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CASE REPORT

Perioperative assessment of oversized lobar graft downsizing in living-donor lobar lung transplantation using three-dimensional computed tomographic volumetry

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Summary

A 15-year-old boy with bronchiolitis obliterans after bone marrow transplantation successfully underwent bilateral living-donor lobar lung transplantation (LDLLT) with segmentectomy of the superior segment of an oversized right lower lobe graft. As the recipient was small for his age, the predicted value of his functional vital capacity of the recipient was difficult to determine preoperatively. Three-dimensional computed tomography (CT) volumetry revealed that the ratio of donor graft volume to recipient hemithorax volume was 159% on the right side and 82% on the left side. The patient is alive and well 7 months after transplantation, and three-dimensional CT volumetry revealed that the right and left donor lungs were still compressed to 73% and 84% of the original size, respectively. In LDLLT, segmentectomy of the superior segment of the lower lobe is a useful option for downsizing an oversized graft and three-dimensional CT volumetry can provide meaningful data for size matching.

Introduction

Lung transplantation is the only option for many patients with end-stage lung diseases; however, the shortage of suitable donors is still a serious problem. To save the life of a rapidly deteriorating critically ill patient, living-donor lobar lung transplantation (LDLLT) has been performed successfully [1,2]. Size matching between donor and recipient is an important issue in LDLLT [3–6]; however, there have been no reports describing clinical experience of downsizing procedures for LDLLT. Although three-dimensional computed tomography (3D-CT) volumetry provides informative data for size matching in liver transplantation, there have been only a few reports on the use of this technique in lung transplantation [3,7]. We herein report our experience of LDLLT with downsizing an oversized donor lung by segmentectomy of the superior segment of the right lower lobe. To the best of our knowledge, this is the first report describing the downsizing procedure in LDLLT and the perioperative assessment of graft lung volume using 3D-CT volumetry in bilateral LDLLT.

Case report

A 15-year-old boy with severe end-stage pulmonary disease resulting from bronchiolitis obliterans, which developed after bone marrow transplantation, was referred to our hospital. The patient had an adrenal neuroblastoma with multiple bone metastases at the age of 4 years, and underwent surgical resection, followed by high-dose chemotherapy. He finally overcame the disease, but presented with myelodysplastic syndrome at the age of 7 years. He underwent bone marrow transplantation, but developed graft-versus-host disease in multiple organs 5 months after bone marrow transplantation. Although he was treated with immunosuppressant therapy, there was severe progression of bronchiolitis obliterans. At the time of

referral, his height was 120 cm and his weight 16 kg. He was bedridden and could sleep only in a sitting position because of dyspnea, from which he had suffered for more than 1 month. Arterial blood gas measurement on 1.5 l/min O_2 nasal administration revealed a pH of 7.35, arterial pO_2 of 74 mmHg, and arterial pCO_2 of 72 mmHg. After a considered assessment, the patient and his family finally decided that he should receive LDLLT. The donors for the right and left lungs were the patient's father and mother, respectively. His father was 42 years old, 173 cm in height, and 70 kg in weight. His functional vital capacity (FVC) was 5170 ml and total lung capacity (TLC) was 7930 ml. His mother was 45 years old, 155 cm in height, and 61 kg in weight. Her FVC was 2920 ml and TLC was 4110 ml. We previously proposed a method for size matching in LDLLT, which is called Date's formula [2,8]. Given that the right lower lobe consists of five segments, the left lower lobe four, and the whole lung 19, we estimated the graft FVC using the following equation: The graft FVC = measured FVC of the right donor × 5/19 + measured FVC of the left donor × 4/19. When the graft FVC is more than 45% of the predicted FVC of the recipient (calculated according to the recipient's height, age, and gender), we accept the size disparity regardless of the recipient's diagnosis. According to Date's formula, the graft FVC was estimated to be 1975 ml (1360 ml on the right and 615 ml on the left). When the formula for a boy of more than 14 years of age was applied to the recipient [8], the estimated FVC of the graft was 63% of the recipient's predicted FVC (3140 ml). However, the recipient was very small for his age because of the multiple therapy-related growth impairment, and his height (120 cm) was equivalent to that of an approximately 6-year-old child in Japan. When the formula for a boy of <14 years of age was applied [8], the estimated FVC of the graft was 121% of the recipient's predicted FVC (1627 ml). Because of the large discrepancy in these values, 3D-CT volumetry was also performed (Table 1). CT images were obtained during a single respiratory pause at the end of maximum inspiratory effort (TLC) using a multi-detector CT scanner (Aquilion 64; Toshiba Medical Systems, Tochigi, Japan). Whole lung scans were performed at a peak tube voltage of 120 kVp, with variable mAs setting using an automatic exposure control system (SD value 8.5). Contiguous 0.5-mm-thick images, reconstructed using a standard lung reconstruction algorithm (FC 51), were used for volumetric analysis. The whole CT images were transported to a workstation (AZE Virtual Place Lexus; AZE Co., Ltd., Tokyo, Japan) for 3D-CT volumetry. The entire perimeter of each slice of the recipient lung and the donor graft was outlined automatically and then the entire 3D image was visualized and reconstructed. The volume of the lung was also calculated automatically. The right lower lobe graft was 1729 ml and the left lower lobe graft was 759 ml. The recipient's lungs appeared over-inflated because of the bronchiolitis obliterans; his right hemithorax was 1090 ml and his left hemithorax was 929 ml. The ratio of right donor graft to recipient right hemithorax was 159%, whereas the ratio of left donor graft to recipient left hemithorax was 82%. From these results, we deemed that the right donor graft was too large and that it might need to be tailored by anatomical segmentectomy of the superior segment of the right lower lobe (Fig. 1). Transplantation was performed with cardiopulmonary bypass without complications. The right donor graft was visibly too large on site; and thus the downsizing procedure was performed without difficulty on the back table. After reventilation, the graft still appeared oversized macroscopically; however, closure of the chest did not cause hemodynamic instability and blood gas values were satisfactory. The postoperative course was relatively uneventful, except for the long time needed to wean the patient off the ventilator because of muscle weakness

Table 1. Volumetry and pulmonary function data of the recipient and donors.

	Recipient	Pre-LDLLT	Post-LDLLT donor graft volume*		
	Hemithorax volume*	Donor graft volume*	2 months	3 months	6 months
Right	1090	1729	828	921	1014
(After segmentectomy)		(1383)			
Left	929	759	513	585	634
Recipient pulmonary function test					
FVC (ml)				570	790
FEV1 (ml)				510	740
TLC (ml)				–	1460

*Volumes are in ml.

FEV1, forced expiratory volume in 1 s; FVC, functional vital capacity; LDLLT, living-donor lobar lung transplantation; TLC, total lung capacity.

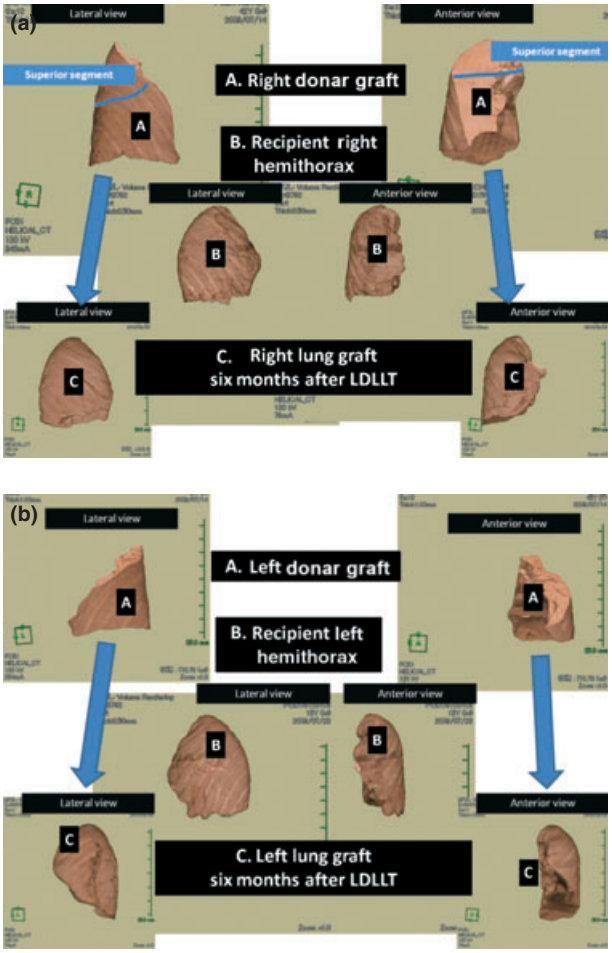

Figure 1 (a) Size matching for the right donor lung and the recipient right hemithorax, using three-dimensional volumetry. (b) Size matching for the left donor lung and the recipient left hemithorax, using three-dimensional volumetry.

caused by the prolonged preoperative bedridden condition. He was completely weaned off the ventilator 40 days after LDLLT and he was discharged home 3 months after LDLLT. At that time, a pulmonary function test showed that FVC was 0.57 l and FEV1 (forced expiratory volume in 1 s) was 0.51 l. 3D-CT volumetry showed that the right and left implanted lung volumes were 921 and 585 ml, respectively. Six months after LDLLT, FVC was 0.79 l and FEV1 was 0.74 l, and the right and left implanted lung volumes had increased to 1014 and 634 ml, respectively. This indicated moderate compression of the donor lungs resulting in a graft 73% and 84% of the original size on the right and left side, respectively (Fig. 1). Arterial blood gas measurement in room air revealed a pH of 7.36, arterial pO_2 of 87 mmHg, and arterial pCO_2 of 46 mmHg. Seven months after LDLLT, he is well and is not dependent on oxygen support. He is still only 121 cm in height, but his weight has increased to 20 kg.

Discussion

Size matching is a very important issue in LDLLT, and in this respect, we have used Date's formula, in which FVC is used as the only reliable variable to assess size compatibility [2,8]. In the current case, a deviation from the standard physical size yielded an erroneous predicted FVC value for the recipient; however, the 3D-CT volumetry data supported the idea that the donor grafts, particularly the right graft, might be too large for the recipient. Furthermore, the right graft would be even more oversized once the chest cavity has returned to its original size after explantation of the diseased lungs. In accordance with these preoperative presumptions and intraoperative findings, we performed a smooth LDLLT with a prepared procedure for downsizing the right graft. Thus, 3D-CT volumetry can provide useful data, particularly for severely diseased recipients with deviant physical sizes, such as small adults and large children. Despite no available data on how much compression the donor lungs can tolerate in the recipient's thorax, our case revealed that the lungs could work when compressed to approximately 70% of their original size. There have been only a few reports on the relationship between pulmonary function test and 3D-CT volumetry and thus both the accumulation of more cases and longer follow-ups are needed to confirm how the transplanted lungs settle in the recipient's thorax.

Various methods of downsizing donor lungs can be applied in lung transplantation, and in most cases, peripheral wedge resection has been performed with excellent results [9–11]. In our case, multiple peripheral wedge resections might have been another option; however, superior segmentectomy of the right lower lobe was selected because it involves a simple anatomical resection, particularly for the lower lobe. As a result, the heart is displaced slightly to the left, suggesting that the right lung graft might be compressing the heart even after segmentectomy of the right lung graft. There is no definite answer as to what will happen if we removed the anterior part or segment of the right lung graft with or without the superior segmentectomy, which might have better adjusted the right lower lobe to the shape of the recipient's right thorax. However, because of the recipient's age, we attempted to leave as much lung volume as possible, taking into consideration his growth after LDLLT. Currently, 7 months after LDLLT, the patient is only 1 cm taller than he was before LDLLT; however, a longer follow-up should be mandatory to evaluate the trend of size matching. We performed segmentectomy on the back table because, as a result of insufficient experience, we lacked confidence in interpreting the results of size matching using a combination of Date's formula and

3D-CT volumetry. In the future, an accumulation of such cases might enable transplant surgeons to perform the segmental resection *in vivo*, thus saving oversized donors an additional segment.

In conclusion, we performed LDLLT with downsizing of the donor lung by segmentectomy of the superior segment of the right lower lobe before implantation. Segmentectomy of the superior segment of the lower lobe was a safe and useful option for the downsizing of an oversized graft in LDLLT. More experience is necessary to better understand the 3D-CT volumetry data; however, 3D-CT volumetry could provide meaningful data for size matching in LDLLT.

Authorship

FC: designed and performed the research, and wrote the paper. TF: collected the data. TS: analyzed the data. TY, DN and JS: collected the data. HS: analyzed the data. TB: analyzed the data. HD: wrote the paper.

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