**ORIGINAL ARTICLE**

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

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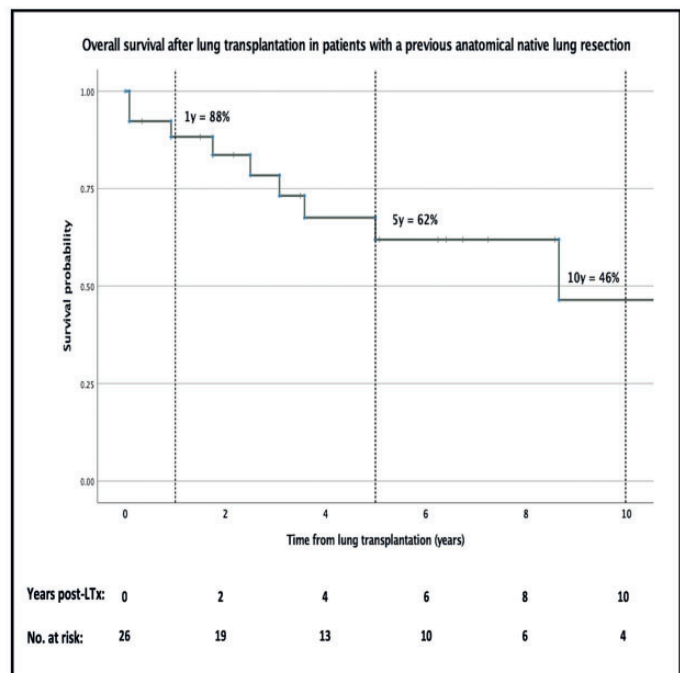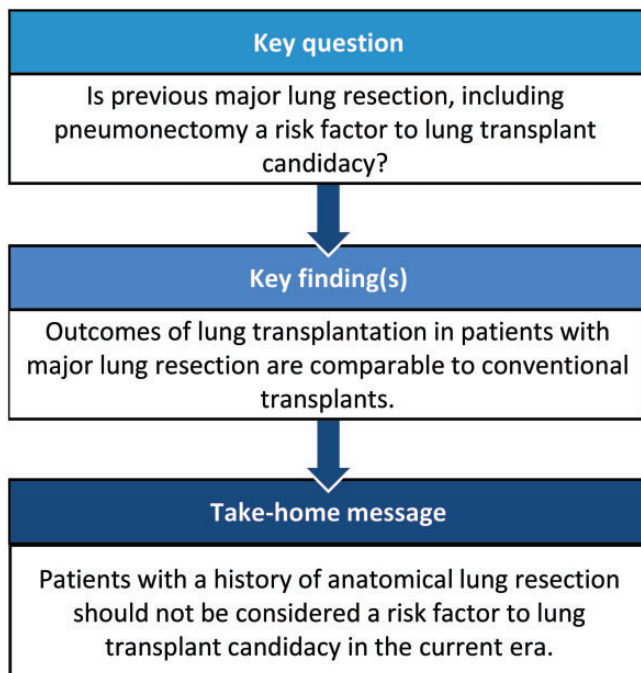[f] Department of Thoracic Surgery, University of Padua, Padua, Italy
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| Key question |
| --- |
| Is previous major lung resection, including pneumonectomy a risk factor to lung transplant candidacy? |

| Key finding(s) |
| --- |
| 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. |



Overall survival after lung transplantation in patients with a previous anatomical native lung resection

1y = 88%
5y = 62%
10y = 46%

| Years post-LTx: | 0 | 2 | 4 | 6 | 8 | 10 |
| --- | --- | --- | --- | --- | --- | --- |
| No. at risk: | 26 | 19 | 13 | 10 | 6 | 4 |

## Abstract

**OBJECTIVES:** History of anatomical lung resection complicates lung transplantation (LTx). Our aim was to identify indications, intraoperative approach and outcome in these challenging cases in a retrospective multicentre 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 January 2005 and July 2020. The primary end point was overall survival (Kaplan–Meier estimation).

**RESULTS:** Out of 2690 patients at 7 European centres, 26 (1%) patients (14 males; median age 33 years) underwent LTx after a previous anatomical lung resection. The 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 tumour (*n* = 2) and others (*n* = 2). Bronchiectasis (cystic fibrosis or non-cystic fibrosis 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:** The 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

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| 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 minimized 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 <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 multicentre 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 multi-centre 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 multicentre 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 (i.e. wedge resection) and lung resections performed after LTx were excluded from the study. Centres were invited to submit their data related to patient and donor characteristics, types of previous lung resections and outcomes. Participating centres were from Leuven—Belgium, Rome, Padua and Milan—Italy, Cordoba—Spain, Szczecin—Poland and Zurich—Switzerland. Centres reviewed their institutional databases to complete required data.

Centres 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 centres. 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 utilized 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 the 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 the 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 an 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 tumour 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 Fig. 1. Additional 3 patients underwent right single LTx, 2 of them were after contralateral pneumonectomies and the remaining one was

**Table 1:** Participating centres

| Centre | 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[a] (*n* = 25) | 19 (18–21) |
| FEV1%[a] (*n* = 25) | 23 (19–30) |
| DLCO[a] (*n* = 19) | 36 (29–47) |
| V/Q scan[a] (*n* = 22) | |
| Perfusion: right (%) | 42 (26–74) |
| Left (%) | 58 (26–74) |
| sPAP[a] (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* (%).
[a]Variable with missing data and number of patients with complete data are given in parenthesis.
CF: cystic fibrosis; COPD: chronic obstructive pulmonary disease; DLCO: diffusion capacity of carbon monoxide; FEV$_1$: forced expiratory volume in 1 s; LTx: lung transplantation; PALR: previous anatomical lung resection; sPAP: systolic pulmonary arterial pressure; V/Q: ventilation–perfusion.

**Table 3:** Characteristics of previous anatomical lung resection

| Parameters | PALR (n = 26) |
|---|---|
| Time from PALR to LTx (years) | 12 (7–21) |
| Indication for PALR, *n* (%) | |
| Infectious | 17 (65) |
| Emphysema | 5 (19) |
| Lung tumour | 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) |

Values are median (first to third quartiles) or *n* (%).
LTx: lung transplantation; PALR: previous anatomical lung resection.

**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[a] (*n* = 22) | 24 (23–27) |
| Length of IMV (days)[a] (*n* = 24) | 2 (1–4) |
| Type, *n* (%) | |
| DBD | 22 (85) |
| DCD | 4 (15) |
| Cause of Brain injury in DBD, *n* (%)[a] (*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* (%).
[a]Variable with missing data, number of donors with complete data are given in parenthesis.
CVA: cerebrovascular accident; DBD: donation after brain death; DCD: donation after circulatory death; EVLP: *ex vivo* lung perfusion; IMV: invasive mechanical ventilation; PALR: previous anatomical lung resection; P/F ratio: arterial partial pressure of oxygen divided by the fraction of inspired oxygen.
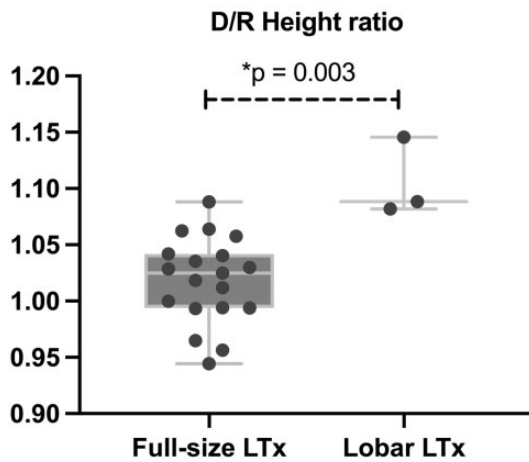
## D/R Height ratio



**Figure 1:** Donor/recipient height ratio.

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 was 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. The 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.

The median follow-up time was 43 months. The 1-, 5- 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] (Fig. 2). CLAD was diagnosed in 10 patients. The 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 multicentre 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 >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

**Table 5:** Perioperative outcomes

| Parameters | PALR—all (n = 26) | s.p. pneumonectomy (n = 2) |
|---|---|---|
| LTx procedure type, n (%) | | |
| Bilateral | 23 (89) | |
| Right single[a] | 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 (min) | 311 (266–385) | 301 (291–) |
| CIT 2nd lung for bilateral LTx (min) | 510 (410–553) | |
| Duration of LTx (min)[b] (n = 23) | 493 (400–550) | 385 |
| Estimated blood loss (ml)[b] (n = 13) | 2000 (900–2750) | N/A |
| Transfusion (units) | | |
| Packed red blood cells[b] (n = 19) | 5 (2–8) | 4.5 (3–) |
| Fresh frozen plasma[b] (n = 19) | 2 (0–7) | 0 (0–0) |
| Platelets[b] (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) | |
| Haemothorax | 5 (19) | |
| Pleural effusion | 3 (12) | |
| Bronchial dehiscence | 1 (4) | |
| 90-Day mortality | 2 (8) | 0 |

Values are median (first to third quartiles) or n (%).
[a]Two right single LTx were performed after previous contralateral pneumonectomies and the other right single LTx was performed after an ipsilateral lobectomy.
[b]Variable with missing data, number of patients with complete data are given in parenthesis.
CIT: cold ischemic time; CPB: cardiopulmonary bypass; ECLS: extracorporeal life support; ECMO: extracorporeal membrane oxygenation; HU-LTx: high urgent LTx; ICU: intensive care unit; LTx: lung transplantation; N/A: not available; PALR: previous anatomical lung resection; s.p.: status post; VA: venoarterial; VV: venovenous.

respiratory failure is similarly limited to LTx [10]. Rusanov *et al.* [11] 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. In-hospital mortality was notably higher for non-CF patients (21%) likely to be related to increased utilization of CPB in the early years of the program [11]. Recently, Rolla *et al.* [12] reported no hospital mortality for CF patients with previous thoracic procedures undergoing LTx. 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].
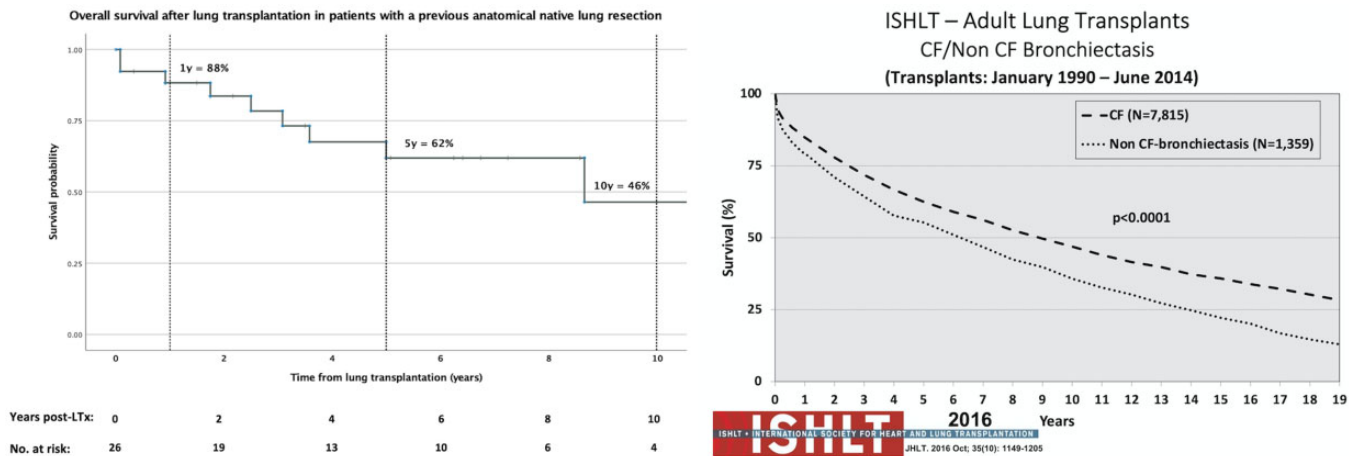
Figure 2: Kaplan–Meier survival curve of lung transplant recipients with a previous anatomical native lung resection compared to the survival curve for patients with bronchiectasis undergoing LTx from the ISHLT registry slides [8]. Source: http://www.ishlt.org/research-data/registries/ttx-registry/ttx-registry-slides

### Table 6: Long-term outcomes

| Parameters | PALR (n = 26) | s.p. pneumonectomy (n = 2) |
|---|---|---|
| FEV1% @ 1 year[a] (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 (%).
[a]Variable with missing data and number of patients with complete data are given in parenthesis.
BOS: bronchiolitis obliterans syndrome; CLAD: chronic lung allograft dysfunction; $FEV_1$: forced expiratory volume in 1 s; LTx: lung transplantation; PALR: previous anatomical lung resection; RAS: restrictive allograft syndrome; s.p.: status post.

Previous studies looking at the impact of previous cardiothoracic procedures are limited with the 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 an 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 the 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 haemodynamic compromise during LTx [16]. The strategy in this cohort was mostly the same, regardless of the previous resection side, explantations were usually started on the least perfused side. In case of a smaller discrepancy between the sides, around 40–60% 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 centres 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 do 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 mobilization 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 manoeuvre is not possible, ECLS—especially CPB—may be considered to establish haemodynamic stability and to control the bleeding. Although the routine use of intraoperative ECMO has been recently popularized [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.* [22] reported the first successful single LTx 8 months after a contralateral pneumonectomy in a paediatric patient with CF and asymmetric thorax. The French experience is the largest series to date summarizing 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 towards 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 the advancement of the venous cannula towards 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 the 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 manoeuvres, 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 *et al.* [26] reported the first successful bilateral LTx after previous pneumonectomy in a patient with destroyed lung. 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]. However, surgical experience in completion pneumonectomy is 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 centres in our opinion. In general, LTx remains controversial in patients with the history of previous lung tumour. Two patients from our cohort underwent pulmonary lobectomies followed by oncological treatment modalities due to stage IIB primary lung cancer in 1 and lung metastasis of neuroblastoma in another paediatric patient. Multiple factors should be considered when evaluating a patient with the history of malignancy for LTx [27]. The decisions to proceed with an LTx were made due to the absence of other contraindications, the disease-free interval of >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 tumour 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 an 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

Besides the multicentre 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 multicentre cohort. A propensity score matching analysis is frequently utilized to generate a control group when conducting multicentre database analysis. Due to the unavailability of a uniform database among participating centres, 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 centres only. The present study is conducted under the umbrella of ESTS LTx working group that has members from 21 centres in 14 countries in Europe, North America and the Middle East. Not all the members participated in data collection. Moreover, some large volume centres 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 centres, especially from Europe in developing a prospective multicentre 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, the 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.

## Funding

**Conflict of interest:** none declared.

## Data availability

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

## Author contributions

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

## Reviewer information

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