Graft Position and Pulmonary Function After Single Lung Transplantation for Obstructive Lung Disease*


Single lung transplantation (SLT) has become a therapeutic option for the treatment of end-stage obstructive lung disease. Between January 1989 and June 1990, there were 14 patients with end-stage obstructive lung disease who underwent SLT. Eleven of these patients were surviving at 1 year following transplantation. Three of the patients had received left-sided SLT, and eight had received right-sided SLT. In the patients receiving left-sided SLT, the native right lung radiographically appeared to compress the left lung graft. In the patients receiving right-sided SLT, the native left lung did not appear to compress the right lung graft. We hypothesized that right SLT may provide a functional advantage over left SLT for patients with obstructive lung disease. We compared pulmonary function test results before and after transplantation (approximately 3 and 12 months) and compared quantitative ventilation-perfusion lung scan results between the patients with left SLT and those with right SLT. Additionally, we compared graded-exercise test results at 3 and 12 months after transplant between the two groups. Our data revealed no statistical difference in pulmonary function test results or graded-exercise test results between the two groups, although patients undergoing right SLT showed greater increases in FEV1, and forced vital capacity than those undergoing left SLT. Quantitative ventilation and perfusion were greater to the graft in patients receiving right-sided SLT than in patients receiving left-sided SLT, most likely due to the larger size of the right lung. We conclude that there is no functional difference between patients undergoing left or right SLT for end-stage obstructive lung disease.

(Chest 1993; 100:444-48)

---

SLT = single lung transplantation; SLT-L = left-sided single lung transplantation; SLT-R = right-sided single lung transplantation; UTHSC-SA = University of Texas Health Science Center at San Antonio

---

S

ingle lung transplantation (SLT) has recently become an accepted therapeutic option for the treatment of end-stage obstructive lung disease. Previously, SLT for obstructive lung disease had been controversial, due to potential graft compression by the hyperinflated native lung resulting in a decrease in ventilation to the lung graft following transplantation.1 At the University of Texas Health Science Center at San Antonio (UTHSC-SA), we have performed SLT for end-stage obstructive lung disease since January 1989. Initially, a left-sided SLT (SLT-L) was performed for several technical reasons. The recipient bronchus is longer on the left, allowing for an easier bronchial anastomosis, and a larger atrial cuff can be preserved on the left lung.3 In these patients, radiographically, the native right lung appeared to compress the left lung graft (Fig 1); therefore our surgical colleagues began performing right lung transplants for emphysematous patients due to the potential ability for the residual hyperinflated lung to displace the diaphragm inferiorly rather than herniating across the midline, as may occur when confined by the relatively fixed liver.4

We hypothesized that the radiographic differences described between those patients undergoing SLT-L and right-sided SLT (SLT-R) may result in differences in lung physiologic parameters following SLT. To test this hypothesis, we compared the results of pulmonary function testing, ventilation and perfusion to the lung graft, gas exchange, and symptom-limited graded maximum cardiopulmonary exercise testing in those patients who received SLT-L with those patients who received SLT-R for end-stage obstructive lung disease.

MATERIALS AND METHODS

Fourteen patients underwent transplantation for end-stage obstructive lung disease at UTHSC-SA in the 18-month period from January 1989 to June 1990. Patients with severe obstructive lung disease with either panlobular emphysema secondary to α1-antitrypsin deficiency or with centrilobular emphysema received SLT. Patients less than 60 years of age with an expected survival of less than 18 months and without evidence of pulmonary infections or significant extrapulmonary disease were selected.4 The thorax of the donor was matched to the thorax of the recipient. The size

---

*From the Division of Pulmonary Diseases/Critical Care, Department of Medicine, and the Division of Cardiothoracic Surgery, Department of Surgery, University of Texas Health Science Center at San Antonio and the Audie L. Murphy Memorial Veterans Hospital, San Antonio, Tex. Presented in abstract form at the 56th annual Scientific Assembly, American College of Chest Physicians, Toronto, Canada, October 22-26, 1990. †Currently with Respiratory Division, McGill University, Montreal, Canada. Manuscript received May 8; revision accepted June 19.

Reprint requests: Dr. Levine, Pulmonary Disease Section (111E), Audie L. Murphy VA Hospital, San Antonio 78284
match was deemed acceptable if the chest circumference of
the donor measured at the level of the nipple was within 3 inches of the
chest circumference of the recipient in all patients.

Table 1 shows the demographics of the subjects. Only those
patients surviving up to 3 months following transplantation were
studied. There were 3 early postoperative deaths among the 14
patients (one secondary to a massive upper gastrointestinal hemor-
rhage, one secondary to an intracerebral hemorrhage, and one
secondary to cytomegalovirus pneumonitis). Thus, 11 patients
survived to form the basis for our study. There were three patients
in the SLT-L group and eight patients in the SLT-R group. There
was no difference in mean age between the 2 groups (SLT-L, 44 ± 4
years; SLT-R, 49 ± 8 years). The left group was comprised of two
female patients, and one male patient, and the right group was
comprised of five female and three male patients. The diagnoses
in the SLT-L group were two patients with panlobular emphysema
secondary to α1-antitrypsin deficiency and one patient with idi-
opathic bronchiolitis obliterans. In the SLT-R group, there were four
patients with centrilobular emphysema secondary to tobacco use
and four patients with panlobular emphysema secondary to α1-
antitrypsin deficiency.

The SLT was performed according to a previously established
surgical protocol.6 Prior to transplantation, following SLT on a
weekly and then a monthly basis, and during episodes of suspected
rejection, each recipient underwent pulmonary function testing as
part of their care by the UTHSC-Straight Lung Transplant Service.
Spirometric analysis, body plethysmographic static lung volume
measurements, single-breath carbon monoxide diffusing capacity,
and arterial blood gas measurements were performed using meth-
ods previously described.7 Symptom-limited, graded cardiopul-
nary exercise testing with gas exchange measurements was per-
formed at 1 month, 3 months, and 12 months after transplantation
at a time when the recipients were clinically stable, without evidence
of acute rejection or infection according to previously described
standards.8 Ventilation and perfusion scans were obtained in each
recipient before transplantation, 2 weeks after transplantation, 3
months after transplantation, and then every 6 months after surgery
as described previously.9

Data were compared between transplant groups using Student’s
t test for unpaired data.6 Data were compared within groups before
and following transplantation using Student’s t test for paired data.6
Values for p of 0.05 or less were considered statistically significant.

RESULTS

Table 2 shows pulmonary function and arterial blood
gas data before transplantation and at approximately 3
months and 12 months following transplantation in
the SLT-L and SLT-R groups. There were no significant
differences in mean time following transplantation at the
3-month period after SLT (SLT-L, 3.4 ± 1.4
months; SLT-R, 2.8 ± 1.0 months) or at the 12-month
period after SLT (SLT-L, 12.8 ± 0.9 months; SLT-R,
12.3 ± 2.7 months). Prior to transplantation, the FEV1
was comparably reduced in both groups. The absolute
mean FEV1 for the SLT-L group was 0.64 ± 0.20 L.
The absolute mean FEV1 for the SLT-R group was
0.48 ± 0.15 L (not significant). At 3 months following
transplantation, both groups showed significant
improvement in FEV1, with comparable absolute values
of 1.81 ± 0.57 L for the left graft recipients and
1.80 ± 0.49 L for the right graft recipients. This
improvement was sustained at the 12-month period
after transplantation. The forced vital capacity (FVC)
was comparably reduced in both groups prior to
transplantation. Following transplantation, both

<table>
<thead>
<tr>
<th>Data</th>
<th>SLT-L</th>
<th>SLT-R</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Age, yr*</td>
<td>44 ± 5</td>
<td>49 ± 8</td>
</tr>
<tr>
<td>Sex</td>
<td>2 F; 1 M</td>
<td>5 F; 3 M</td>
</tr>
<tr>
<td>Diagnoses†</td>
<td>α1-ATD, BO</td>
<td>α1-ATD, COPD</td>
</tr>
</tbody>
</table>

Values are group means ± SD.

α1-ATD, alpha-1-antitrypsin deficiency; BO, bronchiolitis obliterans;
and COPD, chronic obstructive pulmonary disease.
Table 2—Pulmonary Function and Arterial Blood Gas Data*

<table>
<thead>
<tr>
<th>Data</th>
<th>Before SLT</th>
<th>3 mo After SLT</th>
<th>12 mo After SLT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SLT-L</td>
<td>SLT-R</td>
<td>SLT-L</td>
</tr>
<tr>
<td>FEV₁, L</td>
<td>0.64 ± 0.20</td>
<td>0.48 ± 0.15</td>
<td>1.81 ± 0.57†</td>
</tr>
<tr>
<td>% of predicted</td>
<td>19 ± 5</td>
<td>16 ± 6</td>
<td>56 ± 13†</td>
</tr>
<tr>
<td>FVC, L</td>
<td>2.27 ± 0.54</td>
<td>1.48 ± 0.60</td>
<td>2.33 ± 0.66</td>
</tr>
<tr>
<td>% of predicted</td>
<td>53 ± 8</td>
<td>45 ± 10</td>
<td>56 ± 7</td>
</tr>
<tr>
<td>FEV₁/FVC</td>
<td>0.27 ± 0.03</td>
<td>0.27 ± 0.15</td>
<td>0.77 ± 0.10†</td>
</tr>
<tr>
<td>D, ml/min/mm Hg§</td>
<td>...</td>
<td>6.4 ± 5.4</td>
<td>20.3 ± 5.9</td>
</tr>
<tr>
<td>% of predicted</td>
<td>...</td>
<td>24 ± 16</td>
<td>84 ± 18</td>
</tr>
<tr>
<td>TLC, L</td>
<td>8.71 ± 0.40</td>
<td>8.61 ± 2.37</td>
<td>6.61 ± 1.96</td>
</tr>
<tr>
<td>% of predicted</td>
<td>174 ± 25</td>
<td>165 ± 40</td>
<td>112 ± 16†</td>
</tr>
<tr>
<td>PaO₂, mm Hg</td>
<td>62 ± 11</td>
<td>55 ± 5</td>
<td>82 ± 4†</td>
</tr>
<tr>
<td>PaCO₂, mm Hg</td>
<td>44 ± 11</td>
<td>44 ± 14</td>
<td>34 ± 3</td>
</tr>
<tr>
<td>SaO₂ at rest, %§</td>
<td>92 ± 7</td>
<td>89 ± 5</td>
<td>96 ± 1</td>
</tr>
</tbody>
</table>

*Values are group means ± SD.
†p≤0.05 in comparison to before SLT.
‡p≤0.05 in comparison to SLT-L.
§D, Diffusing capacity; and SaO₂, arterial oxygen saturation.

groups showed some improvement in FVC. This improvement only met statistical significance (p<0.05) in the SLT-R group.

Improvements in FEV₁ and FVC were greater for the SLT-R group than the SLT-L group, although there was no statistical difference between the values before and after transplantation in these two groups. The FEV₁/FVC ratio was severely reduced in both groups prior to transplantation, and both left and right graft recipients showed significant improvement and normalization of the FEV₁/FVC ratio at 3 and 12 months following transplantation. There was no significant difference in the degree of improvement of this ratio between left and right lung transplant recipients. Total lung capacity (TLC) was markedly increased prior to transplantation in both groups, and both of the groups showed a reduction in TLC following transplantation. This met statistical significance only for the SLT-L group at 3 and 12 months following transplantation.

The majority of our SLT-L patients were unable to perform a diffusing capacity measurement prior to transplantation. At 3 months following transplantation, left graft recipients had a greater diffusing capacity in comparison to the right graft recipients, but this did not reach statistical significance. At 12 months following SLT, diffusing capacity was found to be similar in both groups.

Prior to transplantation, both groups had comparable arterial hypoxemia. Following transplantation, there was significant improvement in arterial oxygen tension in both groups of patients; however, the arterial oxygen tension in the SLT-R group was significantly higher (p<0.05) than arterial oxygen tensions in the SLT-L group at 3 months after SLT. Arterial carbon dioxide tensions were normal in all patients following transplantation.

Figure 2 illustrates mean quantitative ventilation and perfusion to the respective lung grafts before transplantation and at 3 and 12 months after transplantation. Prior to SLT, both lungs received approxi-
Table 3—Cardiovascular and Ventilatory Parameters*

<table>
<thead>
<tr>
<th>Data†</th>
<th>3 mo After SLT</th>
<th>12 mo After SLT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SLT-L</td>
<td>SLT-R</td>
</tr>
<tr>
<td>Work load at maximum exercise, W</td>
<td>63 ± 15</td>
<td>69 ± 22</td>
</tr>
<tr>
<td>( \dot{V}O_{2\text{max}}, \text{L/min} )</td>
<td>0.88 ± 0.4</td>
<td>0.84 ± 0.31</td>
</tr>
<tr>
<td>% of predicted</td>
<td>40 ± 7</td>
<td>48 ± 15</td>
</tr>
<tr>
<td>HRmax, beats per min</td>
<td>125 ± 13</td>
<td>139 ± 16</td>
</tr>
<tr>
<td>% of predicted</td>
<td>74 ± 8</td>
<td>84 ± 9</td>
</tr>
<tr>
<td>( \dot{V}r_{\text{max}}, \text{L/min} )</td>
<td>37.2 ± 19.9</td>
<td>32.9 ± 13.4</td>
</tr>
<tr>
<td>( Vr_{\text{max}}, % ) of calculated MVV</td>
<td>37 ± 19</td>
<td>52 ± 13</td>
</tr>
<tr>
<td>( Vr_{\text{max}}, \text{L} )</td>
<td>1.27 ± 0.41</td>
<td>1.19 ± 0.33</td>
</tr>
<tr>
<td>( Vr_{\text{max}}, % ) of FVC</td>
<td>54 ± 2</td>
<td>52 ± 7</td>
</tr>
<tr>
<td>( fbmax, \text{breaths per min} )</td>
<td>29 ± 7</td>
<td>27 ± 4</td>
</tr>
<tr>
<td>( SaO_{2\text{max}}, % )</td>
<td>94 ± 3</td>
<td>95 ± 2</td>
</tr>
<tr>
<td>( SaO_{2\text{rest}}, % )</td>
<td>96 ± 1</td>
<td>97 ± 1</td>
</tr>
<tr>
<td>AT, L/min ( \dot{V}O_{2})</td>
<td>0.78 ± 0.35</td>
<td>0.85 ± 0.49</td>
</tr>
<tr>
<td>AT, % of predicted ( \dot{V}O_{2\text{max}} )</td>
<td>29 ± 3</td>
<td>39 ± 12</td>
</tr>
</tbody>
</table>

*Values are group means ± SD.
†\( \dot{V}O_{2\text{max}} \), oxygen consumption at maximum exercise; HRmax, heart rate at maximum exercise; \( \dot{V}r_{\text{max}} \), minute ventilation at maximum exercise; MVV, maximum voluntary ventilation; \( Vr_{\text{max}} \), tidal volume at maximum exercise; \( fbmax \), breathing frequency at maximum exercise; and AT, ventilatory anaerobic threshold.

Immediately equal ventilation and perfusion in all patients. At 3 months following SLT, quantitative ventilation to the right lung graft is significantly greater than ventilation to the left lung graft. Perfusion is also significantly greater to the right transplanted lung than to the left transplanted lung. At 12 months following SLT, more quantitative ventilation and perfusion go to the right-sided SLT than the left-sided SLT, but this difference was statistically significant only for perfusion.

Table 3 shows results of cardiovascular and ventilatory parameters obtained during symptom-limited, graded maximum cycle ergometric exercise testing at 3 months and 12 months following transplantation. The reduced maximum exercise workload and oxygen consumption of the SLT-L group was comparable to that of the SLT-R group. Maximum heart rates and maximum minute ventilation were comparable in the two groups. In both groups, there was evidence of breathing reserve present at the end of exercise, as indicated by the minute ventilation expressed as a percentage of maximum voluntary ventilation. Maximum tidal volume and maximum breathing frequencies were normal in both groups. There was no significant arterial desaturation during exercise in either group. The anaerobic thresholds were comparably reduced in both groups. In summary, there was no ventilatory or cardiovascular limitation to exercise in either group of patients at 3 months or 12 months following transplantation.

**Discussion**

Despite previous controversy surrounding the use of SLT for the treatment of end-stage obstructive lung disease, SLT for obstructive lung disease has been performed successfully.†,‡,§ Traditionally, SLT-L was preferable for technical reasons, such as a longer bronchial recipient stump and a larger recipient atrial cuff.†

Our center initially performed SLT for obstructive disease on the left side, but radiographically we noted significant compression of the transplanted left lung by the native right lung. Subsequently, SLT-R has been performed for this disease due to the theoretic ability of the residual left hyperinflated native lung to displace the diaphragm inferiorly rather than herniating across the midline as may occur when confined by the relatively fixed liver.¶ If preoperative studies confirm a significant discrepancy in pulmonary function, the lung with the worst function is replaced, regardless of whether it is the right or left lung. Despite a technically more difficult surgery when performing SLT-R, with the use of the bronchial anastomotic telescoping technique, none of our patients has developed bronchial anastomotic complications.¶

In our patients, we found no difference in spirometry, lung volumes, or diffusing capacity between patients receiving a right-sided or left-sided lung transplant for the treatment of end-stage obstructive lung disease. Both groups of graft recipients showed significant improvement in spirometry, lung volumes, and arterial oxygen tensions following transplantation, although this improvement was greater in the SLT-R group compared to the SLT-L group. Perhaps this is due to the worse preoperative pulmonary function of the SLT-R group or to the larger size of the human right lung as compared to the left lung. Following transplantation, the right graft recipients have greater ventilation and perfusion to the transplanted lung (possibly secondary to the larger volume of the right lung), less radiographic compression of the trans-
planted lung, and higher resting arterial oxygen tension than those patients receiving left lung transplants; however, despite these differences between the two groups, neither SLT-R nor SLT-L recipients developed significant ventilatory limitation with exercise. These data suggest that the choice of the right versus left graft position in SLT for end-stage obstructive lung disease does not appear to have clinical significance in the stable patient at 1 year following transplantation.

ACKNOWLEDGMENTS: We thank Ms. Toyia Harris for excellent secretarial assistance in preparing the manuscript.

REFERENCES

18th Annual Postgraduate Course on Ultrasound Imaging

Harvard Medical School and the Department of Radiology, Brigham, and Women's Hospital, will sponsor this course March 28-31 at the Westin Hotel, Copley Place, Boston. For information, contact the Department of Continuing Education, Harvard Med-CME, PO Box 825, Boston 02117 (617:432-1525).