Right Heart Failure during Veno-Venous Extracorporeal Membrane Oxygenation for H1N1 Induced Acute Respiratory Distress Syndrome: Case Report and Literature Review

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A 38-year-old male was admitted with symptoms of upper respiratory infection. Despite medical treatment, his symptoms of dyspnea and anxiety became aggravated, and bilateral lung infiltration was noted on radiological imaging studies. His hypoxemia failed to improve even after the application of endotracheal intubation with mechanical ventilator care, and we therefore decided to initiate venovenous extracorporeal membrane oxygenation (VV ECMO) for additional pulmonary support. On his twentieth day of hospitalization, hypotension and desaturation (arterial saturated oxygen <85%) developed, and right ventricular failure was confirmed by two-dimensional echocardiography. Therefore, we changed from VV ECMO to venoarteriovenous (VAV) ECMO, and the patient ultimately recovered. In this case, right ventricular dysfunction and volume overloading were induced by long-term VV ECMO therapy, and we successfully treated these conditions by changing to VAV ECMO.

Key words: 1. Acute respiratory distress syndrome (ARDS) 2. Right ventricular dysfunction 3. Extracorporeal membrane oxygenation

CASE REPORT

A 38-year-old male was admitted to the local hospital with pneumonia. Despite medical treatment, his symptoms did not show any signs of improvement, and he was therefore referred to our hospital. When he arrived at the emergency department, initial arterial blood gas analysis (ABGA) showed a pH of 7.451, a pCO2 of 29.3, a pO2 of 43.6, an HCO3− level of 20.6 mmol/L, and an O2 saturation value of 82.3%, and bilateral lung infiltration was noted on a simple chest X-ray. His heart rate was 121 beats per minute, his respiratory rate was 40 breaths per minute, his blood pressure was 162/94 mmHg, and his body temperature was 37.7°C. He was diagnosed with acute respiratory failure and therefore, after endotracheal intubation, he was supported with mechanical ventilation. On the day that the patient was admitted, despite the 100% oxygen supplied by the ventilator, his ABGA results were as follows: a pH of 7.295, a pCO2 of 54.6, a pO2 of 69.7, a HCO3− value of 26.8 mmol/L, and an O2 saturation value of 91.3%. Therefore, we decided to initiate venovenous extracorporeal membrane oxygenation (VV ECMO) for systemic oxygenation and pulmonary support. VV ECMO (PLS; Maquet, Rastatt, Germany) was established via bilateral femoral cannulation under local anesthesia (Biomedicus 21 Fr ve-
Fig. 1. Abdominal X-ray. Multi-hole 21-Fr long femoral venous cannula (Biomedicus) in both femoral arteries. (A) The right femoral cannula was used for inflow. (B) The newly inserted 17-Fr femoral arterial cannula (Biomedicus, white arrow) was used for venoarteriovenous mode in the right femoral artery.

Fig. 2. (A) On transthoracic echocardiography, an enlarged right ventricle and flattened inverted septum were found with diminished right ventricular function. (B) After changing the mode of extracorporeal membrane oxygenation, decreased right ventricular size and improved right ventricular function were noted.

nous cannula; Medtronic BioMedicus Inc., Anaheim, CA, USA). A right cannula was inserted into the superior vena cava-right atrium junction and a left cannula was inserted at the diaphragm level (Fig. 1A). ECMO flow was initially started with a flow rate of 5.0 L/min, considering the patient’s body weight of 103 kg. After the ECMO insertion, the following ABGA results were obtained: a pH of 7.429, a pCO₂ of 29.5, a pO₂ of 82.9, an HCO₃⁻ value of 19.4 mmol/L, and a saturated O₂ value of 96.6%. The patient was finally diagnosed with influenza (H1N1)-induced acute respiratory distress syndrome (ARDS) and was treated with intravenous antiviral drugs. The patient was also treated for viral pneumonia with superinfected bacterial pneumonia. However, 20 days after admission, despite treatment with intravenous inotropics and high-fractionated oxygen (100%) using ECMO and a mechanical ventilator, his blood pressure decreased to <90 mmHg and his O₂ saturation value fluctuated between 80%–85%. On follow-up echocardiography, a severely dilated right ventricle (RV) with diminished systolic function was noted. A flattened interventricular septum was noted during systole, which suggested pressure overloading in the RV. Additionally, pulmonary hypertension with an estimated pul-
Right Heart Failure during Veno-Venous ECMO

Right Heart Failure (RHF) can develop in ARDS. The main reason for the development of RHF in ARDS is the increase in the pulmonary vascular resistance (PVR). During the treatment of ARDS patients with a mechanical ventilator, the elevation of PVR is caused by hypoxic pulmonary vascular constriction, endothelial hyperplasia, and myointimal proliferation. Mechanical ventilation with positive end-expiratory pressure itself is also a cause of PVR elevation [7-10].

The incidence of RHF related to ARDS has been reported to be 9.6%-25% [10-12]. RHF is known to develop from RV pressure overload, reduced RV contractility, and volume overload [13]. RHF with pulmonary hypertension has poor outcomes in the intensive care unit. In studies addressing hemodynamic variables and survival with pulmonary arterial hypertension, a low cardiac index and high mean right atrial pressure are consistently associated with poor survival [14-16].

Brogan et al. [6] reported a mode change from VV to venoarterial (VA) in 3.3% of ARDS cases in the Extracorporeal Life Support Organization registry between 1986 and 2006. They hypothesized that right heart failure could be one of the causes of mode change.

In our case, the patient’s cardiac function was found to be good on the echocardiography imaging that was performed on...
admission. However, with continuing hypoxia and bilateral lung infiltration that lasted for longer than 20 days despite VV ECMO, his RV function probably decreased due to the increase in PVR caused by the abovementioned factors. This situation was verified by the high central venous pressure, pulmonary arterial pressure, and D-shaped left ventricle found on echocardiography (Fig. 2A). Another reason that VV ECMO may have led to RVF was the long duration of high flow from ECMO. The ECMO flow was non-pulsatile. Non-pulsatile flow has been reported to show disadvantages in tissue perfusion and ventricular recoil function when compared to physiological pulsatile flow [17,18]. Non-pulsatile ECMO flow may sustain RV overloading despite normal RV contraction, which can induce a decrease in RV recoil function. With this hypothesis in mind, we are planning to carry out additional research on this topic in the near future.

ECMO consists of long tubing systems, a membrane oxygenator, and a high-speed rotating centrifugal pump. It can infuse highly oxygenated blood into the venous or arterial circulation, but can also induce a systemic inflammatory reaction, hemolysis, bleeding, or thromboembolism. These problems may also result in vasoconstriction of the pulmonary artery.

As occurred in this case our patient, when RV failure develops, VV-mode ECMO can be changed to VA or VAV mode for unloading the RV volume and RV shear stress. VA or VAV mode infuses the oxygenated blood into the left heart in order to elevate the cardiac output. The unloading effect of RV is better in VA mode than in VAV. However, in cases where pulmonary function has decreased significantly, VA mode alone may not deliver enough oxygen to the tissues.

If the cardiac function of an ARDS patient is good, VA ECMO flow may not reach the aortic root, because the retrograde ECMO outflow may collide with the strong outflow from the patient’s aorta. In such cases, when unsaturated blood is supplied to the proximal aorta (coronary arteries or brachiocephalic arteries), which is a well-known complication of femoral VA ECMO, VAV ECMO can be utilized to overcome the upper body hypoxemia. Therefore, VAV mode is preferable for the treatment of ARDS with RVF. If RVF occurs in a patient with severe ARDS who is being treated with peripheral VV ECMO, adding an arterial cannula to the femoral artery and partially clamping the inflow venous cannula may be an easy solution for overcoming RVF.

In this case, RVF during VV ECMO support was successfully treated by changing the mode to VAV ECMO. This report may be useful to physicians treating RVF in cases of ARDS.

**CONFLICT OF INTEREST**

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

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11. Right Heart Failure during Veno-Venous ECMO

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