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ORIGINAL RESEARCH

The Role of Thoracoscopy in Diagnosis and Treatment of Pleural Disease

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ABSTRACT

Intrathoracic disease involving lungs and pleura encountered frequently and remains a challenging clinical problem.

The definitive diagnosis of lung or pleural disease some times remain unclear despite thoracocentesis, closed pleural biopsy, transthoracic needle aspiration or bronchoscopy. Recent advances in endoscopic technique, video equipment and development of better instrumentation have contributed to the resurgence of thoracoscopy as a diagnostic and thoracoscopic modality.

Keywords: Malignancy, Needle biopsy, Pleural disease, Thoracoscopy, Tumor.

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INTRODUCTION

Thoracoscopic surgery of the chest using a simple rigid scope was first described in terms of its original concept in 1910 by Dr Jacobaeus,[1] a Swedish internist. It proved to be safe and diagnostically accurate. Its major use subsequently was in the era of collapse therapy with lysis of pleuropulmonary adhesions for tuberculosis treatment.[2] With the development of antituberculous drugs in the late 1940s, thoracoscopy was all but abandoned except for diagnosing pleural disease. In 1970, Dr Joe Miller, Jr, at the Emory Clinic, began to match changes in technology with clinical applications and the thoracoscopy has reemerged as an alternative approach to open thoracotomy in the management of chest disease. Minimally invasive thoracic surgery allows the performance of surgical procedures in the chest cavity utilizing small incisions and specially-adapted, video-endoscopic instruments. This affords a quicker and less painful convalescence for the patient. Many procedures which were previously performed with larger incisions can now be done thoracoscopically, with comparable results. Thoracoscopy is useful for the diagnosis and treatment of a variety of intrathoracic processes, such as for solitary pulmonary nodule resection, metastatic resections, open lung biopsies, pericardiectomies, pneumothorax repair, resection of small mediastinal tumors; lung-volume reduction for pulmonary emphysema and pleural space drainage procedures. It has become an alternative approach for sympathectomy for upper extremity hyperhidrosis, sympathetic dystrophy and Raynaud's phenomenon.[3] Good short-term results are reported for achalasia via thoracoscopic esophagomyotomy.[4] Indeed, the indications for VATS continue to evolve.[3-6]

Although thoracoscopy is used for such procedures, adequate controlled trials confirming its superiority to conventional open thoracotomy are lacking. Its evaluation has been based on performance in selected patients by experienced operators. In this review, we discribed the thoracoscopy's technique, advantages, disadvantages, diagnostic utility, therapeutic and operative applications, complications and controversies.

Finally, a few thoughts about future directions of this emerging technology are shared.

PROCEDURE DETAILS

Simple rigid thoracoscopy (without video assistance) must be differentiated from VATS (with video assistance). Simple rigid thoracoscopy is the use of a metal, illuminated scope placed into the pleural space for the purpose of diagnosing pleural disease or performing minor therapeutic maneuvers such as pleurodesis. Video equipment is not used. Operators can use a lighted mediastinoscope, thoracoscope, or laparoscope. The mediastinoscope offers a large working channel and provides for excellent visualization of the pleural space. Simple rigid thoracoscopy can be performed under local anesthesia in an endoscopy suite or under general anesthesia in an operating room.

For simple rigid thoracoscopy, the patient is prepared and draped in the lateral position with the affected side upward. The entry point is usually between the third and sixth intercostal space along the midaxillary line, depending on the indication.

Video-assisted thoracoscopic surgery (VATS) primarily used by thoracic surgeons, VATS is a surgical technique used to potentially minimize the morbidity of an open procedure.

The thoracoscope consists of a slender fiberoptic tube that can be inserted into a 1/2 inch incision in the chest. The image is then combined with a tiny telescopic lens, a powerful light source, and a small video camera and is projected onto a TV screen. The surgeon can literally see into the chest. Then using graspers, endoscopic scissors and

endostaples, the surgeon can perform a whole host of procedures. Recent advances in endoscopic techniques, surgical instrumentation, and air-tight endostaplers have contributed to the resurgence of thoracoscopy as a useful diagnostic and therapeutic modality.

Certain VATS procedures can be performed under local anesthesia, but VATS typically requires general anesthesia and is performed in an operating room. Operators commonly employ the double-lumen endotracheal tube or bronchial blocker for selective lung ventilation.

Thoracoscopy is usually performed through one or several small, less than 2 cm skin incisions made along the intercostal spaces. Patients are placed in the lateral decubitus position, involved side up, although some procedures, such as a thoracic sympathectomy, are performed with patients in the supine position. Pleural trocars can also be safely placed in the axilla, so that axillary thoracotomy IV sedation and local anesthesia are administered using techniques similar to those employed when making a chest tube insertion incision. Many operators prefer general anesthesia with single- or double-lumen endotracheal intubation performed in an operating suite. Certainly, the operating room is the accepted procedural area for diagnostic and therapeutic procedures such as lung biopsies, decortication, or cardiovascular interventions.

Many procedures limited to removal of pleural fluid, visualization, and biopsy of parietal pleura can be performed through a single skin incision made in approximately the fifth to seventh intercostal space along the lateral chest wall of the involved hemithorax. When a 5 to 10 mm pleural trocar and cannula are interted through the incision, the parietal pleura, diaphragm, and lung are well visualized. Pleural fluid is evacuated and parietal pleural biopsy specimens are obtained from both normal- and abnormal-appearing areas. A chest tube is placed through the incision site and connected to a suction device, and the lung is gently reexpanded. Because the duration of chest tube drainage can be only a few hours, many patients are discharged the same day. In years past, this type of procedure was commonly referred to as pleuroscopy. Today, because of the very minimally invasive nature of the procedure, it has become known as 'medical thoracoscopy'.[3] Complications such as bleeding (from parietal pleural biopsy), lung perforation (during trocar insertion), or infection (from inadvertently using nonsterile techniques) are extremely rare.[4]

Advanced diagnostic and therapeutic procedures are usually performed in an operating suite. Multiple incisions allow the introduction of biopsy forceps, endoscopic scissors, electrocautery, suction-irrigation instruments, and grasping forceps to allow greater mobilization of the lung, removal of fibrin deposits or blood clots, and sectioning of adhesions that prevent complete inspection of the pleural space and mediastinum. Sometimes these adhesions also inhibit complete lung expansion; they may also maintain patency of visceral pleural tears in patients with spontaneous or secondary pneumothorax. In patients with complex pleural effusions, suspected underlying trapped lung requiring an attempt at reexpansion using positive pressure ventilation, empyema, and multiloculated pleural effusions from infection or malignancy, the pleural space and mediastinum can be safely explored using general anesthesia and multiple access sites. Although comparative studies have not been performed, it is possible that complication rates may be increased in this setting because of the increased morbidity of patients undergoing these procedures, the use of general anesthesia and the invasive scope of procedures being performed.

Advantages and Disadvantages of Thoracoscopy

Advantages

Thoracoscopy offers the several advantages over more conventional techniques; namely, it (1) potentially permits access to the entire pleural cavity, including both the parietal and visceral pleura, (2) allows for directly visualized biopsies, certainty of representative tissue for diagnosis, and (3) affords control of bleeding, (4) lysis of adhesions allow inspection, (5) recovery time from surgery (shorter hospital stays and a shorter duration of chest tube drainage compared with thoracotomy)[42] and the level of pain experienced by the patient is markedly reduced. Lastly,[6] the small incisions used are better tolerated than the old larger open thoracotomy incisions.

Potential advantages of thoracoscopy over more conventional techniques include certainty of representative tissue for diagnosis, reduced requirements for postoperative analgesia, shorter hospital stays, and a shorter duration of chest tube drainage compared with thoracotomy.[42]

Disadvantages

1. Invasive procedure
2. Cost
3. Loss of bimanual palpation of the lung
4. Loss of binocular vision
5. Moreover, 20% of VATS procedures require conversion to thoracotomy, which can add operative time and cost.[7]

DIAGNOSTIC THORACOSCOPY

Pleural effusions: Algorithms for investigating pleural effusion of unknown etiology typically begin with

thoracentesis percutaneous closed pleural biopsy. Thoracoscopy is often performed because these procedures are nondiagnostic. Cytologic analysis of thoracentesis fluid is positive in 45 to 80% of malignant pleural effusions; however, it is positive in as few as 20% of patients with mesothelioma.[2,12-17] Repeated thoracentesis for cytologic analysis provides limited increases in yield (17 to 22% additional yield for malignancy).[14,18] Thus, closed pleural biopsy in addition is advocated by some authors to further increase the diagnostic yield.[18]

Closed pleural biopsy is reported to be diagnostic for pleural malignancy in approximately 50% of cases.[16,17] A large retrospective study by Prakash[17] involving 414 patients with pleural effusion found malignant disease in 281 (68%) patients. Fluid cytologic study was positive in 163 (58%), closed pleural biopsy positive in 121 (43%), either positive in 183 (65%). However, in only 20 (7%) of the 281 patients with malignant effusion, closed biopsy specimens revealed malignant disease when the fluid cytologic study was negative. This study is often cited as an indication not to do initial concurrent thoracentesis and closed pleural biopsy when malignancy is the primary consideration. If the initial thoracentesis fluid is an exudate, with cytologic study negative for malignancy, it seems reasonable to then repeat thoracentesis with the addition of a closed pleural biopsy. In contrast, it is recommended that thoracentesis and closed pleural biopsy both be performed initially if tuberculosis is the primary consideration because the combined sensitivity for tuberculosis by thoracentesis culture and closed pleural biopsy is greater than 80%.[17,19] Normal findings from thoracentesis and closed pleural biopsy, however, give no assurance that malignancy is absent.

Boutin et al[14] noted three limitations of thoracentesis and closed needle biopsy in evaluating malignant effusions: (1) False-positive cytologic results range from 0.5 to 1.5%; (2) characterizing the type and origin of the cancer is difficult; and (3) the sensitivities depend directly on the stage of the cancer. Moreover, closed needle biopsy is effective in adequately sampling the parietal pleura in only 75% of attempts.[19] Rodriguez-Panadaro et al,[20] by studying 191 autopsies, added that the parietal pleura is less frequently involved with metastatic pleural disease than the visceral pleura. Localized and diaphragmatic tumors are often not even accessible by closed needle biopsy. The above limitations account for some of the reduced diagnostic efficacy of thoracentesis and closed needle biopsy for malignancy.

Despite extensive conventional evaluation, 10 to 27% of patients with pleural effusions remain without a specific diagnosis.[2,4,17,21,22] One third to half of these effusions may ultimately be diagnosed as malignant.[2] Contrary to thoracocentesis and percutaneous CPB, thoracoscopy permits biopsy with direct visualization.[6] Thoracoscopy is commonly performed after one or two thoracocenteses and at least one nondiagnostic closed pleural biopsy.

Thoracoscopy, using either simple rigid or VATS, has very high sensitivity (80 to 100%) for both benign and malignant pleural disease.[2,9,13,14,23-26] Thoracoscopy increases diagnostic yield for effusions after thoracentesis and closed pleural biopsy specimens are nondiagnostic. Thoracoscopy also yields few false-negative results. Boutin et al[14] retrospectively analyzed 215 simple rigid thoracoscopies for EUO. Thoracoscopy successfully identified 131 of 150 (87%) malignant cases whereas repeated pleural cytologic study and closed needle biopsy specimens the day before surgery yielded positive results in only 62 of 150 (41%) malignant cases. Thoracoscopy gave positive results in 63 of 75 (84%) patients with malignancy who had at least two previous negative cytologic specimens and one or more negative closed needle biopsy specimens.[15] Hariis et al[15] reported thoracoscopy had a diagnostic sensitivity of 95% for pleural malignancy and 100% for benign disease. Importantly, malignancy was demonstrated by thoracoscopy in 24 of 35 (69%) patients who had two negative preoperative pleural cytologic specimens and in 27 of 41 (66%) patients who had a preoperative nondiagnostic closed pleural biopsy specimen.

However, limitations in the published literature exist regarding thoracoscopy and its utility in the management of pleural disease. First, most of the studies show a selection bias toward including patients with known malignancy or a high pretest likelihood of malignancy, thereby improving the sensitivity of thoracoscopy.[3,4] Several studies report a high number of mesothelioma cases.[2,5] Data obtained from such studies may not be applicable to an unselected population with EUO. Second, in four series reporting a diagnostic accuracy of 90 to 100%, follow-up was either not stated or lasted less than 6 months.[3-6] In three series in which a total of 822 patients were followed-up for 1 to 5 years, accuracy was only 62 to 85%.[7-9] Third, it is unclear if the benefits of an earlier diagnosis and the clinical certainty of pleural malignancy warrant the costs of the procedure and its potential morbidity. Thus, many questions still remain regarding the selection of patients for thoracoscopy, its timing, and its true impact on the management and outcome of pleural disease.

Tuberculous Pleurisy

The greater debate is whether thoracoscopy is warranted, if tuberculosis is high on the list of differential diagnoses.

In exudative pleural effusions due to tuberculosis, the diagnostic yield of a closed needle biopsy is 70 to 90%. Thoracoscopy is usually unnecessary, therefore, to establish the diagnosis of a tuberculous effusion. A combined yield of only 6% for thoracoscopy preceded by negative thoracentesis and closed needle pleural biopsy has been reported. Thoracoscopy may be beneficial in difficult diagnostic situation, however, when lysis of adhesions is necessary, or when larger amounts of tissue are warranted to assure diagnosis when drug resistance is suspected.

Malignant mesothelioma: Although malignant mesothelioma may be suspected based on a history of asbestos exposure, symptoms, radiographic findings of pleural fluid, thickening, absence of contralateral shift of the mediastinum, and clinical course; diagnostic confirmation is often difficult. The diagnosis of mesothelioma depends foremost on histologic findings.[29] Pleural fluid cytology ranges from 4 to 77%, and representative specimens from closed needle biopsy are rarely of sufficient size and number to allow the full battery of immunohistochemical stains and electron microscopic examination for definitive diagnosis.[7] Obtaining definitive biopsy samples for the diagnosis of mesothelioma is a main indication for thoracoscopy. Even with thoracoscopy, the accuracy of diagnosing mesothelioma may suffer because of inadequate visualization due to extensive adhesions and the inherent difficulties in pathologic identification of this tumor.[8] Thoracoscopy allows removal of large, full-thickness specimens from several involved areas, making it potentially preferable to open pleural biopsy by minithoracotomy, and most certainly preferable to lateral thoracotomy. For patients not considering intrapleural chemotherapy or surgical resection, pleurodesis can be performed at the time of diagnostic thoracoscopy in order to prevent fluid reaccumulation and to delay the onset of life-threatening dyspnea. Although tumor growth through thoracoscopic incision sites has been described,[9] it is probably less frequent than reported. Prevention is possible by treating the area surrounding the incision sites with radiation. Boutin et al[30] recently reviewed the results of simple rigid thoracoscopy in 153 patients with malignant mesothelioma. The main indications were chronic pleurisy (88%) and radiologically detected pleural densities (9%). One quarter of the patients required electrocautery or laser to lyse adhesions. Thoracoscopic biopsy specimens were positive in 150 of 153 (98%) mesothelioma cases. In contrast, the combined sensitivity of pleural cytologic study and closed needle biopsy was only 38%. Thoracoscopy provides equally good tissue samples for diagnosis of mesothelioma compared with thoracotomy?[31] Thoracoscopy also allows accurate staging of mesothelioma, so an unnecessary thoracotomy can be avoided.

Parenchymal Disease

Ultimately, one-third of patients with diffuse lung disease will undergo open biopsy to establish a diagnosis.[32] Open lung biopsy has an operative mortality of 1.7% and risk for serious morbidity of 2.5% in selected patients.[14,33] Thoracoscopic lung biopsy has been proposed as an alternative to open biopsy when bronchoscopic transbronchial biopsy specimens are indeterminate. Thoracoscopy, as opposed to bronchoscopy, can obtain larger pieces of lung tissue under direct visualization.

In addition, it provides tissue for mineralogic studies of the pneumoconioses, and for diagnosis of pulmonary infiltrates or peripheral nodular lesions of unknown etiology. Specimens are usually obtained using an endoscopic stapling device. VATS is now another alternative to open lung biopsy. Various nonrandomized studies have investigated the VATS approach for lung biopsy. Bensard et al[36] retrospectively analyzed 22 consecutive patients with interstitial disease who underwent VATS lung biopsy and compared then with 21 control patients who underwent open biopsy. They concluded that VATS (1) provided equivalent specimen volume, (2) achieved equal diagnostic accuracy, and (3) reduced both the time for pleural drainage and the length of hospital stay. Ferson et al[37] retrospectively compared 47 patients who underwent VATS lung biopsy with 28 historical control patients who underwent open wedge biopsy via limited thoracotomy. The mean operative time was significantly longer in the VATS group (69 *vs* 93 minutes respectively), but there were significantly more complications in the open group (including more bleeding and prolonged air leaks). The duration of hospital stay was shorter in the VATS group (mean, 4.9 to 12.2 days).

The above studies suggest that VATS lung biopsy is an alternative to open biopsy. VATS lung biopsy is suitable for patients in stable condition who are not requiring mechanical ventilation. Ventilator-dependent patients should not undergo biopsies by the VATS approach because they typically cannot tolerate the change to a double-lumen endotracheal tube or the single-lung ventilation technique. For patients requiring mechanical ventilation in most cases, it is advisable to perform an open lung biopsy through an expeditious limited thoracotomy using minimal rib spreading.

A solitary pulmonary nodule (SPN) is a discrete nodule less than 3 cm in diameter that is completely surrounded by lung and is not associated with parenchymal disease or adenopathy.[40] Over 80 different causes have been

reported.[40] Overall, malignant lesions comprise 44% of all SPN, and most (35%) are bronchogenic cancer.[42] The risk of malignancy depends on nodule size, growth rate, patient age, patient smoking exposure and certain radiographic findings.[41-43]

Integrated approaches for the evaluation and management of SPN are described elsewhere.[42-45] Options for managing the SPN include observation, assessment by noninvasive imaging, cytologic or histologic investigation by transthoracic needle biopsy (TTNB) or bronchoscopy, and surgical resection. TTNB has a diagnostic sensitivity ranging from 43 to 97% for malignant lesions but is less effective in yielding a definitive benign diagnosis.[45] But, TRNB is complicated by pneumothorax in approximately 15% of patients.[43-45] It also has a false-positive rate of 1.5 to 3%; the false-negative rate in the presence of malignancy ranges from 3 to 11%.[46-48] Bronchoscopy is useful for larger central lesions but has low diagnostic yield, approximately 10%, for small peripheral lesions.[49,50] If malignancy or a definitive benign diagnosis has not been proved by these less invasive procedures, the SPN can be approached surgically. Mack et al[45] from three collaborative institutions, excised by VATS under general anesthesia undiagnosed selected SPNs in 242 patients. If the nodule was not pleural based or immediately subpleural, preoperative needle localization was used. Wedge excisions were performed using an endostapler alone (72%), a laser (18%), or both (10%). Only two patients required conversion to open thoracotomy because of technical difficulties. A definitive diagnosis was made in every patient. A specific benign diagnosis was obtained in 127 (52%) patients and a malignant diagnosis in 115 (48%). Of the malignant nodules, 51 (44%) were primary lung carcinomas and 64 (56%) were metastases. If the nodule was determined to be a primary lung malignancy, and the patient had adequate pulmonary function (n = 29), an immediate thoracotomy and lobectomy were performed to ensure adequate resection. There was no mortality and the complication rate was 3.6% in the group who underwent thoracoscopy alone. The average hospital stay for the patients who underwent thoracoscopy alone was 2.6 days. Although this report demonstrated 100% diagnostic sensitivity and specificity for an SPN, the exact role and optimal timing of thoracoscopy in the management of SPN is currently not determined.

THERAPEUTIC AND OPERATIVE APPLICATIONS OF THORACOSCOPY

Overview of simple rigid thoracoscopy is still used for effusion management, pneumothorax repair and drainage of uncomplicated empyema or hemothorax. With the development of endostaplers and refinements in instrumentation, thoracic surgeons are also performing VATS procedures for many indications previously reserved for open thoracotomy.

Lung nodules, pleural effusions, and pulmonary infiltrates were the most common indications for VATS procedures. Procedures performed most commonly were wedge resection, pleural biopsy, pleurodesis and lung biopsy. Prolonged air leak was the most common complication.

Current Role of Interventional Thoracoscopy for each of Its Operative Applications

Pleural Applications

Empyema thoracis remains a condition with substantial morbidity and mortality. Selected empyemas can be satisfactorily decompressed with conservative regimens of repeated thoracentesis, or closed tube thoracostomy.[51] More aggressive surgical approaches include open drainage procedures, decortication and thoracoplasty. Recently, thoracoscopy with repeated irrigation of the thoracic cavity has been described. Thoracoscopic success depends on the mechanical removal of infected material and ensuring fun lung reexpansion. Wakabayashi[52] described 20 patients who underwent debridement of chronic empyema by thoracoscopy through a small incision; the lungs reexpanded in 18 (90%). The lung failed to reexpand in two patients, both whom had empyema of more than 4 months' duration. Ridley and Braimbridge[51] reported overall complete resolution of empyema in 18 of 30 (60%) selected patients even though many were investigated at a late stage after initial treatment regimens had failed. Of the 12 patients who did not have complete resolution after thoracoscopy, the empyema resolved in eight (66%) patients after open surgical procedures. Thoracoscopic debridement may provide valuable time to improve the clinical condition of debilitated patients until they can tolerate more aggressive surgical approaches. However, critics have argued that thoracoscopic debridement delays definitive treatment as evidenced by Ridley's 12 (40%) patients who subsequently needed additional surgery after thoracoscopic evacuation failed.[53] Patient selection and the stage of the empyema at intervention are the main determinates of outcome for thoracoscopic debridement of empyema. During the exudative and organizing phase of empyema, thoracoscopic visualization allows debridement of fibrinous adhesions and evacuation of loculated fluid.[32] The timing of thoracoscopic intervention is critical, however, and should be considered when chest tube drainage is unsatisfactory after 3 to 5 days. If thoracoscopy is used, it is important to evacuate the empyema early before adhesions become too dense and an organized 'peel' develops.[29] The use of thoracoscopy for

complete debridement, pleurectomy, and decortication for empyema management has yet to be adequately proved. The precise role for thoracoscopy instead of chest tube drainage, instillation of fibrinolytic agents, rib resection, or thoracotomy-decortication is still controversial.

Malignant Pleural Effusions

In addition to diagnosis, an important indication for thoracoscopy in patients with malignant pleural effusions is pleurodesis.[10] Complete evacuation of pleural fluid, maximization of lung expandability by removing adhesions, and pleurodesis by talc insufflation (also known as talc poudrage) results in short and long-term success rates of (is greater than) 90%.[11] Distribution of sterile, asbestos-free, US Pharmacopeia-approved talk powder on all pleural surfaces is confirmed by thoracoscopic visualization. Following pleurodesis, low-grade fevers should be expected in up to 30% of patients, and hospitalization duration averages 4.8 days. Pleurodesis can also be achieved by pleurectomy using standard dissection techniques or hydrodissection.[12] Because survival of patients with advanced pleural carcinomatosis is often short, the risks and benefits of thoracoscopic pleurodesis must be carefully weighed against those of repeated thoracentesis, tube thoracostomy, or bedside pleurodesis through an indwelling chest tube. The talc stimulates an adhesive obliterative pleuritis. Austin and Flye[54] reported an overall 90% effectiveness for talc compared with 87% for tetracycline and 55% for tube thoracotomy alone in malignant pleural effusions. Thus, thoracoscopic tale poudrage is an effective option for managing symptomatic effusions; however, it usually requires general anesthesia in a high-risk population. Talc itself is inexpensive, but the charges for sterilization, general anesthesia, and the operating room can substantially increase the total cost. Talc can be simply administered by slurry through tube thoracostomy, but only a limited number of patients have been studied. Appropriate dosages, measures to ensure complete pleural distribution, and adverse effect profiles for slurry have not been determine.[55] Moreover, talc's overall effect on patient outcome in malignant pleural disease is questionable as evidenced by the poor survival in the patients of Ohri et al.[10] Currently, thoracoscopic talc poudrage is reserved for the selected symptomatic group that does not respond to other agents applied through closed tube thoracostomy.[54,55] It is also performed in those patients with good performance status and a reasonable expected survival.

Recurrent Pleural Effusions of Benign Etiology

Recurrent pleural effusions of benign etiology are frequently caused by heart failure, cardiac surgery, nephrotic syndrome, connective tissue diseases, and other inflammatory disorders. Thoracoscopy may be warranted when recurrent effusions cause symptoms and are not controlled by repeated large-volume thoracentesis. Usually, pleural biopsy specimens are obtained to exclude infectious or neoplastic etiologies, and pleurodesis is performed. Results are usually excellent when talc is used, with success rates varying from 65 to (is greater than) 90%.

Chylothorax

Thoracoscopy has changed diagnostic and therapeutic approaches to patients with chylothorax. Chylothorax is usually caused by trauma or malignancy (primarily lymphoma). Thoracoscopic exploration may precede or replace an open thoracotomy. If the torn thoracic duct is visualized (having the patient drink heavy cream about 1 hour prior to the procedure may facilitate its detection), it can be clipped or ligated endoscopically. Although survival is often limited in case of chylothorax from lymphoma, talc pleurodesis may provide satisfactory resolution of effusions and prevent deterioration of respiratory, nutritional and immunologic status.[18]

Parenchymal Applications

Spontaneous pneumotherax may occur in any individual, including those without existing lung disease. It is almost always caused by the rupture of a subpleural bleb or bullae.[55] The choice of treatment depends on the size, symptoms, presence of continued air leak and the recurrence rate. Small, asymptomatic pneumothoraces in patients with adequate cardiopulmonary reserve may be managed by simple aspiration or observation. If the pneumothorax is large or symptomatic, closed tube thoracostomy is the main therapeutic approach. But with a recurrence rate of 30% after the first episode and even higher for each subsequent recurrence, this may not be effective.[56] Thoracoscopy provides an excellent alternative to repeated chest tube drainage in patients with recurrent or prolonged [usually (is greater than) 5 days] pneumothorax.[24] Thoracoscopy allows definitive treatment or inspection prior to performance of a lateral or axillary thoracotomy.[25] Various thoracoscopic techniques are available to manage spontaneous pneumothorax; namely talc poudrage, laser therapy and stapling. Thoracoscopic findings in patients with spontaneous pneumothorax include normal appearance, pleural adhesions, small blebs [(is less than) 2 cm] on the visceral pleural surface, and large bullae [(is greater than) 2 cm]. Lesions can be removed using electrocautery, argon plasma coagulation, or stapled lung resection, with results that are similar to those obtained after open thoracotomy (although the resulting pleurodesis may be

somewhat less effective: Recurrence rates are reportedly 5 to 10% *vs* only 1 to 3% after open thoracotomy.[26] Talc insufflation for pleurodesis may also be effective.[27] Although most operators perform these procedures using general anesthesia, thoracoscopic wedge resection of blebs and bulla using local anesthesia has been reported.[28]

Endoscopic photocoagulation by argon or neodymium: Yttrium-aluminum-gamet (ND:YAG) lasers can be used as curative therapy for pneumothorax. Torre et al coagulated blebs and partially scarred parietal pleura through the thoracoscope in 85 patients with spontaneous pneumothorax. There were no complications despite the use of general anesthesia. The average hospital stay was 5 days. Eighty (94%) patients were treated successfully by thoracoscopy and laser follow-up, 5 to 86 months. Thoracoscopy and laser failed early in two patients; both patients had lesions larger than 2 cm. Three other patients developed a later recurrance of pneumothorax. Each required thoracotomy.

Thoracoscopy, with its various modalities, is successful with a low recurrence rate for spontaneous pneumothorax. Some argue that the indications for operative intervention in the patient with a spontaneous pneumothorax have changed since the advent of the VATS technique.[39] Some surgeons now perform VATS sooner if chest tube thoracostomy is not effective by 72 hours.[39] We have been advocating, for various reasons, earlier surgical intervention for persistent air leak irrespective of which technique is employed. Nevertheless, it is still not clear that thoracoscopy is justified in patients presenting with a first episode of pneumothorax. It is clear that thoracoscopy is best suited for pneumothorax from small, visible blebs, whereas thoracotomy is still the surgical treatment of choice for the patient with known substantial bullous disease.[57]

Pulmonary metastasectomy may favorably influence survival in selected patients with certain tumors.[58,59] There are two patient populations that are considered for metastasectomy. The first group consists of patients who will not achieve a survival benefit from resection but in whom a diagnosis of metastatic disease is needed. The second group consists of those patients with a limited tumor burden who may achieve a survival benefit from metastasectomy. Currently, thoracotomy or median sternotomy are the standard surgical approaches for pulmonary metastasectomy. The operative morbidity varies from 5 to 14% and the hospital stay from 8 to 10 days in recent series using these open approaches.[58,60] Dowling et al[58] successfully performed VATS resection of select peripheral lesions in 72 patients by the use of an endostapler, laser, or both. The mean diameter of the resected lesions was 1.6 cm (range, 0.2 to 4.3 cm). The lesions were resected and each had a tumor-free margin of at least 1 cm. The mean duration of chest tube placement and hospital stay were 2.1 and 4.1 days respectively. Seven patients (10%) experienced a complication (three patients had prolonged air leaks).

There are several limitations to the VATS approach. First, only peripheral lesions are accessible by this technique. Second, the operator cannot perform careful bimanual palpation of the lungs; thus, resection may be incomplete. In a retrospective study, Roth et al[61] noted that 45% of patients with unflateral metastases present on preoperative chest computed tomography were found to have bilateral metastases present at median stemotomy. Confirmation of equivalent survival by randomized trials among the various surgical approaches for metastasectomy is required before the reported reduced morbidity and length of stay afforded by the thoracoscopic technique can be of significant benefit to the patient.

Emphysematous bullae that compromise aerating adjacent lung can adversely affect patients with limited pulmonary reserve. Although some authors advocate surgical management of diffuse emphysematous disease,[11,62] the main indication for operation in patients with bullous emphysema is the presence of giant bullae.[9] Bullectomy may benefit selected patients if the bullae occupy a significant portion of the hemithorax, and the structure and function of the remaining lung parenchyma are preserved. Wakabayashi et al[11] described 22 patients who underwent thoracoscopic ablative bullectomies with the carbon dioxide (CO_2) laser technique. Patients in this study had advanced emphysema with poor lung mechanics (mean forced expiratory volume in 1 second = 26% predicted). Two patients died postoperatively (one myocardial infarction, one pneumonia); thus, the perioperative mortality was nearly 10%. Three (14%) patients required subsequent thoracotomies for complications but did well. All patients reported improved dyspnea postoperatively. Postoperative pulmonary function tests were available at up to 3 months in 11 patients. FEV_1, FVC, and exercise treadmill times increased significantly indicating objective improvement. Nevertheless, an ill-defined patient selection, prolonged air leaks (mean 13 days), insufficient follow-up data, and the high perioperative surgical mortality in this series make thoracoscopic CO_2 laser bullectomy very controversial.

Kaiser[39] performed 23 consecutive VATS bullectomies for giant bullae and had no mortality. All patients reported functional improvement. Long-term outcome remains to be determined, however, the best candidates for bullectomy are those patients with a striking progression in the size of the bullae with a concurrent decrement in pulmonary function over a relatively short period of time.[39] Larger,

controlled studies are certainly necessary before thoracoscopic ablation can be advocated for the large number of high-risk patients with emphysematous bullous disease.

Lobectomy for localized lung carcimoma is possible using current VATS technology. Kirby et al[6] described successful VATS lobectomy with lymph node staging in 35 of 41 (85%) study patients. Patients were placed in the lateral position for possible posterolateral thoracotomy. Initially, a thoracoscopy port was placed in the seventh or eighth intercostal space in the anterior axillary line. A zero-degree thoracoscope with a video camera was introduced into the pleural space. A second thoracoscopy port was then placed in the eighth or ninth intercostal space in the posterior axillary line. Next, a 6 cm access minithoracotomy incision was placed just below the tip of the scalpula through which larger thoracic instruments could be introduced into the chest. Whenever possible, a muscle-sparing incision was used. This nonrib spreading access incision allowed for better inspection and palpation of the lung, both of which are limitations of the VATS approach. To ensure proper staging of the lung cancer, multiple biopsy specimens of hilar and mediastinal lymph nodes were obtained, in particular in those few patients who had not undergone a staging mediastinoscopy. This VATS technique also allowed for biopsy specimens of lymph node stations that are not readily accessible by mediastinoscopy. These stations include the posterior subcarinal, paraesophageal hilar and inferior pulmonary ligament nodes. This nonrib spreading access incision also allowed for the safe removal of the resected specimen. The special technical considerations for each lobe resection are available in more detail.[6] Of the 41 patients, no major intraoperative complications occurred. Six (14%) patients required conversion to open thoracotomy because VATS lobectomy proved technically impossible. The 35 patients who underwent VATS had an uneventful recovery with a mean hospital stay of 5.7 days. This study indicates that VATS lobectomy is technically accomplishable, but subsequent analysis of cancer recurrence rate and survival data is forthcoming. The VATS approach has not yet been proved superior to standard thoracotomy for lung cancer resection.

In a subsequent prospective, randomized trial, 72 involving 61 patients with presumed clinical stage I non-small cell lung cancer, VATS lobectomy was directly compared with muscle-sparing thoracotomy with lobectomy. Six patients were excluded because of nonmalignant disease (three) or because an attempted VATS lobectomy was converted to thoracotomy (three). There were no significant differences in the operating time, intraoperative blood loss, duration of chest tube drainage, length of hospital stay, or disabling postsurgical pain. More complications occurred in the thoracotomy group. Insufficient time has elapsed to report on the long-term local control and survival in each group. This study underscores the importance of not supplanting accepted open procedures with a VATS operation because of purported advantages and limited evidence of equivalence.

Other Operative Applications

Thoracoscopic esophagomyotomy is a new approach for treating achalasia. Thoracotomy or laparotomy can necessitate significant hospital stays.[4] Medical management by esophageal dilation is occasionally complicated by perforation. Peuegrini et al[4] successfully completed 17 of 19 (89%) cases for achalasia by either a VATS (15) or a laparoscopic (2) Heller myotomy. Two (11%) cases necessitated open procedures. The mean hospital stay was 3 days, the mean lower esophageal pressure was lowered from 32 to 10 mm Hg postoperatively, and no deaths or major complications were reported. In the successful cases, short-term results with regard to dysphagia were excellent or good in 14 (82%), fair in 2 (12%) and poor in 1 (6%). Three (21%) of the 14 patients with initial excellent or good results required a second procedure. Long-term outcome data are not reported.

Pericardial effusions, malignant or benign, can be addressed by the less invasive thoracoscopic pericardiectomy. Under single-lung ventilation using a double-lumen endotracheal tube, thoracic surgeons can obtain an excellent view of the mediastinum. To relieve tamponade, a pericardial window of suitable size is cut. Pericardial fluid is then aspirated from the thorax and an intercostal drain is left for further decompression.[5,64] Hazelrigg et al[65] used VATS to perform pericardiectomy in 35 patients after failed medical management and pericardiocentesis. There were no intraoperative and only four postoperative complications (two dysrhythmias, two pneumonias). Although palliative to terminal patients, thoracoscopy may decrease the number of thoracotomies and limit hospitalizations for malignant pericardial disease.[65,66] Its superiority to the subxiphoid pericardial window for both benign and malignant pericardial disease, however, has not been shown.[76]

Mediastinal Tumors

A thoracoscopic approach has been advocated for patients with posterior and middle mediastinal tumors. Access can be difficult, however, and it may be necessary to convert to open thoracotomy in (is greater than) 10% of instances.[29] Postoperative hospitalization is often less than after thoracotomy, but conversion should not be delayed if there is bleeding, the lesion cannot be appropriately exposed, or tumors are large.

Vasospastic Disease

Thoracoscopic sympathectomies are performed using either electrocautery, dissection, or excision in patients with Raynaud's syndrome, causalgia or essential hyperhydrosis.[30] Exposure is usually through the anterior chest wall, and procedures can be performed bilaterally at a single setting.[31]

Bullectomy and Lung Volume Reduction Surgery

Thoracoscopy is an accepted modality for lung volume reduction surgery, with results that appear similar to those obtained after median sternotomy.[34] Endoscopic stapling can be performed with or without buttressing staple lines. Results of bilateral procedures appear better than unilateral procedures, and costs are often less than with median sternotomy.[35] Although improvements in pulmonary function, exercise performance, and quality of life have been noted,[36] FEV_1 often deteriorates toward baseline prelung resection values within 2 years. The role of thoracoscopy *vs* median sternotomy for bilateral lung volume reduction surgery is currently being evaluated in various trials.

Chest Trauma

Thoracoscopy provides an effective and safe modality by which to initially evaluate and often manage stable patients with blunt or penetrating chest trauma.[37] Diaphragmatic injury, hemothorax, and lung parenchymal lacerations can be treated, although difficulties associated with active bleeding, suboptimal single-lung ventilation, or intense pleural inflammation should prompt conversion to an open thoracotomy.

Cardiovascular Disease

Thoracoscopy can be used for ligation of a patient ductus arteriosus,[38] as well as to harvest internal thoracic artery in patients undergoing coronary bypass grafting.[39] A significant reduction in postoperative pain has been described, attributed to the absence of rigorous chest retractions. It is likely that many other applications for thoracoscopy-assisted cardiovascular surgery will emerge.

LIMITATIONS/ COMPLICATIONS AND FUTURE DIRECTIONS

The thoracoscopic approach to a variety of diagnostic and therapeutic problems has few limitations other than a need to demonstrate safety and cost-effectiveness compared with more conventional approaches.

Morbidity

Known complications of thoracoscopy include bleeding, empyema, wound infection, prolonged air leak, tumor seeding at the entry site and death.[7,11-14] It is difficult to summarize the overall complication rate because it depends on the indication, type of anesthesia, equipment, patient population and experience of the operator.

The incidence of subcutaneous emphysema with thoracoscopy ranges from 0.5 to 7%.[28-30] The risk of infection appears to be low, with only 5 (0.5%) infections recorded in a collected series of 1,145 patients.[10] Postoperative fevers were reported in 16% and persistent air leak in only 2% of 817 simple rigid thoracoscopies.[14]

In a retrospective series of 121 diagnostic thoracoscopies performed under general anesthesia, Page et al[9] reported a total complication rate of 9.1% (predominantly respiratory). In a prospective study of 102 diagnostic thoracoscopies performed under local anesthesia, Menzies and Charbonneau[2] reported 5.5% minor and 1.9% major complication rates. Kaiser and Bavaria[68] reported and overall 10% incidence of complications in their series of 266 various thoracoscopies.

Morbidity from thoracoscopic talc poudrage is minimal. Lange et al[69] studied patients 22 to 35 years after tale poudrage for spontaneous pneumothorax and found only a minimal restrictive pulmonary impairment. Fever (16%) and pain (9%) are other minor side effects from talc.[55] Additional complications, such as ARDS or acute pneumonitis (after high-dose intrapleural talc suspension rather than talc insufflation) have been reported, but are extremely rare.[70,71] Caution must be exercised in performing talc poudrage in the young patient, especially in potential lung transplant candidates, because the obliterative pleuritis and resultant fibrosis will complicate future thoracotomy.

Mortality

Boutin et al[72] reviewed 4,300 simple rigid thoracoscopies (mostly diagnostic) and reported a mortality rate of less than 1%. Page et al[9] reported 1 (0.7%) perioperative death among their 121 patients. Ohri et al[10] had 5 of 100 (5%) patients die postoperatively (mean age, 68 years). The VATS study group reported 38 (2.5%) deaths among their various 1,820 interventional cases performed at more than 40 institutions. No patient died intraoperatively in this collected series. Overall, perioperative mortality rates for thoracoscopy range from 0 to 9%.[2,7,1-11,14,73-75,82]

CONTROVERSIES IN THORACOSCOPY

Who should perform thoracoscopy, pulmonologists or thoracic surgeons—is a primary topic of debate. Thoracoscopy can be performed by a pulmonologist under local/regional anesthesia (medical thoracoscopy) or by a thoracic surgeon under general anesthesia (video-assisted

thoracic surgery). Techniques of thoracoscopic pleural biopsy, fluid drainage, and pleurodesis are now recognized components of the interventional pulmonologist's practice. Unquestionably, most therapeutic and operative procedures are the domain of the thoracic surgeon. It is imperative, therefore, that the pulmonologist and thoracic surgeon have a close working relationship to ensure proper patient care. At this time, it is unclear which anesthesia technique is best for 'diagnostic' thoracoscopy. Several large series confirm its efficacy and safety under local anesthesia.[2,24,74] Nevertheless, performing thoracoscopy in an operating room with assistance from the anesthesiologist, using single-lung ventilation, and the ability to move quickly to open thoracotomy has distinct advantages. However, the operating room approach is more time-consuming and expensive.

Disagreement exists regarding the appropriateness and timing of thoracoscopy for routine investigation of effusions of unknown origin. Management of patients with suspected malignant effusion varies-recommendations range from observation to progressively invasive procedures culminating in a thoracotomy. Currently, thoracoscopy is employed after several attempts by conventional pleural sampling are nondiagnostic. Thoracoscopy does increase the diagnostic yield for both benign and malignant disease. Preoperative patient characteristics (such as history of malignancy at any time) and clinical data that are predictive of finding malignancy at thoracoscopy have been identified.[15] Knowledge of such features will aid patient selection. The impact of thoracoscopy on the long-term outcome of patients having malignant pleural disease is uncertain. Given the poor prognosis of patients with malignant pleural disease, one can argue that the utility and necessity of diagnosing pleural malignancy by thoracoscopy is questionable until further therapeutic options are developed. VATS wedge resection is being used to treat stage I lung carcinoma.[6] It is essential to safeguard against inadequate resection of non-small cell lung carcinoma because this compromises definitive cure.[5] The local recurrence rate with only 1 cm surgical margins is greater than 20%.[76] The lung cancer study group[77,78] data were recently analyzed to compare the effectiveness of wedge resection with lobectomy in the management of stage I non-small cell carcinoma. Patient survival was equivalent between groups, but local recurrence was 25% greater in the lesser wedge resection group.[77-80] It seems prudent, pending further data, that lobectomy be performed if adequate pulmonary function is present.[5,6,79,81]

VATS lobectomy is technically feasible. There is an insufficient number of controlled studies proving that VATS resection with lymph node sampling provides adequate margins, equivalent recurrence rates, and comparable long-term outcome compared with the time-honored open thoracotomy with lymph node dissection. Further prospective trials are currently underway to directly compare VATS with open lobectomy for stage I non-small cell lung carcinoma. We do not routinely perform VATS lobectomy.

The issue of the expense of thoracoscopic surgery is becoming increasingly important. Although some studies suggest that VATS reduces postoperative pain and hospital stay,[7,8,36] a benefit in terms of health-care savings has not been clearly documented.[8,80,82,83] The disposable instrumentation and the video equipment are expensive. It is clear that attempts should be made to use more reusable equipment. Also, complications or inadequate results that require longer stays, subsequent interventions, or result in shorter survival must be accounted for in the final summation of cost. Finally, measuring direct costs alone may not reflect total benefits. Indirect benefits such as an earlier return to work are difficult to assess.

CONCLUSION

Modern thoracoscopy provides a potentially less invasive means to diagnose and to treat a variety of intrathoracic diseases. Simple rigid thoracoscopy is safe and effective for the diagnosis of benign and malignant pleural disease. It is useful for therapeutic procedures, such as pleurodesis and uncomplicated empyema drainage. Current endoscopic and VATS techniques have the potential to limit morbidity and reduce hospital stays for major operations. This ability, however, provides the potential for its overuse. Thoracoscopy's ultimate acceptance should be based on the results of controlled, randomized trials. Further questions still remain regarding its patient selection, operators, timing, effects on long-term outcome and cost-effectiveness.

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