Alternative Position of Cannulae in Veno-venous Extracorporeal Membrane Oxygenation

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Abstract

Optimal positioning of drainage and return cannulae is critically important for minimizing the recirculation in patients with respiratory failure requiring veno-venous extracorporeal membrane oxygenation (VV ECMO). If a drainage cannula is positioned at a low level of right atrium through the femoral vein, flow disturbance due to drainage chattering can occur when the intravascular volume is insufficient, or intrathoracic or intraabdominal pressure is increased. We report a case in which drainage chattering was eliminated and recirculation were decreased by repositioning the drainage and return cannula in a patient with VV ECMO flow disturbance when intrathoracic pressure was increased.

Introduction

When veno-venous extracorporeal membrane oxygenation (VV-ECMO) is applied to a patient with severe respiratory failure, an optimal cannulation technique is essential to minimize recirculation.[1] Recently, a dual lumen cannula for VV-ECMO was reported that it was simple and useful for reducing recirculation.[2] The right internal jugular and right common femoral veins are used in most common for the two vessel cannulation technique. However, the femoral to internal jugular VV-ECMO configuration with drainage and return ports in the inferior vena cava (IVC) and superior vena cava (SVC), respectively, leads to recirculation because the infusion jet is directed toward the drainage port. On the other hand, if the drainage cannula is positioned at low level of right atrium (RA) for decreasing recirculation, flow disturbance due to drainage chattering from changing intrathoracic pressure can occur, can be fatal when a patient is wholly dependent on VV-ECMO. We report a case in which drainage chattering was eliminated and recirculation were decreased by repositioning the drainage and return cannula in a patient with VV ECMO flow disturbance when intrathoracic pressure was increased.

Case report

61-year old male (height; 167 cm, weight; 67 kg, body surface area; 1.76 m^2) with interstitial lung disease waiting for lung transplantation was supported by VV-ECMO because his pulmonary function was worsening. The cannulation was approached conventionally using percutaneous procedure via the right internal jugular (return) and right common femoral vein (drainage) using 15Fr and 23Fr HLS© cannulae (Maquet; Getinge Group, Rastatt, Germany), respectively (Figure 1A). A terumo emergency bypass system (Terumo Corp., Tokyo, Japan) was used and the ECMO was set 4.00 liters per minute, 2400 rotations per minute, an inspired oxygen fraction of 1.0, and a sweep gas flow rate of 4.00 liters per minute. A 28% recirculation rate was measured by the ELSA monitor (Transonic Systems Inc., Ithaca, NY, USA, Figure 1B).[3] Cardiac function and size, as measured by transthoracic echocardiography, were normal without pulmonary hypertension. We could maintain the protective ventilator setting, but flow disturbance occurred due to chatter in the venous drainage circuit when intrathoracic pressure was increased during suctioning in the endotracheal tube. When the chattering occurred, unpredictable volume was added to maintain VV-ECMO flow, and hypoxia was detected, therefore ventilator had to change to the higher tidal volume and plateau airway pressure than protective ventila, occasionally. Although the possibility of recirculation could become higher, we repositioned the drainage cannula at a higher level until SVC and then determined the position of the return cannula by measuring a recirculation rate by the ELSA monitor. Before positioning the return cannula, the recirculation rate was 26%. The first step of the repositioning procedure involved advancing the return cannula 2 cm, which reduced the recirculation rate to 30%. Then we advanced the return cannula by more 1cm and decreased ECMO flow slightly. At this stage, a recirculation rate was 24% and the VV-ECMO flow was remained stable. The protective ventilator setting was also maintained. The next day, a recirculation rate was 14% after VV-ECMO flow was decreased from 4.4 to 4.0 LPM (Figure 2 and 3). After 12 hospital days on VV-ECMO support, lung transplantation was performed successfully and the patient recovered well.

Discussion

VV-ECMO can be applied to patients that are severely hypoxemic and/or hypercapnic despite optimal medical management, including ventilator support. An important consideration of VV-ECMO cannulation is the minimization of recirculation. Dual-site VV-ECMO is usually used in many centers. This involves insertion of a drainage cannula into the femoral vein and advancing it to the junction between the IVC and RA, and then inserting the return cannula into the internal jugular vein and advancing it through the SVC into the RA.[4,5]

Recirculation refers to the reintroduction of oxygenated blood to the drainage cannula without passing through the systemic circulation, and reduces the efficiency of oxygenation by VV-ECMO. Various factors influence recirculation, such as cannulation configuration, cannula positioning, pump speed, extracorporeal blood flow, cannula size, cardiac function, intrathoracic and intraabdominal pressures, and direction of returned blood flow.[2,6] In a previous study, it was recommended that the use of a multistage cannula and cannula position adjustment be used to minimize recirculation.[7] The author demonstrated that the location of the most proximal holes of a multistage cannula drain a larger fraction deoxygenated blood from the upper body and less from the RA junction. Fifteen centimeter between the two cannulae is recommended to decrease recirculation,[4] but if the drainage cannula is positioned at a lower level of RA for maintaining this distance, the ECMO flow disturbance could occur due to chattering. Single-site VV ECMO using a bicaval dual lumen cannula has recently been reported to reduce recirculation as compared with dual site cannulation.[8] However, due to the high cost, single-site VV ECMO could not always be available.

The cannulae position used in the present study have the benefits that deoxygenated blood from upper and lower body are effectively drained, and that VV-ECMO flow disturbance due to chattering can be prevented. Using the described technique, we were able to reduce recirculation by adjusting the position of the return cannula by the ELSA monitor, which measures the amount of recirculation using the ultrasound dilution technique. The cannula repositioning procedure described has an effect similar to a single dual-lumen bicaval cannula but does not impose a cost burden, and complication related to the procedure, such as hemopericardium.[9]

A similar cannula position, called the X-configuration, was reported to reduce the blood recirculation fraction, significantly. However, this configuration has weaknesses that could be used after modifying return cannula by self, and might result in tricuspid valve injury or tricuspid regurgitation if the cannula were positioned through the tricuspid valve.[10]

Conclusion

This report highlight is the described cannula repositioning procedure enabled VV-ECMO flow to be maintained at full support without unnecessary volume addition in a patient even with a low intravascular volume or high intrathoracic/intraabdominal pressure, and recirculation rate could be reduced by ELSA monitor.

Figure 1. Chest AP (1A) and result of ELSA monitor (1B) after applying VV ECMO. The cannula positioned at superior vena cana and junction of right atrium and inferior vena cava. The recirculation, measured by ELSA monitor, was 28%. (Yellow arrow; return cannula, black dot arrow; drainage cannula)

Figure 2. Alternative position of cannulae. A drainage cannula (black dot arrow) was positioned at a higher level until SVC. Overlap distance was 8.75cm between a return cannula (yellow arrow) and a drainage cannula. (2A; chest anteroposterior view, 2B; chest left lateral view)

Figure 3. ELSA monitor during changing a position of cannulae.

3A) Before positioning the return cannula, a recirculation rate was 26%.

3B) After advancing the return cannula 2 cm, a recirculation rate was 30%.

3C) After advancing the return cannula by more 1cm, a recirculation rate was 24%.

3D) The next day, a recirculation rate was 14% after VV-ECMO flow was decreased.

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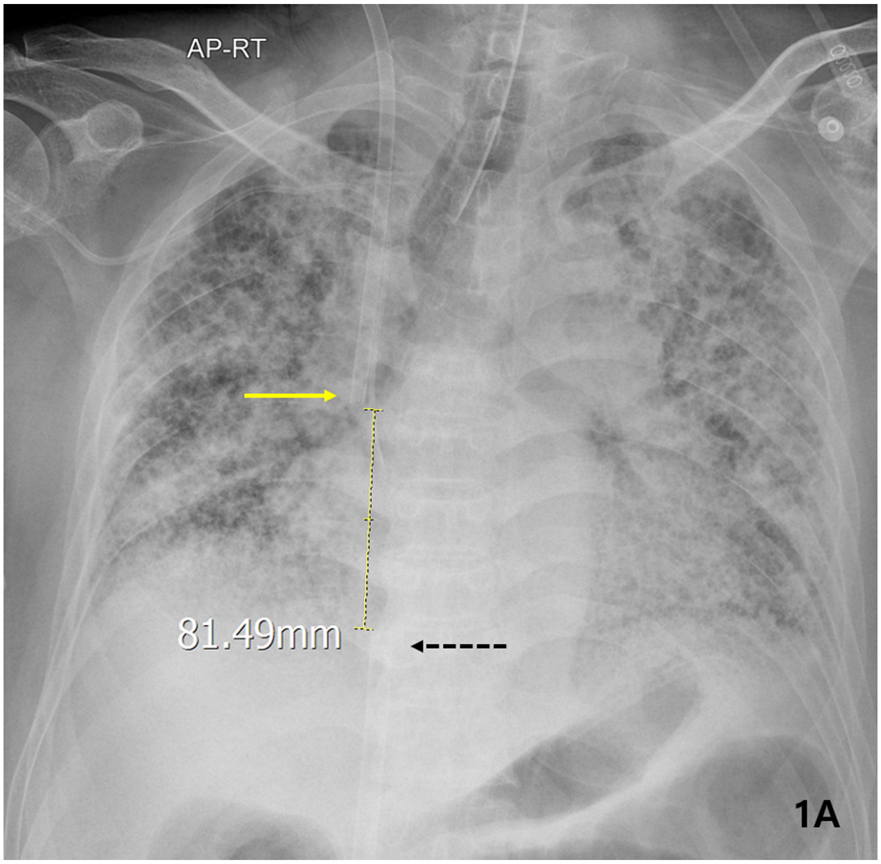
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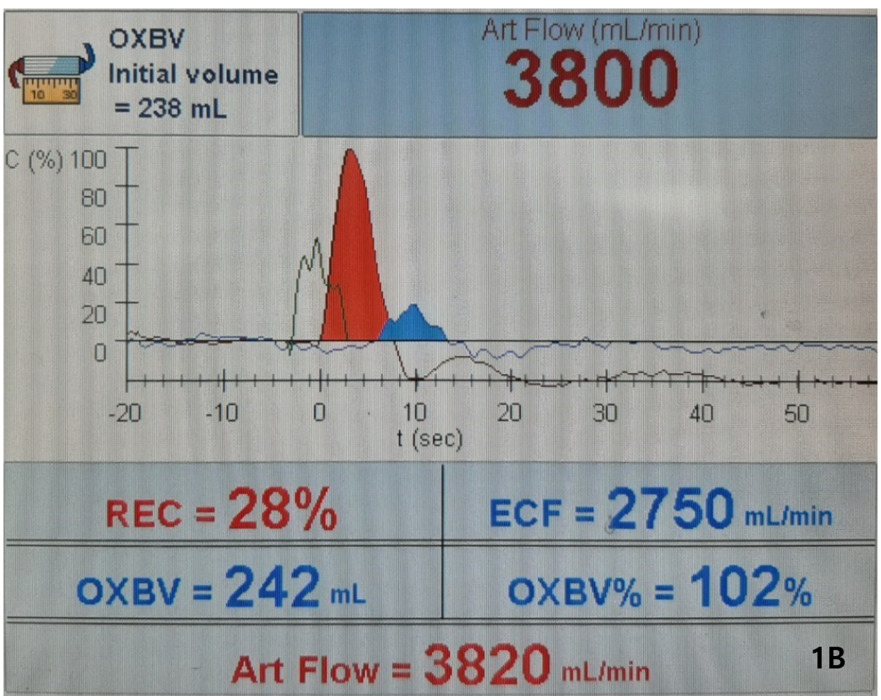
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= 238 mL
Art Flow (mL/min)
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C (%) 100
80
60
40
20
0
-20
-10
0
10
20
30
40
50
t (sec)
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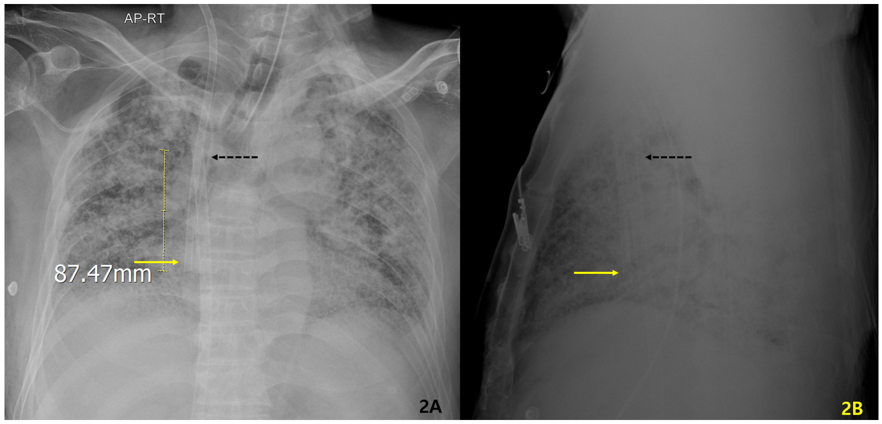
1B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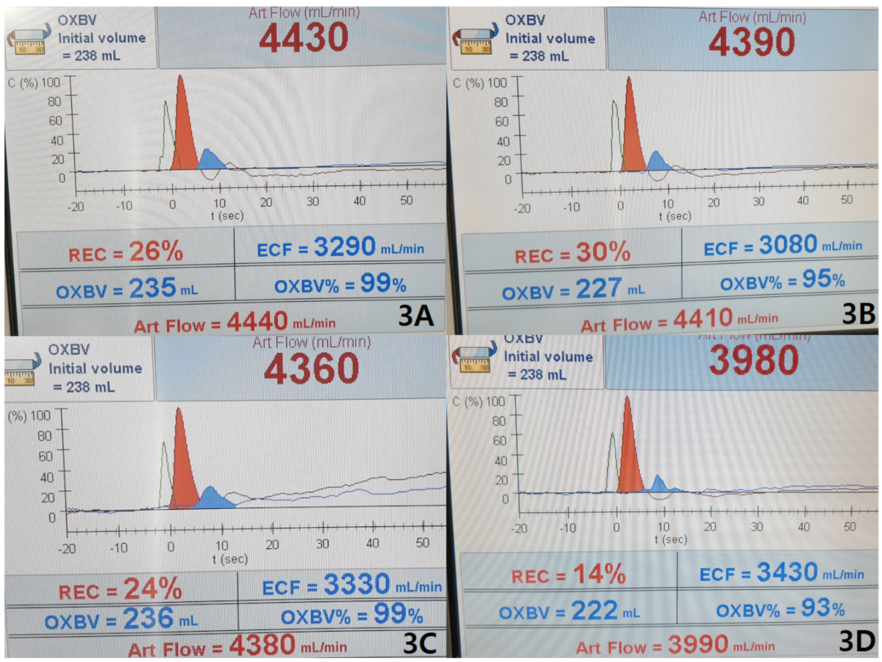
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Art Flow (mL/min)
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C (%) 100
t (sec)
REC = 26%
ECF = 3290 mL/min
OXBV = 235 mL
OXBV% = 99%
Art Flow = 4440 mL/min
3A
OXBV
Initial volume
= 238 mL
Art Flow (mL/min)
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REC = 30%
ECF = 3080 mL/min
OXBV = 227 mL
OXBV% = 95%
Art Flow = 4410 mL/min
3B
OXBV
Initial volume
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Art Flow (mL/min)
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REC = 24%
ECF = 3330 mL/min
OXBV = 236 mL
OXBV% = 99%
Art Flow = 4380 mL/min
3C
Initial volume
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3980
REC = 14%
ECF = 3430 mL/min
OXBV = 222 mL
OXBV% = 93%
Art Flow = 3990 mL/min
3D