Lung transplantation in patients with a history of anatomical native lung resection[#]

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Visual Abstract

Key question: Is previous major lung resection, including pneumonectomy a risk factor to lung transplant candidacy?

Key findings: Outcomes of lung transplantation in patients with major lung resection are comparable to conventional transplants.

Take-home message: Patients with a history of anatomical lung resection should not be considered a risk factor to lung transplant candidacy in the current era.

Central image

Abstract

OBJECTIVES: History of anatomical lung resection complicates lung transplantation (LTx). Our aim was to identify indications, intra-operative approach, and outcome in these challenging cases in a retrospective multicenter cohort analysis.

METHODS: Members of the ESTS Lung Transplantation Working Group were invited to submit data on patients undergoing LTx after a previous anatomical native lung resection between 01/2005 and 07/2020. The primary end-point was overall survival (Kaplan-Meier estimation).

RESULTS: Out of 2690 patients at 7 European centers, 26 (1%) patients (14 male; median age 33 years) underwent LTx after a previous anatomical lung resection. Median time from previous lung resection to LTx was 12 years. The most common indications for lung resection were infections (n=17), emphysema (n=5), lung tumor (n=2), and others (n=2). Bronchiectasis (cystic fibrosis (CF) or non-CF related) was the main indication for LTx (n=21), followed by COPD (n=5). Two patients with a previous pneumonectomy underwent contralateral single LTx and 1 patient with a previous lobectomy had ipsilateral single LTx. The remaining 23 patients underwent bilateral LTx. Clamshell incision was performed in 12 (46%) patients. Moreover, LTx was possible without extracorporeal life support in 13 (50%) patients. 90-day mortality was 8% (n=2) and the median survival was 8.7 years.

CONCLUSIONS: History of anatomical lung resection is rare in LTx candidates. The majority of patients are young and diagnosed with bronchiectasis. Although the numbers were limited, survival after LTx in patients with previous anatomical lung resection, including pneumonectomy is comparable to reported conventional LTx for bronchiectasis.

Keywords: lung transplantation; lung resection; patient selection

ABBREVIATIONS

CF	Cystic fibrosis
CLAD	Chronic lung allograft dysfunction
CPB	Cardiopulmonary bypass
ECLS	Extracorporeal life support
ECMO	Extracorporeal membrane oxygenation
ESTS	European Society of Thoracic Surgeons
ISHLT	International Society for Heart and Lung Transplantation
LTx	Lung transplantation
PPS	Postpneumonectomy syndrome

INTRODUCTION

Reoperation in thoracic surgery is a risk factor for complications. Advances in perioperative management have minimised unwanted effects of previous thoracic surgery in patients undergoing lung transplantation (LTx).[1,2] Nevertheless, previous thoracic surgery remains considered a risk factor to LTx candidacy[3], probably due to the inclusion of a broad range of thoracic procedures from minimally invasive procedures to open resections in previous publications. Data remain scarce for patients undergoing LTx after a major lung resection.

Patients with previous lung resections would require a completion pneumonectomy during LTx, which is often considered a high-risk procedure especially for benign indications.[4] Donor lung size reduction may also be needed to overcome a potential size discrepancy between resected and non-resected sites related to a shrunken chest years after a lung resection.[5] LTx in patient with a previous contralateral pneumonectomy requires special considerations. The success of this rare procedure largely depends on the management of mediastinal shift related changes.[6]

The prevalence of LTx in patients with a history of previous lung resection has been found to be less then 1% according to a recent database review.[7] Although this study is the largest case series

published to date, it has several limitations related to the nature of a large database review with limited data available.[7] It is important to accumulate more data in a multicenter project to collect more evidence to support the indication for LTx in future candidates with previous lung resection in the current era. Our aim was to identify indications, specific surgical methodology and outcomes in this patient population in a retrospective multicenter cohort analysis organized by the members of the European Society of Thoracic Surgeons (ESTS) LTx Working Group.

PATIENTS AND METHODS

Ethics Statement

The study was conducted in accordance with the Declaration of Helsinki. The study was approved by the Ethics Board Leuven, project S51577. Individual consent for this retrospective analysis was waived. In this multicenter study, the members of ESTS LTx Working Group were invited to submit data for patients undergoing single or bilateral LTx after a previous anatomical native lung resection, including segmentectomy, lobectomy, bilobectomy, or pneumonectomy between January 2005 and July 2020. Patients with a previous non-anatomical lung resection (ie. wedge resection) and lung resections performed after LTx were excluded from the study. Centers were invited to submit their data related to patient and donor characteristics, types of previous lung resections, and outcomes. Participating centers were from Leuven-Belgium, Rome-, Padua-, Milan-Italy, Cordoba-Spain, Szczecin-Poland, and Zurich-Switzerland. Centers reviewed their institutional databases in order to complete required data. Centers listed their patients according to the institutional protocols developed from international guidelines.[3] LTx technique, perioperative management, and post-LTx follow-up were not unified among centers. The primary end-point of the study was overall patient survival. Follow-up was completed by the end of 2020 in all patients.

IBM SPSS Statistics, Version 27 (IBM Corp., Armonk, NY, USA) and GraphPad Prism 9 (La Jolla, CA, USA) were utilised to analyse all data. Continuous variables were expressed as the median (first to third quartiles). Categorical variables were presented as the total number of patients and percentages.

Chronic lung allograft dysfunction (CLAD)-free survival was calculated from the date of LTx to date of CLAD diagnosis or mortality for patients surviving to hospital discharge. Mann-Whitney test was utilized to compare the donor/recipient height ratio. Overall survival was calculated from the date of LTx to date of mortality or the last follow-up date. Kaplan–Meier survival estimation was utilized to present survival. Missing variables were excluded from the data analysis.

RESULTS

During the study period, a total of 2690 patients underwent a LTx. Of those, 26 had a history of anatomical lung resection, which constituted the study group with a prevalence of 1% in this cohort (Table 1).

Recipients were remarkably young with a median age of 33 years. Cystic fibrosis (CF) or non-CF related bronchiectasis was the main indication for LTx in 21, followed by chronic obstructive pulmonary disease in 5 patients. The median time from listing to LTx was 8 months. Recipient characteristics are listed in Table 2.

The median time from lung resection to LTx was 12 years. The most common indications for lung resection were infections in 17, emphysema in 5, and lung tumor in 2 patients. All lung resections were performed as open procedures, lobectomy being the most frequent in 18 patients. Details of the procedures are presented in Table 3.

Recipients received lungs from young donors with a median age of 41 years. Majority of these lungs (85%) were procured from donation after brain death with excellent arterial blood gases. Two lungs were evaluated with ex-vivo lung perfusion prior to LTx. Donor characteristics are listed in Table 4.

Majority of LTx procedures were performed bilaterally in 23 patients. Three of them required lobar LTx due to significant donor/recipient size mismatching, which is illustrated in Figure 1. Additional 3 patients underwent right single LTx, 2 of them were after contralateral pneumonectomies and the remaining one was after an ipsilateral lobectomy. Clamshell incision was performed in 12 patients. Moreover, LTx was possible without extracorporeal life support (ECLS) in half of the cohort. LTx were

performed using cardiopulmonary bypass (CPB) in 5 patients, including 2 patients with previous pneumonectomies. Five patients required postoperative extracorporeal membrane oxygenation (ECMO) support and tracheostomy. Median intensive care unit stay was 11 days. Overall, 90-day mortality was 8% in 2 patients related to primary graft dysfunction and shock. Short-term outcomes of entire cohort and status after pneumonectomy subgroup are presented in Table 5.

Median follow-up time was 43 months. The 1-year, 5-year, and 10-year survival rates were 88%, 62%, and 46%, which were comparable to the International Society for Heart and Lung Transplantation (ISHLT) registry in patients undergoing LTx for CF or non-CF bronchiectasis[8] (Figure 2). CLAD was diagnosed in 10 patients. Median CLAD-free survival was 61 (95% Confidence Interval: 54-67) months. Additional to the 90-day mortality, there were 7 deaths during the follow-up due to CLAD in 6 cases and infection in 1 patient, resulting in an overall mortality of 9 patients. Long-term outcomes of entire cohort and status after pneumonectomy subgroup are presented in Table 6.

DISCUSSION

In this study, we investigated the incidence, patient characteristics, and outcomes in LTx recipients after a previous anatomical native lung resection and found that the operation is feasible and short- and long-outcomes of this unique cohort were excellent with an overall median survival of 8.7 years. Our multi-center cohort consists of a moderate sample size with 26 patients and has unique characteristics if compared to the ISHLT registry regarding the recipient age and diagnosis.[8,9] With a median age of 33 years, the study cohort is undoubtedly younger than the ISHLT registry (median age>50).[9] Furthermore, only 18% of the registry patients are diagnosed with CF or non-CF bronchiectasis, whereas this was more than 80% in our cohort.[8] Therefore, we decided to compare the outcomes of this study with patients undergoing LTx for bronchiectasis in the literature.

Although the underlying mechanisms leading to bronchiectasis and treatment options are different in patients with CF versus non-CF related bronchiectasis, treatment for patients with respiratory failure are similarly limited to LTx.[10] Rusanov et al. looked at the outcomes of LTx in patients with

bronchiectasis and reported comparable long-term survival (8.4 years for CF and 7.1 years for non-CF cohorts) with our cohort and the ISHLT registry.[11] In-hospital mortality was notably higher for non-CF patients (21%) likely to be related to increased utilisation of CPB in the early years of the program.[11] Recently, Rolla et al. reported no hospital mortality for CF patients with previous thoracic procedures undergoing LTx.[12] In our cohort, early mortality rate was 8% after LTx related to surgical complications. Notably, CPB was the choice of intraoperative support in these patients. If required, ECMO is the preferred intraoperative ECLS method during LTx nowadays.[13]

Previous studies looking at the impact of previous cardiothoracic procedures are limited with inclusion of a wide range of surgical procedures in the assessment of LTx outcomes.[1,2,14] The largest study to date investigating the role of previous major resection in LTx candidates found an increased risk of dialysis and 90-day mortality early after LTx, but acceptable long-term outcomes.[7] Similar to our report, this study also included patients with both lobectomies (80%) and pneumonectomies (20%). However, only 13% of their cohort had bronchiectasis for LTx indication and 15% of the lung resections were performed after a previous LTx. Furthermore, the prevalence of bilateral LTx was much lower (60%) than in our cohort (89%). They also did not list the indication, timing, and laterality of previous lung resections.[7]

All previous lung resections in our cohort were performed by an open procedure. In general, redo thoracotomies carry increased risk for complications related to adhesions.[15] Due to increased risks at the operated side, one might think of starting implantation from the non-operated "clean" side during LTx. In case of bilateral sequential LTx ventilation-perfusion scintigraphy has an important role to answer the question of which lung should be implanted first. Common practice is to start from the least perfused lung to avoid hemodynamic compromise during LTx.[16] The strategy in this cohort was mostly the same, regardless of previous resection side, explantations were usually started on the least perfused side. In case of a smaller discrepancy between the sides, around 40 to 60% range, we tend to start implanting the right lung first, since the vascular bed is larger in the right lung and exposure

of the right hilum is superior, compared to left, especially if a sternum-sparing anterior thoracotomy is used.

The rate of lobar LTx varies across centers ranging from 4% to as high as 24%.[17] In our cohort there were 3 lobar LTx (12%). One would expect to observe higher size-reduced LTx rates in patients with previous lung resection due to expected reduction in chest cavity volume. Whether compensatory lung growth or alveolar dilatation, increase in the remaining lung volume after pulmonary resection is a well-known phenomenon.[18] Although the donors were more healthy, the Kyoto group demonstrated compensatory lung growth in living LTx donors after lower lobectomy.[19] When we look at the donor/recipient size matching, the stature of full-size LTx recipients was relatively normal and the donor/recipient height ratio was well balanced. Whereas lobar LTx cases were small stature recipients receiving lungs from relatively taller donors. Although body height alone is not a good indicator for ideal size matching, our results indicate that postresection changes in the chest cavity does not increase the need for donor size reduction in patients with CF or non-CF bronchiectasis undergoing bilateral LTx.

Completion pneumonectomy carries substantial risks associated with bleeding after an anatomical lung resection. Surgical anatomical planes of hilar vascular structures are usually distorted intrapleurally, rendering dissection difficult with increased risk of accidental vascular injuries. In case of difficulties, intraparenchymal dissection may facilitate exposure of vascular planes. Alternatively, central intrapericardial control of pulmonary veins may increase the safety of hilar dissection. Regarding the right pulmonary artery, planes medial to the superior vena cava or intrapericardial access may be used for dissection. On the left side however, division of ductus Botalli may ease mobilisation of the pulmonary artery. In cases of pericardial adhesions, a posterior approach may be preferred starting from the division of the bronchus and then the vessels during left completion pneumonectomy.[20] In case of bleeding, central control is essential to avoid catastrophic complications. When this maneuver is not possible, ECLS - especially CPB - may be considered to establish hemodynamic stability and to control the bleeding. Although the routine use of intraoperative ECMO

has been recently popularised,[21] we personally tend to avoid ECMO whenever possible to avoid unwanted effects of anticoagulation during LTx surgery. We noted excessive bleeding problems especially after initiation of ECMO support during LTx in patients with post-thoracotomy adhesions in this study. Recently we experienced that using an energy device (like the Aquamantys™ Bipolar Sealer) is quite effective during difficult pneumonectomies under ECLS.

Although the number is limited to 2 patients in our cohort, previous pneumonectomy requires special considerations during LTx related to postpneumonectomy changes.[6] Here we refer to metachronous pneumonectomy performed months or years before contralateral LTx. Piotrowski et al. reported the first successful single LTx 8 months after a contralateral pneumonectomy in a paediatric patient with CF and asymmetric thorax.[22] The French experience is the largest series to date summarising the surgical considerations in this challenging patient group.[6] Considering surgical incisions, right single LTx were performed via clamshell incisions, which consist of a limited contralateral anterior thoracotomy in both patients with previous left pneumonectomies in our series. Depending on the surgeons' experience, these procedures can safely be performed via posterolateral thoracotomy or median sternomy as well.[6] In some patients postpneumonectomy syndrome (PPS) like changes may occur due to extreme rotation of the heart and the great vessels toward the empty hemithorax.[23] In such patients preoperative CT-scan should be carefully examined when planning the cannulation strategies and size-matching.[22] Undoubtedly CPB is the choice of ECLS during implantation in these patients. We were able to perform these procedures using central cannulation without noted difficulties. In cases of difficulties in central cannulation due to rotation of the heart, femoral venous access seems to be a good solution. It should be noted that rotation of intrathoracic inferior vena cava may preclude advancement of the venous cannula toward the heart. In such cases, using cervical approach cannulation of the right jugular vein may be indicated.[6] Indeed, adhesions related to previous lung resection after pneumonectomy are not a major concern due to contralaterality of the planned single LTx procedure. There are other factors to take into consideration, such as the size of allograft and dissection techniques during implantation. In cases of severe asymmetry an oversized

single LTx may be considered.[24] Regarding anastomoses of hilar structures, PPS like changes may create technical difficulties regardless the laterality of the procedure.[25] Here, alongside mediastinal dissection and repositioning maneuveurs, it is important to maintain lengthy arterial and venous cuffs to avoid overstretching after reperfusion. Patients with established PPS undergoing single LTx may also be a candidate for simultaneous prostheses implantation.[26] Possibilities are countless when considering LTx associated with priori, simultaneous or delayed pneumonectomy. Ris and colleagues reported the first successful bilateral LTx after previous pneumonectomy in a patient with destroyed lung.[26] Although unilateral LTx remains the preferred approach in this unique subset of LTx candidates, a bilateral LTx may be considered in appropriate candidates after careful benefit-risk assessment.

Other than established contraindications, history of a previous thoracic surgery, including anatomical lung resections alone is not considered an absolute contraindication rather a risk factor to LTx candidacy.[3] Due to expected dense adhesions experience in completion pneumonectomy are warranted. Candidates with a previous pneumonectomy consist of the most risky population in this group. Anatomical changes implying PPS should be carefully examined and the surgical plan should include laterality of transplant, cannulation strategies, size-matching and implantation techniques to avoid any catastrophic event during LTx. Ideally these procedures should be performed in experienced centers in our opinion. In general, LTx remains controversial in patients with history of previous lung tumor. Two patients from our cohort underwent pulmonary lobectomies followed by oncological treatment modalities due to Stage IIB primary lung cancer in one and lung metastasis of neuroblastoma in another paediatric patient. Multiple factors should be considered when evaluating a patient with history of malignancy for LTx.[27] The decisions to proceed with a LTx were made due to the absence of other contraindications, the disease-free interval of more than 5 years, and progressive worsening of respiratory function in both patients. The patient with a history of lung cancer is still alive 8 years after initial lung tumor treatment and 2 years after LTx with no signs of relapse. Sadly, the other patient died during early postoperative period after LTx. Decision to proceed with a LTx after

any malignancy is not always straightforward. In selected patients LTx may be an option after careful evaluation including the oncologist's opinion.[3]

Limitations

Beside the multicenter strength of the study, it has several limitations. Other than its retrospective nature, the main limitation is the lack of a comparison group within the multicenter cohort. A propensity score matching analysis is frequently utilized to generate a control group when conducting multicenter database analysis. Due to unavailability of a uniform database among participating centers, such analysis was not possible. As a result of shortage of publications on this very selected subset of LTx candidates we did not perform a systematic review as well. Instead, we executed a focused literature review including all high-quality articles especially in patients with a previous pneumonectomy. Furthermore, our cohort consisted of patients from 7 European centers only. Present study is conducted under the umbrella of ESTS LTx working group that has members from 21 centers in 14 countries in Europe, North America, and the Middle East. Not all the members participated in data collection. Moreover, some large volume centers from Europe are not a member of the working group, which further increases the bias in this study. Future efforts are warranted to engage other centers especially from Europe in developing a prospective multicenter LTx database under ESTS. Finally, some of the important variables such as estimated blood loss and transfusion requirements, and primary graft dysfunction score were not available for all patients.

CONCLUSION

In conclusion, history of anatomical native lung resection is a rare clinical entity in LTx candidates. The majority of LTx candidates are young and diagnosed with CF or non-CF related bronchiectasis. Although the numbers were limited, survival after LTx in patients with previous anatomical lung resection, including pneumonectomy is good and comparable to reported conventional LTx for CF and non-CF related bronchiectasis.

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None

Conflict of Interest

Nothing to declare

Author contributions

Ilker Iskender: Methodology; Data curation; Formal analysis; Investigation; Visualization; Writing—original draft. **Ylenia Pecoraro**: Data curation; Investigation; Writing—review & editing. **Paula Moreno Casado**: Data curation; Resources; Investigation; Writing—review & editing. **Bartosz Kubisa**: Data curation; Resources; Investigation; Writing—review & editing. **Marco Schiavon**: Data curation; Resources; Investigation; Writing—review & editing. **Eleonora Faccioli**: Data curation; Investigation; Writing—review & editing. **Jonas Ehrsam**: Data curation; Investigation; Writing—review & editing. **Francesco Damarco**: Data curation; Investigation; Writing—review & editing. **Mario Nosotti**: Data curation; Resources; Investigation; Writing—review & editing. **Ilhan Inci**: Data curation; Resources; Investigation; Writing—review & editing. **Federico Venuta**: Data curation; Resources; Investigation; Writing—review & editing. **Dirk Van Raemdonck**: Conceptualization; Methodology; Resources; Supervision; Visualization; Writing—review & editing. **Laurens J. Ceulemans**: Conceptualization; Methodology; Resources; Supervision; Visualization; Writing—review & editing.

Data Availability

The data supporting the findings of this study will be made available on reasonable request to the corresponding author (LJC).

Figure Legends

Central Image: Survival curve of lung transplant recipients with a previous anatomical native lung resection

Figure 1: Donor/Recipient height ratio

Figure 2: Kaplan-Meier survival curve of lung transplant recipients with a previous anatomical native lung resection compared to the survival curve for patients with bronchiectasis undergoing LTx from the ISHLT registry slides[8]

Table 1: Participating centers

Center	Total number of LTx (2005-2020)	Number of LTx after PALR	% of LTx after PALR
Leuven, BE	944	14	1.5
Rome, IT	154	3	1.9
Cordoba, ES	497	3	0.6
Szczecin, PL	82	2	1.2
Padua, IT	368	2	0.5
Zurich, CH	382	1	0.3
Milan, IT	263	1	0.4
Total	**2690**	**26**	**1**

LTx: Lung transplantation; PALR: Previous anatomical lung resection

Table 2: Recipient characteristics

Parameters	PALR (n=26)
Age at LTx; years	33 (22–49)
Sex	
Male; n (%)	14 (54)
Female; n (%)	12 (46)
*Body mass index (n=25)	19 (18–21)
*FEV1% (n=25)	23 (19–30)
*DLCO (n=19)	36 (29–47)
*V/Q Scan (n=22)	
Perfusion; Right (%)	42 (26–74)
Left (%)	58 (26–74)
*sPAP; mmHg (n=18)	39 (33–42)
Indication for LTx; n (%)	
CF	15 (58)
Bronchiectasis	5 (19)
COPD	5 (19)
Kartagener	1 (4)
Time from listing to LTx; months	8 (2–18)

Values are median (first to third quartiles) or n: number (%).

LTx: Lung transplantation; PALR: Previous anatomical lung resection; FEV_1: forced expiratory volume in 1 s; DLCO: diffusion capacity of carbon monoxide; V/Q: Ventilation-Perfusion; sPAP: systolic pulmonary arterial pressure; CF: Cystic fibrosis; COPD: Chronic obstructive pulmonary disease.

*Variable with missing data, number of patients with complete data are given in parenthesis

Table 3: Characteristics of PALR

Parameters	PALR (n=26)
Time from PALR to LTx; years	12 (7–21)
Indication for PALR; n (%)	
Infectious	17 (65)
Emphysema	5 (19)
Lung tumor	2 (8)
Lung cirrhosis	1 (4)
Atelectasis	1 (4)
PALR Type; n (%)	
Segmentectomy	2 (8)
Lobectomy	18 (69)
Lobectomy+Segment	2 (8)
Bilobectomy	1 (4)
Bilateral lobectomy	1 (4)
Pneumonectomy	2 (8)

374 Values are median (first to third quartiles) or n: number (%).
375 LTx: Lung transplantation; PALR: Previous anatomical lung resection.
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Table 4: Donor characteristics

Parameters	PALR (n=26)
Age; years	41 (23–52)
Sex	
Male; n (%)	15 (58)
Female; n (%)	11 (42)
*Body mass index (n=22)	24 (23–27)
*Length of IMV; days (n=24)	2 (1–4)
Type; n (%)	
DBD	22 (85)
DCD	4 (15)
*Cause of Brain injury in DBD;n (%) (n=23)	
Trauma	14 (61)
CVA	9 (39)
P/F ratio	466 (391–522)
EVLP; n (%)	2 (8)

Values are median (first to third quartiles) or n: number (%).
PALR: Previous anatomical lung resection; IMV: Invasive mechanical ventilation; DBD: Donation after brain death; DCD: Donation after circulatory death; CVA: Cerebrovascular accident; P/F ratio: Arterial partial pressure of oxygen divided by the fraction of inspired oxygen; EVLP: Ex vivo lung perfusion.
*Variable with missing data, number of donors with complete data are given in parenthesis

Table 5: Perioperative outcomes

Parameters	PALR - All (n=26)	s.p. Pneumonectomy (n=2)
LTx procedure type; n (%)		
Bilateral	23 (89)	
#Right Single	3 (11)	2 (100)
Donor lung size reduction		None
Lobar LTx	3 (12)	
Non-anatomical resection	1 (4)	
LTx incision; n (%)		
Clamshell	12 (46)	2 (100)
Anterolateral thoracotomy	10 (38)	
Posterolateral thoracotomy	4 (15)	
HU-LTx; n (%)	3 (12)	None
Preoperative ECLS; n (%)		
VV ECMO	2 (8)	Non
CIT 1st lung; mins	311 (266–385)	301 (291–)
CIT 2nd lung for bilateral LTx; mins	510 (410–553)	
*Duration of LTx; mins (n=23)	493 (400–550)	385
*Estimated blood loss; mL (n=13)	2000 (900–2750)	N/A
Transfusion (units)		
*Packed red blood cells (n=19)	5 (2–8)	4.5 (3–)
*Fresh frozen plasma (n=19)	2 (0–7)	0 (0–0)
*Platelets (n=19)	0 (0–1)	1 (0–)
Intraoperative ECLS; n (%)		
Off pump	13 (50)	
VA ECMO	7 (27)	
CPB	5 (19)	2 (100)
VV ECMO	1 (4)	
Postop ECLS; n (%)		
None	21 (81)	2 (100)
VA/VV ECMO	5 (19)	
ICU stay; days	11 (6–17)	7 (7)
Hospital stay; days	36 (23–46)	23 (23–)
Complications, any; n (%)	18 (69)	2 (100)
Tracheostomy	5 (19)	
Revision	9 (35)	
Hemothorax	5 (19)	
Pleural effusion	3 (12)	
Bronchial dehiscence	1 (4)	
90-days mortality	2 (8)	0

Values are median (first to third quartiles) or n: number (%).s.p. status post. N/A: not available. LTx: Lung transplantation; PALR: Previous anatomical lung resection; HU-LTx: High urgent LTx; ECLS: Extracorporeal life support; ECMO: Extracorporeal membrane oxygenation; CPB: Cardiopulmonary bypass; VA: Venoarterial; VV: Venovenous; ICU: Intensive care unit.
*Variable with missing data, number of patients with complete data are given in parenthesis
#Two right single LTx were performed after previous contralateral pneumonectomies and the other right single LTx was performed after an ipsilateral lobectomy.

Table 6: Long-term outcomes

Parameters	PALR (n=26)	s.p. Pneumonectomy (n=2)
*FEV1% @ 1-year (n=22)	75 (59–85)	61 (48–)
CLAD, any; n (%)	10 (39)	1 (50)
BOS	8 (31)	1 (50)
RAS	1 (4)	
BOS/RAS combined	1 (4)	
Mortality; n (%)	9 (35)	1 (50)
CLAD	6 (23)	1 (50)
Early postop	2 (8)	
Infectious	1 (4)	
Follow-up time after LTx; months	43 (17–83)	107 (60–)

Values are median (first to third quartiles) or n: number (%). s.p. status post.
LTx: Lung transplantation; PALR: Previous anatomical lung resection; FEV_1: forced expiratory volume in 1 s; CLAD: Chronic lung allograft dysfunction; BOS: Bronchiolitis obliterans syndrome; RAS: restrictive allograft syndrome.
*Variable with missing data, number of patients with complete data are given in parenthesis

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Figure 1