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Case Reports

Patent Foramen Ovale–Related Hypoxemia After Bilateral Lung Transplant

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Abstract

A 64-year-old man with interstitial pulmonary fibrosis and a small patent foramen ovale with right-to-left shunting underwent bilateral lung transplant without closure of the patent foramen ovale. Postoperatively, the patient remained persistently hypoxemic with partial response to high-flow oxygen. Investigations revealed the presence of a large patent foramen ovale with right-to-left shunting on echocardiography and a shunt fraction of 21% on cardiac catheterization. Two months after the lung transplantation, primary surgical repair of the patent foramen ovale was performed with immediate improvement in oxygenation. Three years postoperatively, the patient remained oxygen independent.

Keywords: Foramen ovale, patent; lung transplantation; hypoxia; pulmonary fibrosis

Case Report

Hypoxemia after lung transplantation (LTx) is common and mostly occurs as a result of the defect of the pulmonary alveolar capillary barrier, including alveolar collapse, diffuse alveolar damage, ventilation-perfusion mismatch, and alveolar–capillary membrane damage. Rarely, an intracardiac right-to-left (Rt-to-Lt) shunting through the patent foramen ovale (PFO) is responsible for hypoxemia following LTx.[1,2] This case is of a 64-year-old man who developed acute hypoxemia after bilateral orthotopic LTx as a result of Rt-to-Lt shunting through the PFO, with subsequent resolution of hypoxemia after surgical closure of the PFO.

Presentation and Physical Examination

A 64-year-old man presented to the department of cardiothoracic surgery with respiratory failure. The patient's condition was evaluated, and he was deemed a candidate for lung transplantation. During hospitalization, his condition rapidly deteriorated, mandating intubation. Transesophageal echocardiography (TEE) revealed good left ventricular function, right ventricular enlargement with mild dysfunction, a small PFO with Rt-to-Lt shunting (Fig. 1A), and mean pulmonary artery pressure of 22 mm Hg. An agitated saline test demonstrated a small to moderate PFO (Fig. 1B). Coronary angiography was negative for substantial coronary artery disease. The patient underwent bilateral sequential LTx on venoarterial extracorporeal membrane oxygenation support. The PFO was not closed because it was deemed small in size on TEE. The patient's postoperative course was complicated by primary graft dysfunction, which required continuation of venoarterial extracorporeal membrane oxygenation support for 2 days and by large-size bilateral lungs, which required a wedge resection of the right lower lobe and the left upper lobe (lingula). Postoperatively, the patient experienced significant hypoxemia, which partially responded to high-flow oxygen at 100% fraction of inspired oxygen. Despite high-flow oxygen, repeated bronchoscopies, and lavage, his saturation

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remained in the high 80s and low 90s. His chest x-ray was normal, and investigations for other pulmonary causes of hypoxemia were noncontributory. On postoperative day 25, during the evaluation for other causes of hypoxemia, a large PFO with substantial Rt-to-Lt shunting was seen on echocardiography. Right heart catheterization confirmed that the shunt fraction was 21%.

Medical History

The patient has a history of interstitial pulmonary fibrosis.

Differential Diagnosis

The differential diagnosis of the case includes primary graft dysfunction, atelectasis, pneumonia, pulmonary edema, acute respiratory distress syndrome, and pulmonary arteriovenous communication.

Technique

The patient was scheduled to have percutaneous device closure of the PFO; however, because of a lack of insurance coverage, the patient underwent surgical closure of the PFO with primary suturing on mild hypothermic cardioplegic arrest through right thoracotomy on postoperative day 55. The approach was through the right fourth intercostal space. The right lung was meticulously dissected off the right atrium. Given the previous double lung transplant, dissection was challenging. Bicaval cannulation was instituted through the right internal jugular vein and right femoral vein. Arterial cannulation was instituted through the right femoral artery. The ascending aorta was carefully dissected. An aortic root cardioplegia catheter was inserted to perfuse the cardioplegia and to vent the left ventricle. Cardiopulmonary bypass was initiated, and the superior vena cava was dissected. Aortic cross-clamping was gently applied, and the heart was nicely arrested. Afterward, the superior vena cava was snared, and the patient was cooled down to 34 °C. Intraoperatively, the PFO was 5 to 6 mm in size with no sign of tears. The presence of a large eustachian valve was also noted. The patient made significant improvement in his oxygenation immediately after surgery. His partial pressure of oxygen in the blood prior to PFO closure was 159 mm Hg at 100% fraction of inspired oxygen, and it improved to 314 mm Hg at 70% fraction of inspired oxygen after PFO closure. An intraoperative TEE saline agitated test showed complete closure of the PFO (Fig. 1C).

Key Points

- Hypoxemia after LTx is not rare, and common causes such as primary graft dysfunction, atelectasis, pneumonia, pulmonary edema, adult respiratory distress syndrome, and pulmonary arteriovenous communication should be ruled out.
- If the patient is still hypoxic after ruling out these common causes, the possibility of PFO with Rt-to-Lt shunting should be considered and ruled out.
- Device closure of large PFO with substantial shunting should be considered if confirmed as a treatment of choice.

Abbreviations and Acronyms

LTx	lung transplantation
PFO	patent foramen ovale
Rt-to-Lt	right to left
TEE	transesophageal echocardiography

Outcome

The patient remained oxygen independent and was discharged home on postoperative day 8 after his second surgery.

Latest Follow-Up

At last follow-up, 3 years postsurgery, the patient was doing well without recurrence of hypoxemia.

Discussion

Post-LTx hypoxemia occurs mostly because of primary graft dysfunction and is presumed to result from ischemia-reperfusion injury and a lack of bronchial artery circulation in the transplanted lungs. Other, less common causes are atelectasis, pneumonia, pulmonary edema, acute respiratory distress syndrome, and pulmonary arteriovenous communication.[1,3] Rarely, post-LTx hypoxemia has been reported because of unrecognized or unrepaired PFO that results in significant Rt-to-Lt shunting.[4,5]

Patent ovale foramen is a common anatomic finding seen in 25% to 30% of the general population.[6] It is usually small and without any hemodynamic consequences, but if a shunt occurs, it usually goes from left to right because of a decrease in pulmonary artery pressure and an improvement in right ventricular compliance following LTx; however, a few cases of hypoxemia after unilateral LTx, resulting from persistent Rt-to-Lt shunting across a PFO, have been reported.[4,5] The etiopathogenesis of

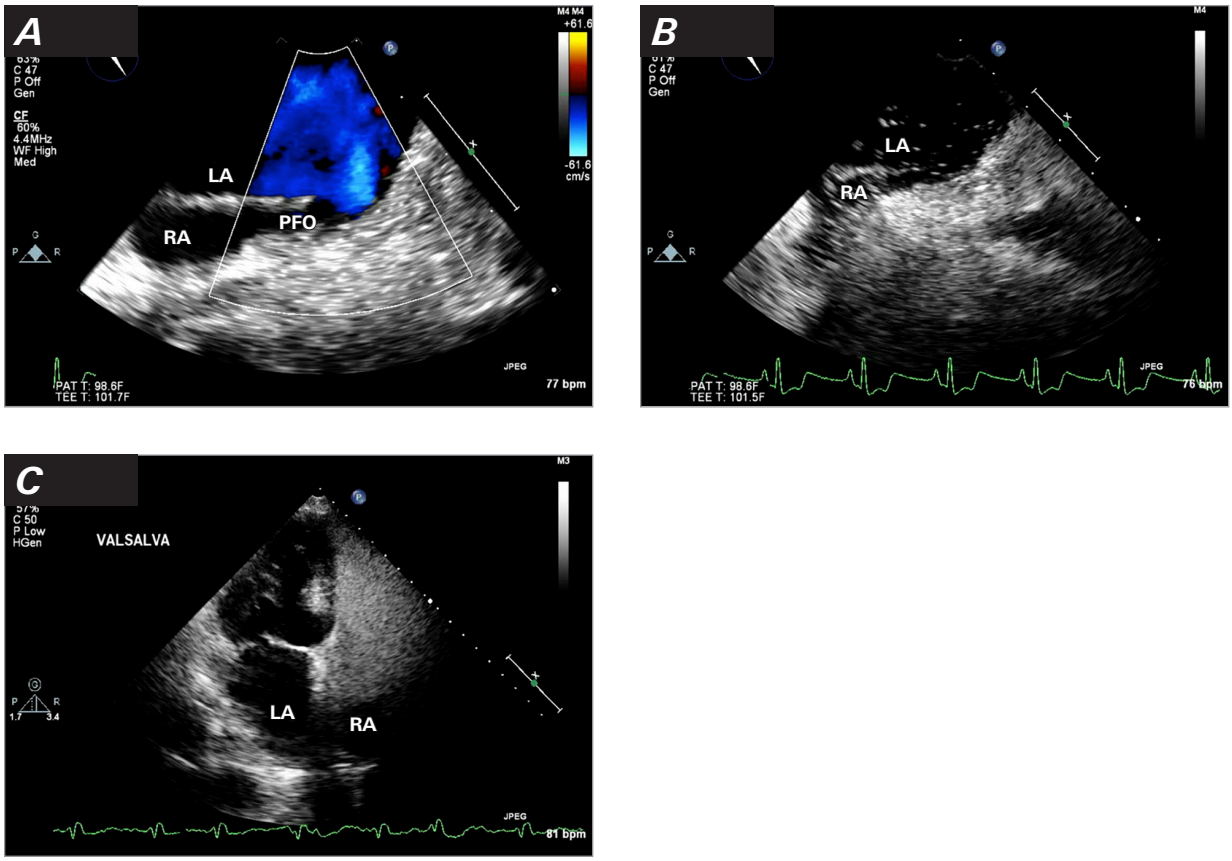

Fig. 1 Two-dimensional echocardiogram with color Doppler shows **A**) tunnel-shaped patent foramen ovale, **B**) agitated saline test before repair with shunting of bubbles to the left atrium, and **C**) agitated saline test after repair without shunting of bubbles to the left atrium.

Supplemental motion image is available for Figure 1A, Figure 1B, and Figure 1C.

LA, left atrium; PFO, patent foramen ovale; RA, right atrium.

persistent Rt-to-Lt shunting across the PFO after LTx is not well understood. It has been postulated that after unilateral LTx, anatomic alterations in the position of the interatrial septum resulting from the mediastinal shift may open the physiologically closed PFO, and the presence of a large eustachian valve may direct blood from the inferior vena cava preferentially to the left atrium across the PFO.[4,5,7,8] All reported cases of hypoxemia following LTx have followed unilateral LTx.

The present case is the first report of pulmonary hypoxemia resulting from Rt-to-Lt shunting across the PFO after bilateral LTx. Both of the patient's lungs were oversized to the pleural cavity, despite the wedge resection. Because of the fixed thoracic space, the oversized lungs may have distorted the position of the heart, resulting in an alteration in the geometry of the interatrial septum, with physiological enlargement of the previously small PFO and obligatory shunting of blood from the inferior vena cava into the left atrium (Fig. 2). In this patient, the combined effect of the physiologic enlargement of the PFO, and the obligatory shunting of blood from the inferior vena cava resulted in an increase of the previously small shunt to a shunt fraction of 21%. The presence of a moderate-size PFO and the absence of signs of injury to the interatrial septum further substantiated this hypothesis. The hypoxemia that ensues from Rt-to-Lt shunting results in significant dyspnea that has a negative impact on the patient's quality of life.[9] It is therefore recommended that all patients undergoing unilateral or bilateral LTx should be carefully investigated for the presence of PFO, its size, and the amount of shunting in echocardiography using contrast and bubble studies facilitated by the Valsalva maneuver.[10] The same findings should be further

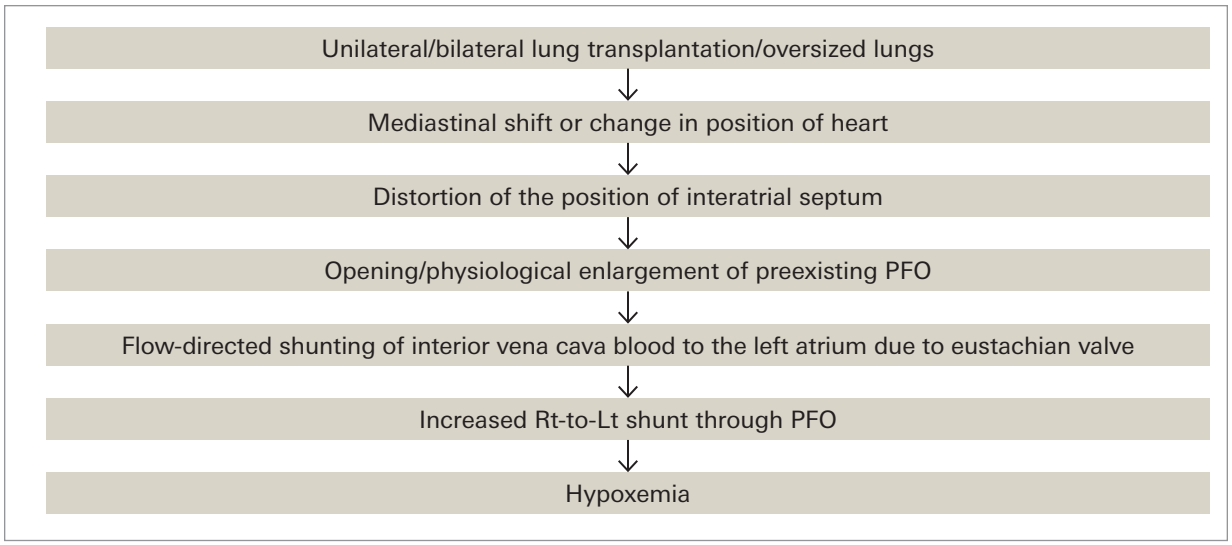

Fig. 2 Diagram shows pathogenesis of Rt-to-Lt shunting across the PFO after bilateral lung transplant.

PFO, patent foramen ovale; Rt-to-Lt, right to left.

confirmed during intraoperative TEE. In the presence of a large PFO or significant shunting, the PFO should be surgically closed at the time of LTx. If expertise is not available, however, the PFO should be closed percutaneously with a device soon after the LTx. For any patients in whom PFO was absent on preoperative echocardiography or not closed during LTx either because of lack of expertise or the small size of the PFO, any unexplained post-LTx hypoxemia, especially in the presence of normal chest radiography, should prompt an early investigation for PFO and the direction of the shunting.[5,7] Percutaneous device closure is the preferred treatment for PFO in post-LTx patients. If percutaneous device closure is not feasible because of the lack of facility or other issues, surgical closure can be safely performed with good outcomes.

Conclusion

Post-LTx hypoxemia resulting from Rt-to-Lt shunting across PFO is a rare and potentially treatable etiology. Unexplained hypoxemia early after LTx should prompt an investigation for PFO. Percutaneous device closure is the treatment of choice; however, surgical closure of PFO can also be performed safely.

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