Living-Donor Lobar Lung Transplantation

5

Hiroshi Date

5.1 History and Concept

Living-donor lobar lung transplantation (LDLLT) was developed to offset the mismatch between supply and demand for those patients awaiting deceased donor lung transplantation (DDLT). LDLLT was introduced by Starnes and his colleagues as an alternative form of treatment for patients who had a decline in their physical condition and a limited life expectancy. A single donor was used at the outset, and successful living-donor single-lobe transplantation has been reported [1]. However, the subsequent experience with single-lobe transplantation was not satisfactory. Therefore, Starnes' group developed bilateral LDLLT in which two healthy donors donate their right or left lower lobes (Fig. 5.1) [2]. Since then, bilateral LDLLT has been performed as a lifesaving procedure to deal with the shortage of deceased donors. Because only two lobes are transplanted, LDLLT seems to be best suited for children and small adults, and initially it was applied almost exclusively to patients with cystic fibrosis [3]. However, it is now established that LDLLT can be applied to both pediatric and adult patients with restrictive, obstructive, infectious, and vascular lung diseases when the size matching is acceptable [4–6]. Successful LDLLTs have been reported for patients receiving oversized as well as undersized grafts. In our institution, the 5-year survival after LDLLT is 88.2%.

As of 2013, LDLLT has been performed on approximately 400 patients worldwide. Although LDLLT began in the USA, it has decreased there because of the recent change by the Organ Procurement and Transplantation Network to an urgency/benefit allocation system for deceased donor lungs. During the past several years, reports on LDLLT came mostly from Japan, where the average waiting time for a deceased donor lung is more than 2 years.

5.2 Recipient Selection

The candidate for LDLLT should be less than 65 years old and have progressive lung disease. All recipients should fulfill the criteria for conventional DDLT. Because of possible serious complications with the donor lobectomy, LDLLT should be indicated only for critically ill patients who are unlikely to survive the long wait for deceased lungs. On the other hand, when the recipient is too sick, it would not be justified to perform two lobectomies from two healthy donors. In our experience with LDLLT, all patients were oxygen-dependent, 55% were bedbound, and 13% were on a ventilator at the time of transplantation. Controversy exists as to whether LDLLT can be applied to patients already on a ventilator or requiring retransplantation. The St. Louis group reported that LDLLT provided better survival than conventional DDLT for retransplantation [7]. Perioperative mortality of retransplantation was only 7.7% in the patients who had LDLLT versus 42.3% in the DDLT group. We also reported successful LDLLT procedures for ventilator-dependent patients [8, 9]. In contrast, the University of Southern California (USC) group reported in a series of 123

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LDLLTs that patients on ventilators preoperatively had significantly worse outcomes, with an increased risk of death in those undergoing retransplantation [10]. Successful LDLLT has been reported in two patients on extracorporeal membrane oxygenation (ECMO) by the Okayama group [11]. In both patients, bridging time of ECMO to LDLLT was 2 days, and both could be weaned from cardiopulmonary bypass support immediately after transplantation in the operating room.

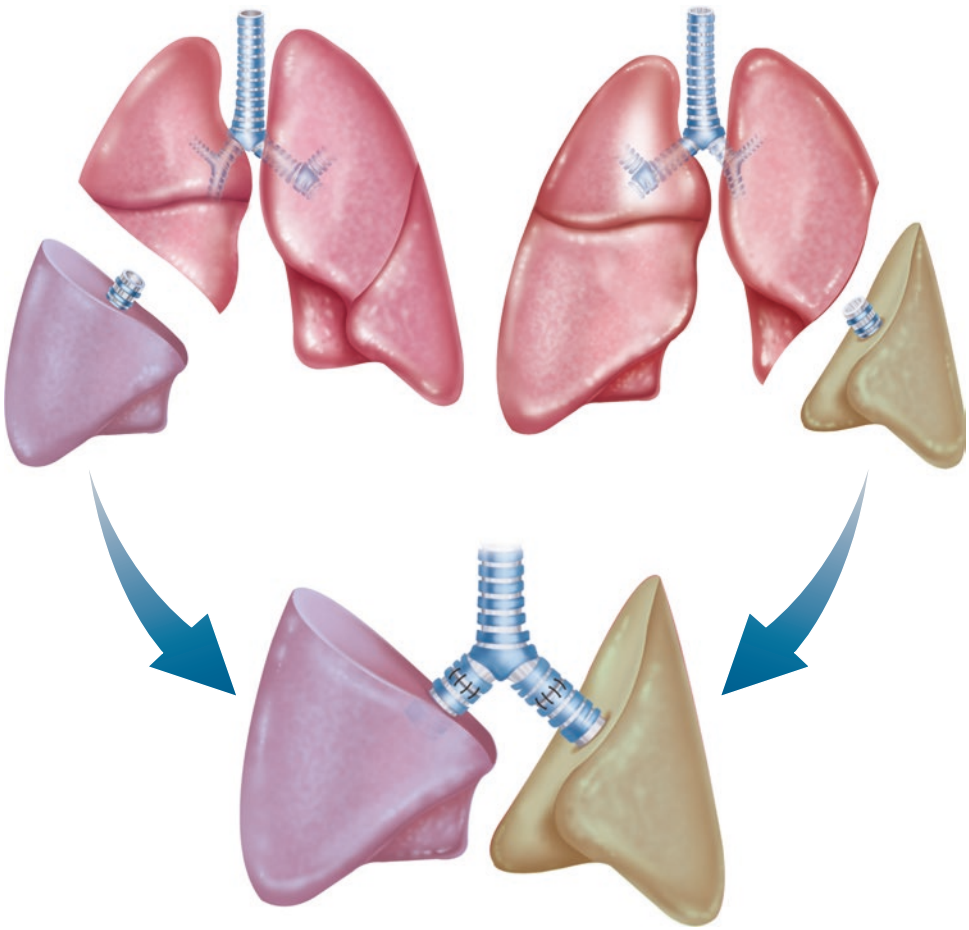
Because only two lobes are transplanted, cystic fibrosis represents the most common indication for LDLLT in the USA because these patients have a small body size.

Figure 5.1

Bilateral living-donor lobar lung transplantation. Right and left lower lobes from two healthy donors are implanted in a recipient in place of whole right and left lungs

The distribution of diagnoses is quite unique in Japan, where cystic fibrosis is a very rare disease. We have accepted patients with various lung diseases for LDLLT, including hypertensive, restrictive, obstructive, and infectious diseases. In our experience, interstitial pneumonia, bronchiolitis obliterans, and pulmonary hypertension were the three major indications. Most of the patients with interstitial pneumonia were on systemic corticosteroid therapy [12]. Most of those with bronchiolitis obliterans had previously undergone hematopoietic stem-cell transplantation for various malignancies such as leukemia [13, 14], whereas patients with idiopathic pulmonary arterial hypertension were on high-dose epoprostenol therapy [15].

Figure 5.1



5.3 Donor Selection

Eligibility criteria for living lobar lung donation at Kyoto University are summarized in Table 5.1. Although immediate family members (relatives within the third degree or a spouse) have been the only donors in our institution, non-Japanese institutions have accepted extended family members and unrelated individuals [16]. Extracting more than one lobe from the donor should be prohibited.

Potential donors should 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 risks, benefits, and alternative treatment available to the recipient. In our institution, potential donors are interviewed at least three times to provide them with multiple opportunities to question, reconsider, or withdraw as a donor.

After a suitable donor pair is found, the larger donor with better vital capacity is selected for the donation of the right lower lobe and the second donor for removal of the left lower lobe.

Three-dimensional multidetector computed tomography (CT) angiography reconstruction is created for the confirmation of the pulmonary arterial and venous anatomy (Fig. 5.2) [17]. The completeness of the pulmonary fissures is carefully evaluated by high-resolution computed tomog-

Figure 5.2

Three-dimensional CT angiography in a typical right donor. A white dotted line shows the planned cutting oblique line of the pulmonary artery in order to preserve the middle lobe branches

Table 5.1 The eligibility criteria for living lung donation (Kyoto University)

Medical criteria:
Age 20–60 years
ABO blood type compatible with recipient
Relatives within the third degree or a spouse
No significant past medical history
No recent viral infection
No significant abnormalities on echocardiogram or electrocardiogram
No significant ipsilateral pulmonary pathology on CT
Arterial oxygen tension ≧ 80 mmHg (room air)
Forced vital capacity, forced expiratory volume in 1 s ≧ 85% of predicted
No previous ipsilateral thoracic surgery
No active tobacco smoking
Social and ethical criteria:
No significant mental disorders documented by a psychiatrist
No ethical issues or concerns about donor motivation

raphy. Although HLA matching is not required for donor selection, a prospective crossmatch to rule out the presence of anti-HLA antibodies is performed.

5.4 Size Matching

Appropriate size matching between the donor and recipient is important in LDLLT. It is often inevitable that small grafts are implanted in LDLLT patients in whom only two lobes are implanted. Excessively small grafts may cause high pulmonary artery pressure resulting in lung edema [18]. A pleural space problem may increase the risk of empyema. Overexpansion of the donor lobes may contribute to obstructive physiology by early closure of small airways [19]. On the other hand, the adult lower lobe might be too big for small children. The use of oversized grafts could cause high airway resistance, atelectasis, and hemodynamic instability by the time of chest closure [20].

Figure 5.2

5.4.1 Functional Size Matching

For functional size matching, we utilize graft forced vital capacity (FVC) [21]. We have previously proposed a formula to estimate the graft FVC based on the donor's measured FVC and the number of pulmonary segments implanted [5]. Given that the right lower lobe consists of five segments, the left lower lobe of four, and the whole lung of 19, total FVC of the two grafts is estimated by the following equation:

Total FVC of the two grafts
– measured FVC of the right lobe donor × 5 / 19 +
measured FVC of the left lobe donor × 4 / 19.

When the total FVC of the two grafts is more than 45% of the predicted FVC of the recipient (calculated from a knowledge of height, age, and sex), we accept the size disparity.

Total FVC of the two grafts /
predicted FVC of the recipient > 0.45.

Figure 5.3

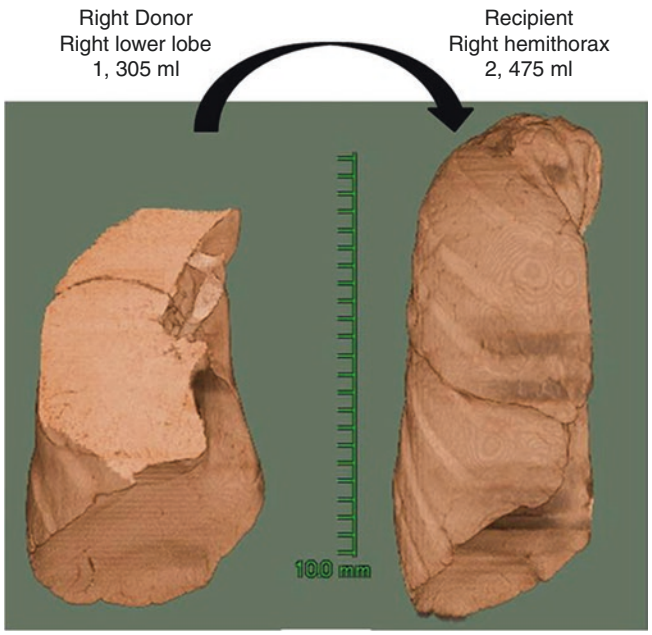
Anatomical size matching for the right donor graft and the recipient's right hemithorax using three-dimensional volumetry. The recipient was an adult female with bronchiolitis obliterans whose right hemithorax was 2475 mL. The right donor was her son, whose right lower lobe was 1305 mL. The ratio of the right donor graft to the recipient's right hemithorax was estimated to be 52.7%. The recipient's adaptation to the small graft was remarkable. Postoperative chest radiograph showed no detectable dead space

For patients with pulmonary hypertension, the ratio should be more than 0.5. The recipient's mean measured FVC at 6 months after LDLLT was well correlated with the estimated graft FVC [21]. In contrast, we found no significant correlation between the recipient's predicted FVC and the recipient's measured FVC. These results indicate that the amount of lung tissue implanted, not factors such as diagnosis, determines recipient FVC.

5.4.2 Anatomical Size Matching

For anatomical size matching, three-dimensional CT (3D-CT) volumetry is performed both for the donor and the recipient (Fig. 5.3) [22, 23]. CT images are obtained using a multidetector CT scanner during a single respiratory pause at the end of maximum inspiratory effort. The upper and lower threshold of anatomical size matching has not been

Figure 5.3



determined yet. We have accepted a wide range of volume ratio between the donor's lower lobe graft and the corresponding recipient's chest cavity. When the ratio was within 40–160%, we found that the recipient's adaptation ability for undersized or oversized grafts was remarkable.

5.5 Surgical Technique

Three surgical teams and a back table team are required to perform bilateral LDLLT. They communicate with each other closely to minimize graft ischemic time. The recipient and the right-side donor are brought to the operating room at the same time. The left-side donor is brought to the theater 30 min later.

5.5.1 Donor Lobectomy

The most common procedure involves a right lower lobectomy from a larger donor and a left lower lobectomy from a smaller donor. After induction of general anesthesia, donors are intubated with a left-sided double-lumen endotracheal tube. Fiber-optic bronchoscopy was performed to determine

Figure 5.4

Dissection and division of the right inferior pulmonary vein for donor right lower lobectomy. The pericardium surrounding the inferior pulmonary vein is opened circumferentially. A vascular clamp is placed on the intrapericardial left atrium. Two 5-0 Prolene corner stitches can be placed peripheral to the clump before division. In the event of slippage of the left atrial clamp, the stitches can be pulled up and the left atrium can be reclamped

if lower lobectomy was feasible, leaving adequate length for closure on the donor bronchus and adequate length for anastomosis in the recipient.

The donors are placed in the lateral decubitus position, and a posterolateral thoracotomy is performed though the fifth intercostal space. Fissures are developed using linear stapling devices. The pericardium surrounding the inferior pulmonary vein is opened circumferentially. Dissection in the fissure is carried out to isolate the pulmonary artery from the lower lobe and to define the anatomy of the pulmonary arteries in relation to the middle lobe in the right-side donor and to the lingular segment in the left-side donor. If the branches of the middle lobe artery and the lingular artery are small, they are ligated and divided. However, if such branches are large enough, arterioplasty using an autopericardial patch should be performed [17].

Two thousand units of heparin and 125 mg of methylprednisolone are administered intravenously. After placing vascular clamps in appropriate positions, the division of the pulmonary vein (Fig. 5.4), the pulmonary artery (Fig. 5.5), and the bronchus (Fig. 5.6) is carried out in this order.

Figure 5.4

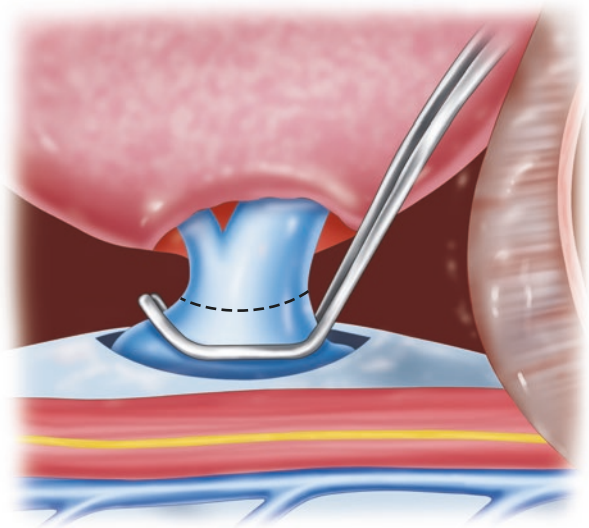


Figure 5.5

Division of the right inner lobar pulmonary artery for donor right lower lobectomy. Dissection in the fissure is carried out to isolate the pulmonary artery to the lower lobe and to define the anatomy of the pulmonary arteries to the middle lobe on the right side of the donor. The distance between the superior segmental artery and the middle lobe artery is variable. After placing a vascular clamp, the interlobar pulmonary artery is divided in an oblique fashion

Figure 5.6

Division of the right lower bronchus. A 25-gauge needle is inserted through the bronchus at the level of the planned division line. Simultaneous bronchoscopy is conducted for internal examination. The right lower bronchus is divided along an oblique line above the segmental bronchus to the superior segment inferiorly to just below the takeoff of the middle lobe bronchus

Figure 5.5

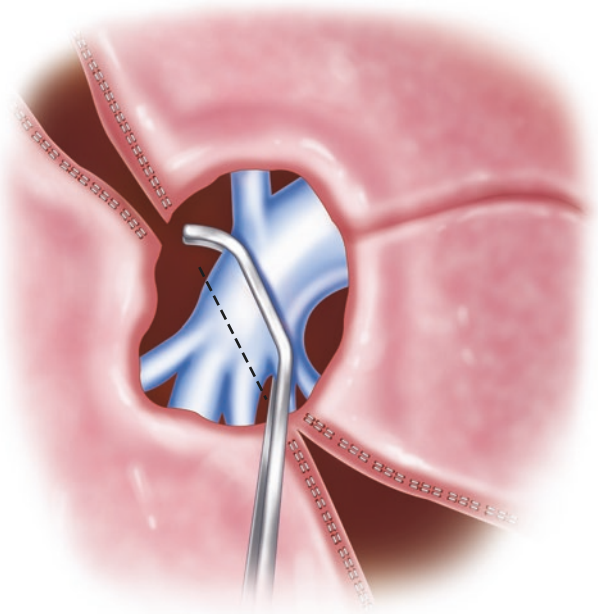
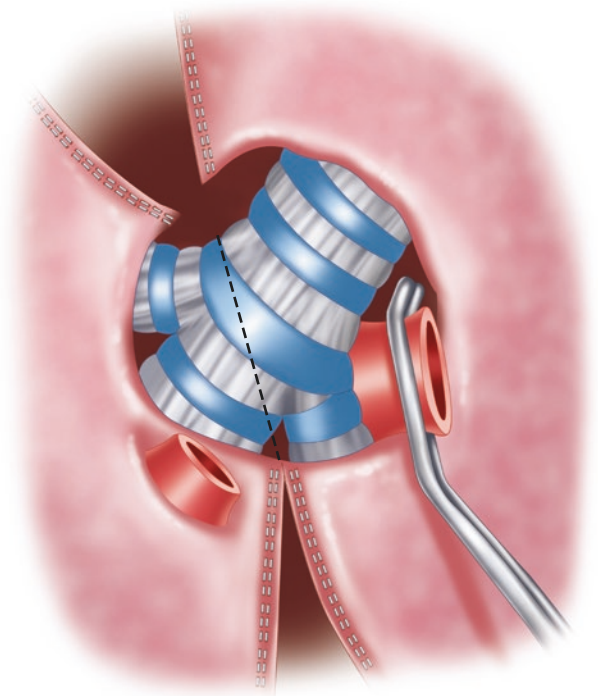


Figure 5.6



Vascular stamps are closed with 5-0 polypropylene running suture. The bronchus is closed with 4-0 polypropylene interrupted sutures. The bronchial stamp is covered with pedicled pericardial fat tissue.

On the back table, the lobes are flushed with preservation solution both antegradely and retrogradely from a bag about 50 cm above the table. The lobes are gently ventilated with room air during the flush.

5.5.2 Recipient Implantation

Recipients are anesthetized and intubated with a single-lumen endotracheal tube in children and with a left-sided double-lumen endotracheal tube in adults. The "clamshell" incision is used, and both chest cavities are entered through the fourth intercostal space. The sternum is notched at the level of transection by aiming the sternal saw at a 45° angle

Figure 5.7

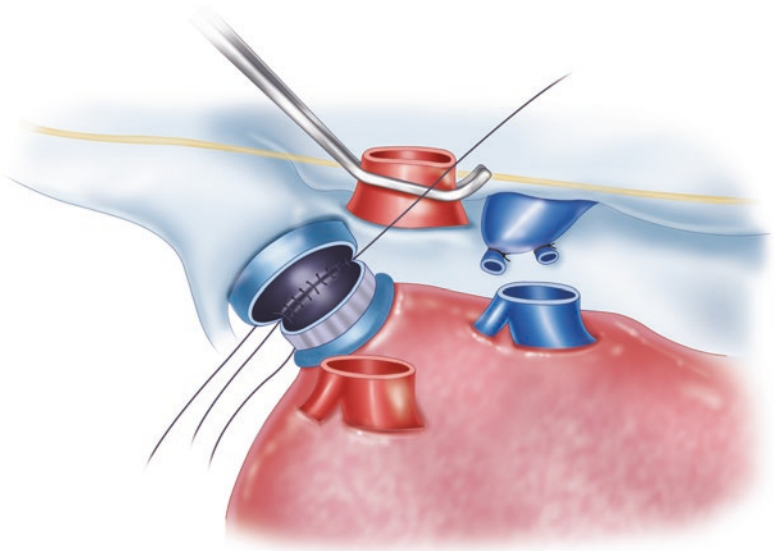
Bronchial anastomosis in the right lower lobe implantation. The bronchial anastomosis begun with a running 4-0 polydioxanone suture for the membranous portion and completed with simple interrupted sutures or a running suture for the cartilaginous portion

and cutting toward the midpoint to facilitate postoperative sternal adaptation.

Pleural and hilar dissections are performed as much as possible before heparinization to reduce blood loss. The ascending aorta and the right atrium are cannulated after heparinization, and patients are placed on standard cardiopulmonary bypass (CPB). After bilateral pneumonectomy, hilar preparation is performed to facilitate subsequent implantation. The chest is irrigated with warm saline containing antibiotics.

The right lower lobe implantation is performed, followed by the left lower lobe implantation. The bronchus, the pulmonary vein, and the pulmonary artery are anastomosed consecutively. The bronchial anastomosis is undertaken first with a running 4-0 polydioxanone suture for the membranous portion and completed with simple interrupted sutures or a running suture for the cartilaginous portion (Fig. 5.7). We use end-to-end anastomosis when the bronchial size is equivalent and telescoping technique when the discrepancy

Figure 5.7



in bronchial size is obvious. The bronchial wrapping is not employed except for patients on high-dose steroid therapy. The venous anastomosis is conducted between the donor inferior pulmonary vein and the recipient superior pulmonary vein using a running 6-0 polypropylene suture (Fig. 5.8). The pulmonary arterial anastomosis is completed in an end-to-end fashion using a running 6-0 polypropylene suture (Fig. 5.9).

Just before completing the bilateral implantations, 500 mg to 1 g of methylprednisolone is given intravenously and

Figure 5.8

Pulmonary venous anastomosis in the right lower lobe implantation. The venous anastomosis is conducted between the donor's inferior pulmonary vein and the recipient's superior pulmonary vein using a running 6-0 polypropylene suture

Figure 5.9

Pulmonary arterial anastomosis in the right lower lobe implantation. The pulmonary arterial anastomosis is completed in an end-to-end fashion using a running 6-0 polypropylene suture

nitric oxide inhalation is initiated at 20 ppm. Once both lungs are reperfused and ventilated, CPB is gradually weaned and then removed.

The alternative strategy for cardiopulmonary support during the recipient's operation for LDLLT is the use of extracorporeal membrane oxygenation (ECMO) via the femoral artery and vein. ECMO allows a lower dose of heparin, which seems to reduce the perioperative bleeding [24]. It is especially useful when extensive pleural adhesions are found. Activated clotting time is maintained to be around 200 s. We have utilized ECMO instead of CPB in most LDLLT procedures since 2012.

Figure 5.8

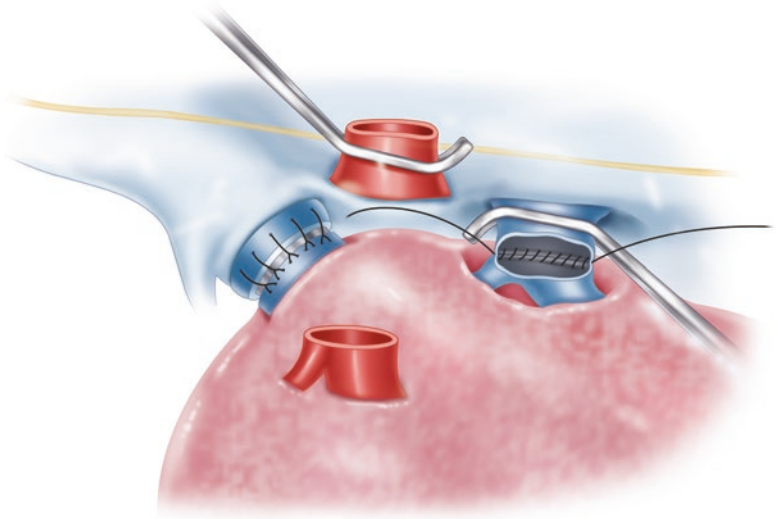
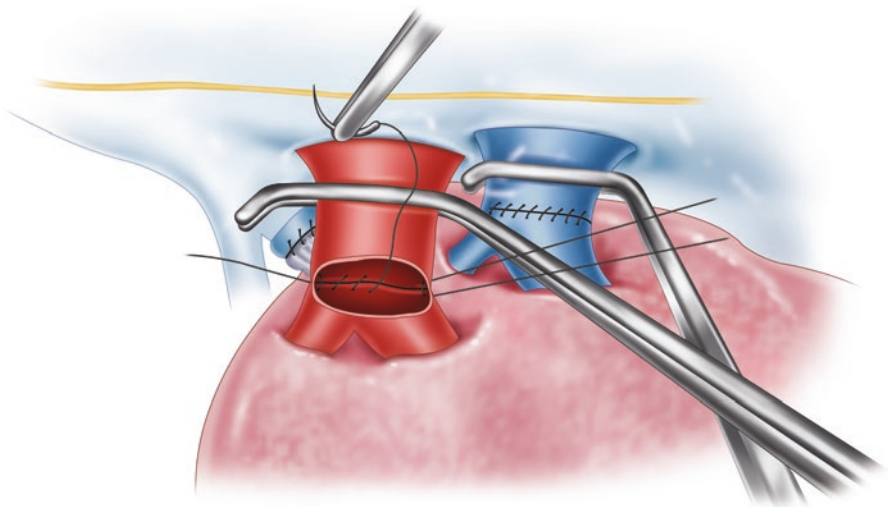


Figure 5.9



5.6 LDLLT Using Oversized Grafts

For small children, the adult lower lobe might be too big. The use of oversized grafts could cause high airway resistance, atelectasis, and hemodynamic instability by the time of chest closure [20]. To overcome these problems, we have developed several techniques, including single-lobe transplantation with or without contralateral pneumonectomy, delayed chest closure, and downsizing the graft.

Single LDLLT from a single living donor can be performed for selected small recipients. We retrospectively investigated 14 critically ill patients who had undergone single LDLLT at three lung transplant centers in Japan [25]. The 3- and 5-year survival rates were 70% and 56%, respectively. Survival among these 14 patients was significantly worse than survival in a group of 78 patients undergoing bilateral LDLLT during the same period. Single LDLLT provides acceptable results for sick patients

Figure 5.10

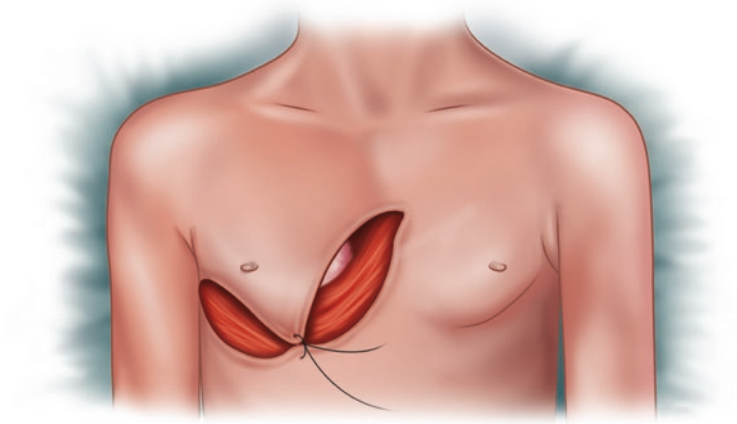
Delayed chest closure. A 6-year-old girl underwent right single-lobe transplantation from her mother. The graft was 207% bigger than the recipient's right chest cavity. We closed the chest loosely only by the skin closure. The following day, her chest could be completely closed

who would die soon otherwise. However, bilateral LDLLT appears to be a better option if two living donors are found.

We reported successful right lower lobe transplantation and simultaneous left pneumonectomy in an 8-year-old girl on a ventilator [9]. The graft donated by her mother was estimated to be 200% larger than the right chest cavity of the recipient.

It has been reported that delayed chest closure (Fig. 5.10) can be safely used after deceased donor bilateral lung transplantation. This technique can be applied to LDLLT [26]. The oversized graft volume is expected to decrease during the waiting period by improvement of pulmonary edema, and the dimensions of the recipient's right side of the heart are expected to decrease because of the reduction in the afterload after LDLLT.

Figure 5.10



We reported another strategy for oversized grafts by downsizing a graft on a back table. A 15-year-old boy with bronchiolitis obliterans successfully underwent bilateral LDLLT with segmentectomy of the superior segment of an oversized right lower lobe graft obtained from his father [27].

5.7 LDLLT Using Undersized Grafts

When grafts are too small, a limited amount of vascular bed might cause high pulmonary artery pressure, resulting in lung edema [18]. Intrathoracic dead space can remain and cause complications, such as postoperative bleeding, persistent air leakage, and empyema. Moreover, hyperinflation of the grafted lungs may result in insufficient respiratory dynamics or hemodynamic collapse after LDLLT [19].

We reported a successful LDLLT in which a very large mismatch between donor lungs and recipient chest cavity was solved by sparing the bilateral native upper lobes [28]. The recipient, a 44-year-old man with bronchiolitis obliterans, was 17 cm taller than his donors, his sister and his wife. Regarding anatomical size matching, the volume ratio of the graft was only 22% on the right side and 36% on the left side. By sparing the native upper lobes, adequate chest cavity space for small grafts was provided. Forced expiratory

Figure 5.11

Left upper lobe-sparing bilateral living-donor lobar lung transplantation. The recipient was a 54-year-old male with idiopathic pulmonary fibrosis. The right donor was his son, and the left donor was his wife. (**a**) Preoperative coronal view of CT showed dominant pulmonary fibrosis in the right lung. (**b**) Postoperative CT showed spared native left upper lobe (*black arrow*) and implanted donor lower lobes (*white arrows*)

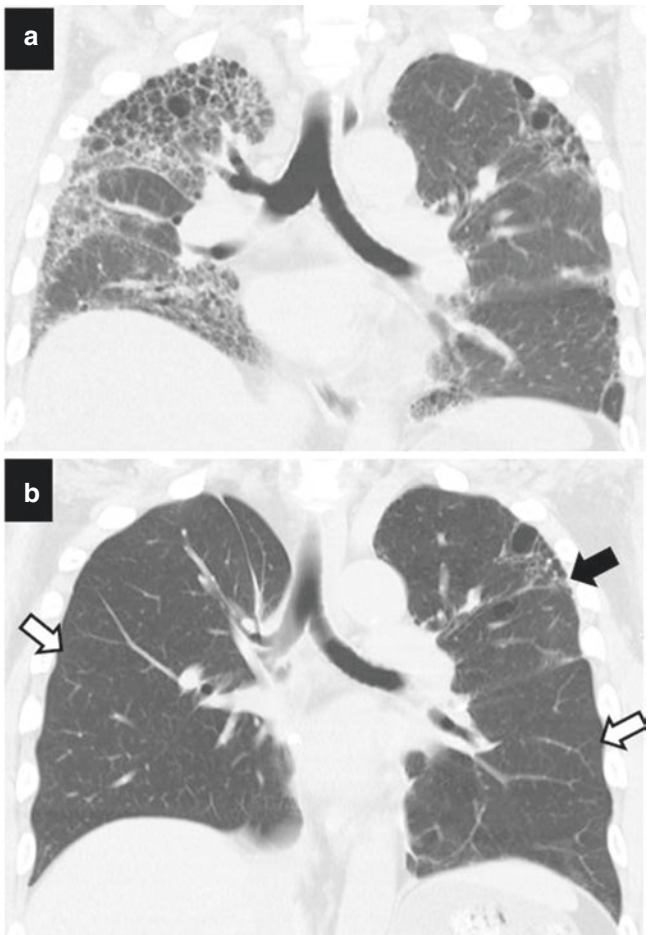
volume in 1 s improved dramatically from 590 mL to 2090 mL. Candidates for this approach should have no infection in the spared lobes and minimal pleural adhesion with well-developed interlobar fissures. We have successfully applied this technique to patients with bronchiolitis obliterans, pulmonary fibrosis (Fig. 5.11), and chronic hypersensitivity pneumonia.

5.8 Postoperative Management

The patient is kept intubated for at least 3 days to maintain optimal expansion of the implanted lobes. We use pressure-limited ventilation and keep maximal ventilation pressure at less than 25 cm H_2O. Fiber-optic bronchoscopy is performed every 12 h during intubation to assess donor airway viability and to suction any retained secretions. Bedside postoperative pulmonary rehabilitation is initiated as soon as possible.

Postoperative immunosuppression consists of triple drug therapy with cyclosporine (CSA) or tacrolimus (FK), mycophenolate mofetil (MMF), and corticosteroids. Induction cytolytic therapy is not used. The combination of CSA + MMF + steroid is chosen for patients with infectious lung diseases, pediatric patients, and patients on steroids, while the combination of FK + MMF + steroid is used for other patients. Apart from 125 mg of methylprednisolone during the first 3 days, all immunosuppressive medication is given via the nasal tube inserted in the proximal jejunum.

Figure 5.11



Under careful monitoring of daily serum creatinine levels, CSA and FK trough levels are often reduced to below the target range.

Acute rejection is determined on the basis of radiographic and clinical findings without transbronchial lung biopsy because the risk of pneumothorax and bleeding after transbronchial lung biopsy may be greater after LDLLT. Because two lobes are donated by different donors, acute rejection is usually seen unilaterally. Early acute rejection episodes are characterized by dyspnea, low-grade fever, leukocytosis, hypoxemia, and diffuse interstitial infiltrate on chest radiographs and CT scans. A trial bolus dose of methylprednisolone of 500 mg is administered, and various clinical signs are carefully observed. If acute rejection is indeed the problem, two additional daily bolus doses of methylprednisolone are given. If acute rejection is encountered more than three times, CSA is switched to FK.

5.9 Results

5.9.1 Outcome of Living Donors

Successful LDLLT largely depends on donor outcome. In our experience, all donors have returned to their previous life styles without any restrictions. However, long-term outcomes of live donors have not been well documented because the donor follow-up generally continues for 1 year and then stops. More studies are needed to understand the long-term results of living lung donors.

Relatively high morbidity after lobectomy has been described in the previous reports, but there has been no reported perioperative mortality [29, 30]. Morbidity rates have varied from 20% to 60%, depending on the definition of complications. Common complications are pleural effusion, bronchial stamp fistulas, hemorrhage, and arrhythmias. The Vancouver Forum Lung Group summarized the world experience on approximately 550 living lung donors in 2006 [16]. Approximately 5% of them have experienced complications requiring surgical or bronchoscopic intervention.

Relatively high morbidity after living-donor lobectomy as compared to standard lobectomy may be explained by three technical differences between the two surgical procedures. First, the circumferential pericardiotomy surrounding the inferior pulmonary vein may increase the risk of arrhythmias and pericarditis. Second, an oblique transection of the right lower lobe bronchus may increase the risk of bronchial fistula and stenosis. Third, administration of heparin may increase the risk of bleeding in the perioperative period.

The Massachusetts General Hospital reported that living lung donors enjoyed generally satisfactory physical and emotional health [31]. Donors reported positive feelings about donation but wished to be recognized and valued by the trans-

Figure 5.12

Survival rates after living-donor lobar lung transplantation at Kyoto University. The 1-, 3-, and 5-year survivals were 92.0%, 88.2%, and 88.2%

plant team and the recipient. The Okayama group reported that the average quality of life in the living lung donors was better than that of general population [32]. However, a fatal outcome in the recipient significantly impacted donor mental health. Interestingly, there was a significant correlation in mental health scores between the paired donors.

The Massachusetts General Hospital group reported that mean donor FVC decreased by 16% ± 3% [31]. Postdonation FVC value was higher than the preoperatively predicted value. We prospectively evaluated pulmonary function 3, 6, and 12 months after donor lobectomy [33]. FVC and FEV_1 recovered constantly up to more than 90% of the preoperative value 1 year after donor lobectomy.

5.9.2 Outcome of LDLLT Recipient

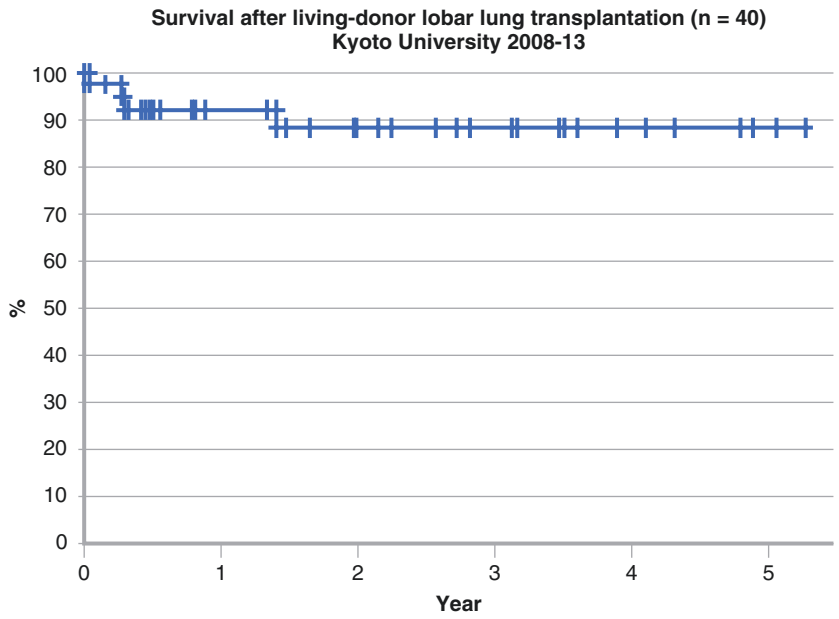
There are only four groups that have reported a summary of recipient outcome. The USC group published their 10-year experience on 123 LDLLT recipients, including 39 children [10]. In their series, retransplantation and mechanical ventilation were identified as risk factors for mortality. The 1-, 3-, and 5-year survival rates were 70%, 54%, and 45%. The St. Louis group reported similar results (5-year survival 40%) in 38 pediatric LDLLT recipients [34], while in Brazil, 16 LDLLTs were performed with a 56% 3-year survival [35]. The Okayama University group reported on 47 LDLLTs by the author of this chapter with an 88% 5-year survival [36].

At the Kyoto University, we performed LDLLT in 40 patients from June 2008 to August 2013. There were 23 females and 17 males with ages ranging from 6 to 64 years (average 37.2 years). Twelve patients were children and 28 were adults. Recipient's diagnoses were listed in Table 5.2. The most common indication was interstitial pneumonia and bronchiolitis obliterans, followed by pulmonary hypertension. All 40 patients were very sick and required oxygen inhalation preoperatively. Twenty-two patients (55%) were bedbound, and five (13%) were on a ventilator for as long as 7 months at the time of transplantation. Bilateral LDLLT was performed in 30 patients and single LDLLT was performed in 10 small patients. There were three early deaths, for a hospital mortality of 7.5%. Two recipients died of graft failure because of an excessively small graft after single LDLLT. One died of aspiration pneumonia. There was only one late death caused by chronic allograft dysfunction, which occurred at 17 months. The 1-, 3-, and 5-year survivals were 92.0%, 88.2%, and 88.2% (Fig. 5.12).

Table 5.2 Diagnoses for LDLLT at Kyoto University

Diagnoses	Number
Interstitial pneumonia	17
Bronchiolitis obliterans	15
Pulmonary hypertension	3
Bronchiectasis	2
Retransplantation	2
Chronic hypersensitivity pneumonia	1
Total	40

Figure 5.12



The question of whether two pulmonary lobes can provide a sufficient long-term pulmonary function and clinical outcome to recipients has been recently answered. The USC group reported that LDLLT provided comparable intermediate and long-term pulmonary function and exercise capacity to bilateral DDLT in adult recipients surviving more than 3 months after transplantation [37]. Similar results were reported from Okayama, where the measured recipient FVC reached 123% of the estimated graft FVC of two donor lobes at 36 months after LDLLT (calculated based on the donor FVC and the number of segments implanted) [38].

5.10 Comparison with Deceased Lung Transplantation

Advantages and disadvantages of LDLLT compared to DDLT are summarized in Table 5.3.

In general, the ischemic time for LDLLT is much shorter than that for DDLT. In our experience, the ischemic time of the right graft was 146 ± 7 min and that of the left graft was 136 ± 7 min. Although only two lobes are transplanted, LDLLT seems to be associated with less frequent primary graft failure. Because the living donor receives careful evaluation, infection transmitted from the living-donor graft is very rare. We believe that using a "small but perfect graft" is a great advantage in LDLLT.

Bronchiolitis obliterans syndrome (BOS) has been the major complication after DDLT, and it has been suggested that LDLLT was associated with a lower incidence of BOS, especially in pediatric patients. Furthermore, the shorter ischemic time in LDLLT could explain the lower incidence of BOS. Transplanting two lobes from two different donors appears to be beneficial in the long-term because the contralateral unaffected lung may function as a reservoir in case of unilateral BOS [39].

The greatest and most unavoidable disadvantage of LDLLT is two lobectomies from two healthy donors. Because of possible serious complications in the donor lobectomy, LDLLT should be performed only in a well-prepared program.

Table 5.3 Comparison between LDLLT and DDLT

	LDLLT	DDLT
Waiting time	Short	Long
Schedule	Planned	Unplanned
Ischemic time	Short	Long
Graft size	Small	Full
Primary graft failure	Infrequent	10–20%
Infection transmitted from graft	Infrequent	Frequent
Number of teams	3	2
Chronic rejection	Often unilateral	Major cause of death

5.11 Conclusion

LDLLT can be performed for various lung diseases both for adults and children. It appears to provide similar or better survival than DDLT. Size mismatching can be overcome to a certain extent using various surgical techniques.

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