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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 pCO_2 of 29.3, a pO_2 of 43.6, an HCO_3^- level of 20.6 mmol/L, and an O_2 saturation value of 82.3%, and bilateral lung infiltration was noted on a simple chest X-ray. His heart rate was 12l 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 pCO_2 of 54.6, a pO_2 of 69.7, a HCO_3^- value of 26.8 mmol/L, and an O_2 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-

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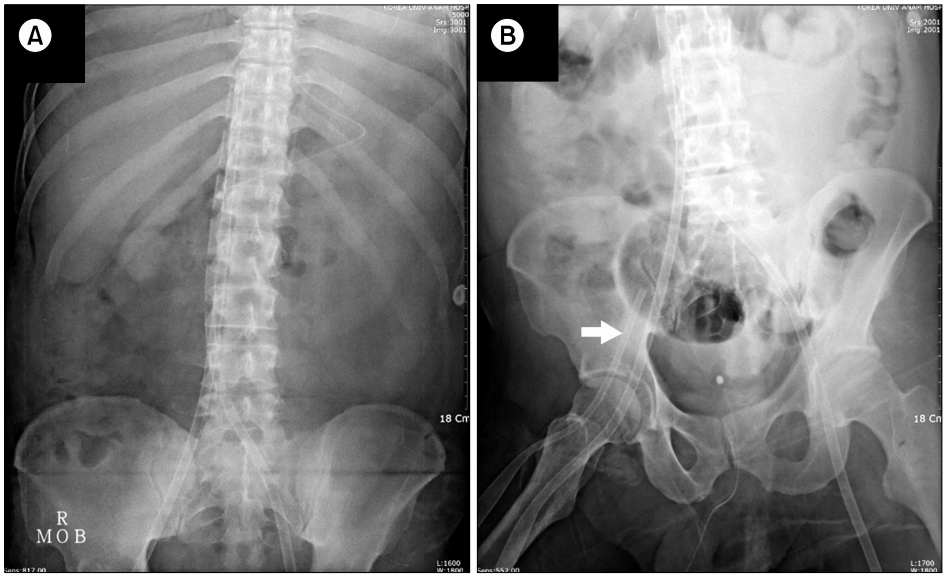

Fig. 1. Abdominal X-ray. Multi-hole 21-Fr long femoral venous cannula (Biomedicus) in both femoral arteries. (A) The right femoral cannula was used for inflow. (B) The newly inserted 17-Fr femoral arterial cannula (Biomedicus, white arrow) was used for venoarteriovenous mode in the right femoral artery.

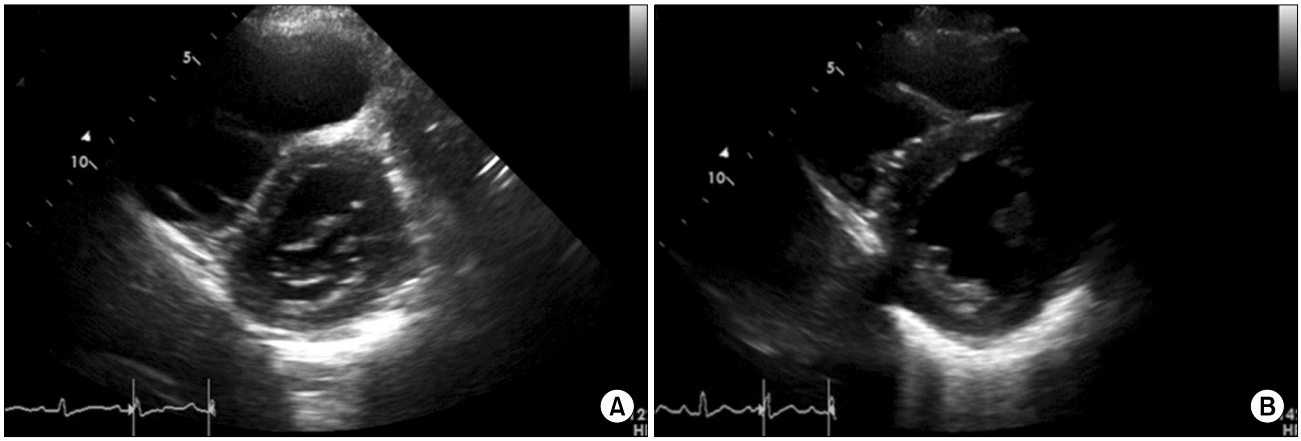

Fig. 2. (A) On transthoracic echocardiography, an enlarged right ventricle and flattened inverted septum were found with diminished right ventricular function. (B) After changing the mode of extracorporeal membrane oxygenation, decreased right ventricular size and improved right ventricular function 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 pCO_2 of 29.5, a pO_2 of 82.9, an HCO_3^- value of 19.4 mmol/L, and a saturated O_2 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 O_2 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-

monary arterial pressure of 40 mmHg (Fig. 2A) and a central venous pressure of 21.5 mmHg were noted, which indicated the existence of right ventricular dysfunction. Laboratory findings showed worsening of end organ function: the ratio of aspartate transanimase to alanine transaminase was 151:96, his bilirubin level (total/direct) was 14.8/8.4 mg/dL, his D-dimer level was 3.34 μg/mL, and his fibrinogen level was 468 mg/dL. We decided to add adjunctive cardiac support and changed the ECMO mode from VV mode to venoarteriovenous (VAV) mode. We inserted an additional 15 Fr Biomedicus arterial cannula into the right femoral artery (Fig. 1B), changed the oxygenator, and created a Y-shaped inflow line. In order to unload the RV pressure, we partially clamped the venous input cannula at approximately 90% of its diameter and maintained an ECMO flow rate of 5.5–6.0 L/min. Approximately 5 L of blood flow was infused into the femoral artery through the new arterial cannula, and the remnants were infused into the right atrium through the venous input cannula. After changing the ECMO mode, the RV size decreased to close to normal, and the interventricular septal flattening disappeared. Improved RV systolic function was noted on echocardiography (Fig. 2B), and O_2 saturation also increased. We changed the degree of clamping of the venous input cannula according to the changing conditions of the patient.

The patient's condition gradually improved as his pneumonia resolved, and we eventually decided to wean him from ECMO based on his lung function status. After 37 days of hospitalization, we removed the right femoral venous inflow line, and on the next day we successfully weaned the patient from ECMO. On day 42, the patient was weaned from the mechanical ventilator, and on day 54, he was transferred from the intensive care unit to the general ward. After a long period of rehabilitation therapy, his tracheostomy cannula was also removed successfully. After four months of hospitalization, the patient was finally discharged without any complications.

DISCUSSION

When avian flu was widespread worldwide in the early 2000s, cases of ARDS due to influenza also increased abruptly. When severe respiratory failure is refractory to medical and conventional mechanical ventilator therapy, VV ECMO is the last line of treatment. VV ECMO can supply oxygenated blood to the right atrium and reduce the burden of the mechanical ventilator. Thus, it provides time for the patient's lungs to rest and recover from respiratory failure and shock. Hill et al. [1] reported the first case of a patient who recovered from trauma-induced adult respiratory failure through the application of VV ECMO treatment. Bartlett was a pioneer of ECMO in the modern era. He and his colleagues showed the possibilities of ECMO to be an effective treatment for respiratory failure and cardiogenic shock [2,3]. In the CESAR (Conventional Ventilation or ECMO for Severe Adult Respiratory Failure) trial, which was a multicenter randomized controlled trial comparing conventional ventilation to ECMO for severe respiratory failure, ECMO showed a survival benefit of six months. The results of ECMO in that group were excellent, with reported survival rates of 68%–77% [4,5]. Brogan et al. [6] reported a survival rate of 50% in adults with severe respiratory failure who were treated with ECMO support.

Right ventricular failure (RVF) can develop in ARDS. The main reason for the development of RVF 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 RVF related to ARDS has been reported to be 9.6%–25% [10-12]. RVF is known to develop from RV pressure overload, reduced RV contractility, and volume overload [13]. RVF 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 heart. 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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