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# Living-Donor Lung Transplantation for Post–COVID-19 Respiratory Failure

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**This report describes a case of coronavirus disease 2019 (COVID-19)–associated respiratory failure requiring urgent living-donor lobar lung transplantation (LDLLTx). Severe hypoxia requiring extracorporeal membrane oxygenation (ECMO) developed in a 57-year-old woman with positive viral status. Her respiratory function deteriorated, with almost totally collapsed lungs. All of her other organs functioned well. After 104 days of ECMO support, she underwent urgent LDLLTx using cardiopulmonary bypass. The grafts worked well, and she was weaned from cardiopulmonary bypass after reperfusion. LDLLTx is an option for selected patients with post–COVID-19 end-stage respiratory failure.**

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Coronavirus disease 2019 (COVID-19) has spread worldwide since December 2019 as a result of the unprecedented pandemic.[1] Patients with end-stage COVID-19-related respiratory failure require mechanical ventilation or extracorporeal membrane oxygenation (ECMO). In some countries, lung transplantation (LTx) has become a treatment option for irreversible lung function deterioration.[2,3] We report a successful case of severe respiratory failure caused by COVID-19 in a patient who was treated with urgent living-donor lobar LTx (LDLLTx).

A 57-year-old woman without any past medical history experienced body weakness, reduced level of consciousness, and difficulty in walking. She was admitted to a local hospital through the emergency department. Her blood oxygen saturation level was 78% with reservoir mask oxygen (10 L/min). The chest roentgenogram showed generalized opacities over the lung fields (Figure 1A). The chest computed tomographic scans showed bilateral pulmonary opacification with ground-glass opacities and dense consolidation in the ventral and dorsal lung fields, respectively (Figures 2A, 2B).

She was intubated and mechanically ventilated immediately; however, her $Pao_2$ with pure oxygen was 57 mm Hg. She received a diagnosis of severe acute respiratory distress syndrome (ARDS) related to COVID-19 on the basis of positive results of the polymerase chain reaction for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Consequently, ECMO was established through inflow cannulation of the right jugular vein and outflow cannulation of the left femoral vein.

Repeat chest roentgenogram (Figure 1B) and computed tomographic scans (Figures 2C, 2D) performed 3 months after admission revealed exacerbation of lung damage, which was considered irreversible, but all of her other organs functioned well. She was subsequently referred to our team; we deemed the patient to be a candidate for LDLLTx after evaluation. Potential donors were evaluated, and after careful deliberation we concluded that her husband and son were suitable living donors. Functional size matching calculated using forced vital capacity was 79%. She was transferred to our hospital (Kyoto University Hospital, Kyoto, Japan) under ECMO support 102 days after admission to the local hospital. The patient was alert and awake, and the donors were counseled appropriately regarding the risks and benefits of LDLLTx. Informed consent was obtained from the recipient and both donors.

The lungs, which were exposed through the clamshell incision, appeared almost completely shrunken and collapsed (Figure 3A). Cardiopulmonary bypass (CPB) was established after full heparinization; a dual-stage cannula was inserted into the right atrium, an arterial cannula was inserted into the ascending aorta, and a vent was placed into the pulmonary trunk. Subsequently, the preexisting ECMO circuit was removed. The patient's son's right lower lobe and her husband's left lower lobe were procured, and both grafts were flushed with ET-Kyoto solution (Otsuka Pharmaceutical Factory, Tokushima, Japan) under ventilation. Both pneumonectomies were performed, and the procured lower lobes were implanted and then ventilated and reperfused (Figure 3B). The patient was smoothly weaned from CPB, and the circuit was removed. The chest was

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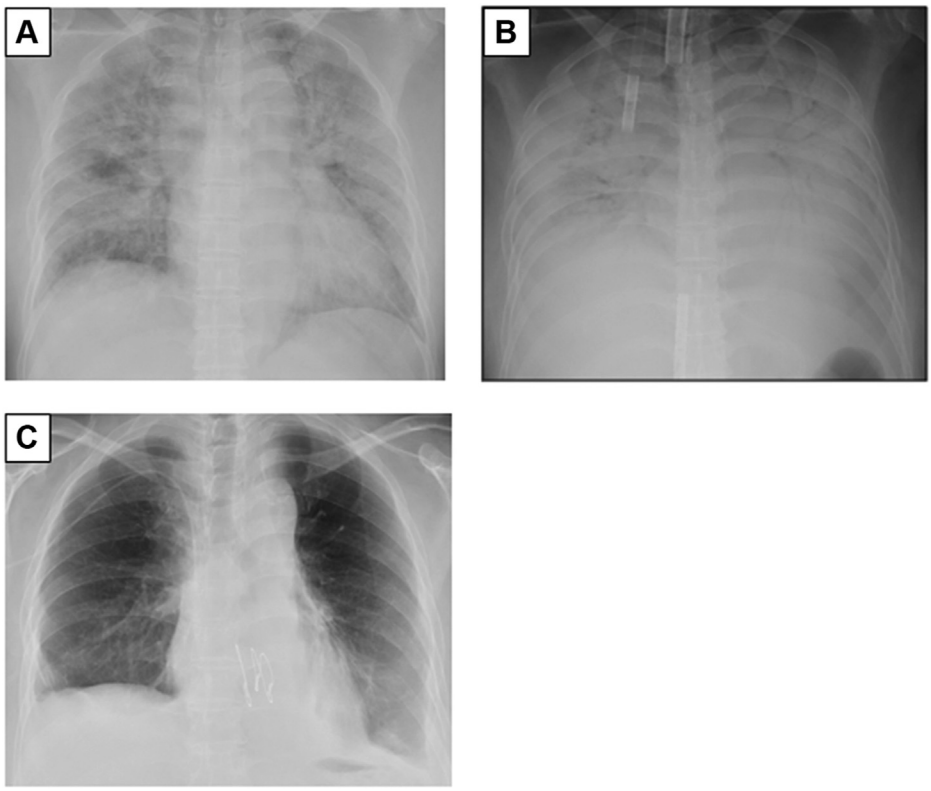


**FIGURE 1** Chest roentgenograms. (A) Bilateral severe infiltration on admission to the local hospital. (B) Near-total lung collapse just before lung transplantation at our hospital. (C) Clear lung fields 4 months after living-donor lobar lung transplantation.

tentatively closed using a Gore-Tex (W.L. Gore & Associates, Newark, Delaware) soft tissue patch because the tidal volume dropped with direct closure. The total graft ischemic time was 226 and 148 minutes in the right and left lungs, respectively. The $Pao_2$ on intensive care unit admission was 441 mm Hg with 100% oxygen inhalation.

On postoperative day 2, the chest was closed completely. The grafts worked very well; however, the patient was weaned from the ventilator after 2 months probably because of weakness of the respiratory muscles. Four months after LDLLTx, she was doing well, without any episode of infection or rejection (Figure 1C). She could walk for 150 m and was transferred to the local hospital for further rehabilitation. Histopathologic examination of the resected lung specimens showed pulmonary fibrosis, focal alveolar hemorrhage, and organized thrombosis of the pulmonary artery.

## COMMENT

Our patient with end-stage post-COVID-19 respiratory failure underwent LDLLTx. An international survey conducted in 2020 reported that 81% of centers declared a reduction in LTx rates.[4] In our country, donor shortage is severe, and LDLLTx was thought to be the only method to save this patient's life.

So far, several reports have referred to the indications and timing of LTx for patients with severe COVID-19-associated ARDS.[3,5,6] Fortunately, our patient met the recommended criteria: fulfillment of the standard criteria for LTx, sufficient time elapsed to exclude native lung recovery, absence of irreversible concomitant organ failure, negative SARS-CoV-2 virology status, and ability to participate in physical rehabilitation. Schaheen and colleagues[6] mentioned that donor lungs should be sized appropriately, with consideration of the restrictive nature of the recipient's chest wall in the acute illness period. The implanted lower lobes were still larger than our patient's shrunken chest cavities, thus necessitating delayed chest closure (Figure 3B). From this standpoint, LDLLTx may be suitable for patients with COVID-19-related lung failure.

Ahmadi and colleagues[7] reported that a hypercoagulable state and oxygenator failure were the most important causes of venovenous (V-V) ECMO failure in patients with COVID-19. Our patient also required

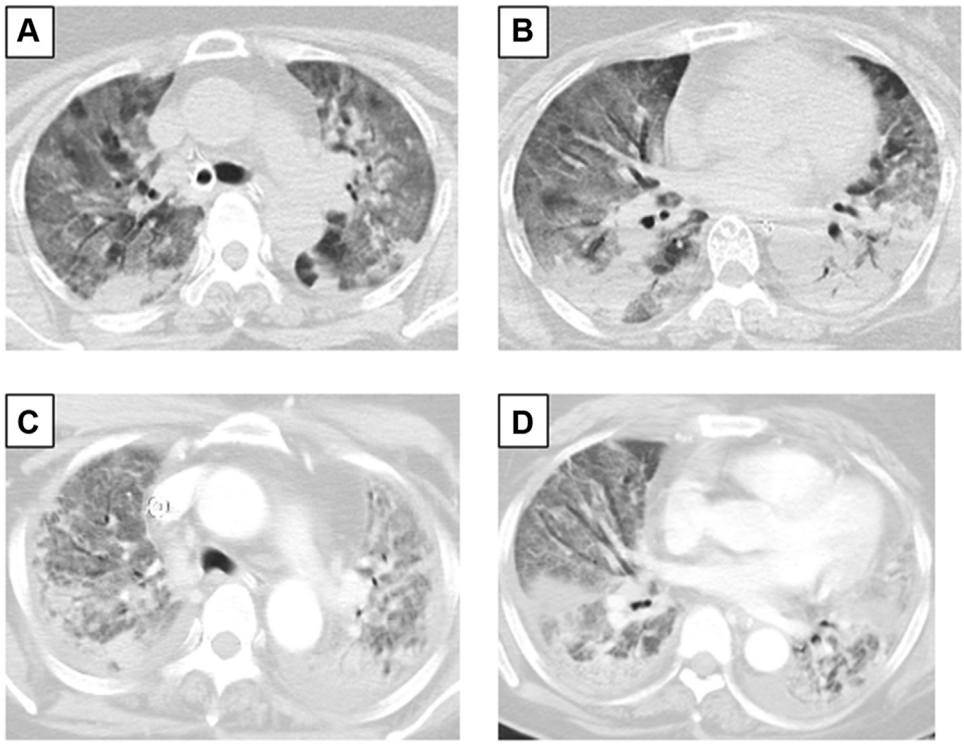


**FIGURE 2** Chest computed tomography (A) and (B) on admission of the patient to the local hospital and (C) and (D) 2 months later. (A) Bilateral symmetric pulmonary opacification with ground-glass opacities in the ventral lung fields. (B) Dense consolidation in the dorsal area. (C) Worsening ground-glass opacities in the ventral lung fields. (D) Increasing regions of dense consolidation.

recurrent circuit changes, she had thrombus formation in the large veins despite controlled heparinization, and the explanted lungs showed pulmonary artery thrombosis. Guihaire and colleagues[8] stated that high blood flow and anticoagulation at levels higher than conventional practice may be required for V-V ECMO in patients with COVID-19-related ARDS because of the thrombotic hematologic profile of COVID-19. Bharat and colleagues3 reviewed the intraoperative configuration in a consecutive case series. These investigators reported that all procedures were performed using central venoarterial ECMO support, and pretransplant V-V ECMO was empirically continued after LTx in anticipation of a high risk of primary graft dysfunction.[3] We considered the

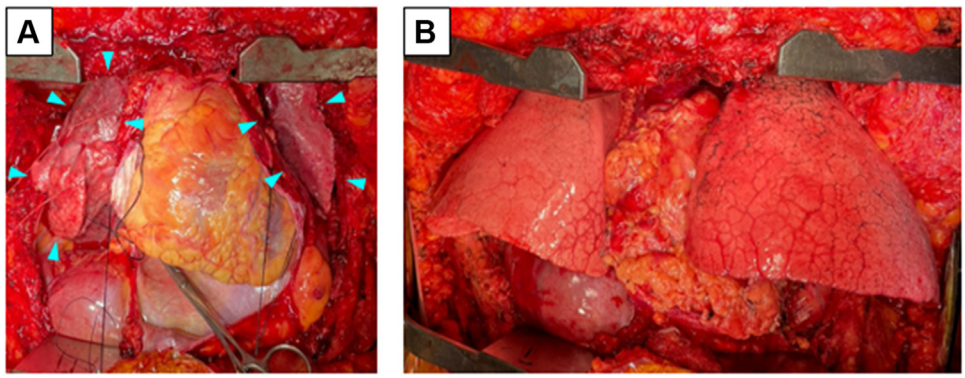


**FIGURE 3** Intraoperative findings. (A) Fibrotic and extremely shrunken lungs just after opening the chest (arrowheads indicate collapsed lungs). (B) Well-ventilated and reperfused donated lower lobes.

possibility of embolization during decannulation of the current ECMO cannulas, which were placed 3 months previously. Therefore, we decided to establish CPB anew and removed the patient from V-V ECMO before explanting the native lungs.

LDLLTx may be a possible treatment option for patients with post-COVID-19 end-stage respiratory failure.

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## REFERENCES

**1.** Guan WJ, Ni ZY, Hu Y, et al. Clinical characteristics of coronavirus disease 2019 in China. *N Engl J Med*. 2020;382:1708-1720.

**2.** Bharat A, Querrey M, Markov NS, et al. Lung transplantation for pulmonary fibrosis secondary to severe COVID-19. Preprint. Posted online October 27, 2020. *medRxiv*. 2020.10.26.20218636. https://doi.org/10.1101/2020.10.26.20218636.

**3.** Bharat A, Machuca TN, Querrey M, et al. Early outcomes after lung transplantation for severe COVID-19: a series of the first consecutive cases from four countries. *Lancet Respir Med*. 2021;9:487-497.

**4.** Coiffard B, Lepper PM, Prud'Homme E, et al. Management of lung transplantation in the COVID-19 era-an international survey. *Am J Transplant*. 2021;21:1586-1596.

**5.** Cypel M, Keshavjee S. When to consider lung transplantation for COVID-19. *Lancet Respir Med*. 2020;8:944-946.

**6.** Schaheen L, Bremner RM, Walia R, Smith MA. Lung transplantation for coronavirus disease 2019 (COVID-19): the who, what, where, when, and why. *J Thorac Cardiovasc Surg*. 2022;163:865-868.

**7.** Ahmadi ZH, Jahangirifard A, Farzanegan B, et al. Extracorporeal membrane oxygenation and COVID-19: the causes of failure. *J Card Surg*. 2020;35:2838-2843.

**8.** Guihaire J, Owyang CG, Madhok J, et al. Specific considerations for venovenous extracorporeal membrane oxygenation during coronavirus disease 2019 pandemic. *ASAIO J*. 2020;66:1069-1072.