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CASE REPORT

Living-donor lung transplantation after surgical repair of transposition of the great arteries

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Abstract
Pediatric pulmonary hypertension after surgery for congenital heart disease is a significant complication. We present a case of living-donor lung transplantation for a 12-year-old girl with pulmonary hypertension after surgical repair of transposition of great arteries. Despite repairing the transposition of great arteries, her growth was severely restricted because of progressive pulmonary hypertension; thus, lung transplantation was discussed. Standard bilateral lobar transplantation seemed unfeasible due to oversized grafts, so we performed a single lobar transplantation. Unexpectedly, she developed complications and died 3 months postoperatively despite another emergent lobar transplantation. We discussed the challenges and potential solutions regarding lobar size mismatching.

Keywords Lung transplantation · Pulmonary hypertension · Transposition of great vessels

Introduction

Lung transplantation (LTx) is one of the therapeutic options for children with severe lung disease. While the development of pediatric cardiology has improved survival duration in children with congenital heart disease (CHD), pulmonary hypertension (PH) is an important complication in patients with CHD [1, 2]; this is also true in patients with transposition of the great arteries (TGA). Cordina et al. reported that 3.5% of the patients with TGA developed late-onset severe PH; these patients were less likely to respond to vasodilator therapy [3].

LTx could play a more significant role in treating patients who have severe PH resistance to medical treatments. However, completing lung transplantation for these patients poses several challenges, including mediastinal and hilar adhesions, and bleeding from collateral vessels in the thorax.

Here, we present a case in which primary graft dysfunction (PGD) and recurrent and refractory bleeding complicated the postoperative course, leading to patient death.

Case

A female patient was diagnosed with TGA, ventricular septal defect (VSD), and mild left ventricular outflow obstruction at birth. At 2 years and 4 months of age, the Jatene procedure and closure of ASD and VSD were performed. However, the patient developed PH. Beraprost was started for the PH at the age of 3. Despite home oxygen therapy, bosentan, sildenafil, and epoprostenol, the PH exacerbated and right heart failure, complicated with thrombocytopenia, progressed. She was referred to our hospital at 12 years old for a potential living-donor LTx.

Preoperatively, her height and body weight were 125.9 cm (−4.4 SD) and 24.9 kg (−2.3 SD), respectively. She had New York Heart Association functional class IV heart failure and was taking 5.0 mg/kg/day of bosentan, 1.2 mg/kg/day of sildenafil, 70 ng/kg/min of epoprostenol, 3 μg/kg/min of dobutamine, and 0.25 μg/kg/min of olprinone. Echocardiography showed satisfactory left ventricular function.

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Cardiac catheterization showed a mean pulmonary pressure of 59 mmHg with a pulmonary vascular resistance of 18.4 Wood units m^2.

We discussed the possible treatment options with her parents multiple times and informed that outcomes of lung may not be favorable since there was a dearth of data on LTx for PH after repair of TGA at that time. Eventually, they agreed to proceed with living-donor LTx. The operation was approved by the ethical committee of Kyoto University Hospital.

Her condition was too severe to wait for cadaveric LTx. The patient's parents were valid donors and volunteered to donate a lobe of their lungs to their child. Thus, living-donor LTx was chosen. Mediastinal and hilar adhesions due to a previous operation, pancytopenia due to right-sided heart failure, and resultant hepatomegaly were potential perioperative problems. Initially, we planned a standard bilateral lower lobe transplant. Using three-dimensional CT, her right and left chest cavity volumes were estimated to be 755 and 670 ml, respectively, whereas the right lower lobe volumes of her father and mother were 1350 and 1198 ml, respectively. Bilateral LTx was considered unfeasible due to her small thorax, so a single lobar transplantation was chosen. Regarding functional size matching, the estimated forced vital capacity (FVC) of the father's right lower lobe was 979 ml (56.6% of the patient's predicted FCV), which was acceptable because it was more than 45% of her predicted FVC [4], whereas that of the mother's right lower lobe was 742 ml (42.9% of the predicted FCV).

The father's right lower lobe was transplanted into her right chest cavity. The operative and extracorporeal circulation times were 557 and 279 min, respectively. Although she was weaned from cardiopulmonary bypass after reperfusion, the graft failed to function resulting in declining oxygenation. Therefore, extracorporeal membrane oxygenation (ECMO) was started to assist the patient's oxygenation at the end of the operation and chest closure was delayed until postoperative day (POD) 6. Despite the ECMO support, hypoxemia and radiologic infiltrates in the graft persisted. Transesophageal echocardiography suggested that more pulmonary blood flow was supplied to the right lung than to the left.

To resolve the mismatch between ventilation and pulmonary blood flow, we emergently performed a left single-lobe lung transplantation from her mother on POD 17. However, the ventilation of the left graft was impaired because of bleeding from the right graft's bronchus. Therefore, the left graft was removed on POD 19. The patient died on POD 95.

Discussion

We experienced a LTx for a case with severe PH after TGA repair, whose condition was uncontrollably progressive despite maximal medical treatments. Zijlstra et al. reported 25 patients who developed PH after repair of TGA, concluding that prognosis was poor and comparable with idiopathic PH, suggesting LTx is indicated for both entities [5]. Although it was controversial whether living-donor LTx was indicated for such a critically ill patient, we decided to proceed with living-donor LTx following adequate ethical judgement and confirmation of the willingness for lung donation.

Previously, Watanabe et al. reported a successful cadaveric bilateral LTx in a 25-year-old male patient with PH who had undergone a TGA repair [6]. In contrast, our patient was a 12-year-old girl with progressive PH whose physical growth had been severely restricted. Due to the small size and hemodynamic instability of our patient, a living-donor LTx was required. This case uncovered several problems that can occur in lung transplantation for severe PH after surgeries for CHD in small patients.

Heart–lung transplantation was not realistic because of an extreme shortage of pediatric cadaveric donors in Japan and we considered that LTx alone would be contributing to recovery of her hemodynamics because her cardiac function was not significantly impaired [7]. Initially, we planned a standard bilateral lower lobe transplant. However, considering the patient's small chest cavity, we determined it was not feasible. Therefore, we decided on a single lobar transplantation. Regarding graft selection, her father's right lower lobe was chosen for transplantation. Although the right lower lobe graft was 179% of the ideal size, we expected a postoperative mediastinal shift and shrinkage of the left native lung, resulting in the recipient's thorax adjusting to an oversized single-lobe graft as in other patients with no history of previous thoracotomy who received a single lobar LTx (Fig. 1). Immediate postoperative hypoxemia was likely associated with primary graft dysfunction, for which ECMO support was started. Although we are not able to evaluate quantitatively, no thoracic adjustment occurred (Fig. 1) after delayed chest closure, which was potentially due to the adhesions associated with her postoperative state and potentially worsened her situation.

The second problem was that majority of pulmonary blood flow was directed to the right transplanted graft due to its lower resistance, resulting in pulmonary edema and a mismatch between ventilation and perfusion. We performed an emergent left lower lobe transplantation to relieve the imbalance between the right and left pulmonary blood flow. However, the newly transplanted left graft failed to function because of refractory airway bleeding from the right-sided graft (Fig. 2). This hemorrhage resulted presumably from alveolar hemorrhage due to PGD enhanced by multiple factors, such as collateral vessels, pancytopenia, and extracorporeal membrane oxygenation. Regarding collateral vessels, it might be beneficial to evaluate and possibly embolize them percutaneously before LTx.

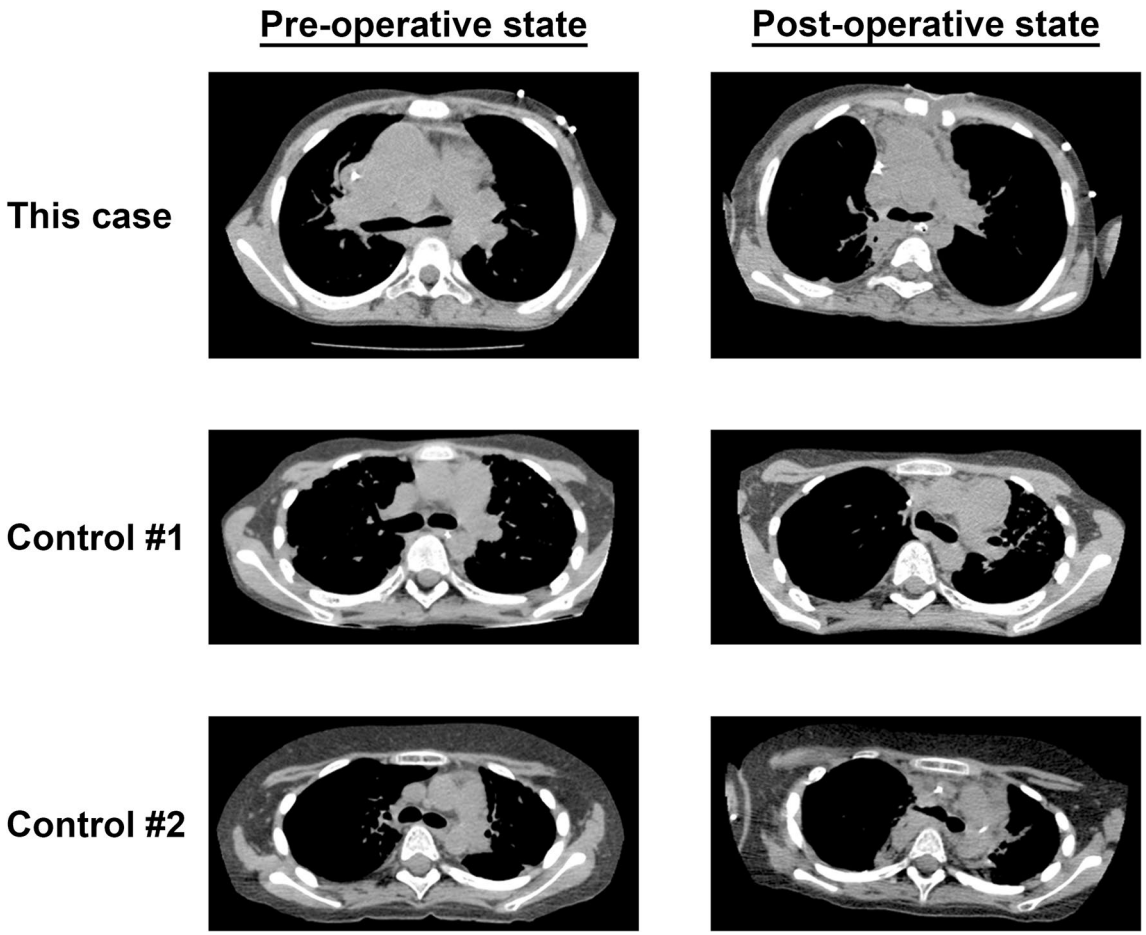

Fig. 1 Postoperative mediastinal shift and shrinkage of native left lung in our patient versus previous patients. The recipient thorax did not adjust despite an oversized single-lobe graft, as has previously been reported (Control #1 and #2). Control #1 and #2 are a 12-year-old boy and an 8-year-old girl, respectively, both of whom received right lower lobar transplantation for lung injury induced by bone marrow transplantation

Retrospectively, although we did not perform a bilateral transplant, balancing the risk (size mismatch, longer operative time and more blood loss) and the benefit (better vascular bed), a bilateral lobar LTx might have been a better option because the primary graft dysfunction and persistent airway bleeding might have been avoided. However, postoperative chest closure might have been more difficult and delayed due to anatomical size mismatching, which may be more likely to result in postoperative wound infection [8]. Size mismatching, as seen in this case, remains a problem to be solved in pediatric LTx recipients.

Therefore, decision to proceed with LTx with oversized grafts in pediatric patients with a history of CHD repair should be carefully made, though ISHLT mentions that living-donor lobar lung transplantations are still acceptable as a therapeutic option in experienced institutes for pediatric patients [9] and currently available case reports [10, 11] suggested that living-donor LTx could be a life-saving treatment for critically ill patients such as those on mechanical ventilation or even on extracorporeal membrane oxygenation. In our case, both preoperative and perioperative managements need improvement and, for that purpose, sharing both successful cases and unfortunate cases is required and important. We hope this case report will be the basis for future improvements.

Conclusions

This case emphasizes the fact that size mismatching remains a challenge in living-donor LTx.

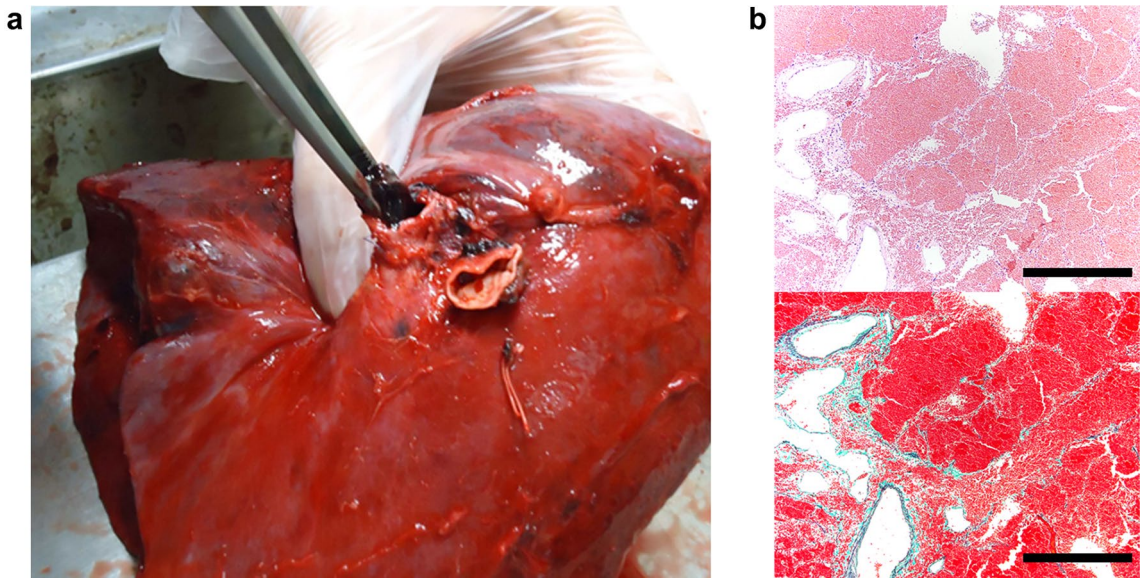

Fig. 2 The resected left lower lobe graft. **a** The bronchus of the graft was occluded by a blood clot. **b** The cross-section of the removed graft showed the alveoli were filled with blood. Upper panel: hematoxylin and eosin stain. Lower panel: Elastica and Masson stain. Bar: 500 μm

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

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