Predictors of Prolonged Air Leak After Pulmonary Lobectomy

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Background. The objective of this study was to identify the predictors of prolonged air leak (air leak longer than 7 days) in patients submitted to pulmonary lobectomy for lung cancer.

Methods. A retrospective analysis on 588 patients operated on of pulmonary lobectomy from January 1995 through June 2003 was performed. Univariate and logistic regression analyses were performed to generate a model predicting the risk of prolonged air leak. Bootstrap resampling technique was used to validate the regression model.

Results. A prolonged leak was exhibited by 15.6% of patients. Logistic regression analysis demonstrated that significant independent predictors of prolonged air leak were a reduced predicted postoperative forced expiratory volume in 1 second \((p < 0.0001\), the presence of pleural adhesions \((p = 0.003)\), and upper resections \((p = 0.006)\). Bootstrap resampling analysis confirmed the reliability of these variables. A regression equation was generated for the prediction of the risk of prolonged air leak.

Conclusions. We report that a low predicted postoperative forced expiratory volume in 1 second, the presence of pleural adhesions, and the upper lobectomy or bilobectomy increased the risk of air leak persisting for more than 7 days. A model was generated to calculate this risk and assist the surgeon in taking extra measures to prevent such complication (ie, optimizing bronchodilator treatment, pleural tent, sealants, buttressed staple lines, water seal, and chest tube drainage).

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Prolonged air leak (PAL) after pulmonary resection remains a frequent complication that may cause more severe morbidity, such as empyema, and prolong the need for chest tubes and hospitalization. It increases the frequency of inpatient and outpatient resources utilization, having a major impact on hospital costs.

Identifying the factors that predict a postoperative PAL may assist the surgeon in taking all the appropriate measures during operation in order to prevent such complication. Therefore, the objective of this study was to identify the preoperative and intraoperative predictors of an air leak persisting for more than 7 days after pulmonary lobectomy for lung cancer.

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Patients and Methods

Six hundred thirty-one patients underwent pulmonary lobectomy or bilobectomy for nonsmall cell lung cancer (NSCLC) at our institution from January 1995 through June 2003, and were taken into consideration for the present study. Forty-three patients were excluded from the analysis for incomplete data (10 patients), bronchoplastic procedures (18 patients), postoperative positive pressure ventilation for more than 24 hours (7 patients), or because they died postoperatively before the seventh postoperative day (8 patients). Seven patients who died beyond the seventh postoperative day and were not submitted to mechanical ventilation were included. A total of 588 patients (110 females, 478 males) formed the dataset of the present study. This is a retrospective analysis performed on a prospectively compiled database.

Resectability was evaluated by means of computed tomographic (CT) scan, bronchoscopy, and, when indicated, mediastinoscopy. Operability was assessed by means of arterial blood gas analysis, pulmonary function tests, electrocardiogram, echocardiography, and more invasive cardiologic tests if needed (ie, in case of a hemodynamically unstable coronary artery disease and cardiac failure). From January 2000, a symptom-limited stair climbing test was systematically administered for risk stratification to all patients who were able to perform it. All patients who underwent pulmonary resection were deemed in a hemodynamically stable state before operation. A predicted postoperative forced expiratory volume in 1 second \((\text{ppoFEV}_{1})\) less than 30% of predicted was used as a respiratory exclusion criteria, according to Markos and coworkers [1]. Since the introduction of the stair climbing test even those patients with a critical ppoFEV\(_{1}\), but who exhibited an adequate cardiopulmonary reserve, underwent operation [2].

The same surgical team performed all the procedures through a muscle-sparing lateral thoracotomy whenever possible. The following operations were performed in order of frequency: right upper lobectomy (163 patients),
Abbreviations and Acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>DLCO</td>
<td>carbon monoxide diffusion lung capacity</td>
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<tr>
<td>FEV₁</td>
<td>forced expiratory volume in 1 second</td>
</tr>
<tr>
<td>FVC</td>
<td>forced vital capacity</td>
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<tr>
<td>NSCLC</td>
<td>nonsmall cell lung cancer</td>
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<tr>
<td>PAL</td>
<td>prolonged air leak</td>
</tr>
<tr>
<td>ppoFEV₁</td>
<td>predicted postoperative FEV₁</td>
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<tr>
<td>RV/TLC</td>
<td>residual volume to total lung capacity ratio</td>
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</table>

left upper lobectomy (159 patients), left lower lobectomy (98 patients), right lower lobectomy (70 patients), right lower bilobectomy (37 patients), middle lobectomy (33 patients), and right upper bilobectomy (28 patients). Mechanical staplers were used to develop incomplete fissures in 80% of patients, and to close the bronchus in all patients. Twenty percent of patients had completely developed or filmy fissures, which did not require the use of staplers. After completion of the lobectomy, a mediastinal lymphadenectomy was performed in all patients. Moreover, after reinsertion of the lung, air leaks were pinpointed by squirting sterile water over the lung and sutured before chest closure.

From June 1998, in the patients submitted to upper lobectomies or bilobectomies, a pleural tent was created after the completion of the lung resection, initially as a part of a prospective randomized trial [3] and then from February 2002 as a routine procedure whenever possible. A total of 150 upper lobectomies or bilobectomies in the present dataset had a pleural tent procedure. Two chest tubes were positioned before the closure of the thoracotomy, one anteriorly into the apex and one in a posterior-inferior position. During the postoperative period the chest tubes were placed on suction (−10/−20 cm H₂O) and then converted to water seal when minimal or no air leak was evident, or in case of a persistent air leak as an attempt to stop it. A prospective trial of suction versus water seal chest tube drainage is currently underway at our institution. Chest tubes were removed when the quantity of the effusion was less than 200 mL in 24 hours and when no evidence of air leak was present (after a 24-hour clamping trial). This chest tube management was applied to all patients in this series and it is the standard policy at our institution. During the postoperative period, chest physiotherapy and incentive spirometry were administered to all patients, in addition to bronchodilators if needed.

For the purpose of this study, an air leak that persisted for more than 7 days was termed prolonged. Even though this cutoff value is arbitrary, it is generally accepted in the literature. Due to the use of different types of drainage apparatuses, a quantitative analysis of the air leak was not possible in this study.

The following preoperative variables were tested for a possible association with PAL: age, pulmonary function tests (forced expiratory volume in 1 second [FEV₁]), forced vital capacity [FVC], FEV₁ to FVC ratio [FEV₁/FVC ratio], residual volume to total lung capacity ratio [RV/TLC ratio], predicted postoperative FEV₁ [ppoFEV₁], arterial oxygen tension, arterial carbon monoxide level, preoperative hemoglobin level, preoperative serum albumin level, diabetes mellitus, neoadjuvant chemotherapy, smoking history (in pack years), and use of systemic steroids. Furthermore, the following intraoperative variables were taken into consideration: type of resection (extended vs nonextended), side (right vs left), site of resection (upper vs lower), presence of pleural adhesions, and length of the staple line created in the lung (in centimeters). FEV₁, FVC, and ppoFEV₁ were expressed as percentage of predicted for age, gender, and height according to the European Community for Steal and Coal prediction equations [4]. The ppoFEV₁ was calculated on the basis of the functioning segments removed during operation and was estimated by CT scan and bronchoscopy [5]. If the calculated ppoFEV₁ was less than 50% of predicted values, a quantitative lung perfusion scan was performed according to Markos and colleagues [1].

We computed the number of pack years of smoking as the total number of years smoked multiplied by the average number of cigarettes smoked per day, divided by 20.

Extended resections were defined as follows: extrapleural resections or lung resections associated with resection of the chest wall, diaphragm, or mediastinal structures. In this series, 35% of the extended resections were extrapleural ones, 35% were associated with chest wall resection, 30% were associated with resection of the diaphragm, pericardium or other mediastinal structures.

For the purpose of this study, the following lung resections were classified as “upper” resections: right and left upper lobectomies, right upper bilobectomy, and middle lobectomy. “Lower” resections included: right and left lower lobectomies, and right lower bilobectomy. Only dense pleural adhesions occupying more than 30% of a lobe or more than one lobe were taken into consideration for the analysis.

Statistical Analysis

Numerical variables were compared by means of the unpaired Student's t test, and the χ² test was used to compare categorical variables. Variables with a p less than 0.1 at univariate analysis were then used as independent variables in a stepwise logistic regression analysis (dependent variables: presence of PAL), with a p = 0.05 criterion for retention of variables in the final model. To avoid multicollinearity, only one variable in a set of variables with a correlation coefficient more than 0.5 was used in the multivariate analysis. The multivariate procedure was validated by bootstrap bagging with 1000 samples. In the bootstrap procedure, repeated samples of 589 observations (the same number of observations as the original database) were selected with replacement from the original set observations. For each sample, stepwise logistic regression was performed entering the preoperative and intraoperative variables with p less than 0.1 at univariate analysis. The stability of the final
Table 1. Characteristics of 588 Patients in this Study Undergoing Pulmonary Lobectomy From January 1995 through June 2003

<table>
<thead>
<tr>
<th>Variables</th>
<th>Patients With PAL</th>
<th>Patients Without PAL</th>
<th>p Value</th>
</tr>
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<tbody>
<tr>
<td>Age</td>
<td>68.0 (8.2)</td>
<td>66.3 (9.5)</td>
<td>0.1</td>
</tr>
<tr>
<td>FEV₁ (%)</td>
<td>79.3 (20.9)</td>
<td>90.0 (20.5)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>FVC (%)</td>
<td>93.3 (17.4)</td>
<td>98.2 (18.2)</td>
<td>0.02</td>
</tr>
<tr>
<td>FEV₁/FVC ratio</td>
<td>0.66 (0.12)</td>
<td>0.71 (0.11)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>RV/TLC ratio</td>
<td>0.45 (0.09)</td>
<td>0.43 (0.09)</td>
<td>0.3</td>
</tr>
<tr>
<td>ppoFEV₁ (%)</td>
<td>63.3 (16.1)</td>
<td>72.5 (17.5)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>PacO₂ (mm Hg)</td>
<td>81.1 (12.2)</td>
<td>80.0 (12.2)</td>
<td>0.5</td>
</tr>
<tr>
<td>Preoperative hemoglobin (g/dL)</td>
<td>37.7 (4.1)</td>
<td>38.2 (5.3)</td>
<td>0.5</td>
</tr>
<tr>
<td>Preoperative serum albumin (g/dL)</td>
<td>13.5 (1.9)</td>
<td>13.7 (1.7)</td>
<td>0.2</td>
</tr>
<tr>
<td>PacO₂ (mm Hg)</td>
<td>4.1 (0.8)</td>
<td>4.3 (2.1)</td>
<td>0.4</td>
</tr>
<tr>
<td>Diabetes mellitus (%)</td>
<td>10.3%</td>
<td>10.5%</td>
<td>0.9*</td>
</tr>
<tr>
<td>Neoadjuvant chemotherapy (%)</td>
<td>10.9%</td>
<td>11.3%</td>
<td>0.9*</td>
</tr>
<tr>
<td>Pack years</td>
<td>47.5 (27.3)</td>
<td>41.3 (29.1)</td>
<td>0.09</td>
</tr>
<tr>
<td>Steroid use (%)</td>
<td>0.01%</td>
<td>0.01%</td>
<td>0.8*</td>
</tr>
</tbody>
</table>

*a Chi-square test.

The results are expressed as means ± standard deviations unless otherwise indicated.

FEV₁, FVC, and ppoFEV₁ are expressed as percentage of predicted values for age, gender, and height.

Results

The characteristics of the patients in this study are depicted in Table 1. Ninety-two patients (15.6%) experienced a PAL. They represented 28.8% of the 319 patients with an air leak on the first postoperative day. Of the 92 patients with PAL, 46.7% (43 patients) had an air leak lasting more than 14 days, 28.3% (26 patients) had a PAL longer than 21 days, and 12% (11 patients) had a PAL longer than 1 month.

All patients with PAL were treated conservatively with chest physiotherapy and incentive spirometry, with the exception of 1 patient who required reoperation for suture of a parenchymal injury caused by a fractured rib.

Patients with PAL experienced a higher rate of postoperative morbidity with respect to those without PAL (26.1% vs 16.7%; p = 0.03). In particular, they revealed a higher rate of empyema (11.9% vs 1.0%; p < 0.0001), fever greater than 38°C for more than 3 days without an identified cause (6.5% vs 2.0%; p = 0.01), and pneumonia (11.9% vs 5.6%; p = 0.02).

The PAL increased the utilization of outpatient resources. In fact, 32 patients with PAL (34.8%) were discharged with a Heimlich valve. Of these patients, 13 had their air leaks stopped within 3 weeks, 12 within 4 weeks, and 7 within 2 months. They had a total of 132 outpatient visits (a mean of 4.1 visits per person versus a mean of 1.0 visit per person in patients without PAL, p < 0.0001). Seven patients had 2 visits each, 7 patients had 3 visits each, 8 patients had 4 visits each, 3 patients had 5 visits each, 4 patients had 6 visits each, 1 patient had 7 visits, 1 patient had 9 visits, and 1 patient had 10 visits.

Tables 2 and 3 illustrate the results of the univariate comparison between patients with and without PAL. In
Table 4. Frequency of Occurrence of Independent Variables in 1000 Bootstrap Resampling Models

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Frequency of Occurrence</th>
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<tbody>
<tr>
<td>Pleural adhesions</td>
<td>79.5%</td>
</tr>
<tr>
<td>ppoFEV₁</td>
<td>77.6%</td>
</tr>
<tr>
<td>Site of resection (upper lobectomy)</td>
<td>60.8%</td>
</tr>
<tr>
<td>FVC</td>
<td>22.9%</td>
</tr>
<tr>
<td>Pack years</td>
<td>8.1%</td>
</tr>
<tr>
<td>FEV₁/FVC ratio</td>
<td>5.9%</td>
</tr>
</tbody>
</table>

Dependent variable is presence of prolonged air leak.

FEV₁ = forced expiratory volume in 1 second; FVC = forced vital capacity.

particular, compared with patients without PAL, those with PAL had a significantly reduced FEV₁ (p < 0.0001), FVC (p = 0.02), FEV₁/FVC ratio (p < 0.0001), and ppoFEV₁ (p < 0.0001). Moreover, they had a greater frequency of pleural adhesions (p = 0.0002) and upper resections (p = 0.04).

Carbon monoxide diffusion lung capacity (DLCO) expressed as percentage for age, gender, and height was systematically evaluated from January 2000 in 275 patients of this series. Patients with PAL (41 patients) had a lower DLCO compared with those without PAL (234 patients; 72.7% vs 79.0%; 0.06). However, due to its low prevalence in this series of less than 50%, this variable was not used in the logistic regression analysis.

Logistic regression analysis indicated that significant independent predictors of PAL were a reduced ppoFEV₁ (regression coefficient: -0.033; p < 0.0001), the presence of pleural adhesions (regression coefficient: 0.74; p = 0.003), and an upper resection (regression coefficient: 0.75; p = 0.006).

Table 4 presents the frequency of occurrence of the independent variables in 1000 bootstrap resampling models. Pleural adhesions (79.5%), ppoFEV₁ (77.6%), and upper resection (60.8%) were the only variables to remain significant in more than 50% of the bootstrap models, indicating their reliability.

The logistic regression analysis yielded the following regression equation for the prediction of the risk of PAL: risk of PAL = e^(-0.249 - 0.033 × ppoFEV₁ + 0.74 × pleural adhesions + 0.75 × upper resection)/1 + e^(-0.249 - 0.033 × ppoFEV₁ + 0.74 × pleural adhesions + 0.75 × upper resection). Pleural adhesions and upper resection were coded as follows: 1 in case of presence of the variables, and 0 in case of absence of the variables. The coefficient of determination (R-squared) of this logistic model was 0.20.

We then separately analyzed upper and lower resections. In upper resections (383 patients) there was a PAL rate of 17.7% (68 patients). Compared with patients without PAL, those with PAL had a lower FEV₁ (80.7% vs 91.3%; p = 0.0002), FEV₁/FVC ratio (0.66 vs 0.72; p < 0.0001), and ppoFEV₁ (65.5% vs 75.2%; p < 0.0001). They also exhibited a greater frequency of extended resections (19.7% vs 10.7%; p = 0.04) and pleural adhesions (45.5% vs 29.4%; p = 0.01). Logistic regression analysis indicated that significant predictors of PAL after upper resections were a reduced FEV₁/FVC ratio (regression coefficient: -4.57; p = 0.0004) and the presence of pleural adhesions (regression coefficient: 0.62; p = 0.04).

In lower resections (205 patients) there was a PAL rate of 11.7% (24 patients). Compared with patients without PAL, those with PAL had a lower FEV₁ (76.4% vs 87.8%; p = 0.01), FVC (87.9% vs 97.6%; p = 0.02), ppoFEV₁ (57.4% vs 67.9%; p = 0.004), and a greater frequency of pleural adhesions (65.2% vs 31.3%; p = 0.001). Logistic regression analysis revealed that significant predictors of PAL after lower resections were a reduced ppoFEV₁ (regression coefficient: -0.039; p = 0.015) and the presence of pleural adhesions (regression coefficient: 1.27; p = 0.008).

In this series, 150 patients who underwent upper resections had a pleural tent procedure and they experienced an air leak duration lower than that of the patients who underwent upper resections without pleural tent (2.4 days vs 7.3 days, respectively; p < 0.0001). Their air leak duration was even lower than that of the patients who underwent lower resections (2.4 days vs 3.7 days, respectively; p = 0.06).

Comment

The objective of the present study was to identify the predictors of PAL after pulmonary lobectomy for lung cancer. The PAL rate in our series was similar to that reported by other authors [6–8], even though they studied populations of patients who underwent wedge resections and segmentectomies [6, 8], or restricted the analysis to right upper lobectomies only [7].

We focused our analysis on pulmonary lobectomy only, inasmuch as it has been reported that this procedure is a greater risk for developing postoperative PAL compared with lesser resections, presumably because a larger residual pleural space precludes the parieto-visceral pleura apposition [9].

Many studies reported that PAL prolonged the hospital stay and increased the hospital costs [7, 10, 11]. Moreover, in this analysis, patients with PAL demonstrated an increased rate of postoperative morbidity, such as empyema, fever, and pneumonia. Even though the occurrence of these complications may be elicited by the persistence of a residual pleural space, chest tubes and a continuous bronchial-alveolar seepage into the pleural cavity, the effect of common risk factors, such as empyema, fever, and pneumonia, were not analyzed. However, the presence of pleural adhesions, which were significant predictors of PAL, may explain this association.

Furthermore, more than one-third of the patients with PAL were discharged with a Heimlich valve, which required a mean of 4.1 outpatient visits per person, increasing hospital resources utilization. We did not standardize the use of Heimlich valves. They were applied at variable postoperative periods, depending on the clinical, psychologic, and social conditions of the patients. After discharge of the patients with a Heimlich valve, we monitor them in our outpatient facility once a week for physical examination, air leak assessment, and patient counseling.
Therefore, identifying the preoperative and intraoperative predictors of PAL may be clinically useful for taking additional measures to prevent this complication and reduce medical expenditure, and for counseling preoperatively those patients at increased risk of PAL. Logistic regression analysis, validated by a bootstrap resampling procedure, demonstrated that significant predictors of PAL were a reduced ppoFEV₁, the presence of pleural adhesions, and the upper resections. A logistic regression equation was generated for predicting the risk of PAL. For instance, in case of a hypothetical patient with a ppoFEV₁ of 40% of predicted, undergoing an upper lobectomy with pleural adhesions, the risk of developing PAL would be 47%. In a more favorable case of a patient with a ppoFEV₁ of 80% of predicted, undergoing a lower lobectomy without pleural adhesions, the risk of PAL would be only 5%.

Reduced pulmonary function variables may be associated with the occurrence of PAL, because they are the expression of an increased airways resistance and pathologic parenchymal changes [7, 9]. We previously reported that ppoFEV₁ was a significant predictor of PAL in a series of patients undergoing upper lobectomies [12]. In lung cancer patients, ppoFEV₁ could be a more reliable indicator of a preexisting pulmonary disease because it is less affected by the volume of the neoplasm, the associated atelectasis and the consequent ventilation/perfusion mismatch, compared with the preoperative spirometric variables. Therefore, in patients with a reduced ppoFEV₁, respiratory function should be optimize before operation by means of medical treatment and chest physiotherapy, in order to reduce the risk of occurrence of PAL.

Upper resections often result in a residual apical pleural space, which predisposes to longer pulmonary air leaks due to a poor visceral-parietal pleura apposition [7, 13, 14]. We and other authors have found that the pleural tent was a safe and quick procedure that reduced the incidence of PAL, shortened the hospital stay, and decreased the cost of hospital stay [3, 14, 15], which warrants, whenever possible, its use after upper lobectomy or bilobectomy. In this study, the upper resections with a concomitant pleural tent procedure had an air leak that was shorter than that occurring after upper resections without pleural tent, and even shorter than that after lower resections.

The presence of pleural adhesions increased the risk of PAL and was the only significant independent variable predicting PAL after both upper and lower resections. The mobilization of the lung during the division of the adhesions may cause lung parenchyma injuries, particularly when blinded maneuvers of blunt dissection are performed. Therefore, in the presence of dense and diffuse pleural adhesions, a careful dissection is recommended, avoiding, whenever possible, undue tractions and blinded procedures, and choosing an extrapleural plane of dissection if needed [16].

Only 3 patients in this series had a history of previous ipsilateral thoracotomy and, therefore, this event was not used as a variable in the analysis. All the 3 patients had completion of lobectomies after wedge resections for suspected lung metastases, which after the definitive histologic examination turned out to be primary lung cancers. Of these patients, 1 patient with a right lower lobectomy had an air leak lasting for 2 days, 1 patient with a lower left lobectomy had an air leak lasting 5 days, and 1 patient with a right upper lobectomy had an air leak of 1 day.

In the presence of an increased risk of PAL, other measures have been reported to be effective such as the use of buttressed staple lines [17], the use of pneumoperitoneum after lower lobectomy [18–20], the application of sealants [21–23], and the use of water seal chest tube drainage rather than suction in the postoperative period [24, 25]. In conclusion, we were able to develop a logistic regression equation predicting the risk of PAL in patients undergoing pulmonary lobectomy for lung cancer. This model may assist the surgeon in the choice of additional preventive procedures in those patients at increased risk of PAL.

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INVITED COMMENTARY

Prolonged air leak in most surgical series is the most common complication after partial lung resection and is usually the primary determinant of length of stay. Brunelli et al report on a study of prolonged air leak after lobectomy from a large prospective database. The study organization was thoughtful and the data were well analyzed, including the use of bootstrap analysis to validate the results of the multivariate logistic regression analysis. The results are not particularly new but are a useful solid benchmark for factors associated with a prolonged air leak after lobectomy. The inclusion of only lobectomy patients, the prospective data collection and the detailed pulmonary function test data lead me to consider this report a solid reference for prolonged air leak after lobectomy. It is no surprise that more severe obstructive lung disease, upper lobe resections, and severe adhesions are risk factors for prolonged air leak.

At first glance, a surgeon might think, so what, none of these factors can be modified so why worry about it. I doubt that any medical therapy for chronic obstructive pulmonary disease has any significant effect on air leaks, but no reasonable person would argue the point that patients should be in optimal condition for elective pulmonary resection. Likewise, there is no choice in what lobe(s) a resection is done. The surgeon does, however, have direct control over the conduct of the operation and the postoperative management, both of which can be favorably shifted toward less morbidity from air leaks. Intraoperative factors that can lessen air leaks include careful dissection of hilar areas and adhesion areas to avoid visceral pleural injury (obviously), use of a pleural tent after upper lobectomy, the use of buttressed staple lines in the presence of severe emphysema, the use of lung sealants for leaking areas that are not amenable to suture or stapling, inspecting the lung after resection to search for leaks and eliminating or reducing them as much as possible as a routine step in every pulmonary resection, and stapling the entire fissure if there is any degree of an incomplete fissure rather than dissecting the vessels in the fissure first and then stapling the remaining incomplete fissure (so called fissure-less lobectomy). Postoperative measures to reduce air leaks include efforts directed at maximizing lung expansion (adequate pain relief, incentive spirometry, and chest physiotherapy), selective use of pneumoperitoneum to obliterate basilar spaces after lower lobectomy, and use of water seal rather than suction drainage of the pleural space. Him-
lich valves can be used in appropriate patients to allow earlier discharge in the presence of an air leak to reduce hospital stay and allow the patient the comfort of his/her home. Of note, the old commonly accepted definition of a prolonged air leak was 7 days but is not really appropriate in the fast-track hospital setting of today. Most patients are now discharged by the fourth day in the absence of any complications after lobectomy. Accordingly, a more modern definition would be a leak that delays discharge or is present beyond the third day.

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