Study objective: The presence of pleural adhesions may render video-assisted thoracoscopic surgery (VATS) difficult or impossible. The aim of this study was to assess the value of chest CT in the detection of pleural adhesions prior to VATS.

Design: Prospective study of the accuracy of chest CT in detecting pleural adhesions prior to VATS.

Setting: Tertiary-referral teaching hospital and Veterans Administration hospital.

Patients: Between July 1994 and March 1995, 63 consecutive patients undergoing 64 VATS procedures were evaluated with chest CT prior to surgery.

Measurements and results: Preoperative scans were interpreted by consensus of two pulmonary radiologists prior to surgery. Suspected pleural adhesions and other findings related to the pleura were recorded on a form given to the surgeon prior to VATS. The surgeon confirmed or excluded each suspected adhesion during VATS, and documented any other lesions not identified preoperatively. Patient-by-patient and lesion-by-lesion analyses were performed. Pleural adhesions were correctly identified by CT in 28 of 39 cases (sensitivity, 71%) and excluded in 18 of 25 cases (specificity, 72%). On a lesion-by-lesion basis, 73 adhesions were identified during VATS, of which only 28 were identified prospectively at CT. There were 45 missed adhesions and 20 adhesions that were suggested falsely (sensitivity, 38%; specificity, 46%). Eighteen pleural spaces were correctly identified as being free of pleural adhesions.

Conclusions: CT is moderately sensitive and specific for preoperative identification of pleural adhesions in patients undergoing VATS but its accuracy is poorer for individual lesions.

Key words: CT; pleural adhesions; video-assisted thoracoscopic surgery

Abbreviations: HRCT = high-resolution CT; VATS = video-assisted thoracoscopic surgery

Video-assisted thoracoscopic surgery (VATS) has become an important tool for the thoracic surgeon and has gained widespread acceptance. Adhesions between the visceral and parietal pleura prevent the lung from collapsing when air or carbon dioxide is introduced into the pleural space at the start of thoracoscopy. Adhesions may be filmlike and flimsy, needing blunt dissection, or thick and vascularized, requiring cautery. Pleural adhesions increase the risk of lung injury from the video-telescope and in severe cases prevent access to the pleural space, requiring conversion to open thoracotomy. The aim of this study was to evaluate prospectively the utility of thoracic CT scans in the detection of pleural adhesions prior to VATS.

Materials and Methods

The study population consisted of 63 consecutive patients with available CT scans who were referred to the thoracic surgeon (MJK) and presented between July 1994 and March 1995. Sixty-four thoracoscopic procedures were performed because one patient had a metastatectomy performed on each lung at separate operations, and had separate CT scans performed prior to each VATS procedure. There were 41 men and 22 women, with a mean age of 54 years (range, 23 to 82 years). The indications for the 64 VATS procedures were node resection.
(n = 22), biopsy of interstitial lung disease (n = 12), staging for lung cancer (n = 13), emphysema surgery (n = 7), empyema decortication (n = 6), pleural biopsy (n = 3), and pericardial biopsy (n = 1).

The pleura on the side of the planned surgery was evaluated at CT for the presence of adhesions by the consensus of two thoracic radiologists. There are no accepted definitions in the literature for pleural adhesions as an entity distinct from pleural thickening. Indeed, without intervening fluid the normal parietal and visceral pleura cannot usually be resolved as separate structures. We chose the following criteria for predicting the presence of adhesions based on the CT literature concerning pleural disease and pleural thickening in general:16 (1) pleural thickening > 3 mm; (2) high attenuation or enhancing bands in pleural fluid or loculation of pleural effusions; (3) subpleural interstitial disease with visceral pleural retraction or associated pleural thickening; (4) signs of empyema including visceral and parietal pleural enhancement with intervening fluid (split pleura sign); and (5) bands crossing a pneumothorax. If any of these findings was present, an adhesion was recorded. Chest radiographs were not part of the evaluation.

The CT scan technique was not standardized. CT scans were performed at outside institutions in 10 patients. At our institution, CT scans were performed for a variety of indications; some required the use of contrast or high-resolution computed tomography (HRCT) techniques. There were 27 contrast-enhanced CT scans and 37 noncontrast CT scans. HRCT was performed in 12 patients, 6 of whom also had conventional CT scans. All scans were performed within 1 month prior to the VATS procedures. Positions of adhesions, as predicted from the CT scans, were marked on frontal, posterior, and lateral diagrams of the lungs by bronchopulmonary segment locations. Any other relevant findings, such as pneumothorax, pleural fluid, or calcification, were also noted. A judgment was made as to whether adhesions were vascular or nonvascular on contrast CT scans.

To correlate with findings at surgery, a grading system for size of adhesions was used (Table 1). This scheme was devised so that both the radiologist using CT and the surgeon using VATS could approximate the size of adhesions by using the surface area of lung covered.

Correlation with CT was obtained at VATS by a single surgeon (MJK) who used the diagrams to decide if the CT findings concerning adhesions were correct. The positions of all adhesions found at VATS were marked on the diagrams submitted by the radiologists and, where possible, photographs were taken for radiologic-pathologic correlation (Fig 1). The surgeon recorded whether adhesions were vascular or nonvascular. The presence or absence of pleural fluid, calcification, and subpleural lung findings was also documented. The technique used for VATS was as described elsewhere.1,2

Table 1—Grading System Used for Extent of Adhesions by Radiologists and Surgeon

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>No adhesions, complete lung collapse with artificial pneumothorax prior to VATS</td>
</tr>
<tr>
<td>1</td>
<td>Less than the surface area of one bronchopulmonary segment covered by adhesions</td>
</tr>
<tr>
<td>2</td>
<td>At least one bronchopulmonary segment covered by adhesions, but less than the surface area of one lobe (lingula counted as a separate lobe)</td>
</tr>
<tr>
<td>3</td>
<td>At least the surface area of one lobe covered by adhesions, but less than complete symphysis (fusion) of the visceral and parietal pleura</td>
</tr>
<tr>
<td>4</td>
<td>Complete symphysis of the pleural surfaces</td>
</tr>
</tbody>
</table>

Statistical Analysis

The diagrams of radiologically predicted and VATS-detected adhesions were used to calculate the sensitivity and specificity of CT for detecting adhesions, using both patient-by-patient and lesion-by-lesion analyses.

In patient-by-patient analysis, simple presence or absence of adhesions for each patient was used to categorize true positives and true negatives. If adhesions were falsely suggested by CT, the patient was categorized as a false positive in the patient-by-patient analysis. A false negative occurred if one or more adhesions were found at VATS and the CT was read as negative. A true positive was recorded if both CT and VATS showed pleural adhesions, but a precise match of location and number was not required. In the lesion-by-lesion analysis, any area of pleural adhesions missed or undergraded by CT was deemed a false negative. A false positive was defined as any difference in grading in which the radiologists overestimated the degree of adhesions found during VATS.

To analyze the accuracy of CT prediction of the grade of adhesions, simple percentage agreement between VATS and CT was calculated. A weighted kappa statistic was also calculated to assess the correlation between CT and VATS for the grading of pleural adhesions.7,8

![Figure 1. Top: contrast-enhanced CT scan in a 77-year-old woman shows nodular pleural thickening around the right lower lobe extending into the major fissure. Prospective evaluation predicted extensive pleural adhesions (true positive). Bottom: video camera image from VATS decortication and biopsy procedure performed the next day. Pleural synchisys is present with extensive gelatinous adhesions coating the visceral pleural surfaces. A cautery probe is seen.](image-url)
Receiver operating characteristic analysis was not used in this study because the emphasis was on the agreement between radiologist observation (CT) and VATS. VATS was not considered to be a true gold standard, and adhesions were documented when and as seen. The surgeon had access to the radiologists' observations in the operating room.

**Results**

**Patient-by-Patient Analysis**

Eighteen pleural spaces were correctly predicted to be free of adhesions (true negatives). In 28 patients, CT correctly suggested the presence of adhesions in the operated pleural space. Seven patients had one or more adhesions that were suggested by CT but could not be confirmed during VATS. In 11 patients, one or more adhesions were seen during VATS but the CT of the pleura was deemed to be normal. These results yield a sensitivity of 71% and a specificity of 72% for CT in detecting adhesions on a per-patient basis. Grading of adhesion severity was not considered here.

**Grading of Adhesion Severity**

Complete pleural symphysis or fusion of the pleural surfaces (grade 4 adhesions) was detected during VATS in nine of our cases (14%). The final pathologic diagnoses in these patients were empyema (n = 4), lung cancer (n = 2), and pleural or pericardial malignancy (n = 3). We correctly predicted symphysis in two of nine cases (sensitivity, 22%). Two patients were interpreted to be completely free of adhesions based on CT, but had symphysis identified during VATS. No patient was read as falsely positive for symphysis (specificity, 100%). There were several different outcomes in the symphysis group. In four patients, debridement and decortication for empyema was possible using VATS. Conversion to open thoracotomy occurred in two patients because the VATS procedure could not be performed. Limited biopsies using VATS were possible after extensive dissection in the other three patients.

**Lesion-by-Lesion Analysis**

A total of 73 adhesions were found at VATS in the 64 procedures. There were 28 CT true positives, 45 false negatives, 20 false positives, and 17 true negatives (sensitivity, 38%; specificity, 46%). At least one adhesion was missed on CT in 30 patients, at least one adhesion was suggested falsely on CT in eight patients, and a completely correct pattern of adhesions was predicted in nine patients.

**Contrast vs Unenhanced CT (Lesion-by-Lesion)**

In the 27 patients whose CT scans were done with IV contrast, 5 of the 26 adhesions seen during VATS were identified correctly and 21 were missed by CT (sensitivity, 19%; specificity, 41%). In the 37 patients whose CT scans were performed without contrast, 47 adhesions were detected at VATS; 23 adhesions were identified correctly and 24 were missed by CT (sensitivity, 49%; specificity, 50%). In the 27 patients who underwent contrast CT, only 1 of 11 vascular adhesions (9%) was correctly identified as showing enhancement. Four vascular adhesions were incorrectly thought to be nonvascular, and the remaining six were missed entirely by CT.

**HRCT Scans**

HRCT scans were obtained in 12 patients who had 20 adhesions detected at VATS; 6 adhesions were true-positive and 14 were false-negative on CT (sensitivity, 30%; specificity, 43%). In the non-HRCT group of 52 procedures, there were 53 adhesions, 22 of which were true-positive and 31 of which were false-negative on CT (sensitivity, 41%; specificity, 47%).

**Size of Adhesions**

Table 2 shows the cross-correlation data between VATS and CT for size of adhesions based on the five-point grading scheme (Table 1). The percentage agreement between VATS and CT for surface area of lung covered by adhesions was 48%. The weighted kappa was 0.38, corresponding to fair agreement.

**Other Findings**

Of the specific signs used to predict adhesions on CT in the present study, areas of pleural thickening were present in 28 cases, bands in pleural fluid in 3 cases, pleural disease associated with underlying interstitial lung disease in 6 cases, evidence of empyema in 3 cases, and bands within a pneumothorax in 3 cases. Bands within pleural fluid were seen during VATS in six cases; in only three of these cases were bands prospectively predicted by CT. In all

<table>
<thead>
<tr>
<th>CT</th>
<th>0</th>
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<tr>
<td>VATS</td>
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*Complete agreement is shown along the diagonal. Percentage agreement = 48%. Weighted kappa statistic (intraclass correlation coefficient) = 0.38.
three cases where a pneumothorax was seen on the preoperative CT, the correct pattern of adhesions was predicted. Calcification of the pleura was seen on seven preoperative CT scans. During VATS, three of these were asbestos-related plaques, which typically do not cause adhesions unless associated with diffuse asbestos-related pleural thickening. The adhesions seen during VATS in these patients did not correlate with sites of calcification. Another patient had calcifications that appeared inflammatory in origin on CT and that correlated with an area of adhesions seen at VATS. There were three cases where CT predicted small calcifications and no calcifications were seen during VATS.

**DISCUSSION**

The detection of pleural adhesions prior to surgery has received little attention in the radiology literature. Hansell and Strickland\(^9\) made brief reference to HRCT detection of adhesions in cystic fibrosis patients and possible complications at lung transplantation caused by adhesions. More recently, it has become clear that even the presence of severe pleural adhesions does not preclude pleural thickening identified by preoperative CT might predict difficulty inserting the instruments. VATS may be used to access each pleural space prior to lung stapling during lung volume reduction surgery, and adhesions may prevent the completion or reduce the success of this procedure.\(^11\) In addition to surgical procedures, intraparenchymal placement occurs in 1.5 to 12% of chest tube insertions, often because of pleural adhesions.\(^12\) If a CT scan were available prior to tube placement, a safe site for placement might more easily be selected.

Articles on CT of the pleura have addressed the issue of the diagnosis of inflammatory and neoplastic disease and have established criteria for the diagnosis of pleural thickening.\(^5,6\) Most inflammatory and neoplastic pleural diseases result in adhesions between the visceral and parietal pleura. Given the filmy and nonvascular nature of many adhesions when dissected at surgery, it is not surprising that CT is unable to resolve them separately from the pleural surfaces. This study confirms that the presence of adhesions may often be surmised by accompanying pleural thickening. However, there are many cases in which adhesions are present even though pleural thickening is not detected by either CT or VATS. Conversely, pleural thickening may be present on CT despite the absence of adhesions identified during VATS.

Pleural adhesions were correctly identified in 28 of 39 cases and excluded in 18 of 25 cases when the data were analyzed on a patient-by-patient basis. Analysis of the data on a procedural or patient-by-patient basis is in keeping with other thoracic surgical–radiologic correlation studies in the literature. While it is not as rigorous a standard as a lesion-by-lesion approach, it may be of more practical benefit. The surgeon is generally not concerned about each individual adhesion or grading of adhesions, but the knowledge that there is a high probability of some adhesions is of value. The surgical approach might then be modified accordingly.

CT is of only moderate utility in predicting adhesions seen during VATS, and complete symphysis can occur with a normal pleural appearance on CT. However, if the surgeon had used the CT scan to determine his approach, no patient in this series would have been inappropriately prevented from undergoing a thoracoscopic procedure because there was no case of a false-positive complete pleural symphysis. Indeed, the tendency in both this group of patients and the study group overall was to underestimate the extent of fusion between the pleural layers on preoperative CT scanning (Table 2). Symphysis is not necessarily a contraindication to VATS. It is to be expected in cases of empyema where the intention is to perform a thoracoscopic decortication. Pleural symphysis occurred in each of the four cases of empyema in this series.

An accompanying pneumothorax noted on CT was more valuable than pleural thickening in correctly predicting adhesions at VATS, but was seen in only three cases. An artificial pneumothorax is created by the surgeon prior to VATS. In order to take advantage of the superiority of better visualization of adhesions with pneumothorax on CT, a pneumothorax could be produced carefully with a blunt needle prior to CT. This could be done in conjunction with the VATS procedure. Pneumothorax could be used to check for complete lung collapse or presence of adhesions in cases where adhesions are strongly suspected.

In this study, IV contrast and HRCT did not significantly improve the detection of adhesions. However, the numbers in the HRCT and contrast groups were small. Those patients who underwent only HRCT (n = 6) might have been limited by sampling error because our protocol for HRCT usually involves 1-mm thick sections at 10-mm intervals.
Contrast-enhanced CT was very poor at predicting whether adhesions were vascular (9%). Nevertheless, the absence of any false-positive vascular adhesions in contrast CT scans suggests that any pleural enhancement should be regarded as significant. Theoretically, spiral CT in the arterial phase might be more sensitive for vascular pleural adhesions.

Our study has several limitations. In 10 cases, CT scans were performed at outside institutions, and no repeat CT scan tailored to look at the pleura was obtained for these patients. The CT scan technique was not standardized, which led to variability in slice thickness and the use of contrast or the HRCT technique. These factors could have led to some underestimation of the extent of pleural thickening. However, this variation in technique reflects clinical practice, because different scan protocols are used depending on the indication for thoracic CT.

In this study, surgery was used as the standard of reference to assess adhesions. Reduced visualization in difficult cases may decrease the accuracy of complete pleural assessment by VATS. Bias could have occurred in cases in which dense adhesions were present at the entry point. The tendency might thus be to overestimate the extent of adhesions during VATS in the rest of the pleural space. Whether such bias was present cannot be proved without open thoracotomy. In those patients whose VATS procedures were converted to thoracotomy (n = 2), the estimate during VATS of the extent of adhesions was correct.

Finally, the surgeon was not blinded to the CT reading and thus could have been biased by knowledge of the CT scan findings. Given the numerous disparities in the lesion-by-lesion analysis between CT and VATS, however, we consider this an unlikely source of bias.

In conclusion, CT is moderately sensitive and specific for the detection of pleural adhesions prior to VATS. Because most patients have a CT scan prior to surgery, the surgeon is likely to find observations on CT useful with respect to the possible presence or absence of adhesions and sites of pleural disease. If the surgeon requires more accurate preoperative assessment of the site and extent of adhesions, a diagnostic pneumothorax in the radiology department or in the operating room followed by CT might be considered.

REFERENCES

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