This is performed on the first postoperative day and daily for 3 days thereafter.

Thoracoscopy is an extremely successful minimally invasive technique for pleural debridement in these complicated patients. Most of these procedures are completed within an hour. Prolonged air leak and persistent fever with incomplete pleural debridement are possible early postoperative complications. One of our patients required a second thoracoscopic procedure to drain a retained locule that we believe was missed during the first operation. Otherwise, all our patients responded quickly to pleural debridement. None developed a fibrothorax.

Biopsy of Mediastinal Malignancy

The mediastinum is the most common intrathoracic location for malignancies in children. In the anterior mediastinum, lymphomas present as enlarged hilar lymph nodes. Posteriorly, neuroblastomas and neural tumors predominate. Thoracoscopy is a particularly useful technique for obtaining tissue biopsy in those patients with very large anterior mediastinal masses causing compression of the airway. These patients greatly risk of airway obstruction with general anesthesia so rapid thoracoscopic biopsies under regional block are very useful. Thoracoscopy is usually used for obtaining biopsies of anterior mediastinal masses, as complete excision of these lesions is usually not feasible or necessary. Some surgeons attempt complete excision of localized posterior mediastinal tumors which improves prognosis for these lesions.

For, patients undergoing thoracoscopy for mediastinal masses, a preoperative CT or MRI of the chest helps to define the anatomy in the region of the mass including relationships with the great vessels and esophagus. They also assist in planning trocar placement. Depending upon the clinical presentation, correction of a coagulopathy or thrombocytopenia may be necessary prior to thoracoscopy. Since these patients all require some manipulation of the mediastinum we prefer general anesthesia with unilateral ventilation if the children are suitable candidates. Children with anterior mediastinal lesions are rolled posteriorly from a full lateral thoracotomy position, while patients with posterior lesions are rolled anteriorly. For exposure of anterior mediastinal lesions the initial 10mm telescope trocar is placed in the 5th or 6th intercostal space in the anterior axillary line (Fig. 12.2). A judgement is then made with regard to placement of the additional trocars. Generally, a 5 mm working trocar is placed anteriorly, one or two interspaces cephalad to the telescope and a second is placed in the same interspace posteriorly. Prior to obtaining a biopsy of the mediastinal mass the entire thoracic cavity and pulmonary surface are carefully inspected to identify other areas of involvement in cases of malignancy. Any pleural fluid present is collected in a Lukens trap for culture and cytology. Other suspicious areas are biopsied individually. A Maryland dissector and 5 mm Metzenbaum scissors are then used to open the mediastinal pleura overlying the lesions to be biopsied. Cup biopsy forceps are used to obtain generous biopsies from the surface of these lesions. The coagulation cautery can be used through these insulated forceps for local hemostasis. We have preferred to take several biopsies through the initial biopsy site in order to sample tissue from deeper within these lesions. At the completion of the use of the cup biopsy forceps, a transthoracic Tru-Cut biopsy needle is passed well into the lesion to obtain deep specimens. Final hemostasis is achieved with the electrocautery.

The initial 10 mm trocar is usually placed in the 6th intercostal space posterior axillary line in patients with posterior mediastinal lesions (Fig. 12.3). A second 5mm trocar is placed two interspaces cephalad in the anterior axillary line for retracting the lung anteriorly. The 5 mm working trocar is placed posterior to the telescope in an interspace selected to allow sufficient working distance to approach the lesion. The parietal pleura can be dissected off of the lesion with Metzenbaum scissors. Generally these tumors are considerably firmer than those encountered in the anterior mediastinum and it may be difficult to obtain a suitable piece of tissue with the cup biopsy forceps. In that case, the scissors or cautery can be used to excise a large piece from the main tumor. Hemostasis is obtained with the electrocautery. We have

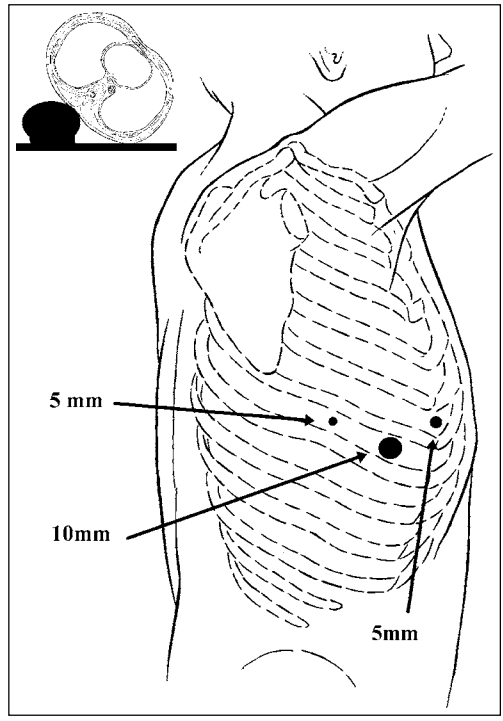


Fig. 12.2. Diagram showing approach for an anterior mediastinal mass. The telescope is inserted through the 10mm port (anterior axillary line). A cup-biopsy forceps is used through the anterior 5mm port while the more posterior 5mm port is for a retractor. Inset indicates chest tilt to achieve favorable posterior lung displacement for the operation.

not attempted to excise posterior mediastinal solid tumors completely using thoracoscopy, but others have described this technique and have had limited success with it.

The operative sites in both anterior and posterior mediastinal masses are irrigated and blood is suctioned from the pleural space. A small epidural catheter is threaded through the posterior trocar and positioned in the paravertebral space with forceps passed through the anterior trocar. A 18-24 French chest tube is placed through the 10mm trocar tract and the anterior trocar site is closed with subcuticular sutures.

If the postoperative chest x-ray demonstrates full expansion of the lung and there is no continued air leak, the chest tube can be placed on under-water seal immediately and removed the following morning. Some surgeons prefer not to use chest tubes in these patients unless the visceral pleura was violated during the dissection. Postoperatively, these patients receive intrapleural Marcaine through the epidural catheter for analgesia (0.7 cc/kg of 0.25% Marcaine with epinephrine every 4 hours). The chest tube is generally removed the following morning and the epidural catheter can be removed just prior to discharge from the hospital.

Most of these procedures are completed in less than an hour. We converted one patient to an open thoracotomy because a mediastinal hemangioma could not be safely resected with thoracoscopic techniques. The principle postoperative concern is bleeding, although none of our patients has required transfusion. Thoracoscopic biopsy of mediastinal masses is highly accurate. One false negative biopsy of an

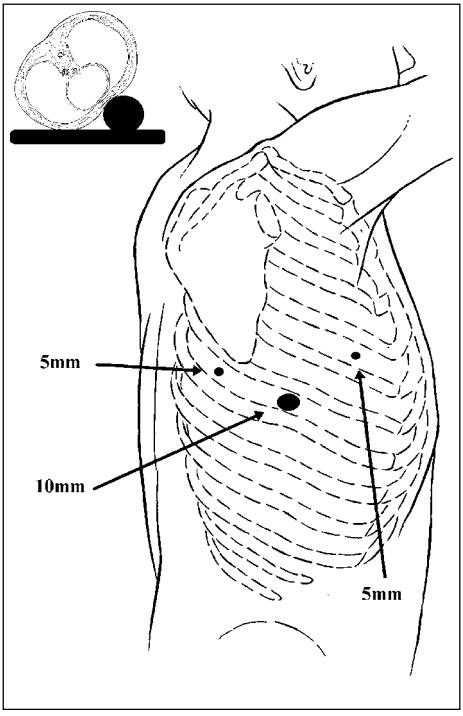


Fig. 12.3. Diagram showing approach for a posterior mediastinal mass. The 10mm telescope port is placed in the posterior axillary line. A retractor is used through the anterior 5mm port while a cup-biopsy forceps or scissors is used through the posterior port. Inset indicates chest tilt to achieve favorable anterior lung displacement for the operation.

anterior mass occurred early in our experience and we believe that deeper biopsy specimens including needle biopsy will minimize this complication.

Lung Biopsy

Thoracoscopy was originally utilized in children to obtain lung biopsy specimens in immuno-compromised hosts with interstitial pneumonitis. It remains an excellent technique for these patients with some important exceptions. In reviewing the overall published experience with pediatric thoracoscopy in 1993 it was evident that the majority of the significant complications of the procedure were encountered in thoracoscopic lung biopsy in children on high-pressure mechanical ventilation. I currently believe that these patients are served better with an open lung biopsy utilizing stapling instruments for pneumostasis. It is very difficult to maintain an adequate pneumothorax for thoracoscopy in these patients and persistent air leaks are quite common. Otherwise, thoracoscopic lung biopsy for interstitial pneumonitis is an excellent, safe and highly accurate technique. In patients with localized pulmonary infiltrates we usually identify the areas of infiltrate without difficulty by thoracoscopy. It is important for these patients to breath spontaneously during the procedure so that ipsilateral atelectasis does not develop. It is useful to also obtain a piece of the more normal appearing adjacent pulmonary parenchyma to allow the pathologist to construct a spectrum of the disorder.

Preoperative imaging with frontal and lateral chest radiographs is usually sufficient to localize the area to be biopsied. Occasionally, localized infiltrates are better identified by CT scan. Children undergoing thoracoscopy for lung biopsy generally are operated upon under general anesthesia, although the procedure may be performed with intravenous sedation and regional block. If these patients breathe spontaneously, the need for positive pressure ventilation is avoided. In diffuse processes, we choose to biopsy the most severely affected lung. Patients with diffuse disease are placed in the full lateral position and patients with localized processes are rolled from full lateral in the direction opposite their lesion. The initial 10 mm telescopic trocar is placed in the 6th intercostal space, midaxillary line for diffuse processes and in the same vertical axis as the infiltrate in localized processes. A 5 mm retracting trocar is placed two interspaces cephalad and anterior to the telescope. If the endoscopic stapler is needed, a 12 mm expandable trocar is placed posteriorly and as caudally in the chest as it is safe. Any pleural fluid present is collected in a Leukins' trap and sent for cytology and culture. We generally obtain biopsies from each ipsilateral lobe and start at the edge of the lobe in the fissure. For small patients, in whom use of the stapler is difficult, a generous piece of lung is sheared off using the cup biopsy forceps. Bleeding from the raw pulmonary surface is controlled by electrocautery. Alternatively two Endoloops are secured beneath a tuft of pulmonary tissue and the tissue distal to these is excised. In children with localized disease, a generous wedge biopsy of the area of infiltrate is obtained or multiple cup biopsy pieces from this region are retrieved. Pieces of the adjacent more normal appearing lung are also obtained either with the stapler or cup biopsy forceps. A small pleural catheter is placed through the posterior trocar and guided into the paravertebral space with a forceps from the anterior trocar. A 16-24 French chest tube is placed through the 10mm trocar tract. The anterior trocar tract is closed with subcuticular sutures.

Thoracoscopic resection of pulmonary nodules in children is a controversial procedure. Often operative identification of these nodules is difficult, unless they are immediately subpleural. In addition, many surgeons feel that it is important to remove all of the parenchymal nodules in children with metastatic neoplasms, such as osteogenic sarcoma. This is very difficult to do by thoracoscopy because it is difficult to "palpate" the pulmonary tissue and identify deeper situated nodules. On the other hand, children with newly detected pulmonary nodules, in the absence of obvious primary tumors elsewhere, may make excellent candidates for thoracoscopic resection.

Preoperative imaging with thoracic CT scans is very important in these children to identify the nodules in the subpleural location. This will determine the side of the procedure in children with bilateral disease, the position of the patient, and the initial trocar placement. Since identification of these nodules often requires complete collapse and "palpation" of the pulmonary parenchyma with the thoracoscopic instruments, general anesthesia with unilateral ventilation is very helpful. Patients are placed in the full lateral position and rolled somewhat anteriorly or posteriorly depending upon the target nodule location. We prefer to place the initial 10 mm telescope trocar in the 6th intercostal space, through the anterior axillary line. The trocar for the retracting and palpating instruments is placed anteriorly two interspaces cephalad to this. The pulmonary surface is carefully inspected and compressed with a grasping forceps. Oftentimes, these lesions cause a bulge or dimpling of the overlying visceral pleura. When the lesion has been identified, the 12 mm trocar for the

stapling device is placed as caudal in the chest as possible through a posterior position. A generous wedge of lung is removed surrounding the nodule, usually using several staple loads. Possible malignant lesions should be placed in a retrieval bag passed through the 12 mm trocar and the specimens are removed through that trocar. Depending upon the clinical situation, several nodules may be removed in this fashion. The thoracic cavity is carefully evaluated for other evidence of metastatic spread. An epidural catheter is placed through the posterior trocar and positioned in the paraspinous region. A 16-24 French chest tube is placed through the telescope trocar tract. The remaining trocar site is closed with subcuticular sutures. These patients are maintained on chest suction until the air leak subsides and are then watched for at least 12 hours on underwater seal before removing the chest tube. Intrapleural Marcaine is used for postoperative analgesia.

Thoracoscopy has proven to be a very accurate technique for diagnosis of diffuse or localized pulmonary infiltrates and pulmonary nodules in children. Bleeding and prolonged air leak are possible immediate postoperative complications. Many of the immunocompromised children with diffuse interstitial pneumonitis have associated coagulopathies. Component blood products may be necessary to correct these in the perioperative period. Prolonged air leaks were encountered typically in patients on mechanical ventilation and patients with pneumocystis carinii pneumonia. The lung in the latter group of patients is often quite stiff and does not achieve full lung expansion postoperatively. Conversion to an open thoracotomy is unusual in the patients with pulmonary infiltrates, although it may be necessary in as many as 20% of children with pulmonary nodules whose lesions cannot be identified with thoracoscopic techniques. A limited thoracotomy incision can allow manual palpation of the lung. Preoperative image guided needle localization or dye injection may be helpful in patients whose nodules appear to be deeper within the parenchyma.

Resection of Mediastinal Cysts and Tumors

Thoracoscopy provides an excellent technique for resection of mediastinal cysts which in children usually are bronchogenic or esophageal duplication cysts. Most lesions do not communicate with the airway or esophagus directly and are dissected safely from these structures. Complete thoracoscopic resection of mediastinal tumors is somewhat controversial. Most of these tumors represent lymphomas and resection is not an issue in those patients. There are a modest number of children, however, with posterior mediastinal neuroblastoma which may be amenable to thoracoscopic resection. Most of these lesions are reasonably well circumscribed, although they may extend through an intervertebral foramen into the spinal canal. We have no experience in resecting neuroblastomas, but Hazelrigg recently reported within a series of adult patients a thoracoscopic resection of a thoracic neuroblastoma.

A preoperative thoracic CT scan is essential to define the relationship of the cyst to surrounding vital mediastinal structures. The subcarinal region is accessed most easily from the posterior right hemithorax, dissecting caudad to the azygous vein. Otherwise, the procedure is performed on the side of principle cyst involvement indicated by CT scan. Children with solid tumors of the mediastinum should have preoperative blood and urine studies for tumor markers. Since resection of these lesions requires considerable mediastinal dissection, general anesthesia with unilateral ventilation is preferred. We place these patients in a full lateral position and the

initial 10 mm telescope trocar is placed in the mid or anterior axillary line in the 6th intercostal space. The majority of the bronchogenic cysts will be in the paratracheal and hilar regions and are accessed best anterior to the pulmonary hilum. Most esophageal duplications are in the posterior mediastinum and in those cases, the telescope trocar is placed in the posterior axillary line with the patient rolled somewhat forward from a true lateral position. Dissecting instruments are passed through a 5 mm port placed anterior to the telescope approximately two interspaces cephalad. The retracting instruments are passed through a 5 mm port placed posteriorly. The parietal pleura around the circumference the lesion is opened and the cyst is dissected either with Metzenbaum scissors or with the hook cautery. The vagus and phrenic nerves may be displaced by these cysts and it is helpful to identify the path of these nerves in the superior mediastinum before commencing the dissection. Care must be taken not to injure the membranous trachea or esophageal wall with the cautery and the current should be maintained at a low level. Most of these cysts are too large to remove from the chest without decompression and we have passed a transthoracic needle to aspirate the mucus from the interior of the cyst. The cyst is then grasped with Prestige graspers and removed through the 10mm trocar, switching to a 5 mm telescope for visualization. The bed of the cyst is examined carefully for hemostasis. In cases of bronchogenic cysts the mediastinum is evaluated carefully for other cysts as occasionally these lesions will be multiple. A pleural catheter for analgesia is passed through the posterior trocar and a 12-16 French tube is placed through the telescope trocar. The anterior trocar site is closed with subcuticular sutures. Some surgeons have preferred not to use chest tubes in these patients, merely evacuating the air from the hemithorax prior to removing the last port.

Thoracoscopic resection has become the preferred method for removal of bronchogenic and esophageal duplication cysts in children. Dissection of some of these cysts may be tedious, but most of these procedures are completed within two hours. The majority of these children are discharged from the hospital within 48 hours of surgery with minimal postoperative pain.

Pneumothorax

Thoracoscopy was first used in the early part of the 20th century for creation of a pneumothorax for treatment of patients with pulmonary tuberculosis. During the past decade, thoracoscopy has become the procedure of choice for treatment of most children with spontaneous pneumothorax. All of the traditional open surgical procedures used for creation of a pleurodesis, such as pleural abrasion, apical pleurectomy, and chemical pleurodesis are performed successfully by thoracoscopy. We favor the creation of a talc pleurodesis for most children with spontaneous pneumothorax and have found it to be uniformly successful in preventing recurrences. There is some debate regarding the use of talc in patients with a good long term prognosis because of concerns of late talc sequelae. As yet clinical experience and experimental data do not support those concerns.

Children who have experienced a single pneumothorax have a >50% likelihood of suffering a recurrence on the ipsilateral side. With the development of a second ipsilateral pneumothorax the recurrence rate approaches 75-80%. In certain circumstances a pleurodesis is warranted after the initial pneumothorax, while most otherwise healthy individuals are offered pleurodesis after development of a second

pneumothorax. Patients with diffuse underlying pulmonary disease, such as those with cystic fibrosis, may suffer severe respiratory embarrassment or death with the onset of a pneumothorax. For this reason, we favor proceeding directly to pleurodesis after initial pneumothorax in patients with cystic fibrosis. Likewise, patients with bilateral spontaneous pneumothoraces should undergo bilateral pleurodesis. For patients who live or work a great distance from routine medical care or are employed in certain types of jobs, such as pilots or divers, establishment of a pleurodesis after the first pneumothorax is warranted.

A frontal chest radiograph demonstrating a pneumothorax is sufficient for preoperative imaging. If these children are stable from a respiratory standpoint we prefer to proceed directly with thoracoscopy rather that placing a preoperative chest tube. General anesthesia with an endotracheal tube is standard management. Unilateral ventilation may be helpful in identifying apical blebs, but it is certainly not necessary in all cases. Older patients with pneumothorax can undergo thoracoscopy satisfactorily with intravenous sedation and regional block techniques. Equipment for a tube thoracostomy should be available during anesthesia induction in case of sudden respiratory decompensation associated with an expanding pneumothorax. The patients are placed in the full lateral position and the initial 10mm telescope trocar is inserted through the sixth intercostal space, midaxillary line. We employ a 0° telescope to explore the visceral pleural surface looking for subpleural blebs, although other authors feel that the 30° scope gives a better view of the pulmonary apex. If a bleb is encountered, which has been the case in only about 15% of our children with spontaneous pneumothorax, a 12 mm trocar is placed in the posterior axillary line 2 interspaces caudad to the telescope and a 5 mm trocar is placed in the anterior axillary line 2 interspaces cephalad to the telescope. The bleb is stapled, excised from the pulmonary-surface, and withdrawn through the 12 mm trocar. We use an atomizer to apply sterile pure USP talc to the visceral and parietal pleural surfaces. The parietal pleura at the apex is densely coated while a light dusting of talc is used for the remainder of the pulmonary surface. Approximately 2-4 gms of talc are used in an adolescent sized patient. After the entire pleura has been dusted, the anterior and posterior trocars are removed and these sites are closed in layers with absorbable suture. A 14-16 French chest tube is placed through the trocar tract in the mid axillary line. We do not employ intrapleural Marcaine in this group of patients to prevent local anesthetic washing the talc from the pleural surface and reducing pleurodesis in some areas. If one selects a pleural abrasion, we convert the trocar in the posterior axillary line to a 10 mm trocar. Folded polypropylene mesh(Marlex) is grasped with a 5 mm Prestige forceps, passed through this trocar, and used to abrade the parietal pleura. The entire parietal pleura from the apex to the diaphragm surface is abraded in this manner. Access to all chest areas is facilitated by transferring the grasper with Marlex to the mid-axillary trocar and passing the telescope posteriorly. If one elects instead to perform an apical pleurectomy, one 5 mm trocar is placed in the posterior axillary line and one is placed in the anterior axillary line. Using a spatula-tipped cautery, the parietal pleura overlying the 5th rib is incised from the transverse process to the costal cartilage. Using the spatula tip as a blunt dissector, we strip the apical pleura from the chest wall without particular difficulty. After performing an apical pleurectomy, we abrade of the parietal pleura

caudad to the pleurectomy level by converting to a 5 mm telescope and using the Prestige grasper with Marlex through the 10 mm trocar.

Thoracoscopic treatment of spontaneous pneumothorax appears to be at least as successful as similar open procedures in children. These procedures are performed quite rapidly and a talc pleurodesis generally takes about 30 minutes to complete. Persistent air leak with failure of full expansion of the lung is the most common immediate postoperative complication. Two ipsilateral recurrent pneumothoraces occurred in our patients with cystic fibrosis who had thoracoscopic pleural abrasion. We had no recurrences using talc pleurodesis.

Closure of Patent Ductus Arteriosus

The introduction of smaller and shorter thoracoscopic instruments has allowed for the successful thoracoscopic closure of a patent ductus arteriosis (PDA), even in small infants. Patients with isolated PDA anomalies are the best candidates for this procedure, but some surgeons use thoracoscopic closure before performing more complex congenital cardiac surgery. Because of limitations in metallic clips size, a ductus larger than 7-9 mm may be too big for this technique.

Routine cardiac evaluations including transthoracic echocardiography are performed in these patients. The operation is performed under general anesthesia with endotracheal intubation. The patient is placed in the right lateral decubitus position. The surgeon stands toward the back of the patient with the assistant opposite. The thoracoscope is placed through a trocar inserted through the third intercostal space in the posterior axillary line. The 3 mm instruments are ideal for this procedure in small infants, although 5 mm telescopes can be used in larger patients. A second trocar is placed through the same interspace in the midaxillary line for retracting the lung inferiorly. The third trocar is placed in the fourth intercostal space below the scapula and dissecting instruments are placed through this. The mediastinal pleura overlying the descending aorta and ductus is opened longitudinally. The ductus is carefully dissected with blunt dissection above and below. The recurrent laryngeal nerve is identified and retracted medially with the mediastinal pleura. The posterior trocar is then removed and a 5 mm clip applier is placed through that incision. Two clips are placed across the ductus with careful observation to be certain that the entire ductus is encompassed within the clips. In older patients, transesophageal echocardiography interpretation confirms complete obliteration of ductal flow prior to removing the trocars. In small infants transthoracic echocardiography is performed immediately following the procedure while the patients remain anesthetized in the operating room. The trocars are removed and a 10 French chest tube is inserted through the trocar site in the posterior axillary line. If the postoperative chest x-ray shows no residual pneumothorax and the visceral pleura has not been violated, the chest tube is removed 8-12 hours postoperatively.

Although not universally accepted by cardiac surgeons, thoracoscopic closure of a PDA in carefully selected patients appears to be safe and effective.

Exposure of the Thoracic Spine

The use of thoracoscopy to facilitate diskectomy and spinal fusion in children was first described about 5 years ago. The advantages of the technique have been felt to include shorter operative time and reduced postoperative pain. Most children

undergoing anterior spinal procedures should be considered candidates for this technique, unless they have had previous thoracic surgery. The preoperative evaluation is usually performed by the orthopedic service and includes detailed spine radiographs.

The patient is placed in the lateral decubitus position with the convex side of the spine elevated. Pressure points must be carefully padded and the patient firmly secured to the operating table. Adequate exposure of the spine requires unilateral pulmonary ventilation. In older children this is achieved by double lumen endotracheal tubes while, in younger children, bronchial blockers or mainstem intubation may be used. The patient is rolled forward from a true lateral decubitus position to allow the lung to drop away from the spine. The initial trocar for the telescope is placed in the mid to posterior axillary line in an interspace at 9:00 to the apex of the spinal curvature. The trocar for the curette is placed directly over the disks to be removed. In some cases the curette and operating instruments are passed through the chest wall without the use of trocars. Extra such incisions are made depending upon the number of disks to be removed. As disks further from the apex of the curve are approached, a 30° telescope provides better direct visualization. On occasion, the trocar for the telescope itself must be moved cephalad or caudad. Following completion of the diskectomy and fusion, the thoracic cavity is irrigated and final hemostasis is achieved. A small chest tube is inserted through one of the instrument ports and a epidural catheter for intrapleural analgesia is placed through the inferior instrument port. The ipsilateral lung is inflated under direct vision and the telescope and trocar are removed. The trocar sites are closed with interrupted Vicryl sutures.

Summary

Over the past two decades more surgeons accept the utility of thoracoscopy in managing pediatric patients. Most Pediatric Surgeons consider thoracoscopy as the optimal method for management of many intrathoracic disorders and newer uses of the technique continue to be described. Pediatric patients pose challenges principally related to their size and smaller instruments have had to be developed. In some cases, small patient size hampers thoracoscopic techniques because of our inability to achieve adequate visualization. The typical pediatric population has very few contraindications to the use of thoracoscopy. Most coagulation disorders correct rapidly with blood products or specific clotting factors. Few children have had previous thoracic operations or other causes of dense pleural adhesions that prevent access to the pleural space. Intrathoracic tumors encountered in a typical Pediatric Surgical practice are vastly different than adult neoplasms. Thoracoscopy provides a safe and accurate technique for obtaining biopsy specimens in these patients. Many congenital intrathoracic lesions, such as bronchogenic cysts, are resected successfully by thoracoscopic techniques. Despite recent progress more sophisticated thoracoscopic instruments and better retraction devices will allow further expansion of this frontier. Innovative procedures continue to be described and many will achieve wide acceptability. It is essential that today's Pediatric Surgeon be facile in thoracoscopic procedures in order to provide state of the art care to their patients.

Pediatric Thoracoscopy Instruments

Quantity	Item	Comments
1	Cuff biopsy forcep, insulated	Useful for PDA and mediastinal cysts, for biopsy.
1	Cup biopsy forcep, long	
1	Right angle dissector	
1	Grasper, ratcheted	For pleural retraction
1	Grasper, large	Mediastinal dissection
1	Grasper, small	" "
1	Maryland dissector, insulated	" "
2	Prestige Grasper, insulated	Mediastinal dissection
1	Metzenbaum scissor, insulated	" "
1	Hook Scissor, insulated	Opening mediastinal pleura
1	Hook Scissor, micro	" " "
1	Suction-irrigation tube	
1	Suction, 10 mm	Useful for empyema
1	Babcock Tissue forcep, insulated	For lung retraction
1	Alyce Tissue forcep, insulated	" " "
1	Curved endo needle holder	

Thoracoscopic Treatment of Pericardial Disease

Joseph T. Walls

Thoracoscopic procedures are performed most commonly for drainage of pericardial fluid, pericardial resection, and procurement of fluid and tissue for diagnostic examination. Of these, treatment of pericardial effusion and diagnostic procedures are the most frequent. Also, direct thoracoscopic closure of congenital pericardial defects and removal of pericardial cysts have been performed. There are numerous pericardial pathologic processes (see Table 13.1) in which thoracoscopic procedures may become popular depending on further refinement in instrumentation and techniques.

Anatomy

The parietal pericardium is composed of a fibro-collagenous layer with a serous single-celled layer of mesothelial cells. The visceral pericardium is a monocellular serosal layer over the cardiac surface, which is designated the epicardium. Both pericardial layers fuse at the level of the ascending aorta, pulmonary artery, superior and inferior vena cavae, and pulmonary veins. The fibrous portion of the pericardium is continuous with the deep cervical fascia. The transverse sinus is posterior to the ascending aorta and pulmonary artery and anterior to the atria and superior vena cava. The oblique sinus is between the right and left pulmonary veins and medial to the inferior vena cava, leaving the posterior portion of the left atrium bare of pericardium.

The parietal pericardium is normally adherent to the sternum at the manubrium and xiphoid process and is attached to the central tendon of the diaphragm. The pericardium is innervated by the phrenic and vagal nerves and its arterial supply is derived from dorsal aortic branches and pericardiophrenic arteries. Venous drainage is into veins accompanying the arterial supply. The visceral pericardium is drained by a superficial plexus of cardiac lymphatics into tracheal and bronchial mediastinal lymph nodes. Drainage of the parietal pericardium is into anterior and posterior mediastinal lymph nodes. Fibro-collagenous tissue of the fibrosa contains elastic fibers that become less plentiful with aging. The thickest portion of the fibrous tissue is over the thinnest portion of the myocardium.

Pericardial Fluid

The space between the parietal and the visceral pericardium normally contains between 15 and 50 mm of fluid. The fluid has characteristics of plasma ultra filtrate. Extensive cardiac and pericardial lymphatic plexuses transport interstitial fluid, lymph, and pericardial fluid to the venous circulation. The fluid is normally clear and has electrolyte concentrations equaling plasma ultrafiltrate. Protein levels are lower than

Table 13.1. Pericardial disease

Congenital
Partial absence to complete absence
Cysts
Neoplastic
Benign (lipomas, hemangiomas, fibromas)
Primary malignant (sarcoma, malignant teratoma)
Metastatic disease (carcinomas—Lung, breast, leukemia, lymphoma)
Collagen disease
Pericarditis
idiopathic
viral
bacterial (purulent)
tuberculous
amoebic
echinococcal

plasma, but albumin is present in a higher ratio than total plasma proteins. The molecular weight and osmolarity is less than plasma. The pericardial fluid contains immunologic constituents as well as prostacyclin. The fluid has a fibrinolytic characteristic. Myocardial cell enzymes and complement factors are present in pericardial fluid and may be abnormal in pathologic conditions.

Function

The pericardium protects the heart from external friction and other forces while providing a barrier to inflammation from contiguous structures. Its attachments to the diaphragm and sternum help maintain the position of the heart and great vessels. It also protects the heart from acute over-distention.

Pericardial Disease

Spodick defined cardiac tamponade as hemodynamically significant cardiac compression from accumulating pericardial contents that evoke and defeat compensatory mechanisms. The compression may be due to effusion (sterile or infected), blood, tumor, gas, or foreign body. The most common VATS pericardial procedures at present are partial pericardiectomy with drainage of pericardial effusion and procurement of specimens for diagnostic studies. The degree of hemodynamic compromise depends on the volume of pericardial contents and the rate at which the volume occurs. Whereas a liter of pericardial volume accumulation over a long period of time may be tolerated without hemodynamic compromise, the acute accumulation of as little as 200 ml of fluid may cause significant hemodynamic compromise. The greatest initial effect is on the right side of the heart causing increased central venous pressure in patients despite normal intravascular volume. Left ventricular dysfunction occurs from external compression of the pericardial contents and from a leftward shift of the intraventricular septum from increased right heart filling pressures. Fall in systolic arterial blood pressure greater than 10 mmHg. during normal inspiration (pulsus paradoxus) may be observed. However, this phenomenon occurs in other conditions or may be absent in tamponade patients

with underlying cardiac dysfunction, localized tamponade or positive pressure ventilation. Constrictive pericarditis results from several diseases. Both cardiac tamponade and constrictive pericarditis must be differentiated from restrictive cardiomyopathy.

Pericarditis

Pericarditis may occur as the primary manifestation of a cardiac, pulmonary, or systemic disease. Idiopathic and viral pericarditis are treated medically; however, pericardial effusion or constriction that reduces cardiac function usually requires surgical intervention.

Uremic pericarditis occurs in approximately 20% of patients receiving hemodialysis and is not uniformly correlated with the level of blood urea nitrogen and serum creatinine. VATS pericardial resection and drainage is useful for excessive fluid compressing the heart or constrictive pericarditis. Tuberculous pericarditis begins in a fibrinous phase from contamination by hematogenous, lymphatic, lung, pleura, or mediastinal lymphadenopathy. The disease may progress to effusive and fibrous involvement without tamponade, or may progress to a fibrous constrictive involvement. Frequently the pericardium calcifies and becomes adherent to the myocardium and coronary arteries. Pericardial fluid aspiration relieves cardiac tamponade and provides a diagnostic specimen. Open drainage should not be performed in the acute phase. Chronic constrictive pericarditis usually requires an open procedure, however, innovative combined open and VATS procedures may be helpful, especially for resection of the posterior pericardium.

Purulent pericarditis is most often caused by Staphylococcus or gram-negative organisms. Hemophilus influenzae is a common causative organism in children. The route of infection is usually from pneumonic, hematogenous, or subdiaphragmatic spread. While pericardial drainage is necessary, the thick, purulent exudative fluid may be difficult to evacuate. Early pericardiectomy is frequently necessary because of the high incidence of constriction from purulent pericarditis.

Approximately half of uremic patients from untreated chronic renal disease develop uremic pericarditis. Of those patients with chronic uremia who are treated by dialysis, approximately 20% will develop uremic pericarditis (Frame 1983). Increasing dialysis frequency may help temporarily; however, most uremic patients that require thoracic surgical attention have symptomatic pericardial effusions as well as uremic pericarditis.

Neoplastic Disease

Most neoplastic involvement of the pericardium is associated with pericardial effusion. Cardiac tamponade may be a presenting symptom. Pericardial aspiration performed under echocardiographic guidance aids with the diagnosis in 75% of the patients. However, pericardial biopsy is usually required for confirmation and pericardial resection to relieve compression is indicated.

Of those patients with noncardiac tumors, approximately 10% develop cardiac involvement. In these cases, approximately 85% affect the pericardium (Hawkins 1989). Carcinoma of the lung, breasts, leukemias, lymphomas, and melanoma are the most common neoplasms causing pericardial metastasis. Although primary pericardial tumors are unusual, mesotheliomas, sarcomas and malignant ter-

atomas may occur. Lipomas, hemangiomas and fibromas are benign tumors involving the pericardium.

Procedure

Left thoracoscopy is preferred unless anatomic or technical features exist which indicate a right sided approach. Concomitant unilateral pulmonary or pleural lesions, localized pericardial defects, cysts, diverticulae, or neoplastic pathologic processes favors use of that hemithorax.

If the patient's hemodynamics are labile in the presence of a large pericardial effusion, pericardiocentesis should be performed to the evacuate the effusion and establish stable hemodynamics. A pulmonary flow catheter is useful in monitoring the hemodynamics and verifying that a stable state has been reached.

With the patient in the lateral decubitus position under general endotracheal anesthesia with bronchus blockers or double lumen tube in place, intercostal ports are inserted. The initial port site is placed posterior to the posterior axillary line to avoid cardiac structures. Entry is made into the third intercostal space to allow two lower working ports to be placed as a triangulated base inferiorly (Fig. 13.1).

A large chronic pericardial effusion may enlarge the pericardial space so extensively that the pericardial surface lies against the lateral thorax. Aspiration of pericardial fluid with a long needle inserted through a working port anterior to the phrenic nerve allows verification that a pericardial space is present and allows forceps to grasp the pericardium securely. The pericardium is opened over the left ventricle anterior to the phrenic nerve and enlarged to remove at least a 4 cm square of pericardium. Not incising over the left atrium initially avoids injury to the left atrial appendage and concomitant hemorrhage. Pericardial tissue and fluid are submitted for analyses.

Other pericardial procedures that require resection of lesions, procurement of biopsy specimens or closure of small defects in the pericardium may be performed through similar port access configurations.

Bilateral thoracoscopic procedures allow extensive pericardial resection. However, classic chronic calcific constrictive pericarditis indicates an open procedure. This avoids injuries to coronary arteries and myocardium during extensive pericardial resections over right and left ventricles, atriae, and vena cavae leaving Phrenic nerve pedicles are preserved bilaterally.

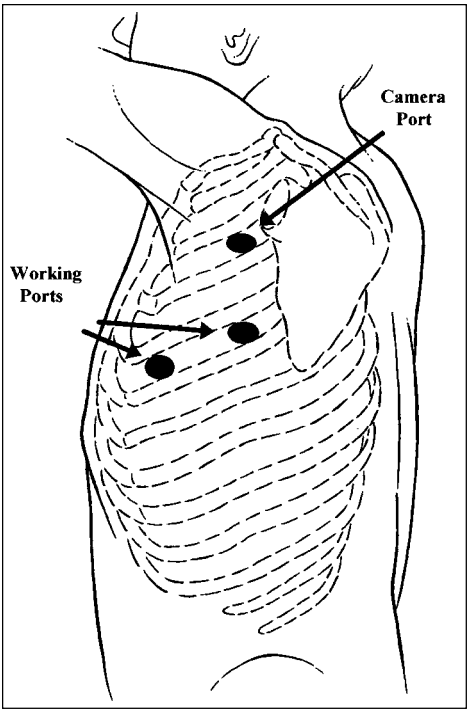


Fig. 13.1. Diagram of port placements for thoracoscopic pericardial procedure.

References

1. Fowler NO. The Pericardium in Health and Disease Mount Kisco, NY: Futura Publishing Company, Inc. 1985.
2. Spodick D. Macrophysiology, microphysiology and anatomy of the pericardium: A synopsis. Am Heart J 1992; 124:1046-1051.
3. Douglas JM Jr. The Pericardium. In: Sabiston DC, Spencer FC eds. Surgery of the Chest. Philadelphia, PA: W.B. Saunders Co. 1995.
4. Morgan RJ, Stephenson LW, Woolf PK et al. Surgical treatment of pericarditis in children. J Thorac Cardiovasc Surg 1983; 527-531.
5. Hawkins JW, Vacek JL. What constitutes definitive therapy of malignant pericardial effusion? "Medical" versus surgical treatment. Am Heart J 1989; 118:428-432.
6. Hazelrigg SR, Mack MJ, Landreneau RJ et al. Thoracoscopic pericardiectomy for effusive pericardial disease. Ann Thor Surg 1993; 56:792-795.

Appendix I: Vendor Contact Information

Name Location	Product	Phone Toll-free Fax	E-mail Website
All Vendors			
ARMM, Inc Huntington Beach, CA	Silicone Chest tubes	714-848-8190 None 714-848-6141	info@armminc.com www.armminc.com
Aesculap Center Valley, PA	Reusable ports, VATS instruments	———— 800-282-9000	Products@AESCULAP.de www.aesculap.com
Atrium Medical Corporation Hudson, NH	Chest drainage system	603-880-1433 None 603-880-4545	webmaster@atriummed.com www.atriummed.com
Axiom Medical Rancho Dominquez, CA	Silicone chest tubes, Local anesthesia chest tube	310-898-1779 800-221-8569 310-632-1326	Sales@axiommed.com www.axiommed.com
Baxter Healthcare Deerfield, IL	Tissue sealant	847-940-5856 800-241-9360 847-940-6622	inforequest@ tissuesealing.com tissuesealing.com
Bio-Vascular St. Paul, MN	Pericardial Staple Reinforcement	651-603-3700 800-255-4018 651-642-9018	info@biovascular.com (or website) www.biovascular.com
Boss Instruments, LTD Nashville, TN	Laparoscopic Instruments	615.885.2231 800.210.2677 615.885.2992	boss@bossinst.com www.bossinst.com
Bryan Corporation Woburn, MA	Intrapleural Talc	781-935-0004 800-343-7711 781-935-7602	info@bryancorp.com www.bryancorporation.com
C.R. Bard, Inc., Bard Medical Division Covington, GA	Monopty Core Needle	770-784-6100 800-526-4455 770-385-4455	www.bardmedical.com/ contact/index.cfm www.bardmedical.com
Circon Santa Barbara, CA	Video systems	805-685-5100 888-524-7266 805-968-1645	meded@circon.com www.circoncorp.com

Name Location	Product	Phone Toll-free Fax	E-mail Website
Computer Motion Goleta, CA	Endoscope positioning robot	805-685-3729 800-739-8000 805-685-9277	info@ComputerMotion.com computermotion.com
ConMed Utica, NY	Argon Beam Coagulator, Endoscopic Instr.	315-797-8375 800-765-8375 315-797-0321	info@conmed.com www.conmed.com
Cook Critical Care Bloomington, IN	Pleural drains Bronchial blocker (Arndt)	812.339.2235 800.457.4500 800.554.8335	criticalcare@cook-inc.com http://www.cookgroup.com/cook_critical_care
Cook-OB-GYN Spencer, IN	Lap Sac	812-829-4891 800-457-4448 800-837-4130	cookobg@kiva.net www.cookobgyn.com
Dexide, Inc. Fort Worth, TX	FRED	817-589-1454 800-645-3378 817-589-3783	sales@dexide.com http://www.dexide.com
Electroscope, Inc Boulder, CO	Electroshield Instruments	303-444-2600 800-998-0986 303-444-4597	info@encision.com www.electroscope.com
Elmed Inc., Addison, IL	Laparoscopic Instruments, Cautery	630-543-2792 None 630-543-2102	webmaster@elmed.com elmed.com/
Estech Danville, CA	3D Video system	925-648-2033 None 925-648-2034	——————— ———————
Ethicon Endo-Surgery/Ethicon, Inc. Cincinnati, OH	Endoscopic Staplers; Harmonic Scalpel	513-786-7000 800 873-3636 513-786-7912	EEScustsup@EESUS.JNJ.com www.medprofed.com www.jnjgateway.com
Fujinon Inc. Wayne, NJ	Video systems and Endoscopes Flexible	973-633-5600 800-872-0196 973-633-8818	None www.fujinon.com
Genzyme Tucker, GA	VATS tools, Snowden pencer, Focal Seal, Reusable retractor	770-496-0952 800-367-7874 770-934-8659	None www.genzyme.com
Imagyn Medical Technologies Irvine, CA	Articulating staplers, Reusable ports, 2 mm endoscopes, Detachable tip instruments	949-809-0800 800-876-4584 949-809-1975	Info@imagyn.com www.imagyn.com
Innerdyne, Inc Sunnyvale, CA	Ports (Step Cannula)	408-745-6010 None	www.innerdyne.com/contact.htm www.innerdyne.com

Name Location	Product	Phone Toll-free Fax	E-mail Website
Intuitive Surgical, Inc. Mountain View,CA	Computer enhanced surgery system	650-237-7000 888-868-4647 650-526-2066	sales_marketing @intusurg.com www.intuitivesurgical.com
Kapp Surgical Instruments, Inc. Cleveland, OH	Strip-T's Surgical Organizer Custom tools	216-587-4400 800-282-KAPP 216-587-0411	info@kappsurgical.com www.kappsurgical.com
Karl Storz Endoscopy-America, Inc Culver City, CA	Video Systems and Endoscopes; VATS Instruments; Reusable trocars	310-338-8100 800-421-0837 310-410-5530	karlstorz-marketing @karlstorz.de www.karlstorz.com
Mediflex Islandia, NY	Self retaining endoscope/instrument holders/laparoscopic instruments	704-854-3142 800-879-7575 704-854-3996	DrDaughn@aol.com OR Website www.mediflex.com
Microline Beverly, MA	Laparoscopic instruments	978-922-9810 None 978-922-9209	scorcoran@ microlineinc.com microlineinc.com
Olympus America, Inc. Melville, NY	Videoscope systems, deflectable	631-844-5000 800-645-8100 631-844-5728	spdinfo@olympus.com www.olympusamerica.com
Pilling Surgical Ft. Washington, PA	Minimally invasive instruments (Landreneau or Kaiser)	800-523-2579 800-523-6507 800-332-2308	bshore@pillingsurgical.com www.pillingsurgical.com
Richard Wolf Instruments Vernon Hills, IL	Instruments, Talc Insufflator, Ports, Videoscopes	708-913-1113 800-323-9653 708-913-1488	www.richard-wolf.com/ english/e_indexg.htm www.richard-wolf.com
Sanofi New York, NY	Photofrin(R) for photodynamic therapy	212-551-4964 800-446-6267 212-551-4916	——— webmaster@ sanofi-synthelabo.com
Scanlon International, Inc St. Paul, MN	Specialty instruments, Knot Pusher	651-298-0997 800-328-9458 651-298-0018	info@scanlangroup.com www.scanlangroup.com
Scion Miami, FL	Endoscopic instruments, Clip appliers	305-263-8199 888-263-4400 305-263-8189	On website www.scioninternational.com
Smith-Nephew Andover, MA	Dyonics Video Systems and Endoscopes	978-749-1000 800-343-5717 800-554-6105	On website www.endoscopy1.com
Snowden-Pencer Tucker, GA	Endoscopic Instruments	404-496-0952 800-367-7874 404-934-4922	snowdenpencer @genzyme.com www.snowdenpencer.com

Name Location	Product	Phone Toll-free Fax	E-mail Website
Sofamor Danek Memphis, TN	Endoscopic spine instruments	———— 800-876-3133 901-396-0356	hrinfo@sofamordanek.com www.sofamordanek.com
Source Vascular, Inc. Palm Harbor, FL	James Intrapleural Catheter	813-994-0271 None 813-991-5802	SourceVasc@aol.com ————
Stryker Endoscopy Santa Clara, CA	Endoscopic video systems and telescopes, Laparoscopic tools	408-567-9100 800-624-4422 800-729-2917	On website www.strykerendo.com
United States Surgical Corp. Norwalk, CT	Endoscopic Staplers; Disposable instruments; Access ports; Fog elimination (FRED(tm))	203-845-1000 800-722-8772 800-544-8772	larry.heaton@ussurg.com www.ussurg.com
V. Mueller Division McGaw Park, IL	Laparoscopy tools	847-689-8410 800-323-9088 847-578-6811	On website www.allegiance.net
Vista Cardiothoracic Westborough, MA	3D Video System	508-366-3668 888-847-8268 508-366-1543	cservice@vistamt.com www.vistamt.com
W.L. Gore & Associates, Inc. Flagstaff, AZ	Staple line reinforcement	520-779-2771 800-437-8181 520-774-5793	Staplelinereinforcement @wlgore.com www.gore.com
Weck Closure Systems Research Triangle Park, NC	Endoscopic Clips	919-544-8000 800-234-9325 800-932-5329	info@weckclosure.com OR webmaster @weckclosure.com www.weckclosuresystems.com
DRAINS			
ARMM, Inc Huntington Beach, CA	Silicone Chest tubes	714-848-8190 None 714-848-6141	info@armminc.com www.armminc.com
Axiom Medical Rancho Dominquez, CA	Silicone chest tubes, Local anesthesia chest tube	310-898-1779 800-221-8569 310-632-1326	Sales@axiommed.com www.axiommed.com
Cook Critical Care Bloomington, IN	Pleural drains, Bronchial blocker (Arndt)	812.339.2235 800.457.4500 800.554.8335	criticalcare@cook-inc.com www.cookgroup.com /cook_critical_care
Source Vascular, Inc. Palm Harbor, FL	James Intrapleural Catheter	813-994-0271 None 813-991-5802	SourceVasc@aol.com ————

DISPOSABLE INTRUMENTS

Ethicon Endo-Surgery/Ethicon, Inc. Cincinnati, OH	Endoscopic Staplers; Harmonic Scalpel	513-786-7000 800 873-3636 513-786-7912	EEScustsup@EESUS.JNJ.com www.medprofed.com OR www.jnjgateway.com
Innerdyne, Inc Sunnyvale, CA	Ports (Step Cannula)	408-745-6010 None ————	www.innerdyne.com/contact.htm www.innerdyne.com
United States Surgical Corp. Norwalk, CT	Endoscopic Staplers; Disposible instruments; Access ports; Fog elimination (FRED(tm))	203-845-1000 800-722-8772 800-544-8772	larry.heaton@ussurg.com www.ussurg.com

MISCELLANEOUS PRODUCTS

Atrium Medical Corporation Hudson, NH	Chest drainage system	603-880-1433 None 603-880-4545	webmaster @atriummed.com www.atriummed.com
Baxter Healthcare Deerfield, IL	Tissue sealant	847-940-5856 800-241-9360 847-940-6622	inforequest @tissuesealing.com tissuesealing.com
Bio-Vascular St. Paul, MN	Pericardial Staple Reinforcement	651-603-3700 800-255-4018 651-642-9018	info@biovascular.com (or website) www.biovascular.com
Bryan Corporation Woburn, MA	Intrapleural Talc	781-935-0004 800-343-7711 781-935-7602	info@bryancorp.com www.bryancorporation.com
C.R. Bard, Inc., Bard Medical Division Covington, GA	Monopty Core Needle	770-784-6100 800-526-4455 770-385-4455	www.bardmedical.com /contact/index.cfm www.bardmedical.com
Cook-OB-GYN Spencer, IN	Lap Sac	812-829-4891 800-457-4448 800-837-4130	cookobg@kiva.net www.cookobgyn.com
Ethicon Endo-Surgery/Ethicon, Inc. Cincinnati, OH	Endoscopic Staplers; Harmonic Scalpel	513-786-7000 800 873-3636 513-786-7912	EEScustsup@EESUS.JNJ.com www.medprofed.com OR www.jnjgateway.com
Kapp Surgical Instruments, Inc. Cleveland, OH	Strip-T's–Surgical Organizer–Custom tools	216-587-4400 800-282-KAPP 216-587-0411	info@kappsurgical.com www.kappsurgical.com
Richard Wolf Instruments Vernon Hills, IL	Instruments, Talc Insufflator, Ports, Videoscopes	708-913-1113 800-323-9653 708-913-1488	www.richard-wolf.com/english/e_indexg.htm www.richard-wolf.com

MISCELLANEOUS PRODUCTS

Sanofi New York, NY	Photofrin(R) for photodynamic therapy	212-551-4964 800-446-6267 212-551-4916	——————— webmaster@sanofi- synthelabo.com
W.L. Gore & Associates, Inc. Flagstaff, AZ	Staple line reinforcement	520-779-2771 800-437-8181 520-774-5793	staplelinereinforcement @wlgore.com www.gore.com
Weck Closure Systems Research Triangle Park, NC	Endoscopic Clips	919-544-8000 800-234-9325 800-932-5329	info@weckclosure.com OR webmaster @weckclosure.com www.weckclosuresystems.com

REUSABLE PRODUCTS

Aesculap Center Valley, PA	Reusable ports, VATS instruments	——————— 800-282-9000 ———————	Products@AESCULAP.de www.aesculap.com
Boss Instruments, LTD Nashville, TN	Laparoscopic Instruments	615-885-2231 800-210-2677 615-885-2992	boss@bossinst.com www.bossinst.com
Circon Santa Barbara, CA	Video systems	805-685-5100 888-524-7266 805-968-1645	meded@circon.com www.circoncorp.com
ConMed Utica, NY	Argon Beam Coagulator, Endoscopic Instruments	315-797-8375 800-765-8375 315-797-0321	info@conmed.com www.conmed.com
Electroscope, Inc Boulder, CO	Electroshield Instruments	303-444-2600 800-998-0986 303-444-4597	info@encision.com www.electroscope.com
Elmed Inc. Addison, IL	Laparoscopic Instruments, Cautery	630-543-2792 None 630-543-2102	webmaster@elmed.com elmed.com
Genzyme Tucker, GA	VATS tools, Snowden pencer, Focal Seal, Reusable retractor	770-496-0952 800-367-7874 770-934-8659	None www.genzyme.com
Imagyn Medical Technologies Irvine, CA	Articulating staplers, Reusable ports, 2mm endoscopes, Detachable tip instruments	949-809-0800 800-876-4584 949-809-1975	Info@imagyn.com www.imagyn.com
Kapp Surgical Instruments, Inc. Cleveland, OH	Strip-T's–Surgical Organizer– Custom tools	216-587-4400 800-282-KAPP 216-587-0411	info@kappsurgical.com www.kappsurgical.com

REUSABLE PRODUCTS

Karl Storz Endoscopy-America, Inc Culver City, CA	Video Systems and Endoscopes; VATS Instruments; Reusable trocars	310-338-8100 800-421-0837 310-410-5530	karlstorz-marketing @karlstorz.de www.karlstorz.com
Mediflex Islandia, NY	Self retaining endoscope/instrument holders/ laparoscopic instruments	704-854-3142 800-879-7575 704-854-3996	DrDaughn@aol.com OR on Website www.mediflex.com
Microline Beverly, MA	Laparoscopic instruments	978-922-9810 None 978-922-9209	scorcoran @microlineinc.com microlineinc.com
Pilling Surgical Ft. Washington, PA	Minimally invasive instruments (Landreneau or Kaiser)	800-523-2579 800-523-6507 800-332-2308	bshore@pillingsurgical.com www.pillingsurgical.com
Richard Wolf Instruments Vernon Hills, IL	Instruments, Talc Insufflator, Ports, Videoscopes	708-913-1113 800-323-9653 708-913-1488	www.richard-wolf.com/ english/e_indexg.htm www.richard-wolf.com
Scanlon International, Inc St. Paul, MN	Specialty instruments, Knot Pusher	651-298-0997 800-328-9458 651-298-0018	info@scanlangroup.com www.scanlangroup.com
Scion Miami, FL	Endoscopic instruments, Clip appliers	305-263-8199 888-263-4400 305-263-8189	On website www.scioninternational.com
Snowden-Pencer Tucker, GA	Endoscopic Instruments	404-496-0952 800-367-7874 404-934-4922	snowdenpencer @genzyme.com www.snowdenpencer.com
Sofamor Danek Memphis, TN	Endoscopic spine instruments	——————— 800-876-3133 901-396-0356	hrinfo@sofamordanek.com www.sofamordanek.com
Stryker Endoscopy Santa Clara, CA	Endoscopic video systems and telescopes, laparoscopic tools	408-567-9100 800-624-4422 800-729-2917	On website www.strykerendo.com
V. Mueller Division McGaw Park, IL	Laparoscopy tools	847-689-8410 800-323-9088 847-578-6811	On website www.allegiance.net
ROBOTIC SYSTEMS			
Computer Motion Goleta, CA	Endoscope positioning robot	805-685-3729 800-739-8000 805-685-9277	info@ComputerMotion.com computermotion.com

Intuitive Surgical, Inc Mountain View, CA	Computer enhanced surgery system	650-237-7000 888-868-4647 650-526-2066	sales_marketing @intusurg.com www.intuitivesurgical.com
STAPLER SYSTEMS			
Ethicon Endo-Surgery/Ethicon, Inc. Cincinnati, OH	Endoscopic Staplers Harmonic Scalpel	513-786-7000 800 873-3636 513-786-7912	EEScustsup@EESUS.JNJ.com www.medprofed.com OR www.jnjgateway.com
Imagyn Medical Technologies Irvine, CA	Articulating staplers, Reusable ports, 2 mm endoscopes, Detachable tip instruments	949-809-0800 800-876-4584 949-809-1975	Info@imagyn.com www.imagyn.com
United States Surgical Corporation Norwalk, CT	Endoscopic Staplers Disposible instruments; Access ports; Fog elimination (FRED(tm))	203-845-1000 800-722-8772 800-544-8772	larry.heaton@ussurg.com www.ussurg.com
VIDEO SYSTEMS			
Circon Santa Barbara, CA	Video systems,	805-685-5100 888-524-7266 805-968-1645	meded@circon.com www.circoncorp.com
Estech Danville, CA	3D Video system	925-648-2033 None 925-648-2034	———————
Fujinon Incorporated Wayne, NJ	Video systems and Endoscopes–Flexible	973-633-5600 800-872-0196 973-633-8818	None www.fujinon.com
Imagyn Medical Technologies Irvine, CA	Articulating staplers, Reusable ports, 2 mm endoscopes, Detachable tip instruments	949-809-0800 800-876-4584 949-809-1975	Info@imagyn.com www.imagyn.com
Karl Storz Endoscopy-America, Inc Culver City, CA	Video Systems and Endoscopes; VATS Instruments; Reusable trocars	310-338-8100 800-421-0837 310-410-5530	karlstorz-marketing @karlstorz.de www.karlstorz.com
Olympus America, Inc. Melville, NY	Videoscope systems, deflectable	631-844-5000 800-645-8100 631-844-5728	spdinfo@olympus.com www.olympusamerica.com
Richard Wolf Instruments Vernon Hills, IL	Instruments, Talc Insufflator, Ports, Videoscopes	708-913-1113 800-323-9653 708-913-1488	www.richard-wolf.com/ english/e_indexg.htm www.richard-wolf.com

STAPLER SYSTEMS

Smith-Nephew Andover, MA	Dyonics Video Systems and Endoscopes	978-749-1000 800-343-5717 800-554-6105	On website www.endoscopy1.com
Stryker Endoscopy Santa Clara, CA	Endoscopic video systems and telescopes, laparoscopic tools	408-567-9100 800-624-4422 800-729-2917	On website www.strykerendo.com
Vista Cardiothoracic Westborough, MA	3D Video System	508-366-3668 888-847-8268 508-366-1543	cservice@vistamt.com www.vistamt.com

Operative Procedure	**Pleuroscopy and biopsy (Sugarbaker)**
Preoperative preparation	Routine, CT Scan
Anesthetic concerns	Double lumen endotracheal tube or preferred method of split lung ventilation
Other endoscopic equipment needed	
Patient position	Lateral decubitus position
Patient monitoring	Standard
Catheters	
Video system needed	Standard 0 & 30 degree scopes
Special supplies	
Reusable tools	Standard biopsy forceps
Ports	Two, Camera and Instrument
Disposable instruments	
Chest tube	Single, standard tube
Port closing sutures	Standard
Instruments needed to open chest*	
Postoperative care	Post anesthesia care unit
Special exceptions or equipment	May need sputum trap for fluid cytology.
*Confirm before opening	

Operative Procedure	**Blebectomy and pleurodesis (Sugarbaker)**
Preoperative preparation	Routine, CT Scan
Anesthetic concerns	Double lumen endotracheal tube or preferred method of split lung ventilation
Other endoscopic equipment needed	
Patient position	Lateral decubitus position
Patient monitoring	Standard
Catheters	Urinary (for long procedures)
Video system needed	5 or 10 mm scope
Special supplies	
Reusable tools	Endoscopic lung clamp
Ports	Three, Camera and two instrument
Disposable instruments	Endoscopic linear stapler
	Bovie scratch pad
Chest tube	Single, standard tube
Port closing sutures	Standard
Instruments needed to open chest*	
Postoperative care	Post anesthesia care unit
Special exceptions or equipment	Pericardial or PTFE staple line reinforcement

*Confirm before opening

Operative Procedure	**Lung biopsy for diffuse lung disease (DeCamp)**
Preoperative preparation	High resolution CT Scan – patient not acutely ill requiring mechanical ventilation
Anesthetic concerns	Double lumen endotracheal tube or preferred method of split lung ventilation
	May need CPAP or intermittent ventilation of operative side.
Other endoscopic equipment needed	
Patient position	Lateral decubitus position
Patient monitoring	Standard
Catheters	
Video system needed	Standard 0 & 30 degree scopes
Special supplies	Microbiology "protected" brush Anaerobic transport media
Reusable tools	Lung grasping clamp
Ports	Three, Camera and two instrument
Disposable instruments	Extraction sac
	Endoscopic stapler
Chest tube	Single, standard tube
Port closing sutures	Standard
Instruments needed to open chest*	Tools for open lung biopsy
Postoperative care	Post anesthesia care unit, ICU if needed
Special exceptions or equipment	Patient on ventilator probably will require open procedure.
	Multiple biopsies generally performed from different areas of the lung. Availability of pathologist for frozen section in selected cases,

*Confirm before opening

Operative Procedure	**Lung nodule wedge excision (Sonett)**
Preoperative preparation	Routine, CT Scan in room, Possible localization
Anesthetic concerns	Double lumen endotracheal tube or preferred method of split lung ventilation
Other endoscopic equipment needed	
Patient position	Lateral decubitus position
Patient monitoring	Standard
Catheters	Optional unless prolonged case.
Video system needed	Standard 0 & 30 degree scopes
	CO2 insufflator
Special supplies	
Reusable tools	Operating telescope with 5 mm channel
	45 cm endoscopic scissors
	Blunt probe
	Lung masher
Ports	Three (2 x 5mm, 1 x 10mm)
Disposable instruments	Endoscopic 45mm linear cutter
	Specimen extraction sac
Chest tube	Single, standard tube
Port closing sutures	Standard
Instruments needed to open chest*	Thoracotomy tools if not able to excise nodule
Postoperative care	Post anesthesia care unit
Special exceptions or equipment	May need localization of mass by CT scan immediately before operation
	May need laser for deep nodules
	May need fibrin glue sealant.

*Confirm before opening

Operative Procedure	**VATS Lobectomy (Swanson)**
Preoperative preparation	Routine, CT Scan, PFT's
Anesthetic concerns	Double lumen endotracheal tube or preferred method of split lung ventilation
Other endoscopic equipment needed	Possible bronchoscopy and/or mediastinoscopy before resection
Patient position	Lateral decubitus position
Patient monitoring	Standard, Possible arterial line
Catheters	Urinary, possible NG tube as well
Video system needed	Standard 0 & 30 degree scopes
Special supplies	
Reusable tools	Ringed retractor
	Thoracoscopic ring forceps
	Standard cautery, scissors, and dissector
	Pediatric retractor for non-rib spreading exposure through access thoracotomy
Ports	Access thoracotomy < 8 cm
	Camera and one to two accessory ports
Disposable instruments	Endoscopic cutter
	Red rubber or similar catheter to pass stapler anvil or cartridge around tissue
	Heavy duty extraction sac
Chest tube	Single, standard tube
Port closing sutures	Standard for ports
	Access thoracotomy closure sutures
Instruments needed to open chest*	Standard thoracotomy tray
Postoperative care	Post anesthesia care unit or ICU
Special exceptions or equipment	May need wedge or needle biopsy of lung before lobectomy.

*Confirm before opening

Operative Procedure	**VATS Esophageal lymph node dissection (Swanson)**
Preoperative preparation	Routine, CT Scan, Possible UGI
Anesthetic concerns	Double lumen endotracheal tube or preferred method of split lung ventilation
Other endoscopic equipment needed	Esophagoscope—preceding operation
Patient position	Left lateral decubitus position
Patient monitoring	Standard
Catheters	Bladder, NG tube
Video system needed	Standard 0 & 30 degree scopes
Special supplies	
Reusable tools	Cautery, endoscopic
	Lung retractor
	Routine dissection tools
	Harmonic Scalpel-Ethicon
Ports	Three, one camera and two instrument
Disposable instruments	Endoscopic vascular cutter for azygous vein
Chest tube	Single, standard tube
Port closing sutures	Standard
Instruments needed to open chest*	
Postoperative care	Post anesthesia care unit
Special exceptions or equipment	May have laparoscopy or feeding jejunostomy at same time.

*Confirm before opening

Operative Procedure	**VATS Trauma Exploration (Jones)**
Preoperative preparation	CXR, possible CT Scan
Anesthetic concerns	Double lumen endotracheal tube or preferred method of split lung ventilation. May need bronchus blocker if cannot reintubate.
	Check any contralateral chest tube system after in lateral decubitus position to prevent pneumothorax on ventilated side.
Other endoscopic equipment needed	May need bronch or EGD if other injuries mandate.
Patient position	Lateral decubitus position
Patient monitoring	As dictated by concomitant injuries,
Arterial line	
Catheters	Bladder, possible NG
Video system needed	30 and 45 degree scopes
Special supplies	Needle to determine site of fluid collection
Reusable tools	Large caliber suction.
	Retractor fan.
Ports	Three, Camera and two instrument
Disposable instruments	Possible endoscopic clips
	Possible endoscopic stapler to repair lung injury
Chest tube	One to two tubes
Port closing sutures	Standard
Instruments needed to open chest*	Open thoracotomy tray available
Postoperative care	Post anesthesia care unit or ICU as needed
Special exceptions or equipment	May need Keith needle with heavy suture for encircling persistent intercostal bleeding refractory to clips or cautery.

*Confirm before opening

Operative Procedure	**Esophageal myotomy (Hazelrigg)**
Preoperative preparation	Routine, motility studies
Anesthetic concerns	Double lumen endotracheal tube or preferred method of split lung ventilation
Other endoscopic equipment needed	Upper GI endoscopy
Patient position	Right lateral decubitus position
Patient monitoring	Standard
Catheters	Bladder, Nasogastric
Video system needed	Standard 0 & 30 degree scopes, Monitors shifted to foot of bed
Special supplies	
Reusable tools	Endoscopic scissors
	Cautery
	Fan retractor
	Ring forceps
Ports	Five ports
Disposable instruments	
Chest tube	Single, standard tube
Port closing sutures	Standard
Instruments needed to open chest*	Thoracotomy tray
Postoperative care	Post anesthesia care unit
Special exceptions or equipment	May need antireflux wrap at same time.

*Confirm before opening

Operative Procedure	**Thoracoscopic sympathectomy (Krasna)**
Preoperative preparation	Routine
Anesthetic concerns	Double lumen endotracheal tube or preferred method of split lung ventilation
Other endoscopic equipment needed	Intubating bronchoscope
Patient position	Lateral decubitus position (single side) OR
	Semi-fowler (bilateral sympathectomy)
Patient monitoring	Standard
Catheters	
Video system needed	Standard 0 scope
Special supplies	
Reusable tools	Long hook cautery.
Ports	One or two, depending on whether operating port of thoracoscope can be used.
Disposable instruments	None
Chest tube	Optional
Port closing sutures	Standard
Instruments needed to open chest*	
Postoperative care Post anesthesia care unit	
Special exceptions or equipment	

*Confirm before opening

Operative Procedure	**VATS Mediastinal Cyst Excision (Demmy)**
Preoperative preparation	Routine, CT Scan in room
Anesthetic concerns	Double lumen endotracheal tube or preferred method of split lung ventilation
	Optional warm air patient warmer
Other endoscopic equipment needed	Intubating bronchoscope
Patient position	Lateral decubitus position
Patient monitoring	Standard
Catheters	Bladder catheter optional.
Video system needed	Standard 0 & 30 degree scopes OR
	Flexible thoracoscope
Special supplies	
Reusable tools	Endoscopic dissector and graspers
	Long, narrow jaw Babcock clamps
	Hook cautery
	Yankauer suction
Ports	Reusable metal, 2 x 10mm, 1 x 12mm
Disposable instruments	Specimen extraction sac*
	Endoscopic clip appliers*
	Endo-retract™*
	Cautery extension piece
	Sputum trap*
	Culture media*
	Spinal needle (18 or 20 guage)*

Chest tube	Intrapleural anesthesia catheter or Silicone, 28F
Port closing sutures	Standard
Instruments needed to open chest*	Thoracotomy tray
Postoperative care	Post anesthesia care unit
Special exceptions or equipment	

*Confirm before opening

Operative Procedure	**Pleural debridement for empyema, pediatric (Rodgers)**
Preoperative preparation	Routine, CT Scan
	Radiologist marks site of most fluid.
Anesthetic concerns	Double lumen endotracheal tube or preferred method of split lung ventilation
Other endoscopic equipment needed	
Patient position	Lateral decubitus position
Patient monitoring	Standard
Catheters	Bladder if case prolonged
Video system needed	Standard 5 mm telescope
Special supplies	
Reusable tools	5mm Prestige‰ grasping instrument
Ports	Two or Three, 5mm & 10mm
Disposable instruments	Leukin's trap
Chest tube	Single, standard tube, 20-26F
Port closing sutures	Standard
Instruments needed to open chest*	
Postoperative care	Post anesthesia care unit
Special exceptions or equipment	May need Urokinase to dissolve rind.

*Confirm before opening

Operative Procedure	**Pericardial Resection (Walls)**
Preoperative preparation	Routine, Echocardiogram
Anesthetic concerns	Double lumen endotracheal tube or preferred method of split lung ventilation
Other endoscopic equipment needed	
Patient position	Right lateral decubitus position
Patient monitoring	Arterial line, may need pulmonary artery catheter
Catheters	Bladder
Video system needed	Standard 0 & 30 degree scopes
Special supplies	Culture and/or cytology specimen materials
Reusable tools	Endoscopic scissors
Ports	Three, Camera and two instrument
Disposable instruments	Long needle for aspirating pericardium
Chest tube	Single, standard tube
Port closing sutures	Standard
Instruments needed to open chest*	Thoracotomy tray
Postoperative care	Post anesthesia care unit or ICU
Special exceptions or equipment	May need pericardiocentesis before induction of anesthesia to stabilize patient.

*Confirm before opening

Operative Procedure

Preoperative preparation

Anesthetic concerns

Other endoscopic equipment needed

Patient position

Patient monitoring

Catheters

Video system needed

Speical supplies

Reusable tools

Ports

Disposable instruments

Chest tube

Port closing sutures

Instruments needed to open chest*

Postoperative care

Special exceptions or equipment

*Confirm before opening

Operative Procedure

Preoperative preparation

Anesthetic concerns

Other endoscopic equipment needed

Patient position

Patient monitoring

Catheters

Video system needed

Speical supplies

Reusable tools

Ports

Disposable instruments

Chest tube

Port closing sutures

Instruments needed to open chest*

Postoperative care

Special exceptions or equipment

*Confirm before opening

Operative Procedure

Preoperative preparation

Anesthetic concerns

Other endoscopic equipment needed

Patient position

Patient monitoring

Catheters

Video system needed

Speical supplies

Reusable tools

Ports

Disposable instruments

Chest tube

Port closing sutures

Instruments needed to open chest*

Postoperative care

Special exceptions or equipment

*Confirm before opening

Operative Procedure

Preoperative preparation

Anesthetic concerns

Other endoscopic equipment needed

Patient position

Patient monitoring

Catheters

Video system needed

Speical supplies

Reusable tools

Ports

Disposable instruments

Chest tube

Port closing sutures

Instruments needed to open chest*

Postoperative care

Special exceptions or equipment

*Confirm before opening

Operative Procedure

Preoperative preparation

Anesthetic concerns

Other endoscopic equipment needed

Patient position

Patient monitoring

Catheters

Video system needed

Speical supplies

Reusable tools

Ports

Disposable instruments

Chest tube

Port closing sutures

Instruments needed to open chest*

Postoperative care

Special exceptions or equipment

*Confirm before opening

G

H

I

L

M

N

P

R

S

T

U

W

Z

Dedication

Dedicated to Maryellen and our tenacious twins, Michael and Tara. Thank you for your love and generous support.

Editors

Todd L. Demmy, M.D.
Associate Professor
Division of Cardiothoracic Surgery
Chief, Thoracic Oncology
Ellis Fischel Cancer Center
University of Missouri-Columbia
Columbia, Missouri, U.S.A.
Chapters 1, 7, 10

Contributors

Oliver A. R. Binns, M.D.
Thoracic and Cardiovascular Surgery
University of Virginia
Charlottesville, Virginia, U.S.A.
Chapter 8

Ben D. Davis, M.D.
Division of Thoracic Surgery
Brigham and Women's Hospital
Harvard Medical School
Boston, Massachusetts, U.S.A.
Chapter 2

Malcolm M. DeCamp Jr., M.D.
Surgical Director, Lung Transplant Program
Staff Surgeon, Department of Thoracic and Cardiovascular Surgery
The Cleveland Clinic Foundation
Cleveland, Ohio, U.S.A.
Chapter 3

Stephen R. Hazelrigg, M.D.
Professor and Chairman
Southern Illinois University School of Medicine
Division of Cardiothoracic Surgery
Springfield, Missouri, U.S.A.
Chapter 9

Michael T. Jaklitsch, M.D.
Division of Thoracic Surgery
Brigham and Women's Hospital
Assistant Professor
Harvard Medical School
Boston, Massachusetts, U.S.A.
Chapter 2

Xiaolong Jiao
Instructor in Surgery
Division of Thoracic Surgery
University of Maryland Medical System
Baltimore, Maryland, U.S.A.
Chapter 11

David R. Jones, M.D.
Assistant Professor of Surgery
Thoracic and Cardiovascular Surgery
University of Virginia
Charlottesville, Virginia, U.S.A.
Chapter 8

Mark J. Krasna, M.D.
Professor and Chief
Division of Thoracic Surgery
University of Maryland Medical System
Baltimore, Maryland, U.S.A.
Chapter 11

Chong-Hee Lim, M.D.
Fellow, Department of Thoracic and Cardiovascular Surgery
The Cleveland Clinic Foundation
Cleveland, Ohio, U.S.A.
Chapter 3

David P. Mason, M.D.
Department of Surgery
Brigham and Women's Hospital
Harvard Medical School
Boston, Massachusetts, U.S.A.
Chapters 5, 6

Bradley M. Rodgers, M.D.
Professor of Surgery and Pediatrics
Chief, Division of Pediatric Surgery
University of Virginia Health System
Children's Medical Center
Charlottesville, Virginia, U.S.A.
Chapter 12

Joshua R. Sonett, M.D.
Assistant Professor Surgery
Director of Lung Transplantation
Division of Thoracic Surgery
University of Maryland Medical Center
Chief Thoracic Surgery
Baltimore Veterans Medical Center
Baltimore, Maryland, U.S.A.
Chapter 4

David J. Sugarbaker, M.D.
Vice Chair, Department of Surgery
Chief, Division of Thoracic Surgery
Brigham and Women's Hospital
Philip L. Lowe Senior Surgeon and Chief Department of Surgical Services
Dana-Farber Cancer Institute
Harvard Medical School
Boston, Massachusetts, U.S.A.
Chapter 2

Scott J. Swanson, M.D.
Associate Chief, Division of Thoracic Surgery
Director, Lung Transplantation
Brigham and Women's Hospital
Assistant Professor of Surgery
Harvard Medical School
Boston, Massachusetts, U.S.A.
Chapters 5, 6

Joseph T. Walls, M.D.
Professor, Division of Cardiothoracic Surgery
University of Missouri-Columbia
Columbia, Missouri, U.S.A.
Chapter 13

Preface

Video-Assisted Thoracic Surgery (VATS) or Thoracoscopy has been applied to almost every organ system within the chest. For some operations, VATS has supplanted the open approaches that were standard for many years. For other procedures, it has enhanced complex open techniques and replaced them in appropriate cases. The influx of rapidly evolving technology that accompanied these newer techniques has required integration into the already complex algorithms used in the diagnosis and treatment of chest disease. Frequently, confusion has arisen regarding the appropriate application of this technology and the preparation needed to provide it to patients. Pertinent topics for discussion are preoperative imaging/localization, anesthesia/airway management, patient positioning, video/assistant positioning, special supplies, and postoperative care. The purpose of this book is to provide a framework based on these and other issues to share helpful technical tips, assist operating room personnel preparing supplies, limit unnecessary costs, and define VATS limitations as well as its present role in the overall scheme of thoracic surgery. The target readership of this essay includes practicing surgeons, medical students, operating room nurses, technicians, physician assistants, and administrative personnel interested in reducing cost and increasing efficiency while offering this relatively new technology.

Acknowledgments

I wish to acknowledge the faculty and staff of the Ellis Fischel Cancer Center and the Thoracic Surgeons of the Cancer and Leukemia Group B. The supportive cultures of both organizations allowed me to develop careers in Thoracic Oncology and Minimally Invasive Surgery.

Finally, I wish to express my extreme good fortune to have a dedicated, tireless, and loyal assistant, Pamela Adams, whose superb organizational skills are indispensible.