Videothoracoscopy Versus Thoracotomy for the Treatment of Spontaneous Pneumothorax: A Propensity Score Analysis

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Background. Few randomized controlled trials have been published on outcomes after treatment of spontaneous pneumothorax. The objective of this study was to assess recurrence, pulmonary complications, prolonged air leak, and hospital duration of stay in patients undergoing videothoracoscopic surgery (VATS) or thoracotomy for spontaneous pneumothorax.

Methods. From January 2005 to December 2012, 7,396 patients underwent operations for spontaneous pneumothorax and were entered into the French national database. The propensity score, which is the conditional probability of assignment to a particular treatment given a vector of observed covariates, was used for the analysis. Three statistical analyses were performed: matching, subclassification, and the inverse probability of treatment weighting. The primary end point was recurrence, defined as a pneumothorax requiring a chest tube or new operation. The secondary end point was pulmonary complications, prolonged air leak, and hospital duration of stay.

Results. VATS was performed in 6,419 patients and thoracotomy in 997 patients. Pleurodesis was performed by abrasion or pleurectomy in 5,873 patients (79%) and by using a chemical agent in 1,523 patients (21%). The median time to recurrence was 3 months (range, 1 to 76 months). The recurrence rate was higher in the VATS group regardless of the statistical analysis that was used: 2.1 for unmatched samples, 2.5 for matched samples, 2.3 for subclassification, and 1.7 for the inverse probability of treatment weighting. VATS significantly reduced the hospital duration of stay by 1 day but did not significantly reduce pulmonary complications or prolonged air leak.

Conclusions. VATS reduced the hospital duration of stay, but the risk of recurrence was higher. This information should be delivered to patients before pneumothorax operations.

(Ann Thorac Surg 2015;99:258–64) © 2015 by The Society of Thoracic Surgeons

Spontaneous pneumothorax (SP) remains a significant health problem because of the high recurrence rate during thoracic drainage and conservative treatments [1]. SP can appear under two forms: primary SP occurs in otherwise healthy patients, most commonly in tall, young, lean men, and particularly in those who smoke [2]. Secondary SP occurs as a complication of an underlying lung disease, which most often is chronic obstructive pulmonary disease [2, 3].

The British Thoracic Society guidelines defined the surgical indications accepted for SP [4] but did not clearly define recommendations for the surgical approach between open thoracotomy and video assisted thoracic surgery (VATS). A recent meta-analysis by Barker and colleagues [5] reported a fourfold increase in the recurrence of pneumothorax after VATS pleurectomy compared with open pleurectomy [5], but a second meta-analysis by Sedrakayan and colleagues [6] did not show this difference. Regarding advantages of VATS vs open thoracotomy, most authors reported low morbidity [7], a shorter hospital stay [6, 8–12], and less postoperative pain [9, 13–16]. But no data are available for prolonged air leaks and postoperative pulmonary complications. The objective of this study was to assess pneumothorax recurrence rate, postoperative pulmonary complications, prolonged air leak, and hospital duration of stay in patients undergoing VATS or thoracotomy for SP by analyzing the French practices from national clinical database of the French Society of Thoracic and Cardiovascular Surgery.
Patients and Methods

Data Collection

Epithor is a government-recognized clinical database, financially supported by the National Cancer Institute (Institut National du Cancer) for data-quality monitoring. Epithor is accredited by the French Health Authorities (Haute Autorité de Santé), a governmental agency dedicated to improving the quality of patient care and to guaranteeing equality within the health care system, as a methodologically appropriate tool to assess professional surgical practices. Participation in Epithor is now a requirement for medical accreditation and thoracic surgery unit certification in France [17]. The accuracy of data collection is checked in regular external on-site audits initiated in 2010. Data for this study were collected from 32 university hospitals, 16 nonuniversity hospitals, and 50 private hospitals, representing more than 70% of all thoracic surgical procedures performed in France annually.

Data are sent by the Internet to the national database; surgeons and patients are anonymous. Surgeons can check the quality of their data entries by comparing themselves against the national data through a quality score ranging from 0% to 100%. The exhaustive collection of the data is also guaranteed by the on-site quality audit that takes place in the departments involved in Epithor.

The French Society of Thoracic and Cardiovascular Surgery Institutional Review Board approved the electronic prospective database used for this study and the study itself. Patient consent was obtained for entry into the prospective database, and patients were aware that these data would be used for clinical research purposes. The French Society of Thoracic and Cardiovascular Surgery Institutional Review Board certified that this study respected the current regulations framing clinical research in France, referenced as “CERC-SFCTCV-2014-3-12-8-59-41-PAFL.”

Patients

From January 2005 to December 2012, 7,396 patients underwent operations for SP and were entered into the French national database. Of these patients, 977 were treated by open thoracotomy and 6,419 by VATS. Baseline demographics included age, gender, smoking, American Society of Anesthesiologists score, body mass index, medical history, and thoracic surgical history.

Three statistical analyses were performed: matching, subclassification, and the inverse probability of treatment weighting (IPTW) approach [19]. We evaluated the ability of three PS techniques to balance the measured covariates between VATS and thoracotomy by reducing the standardized bias [19, 20]. Our decision criterion considered a covariate balanced if the standardized bias was less than 0.1 [20]. The standardized bias is the difference of the sample means in the VATS and thoracotomy subsamples divided by the standard deviation in the full-treated group [21]. This three-PS technique reduced covariate imbalance and improved covariate balance across the treatment groups measured by standardized bias. The method is much better than the standardized bias and is close to 0 for each of the covariates across two groups.

Finally, the odds ratio was used for dichotomous variables such as recurrence, pulmonary complications, and prolonged air leak, and the difference of means was used for the hospital duration of stay. Logistic models and linear regression were used. For this study, we used three programs written for R software: “Matchit,” “Twang,” and “Zelig” (http://www.r-project.org).

Surgical Technique

Under general anesthesia and after selective endotracheal intubation, the patients were placed in the lateral decubitus position, and the ipsilateral lung was deflated. The approach for open thoracotomy was through the fifth intercostal space, and then apical pleurectomy or mechanical abrasion was performed. After lung exploration, apical stapling was performed.

For the VATS approach, a 10-mm fiberoptic scope was first inserted through the sixth or seventh intercostal space. Under endoscopic guidance, 2 additional trocars were introduced through the fourth and fifth intercostal spaces on the anterior and posterior axillary lines. Apical stapling was performed, followed by apical pleurectomy, mechanical abrasion, or chemical pleurodesis. At the end of each procedure, a chest tube was introduced through the most anterior port.
Table 1. Characteristics of Patients Undergoing Operations for Pneumothorax

<table>
<thead>
<tr>
<th>Variable</th>
<th>Thoracotomy Group (n = 977)</th>
<th>VATS Group (n = 6,419)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>Male</td>
<td>761 (78)</td>
<td>4,984 (77)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>216 (22)</td>
<td>1,435 (23)</td>
</tr>
<tr>
<td>Age, y</td>
<td>40 ± 17</td>
<td>32.5 ± 14</td>
<td>0.0001</td>
</tr>
<tr>
<td>Smoker</td>
<td>248 (25)</td>
<td>2,335 (36)</td>
<td>0.0001</td>
</tr>
<tr>
<td>ASA classiﬁcation</td>
<td>1</td>
<td>525 (54)</td>
<td>4,787 (75)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>302 (31)</td>
<td>1,267 (20)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>150 (15)</td>
<td>365 (5)</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>22 ± 3.5</td>
<td>21 ± 3</td>
<td>0.0001</td>
</tr>
<tr>
<td><strong>Respiratory history</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asthma</td>
<td>12 (1)</td>
<td>177 (3)</td>
<td>0.005</td>
</tr>
<tr>
<td>Chronic bronchitis</td>
<td>244 (25)</td>
<td>1,022 (16)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Emphysema</td>
<td>195 (20)</td>
<td>801 (12)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Chronic respiratory failure</td>
<td>45 (5)</td>
<td>90 (1)</td>
<td>0.0001</td>
</tr>
<tr>
<td><strong>Cardiovascular history</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>23 (2)</td>
<td>40 (0.6)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Cardiac arrhythmia</td>
<td>11 (1)</td>
<td>44 (0.7)</td>
<td>0.13</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>8 (1)</td>
<td>43 (0.7)</td>
<td>0.6</td>
</tr>
<tr>
<td>Peripheral arterial disease</td>
<td>20 (2)</td>
<td>40 (0.6)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Stroke</td>
<td>4 (0.4)</td>
<td>31 (0.5)</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Malignancy history</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malignant disease</td>
<td>37 (4.2)</td>
<td>147 (2)</td>
<td>0.005</td>
</tr>
<tr>
<td>Chemotherapy</td>
<td>21 (2)</td>
<td>64 (1)</td>
<td>0.002</td>
</tr>
<tr>
<td>Radiotherapy</td>
<td>13 (1)</td>
<td>38 (0.6)</td>
<td>0.009</td>
</tr>
<tr>
<td>Steroid therapy</td>
<td>2 (0.2)</td>
<td>11 (0.2)</td>
<td>0.8</td>
</tr>
<tr>
<td><strong>Surgical management</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior thoracotomy</td>
<td>101 (10)</td>
<td>349 (5)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Procedure</td>
<td>Pleurectomy or abrasion</td>
<td>910 (93)</td>
<td>4,963 (77)</td>
</tr>
<tr>
<td></td>
<td>Chemical pleurodesis</td>
<td>67 (7)</td>
<td>1,456 (23)</td>
</tr>
<tr>
<td>Bullectomy</td>
<td>562 (57)</td>
<td>4,242 (66)</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

* Continuous variables are shown as the mean ± standard deviation and categoric variables as number (%).

ASA = American Society of Anesthesiologists Physical Status Classiﬁcation; VATS = video-assisted thoracoscopic surgery.

Variables Used for PS Analysis

The 18 variables used to estimate the PS were age, sex, American Society of Anesthesiologists Physical Status Classiﬁcation, tobacco use, asthma, chronic bronchitis, emphysema, chronic respiratory failure, coronary artery disease, cardiac arrhythmia, history of peripheral vascular disease, history of malignant disease, steroids, previous thoracic operation, previous cerebrovascular accident, body mass index, bullectomy, and type of pleurodesis. Histories of cardiovascular and malignant disease were included because of their prevalence in secondary SP patients.

Results

Patient Characteristics

Of the 7,396 patients who met inclusion criteria, 977 (13%) were treated by open thoracotomy and 6,419 (87%) by VATS. Patient demographics and management are reported in Table 1. Briefly, patients treated by thoracotomy were older, fewer were smokers, and they had a higher body mass index, more comorbidities, more severe respiratory, malignant, and cardiovascular histories, and more a frequent history of thoracotomy (Table 1).

Description of the Procedures

The characteristics of the surgical procedure are reported in Table 1. Patients treated by thoracotomy underwent more pleurectomy or abrasion and less bullectomy. Mechanical pleural abrasion or pleurectomy was performed in 5,873 patients (79%), and chemical pleurodesis was performed in 1,523 (21%; Table 1).

PS Estimation and Application

This PS had area under the receiver operating characteristic curve of 0.77 (95% conﬁdence interval, 0.75 to 0.785). The distribution of standardized biases resulting from each of these three PS techniques is reported in Table 2. Two PS techniques, matching and subclassiﬁcation, met our decision criterion and balanced all of the measured covariates (Table 2). The median distribution of standardized biases was 0.0136 for the generic matching approach (quartile range, 0.03 to 0.034), 0.046 for subclassiﬁcation (quartile range, 0.038 to 0.057), and 0.0155 for IPTW (quartile range, 0.003 to 0.034). For the subclassiﬁcation method, the covariate balance was worse than for the other two methods (matching and IPTW; Table 2).

Outcome

SP recurred in 3.8% of patients (246 of 6,419) in VATS group and in 1.8% (18 of 977) in thoracotomy group.

Table 2. The Distribution of the Standardized Bias From the Three Methods to Measure the Quality of the Covariate Balance Between Video-Assisted Thoracoscopic Surgery and Thoracotomy

<table>
<thead>
<tr>
<th>Propensity Score Technique</th>
<th>Median*</th>
<th>Quartile 1–3</th>
<th>Patients (No.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matching</td>
<td>0.0136</td>
<td>0.003–0.03</td>
<td>7,256</td>
</tr>
<tr>
<td>Subclassiﬁcation</td>
<td>0.046</td>
<td>0.037–0.057</td>
<td>7,396</td>
</tr>
<tr>
<td>IPTW</td>
<td>0.0155</td>
<td>0.003–0.034</td>
<td>6,941</td>
</tr>
</tbody>
</table>

* Among the 18 variables of the propensity score, the standardized diﬀerences for the matching and IPTW methods between video-assisted thoracoscopic surgery and thoracotomy were close to 0. The covariate balance was thus satisfactory for these two methods.

IPTW = inverse probability of treatment weighting.
(unmatched sample). The median time to recurrence was 3 months (range, 1 to 76 months). The recurrence rate was significantly higher in the VATS group regardless of the statistical analysis used: 2.1 for unmatched samples, 2.5 for matched samples, 2.3 for subclassification, and 1.7 for the IPTW (Table 3). The rate of pulmonary complications was 8% (n = 535) for the VATS group and 12% (n = 119) for the thoracotomy group. Only after subclassification methods did VATS reduce significantly pulmonary complications (Table 3). VATS did not significantly reduce prolonged air leak (Table 3). After PS methods, hospital duration of stay was reduced by an average of 1 day in patients operated on by VATS (Table 3).

**Comment**

Primary SP is relatively common, with an incidence of 18.0/100,000 in men and 6.1/100,000 in women [1]. Surgical management to prevent the recurrence of a SP should be reserved for the second pneumothorax occurrence [22]. Surgical management of SP responds to practices guidelines edited by the British Thoracic Society in 2003, which described the open thoracotomy associated to pleurectomy as the gold standard technique to prevent recurrence of pneumothorax [23]. However since 1992, VATS has been widely adopted for lung and pleural diagnostic procedures and increasingly used for the management of pneumothorax [24]. The technical aspects are still the same regardless of the surgical access: the objective is to prevent recurrence by removing the causative blebs and bullae at the apex of the lung and to create a pleurodesis so that any future leaks cannot progress to pneumothorax [24]. Nowadays, VATS for the management of SP is considered an effective and safe technique by some authors [6, 25], with low morbidity and less pain than open thoracotomy [9, 14, 25]. However the recommendations to choose the surgical access were based on practice preferences of the surgeons represented at the consensus meeting, despite acknowledgment that existing clinical trials did not show that VATS was better than thoracotomy in the prevention of pneumothoraces [5]. Furthermore, no large-scale multicenter randomized control trials have been conducted at present to compare the VATS approach with open pleurectomy for the management of SP. Only three prospective randomized control trials have been conducted, which included fewer than 100 patients [9, 26, 27].

**SP Management**

Our study objective was to obtain a reflection of the practices in France for the management of SP: approximately 87% of the patients were treated by VATS, and 93% of VATS group and 77% of thoracotomy group were operated on with pleurectomy or abrasion instead of chemical pleurodesis. Because of the successful and well-tolerated VATS procedure, the use of surgical chemical pleurodesis will continue to decrease and would be reserved for patients who are unwilling or too unwell to undergo a VATS procedure [4]. However, no data from a randomized control trial are available concerning the pleurodesis technique whatever the surgical approach. In our study, no details are available concerning the type of chemical pleurodesis used or the exact number of pleurectomies or abrasions performed.

**Recurrence Rate**

Our study shows a significantly higher recurrence rate of pneumothorax after management by VATS: 3.8% of patients in VATS group vs 1.8% in thoracotomy group. These results were the same regardless of the type of PS analysis, except for the IPTW procedure, in which the reduction of the sample size with regard to the PS-matched samples could explain the absence of a significant difference. Barker and colleagues [5], in their meta-analysis, found a fourfold increase in the recurrence of pneumothoraces when a similar pleurodesis procedure was done with a VATS approach compared with an open approach, with randomized and non-randomized trials showing similar recurrence rates. Several studies reported no recurrence after pleurodesis by VATS [28–30], whereas other studies reported recurrence rates similar to ours [10, 31–33]. Moreover, several studies reported very high recurrence rates, higher than 6% [26, 34–36]. No technical differences in the pleurodesis procedure could explain this variability in the recurrence rate.

**Prolonged Air Leaks and Hospital Stay**

Concerning prolonged air leaks, we did not find any differences between the two surgical accesses, and VATS

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**Table 3. Different Outcome Variables in Favor of Video-Assisted Thoracoscopic Surgery**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Recurrence</th>
<th>Pulmonary Complications</th>
<th>Prolonged Air Leak &gt;7 Days</th>
<th>Hospital Stay (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unmatched sample</td>
<td>2.1 (1.3–3.66)*</td>
<td>0.65 (0.53–0.82)*</td>
<td>0.9 (0.7–1.17)</td>
<td>$-1.66 \ (-1.96 \ to \ 1.36)^{y}$</td>
</tr>
<tr>
<td>Matched sample</td>
<td>2.5 (1.4–4.3)*</td>
<td>0.83 (0.65–1.06)</td>
<td>1.17 (0.83–1.47)</td>
<td>$-0.9 \ (-1.2 \ to \ 0.6)^{y}$</td>
</tr>
<tr>
<td>Subclassification</td>
<td>2.3 (1.4–3.77)*</td>
<td>0.78 (0.62–0.98)*</td>
<td>1.05 (0.8–1.37)</td>
<td>$-0.96 \ (-1.26 \ to \ 0.66)^{y}$</td>
</tr>
<tr>
<td>IPTW</td>
<td>1.7 (0.8–3.5)</td>
<td>0.87 (0.65–1.16)</td>
<td>1.12 (0.8–1.6)</td>
<td>$-1 \ (-1.44 \ to \ 0.53)^{y}$</td>
</tr>
</tbody>
</table>

* $p < 0.05$, indicating a significant difference.

The 95% confidence interval is shown in parentheses.

IPTW = inverse probability of treatment weighting.
did not significantly reduce prolonged air leak. In 1998 Horio and colleagues [37] reported a study of 90 patients, 51 in the VATS group and 44 in the thoracotomy group. They documented a shorter postoperative duration of chest tube drainage after VATS for recurrent pneumothorax and a higher recurrence rate than with the transaxillary approach [37]. However, that study is old, and the number of patients was too low to conclude a shorter duration of chest tube drainage for the VATS approach.

All of studies in the literature reporting outcomes of VATS for SP show a significantly shorter hospital duration of stay for VATS than for thoracotomy [6, 9, 37]. Indeed, Sedrakyan and colleagues [6], in a meta-analysis of pneumothorax operations that included three trials, showed a significantly shorter hospital stay for the VATS group [6]. Our data showed the same tendency, with a reduction by an average of 1 day in patients operated on by VATS.

Postoperative Pulmonary Complications
Freixinet and colleagues [26] investigated pulmonary complications rates for 46 patients undergoing VATS and 44 undergoing an open transaxillary approach for primary SP. They did not find any significant difference between the two groups because the study population was too small. In our study, the rate of pulmonary complications was lower for the VATS approach (8% vs 12%), but this reduction was only significant after subclassification methods. We note that two randomized controlled trials reported the decrease in the forced expiratory volume in 1 second [38] was significantly less and the value of the partial pressure of oxygen [27] was higher in the days after a VATS approach than after thoracotomy. These observations might explain a tendency in the decrease of pulmonary complications after surgical management of pneumothorax by the VATS approach instead of the thoracotomy approach.

This study has several limitations, including the retrospective analysis and the lack of information regarding the pleurodesis technique, the type of thoracotomy, the original chest tube duration before removal, and symptoms or signs at presentation. For recurrences, only patients requiring a chest tube insertion or an operation were recorded. However, the large number of patients in both groups allows powerful comparisons. This study describes clinical practices of several years, including academic and nonacademic centers from the French Society of Thoracic and Cardiovascular Surgery database. We acknowledge that this is the first study on this subject to include so many patients. However, we cannot be certain that the PS neutralizes perfectly all the variables of confusion; for evidence, the three used methods do not give strictly similar results. Even though this study has a high level of evidence, its conclusions will never have the same strength as those of a multicenter randomized control trial.

With respect to the limitations, this study allows to conclude that the VATS approach for SP surgical management leads to a higher risk of recurrence, despite a shorter hospital stay and fewer pulmonary complications. As do Barker and colleagues [5], we think that the surgeon needs to inform the patient of this recurrence risk and to decide with the patient the appropriate approach for that person’s case. VATS seems to be a good option for pneumothorax operations given the expected benefits in terms of pain and pulmonary complications. In the light of our experience, VATS should be proposed to young patients who present with a primary SP, whereas the open thoracotomy approach should be reserved for patients who present with secondary SP, in whom we more frequently find larger bullae, which are easier to treat by thoracotomy.

We are grateful to all the French thoracic surgeons who participated in this study for their essential collaboration.

References


INVITED COMMENTARY

Using the French national database Epithor, Pages and colleagues [1] demonstrate that pneumothorax recurrences that require intervention occur more frequently among patients undergoing the video-assisted thoracoscopic surgery (VATS) approach than the open approach (VATS, 3.8%; versus open, 1.8%). The incidence of prolonged air leaks was not different between the two approaches and pulmonary complications were associated inconsistently with the approach depending upon the method of comparison. The authors should be applauded for presenting meaningful data that can be used in deciding how to approach surgically a patient with a spontaneous pneumothorax, particularly as it pertains to setting expectations. In the era of patient-centered care, it is important to have this type of data to allow for a balanced discussion regarding the VATS approach in managing a spontaneous pneumothorax.

Their analysis, at least by the subclassification method, also hints at the possibility that pulmonary complications are associated with the open approach. Given that prolonged air leaks were not associated with either approach and the VATS approach was associated with shorter length of stays, pulmonary complications in the context of the open approach could be inferred as being associated with prolonged length of stays. This subtle nuance is important because it underscores the need to focus on avoiding pulmonary complications with any approach, regardless of the development of a prolonged air leak.

In addition, in many large databases, aside from The Society of Thoracic Surgeons database, a distinction between a persistent parenchymal air leak and an airway bronchopleural fistula is not always made from a coding standpoint. As a result, the former may be miscoded, no further insight gained, and lessons on this complication