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Case Report

Percutaneous OxyRVAD in a Patient with Severe Respiratory Failure and Right Heart Failure: A Case Report

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Venovenous extracorporeal membrane oxygenation (VV ECMO) is often used in cases of severe respiratory failure, especially in patients considered for lung transplantation. However, because many lung diseases can ultimately result in right heart failure, the treatment of secondary right heart failure can present a challenge when the patient is already under VV ECMO support. In such cases, an oxygenated-right ventricular assist device (OxyRVAD) can be used. OxyRVAD is designed to maintain anterograde blood flow and prevent right ventricular distension. Moreover, the pulmonary arterial cannula can be inserted percutaneously. We report a case in which percutaneous OxyRVAD was successfully implemented to manage right heart failure in a patient with respiratory failure who was on VV ECMO.

Keywords: Oxygenated-right ventricular assist device, Right heart failure, Extracorporeal membrane oxygenation, Case reports

Case report

In cases of severe respiratory failure, venovenous extracorporeal membrane oxygenation (VV ECMO) is often the treatment of choice and is frequently used as a bridge to lung transplantation [1]. However, many lung diseases can progress to right heart failure with pulmonary hypertension, posing a challenge in treating secondary right heart failure in patients already receiving VV ECMO support. In such instances, conversion to venoarterial (VA) or veno-venoarterial (VVA) ECMO may be necessary to provide both oxygenation and right heart support. Nonetheless, VA ECMO is associated with significant complications, including left ventricular distension and lower extremity ischemia [2,3], and managing arterial and oxygenated venous flow in VVA ECMO can be problematic [4]. Consequently, treating severe right heart failure in end-stage lung disease remains a complex issue. The oxygenated-right ventricular assist device (oxyRVAD), which connects the right atrium to the pulmonary artery, offers a potential alternative for such challenging cases. OxyRVAD can maintain anterograde blood flow, prevent right ventricular distension, and preserve transpulmonary blood flow. We report a case in which percutaneous oxyRVAD was successfully utilized to manage right heart failure in a patient with respiratory failure who was on VV ECMO support.

A 41-year-old man with a history of acute myeloid leukemia who had previously undergone an allogenic peripheral blood stem cell transplantation in 2015 was admitted for an acute exacerbation of bronchiolitis obliterans organizing pneumonia (BOOP). He had been hospitalized multiple times for BOOP exacerbations and was most recently discharged with home oxygen therapy just 4 days prior. In the previous year, the patient required VV ECMO support for 3 weeks due to acute respiratory distress syndrome associated with coronavirus disease 2019. Upon admission, he presented with dyspnea and increasing desaturation despite receiving high-flow nasal cannula oxygen at 60 L/min and a fraction of inspired oxygen (FiO_2) of 95%. After being transferred to the intensive care unit (ICU), intubation was necessary. Despite full mechanical ventilation support with FiO_2 at 100% and a positive end-expiratory pressure of 10 cmH_2O, the patient exhibited persistent CO_2 retention. With lung transplantation under consideration, VV ECMO was initiated as a bridge to transplantation. The VV ECMO was inserted on the day of ICU admission using a Quadrox PLS circuit (Maquet, Hirrlingen, Germany). Bedside cannulation in the ICU was performed using the

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Seldinger technique with ultrasound guidance. A 19F venous drain cannula (Bio-medicus venous cannula; Medtronic Inc., Minneapolis, MN, USA) was placed in the right femoral vein, and a 15F cannula (Bio-medicus artery cannula; Medtronic Inc.) was inserted into the right internal jugular vein (RIJV) (Fig. 1A). The initial ECMO flow rate was set at 2.68 L/min with an FiO_2 of 100% and a gas sweep of 6.5 L/min.

Percutaneous dilatational tracheostomy was performed on day 8 of ECMO support. The patient continued to experience palpitations, chest discomfort, and dyspnea. By day 12 on ECMO, the patient's right heart function began to deteriorate. Echocardiography showed a slightly D-shaped left ventricle, along with dilation of the right ventricle (RV) and right ventricular dysfunction (Fig. 2A). Intravenous norepinephrine at 0.1 μg/kg/min and milrinone at 0.4 μg/kg/min were administered to manage hypotension. Continuous renal replacement therapy was initiated on day 17 of ECMO due to progressive renal impairment. The patient's serum B-type natriuretic peptide (BNP) level rose to 21,075 pg/mL, and there were indications of hepatic congestion. As the patient's condition continued to decline despite comprehensive medical management, an OxyRVAD was inserted.

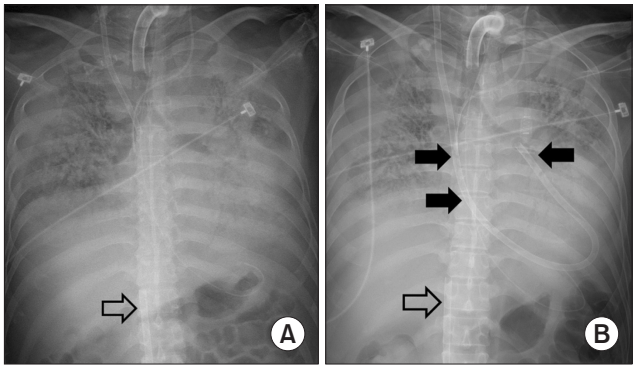

Fig. 1. Chest radiographs before (A) and after (B) oxygenated right ventricular assist device (OxyRVAD) insertion. Filled black arrows mark the pulmonary artery cannula, whereas empty arrows indicate the tip of the draining cannula.

On ECMO day 19, the patient was transferred to the angiography room for a configuration switch to an OxyRVAD. A 5F introducer sheath (Radiofocus Introducer II; Terumo Cardiovascular Systems Corp., Tokyo, Japan) was placed in the left common femoral artery under ultrasound guidance as a precaution in case VA ECMO insertion became necessary. Following the administration of 3,000 units of heparin intravenously, a 17F cannula was inserted into the left common femoral vein (LCFV) using fluoroscopic guidance. The cannula in the RIJV was clamped, and a newly primed VV ECMO Quadrox PLS circuit (Maquet) was initiated with inflow from the LCFV and outflow to the right common femoral vein (RCFV). The original RIJV cannula was then punctured, and a 0.035 guidewire (Radiofocus guidewire; Terumo Cardiovascular Systems Corp.) was threaded into the pulmonary artery. This RIJV cannula was exchanged for a 7F angiographic catheter (Judkins Right, Goodtec; Goodman, Nagoya, Japan). Although a 0.035 Amplatz Super Stiff guidewire (Boston Scientific, Marlborough, MA, USA) was used to attempt to advance the 17F cannula into the pulmonary artery, the cannula could not be maneuvered through the acute angle of the RV. Instead, the 17F cannula (Bio-medicus venous cannula; Medtronic Inc.) was successfully positioned in the main pulmonary artery using a stiffer Lunderquist Extra-Stiff wire (Cook Medical, Bloomington, IN, USA). The inflow cannula in the LCFV was then disconnected from the circuit and attached to the RIJV cannula, establishing a pulmonary artery inflow via the RIJV and outflow via the RCFV (Fig. 1B). An ECMO flow rate of 3.95 L/min was achieved with an FiO_2 of 100% and a gas sweep of 4.0 L/min, after which the patient was transferred back to the ICU.

A follow-up echocardiogram performed 1 day after the

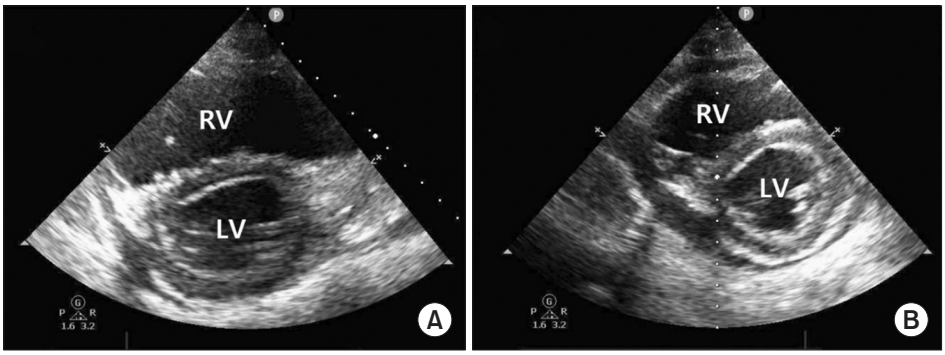

Fig. 2. Echocardiograms demonstrating right ventricular function. (A) Before OxyRVAD insertion, showing a slightly D-shaped left ventricle (LV). (B) Day 9 after OxyRVAD insertion, showing decreased right ventricle (RV) volume.

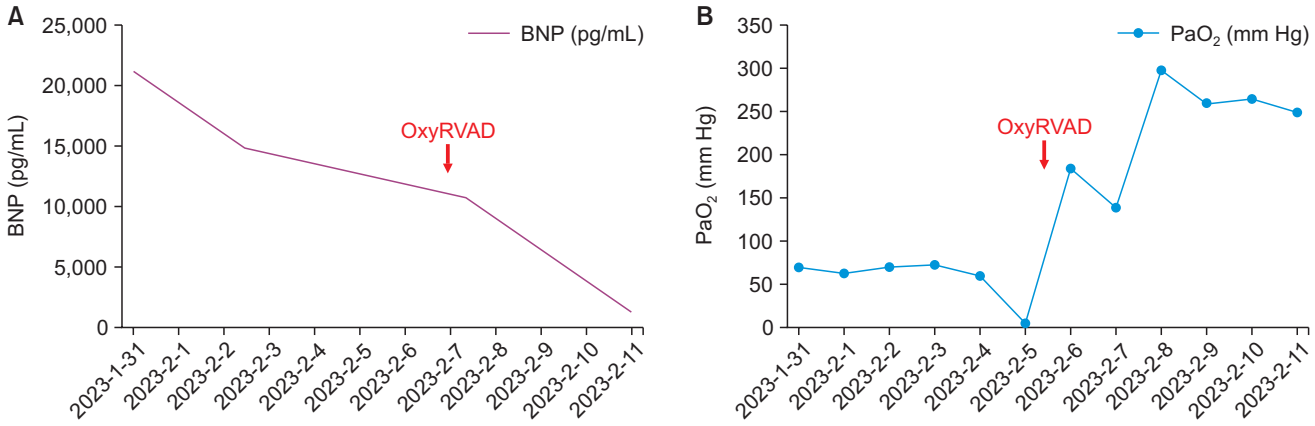

Fig. 3. Serial changes in laboratory findings before and after OxyRVAD initiation. Levels of B-type natriuretic peptide (BNP) (A) and oxygen partial pressure (PaO_2) (B).

insertion of the OxyRVAD revealed a reduction in pulmonary hypertension and RV volume (Fig. 2B). Concurrently, the patient's serum BNP levels decreased to 10,716 pg/mL (Fig. 3A), and the arterial blood oxygen partial pressure (PaO_2) rose from 59.9 to 231 mm Hg, indicating improved ECMO efficacy (Fig. 3B). The patient remained stable and alert, exhibiting signs of recovery from liver and kidney dysfunction. Regrettably, on the 39th day of ECMO, which was 20 days post-OxyRVAD insertion, the patient developed septic shock. The patient's condition worsened, characterized by persistent hypotension and metabolic acidosis. By the 43rd day of ECMO, 24 days after the OxyRVAD was applied, life support was discontinued at the request of the family, and the patient subsequently died.

The need for informed consent was waived by the Institutional Review Board (no., KC23ZASI0718)

Discussion

VV ECMO can be considered for patients with severe respiratory failure, particularly those who are candidates for lung transplantation. Right heart failure is a potential complication that may necessitate supplementary cardiac support. While fluid optimization, inotropes, and inhaled nitric oxide represent established treatments for right heart decompensation, these interventions may prove insufficient in patients who are hemodynamically unstable [5,6].

Additional mechanical support, such as VA or VAV ECMO, may be needed in such cases. However, the use of additional ECMO support can lead to an increased risk of complications, including bleeding, thromboembolisms, limb ischemia, and intracardiac thrombosis. The OxyRVAD system presents a viable alternative in these situations, as it maintains anterograde blood flow, which helps prevent right ventricular distension and preserves transpulmonary blood flow [7,8]. OxyRVAD operates by draining venous blood from the right atrium and reinfusing oxygenated blood directly into the pulmonary artery, thus sustaining circulation and oxygenation in the right heart [9]. Previous research has indicated that RVAD is associated with significantly fewer thromboembolic complications compared to VA ECMO [7], resulting in long-term advantages [9].

Previous case studies and series on OxyRVAD applications have primarily documented the implementation of OxyRVAD through a left anterior thoracotomy while the patient is under general anesthesia [10-12]. However, OxyRVAD insertion under general anesthesia may introduce additional risks, including time delays and hemodynamic instability. Thoracotomy may also increase operative risks, such as bleeding and wound infection. Consequently, an alternative percutaneous procedure that can be performed under local anesthesia may be a viable option. Percutaneous OxyRVAD has been demonstrated to be effective in patients with pulmonary hypertension [13].

Due to our patient's hemodynamic instability, we deemed the transition to OxyRVAD with ECMO through thoracotomy under general anesthesia excessively hazardous. Consequently, we opted for a percutaneous approach to OxyRVAD placement under local anesthesia, which presented a relatively simpler procedure. Although the patient was not successfully bridged to transplantation, there was an improvement in arterial blood gas levels and a reduction in pulmonary hypertension following the OxyRVAD intervention. In summary, OxyRVAD in conjunction with ECMO can be effectively utilized in patients suffering from severe respiratory failure and right heart failure. We antici-

pate that future cases may showcase successful bridging to lung transplantation.

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Conceptualization: GYY, DYK. Data curation: GYY. Formal analysis: GYY. Project administration: JL, SBH, DYK. Visualization: GYY. Writing–original draft: GYY. Writing–review & editing: GYY, JL, SBH, DYK. Final approval of the manuscript: all authors.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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