TRANSPLANT INTERNATIONAL

Transplant International ISSN 0934-0874

ORIGINAL ARTICLE

Lobar lung transplantation—Is it comparable with standard lung transplantation?

Alexis Slama, Bahil Ghanim, Thomas Klikovits, Axel Scheed, Mir A. Hoda, Konrad Hoetzenecker, Peter Jaksch, Jose Matilla, Sharokh Taghavi, Walter Klepetko and Clemens Aigner

Department of Thoracic Surgery, Medical University of Vienna, Vienna, Austria

Keywords
extracorporeal support, lobar, lobar lung transplantation, lung transplantation, size-mismatch.

Correspondence
Assoc.-Prof. Priv. Doz. Dr. Clemens Aigner MBA, Department of Thoracic Surgery, Medical University of Vienna, Währinger Gürtel 18-20, 1090 Vienna, Austria.
Tel.: +43 1 40400 5644;
fax: +43 1 40400 5100;
e-mail: clemens.aigner@meduniwien.ac.at

Conflicts of interest
The authors have nothing to disclose.

Received: 19 December 2013
Revision requested: 17 January 2014
Accepted: 5 May 2014
Published online: 17 June 2014

doi:10.1111/tri.12348

Summary

Lobar lung transplantation is used mainly for urgent small recipients who are less likely to obtain size matched lungs in due time. Only limited numbers have been published, and we herewith report the largest series of lobar-LuTX. We analyzed our LuTX database from 1/2001 to 12/2012 and compared the outcome of lobar-LuTX recipients with those receiving standard LuTX. Seven hundred and seventy-eighty LuTX (group 1) were performed either in standard technique by implanting the whole lungs (n = 539) or with downsizing by wedge resection of the right middle lobe and/or the left lingula (n = 239). One hundred and thirty-eight LuTX were performed in lobar technique (group 2) to overcome more pronounced size discrepancies. Patients in group 1 had a different spectrum of diagnoses and were less frequently bridged to LuTX ($P < 0.001$). Intubation time, ICU stay, and hospital stay were shorter in group 1 ($P < 0.001$). One-year survival was 84.8% vs. 65.1%, and 5-years survival 69.9% vs. 54.9% ($P < 0.001$). In multivariate analyzes, procedure, diagnosis, and pre-operative bridging were shown to be significant prognostic factors in survival. Early postoperative outcome in Lobar LuTX was significantly inferior to standard LuTX recipients. However, survival rates of successfully dismissed patients were comparable with standard LuTX (P = 0.168); thereby, Lobar-LuTX remains an important option in the management of urgent small recipients.

Background

Lung transplantation is well established as the standard therapy for end stage lung failure. Two decades and numerous achievements since the beginnings of lung transplantation, graft incompatibilities, and donor lung shortage are still major limiting factors. Several organizational and technical progresses have been adopted to increase organ supply. Among operative techniques, segmental resection [1,2], lobar transplantation [3,4], and split transplantation [5,6] have been developed since 1994 to overcome the shortage of small donor lungs for pediatric and small adult recipients. These procedures eased size restrictions within the donor pool and maximized donor lung utilization and thereby reduced waiting time and waiting list mortality.

Whereas smaller size discrepancies between donor and recipient can be overcome by peripheral wedge resection, more pronounced size differences demand lobar or split lung transplantation. Yet, due to the challenging technical aspects, only few centers have adopted the lobar transplantation method in their clinical routine [7–10], and only a very limited number of papers report long-term outcome with lobar transplantation from deceased donors [11–13].

We previously reported our early experience with different forms of deceased donor size-reduced LuTX, with regard to waiting time implications, perioperative complications, and short term outcomes in 2003 [14,15]. Since that time, the number of unilateral and bilateral lobar LuTX at our institution has significantly increased and we now summarize our extended experience.

Patients and methods

This publication reports the analysis of our prospective lung transplant database from 1/2001 to 12/2012. Approval was given by the ethics committee of the Medical University Vienna (nr. 1363/2013).

During this observation period 945 patients underwent primary lung transplantation at our center. Patients who underwent a combined heart lung transplantation ($n = 15$) and split transplantation ($n = 14$) were excluded from the analysis. Of the remaining 916 patients, 796 (86.9%) underwent bilateral LuTX and 122 (13.1%) underwent single LuTX. The type of surgery (SLuTX or BLuTX) was not taken into account for group assignment and statistical evaluation. Five hundred and thirty-nine (58.8%) patients underwent standard LuTX of whole lungs, 239 (26.1%) underwent a size reduction by resection of the right middle lobe and/or the left lingula, 45 (4.9%) underwent a double sided lobar transplantation, and 93 (10.2%) underwent a single sided lobar transplantation in combination with a standard or size-reduced LuTX on the contralateral side. Patients were assigned into groups according to the performed size reducing technique (Table 1).

Size matching was based on the calculated TLC of the donor and the predicted and actual TLC of the recipient prior to organ recovery. No cut-off values were used and the decision to accept oversized lungs for successive lobar LuTX was solely based on the estimated urgency of the recipient. The definite choice of procedure was made during surgery after comparison of the thoracic cavity and the size of the donor lungs. Wedge resections were performed to correct small size discrepancies, whereas lobar LuTX were carried out to correct more significant size-mismatches. Donor lung recovery was performed en bloc and the separation for lobar LuTX was achieved on a back table prior to implantation. Handling of the lobes was standardized. Parenchymal bridges were divided with commercial stapler devices, and peribronchial tissue was preserved to guarantee sufficient bronchial blood supply. The bronchial anastomosis was performed in an end to end fashion with a 5/0 PDS running suture, and bronchial size discrepancies were adjusted over the whole circumference. For vascular anastomosis, stumps were kept as short as possible in order to avoid any kinking. The venous anastomosis was either performed with one pulmonary venous stump in cases of extraordinary size-mismatch or with use of the whole atrial cuff to guarantee a wide lumen. Usually, bilateral LLuTX were performed with extracorporeal support to avoid initial overflow of the first implanted lobe.

Table 1. Group assignment and number of cases.

Main groups	Sub-groups	Total	DLuTX	SLuTX
Group 1: no or minor size reduction ($n = 778$)	Group 1.1. no size reduction	$n = 539$	428	111
	Group 1.2. size reduction by lingula and/or middle lobe resection	$n = 239$	230	9
Group 2: lobar LuTX ($n = 138$)	Group 2.1. unilateral lobar transplantation with contralateral standard LuTX	$n = 93$	93	0
	Group 2.2. bilateral lobar transplantation	$n = 45$	45	0
Total		916	796	120

Size-reduced lung transplantation by wedge resection consisted of resecting the right middle lobe and/or the left lingula and was usually performed after implantation of the entire lung.

The performed statistical analysis compares the short and long-term outcome of lobar LuTX recipients (group 2) to those receiving standard donor organs or downsizing by simple wedge resection (group 1). Furthermore, a subanalysis was performed with the groups presented in Table 1. The analysis was conducted using IBM SPSS Statistics 21. Descriptive statistics were used, and data are expressed as median and range. Data in parenthesis are always expressed as group 1 versus group 2. Metric data were compared using *t*-test, and nominal data were compared by means of chi-squared test. Survival of patients between the groups was presented using Kaplan-Meier curves with *P* values calculated using log-rank (Mantel-cox) tests. Additionally, a cox regression analysis was performed to determine the impact and the independence of different factors on survival. The cox regression model was adjusted for age, recipient diagnosis, performed procedure (SLuTX, DLuTX), size reducing measures, and bridging-to-LuTX options. Two-sided *P* values <0.05 were considered to be statistically significant.

Results

Recipient demographics

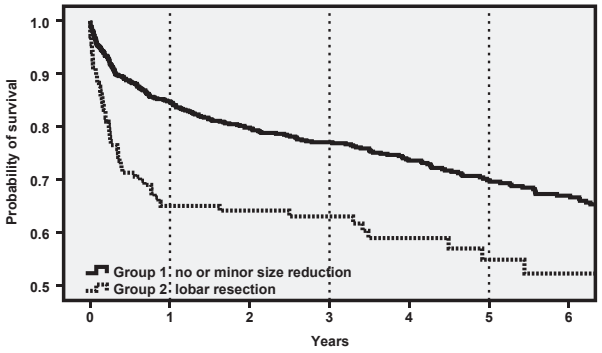
Patients in group 1 were significantly older than patients in group 2 [51.6 (0.6–71.4) vs. 36.4 (7.3–72.2) years; $P < 0.001$]. Furthermore, pediatric patients (<18 years) were significantly more likely to obtain a lobar transplantation (3.9% vs. 14.5; $P < 0.001$). In group 1, there were significantly less female patients (45.2% vs. 58.0%; $P = 0.006$). The spectrum of diagnoses was significantly different in both groups (Group 1 versus Group 2; CF:

Table 2. Recipient characteristics.

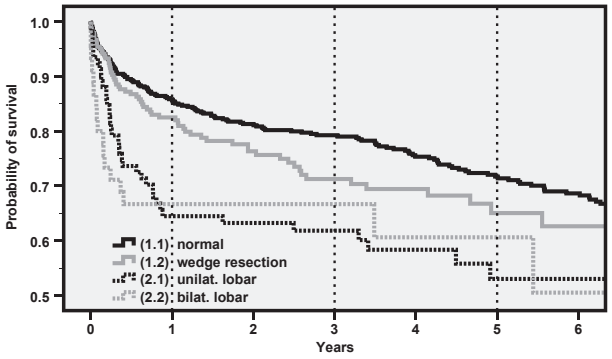
	Main groups			Sub-groups				
	Group 1 no or minor size red	Group 2: lobar LuTX	*P* values	1.1. normal	1.2. wedge resection	2.1 unilat. Lobar	2.2. bilat. Lobar	*P* values
Age								
Median (range)	51.6 (0.6–71.4)	36.4 (7.3–72.2)	<0.001	53 (4.0–71.4)	47.4 (0.6–70.8)	36.8 (7.3–66.5)	36.2 (11.4–72.2)	<0.001
Pediatric (%)								
<18 years old	30 (3.9)	20 (14.5)	<0.001	25 (4.6)	5 (2.1)	12 (12.9)	8 (17.8)	<0.001
Sex (%)								
Male	426 (54.8)	58 (42.0)	0.006	313 (58.1)	113 (47.3)	43 (46.2)	15 (33.3)	0.001
Female	352 (45.2)	80 (58.0)		226 (41.9)	126 (57.7)	50 (53.8)	30 (66.7)	
Diagnosis (%)								
COPD	314 (40.4)	16 (11.6)	<0.001	228 (42.3)	86 (36.0)	11 (11.8)	5 (11.1)	<0.001
Fibrosis	151 (19.4)	46 (33.3)		99 (18.4)	52 (21.8)	32 (34.4)	14 (31.1)	
PPH	47 (6.0)	8 (5.8)		36 (6.7)	11 (4.6)	5 (5.4)	3 (6.7)	
CF	143 (18.4)	48 (34.8)		86 (16.0)	57 (23.8)	33 (35.5)	15 (33.3)	
BO after BMTx	7 (0.9)	2 (1.4)		3 (0.6)	4 (1.7)	2 (2.2)	0	
Bronchiectasia	11 (1.4)	4 (2.9)		9 (1.7)	2 (0.8)	1 (1.1)	3 (6.7)	
CTEPH	19 (2.4)	2 (1.4)		16 (3.0)	3 (1.3)	2 (2.2)	0	
Alpha 1	39 (5.0)	0		31 (5.8)	8 (3.3)	0	0	
LAM	15 (1.9)	3 (2.2)		10 (1.9)	5 (2.1)	2 (2.2)	1 (2.2)	
Other	32 (4.0)	9 (6.4)		21 (3.9)	11 (4.5)	5 (5.4)	4 (8.8)	
Type of listing (%)								
Normal	717 (92.5)	107 (78.1)	<0.001	510 (95.1)	207 (86.6)	78 (83.9)	29 (65.9)	<0.001
High urgent	58 (7.5)	30 (21.9)		26 (4.9)	32 (13.4)	15 (16.1)	15 (34.1)	
Ventilation at time of listing (%)								
Not intubated	731 (94.3)	110 (80.3)	<0.001	510 (95.1)	221 (92.5)	77 (82.8)	33 (75.0)	<0.001
Intubated	44 (5.7)	27 (19.7)		26 (4.9)	18 (7.5)	16 (17.2)	11 (25.0)	
Bridging (%)								
Not ventilated	716 (92.5)	105 (76.6)	<0.001	504 (94.2)	212 (88.7)	73 (78.5)	32 (72.7)	<0.001
Noninvasive ventilation	11 (1.4)	4 (2.9)		4 (0.7)	7 (2.9)	3 (3.2)	1 (2.3)	
Solely intubated	28 (3.6)	10 (7.3)		20 (3.7)	8 (3.3)	7 (7.5)	3 (6.8)	
ECMO	19 (2.5)	18 (13.1)		7 (1.3)	12 (5.0)	10 (10.8)	8 (18.2)	

Table 3. Perioperative outcome after LuTX.

	Main groups			Sub-groups				
Number of cases	Group 1: no or minor size red $n = 778$	Group 2: lobar LuTX $n = 138$	*P* values	1.1. normal $n = 539$	1.2. wedge resection $n = 239$	2.1 unilat. Lobar $n = 93$	2.2. bilat. Lobar $n = 45$	*P* values
ECMO (%)								
No support	348 (50.1)	28 (20.9)	<0.001	246 (53.4)	102 (43.8)	22 (24.4)	6 (13.6)	<0.001
Intraoperative	217 (31.3)	49 (36.6)		143 (31.0)	74 (31.8)	38 (42.2)	11 (25.0)	
Intra- and postoperative	85 (12.2)	28 (20.9)		50 (10.8)	35 (15.0)	14 (15.6)	14 (31.8)	
Postoperative only	9 (1.3)	3 (2.2)		7 (1.5)	2 (0.9)	3 (3.3)	0	
Pre- and intraoperative	12 (1.7)	8 (6.0)		4 (0.9)	8 (3.4)	6 (6.7)	2 (4.5)	
CPB	11 (1.6)	4 (3.0)		5 (1.1)	6 (2.6)	1 (1.1)	3 (6.8)	
IntraOp ex + postOp	2 (0.3)	3 (2.2)		1 (0.2)	1 (0.4)	1 (1.1)	2 (4.5)	
Pre- ,intra- and postoperative	10 (1.4)	11 (8.2)		5 (1.1)	5 (2.1)	5 (5.6)	6 (13.6)	
Day of extubation	1 (0–134)	6 (1–61)	<0.001	1 (0–134)	2 (0–64)	5 (1–61)	6 (1–30)	<0.001
ICU time	6 (1–180)	17 (1–122)	<0.001	6 (1–160)	7 (1–180)	17 (1–99)	19 (1–122)	<0.001
Hospital stay	22 (1–180)	33.5 (1–147)	<0.001	22 (1–160)	23 (1–180)	36 (5–137)	32.5 (1–147)	<0.001
Time to BOS >0p	896 (96–3844)	822 (388–1572)	n.s.	910 (99–3844)	893 (96–2261)	866 (388–1342)	822 (667–1572)	n.s.
In-hospital death (%)	59 (7.6)	28 (20.3)	<0.001	39 (7.2)	20 (8.4)	15 (16.1)	13 (28.9)	<0.001
Re-LuTX (%)	46 (6.0)	8 (6.2)	n.s.	39 (7.3)	7 (3.0)	6 (6.7)	2 (4.9)	n.s.
30-day mortality (%)	34 (4.4)	14 (10.2)	0.005	23 (4.3)	11 (4.6)	6 (6.5)	8 (17.8)	0.001



(a)	1 year survival	3 year survival	5 year survival
Group 1 (normal/size red.)	0.848	0.771	0.699
Group 2 (lobar LuTX)	0.651	0.631	0.549



(b)	1 year survival	3 year survival	5 year survival
Group 1.1 normal	0.858	0.792	0.717
Group 1.2 size reduced	0.825	0.712	0.650
Group 2.1 unilateral lobar	0.645	0.618	0.530
Group 2.2 bilateral lobar	0.667	0.667	0.606

Figure 1 Kaplan-Meier curves comparing survival after LuTX according to the performed size reducing measure. (a) Survival curves of the main groups ($P < 0.001$). (b) Survival curves of the sub-groups (significant differences determined by log-rank test: 1.1 vs. 2.1 $P < 0.001$; 1.1 vs. 2.2 $P = 0.005$; and 1.2 vs. 2.1 $P = 0.026$).

18.4% vs. 34.8%; Fibrosis: 19.4% vs. 33.3%; PAH: 6.0% vs. 5.8%; COPD: 40.4% vs. 11.6%; and $P < 0.001$). Patients in group 2 were significantly more frequently listed as "high urgent" (7.5% vs. 21.9%; $P < 0.001$) and required more often a bridging therapy prior to LuTX (7.5% vs. 23.3%; $P < 0.001$). These bridging options were: noninvasive ventilation (1.4% vs. 2.9%), intubation without ECMO (3.6% vs. 7.3%), and ECMO (2.5% vs. 13.1%). As the largest portion of the observation period was before implementation of the lung allocation score (LAS) at our center, no meaningful calculations could be performed regarding LAS. Recipient characteristics are presented in Table 2.

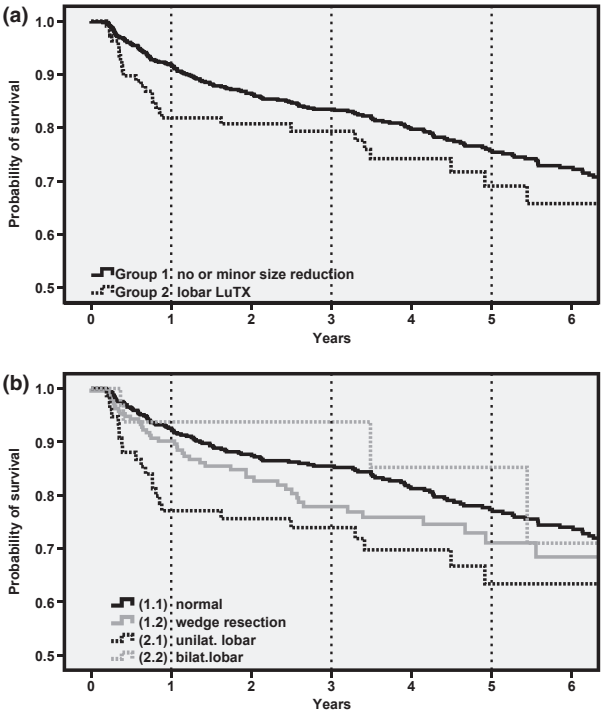


Figure 2 Kaplan-Meier curves comparing survival after exclusion of in-hospital deceased patients according to the performed size reducing measure. (a) Survival curves of the main groups ($P = 0.168$). (b) Survival curves of the sub-groups. (1.1 vs. 1.2 $P = 0.178$; 1.1 vs. 2.1 $P = 0.019$; 1.1 vs. 2.2 $P = 0.568$; 1.2 vs. 2.1 $P = 0.221$; 1.2 vs. 2.2 $P = 0.279$; and 2.1 vs. 2.2 $P = 0.09$).

Donor characteristics

Donors were more often males (54.1%). Within the two groups, the sex of the donors did not differ significantly (males group 1: 52.3%; males group 2: 63.2%; $P = 0.062$). Causes of death showed no significant difference between the groups. Donor height, donor weight, and donor TLCp were significantly higher in group 2 [170 cm (106–201) vs. 175 cm (150–190) $P = 0.007$; 70 kg (15–130) vs. 75 kg (22–110) $P = 0.026$; and 5.8 l (1.4–9) vs. 6.9 l (4.1–8.1)] $P = 0.002$. The duration of intubation of the donors and the PaO2 prior to organ recovery (Fio2 = 1.0) did not differ significantly between the groups.

Intra- and perioperative characteristics

Intraoperative extracorporeal support (routinely performed with central veno-arterial ECMO at our center) was used more frequently in group 2 (46.6% vs. 71.7%; $P < 0.001$). In group 2, recipients remained more often postoperatively prolonged on ECMO (13.6% vs. 29.1%; $P < 0.001$) and they were more often in need for postoperative ECMO support due to primary graft dysfunction (PGD) (1.6% vs. 4.4%; $P < 0.001$). Postoperative ECMO support was always

achieved by peripheral VA cannulation. Cardio pulmonary bypass (CPB) was used in the early part of the evaluation period or in case of concomitant cardiac procedures (group 1: 1.6% vs. group 2: 3.0%). Details of the use of extracorporeal support are presented in Table 3.

Recipient outcome

Perioperative complications were more frequent in group 2. These patients needed more often a surgical revision (8.4% vs. 18.8%; $P < 0.001$) and had more often reperfusion edema in the first X-ray image after LuTX (17.8% vs. 44.1%; $P < 0.001$).

Patients who underwent lobar LuTX (group 2) remained longer intubated after surgery [1.0 (0–134) vs. 6.0 (1–61) days $P < 0.001$]. They remained longer on the ICU [6.0 (1–180) vs. 17.0 (1–122) days; $P < 0.001$] and remained hospitalized for a longer period of time [22.0 (1–180) vs. 33.5 (1–147) days; $P < 0.001$].

In-hospital mortality (7.6% vs. 20.3%; $P < 0.005$) and 30-day mortality were lower in group 1 (4.4% vs. 10.2%; $P = 0.005$).

Causes of death showed no significant differences between the two groups neither in successfully dismissed patients (noncmv infection: 60.9% vs. 74.1%; bronchiolitis 10.3% vs. 14.8%; cardiac 3.8% vs. 0.0%; graft failure 1.3% vs. 0.0%; $P = 0.47$) nor in patients deceased without being discharged from hospital (noncmv infections: 56.4% vs. 50%; graft failure 10.9% vs. 17.9%; cardiac 7.3% vs. 10.7%; multiorgan failure 5.5% vs. 7.1%; $P = 0.58$).

Long-term survival was significantly better in group 1 (1 year 84.8% vs. 65.1%; 3 years 77.1% vs. 63.1%; 5 years 69.9% vs. 54.9%; $P < 0.001$; Fig. 1). Within the subgroups, log-rank test showed no significant survival difference between the normal (1.1) and the wedge resection (1.2) groups nor between the unilateral (2.1) and the bilateral (2.2) lobar groups. In a second univariate survival analysis, only patients who were successfully dismissed from hospital were taken into account ($n = 829$). In this survival analysis conditional on hospital discharge, no significant difference in survival could be observed between both groups ($P = 0.168$; Fig. 2). In multivariate survival analyzes, recipient sex ($P = 0.03$), age ($P < 0.01$), and certain diagnosis (COPD: $P < 0.01$) were found to be significant independent prognostic factors. Furthermore the choice of procedure ($P < 0.01$), the type of size reduction (lobar LuTX: $P < 0.01$), and the preoperative bridging (intubation: $P = 0.01$; ECMO: $P = 0.01$) showed highly significant impact on survival. Hazard ratios and confidence intervals are presented in Table 4.

However, the time from LuTX to the diagnosis of BOS >0p was comparable between both groups (896 (96–3844) vs. 822 (388–1572) days; $P =$ n.s.).

Table 4. Cox regression model adjusted for patient and procedure characteristics.

Characteristics	Adjusted HR	95% CI	*P* values
Sex			
Male	1		
Female	0.77	0.60–0.98	0.037
Age	1.02	1.01–1.03	0.000
Diagnosis			
COPD	1		0.003
Fibrosis	0.81	0.59–1.11	0.182
CF	0.85	0.51–1.40	0.511
PPH	1.75	0.98–3.12	0.058
Others	1.51	1.06–2.15	0.022
Type			
DLuTX	1		
SLuTX	1.77	1.29–2.43	0.000
Sub-groups			
Normal	1		0.000
Wedge resection	1.33	0.99–1.79	0.058
Unilat. Lobar	2.38	1.63–3.48	0.000
Bilat. Lobar	2.35	1.38–4.01	0.002
Bridging			
No bridge	1		0.008
Noninvasive ventilation	1.64	0.60–4.50	0.334
Intub	2.06	1.19–3.57	0.010
ECMO	1.90	1.13–3.21	0.016

Discussion

Despite the worldwide increasing number of LuTX performed, the gap between the potential number of recipients and available donor organs is increasing to an even greater extent. Various achievements have been introduced to increase the available donor pool. Legislative background and organ allocation regulations did have a major impact on waiting list mortality and the indication spectrum of the recipients. This was impressively demonstrated by the shift of COPD toward IPF patients which occurred with the introduction of the LAS score. The extension of donor lung criteria and *in-vivo* improvement of donor lungs by active donor management have become clinical routine. Living donation [8,9,16] and donation after circulatory death do further expand the available donor pool. Finally, the recently introduced evaluation and reconditioning of donor lungs with *ex vivo* lung perfusion (EVLP) has gained enormous interest and holds great potential for the future. Besides all these approaches, there is still a need to use organs from oversized donors.

Downsizing of donor lungs is a method which has already been described in the early days of LuTX. It allows the use of oversized grafts for urgent small adult or pediatric recipients and can also be applied in case of localized pathologies in the donor lung or if the organ is found to be unexpectedly large at organ recovery. Downsizing by wedge

resections is technically easy to perform, and ideally, the middle lobe and lingula areas are removed by simple stapler resection. Lobar transplantation has not gained such a widespread use, and only a few centers use this method routinely [17]. It is a technically more challenging procedure, and it allows reducing donor TLC by up to 60%. The lobes are separated on the back table, and the implantation technique is essentially comparable with standard LuTX.

Size matching is of outmost importance in lobar transplantation. The chest configuration of the donor and recipient has to be taken into account as well as the real and predicted recipient TLC. Original size chest x-rays in a posterior–anterior and lateral view which are taken to the donor hospital by the organ recovery team have also proven to be helpful in estimating the size match at the donor hospital. The final choice which lobes are used is usually taken during the LuTX. In our experience, a TLC size discrepancy of fewer than 20% can be corrected by wedge resection alone whereas a size reduction of 20% to 60% requires either unilateral or bilateral LLuTX. Basically all combination of lobes can be used. The only exception is the combination of the right upper and middle lobe, which requires stapling of the lower lobe bronchus and therefore owns the risk of impaired bronchial stump healing.

There are several reports about results of size-reduced lung transplantation [18,19] and living donor lobar transplantation [7–9] in the literature. However, only very few reports focusing on deceased donor lobar lung transplantation exist [13,20,21]. These three reports from different institutions consist of series of 50, 25, and 23 LLuTX, and comparable results to standard lung transplantation have been documented [13].

The results from our series of 138 patients with either uni- or bilateral LLuTX differ from these previously published reports [13,20,21], as we have shown that in our cohort the outcome of LLuTX is inferior to standard LuTX. Nevertheless, in all three reports such as in this series, recipients receiving LLuTX represent a more urgent and higher risk cohort with significantly more patients being pre-operatively bridged by ventilation or extracorporeal support (Table 5).

Besides this different risk profile, there are several potential technical risks inherent in LLuTX. Above all, the actual diameters of the lobes, especially at the basis of the lungs, are crucially important for postoperative function. Lower lobes with wide diameter in the basal part can lead to compression and atelectasis when implanted in a narrow chest cavity. On the other hand, recent reports have shown that undersized grafts (regarding the donor and recipient pTLC) are associated with a higher incidence of PGD [22,23]. Therefore, the judgment whether the lobe will ultimately fit into the recipient chest has to be performed very carefully and with good knowledge of the diameter of the recipient chest.

Furthermore, there is the potential for several technical risks such as prolonged air leaks, kinking of vascular anastomoses, and remaining dead space which all can have an impact on postoperative outcome. Although we did not observe these problems in a higher rate in our LLuTX group, their presence cannot be denied.

A major issue in lobar lung transplantation is the reduced vascular bed of a single lobe which significantly increases the risk of reperfusion edema. Therefore, extracorporeal membrane oxygenation support (ECMO) is by now routinely used in our center in all patients receiving LLuTX to avoid an overflow of the first implanted lung. In patients receiving an entire lung on the first side and a lobar LuTX on the second side, the procedure could be performed without the use of extracorporeal support. Even with this protective ECMO approach, the initial rate of reperfusion edema after LuTX was significantly higher in the lobar group. This rate of 44% was comparable with previously published results from other centers (32% and 54%) [20,21]. Furthermore, published data showed comparable rates of postoperative ECMO use (20% and 28% vs. 32%) (Table 5).

Table 5. Comparison of published series on deceased donor lobar LuTX.

	Inci 2012 [13]	Mitilian 2013 [20]	Shigemura 2013 [21]	Slama 2014
n	23	50	25	138
Observation period	2000–2012	1988–2012	2012–2012	2001–2012
Preop ECMO	3 (13%)	2 (4%)	7 (28%)	18 (13%)
Preop intubation	1 (4%)	Not reported	9 (32%)	10 (7%)
Intraoperative support	19 (83%) ECMO	16 (32%) ECMO; 16 (32%) CPB	Not reported	96 (70%) ECMO; 4 (3%) CPB
PGD>0	Not reported	27 (54%)	7 (32%)	61 (44%)
Postop ECMO	Not reported	10 (20%)	7 (28%)	45 (32%)
In-hospital death	2 (8.6%)	14 (28%)	2 (8%)	28 (20%)
1-year survival	82%	–	76%	65%
3-year survival	–	60%	–	63%
5-year survival	64%	46%	–	55%

Regarding the long-term outcome of deceased donor LLuTX conditional on hospital survival, we observed that there was no significant difference compared with the standard LuTX group. This gives very profound evidence that the risks are mostly related to the perioperative period. In fact, we were able to identify a comparable incidence of BOS between the two groups.

Summarizing these findings and considering our low waiting list mortality (2011: 8.3%; 2012: 2.5%; 2013: 1.7%), we conclude that deceased donor LLuTX is an important and valid technical variant of LuTX. It especially allows offering urgent and small patients a suitable donor organ in due time, and thus, LLuTX reduces waiting list mortality significantly. Due to the urgency status of the lobar recipients and a higher perioperative risk, a higher in-hospital mortality is observed. However, long-term results are excellent once the critical initial phase has been overcome. Waiting list mortality in this group would be undoubtfully higher if the option of lobar transplantation was not available. Thus, lobar transplantation is and remains an important tool in the management of small adults and pediatric recipients.

Authorship

AS: collected and analyzed the data; wrote the paper. BG and TK: analyzed data. AS, MAH, KH, JM, and ST: performed the procedures. PJ: collected data. WK: performed the procedures; contributed to writing. CA: designed study; performed the procedures; and contributed to writing.

Funding

No funding.

References

1. Wisser W, Klepetko W, Wekerle T, *et al*. Tailoring of the lung to overcome size disparities in lung transplantation. *J Heart Lung Transplant* 1996; **15**: 239.
2. Artemiou O, Wieselthaler G, Zuckermann A, *et al*. Downsizing of the donor lung: peripheral segmental resections and lobar transplantation. *Transplant Proc* 1997; **29**: 2899.
3. Bisson A, Bonnette P, el Kadi NB, Leroy M, Colchen A. Bilateral pulmonary lobe transplantation: left lower and right middle and lower lobes. *Ann Thorac Surg* 1994; **57**: 219.
4. Starnes VA, Barr ML, Cohen RG. Lobar transplantation. Indications, technique, and outcome. *J Thorac Cardiovasc Surg* 1994; **108**: 403; discussion 410–1.
5. Couetil JP, Tolan MJ, Grousset A, *et al*. Experimental bilateral lobar lung transplantation and its application in humans. *Thorax* 1997; **52**: 714.
6. Artemiou O, Birsan T, Taghavi S, *et al*. Bilateral lobar transplantation with the split lung technique. *J Thorac Cardiovasc Surg* 1999; **118**: 369.
7. Oto T, Date H, Hayama M, Ando A, Shimizu N. Peripheral lung volume reduction improved early graft function in severe size mismatched living donor lobar lung transplantation. *Transplant Proc* 2005; **37**: 4515.
8. Bowdish ME, Pessotto R, Barbers RG, Schenkel FA, Starnes VA, Barr ML. Long-term pulmonary function after living-donor lobar lung transplantation in adults. *Ann Thorac Surg* 2005; **79**: 418.
9. Barr ML, Schenkel FA, Bowdish ME, Starnes VA. Living donor lobar lung transplantation: current status and future directions. *Transplant Proc* 2005; **37**: 3983.
10. Patterson GA. Living lobar lung transplantation: is it a necessary option? *Am J Transplant* 2004; **4**: 1213.
11. Marasco SF, Than S, Keating D, *et al*. Cadaveric lobar lung transplantation: technical aspects. *Ann Thorac Surg* 2012; **93**: 1836.
12. Keating DT, Marasco SF, Negri J, *et al*. Long-term outcomes of cadaveric lobar lung transplantation: helping to maximize resources. *J Heart Lung Transplant* 2010; **29**: 439.
13. Inci I, Schuurmans MM, Kestenholz P, *et al*. Long-term outcomes of bilateral lobar lung transplantation. *Eur J Cardiothorac Surg* 2013; **43**: 1220.
14. Aigner C, Jaksch P, Taghavi S, *et al*. Donor total lung capacity predicts recipient total lung capacity after size-reduced lung transplantation. *J Heart Lung Transplant* 2005; **24**: 2098.
15. Aigner C, Winkler G, Jaksch P, *et al*. Size-reduced lung transplantation: an advanced operative strategy to alleviate donor organ shortage. *Transplant Proc* 2004; **36**: 2801.
16. Date H, Yamane M, Toyooka S, Okazaki M, Aoe M, Sano Y. Current status and potential of living-donor lobar lung transplantation. *Front Biosci* 2008; **13**: 1433.
17. Bharat A, Patterson GA. Editorial comment: merits of cadaveric lobar lung transplantation. *Eur J Cardiothorac Surg* 2013; **43**: 1225.
18. Santos F, Lama R, Alvarez A, *et al*. Pulmonary tailoring and lobar transplantation to overcome size disparities in lung transplantation. *Transplant Proc* 2005; **37**: 1526.
19. Mueller C, Hansen G, Ballmann M, *et al*. Size reduction of donor organs in pediatric lung transplantation. *Pediatr Transplant* 2010; **14**: 364.
20. Mitilian D, Sage E, Puyo P, *et al*. Techniques and results of lobar lung transplantations. *Eur J Cardiothorac Surg* 2014; **45**: 365.
21. Shigemura N, D'Cunha J, Bhama JK, *et al*. Lobar lung transplantation: a relevant surgical option in the current era of lung allocation score. *Ann Thorac Surg* 2013; **96**: 451.
22. Eberlein M, Reed RM, Permutt S, *et al*. Parameters of donor-recipient size mismatch and survival after bilateral lung transplantation. *J Heart Lung Transplant* 2012; **31**: 1207.
23. Barnard JB, Davies O, Curry P, *et al*. Size matching in lung transplantation: an evidence-based review. *J Heart Lung Transplant* 2013; **32**: 849.