CARDIAC AND PULMONARY REPLACEMENT

SINGLE OR BILATERAL LUNG TRANSPLANTATION FOR EMPHYSEMA?

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Background: Most programs favor single lung transplantation for emphysema. However, this is controversial, and we have favored bilateral lung transplantation, confining single lung transplantation mainly to use in older patients and those of small stature. **Methods:** A retrospective analysis was done of 119 consecutive lung transplantation procedures for emphysema at Barnes Hospital between 1989 and 1994 (50 single lung, 69 bilateral lung transplants) to (1) identify outcome differences between the two groups and (2) define the appropriate role of these two procedures. **Results:** The single lung transplantation group was older and had a higher proportion of female patients. However, baseline pulmonary function (forced expiratory volume in 1 second), arterial oxygen tension, and exercise tolerance (6-minute walk distance) were similar. After transplantation, 90-day mortality (single lung transplantation 10% versus bilateral lung transplantation 7.2%; $p = 0.74$) and duration of mechanical ventilation, intensive care unit stay, and hospitalization were similar. Both groups achieved a significant and sustained improvement in forced expiratory volume, arterial carbon dioxide tension, arterial oxygen tension, and exercise tolerance within 3 months. However, the improvements in forced expiratory volume, arterial oxygen tension, and exercise tolerance were consistently significantly better in recipients of bilateral transplants at and beyond 6 months. Obliterative bronchiolitis was equally prevalent in both groups. Survival was similar but showed a trend toward better late survival in recipients of bilateral transplants (5-year actuarial survival: bilateral lung transplantation 53% versus single lung transplantation 41%). **Conclusions:** We conclude that (1) both procedures are satisfactory options in emphysema, producing durable results; (2) bilateral lung transplantation is not associated with increased operative mortality or morbidity and achieves superior improvements in spirometry findings, oxygenation, exercise tolerance, and possibly late survival; and (3) the superior improvements in function (and late survival) after bilateral lung transplantation may be attributed to the presence of more pulmonary reserve after the onset of obliterative bronchiolitis. (J Thorac Cardiovasc Surg 1996;112:1485-95)

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Read at the Seventy-sixth Annual Meeting of The American Association for Thoracic Surgery, San Diego, Calif., April 28–May 1, 1996.

Received for publication May 6, 1996; revisions requested June 3, 1996; revisions received July 12, 1996; accepted for publication July 15, 1996.

Lung transplantation is an established treatment modality for end-stage obstructive lung disease, and emphysema now constitutes the most common indication for lung transplantation worldwide.¹ The

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0022-5223/96 \$5.00 + 0 12/6/76513

traditional paradigm held that single lung transplantation (SLT) was unworkable in advanced emphysema. Consequently, considerable initial success was encountered in the use of bilateral lung replacement for emphysema during the mid-1980s.² This was first accomplished with use of the en bloc double lung transplantation technique,² although this was later supplanted by the bilateral sequential lung transplantation (BLT) procedure.³ However, substantial numbers of published reports are now available that have demonstrated first the clinical feasibility of SLT for emphysema⁴⁻⁶ and later the medium-term functional results with this approach.^{7,8} Several reports have compared the early outcomes of single versus bilateral lung replacement in emphysema.⁹⁻¹¹ There remains considerable controversy regarding the ideal application of SLT and BLT in patients with obstructive lung disease, and to date no long-term follow-up studies with comparison of late results have been available. The purpose of this study was to review our experience with SLT and BLT for obstructive lung disease at Barnes Hospital, to try to determine which of these represents the superior transplantation option.

Patients and methods

We retrospectively analyzed 119 consecutive cases of SLT and BLT done for obstructive lung disease (chronic obstructive pulmonary disease caused by cigarette smoking or α_1 -antitrypsin deficiency emphysema) in the Barnes Hospital/Washington University lung transplantation program between July 1, 1988, and December 31, 1994. (Two patients who underwent en bloc double lung transplantation because of obstructive lung disease early during the study interval were deliberately excluded from the analysis.) Technical aspects of the donor¹² and recipient^{13,14} operative procedures and details regarding immunosuppression protocols¹⁵ and posttransplantation follow-up and management¹⁶ have been reported elsewhere. Follow-up was completed on July 1, 1995 (the date of beginning the analysis) or at the time of the recipient's death. Follow-up was complete in all recipients and ranged from 7 to 64 months.

Our general criteria for choosing between SLT and BLT are as follows. BLT is used in younger patients (age generally younger than 50 to 55 years), in patients of large stature (height more than 5 feet, 8 inches), and/or in patients with emphysema accompanied by bullous change. SLT is used in older patients (for example, older than 55 years) or in those of smaller stature (height less than 5 feet, 6 inches).

Preoperative parameters evaluated. The following parameters were reported for all recipients in the two groups (SLT and BLT): (1) age and sex distribution, (2) diagnosis (chronic obstructive pulmonary disease, α_1 -antitrypsin deficiency emphysema), (3) pulmonary function test results (forced expiratory volume in 1 second [FEV₁] as a

percentage of predicted), (4) arterial blood gas values on room air (arterial carbon dioxide tension [Paco₂] and oxygen tension [Pao₂] in millimeters of mercury), and (5) exercise tolerance (evaluated in a standard 6-minute walk test as previously described).⁹

Operative parameters evaluated. The following parameters pertaining to the operative course were evaluated: (1) operation performed (SLT or BLT; for SLT, right or left), (2) graft ischemic time (in minutes; for BLT, the ischemic time was considered to be that of the second allograft inserted), and (3) use of cardiopulmonary bypass.

Postoperative parameters evaluated. The following parameters pertaining to the early and late postoperative periods were evaluated for all recipients in each group. First, early postoperative course evaluation included 90-day mortality, days of mechanical ventilation, days in the intensive care unit, and days in the hospital. Second, Pulmonary function test results (FEV₁), arterial blood gas levels (Paco₂, Pao₂), and exercise tolerance (6-minute walk test) were evaluated for all recipients at 3 and 6 months after operation and then annually until the end of the follow-up interval or until the time of the recipient's death. Third, Recipients in each group were evaluated for the development of bronchiolitis obliterans syndrome (BOS) with the use of previously described criteria.¹⁷ Briefly, BOS was diagnosed if there was a sustained and significant fractional decline in FEV₁ (less than 80% of a previously established postoperative baseline value) more than 3 months beyond the date of the transplantation or if obliterative bronchiolitis was documented pathologically. Fourth, actuarial survival was determined by the Kaplan-Meier method.

Data analysis. Whenever applicable, data are presented as mean plus or minus standard error of the mean. Statistical comparison of values between the SLT and BLT groups was done as follows: tabular data with Fisher's exact test; paired data with the paired *t* test; Kaplan-Meier survival data with the Mantel-Haenszel test; and the remainder with repeated-measures analysis of variance (multivariate comparisons were done with contrast). Values were considered significantly different when the *p* value was less than 0.05.

Results

Fifty (42%) of the 119 patients underwent SLT, and 69 (58%) of 119 underwent BLT. In the SLT group, 19 (38%) of 50 received a right lung allograft, whereas 31 (62%) of 50 received a left lung allograft.

Comparison of preoperative parameters. Recipients in the SLT group were older (SLT 55 ± 1 years vs BLT 49 ± 1 years; *p* < 0.001). Also, the SLT group showed a higher percentage of female patients (SLT 68% women vs BLT 42% women; *p* = 0.009) and patients with chronic obstructive pulmonary disease (SLT 82% chronic obstructive pulmonary disease and 18% α_1 -antitrypsin deficiency emphysema vs BLT 54% chronic obstructive

Fig. 1. PaCO₂ in millimeters of mercury for recipients in both groups preoperatively (*Pre-op*) and during posttransplantation follow-up. All data are shown as mean $\pm$ standard error of mean. *, Significant versus preoperative value; +, significant versus SLT value at corresponding time.

Table I. Comparison of preoperative and operative parameters between groups

	Preoperative			Operative	
	Age (yr)	Gender distribution	Diagnosis	Ischemic time (min)	Use of CPB
SLT	55 $\pm$ 1	M 32%, F 68%	COPD 82%, ATDef 18%	267 $\pm$ 9	1/50 (2%)
<i>p</i> Value	<0.001	0.009	0.002	<0.0001	0.002
BLT	49 $\pm$ 1	M 58%, F 42%	COPD 54%, ATDef 46%	369 $\pm$ 10	14/69 (20%)

Data shown as mean $\pm$ standard error of mean where applicable. CPB, Cardiopulmonary bypass; M, male; F, female; COPD, chronic obstructive pulmonary disease; ATDef, α_1 -antitrypsin deficiency emphysema.

pulmonary disease and 46% α_1 -antitrypsin deficiency emphysema; $p = 0.002$) (Table I). The mean preoperative PaCO₂ level was significantly higher in the SLT group (SLT 47.6 $\pm$ 1.5 mm Hg vs BLT 44.1 $\pm$ 0.9 mm Hg; $p = 0.038$) (Fig. 1). There was no difference between the SLT and BLT groups with respect to preoperative FEV₁ value (SLT 17.6% $\pm$ 0.6% of predicted vs BLT 16.9% $\pm$ 0.5% of predicted; $p = 0.369$), PaO₂ (SLT 54.1 $\pm$ 1.9 mm Hg vs BLT 56.7 $\pm$ 1.3 mm Hg; $p = 0.261$), or distance

covered in the 6-minute walk test (SLT 980 $\pm$ 46 feet versus BLT 993 $\pm$ 49 feet; $p = 0.876$) (Figs. 2 through 4).

Comparison of operative parameters. The mean graft ischemic time was longer in the BLT group (BLT 369 $\pm$ 10 minutes vs SLT 267 $\pm$ 9 minutes; $p < 0.0001$). Also, cardiopulmonary bypass was required with significantly higher frequency in the BLT group (BLT 20% vs SLT 2%; $p = 0.002$, Table I), in every case because of poor first graft function

Fig. 2. FEV₁ as percent of predicted for recipients in both groups preoperatively (*Pre-op*) and during posttransplantation follow-up. All data are shown as mean $\pm$ standard error of mean. *, Significant versus preoperative value; +, significant versus SLT value at corresponding time.

(unsatisfactory hemodynamics or gas exchange). In only one patient in the SLT group was CPB required to repair an inadvertent laceration in the proximal left pulmonary artery.

Comparison of early postoperative course. Table II summarizes the parameters relevant to the early postoperative course. There was no difference between the SLT and BLT groups with respect to 90-day mortality (SLT 10% vs BLT 7.2%; $p = 0.74$). Duration of mechanical ventilation (BLT 3.9 ± 1.0 days vs SLT 2.2 ± 0.3 days) and intensive care unit stay (BLT 5.0 ± 1.0 days vs SLT 3.0 ± 0.3 days) were both longer in the BLT group, although neither of these differences achieved significance ($p = 0.108$ and 0.059 , respectively). Duration of hospital stay was similar between groups (BLT 24.5 ± 1.5 days vs SLT 23.4 ± 1.8 days; $p = 0.652$).

Comparison of late postoperative pulmonary function, gas exchange, and exercise tolerance. A significant improvement in FEV₁, Pao₂, and Pao₂ values and in exercise tolerance was noted within 3 months after transplantation in both groups and was sustained throughout the period of late follow-up (Figs. 1 through 4). The improvements in FEV₁ and Pao₂ values were significantly better in the BLT group (compared with those in the SLT group) from 3 months until 4 and 3 years after transplantation, respectively (Figs. 2 and 3). The improvement in exercise tolerance was significantly better in the BLT group at 6 months, and this superior improvement was maintained until 3 years after transplantation (Fig. 4). There was no difference between groups with respect to Paco₂ values throughout the period of late follow-up (Fig. 1).

Fig. 3. PaO_2 in millimeters of mercury for recipients in both groups preoperatively (*Pre-op*) and during posttransplantation follow-up. All data are shown as mean $\pm$ standard error of mean. *, Significant versus preoperative value; +, significant versus SLT value at corresponding time.

Development of BOS. The development of BOS is summarized in Table III. Recipients were considered at risk for the development of BOS only if they survived at least 90 days after transplantation (64 BLT recipients and 45 SLT recipients). BOS was more prevalent in the SLT group (SLT 23/45 [51%] vs BLT 21/64 [33%]); this difference approached but did not achieve significance ($p = 0.079$). Mortality in recipients with BOS did not differ between groups (SLT, 7 deaths in 23 recipients with BOS [30.4%] vs. BLT, 6 deaths in 21 [28.6%]; $p = 1.00$).

Actuarial survival. Actuarial survival curves for the SLT and BLT groups are shown in Fig. 5. The 1-year survival was 88% after SLT and 84% after BLT. Survival was similar in both groups until 3 years after transplantation (BLT 80% vs SLT 79%). Subsequently, survival declined in both groups, but tended to be better in the BLT group (4-year actuarial survival: BLT 73% vs SLT 51%; 5-year actuarial survival: BLT 53% vs SLT 41%). Although the 5-year actuarial survival appeared better in the BLT group, this difference did not achieve significance ($p = 0.27$).

Discussion

Emphysema has continued to be the fifth leading cause of death in the United States during the past couple of decades and now constitutes the most common indication for lung transplantation worldwide.¹ However, the optimal lung transplantation procedure, single or bilateral lung replacement, continues to be a matter of debate.

On the basis of significant improvements in several parameters including spirometry (FEV_1), blood gas levels (PaCO_2 , PaO_2), and exercise endurance (6-minute walk distance), this study has shown that both SLT and BLT are satisfactory transplantation options in patients with end-stage emphysema. Our study has also shown that both SLT and BLT produce extremely durable results, inasmuch as the improvements in these parameters were sustained as late as 4 years after transplantation. To our knowledge, we report here the longest duration of follow-up in a single-institution comparison of SLT versus BLT for emphysema and provide late confirmation of the medium-term follow-up data of Mal and colleagues⁷ and Levine and associates.⁸ Fur-

Fig. 4. Distance in feet covered in standard 6-minute walk test for recipients in both groups preoperatively (Pre-op) and during posttransplantation follow-up. All data are shown as mean $\pm$ standard error of mean. *, Significant versus preoperative value; +, significant versus SLT value at corresponding time.

Table II. Comparison of early postoperative outcome parameters between groups

	Death <90 days	Duration of mechanical ventilation (days)	Duration of ICU stay (days)	Duration of hospital stay (days)
SLT	5/50 (10%)	2.2 $\pm$ 0.3	3.0 $\pm$ 0.3	23.4 $\pm$ 1.8
p Value	0.74	0.108	0.059	0.652
BLT	5/69 (7.2%)	3.9 $\pm$ 1.0	5.0 $\pm$ 1.0	24.5 $\pm$ 1.5

Data shown as mean $\pm$ standard error of mean where applicable. ICU, Intensive care unit.

thermore, transplantation procedures were accomplished with an acceptably low early (90-day) mortality rate. The 90-day mortality rate did not exceed 10% in either group. These figures compare favorably with mortality statistics for similar SLT and BLT groups reported in the International Registry.¹

Data from the International Registry reveal that almost 80% of lung transplantation procedures done for emphysema in the international experience are SLTs.¹ We report here a different utilization of these two transplantation procedures and actually show a preference for BLT (42% SLT and 58% BLT

in our experience). This obvious discrepancy with the international experience merits a comparison of our SLT and BLT groups. SLT recipients were older and predominantly had chronic obstructive pulmonary disease (82%). The higher percentage of women in the SLT group (68%) may have been a result of stature (see later discussion). The younger age of the recipients of BLT is partly explained on the basis of a higher proportion of patients with α_1 -antitrypsin deficiency (46%), along with our unproven supposition of greater long-term durability of results with BLT.

Our notion is that SLT is a simpler operation and is therefore well-suited to minimize potential operative risks in older patients, in whom complications may be more frequent. We have also thought that SLT is suitable in patients of smaller body habitus, in whom a satisfactory volume of lung allograft can be achieved with a single lung by deliberately oversizing the donor by up to 20%. This size-matching strategy is generally more readily achieved in female patients. It is important to note, however, that although we determined these demographic differences, the two groups were equivalent before operation in terms of functional status, oxygenation, and exercise tolerance.

The decision regarding the choice of SLT versus BLT in emphysema must be based on several considerations. The first of these relates to the technical complexity of the procedure. Intuitively, SLT is a much simpler transplantation option. The procedure should be short and technically straightforward. Operative blood loss should be less and intraoperative hypotensive episodes less frequent and less severe. The graft ischemic time should be shorter, thereby minimizing the incidence of early postoperative graft dysfunction. The necessity for cardiopulmonary bypass should be rare, and the potential need for postoperative inotropic and vasoactive agents should be minimal. In this study, we used graft ischemic time and use of cardiopulmonary bypass as major objective indicators of the "complexity" of the operation and, on this basis, confirmed the greater magnitude of the BLT procedure. We did not find a difference between groups with respect to either 90-day mortality (SLT 10% vs BLT 7.2%) or hospital mortality (SLT 6% vs BLT 7.2%). Although there was a trend to longer duration of mechanical ventilation and intensive care unit stay in the BLT group, neither of these differences achieved significance, and ultimately the duration of hospital stay was similar. Therefore this study has not demonstrated that SLT is associated with lower operative or perioperative risks than BLT. Our failure to demonstrate the anticipated higher mortality in the BLT group may be partially accounted for by the younger status of the patients receiving BLT. However, although the majority of the BLT procedures were done in patients between 46 and 55 years old (40 cases), BLT was also done in patients between the ages of 56 and 60 years (8 cases compared with 18 in the SLT group for this age range) and even in patients 61 years old or more (2 cases compared with 6 SLT cases in this same age range).

Table III. Prevalence of BOS and mortality in recipients with BOS in SLT and BLT groups

	SLT (N = 50)	p Value	BLT (N = 69)
No. at risk for BOS	45		64
Prevalence of BOS	23/45 (51%)	0.079	21/64 (33%)
Mortality in recipients with BOS	7/23 (30.4%)	1.00	6/21 (28.6%)

The scarcity of suitable donors continues to be the main factor limiting more widespread use of lung transplantation. This constitutes another consideration in favor of SLT for emphysema, in that this approach can potentially accomplish twice as many lung transplantations from the same number of donors. However, this rationale is only valid if both lungs in each multiple-organ donor satisfy the traditional rigorous donor criteria.¹² This is illustrated somewhat in our SLT group. Forty-five donors yielded our 50 SLTs for emphysema and 19 other SLTs, for a total of 69 SLTs. However, an opposing argument in favor of BLT can be made on the basis of our recent report on the use of marginal donor lungs.¹⁸ In that report, marginal donors were used as a means of expanding the limited donor pool, and this approach was not found to compromise satisfactory outcome.¹⁸ Analysis of the most recent 52 of the 69 transplantations in our BLT group reveals that 27 (52%) of the 52 recipients of BLT received marginal donor lungs. Of note, 21 (78%) of these 27 marginal donors were deemed marginal on the basis of poor oxygenation ($Pao_2 < 300$ mm Hg on inspired fraction of oxygen = 1.0 and 5 cm water positive end-expiratory pressure) or unsatisfactory chest radiograph (that is, containing infiltrates or contusions). With donors of such marginal status, SLT would rarely be possible. However, we have evolved to using both lungs from such marginal donors frequently in performing BLT in patients with emphysema with satisfactory outcomes as reported here. The specific aspects of BLT in emphysema that facilitate the use of such marginal grafts are (1) a large pleural space, usually devoid of adhesions, which facilitates rapid transplantation of the first graft and (2) use of the most marginal donor lung as the second graft. Thus our liberal use of such marginal donors in BLT for emphysema facilitated the performance of 21 (30%) of our 69 BLT cases, as opposed to accomplishing no transplant at all.

Is SLT equivalent to BLT in the long term? A number of parameters must be evaluated to answer

Fig. 5. Actuarial survival curves for recipients in SLT and BLT groups. Five-year actuarial survival was better in BLT group, but this difference did not achieve significance ($p = 0.27$). S, SLT; B, BLT.

this question, including objective functional parameters, the patients' subjective sense of improvement, the development of BOS, and late survival. On the basis of our data, both SLT and BLT produce significant improvement in all of the chosen objective parameters (FEV_1 , $Paco_2$, Pao_2 , and 6-minute walk distance); however, the improvements in FEV_1 value, oxygenation, and exercise tolerance were all better after BLT, and this superiority was sustained during late follow-up. Improvement in FEV_1 value was significantly better in the BLT group up to 4 years after transplantation. The improvements in Pao_2 level and 6-minute walk distance were significantly better after BLT until 3 years, and it is likely that the relatively smaller number of available measurements at 4 years was the reason that these differences did not achieve significance at this point. With respect to improvement in these selected parameters our findings confirm superiority of BLT over SLT, which was already demonstrated in previously published short-term follow-up studies.^{11,12} However, an important issue, the recipients' subjective sense of improvement after the transplantation, was not specifically addressed in this study.

In a previous report we showed that BOS eventually affects at least 50% of lung transplant recipients and that this entity is equally prevalent in all subgroups of lung allograft recipients, without regard for the underlying diagnosis or the type of transplantation performed.¹⁹ The current study

showed a higher prevalence of BOS in the SLT group (SLT 51% vs BLT 33%). Although this difference was not significant, the findings are likely explained by the fact that 47 of the 50 SLTs were done before January 1, 1994, thereby providing at least 18 months of follow-up for most of the SLT recipients. The 33% prevalence of BOS in the BLT group is somewhat lower than the prevalence figures we previously reported; however, given that 17 of the bilateral transplantation procedures were done between January 1, 1994, and December 31, 1994, this is likely because of the short duration of follow-up for more recent recipients of BLT. The gradual decline in FEV_1 noted in both groups beyond 1 year after transplantation (Fig. 2) is probably the consequence of BOS. Actuarial survival curves for the SLT and BLT groups were similar (Fig. 5). Although this study did not show a difference between groups in the absolute mortality for recipients affected by BOS (SLT 30.4% vs BLT 28.6%), it is still possible that the trend toward better late survival in the BLT group reflects the presence of greater "reserve" (i.e., more functional lung allograft parenchyma) after the onset of BOS.

The high prevalence of BOS¹⁹ and limited survival (at 4 years: BLT 73% vs SLT 51%) lend support to our belief that lung transplantation should be considered only for those patients with emphysema who are ideal candidates in every respect and who have no other therapeutic option. We

have reported lung volume reduction surgery to be an effective procedure for the relief of dyspnea in selected patients with advanced emphysema.²⁰ We have also recently compared a preliminary experience with lung volume reduction surgery versus SLT and BLT for end-stage emphysema.²¹ Other potential strategies include the use of unilateral volume reduction surgery concomitant with SLT or in a staged manner after SLT.²² Thus it appears that volume reduction is a good surgical option that may obviate or delay lung transplantation in selected patients with emphysema eligible for either procedure.

On the basis of the data from the current study, we conclude that both SLT and BLT are highly satisfactory transplantation options in patients with emphysema, both of which produce durable results. The current analysis has shown that BLT produces a superior improvement in spirometry and Pao₂ values and exercise endurance, as well as possibly a tendency to better late survival. We conclude that the choice of SLT or BLT in end-stage emphysema must be individualized to the patient, with particular attention paid to their age, body habitus, and physiologic status. We continue to confine the use of SLT to older recipients and to patients with smaller body habitus. We prefer the use of BLT in younger candidates, in those who are "fit" (other than the end-stage lung disease), and in those patients with larger body habitus.

We gratefully acknowledge the help of Richard B. Schuessler, PhD, in performing the statistical analysis; Carol Cleary for secretarial assistance in preparation of the manuscript; and Mary Pohl, Dottie Bigger, Laura Ochoa, and Greg Richardson in compiling the data.

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Discussion

Dr. J. Kent Trinkle (*San Antonio, Tex.*). Succinctly, the big question is this: in patients with emphysema are two lungs better than one lung and, if so, under what circumstances? In addition, under what circumstances is the larger bilateral operation justified? In the early days of lung transplantation, that is, about 10 years ago, when the alternative was the en bloc double lung procedure, the answer was quite easy: the single lung procedure was safer, simpler, and quite effective, and that was an easy decision. Today with the bilateral procedure the options are a lot closer to call.

The data from this manuscript are quite clear. From 3 months to 3 years, BLT has a big advantage over SLT, in both FEV₁ and Pao₂ values and exercise tolerance. Although the mortality data are improved, the difference does not quite reach statistical significance. A purist would say that the waters are muddied by the selection criteria of older, smaller, and sicker patients, with a tendency toward more women, and that we need a prospective randomized study, but today that is not practical or appropriate.

I would like to introduce one question that refers to patients with SLT, and that is the question of right versus left lung transplantation, because there is an interesting mechanical principle involved. The left diaphragm does not have a liver underneath it and so it is more easily displaced inferiorly during expiration. The first SLT operation that I did for chronic obstructive pulmonary disease was done in January 1988. I thought I was plowing new ground. I did not know that Dr. Mal and his colleagues in Paris had done this several months earlier. However, I did the procedure on the left side, and the transplanted lung looked pathetically small on the plain x-ray film, while on the expiratory film it was virtually a whiteout, with tremendous mediastinal shift. I did three transplantation procedures in a row on the left side with the same kind of results, and then I did three on the right side and did not see this horrible mediastinal shift on expiration, and the FEV₁ findings were dramatically better with the percentage increase almost twice as great in the patients in whom we did the right lung transplantations because of chronic obstructive pulmonary disease. Therefore we developed a simplistic principle that the big lung should go on the left, and in the case of chronic obstructive pulmonary disease the big lung is the native or emphysematous lung.

I am sure the current data answer this question much better than I did because we stopped doing left SLT procedures early on, except for selected anatomic or reoperation reasons. The one question that I think the authors could answer to add to our knowledge, then, would be whether in SLT the procedure should be done on the left or the right.

Dr. Sundareshan. I think the rationale that you give for preferring to do right SLT for emphysema makes perfect sense. Your center has indeed published data showing better objective improvement in those parameters after

right SLT compared with left SLT. Essentially in our study we had a roughly equal distribution of right and left SLT procedures for obstructive lung disease. We did not, however, subanalyze those two groups to compare those outcomes. I agree that that would make an interesting study in itself.

Dr. Magdi Yacoub (*London, England*). About 2 years ago we presented a similar series to the International Society of Heart and Lung Transplantation. However, we were comparing heart/lung transplantation with SLT for emphysema. We found exactly what these authors did in that, although the pattern of survival initially and during the first 5 years was almost identical for heart/lung transplantation and SLT for emphysema, the heart/lung transplant recipients had better respiratory function, better gas exchange, better exercise capacity, and a lower prevalence of obliterative bronchiolitis. Notably, despite the so-called denervation of the heart in these patients, their exercise capacity was superior to that in patients with SLT. The pattern of survival also tended to improve late. We ascribed that to a degree of induced specific immune tolerance. Whether heart/lung versus double lung transplantation contributes something that is better is another point that needs to be addressed.

Dr. Sundareshan. In response to Dr. Yacoub's remarks, I would say that in our experience we have analyzed our lung transplant recipients to document the prevalence of the problem of BOS and have found that it seems to affect recipients of single and bilateral procedures equally, and, in fact, affects all subgroups of our recipients equally without regard for diagnosis, and I think in this study we ultimately showed an equal development of obliterative bronchiolitis in the late survivors. Survival did not differ substantially between our two groups. I think that the problems of donor allocation in this country would probably not really permit more widespread use of heart/lung transplantation in obstructive lung disease.

Dr. Alvaro Montoya (*Chicago, Ill.*). About 3 years ago we reported our experience at Loyola with BLT versus SLT and we found the same results that the group from St. Louis just presented. I was always an advocate of BLT. My problem is the indication for emphysema. The shortage of donors is well known, and expending two lungs in a patient with emphysema might not be that good of an idea, except in patients younger than 40 years old.

I have two questions for Dr. Sundareshan. What about considering an SLT on one side and a lung reduction on the other? Do you have any experience with this procedure? Second, I am curious as to why the average length of stay in the hospital was more than 20 days. In our experience patients undergoing lung transplantation for emphysema did not spend more than 10 days in the hospital.

Dr. Sundareshan. Regarding SLT concomitant with volume reduction operation, there are some reports of that combined procedure emerging now. We have experience with only one such case, which was done within the past few weeks. I therefore do not have any long-term data on which to base a comment about the suitability of that combination.

As to why the average length of stay in this series was more than 20 days in both groups, I think one has to keep

in mind that this study looked at patients who underwent transplantation as early as 1988. Since then our postoperative care has evolved, and in general we have streamlined the care of these patients so that now the patient with uncomplicated emphysema usually does indeed go home from the hospital before 10 days after the operation. Thus our longer length of stay includes a fairly long length of stay for some of the earlier patients in this series.

Dr. Thomas M. Egan (*Chapel Hill, N.C.*). Every day in the United States one patient on the lung transplantation waiting list dies. I commend your efforts to use marginal

donors for BLT because these are donors who might not be used otherwise. If you have a good donor with two good lungs, do you do two SLTs or do you do a BLT for emphysema?

Dr. Sundaresan. It has to be individualized to the recipient. However, if the recipient who is a candidate for those lungs is a young, fit patient, perhaps with α_1 -antitrypsin deficiency, we would do a bilateral transplant on that patient as opposed to splitting the lung block and operating on two older patients with chronic obstructive pulmonary disease.

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