Outcomes of various transplant procedures (single, sparing, inverted) in living-donor lobar lung transplantation

Hiroshi Date, MD,[a] Akihiro Aoyama, MD,[a] Kyoko Hijiya, MD,[a] Hideki Motoyama, MD,[a] Tomohiro Handa, MD,[b] Hideyuki Kinoshita, MD,[c] Shiro Baba, MD,[d] Toshiyuki Mizota, MD,[e] Kenji Minakata, MD,[f] and Toyofumi F. Chen-Yoshikawa, MD[a]

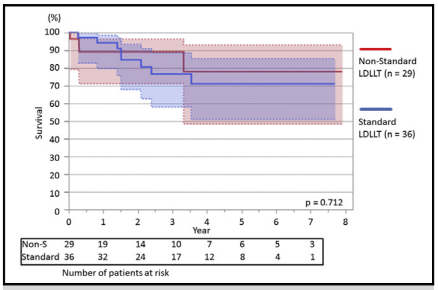
ABSTRACT

Objectives: In standard living-donor lobar lung transplantation (LDLLT), the right and left lower lobes from 2 healthy donors are implanted. Because of the difficulty encountered in finding 2 donors with ideal size matching, various transplant procedures have been developed in our institution. The purpose of this retrospective study was to compare outcomes of nonstandard LDLLT with standard LDLLT.

Methods: Between June 2008 and January 2016, we performed 65 LDLLTs for critically ill patients. Functional size matching was performed by estimating graft forced vital capacity based on the donor's measured forced vital capacity and the number of pulmonary segments implanted. For anatomical size matching, 3-dimensional computed tomography volumetry was performed. In cases of oversize mismatch, single-lobe transplant or downsizing transplant was performed. In cases of undersize mismatch, native upper lobe sparing transplant or right-left inverted transplant was performed. In right-left inverted transplants, the donor's right lower lobe was inverted and implanted into the recipient's left chest cavity.

Results: Twenty-nine patients (44.6%) received nonstandard LDLLT, including 12 single-lobe transplants, 7 native upper lobe sparing transplants, 6 right-left inverted transplants, 2 sparing + inverted transplants, and 2 others. Thirty-six patients (57.4%) received standard LDLLT. Three- and five-year survival rates were similar between the 2 groups (89.1% and 76.6% after nonstandard LDLLT vs 78.0% and 71.1% after standard LDLLT, $P = .712$).

Conclusions: Various transplant procedures such as single, sparing and inverted transplants are valuable options when 2 donors with ideal size matching are not available for LDLLT. (J Thorac Cardiovasc Surg 2016;■:1-8)



Survivals comparing nonstandard versus standard living-donor lobar lung transplantation.

Central Message

We successfully developed various transplant procedures (single, sparing, inverted) to deal with size mismatch in living-donor lobar lung transplantation.

Perspective

Living-donor lobar lung transplantation is indicated for patients who are unlikely to survive the long wait for cadaveric lungs. It is difficult, however, to find 2 donors with ideal size matching. In the setting of size mismatch, our newly developed various transplant procedures (single, sparing, inverted) can be applied to critically ill patients who will die otherwise. The outcome was excellent.

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Lung transplantation has been performed successfully worldwide in patients with end-stage lung disease, and more than 50,000 lung transplants have been reported.[1] Living-donor lobar lung transplantation (LDLLT) had been the only realistic option for most patients in Japan until 2010, when the Japanese organ transplant law was amended so that the family of the brain-dead donors could make the decision for organ donation.[2,3] The revision of the law significantly increased the number of organ donations from brain-dead donors[4]; however, the average waiting time is still more than 800 days, resulting in many deaths of patients on the waiting list. LDLLT often remains the only realistic option for very ill patients, particularly children.

Scanning this QR code will take you to the supplemental videos for the article.

From the Departments of [a]Thoracic Surgery, [b]Respiratory Medicine, [c]Cardiovascular Medicine, [d]Pediatrics, [e]Anesthesia, and [f]Cardiovascular Surgery, Graduate School of Medicine, Kyoto University, Kyoto, Japan.

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Address for reprints: Hiroshi Date, MD, Department of Thoracic Surgery, Graduate School of Medicine, Kyoto University, 54 Kawahara-cho, Shogoin, Sakyo-ku, Kyoto 606-8507, Japan (E-mail: hdate@kuhp.kyoto-u.ac.jp).

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Abbreviations and Acronyms

CLT = cadaveric lung transplantation
ECMO = extracorporeal membrane oxygenation
FVC = forced vital capacity
LDLLT = living-donor lobar lung transplantation
3D-CT = 3-dimensional computed tomography

In a standard LDLLT, the right and left lower lobes from 2 healthy donors are implanted in the recipient in place of whole right and left lungs[5-7]; however, finding 2 healthy blood type−compatible donors with ideal size matching is very difficult. An adult lower lobe may be too large for small children. The use of oversized grafts could cause high airway resistance, atelectasis, and hemodynamic instability by the time of chest closure.[8] To overcome these problems, we have used several techniques, including single-lobe transplantation with or without contralateral pneumonectomy,[9,10] delayed chest closure,[11] downsizing the graft,[12] and middle lobe transplantation. Conversely, it often is inevitable that small grafts may be implanted, particularly in adult male recipients. Excessively small grafts may cause high pulmonary artery pressure and result in lung edema.[13] We have developed lobar-sparing transplantation[14] and right-to-left inverted transplantation protocols[15] for undersize grafts.

Long-term outcomes of these nonstandard LDLLT have not been reported at the present time. The purpose of this retrospective study was to compare outcomes of nonstandard LDLLT patients with those of standard LDLLT patients in our institution.

PATIENTS AND METHODS

Recipient and Donor Selection

Patients being considered for LDLLT should be younger than 65 years old and must meet the criteria for conventional cadaveric lung transplantation (CLT). The policy of our program has been to limit LDLLT to critically ill patients with progressive lung disease who are unlikely to survive the long wait for cadaveric lungs. Our acceptance criteria for living-donors included blood type−compatible immediate family members between 20 and 60 years old. Potential donors had to be competent; willing to donate free of coercion; medically and psychosocially suitable; fully informed of the risks and benefits as a donor; and fully informed of the risks, benefits, and alternative treatments available to the recipient. Each case was carefully reviewed and approved by the institutional Lung Transplant Evaluation Committee.

Size Matching

For "functional size matching," we used graft forced vital capacity (FVC).[16] We previously proposed a formula to estimate the graft FVC based on the donor's measured FVC and the number of pulmonary segments implanted.[2] Given that the right lower lobe consists of 5 segments, the left lower lobe 4 segments and the both lungs 19 segments, total FVC of the 2 grafts was estimated. When the total FVC of the 2 grafts was more than 45% of the predicted FVC of the recipient (calculated from a knowledge of height, age, and sex), we accepted the size disparity. The ratio should be more than 50% for patients with pulmonary hypertension.[17] The FVC size matching was used mainly to evaluate undersized grafts.

For "anatomical size matching," 3-dimensional computed tomography (3D-CT) volumetry was performed both for the donor and the recipient.[12,18] CT images were obtained with a multidetector CT scanner during a single respiratory pause at the end of maximum inspiratory effort. Contiguous 0.5-mm slices, reconstructed with a standard lung reconstruction algorithm, were used for volumetric analysis and the entire CT image was exported to a workstation (AZE Virtual Place Lexus; AZE Co, Ltd, Tokyo, Japan) for 3D-CT volumetry. Via automated segmentation, the volumes of each lung and the graft lobes were calculated automatically. The upper and lower thresholds of anatomical size matching have not been determined at the present time. We have accepted a wide range of volume ratios between the donor's lower lobe graft and the corresponding recipient's chest cavity.[18] The 3D-CT size matching mainly was used to evaluate oversized grafts. The volume ratio upper threshold appeared to be in the vicinity of 200% based on 3D-CT size matching.

Standard LDLLT

In standard LDLLT, the right and left lower lobes from 2 healthy donors were implanted under cardiopulmonary support in the recipient in place of whole right and left lungs. We have used extracorporeal membrane oxygenation (ECMO) instead of conventional cardiopulmonary bypass in most LDLLT procedures since 2012. Activated clotting time was maintained between 180 and 200 seconds.

Strategies for Oversized Grafts

For small children, an adult lower lobe may be too large. We have used several compensatory techniques, including single-lobe transplantation with or without contralateral pneumonectomy,[9,10] delayed chest closure,[9] downsizing the graft,[12] and middle-lobe transplantation. Single LDLLT also was indicated when only one living-donor was found in the family.

Strategies for Undersized Grafts

For large adults, 2 lower lobe grafts may be too small. We have developed 2 transplant procedures, native upper lobe sparing LDLLT[14] and right-left inverted LDLLT.[15] Native upper lobe−sparing LDLLT is indicated when the total graft FVC was less than 60% of the recipient's predicted FVC. The recipient lung should not be infected and the interlobar fissure should be well developed. Ideally, the native upper lobes would be less impaired than the lower lobes as seen on high-resolution CT or would be better perfused on perfusion scintigraphy. The surgical procedure of native upper lobe−sparing transplant was similar to that of standard LDLLT except that the pulmonary vein was anastomosed to the lower pulmonary vein, the pulmonary artery to the interlobar artery, and the bronchus distally to the second carina (Video 1).

In right-left inverted LDLLT, the donor right lower lobe (5 segments) is inverted and implanted into the recipient's left chest cavity instead of the donor left lower lobe (4 segments). It is indicated when total graft FVC was less than 60% of the recipient's predicted FVC or when donor's left lower lobectomy would be technically difficult as the result of interlobar pulmonary artery anatomy.[19] The technical details have been described previously.[15] At the time of left pneumonectomy in the recipient, upper and lower bronchi are stapled separately. After the right lower lobe graft is rotated from its anatomic position to 180° about its superior-inferior axis, the graft is placed in the recipient's left chest cavity. The bronchus is anastomosed to the recipient's left upper bronchus and the left lower bronchial stamp is left closed. The pulmonary artery anastomosis is performed behind the bronchus. The donor pulmonary vein typically is anastomosed to the recipient's left upper pulmonary vein or occasionally to the recipient's left appendage (Video 2).