Pleural Tent After Upper Lobectomy: A Randomized Study of Efficacy and Duration of Effect

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Background. The object of this study was to assess the efficacy and maximum duration of effect of the pleural tent in reducing the incidence of air leak after upper lobectomy.

Methods. Two hundred patients who underwent upper lobectomy were prospectively randomized into two groups: 100 patients who underwent an upper lobectomy and a pleural tent procedure (group 1; tented patients) and 100 patients who underwent only an upper lobectomy and not a pleural tent procedure (group 2; untented patients). The preoperative, operative, and postoperative characteristics of both groups were compared. Then multivariate analyses were used to identify factors predictive of prolonged air leaks and their duration. The reduction of incidences of air leak in the two groups was subsequently compared during successive postoperative periods.

Results. No differences were detected between the two groups in terms of preoperative and operative characteristics. A significant reduction occurred in group 1 patients for the mean duration of air leak in days (2.5 vs 7.2 days; \(p < 0.0001\)), the number of days a chest tube was required (7.0 vs 11.2 days; \(p < 0.0001\)), the length of postoperative hospital stay in days (8.2 vs 11.6 days; \(p < 0.0001\)), and the hospital stay cost per patient ($4,110 vs $5,805; \(p < 0.0001\)). Logistic regression analyses showed that not having undergone a pleural tent procedure was the most significant predictive factor of the occurrence and duration of prolonged air leaks. A greater reduction in the duration of air leaks was observed before postoperative day 4 in group 1, and logistic regression analysis showed that having undergone a pleural tent procedure was the most significant predictive factor of air leaks that persisted for less than 4 days.

Conclusions. Pleural tenting after upper lobectomy was a safe procedure that reduced the duration of air leaks and the hospital stay costs. The benefit from that procedure was achieved before postoperative day 4.


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Parenchymal air leak is a frequent complication after upper lobectomy. One of the most plausible explanations for these leaks is that after upper lobectomy the raw surface of the remaining lung does not remain in opposition to the parietal pleura of the apex. The creation of a pleural tent eliminates a persistent apical pleural space and facilitates the sealing of air leaks. The favorable results of the pleural tent procedure, which are described in a previously published retrospective study [1], prompted us to investigate the effect of the pleural tent prospectively. Preliminary favorable results [2] prompted us to conduct an analysis of the effects of pleural tenting after upper lobectomy in a larger randomized series.

The objectives of this study were to assess the cost–benefit ratio of this procedure in a larger prospective randomized trial and to evaluate the duration of the maximum effect of pleural tenting in reducing air leaks after upper lobectomy.

Patients and Methods

Two hundred consecutive patients who underwent upper lobectomy (194 patients) and right upper bilobectomy (6 patients) for nonsmall cell lung carcinoma at our institution from June 1998 through January 2002 formed the database of this study. The first 50 patients of that population constituted the series reported in our previous analysis [2] of the effect of pleural tenting after upper lobectomy. Because of the conclusion of that study, we have been performing pleural tent procedures routinely after upper lobectomy. For this analysis, we decided to randomize an additional 75 patients to the group who did not undergo a pleural tent procedure.

Thus before an operation the patients were randomized into two groups: 100 patients who underwent an upper lobectomy and a pleural tent procedure (group 1; tented patients) and 100 patients who underwent only an upper lobectomy and not a pleural tent procedure (group...
Table 1. Preoperative Characteristics of Patients Undergoing Upper Lobectomies With Pleural Tent (100 Cases) and Without Pleural Tent (100 Cases)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Pleural Tent</th>
<th>No Pleural Tent</th>
<th>t Value</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>67.2 (8.5)</td>
<td>67.7 (9.2)</td>
<td>0.3</td>
<td>0.7</td>
</tr>
<tr>
<td>FEV1%</td>
<td>87.9 (17.3)</td>
<td>89.6 (24.9)</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>FVC%</td>
<td>95.7 (15.6)</td>
<td>100.0 (21)</td>
<td>1.7</td>
<td>0.1</td>
</tr>
<tr>
<td>FEV1/FVC ratio</td>
<td>0.72 (0.11)</td>
<td>0.70 (0.11)</td>
<td>1.1</td>
<td>0.3</td>
</tr>
<tr>
<td>COPD index</td>
<td>1.59 (0.26)</td>
<td>1.59 (0.33)</td>
<td>0.002</td>
<td>0.99</td>
</tr>
<tr>
<td>PpoFEV1%</td>
<td>71.5 (13.9)</td>
<td>72.7 (19.1)</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>FEF25%-75%</td>
<td>61.6 (25.7)</td>
<td>61.4 (30.3)</td>
<td>0.05</td>
<td>0.96</td>
</tr>
<tr>
<td>Pack-years</td>
<td>43.8 (26.7)</td>
<td>39.9 (26.3)</td>
<td>1</td>
<td>0.3</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>84/16</td>
<td>78/22</td>
<td>1.2a</td>
<td>0.3</td>
</tr>
<tr>
<td>Side (R/L)</td>
<td>56/44</td>
<td>47/53</td>
<td>1.6a</td>
<td>0.2</td>
</tr>
<tr>
<td>PaO2 (mm Hg)</td>
<td>80.7 (11.2)</td>
<td>80.4 (13.2)</td>
<td>0.1</td>
<td>0.9</td>
</tr>
<tr>
<td>PaCO2 (mm Hg)</td>
<td>38.2 (3.7)</td>
<td>39 (6)</td>
<td>1.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Results are expressed as means ± standard deviation unless otherwise indicated.

* a χ² test.

COPD index = chronic obstructive pulmonary disease index; F = female; FEF = forced expiratory flow; FEV1 = forced expiratory volume in 1 second; FVC = forced vital capacity; L = left; M = male; Ppo = predicted postoperative; R = right.

2 untented patients). Patients who underwent chest wall resection or required postoperative mechanical ventilatory support were excluded from the study.

The same surgical team performed the lobectomies by muscle-sparing thoracotomy at the fourth or fifth intercostal space. Mechanical staplers were used to develop incomplete fissures in 80 patients in group 1, in 77 patients in group 2, and to close the bronchus in all patients. Pleural tenting was performed according to the technique previously reported elsewhere [1−4] after completion of the lobectomy and mediastinal lymphadenectomy. From the upper border of the thoracotomy incision, the parietal pleura was dissected down from the endothoracic fascia of the parietal pleura and apex. After the dissection had been completed, the free pleural margin was sutured in its midportion to the intercostal margin (categorical variable).

Two chest tubes were positioned, one anteriorly and one posteriorly, in all patients. In the patients with a pleural tent, the tubes were directed under the tent. During the postoperative period, the chest tubes were placed on suction (−10/−20 cm H2O) and removed when the quantity of effusion was less than 200 mL in 24 hours and when no evidence of air leak was present (after a 24-hour clamping trial).

For the purpose of this study, air leaks that persisted for more than 7 days were termed prolonged. Furthermore, the following complications occurred within 30 days after the operation (or over a longer period if the patient remained hospitalized): atelectasis requiring bronchoscopy, pneumonia, pulmonary edema, adult respiratory distress syndrome, cardiac failure, arrhythmia requiring medical treatment, pulmonary embolism, myocardial infarction, metabolic complications, reoperation.

Statistical Analysis

Numerical variables of the two groups were compared by means of the unpaired Student’s t test, and the χ² test was used to compare categorical variables.

The following preoperative variables were considered: the patient’s age and gender, forced expiratory volume in 1 second (FEV1), forced vital capacity (FVC), FEV1/FVC ratio, forced expiratory flow during the middle half of the forced vital capacity (FEF25−75%), predicted postoperative forced expiratory volume in 1 second (PpoFEV1), index of chronic obstructive pulmonary disease (COPD), smoking (pack-years), side of tumor, arterial oxygen tension (PaO2), and partial pressure (tension) of arterial carbon dioxide (PaCO2).

From the upper border of the thoracotomy incision, the parietal pleura was resected and was estimated by computed tomographic scan and bronchoscopy [6]. If the calculated PpoFEV1 was less than 50% of the predicted value, a quantitative lung perfusion scan was performed according to Markos and colleagues [7].

The COPD index was calculated by adding the FEV1 value in decimal form to the FEV1/FVC ratio, according to Korst and colleagues [8].

Operative variables included the tumor size, the location of the tumor (central and peripheral), the presence of pleural adhesions, the length of the stapled parenchyma, and total operative time.

Postoperative variables included the duration of air leaks in days, the presence of a prolonged air leak, the duration of chest tube use in days, the quantity of pleural effusion during the first 48 hours after the operation, the number of units of postoperative blood transfused, the presence of other complications, the length of postoperative hospital stay in days, and the cost of hospital stay (estimated cost, $500 per day).

Stepwise logistic regression analysis was then performed to assess two models. In model 1 the dependent variable was the presence or absence of a prolonged air leak (categorical variable); in model 2 the dependent variable was the duration of the air leak (continuous variable). The predictors of a prolonged air leak in both models were the patient’s age, size of tumor, FEV1, FVC, FEV1/FVC ratio, PpoFEV1, COPD index, smoking (pack-years), presence of pleural tent or pleural adhesions, length of the staple line, PaO2, and PaCO2.

To identify the maximum duration of the efficacy of the pleural tent, we compared the reduction in the number of patients with air leak occurrence in successive postoperative periods (<2 days, <4 days, <6 days, <8 days, and <10 days, respectively for groups 1 and 2). These differences were assessed by means of Fisher’s exact test.

When groups 1 and 2 were compared, patients in group 1 (those with a pleural tent) had significantly fewer incidences of air leak than those in group 2 did before postoperative day 4 (see Results). A stepwise logistic regression analysis was performed on the entire database...
to identify factors predictive of an air leak that would persist less than 4 days after the operation (the dependent variable). The following independent variables were used: patient age, size of tumor, FEV₁, FVC, FEV₁/FVC ratio, FEF₂₅–₇₅%, PpoFEV₁, COPD index, smoking (pack-years), presence of a pleural tent or pleural adhesions, length of the staple line, PaO₂, and PaCO₂.

Statview 5.0 software (SAS Inc, Cary, NC) was used to perform all statistical tests, which were two-tailed with a significant level of 0.05.

Results

Tables 1, 2, and 3 show the results of comparing groups 1 and 2. No differences in preoperative and operative variables were detected. However, in group 1 (when compared with group 2), there was a 65.7% reduction in the duration of air leaks ($p < 0.0001$), a 56.2% reduction in the incidence of prolonged air leaks ($p = 0.002$), a 37.5% reduction in the duration for which a chest tube was required ($p < 0.0001$), a 29.2% reduction in the length of postoperative hospital stay ($p < 0.0001$), and a mean reduction per patient of $1,695 in the cost of hospital stay ($p < 0.0001$).

In Table 4, the results of the logistic regression analyses

are shown. In model 1, older patient age and the absence of a pleural tent were significant independent predictors of a prolonged air leak. In model 2 the only significant independent variable associated with the duration of air leak was the absence of a pleural tent.

Table 5 shows the results of comparing the reduction in the incidence of air leak in successive postoperative periods with the two groups. A significantly greater decrease in the incidence of air leak was observed in group 1 in the earlier postoperative period when compared with the incidence in group 2 (<2 days and <4 days, respectively). In those patients with an air leak of 4 days of duration or longer, there was no significant difference in air leak duration between tented and untented patients (10.4 ± 4.2 versus 12.6 ± 8.6, respectively; Student’s $t$ test = 1; $p = 0.3$). In Table 6, the results of the logistic regression analysis performed to identify predictors of air leak of less than 4 days of duration are shown; significant independent variables were the patient’s age and presence of a pleural tent.
Comment

Pleural tenting was originally designed to prevent over-expansion of the lung after resection for tuberculosis [3] and was then applied to prevent air leaks after upper lobectomy [9, 10]. Stimulated by the recent use of pleural tenting after lung volume reduction operation [11], some authors retrospectively [1] and prospectively [2, 12] investigated the efficacy of the procedure.

The objectives of this study were to assess the costs and benefits of the pleural tent in a prospective randomized trial and identify the time of maximum duration of efficacy of the procedure.

The results of our analysis confirmed the favorable findings reported previously by our group and others [1, 2, 12].

We found that after upper lobectomy, patients in group 1 exhibited an average of 4.7 fewer days of air leak than patients without the pleural tent. Furthermore, with the tented patients, the mean duration of chest tube use was 4.2 days less, and the mean length of postoperative hospital stay was 3.4 days less. Three patients with a pleural tent and 12 patients without tents were discharged with a Heimlich valve ($\chi^2 = 5.8; p = 0.015$). We also demonstrated that the time taken to perform a pleural tent procedure did not significantly increase the total operative time. In addition, we did not observe a significantly higher risk of postoperative complications or a significant increase in the need for postoperative blood transfusion in patients who underwent pleural tenting.

The results of logistic regression analyses indicated that the absence of a pleural tent was the most significant independent variable associated with a prolonged air leak and with the duration of air leak.

Subsequently, we found that patients with a pleural tent experienced the maximum reduction in duration of air leak before postoperative day 4. Moreover, the presence of a pleural tent was identified as the most significant independent predictor of an air leak lasting less than 4 days (after controlling for the effect of other variables in a multiple regression analysis). Thus we can confidently assume that the greatest reduction rate in the duration of air leak observed in group 1 during the first 4 postoperative days was predominantly an effect of the presence of the pleural tent. However, pleural tenting appeared to exert a diminished beneficial effect after postoperative day 4 in patients who had undergone upper lobectomy.

In conclusion, we have confirmed that pleural tenting is a safe procedure that can be accomplished quickly, and that, when performed, reduces the duration of air leaks and the cost of hospital stay. Even though additional large prospective studies are needed to further confirm this finding, we recommend the routine use of pleural tenting after upper lobectomy.

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**References**


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The 2003 Part I (written) examination will be held at the Radisson Hotel O’Hare, Rosemont, Chicago, IL, on November 23, 2003. The closing date for registration is August 1, 2003. Those wishing to be considered for examination must request an application because it is not automatically sent.

To be admissible to the Part II (oral) examination, a candidate must have successfully completed the Part I (written) examination. A candidate applying for admission to the certifying examination must fulfill all the requirements of the Board in force at the time the application is received.

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