Quantifying the Safety Benefits of Wedge Resection: A Society of Thoracic Surgery Database Propensity-Matched Analysis

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Background. Wedge resection is often used instead of anatomic resection in an attempt to mitigate perioperative risk. In propensity-matched populations, we sought to compare the perioperative outcomes of patients undergoing wedge resection with those undergoing anatomic resection.

Methods. The Society of Thoracic Surgery database was reviewed for stage I and II non-small cell lung cancer patients undergoing wedge resection and anatomic resection to analyze postoperative morbidity and mortality. Propensity scores were estimated using a logistic model adjusted for a variety of risk factors. Patients were then matched by propensity score using a greedy 5- to 1-digit matching algorithm, and compared using McNemar’s test.

Results. Between 2009 and 2011, 3,733 wedge resection and 3,733 anatomic resection patients were matched. The operative mortality was 1.21% for wedge resection versus 1.93% for anatomic resection (p = 0.0118). Major morbidity occurred in 4.53% of wedge resection patients versus 8.97% of anatomic resection patients (p < 0.0001). A reduction was noted in the incidence of pulmonary complications, but not cardiovascular or neurologic complications. There was a consistent reduction in major morbidity regardless of age, lung function, or type of incision. Mortality was reduced in patients with preoperative forced expiratory volume in 1 second less than 85% predicted.

Conclusions. Wedge resection has a 37% lower mortality and 50% lower major morbidity rate than anatomic resection in these propensity-matched populations. The mortality benefit is most apparent in patients with forced expiratory volume in 1 second less than 85% predicted. These perioperative benefits must be carefully weighed against the increase in locoregional recurrence and possible decrease in long-term survival associated with the use of wedge resection for primary lung cancers.

Lobectomy has long been the standard treatment of early stage non-small cell lung cancer (NSCLC). The Lung Cancer Study Group trial, which randomly assigned 267 node-negative patients with tumors smaller than 3 cm to limited resection (wedge resection or segmentectomy) or lobectomy, showed a threefold increased incidence of recurrence with limited resection and confirmed lobectomy as the preferred treatment for Stage IA NSCLC [1]. Wedge resection is advocated as a less morbid operation that may be beneficial in patients with poor lung function, in the elderly, or in patients with other serious comorbidities [2].

Despite the widespread assertion that wedge resection is a less morbid operation than lobectomy, there are little data that quantitate this assertion. Moreover, there are no randomized, or even matched, analyses of perioperative morbidity. Most studies describing the relative risks of lobectomy versus sublobar resection have been single-institution reviews with insufficient power to accurately assess the relative perioperative risks. Most studies have grouped segmentectomy with wedge resection as sublobar resections in a comparison with lobectomy. Segmentectomy, however, is more similar to lobectomy than wedge resection with regard to extent of dissection and duration of operation.

We sought to delineate and quantitate the differences in perioperative mortality and major morbidity between
wedge resection and anatomic resection using The Society of Thoracic Surgery (STS) database. The large number of patients available in this database, the extensive list of preoperative variables, and prospective collection of a standardized set of perioperative adverse events make this database uniquely suited to a propensity-matched analysis.

Patients and Methods

Data Source

The STS database is prospective, with 234 participating sites in the United States and Canada. Data are maintained and analyzed by the Duke Clinical Research Institute in compliance with the Health Insurance Portability and Accountability Act of 1996. Variables are collected on a standardized data form that includes information about patient demographics, medical history, surgical procedures, cancer staging, and outcome. Institutional review boards of each participating site approved the use of this database for quality improvement research.

Patient Population

The study population consists of patients 18 years or older with stage I or II NSCLC, T status 1 or 2, undergoing wedge resection, segmentectomy, or lobectomy at 193 STS participating hospitals between January 1, 2009, and December 31, 2011. All data were collected using STS v2.081 data collection forms. Patients were excluded from the study if they received preoperative chemotherapy or radiation therapy or were treated with sleeve resection or bilobectomy.

Data Collection, Outcome Measurement, and Statistical Method

Data collected for each patient included sex, continuous variables (age at time of surgery, body mass index, preoperative percent predicted forced expiratory volume in 1 second [FEV1], carbon monoxide diffusion capacity as a percent of predicted); binary variables with all missing variables imputed to no (hypertension, congestive heart failure, coronary artery disease, peripheral vascular disease, steroid use, recent smoker, cerebrovascular disease, diabetes, renal insufficiency, surgery by video-assisted thoracoscopic surgery [VATS]); and categorical variables (Zubrod score [0–5], American Society of Anesthesiologists Risk Scale [1–5], status of operation [elective, urgent, or emergent]).

Outcomes measured included operative mortality (death in hospital or within 30 days of operation) and major morbidity, including pneumonia, bronchopleural fistula, pulmonary embolus (PE), ventilator support for greater than 48 hours, need for tracheostomy, myocardial infarction (MI), deep venous thrombosis (DVT), empyema, sepsis, cerebrovascular event, new renal failure, or chylothorax.

Propensity scores for wedge versus anatomic resection were estimated using a logistic model that includes the following variables: age, sex, Zubrod score, American Society of Anesthesiologists Risk Scale, body mass index, hypertension, coronary artery disease, congestive heart failure, renal insufficiency, surgery by VATS, diabetes, current smoker, cerebrovascular disease, peripheral vascular disease, steroid use, clinical status, percent predicted FEV1, and carbon monoxide capacity as a percent of predicted. Wedge resection was the exposure group and anatomic resection was the control group. Patients were then matched using a greedy 5- to 1-digit matching algorithm [3]. The distribution of patient characteristics before and after propensity matching were compared across treatment groups using standardized difference \( \frac{(100(X_2-X_1))/[(S_2^2+S_1^2)/2]^{1/2}} \), where \( X_2 \) and \( X_1 \) denote the sample mean in each group, and \( S_1^2 \) and \( S_2^2 \) denote the sample variances, respectively. The propensity-matched analysis was performed for the entire study population. Separate propensity-matched analyses were performed on six different separate subpopulations (those undergoing surgery by VATS, surgery by thoracotomy, those patients older than or equal to 80 years, those younger than or equal to 70 years, those with preoperative percent predicted FEV1 less than 60%, and those with percent predicted FEV1 greater than 80%). Separate propensity-matched analyses were then performed on patients with predicted FEV1 less than 85%, less than 80%, less than 75%, and less than 70% to determine whether there was an FEV1 cutoff for reduced mortality or morbidity with wedge resection. After each propensity-matched analysis, the similarity of the preoperative variables was confirmed. Outcomes were analyzed using McNemar’s test without any further covariate adjustment. All analyses were performed using SAS version 9.3 (SAS Institute, Cary, NC). A probability value of less than 0.05 was considered statistically significant.

Results

Matched Analysis of Overall Patients

The original cohort contained 19,427 patients with stage I or II NSCLC, T1 or T2 tumors, who underwent wedge resection, segmentectomy, or lobectomy between January 1, 2009, and December 31, 2011. Propensity matching yielded a total of 7,466 matched patients. After propensity matching, the distribution of confounding variables was seen to be remarkably equal (Appendix Table 1). A propensity-matched cohort of 3,733 wedge resection and 3,733 anatomic resection patients showed a 37% decrease in 30-day mortality in the wedge resection cohort (1.21%)
versus the anatomic resection cohort (1.93%; \( p = 0.0118 \); Table 1). A significant decrease in major morbidity was seen with wedge resection (4.53%) compared with anatomic resection (8.97%; \( p < 0.0001 \)). This represents a 49% decrease in the risk of a major morbidity. Significant decreases in the incidence of pneumonia, bronchopleural fistula, prolonged ventilator support, need for tracheostomy, sepsis, and new renal failure were noted, although no significant differences were noted in the incidence of PE, chylothorax, MI, DVT, empyema, or new central neurologic event.

**Matched Analysis of Patients Undergoing Wedge Resection and Anatomic Resection Each by Video-Assisted Thoracoscopic Surgery**

There were 5,288 matched patients (2,644 in each group) undergoing wedge resection and anatomic resection by VATS available for comparison (Appendix Table 2). No difference in operative mortality was seen (0.83% for wedge versus 1.21% for anatomic resection; \( p = 0.4751 \)). There was a 47% decrease in major morbidity seen with wedge resection (3.52%) compared with anatomic resection (6.66%; \( p < 0.001 \)). Significant differences were noted in the incidence of pneumonia, need for tracheostomy, empyema, sepsis, and new renal failure. No differences were noted in the incidence of bronchopleural fistula, PE, prolonged ventilator support, MI, DVT, new central neurologic event, or chylothorax.

**Matched Analysis of Patients Undergoing Wedge Resection and Anatomic Resection by Thoracotomy**

There were 2,004 patients (1,002 in each group) available for propensity matching of patients undergoing wedge resection versus anatomic resection by thoracotomy (Appendix Table 3). There was a trend toward decreased operative mortality with wedge resection (1.80%) as compared with the anatomic resection cohort (2.89%; \( p = 0.1086 \)). There was a 45% reduction in the incidence of major morbidity (6.79% versus 12.38%; \( p < 0.0001 \)). A significant reduction in the incidence of pneumonia, bronchopleural fistula, tracheostomy, and new renal failure was noted. No significant difference was noted in the incidence of PE, prolonged ventilator support, MI, DVT, empyema, sepsis, or new central neurologic event.

**Matched Analysis of Patients Undergoing Wedge Resection and Anatomic Resection With Poor Lung Function**

There were 1,872 matched patients (936 in each group) undergoing wedge resection and anatomic resection with preoperative FEV1 less than 60% predicted (Table 2). There was a 52% reduction in perioperative mortality seen with wedge resection (1.39%) compared with anatomic resection (2.88%). There was a 52% reduction in the incidence of a major morbidity seen with wedge resection (6.30%) compared with anatomic resection (13.14%; \( p < 0.0001 \)). Significant differences were seen in the incidence of pneumonia, bronchopleural fistula, need for tracheostomy, and new renal failure. No difference was seen in PE, prolonged ventilator support, MI, DVT, empyema, sepsis, new central neurologic event, or chylothorax.

**Matched Analyses of Patients Undergoing Wedge Resection and Anatomic Resection With Varying Levels of Pulmonary Function**

There were 4,284 matched patients with FEV1 less than 85% predicted, 3,846 matched patients with FEV1 less than 80% predicted, 3,358 matched patients with FEV1 less than 75% predicted, and 2,850 matched patients with FEV1 less than 70% predicted (Table 3). All subgroups of patients with FEV1 less than 80% predicted were noted to have approximately half the perioperative mortality with wedge resection compared with anatomic resection. The statistical significance was lost when the analysis was

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**Table 1. Incidence of Mortality and Major Morbidity in Matched Populations of Patients Undergoing Lung Resection: Overall Results**

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Overall (n = 7,466)</th>
<th>Wedge Resection (n = 3,733)</th>
<th>Anatomic Resection (n = 3,733)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operative mortality</td>
<td>117 (1.57%)</td>
<td>45 (1.21%)</td>
<td>72 (1.93%)</td>
<td>0.0118</td>
</tr>
<tr>
<td>Major morbidity</td>
<td>504 (6.75%)</td>
<td>169 (4.53%)</td>
<td>335 (8.97%)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>275 (3.68%)</td>
<td>88 (2.36%)</td>
<td>187 (5.01%)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Bronchopleural fistula</td>
<td>24 (0.32%)</td>
<td>7 (0.19%)</td>
<td>17 (0.46%)</td>
<td>0.0412</td>
</tr>
<tr>
<td>PE</td>
<td>21 (0.28%)</td>
<td>9 (0.24%)</td>
<td>12 (0.32%)</td>
<td>0.4913</td>
</tr>
<tr>
<td>Ventilatory support &gt; 48 h</td>
<td>53 (0.71%)</td>
<td>19 (0.51%)</td>
<td>34 (0.91%)</td>
<td>0.0394</td>
</tr>
<tr>
<td>Tracheostomy</td>
<td>66 (0.88%)</td>
<td>14 (0.38%)</td>
<td>52 (1.39%)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>MI</td>
<td>33 (0.44%)</td>
<td>12 (0.32%)</td>
<td>21 (0.56%)</td>
<td>0.1172</td>
</tr>
<tr>
<td>DVT</td>
<td>30 (0.40%)</td>
<td>13 (0.35%)</td>
<td>17 (0.46%)</td>
<td>0.4497</td>
</tr>
<tr>
<td>Empyema</td>
<td>25 (0.33%)</td>
<td>8 (0.21%)</td>
<td>17 (0.46%)</td>
<td>0.0606</td>
</tr>
<tr>
<td>Sepsis</td>
<td>40 (0.54%)</td>
<td>13 (0.35%)</td>
<td>27 (0.72%)</td>
<td>0.0269</td>
</tr>
<tr>
<td>New central neurologic event</td>
<td>26 (0.35%)</td>
<td>11 (0.29%)</td>
<td>15 (0.40%)</td>
<td>0.4142</td>
</tr>
<tr>
<td>New renal failure</td>
<td>81 (1.08%)</td>
<td>23 (0.62%)</td>
<td>58 (1.55%)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Chylothorax</td>
<td>20 (0.27%)</td>
<td>8 (0.21%)</td>
<td>12 (0.32%)</td>
<td>0.3711</td>
</tr>
</tbody>
</table>

DVT = deep venous thrombosis; MI = myocardial infarction; PE = pulmonary embolus.
expanded to include patients with FEV1 greater than 80% predicted.

**Matched Analysis of Patients Undergoing Wedge Resection and Anatomic Resection With Preserved Lung Function**

There were 2,444 matched patients (1,222 in each group) undergoing wedge resection and anatomic resection with preoperative FEV1 greater than 80% predicted (Appendix Table 4). No difference in perioperative mortality was seen. There was a 54% reduction in major morbidity seen in the wedge resection group (2.86%) compared with the anatomic resection group (6.22%; \( p = 0.0001 \)). Pneumonia was the only perioperative event in which a significant difference was seen (1.23% in the wedge resection group versus 3.03% in the anatomic resection group; \( p = 0.0001 \)).

**Matched Analysis of Patients Undergoing Wedge Resection and Anatomic Resection in Patients Younger Than or Equal to 70 Years**

There were 3,878 matched patients (1,939 in each group) younger than or equal to 70 years old (Appendix Table 5). No difference in perioperative mortality was seen. A 48% reduction in major perioperative morbidity was seen in the wedge resection group (4.38%) compared with the anatomic resection group (8.41%; \( p < 0.0001 \)). Significant differences were noted in the incidence of pneumonia, need for tracheostomy, new renal failure, and chylothorax. No differences were seen in the incidence of other major morbidities.

**Matched Analysis of Patients Undergoing Wedge Resection and Anatomic Resection in Patients Greater Than or Equal to 80 Years**

There were 1,068 matched patients (534 in each group) older than or equal to 80 years (Table 4). No difference in perioperative mortality was noted. There was a 36% reduction in major perioperative morbidity seen in the wedge resection group (5.43%) compared with the anatomic resection group (8.43%), a trend that approached statistical significance (\( p = 0.0523 \)). Significant differences were noted in the incidence of pneumonia, but not in other major morbidities.

**Comment**

There are an increasing number of patients with NSCLC who may appropriately be treated with wedge resection and nodal sampling. These are patients with predominantly ground glass lesions and a small nodular component (<8 to 10 mm in nodular diameter). In a recent analysis of 610 consecutive clinical stage IA patients with predominant ground glass component (comprising >50% of tumor diameter), 3-year recurrence-free survival was identical (96.4%, 96.1%, and 98.7%) in patients undergoing lobectomy, segmentectomy, and wedge resection, respectively [4]. A recent analysis by Schuchert and colleagues [5] showed that patients with subcentimeter

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**Table 3. Comparison of Mortality Rate in Propensity-Matched Patients With Different Levels of Pulmonary Function**

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Mortality Rate</th>
<th>Mortality Rate</th>
<th>( p ) Value</th>
<th>N (Matched Cohort)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV1 &lt; 85%</td>
<td>1.12</td>
<td>1.73</td>
<td>0.096</td>
<td>4,284</td>
</tr>
<tr>
<td>FEV1 &lt; 80%</td>
<td>1.14</td>
<td>2.39</td>
<td>0.0031</td>
<td>3,846</td>
</tr>
<tr>
<td>FEV1 &lt; 75%</td>
<td>1.25</td>
<td>2.26</td>
<td>0.0269</td>
<td>3,358</td>
</tr>
<tr>
<td>FEV1 &lt; 70%</td>
<td>1.33</td>
<td>2.53</td>
<td>0.0173</td>
<td>2,850</td>
</tr>
<tr>
<td>FEV1 &lt; 60%</td>
<td>1.39</td>
<td>2.88</td>
<td>0.0231</td>
<td>1,872</td>
</tr>
</tbody>
</table>

FEV1 = forced expiratory volume in 1 second.
cancers treated by wedge resection, segmentectomy, or lobectomy all had identical disease recurrence and identical estimated 5-year survival. With the increased use of computed tomography scan screening, there will likely be an increasing incidence of smaller and more indolent tumors that may be appropriate for resection with wedge resection and nodal sampling.

Although it is intuitive to believe that sublobar resection would be safer than lobectomy, it is by no means established. Many prominent publications comparing sublobar with lobar resections make no mention of perioperative morbidity [6, 7]. Others have shown no significant difference in perioperative morbidity or mortality [8, 9]. In the randomized Lung Cancer Study Group trial, no differences were seen in perioperative morbidity or mortality between the two groups other than with more prolonged postoperative ventilation in the lobectomy cohort [1]. In general, retrospective analyses have not compared equivalent subgroups, have not prospectively collected morbidity data, and have been relatively small. Our analysis of 7,466 matched patients undergoing curative-intent lung resection showed a nearly 50% reduction in major perioperative morbidity with wedge resection compared with anatomic resection. Significant decreases were generally seen in the incidence of pneumonia, bronchopleural fistula, prolonged ventilator support, tracheostomy, sepsis, and acute renal failure. Differences were generally not seen in the incidence of cardiovascular complications, such as MI, DVT, PE, or neurologic events. Pneumonia accounted for roughly half of all major morbidities in both the wedge resection and anatomic resection groups. New renal failure was the second most common major morbidity, whereas the need for tracheostomy was the third most common. A 73% reduction in the need for tracheostomy (from 1.39% to 0.38%), an event that virtually always represents a protracted intensive care unit course and prolonged recovery, may represent the biggest potential benefit of wedge resection in regard to mitigating perioperative adverse events.

There was a 37% reduction in the incidence of mortality associated with wedge resection compared with anatomic resection (1.21% versus 1.93%; \( p = 0.0118 \)). Significant differences in perioperative mortality have rarely been noted in prior reports comparing sublobar with lobar resection, potentially because of the small numbers included in those studies. The Lung Cancer Study Group study showed no significant difference in mortality [1]. Kilic and associates [10] described a 1.3% mortality for segmentectomy compared with a 4.7% mortality for lobectomy in their retrospective review of surgery in the elderly, but this difference was not statistically significant \( (p = 0.24) \). In propensity-matched analyses of the six subgroups (VATS, thoracotomy, age \( >80 \) years, age \( <70 \) years, FEV\(_1 \) \( >80\% \), and FEV\(_1 \) \( <60\% \)), the only group to show a statistically significant difference in mortality was the group of patients with FEV\(_1 \) less than 60% predicted (1.39% mortality with wedge resection versus 2.88% mortality for lobectomy; \( p = 0.0231 \)). As the main attenuation of perioperative complications appears to be in respiratory complications, the main benefit in regard to reduced mortality appears to be in patients with reduced lung function. This benefit appears to apply to all patients with a predicted FEV\(_1 \) less than 80% (Table 3).

Limited resection is used more commonly in the elderly population. The elderly population has a more limited life expectancy, a higher risk of perioperative events, and a higher incidence of comorbidities, all of which would favor limited resection. In an examination of the Surveillance, Epidemiology, and End Results database, Mery and colleagues [11] showed that although in younger patients, lobectomy conferred better long-term survival than wedge resection, older than the age of 74 years, median survival was equivalent in patients undergoing the two procedures. In a retrospective study, Okami and coworkers [8] showed a similar equivalency of

### Table 4. Incidence of Mortality and Major Morbidity in Matched Patients 80 Years or Older Undergoing Wedge Resection or Anatomic Resection

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Overall (n = 1,068)</th>
<th>Wedge Resection (n = 534)</th>
<th>Anatomic Resection (n = 534)</th>
<th>( p ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operative mortality</td>
<td>21 (1.97%)</td>
<td>9 (1.69%)</td>
<td>12 (2.25%)</td>
<td>0.5127</td>
</tr>
<tr>
<td>Major morbidity</td>
<td>74 (6.93%)</td>
<td>29 (5.43%)</td>
<td>45 (8.43%)</td>
<td>0.0523</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>37 (3.46%)</td>
<td>11 (2.06%)</td>
<td>26 (4.87%)</td>
<td>0.0137</td>
</tr>
<tr>
<td>Bronchopleural fistula</td>
<td>2 (0.19%)</td>
<td>1 (0.19%)</td>
<td>1 (0.19%)</td>
<td>0.9999</td>
</tr>
<tr>
<td>PE</td>
<td>6 (0.56%)</td>
<td>3 (0.56%)</td>
<td>3 (0.56%)</td>
<td>0.9999</td>
</tr>
<tr>
<td>Ventilatory support &gt; 48 h</td>
<td>7 (0.66%)</td>
<td>1 (0.19%)</td>
<td>6 (1.12%)</td>
<td>0.0588</td>
</tr>
<tr>
<td>Tracheostomy</td>
<td>9 (0.84%)</td>
<td>3 (0.56%)</td>
<td>6 (1.12%)</td>
<td>0.3173</td>
</tr>
<tr>
<td>MI</td>
<td>4 (0.37%)</td>
<td>1 (0.19%)</td>
<td>3 (0.56%)</td>
<td>0.3173</td>
</tr>
<tr>
<td>DVT</td>
<td>6 (0.56%)</td>
<td>2 (0.37%)</td>
<td>4 (0.75%)</td>
<td>0.4142</td>
</tr>
<tr>
<td>Empyema</td>
<td>2 (0.19%)</td>
<td>1 (0.19%)</td>
<td>1 (0.19%)</td>
<td>0.9999</td>
</tr>
<tr>
<td>Sepsis</td>
<td>3 (0.28%)</td>
<td>2 (0.37%)</td>
<td>1 (0.19%)</td>
<td>0.5637</td>
</tr>
<tr>
<td>New central neurologic event</td>
<td>6 (0.56%)</td>
<td>1 (0.19%)</td>
<td>5 (0.94%)</td>
<td>0.1025</td>
</tr>
<tr>
<td>New renal failure</td>
<td>13 (1.22%)</td>
<td>7 (1.31%)</td>
<td>6 (1.12%)</td>
<td>0.7815</td>
</tr>
<tr>
<td>Chylothorax</td>
<td>3 (0.28%)</td>
<td>2 (0.37%)</td>
<td>1 (0.19%)</td>
<td>0.5637</td>
</tr>
</tbody>
</table>

DVT = deep venous thrombosis; MI = myocardial infarction; PE = pulmonary embolus.
survival benefit between lobectomy and limited resection (in patients older than 75 years), even though a higher incidence of locoregional recurrence was noted in both age groups with limited resection. Kilic and associates [10] showed a lower incidence of major morbidity with segmentectomy compared with lobectomy (11.5% versus 25.5%; \( p = 0.02 \)) in patients older than 75 years with equivalent estimated overall and disease-free 5-year survival. Our analysis showed a comparable decrease in the incidence of major morbidity (by about 50%) in both older and younger patients undergoing wedge resection. No significant difference in operative mortality was seen between wedge resection and lobectomy in either age group.

In this propensity-matched analysis of patients undergoing resection, a 37% reduction in perioperative mortality and 50% reduction in major morbidity were seen in the group undergoing wedge resection compared with anatomic resection. Any potential benefits in reduction of perioperative morbidity and mortality, however, must be carefully weighed against the potential for increased locoregional recurrence and decreased long-term survival. In the only large randomized trial to date, a three-fold increase in locoregional recurrence and a trend (\( p = 0.09 \)) toward decreased survival were seen when limited resection was used instead of lobectomy for T1N0 lesions undergoing resection by thoracotomy [1]. The increased rate of locoregional recurrence was 4% per year. This would represent a 20% absolute increase in recurrence over 5 years. A trend toward a 2% per year increase in death from cancer was noted in this trial. The overall magnitude of differences must be taken into consideration. The data in this propensity-matched study alone cannot be used to guide surgical therapy, or to justify the routine use of wedge resection over anatomic resection.

Another major limitation in our analysis is the inability to separate the segmental resection group from the lobectomy group. Segmentectomy and lobectomy, when performed using VATS technique, have identical CPT codes and were thus entered into the STS database as equivalent procedures. There are significant data to show that segmentectomy may offer comparable oncologic outcomes to lobectomy when performed in skilled hands and used for patients with node-negative tumors smaller than 2 cm [6–8, 10, 12]. Some of these publications show an increased rate of recurrence and potentially worse survival with wedge resection as compared with segmentectomy [13, 14]. An analysis of the American College of Surgeons Oncology Group Z4032 clinical trial, which examined the role of adjuvant brachytherapy after limited resection for clinical stage I cancers, showed that segmentectomy was associated with better lymph node sampling and wider parenchymal margins compared with wedge resection [15]. Thus, a comparison of the relative perioperative risks and benefits of segmentectomy as opposed to lobectomy would be useful. On the other hand, it is not entirely clear that segmentectomy is superior to wedge resection in regard to recurrence or survival. A prospective, nonrandomized multicenter trial comparing wedge resection, segmentectomy, and lobectomy in patients with node-negative tumors demonstrated no significant difference in either overall or disease-free survival among the groups with tumors smaller than 2 cm [6]. A third potential limitation is that incision was not included in the propensity matching. In the initial analysis of 7,466 patients, 47.4% of the anatomic resection patients underwent resection by VATS, whereas 73.3% of the wedge resection patients underwent resection by VATS. It should be noted, however, that in the propensity-matched analysis of VATS versus open lobectomy performed by Paul and colleagues [16], incision had no effect on perioperative mortality. Our separate analyses of patients undergoing resection by VATS only or thoracotomy only showed that the morbidity benefit of wedge resection persisted. In summary, in this propensity-matched analysis, a 37% lower mortality and approximately 50% lower incidence of major morbidity was seen in patients undergoing wedge resection. The mortality benefit was seen mainly in patients with poor lung function, although the morbidity benefit was regardless of age, lung function, or type of incision. Application of this information to guide surgical treatment must carefully take into consideration the possibility for increased recurrence and decreased survival with limited resection as opposed to lobectomy.

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mentectomy for stage I non-small cell lung cancer in the
survival of elderly patients with non-small cell lung cancer
treated with lobectomy or wedge resection within the sur-
veillance, epidemiology and end results database. Chest
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tomy with lymph node assessment an alternative to lobec-
tomy for non-small cell lung cancer of 2 cm or smaller? Ann
on prognosis in patients with non-small cell lung cancer: the
role of segmentectomy as a type of lesser resection. J Thorac
in stage IA non-small cell lung cancer: segmentectomies
result in significantly better cancer-related survival than
versus wedge resection for non-small cell lung cancer in
1747–55.
is associated with lower morbidity than open lobectomy: a
propensity-matched analysis from the STS database. J Thorac

DISCUSSION

DR HIRAN FERNANDO (Boston, MA): I would like to
congratulate Dr Linden and his coauthors on their presentation
and also for sending me the manuscript in advance of this
meeting. This study analyzes over 7,000 patients from the STS
(Society of Thoracic Surgeons) database, addressing the question
of whether wedge resection is associated with lower periopera-
tive morbidity and mortality compared to anatomical resection.
This study does not address, as they mentioned, the question of
oncological effectiveness.

The strengths of the study include a large prospectively
collected data set, with outcomes of operations performed by
cardiothoracic surgeons. The study provides valuable benchmark
data that we can use when discussing appropriate therapy with
patients.

The weakness of the study includes the fact that almost
certainly the patients selected for wedge resection were at higher
risk than patients selected for anatomical resection. The authors
have attempted to overcome this with propensity matching.
However, a concern is that in spite of the binary variables used
for creating these propensity scores, patients who had missing
data were defaulted to zero. For instance, if it was unknown
whether a patient had preexisting congestive heart failure, the
patient defaulted to having no congestive heart failure for the
model. Since the STS database requires a yes or no answer for
this binary variable, I am concerned about the assumption that is
being used.

Accepting these weaknesses, I believe that the authors have
answered their question and demonstrated that wedge resection is
associated with decreased morbidity and mortality compared to
anatomical resection.

I have a question and a recommendation regarding their anal-
ysis. My question is regarding the poor lung function group. Why
did you select an FEV1 (forced expiratory volume in 1 second) less
than 60% and not a lower number, since I doubt that many sur-
geons will be convinced to perform a wedge resection instead of a
lobectomy, even for a very small tumor, based on simply an FEV1
less than 60%. So why not go lower?

Secondly, my comment was related to something you described
in the paper but wasn’t really apparent in the presentation in
that open anatomical resection was associated with a mortality
rate of 2.89% and a major morbidity rate of 12.38%. VATS (vid-
eo-assisted thorascopic surgery) anatomical resection had a
much lower mortality rate of 1.02% and a major morbidity rate of
3.5%. Therefore, there was an approximately threefold increase
in mortality and almost a fourfold increase in morbidity with an
open anatomical resection. This is an important finding and
certainty supports the paper reported by Paul Subrato in 2010
when he also analyzed the STS database, but your work represents
a much larger data set. I think this should be emphasized in your
paper and really supports the role of minimally invasive resections
after surgery.

Once again, congratulations on your manuscript and thank you
to the STS for allowing me to discuss this paper.

DR LINDEN: Thank you, Chrish. In regards to the last comment,
why is the morbidity and mortality so much greater in the tho-
racotomy group than in the VATS group, is this data I didn’t
show in the presentation, but in the thoracotomy group, it’s true,
the major morbidity is 12% with anatomic, 6% for wedge; in the
VATS group it’s about half that. It may not have been so clear in
the paper, but these were separate propensity-matched analyses
that were performed on the thoracotomy patients and on the
VATS patients. The VATS group represented a different group of
patients than the thoracotomy group.

Although you can make comparisons between the groups, it’s
difficult to make accurate comparisons between the groups as they
were selected and matched separately.

In regards to your question, how did we pick FEV1 less than
60% as a cutoff for poor lung function, we did some preliminary
analysis in regards to how many patients would be available for
propensity matching, and when we went below 50%, the number of
patients that we could find that were equivalent between wedge
and anatomic resection was actually quite small, and that’s why we
chose 60% as a cutoff.

Now, in fact we have done some subsequent analysis, and the
protective effect for mortality goes all the way up to 80%. So, even
in patients that have an FEV1 less than 80%, those patients have a
statistically significant lower mortality with wedge than anatomic
resection in propensity-matched analysis.

DR DAVID TOM COOKE (Sacramento, CA): This is an excellent
study and presentation, as well as use of the STS database. I have
two broad questions. First you did a wonderful job of propensity
matching on multiple preoperative clinical variables and patient
demographics. The things that were absent were, A, race and, B,
geographic location and, C, community versus academic prac-
tice. Did you see any differences in the use of nonanatomic
wedge versus anatomic resection based on race, and does the
STS allow you granularity to look at geographic location and
community versus academic practice?

And then the second question I have is, I think most everyone
in the room would have the hypothesis that wedge resection would
have lower morbidity and mortality than anatomic resection. So
what is the take-home message, because at the end of the day, the
treatment of stage I lung cancer will be compared to other mo-
dalities such as SBRT, or stereotactic body radiotherapy, and the
morbidity and mortality in those modalities, and where do you
think this paper fits in that discussion?
DR LINDEN: In regards to the take-home message, it's becoming more and more clear that wedge resection may be an acceptable operation for certain subsegments of clinical stage I cancers. So in patients with predominantly ground glass lesions, especially with a nodular component that's small, maybe 8 mm or smaller, and there is a paper just recently published in *Chest* looking at this, the long-term survival with wedge resection may be the same as with an anatomic resection. And also in the setting of lung cancers found in the setting of CT (computed tomography) screening, just this past week, *JTCVS* (*Journal of Thoracic and Cardiovascular Surgery*) published a study by Nasser Altorki looking at the ELCAP (Early Lung Cancer Action Project) data. So in those patients, these are screened stage I's, the long-term survival was equivalent following wedge resection and anatomic resection, both I think were about 85%. The screened clinical stage I lung cancers are likely to represent a larger proportion of stage I lung cancer patients. Wedge resection may be a more important treatment in the future for these early stage lung cancers.

And then regarding your question of did we look at race or geographic setting or hospital size, that was not evaluated as part of this study, no.

DR RICHARD H. FEINS (Chapel Hill, NC): The significant increase in morbidity between these two, do you think that calls into question the strategy that some adopt that if they don't have a diagnosis on a lesion that it is just as well to go ahead and do a VATS lobectomy, because there really isn't that much difference? There are a lot of people that will not do a diagnosis based upon the assumption, and it seems to me this data calls that into question.

DR LINDEN: Well, there are certainly central lesions where a diagnosis can only be obtained by lobectomy, but certainly, if at all possible, a diagnosis by wedge resection is advisable, and in some set of patients' earliest lung cancers it may be the best therapeutic option as well.

DR JOHN R. BENFIELD (Los Angeles, CA): This is the 50th anniversary of the Society of Thoracic Surgeons, and the database is a sentinel and crucial part of our history. There are, of course, many giants whose names could be mentioned, Richard Clark, in whose honor this and the other papers in this session is named, being among them. But I think it is important to go give special attention to the late Paul Ebert, Past President of the American Association of Thoracic Surgery. It was Paul Ebert's vision, about 25 years ago, that led to the cardiothoracic surgery database. He saw it as a tool that would help our patients by helping us better to understand the results of our operations. And so I offer this tribute to the memory of Dr Paul Ebert.