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Heterotopic lung transplant: a feasible approach to compensate for organ shortages

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Abstract

Lung transplants are still limited by the shortage of suitable donor lungs, especially during the coronavirus disease 2019 pandemic. A heterotopic lung transplant (HLTx), as a flexible surgical procedure, can maximize the potential of donor lungs in an emergency, but its widespread use is hindered by difficulties in anastomosis and paucity of outcome data. We performed a retrospective review of 4 patients, each of whom received an HLTx over 1 year, including 1 left-to-right single HLTx, 2 right-to-left single HLTxs and 1 lobar HLTx (right upper lobe-to-left). The median recipient age was 58.5 years (46–68); 3 patients were male. The postoperative hospital stay was 33 days (30–42). One recipient lived for 10 years and died of bronchiolitis obliterans syndrome; the others were alive with no major morbidity at 12 to 31 months after the operation with a 1-year survival of 100%. The follow-up chest images showed that transplanted lungs could be inflated well and adapted morphologically to fill the thoracic cavity in the short and long term. This study demonstrates that an HLTx is a feasible alternative to a conventional lung transplant in emergency cases and could be considered in selected patients at advanced medical centres.

Keywords: Heterotopic lung transplantation • Inverted lung transplantation • Donor lung

INTRODUCTION

A lung transplant (LTx) has become a widely used life-saving procedure for patients suffering from end-stage lung diseases [1]. However, the shortage of viable donor lungs, especially during the coronavirus disease 2019 pandemic, constrains the widespread use of LTxs [2]. Contrary to the orthotopic lung transplant (OLTx), a heterotopic lung transplant (HLTx) is an LTx in which a single lung or lobe is rotated 180 degrees and implanted into the recipient's contralateral thorax. This technique is unconventional and used only in an emergency, thus maximizing the potential of available donors. We report a case series of HLTxs and discuss critical technical aspects and postoperative outcomes of this strategy.

PATIENTS AND METHODS

Between January 2005 and December 2020, 4 HLTxs were accomplished by our team, including 1 left-to-right single HLTx, 2 right-to-left single HLTxs and 1 lobar HLTx (right upper lobe-to-left).

Pertinent patient information was obtained from medical records and operative videos, following the approval of the

institutional ethics committees of Wuxi People's Hospital. All transplanted organs were obtained from volunteer donations and allocated through the China Organ Transplant Response System.

Size matching was performed by estimating computed tomographic images and predicted total lung capacity. A donor-to-recipient predicted total lung capacity ratio ranging from 75% to 125% could be acceptable [3]. Donor lungs were procured as per our usual protocol [4]. Each HLTx procedure was performed through a lateral thoracotomy without transverse division of the sternum. The surgical workflow for the left-to-right HLTx has been previously described by our centre [5] (Fig. 1A). In the right-to-left HLTx, we performed a bronchial anastomosis with membranous-to-cartilaginous apposition using an end-to-end suturing technique. Then, we pulled the donor lung downwards to expose the superior mediastinum and folded up the donor pulmonary artery (PA) from the posterior hilum into the superior hilum, where the PA anastomosis was conducted with anterior-to-posterior wall apposition. Finally, the pulmonary vein (PV) anastomosis was performed in the posterior mediastinum, without the need of a venous cuff extension (Fig. 1B). The detailed process is shown in Video 1. The bipartition of the donor's right

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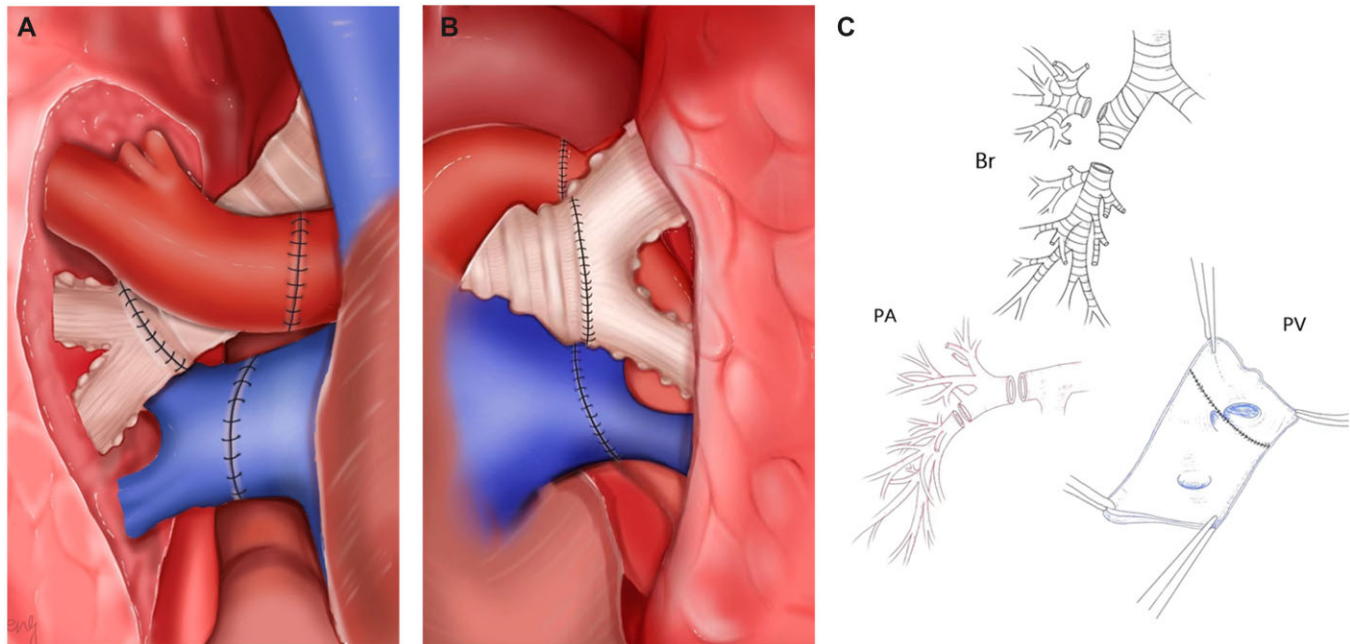
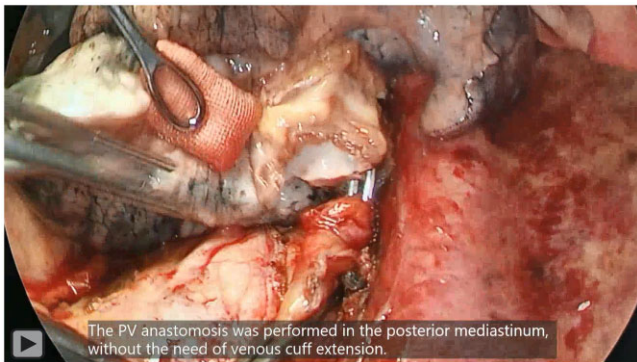


Figure 1: Schema of anastomosis in a left-to-right heterotopic lung transplant (A) and a right-to-left heterotopic lung transplant (B). (C) Splitting of the donor right lung.



Video 1: Intraoperative video of the anastomosis of a right-to-left heterotopic lung transplant.

lung in case 4 had been described recently [6] (Fig. 1C). The donor's right middle and lower lobes were implanted into the right thoracic cavity, and the right upper lobe was inverted and implanted into the left thoracic cavity in a manner similar to that in other right-to-left cases. The anastomotic site of the bronchus was routinely covered with peribronchial tissue.

RESULTS

All patients were in a critical condition and required high-flow oxygen inhalation or ongoing non-invasive ventilation perioperatively. Three recipients (cases 1, 2, and 3) had been scheduled to receive a single LTx because of uneven disease laterality, but the donor lungs on the corresponding sides were unsuitable for transplanting. The contralateral donor lungs were of good quality and roughly matched the thoracic cavities of the recipients. In these cases, HLTx rather than OLTx was selected. Case 4 was a female with a height of 154 cm; her small chest cavity and

pulmonary infection necessitated a bilateral lobar LTx. The perioperative data are presented in Table 1.

All patients were discharged from the hospital without supplemental inhaled oxygen. Case 1 died of bronchiolitis obliterans syndrome 10 years after the operation, and the other recipients were alive with no major morbidity (follow-up of 12–31 months), accounting for a 1-year survival of 100% after an HLTx. Follow-up computed tomographic scans showed that the transplanted lungs expanded well and filled the thoracic cavity (see Supplementary Fig. S1).

DISCUSSION

When there is a shortage of organs, flexible surgical procedures, to some extent, could increase the chance of a transplant. Size-reducing surgical techniques, including lung volume reduction and lobar LTx, have been developed for small recipients [7]. They have demonstrated that the bronchial anastomoses may be performed without anatomic alignment of the bronchi and that the lung morphology may gradually adapt to the shape of the thorax over time. Thus, the HLTx has emerged.

Through an HLTx, any side of the donor lung can be morphologically adjusted to enable a rapid transplant. What's more, Yamamoto *et al.* [8] reported that, as a potential secondary benefit, the edematous portion of the lower lobe of the donor lung can be inverted to the anterior side to act as the prone position ventilation, thereby enabling early reconditioning from the oedema. Therefore, an HLTx may be adapted as a remedial measure for a marginal donor lung.

For the surgical incision, we performed HLTxs through a lateral thoracotomy instead of using a semi-clamshell incision [8, 9], which facilitated the traction of the donor lung and the exposure of the posterior mediastinum with less trauma. Anatomically, the inverted donor lung/lobe in the

Table 1. Patient perioperative data

Case no.	1	2	3	4
HLTx type	Left-to-right	Right-to-left	Right-to-left	RUL-to-left
Diagnosis	AS-related PF	Silicosis	Silicosis	SS-related PF
Recipient age/sex/height (years)/(cm)	68/M/170	46/M/167	50/M/170	67/F/154
Donor age/sex/height (years)/(cm)	29/M/168	39/M/160	44/M/170	48/M/178
Donor-to-recipient pTLC ratio	0.8 ^a	1.1 ^b	1.2 ^b	0.9 ^c
Particular circumstances of donor	Extensive pleural adhesions and old pulmonary tuberculosis in the right lung	The left atrial sleeve was left too short due to vascular variation	Large areas of consolidation in the left lung	-
Intraoperative ECMO	-	-	V-A	V-V
Total cold ischaemia time (h)	3.5	7	7.5	7
Total operative time (h)	4.5	6.5	5	7.5
PGD at 72 h	-	Grade 3	-	-
Postoperative ECMO (days)	-	-	1	2
The intubation time (days)	6	4	2	3
Hospital stay (days)	42	33	30	33

AS: ankylosing spondylitis; ECMO: extracorporeal membrane oxygenation; F: female; M: male; PF: pulmonary fibrosis; PGD: primary graft dysfunction; pLLC: predicted left lung capacity (45% of pTLC); pRLC: predicted right lung capacity (55% of pTLC); pTLC: predicted total lung capacity; RUL: right upper lobe; SS: Sjogren's syndrome; V-A: venoarterial; V-V: venovenous.

^aDonor pLLC/recipient pRLC

^bDonor pRLC/recipient pLLC

^cDonor pRLC/recipient pTLC.

contralateral chest causes obstacles for the anastomosis when performing an HLTx. Among them, the anastomosis of the PA is critical to the fate of the procedure. In a left-to-right HLTx, the PA of the left donor lung after inversion is located above the bronchus and clearly exposed during the operation. So, the PA anastomosis is completed anterior to the bronchial axis (Fig. 1A), an approach similar to that in a conventional right single LTx. However, in a right-to-left HLTx, the PA is anastomosed superior and posterior to the bronchial axis (Fig. 1B), which is more complex and challenging. So far, this technique has been reported only by Chida and colleagues [9], who performed the PA anastomosis as the first step in the case of a right-to-left HLTx, followed by a bronchial anastomosis. An advantage of this sequence is the ease of performing the PA anastomosis with no covering by the bronchus. However, a potential disadvantage is the possibility of vascular kinking after the lung is inflated [10]. Because the bronchus is a rigid structure that mainly determines the position of the implanted lung graft, the bronchial anastomosis was performed first in our right-to-left HLTxs. Once the graft was fixed in its position, we continued to anastomose the PA posterior to the bronchial axis (00'49–01'33 in Video 1) and the PV in the posterior mediastinum (01'37–02'18). Although it may be cumbersome to perform a bronchus and a PA and PV anastomosis from different hilar perspectives, we believe this strategy could better align the channels to prevent kinking after reperfusion.

Though the treatment efficacy of HLTx is satisfactory in this case series, there are limitations worth noting. Firstly, compared with the OLTx, the HLTx is relatively difficult and has a higher risk of bronchial anastomotic stricture, atelectasis and kinking or narrowing of vessels [8], especially in centres with less experience. Secondly, no assignment settings specific for an HLTx in the organ allocation system may result in a slow regulatory approval process. Finally, the sample size was relatively small, and a larger sample size is required.

In conclusion, HLTx can serve as a complement to conventional LTx with good early and long-term results. It could be considered in an emergency at high-level medical centres.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *ICVTS* online.

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This study is performed without any supporting fund.

CONFLICTS OF INTEREST STATEMENT

There were no conflicts of interest for this study.

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