

Bilateral pneumonectomy and lung transplant for COVID-19–induced respiratory failure



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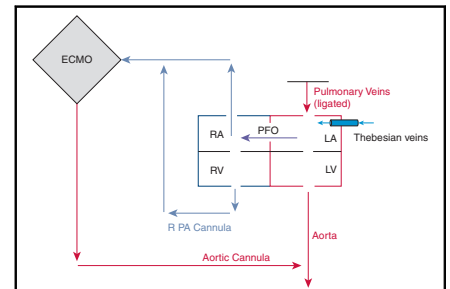
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Novel cannulation strategy used for cardiopulmonary support after bilateral pneumonectomy.

CENTRAL MESSAGE

Bilateral pneumonectomy with a novel cannulation strategy followed by lung transplantation can be a rescue measure for those patients with severe, irreversible lung damage caused by SARS-CoV-2.

See Commentary on page 288.

▶ Video clip is available online.

There are few published descriptions of lung transplant for COVID-19 (Table E1). Here, we describe a COVID-19 polymerase chain reaction (PCR) test-positive patient who underwent bilateral pneumonectomy before lung transplant using a novel cannulation strategy. Institutional review board approval was not required for this case study and the patient provided consent.

A 37 year-old woman was admitted with COVID-19 infection required intubation on day 6, and venovenous (VV) extracorporeal membrane oxygenation (ECMO) on day 8. She was treated for *Stenotrophomonas* superinfection. On day 20, she was enrolled in a trial for application of stem cells via the ECMO circuit, which occurred without complication. For the next several weeks, she required full ECMO with an inability to wean. On day 37, due to persistent positivity (based on PCR test), a cycle threshold (Ct) was obtained and resulted at 30, indicating she may still have a high viral load,¹ which could complicate transplantation. We elected to perform pneumonectomy before transplant to reduce or eliminate the viral reservoir. She was

listed for transplant on day 39, and 3 days later underwent bilateral pneumonectomy at which time her VV ECMO was converted to central venoarterial ECMO using a novel cannulation strategy taking advantage of the patient's known patent foramen ovale (PFO). Venous drainage occurred with 3 cannulas: 1 via the right internal jugular vein and 1 from the left femoral vein. The third cannula was placed in the right pulmonary artery (PA). All blood was returned to a single ECMO device using Y-connectors. The blood was then returned to the patient via an arterial cannula into the ascending aorta. Filling of the left heart occurred primarily from the Thebesian veins (Figure 1). Postoperative echocardiogram demonstrated a decompressed right and left ventricle. There was no evidence of mitral regurgitation and even with the left to right shunt induced by ECMO and the PFO, the left ventricle did fill and was able to expel blood into the aorta with inotropic

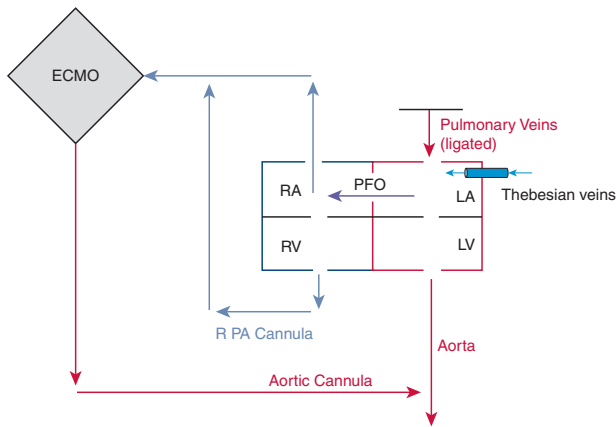


FIGURE 1. Novel cannulation strategy used for cardiopulmonary support after bilateral pneumonectomy. *ECMO*, Extracorporeal membrane oxygenation; *RA*, right atrium; *PFO*, patent foramen ovale; *LA*, left atrium; *RV*, right ventricle; *LV*, left ventricle; *PA*, pulmonary artery.

support. Her chest was closed on postoperative day 2. On day 48, donor lungs were found. The left lung was not appropriate for transplantation but fortunately the right lung was oversized. Based on the length of time she had been on ECMO and now 5 days after bilateral pneumonectomy, the multidisciplinary team believed it was prudent to proceed with single lung transplant. She was converted to VV ECMO and her PA cannula was removed. She tolerated routine postoperative immunosuppression and no additional antiviral therapy was added. Her posttransplant PCR test result converted to negative and remained so (Table 1). She was decannulated from ECMO approximately 8 weeks

after transplant. Six months posttransplant, she was alert and oriented, off mechanical ventilation, and debilitated but participating in rehabilitation.

Substituting the lungs with mechanical support requires a thoughtful strategy that prevents stasis and distention of the heart. Ligation of the PA removes the right heart outlet, and ligation of the pulmonary veins compromises left heart preload. We maintained flow across the right heart by inserting a cannula into the right PA to allow for right ventricle ejection and reduce afterload. For the left heart, we relied on the Thebesian veins for preload. After months of critical illness and refractory hypoxia, our patient’s left heart function was reduced with an ejection fraction <40%, leading to concern about the ability of the left ventricle to maintain adequate ejection. Her PFO provided a strategy by which we could unload the left ventricle, and allow for flow in the left atrium by creating a left to right shunt. Two other strategies for ECMO cannulation after bilateral pneumonectomy are described in the literature (Figure 2 and Video 1). Cypel and colleagues² utilized 2 ECMO circuits to accomplish flow in all 4 chambers, and Barac and colleagues³ modified native anatomy by anastomosing the left PA to the left pulmonary vein to accomplish the same goal. The advantages of our strategy are 2-fold. First, only 1 ECMO device is utilized reducing the risk of thrombosis and hemolysis. Second, it is technically simpler; that is, no anastomosis. This model could be replicated in patients without a PFO by performing atrial septostomy at the time of the pneumonectomy.¹ In our patient, PFO closure at the time of transplant was deferred due to adequate PA pressures.

TABLE 1. Reverse transcription polymerase chain reaction (PCR) results over time

Hospital day	PCR test result	Event
Day 21	Positive	
Day 34	Positive	
Day 39		Bilateral pneumonectomy
Day 42	Positive*	
Day 45		Single lung transplant
Day 46	Negative	
Day 49	Negative	
Day 51	Negative	
Day 54	Negative	
Day 56	Negative	
Day 59	Negative	
Day 61	Negative	
Day 62	Negative	

*The patient turned negative immediately following her single lung transplant. We do not believe this is a result of receiving her single lung transplant, but rather the result of her bilateral pneumonectomy 5 days prior. She did have 1 PCR performed after pneumonectomy that was positive, but we do not have cycle threshold data on this specimen and cannot determine its significance.

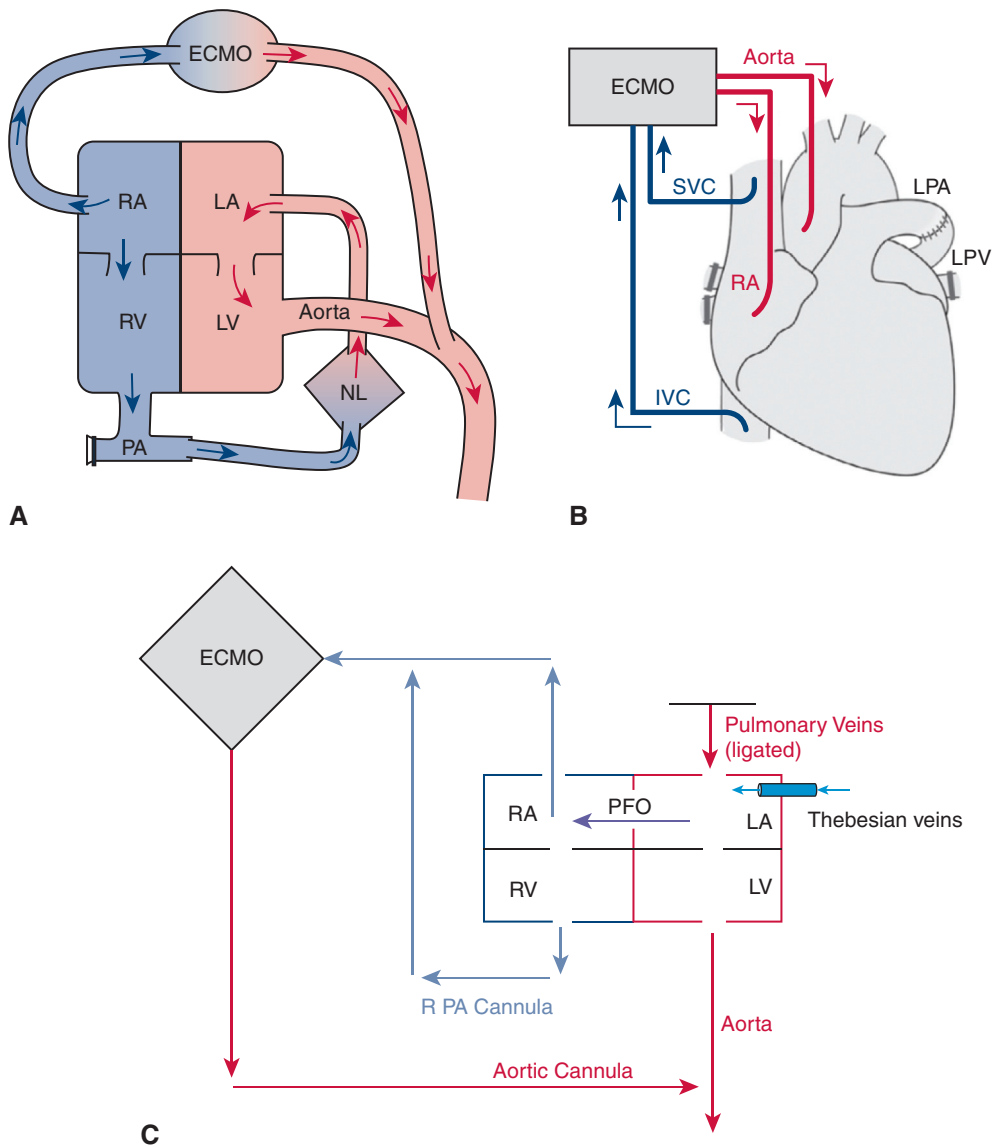


FIGURE 2. Diagram illustrating the 3 published techniques for mechanical support following bilateral pneumonectomy. A, Reprinted from Cypel and colleagues.² Used with permission. B, Reprinted from Barac and colleagues.³ Used with permission. C, Technique described by our treatment team utilizing the native patent foramen ovale (PFO) to ensure flow through the left atrium (LA). ECMO, Extracorporeal membrane oxygenation; RA, right atrium; RV, right ventricle; LV, left ventricle; PA, pulmonary artery.

Ct is used to describe viral load with counts <25 indicative of a high viral load, and counts >31 indicative of low viral load.⁴ Results between 25 and 30 may indicate active ongoing infection. Her Ct results, coupled with her dismal clinical status, led to the strategy of bilateral pneumonectomy first, as has been described in cystic fibrosis patients.^{2,3}

Based on our experience, patients with COVID-19 requiring ECMO for 4 to 6 weeks with no signs of recovery should be considered for transplant. Additionally, if they show signs of persistent viral infection, pneumonectomy before transplant may be the preferred strategy. More study is needed to determine which patients would benefit, particularly at a time when resources are of paramount importance.

Benefits

- Allows for definitive septic source control
- Decreases risk of TRALI or lung injury related to transfusion on donor lungs



VIDEO 1. Brief description of the indications, benefits, and challenges of extracorporeal membrane oxygenation after bilateral pneumonectomy as well as a comparison of 3 described cannulation strategies. Video available at: [https://www.jtcvs.org/article/S2666-2507\(22\)00050-5/fulltext](https://www.jtcvs.org/article/S2666-2507(22)00050-5/fulltext).

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TABLE E1. Published descriptions of lung transplant for COVID-19

Author	Location	Date of publication	No. of patients	Days from infection to transplant	Preoperative PCR status	Technique	Survival (%)
Chen and colleagues ^{E1}	China	June 2020	3	42, 37, 44	Negative	Bilateral lung	66
Han and colleagues ^{E2}	China	August 2020	2	30, 28	Negative	Bilateral lung	100
Lang and colleagues ^{E3}	Vienna, Austria	August 2020	1	58	Positive	Bilateral lung	100
Bharat and colleagues ^{E4}	United States (Chicago, Ill)	December 2020	3	42, 100, 28	Negative	Bilateral lung	100
Ghodsizad and colleagues (current study)	United States (Miami, Fla)	–	1	48	Positive	Bilateral pneumonectomy/ ECMO → single lung	100

PCR, Polymerase chain reaction; ECMO, extracorporeal membrane oxygenation.