Alternative Position of Cannulae in Veno-venous Extracorporeal Membrane Oxygenation for Maintaining Sufficient Flow Support

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Abstract

Blood flow disturbance of veno-venous extracorporeal membrane oxygenation (VV-ECMO) can be risk factor of weaning failure. We report an alternative position of cannulae of VV-ECMO which can maintain blood flow. The recirculation rate could be controlled by adjusting a position of return cannula using dilutional ultrasound monitoring.

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, 3] 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 or intraabdominal 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 HISTORY

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). A terumo emergency bypass system (Terumo Corp., Tokyo, Japan) was used and the ECMO was set 3.80 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) , which measures the amount of recirculation using the ultrasound dilution technique (Fig. 1).[4] 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 blood flow disturbance occurred, unpredictable volume was added to maintain ECMO flow because hypoxia was detected, therefore ventilator had to change to the higher tidal volume and plateau airway pressure than protective ventilation, occasionally.

Although the possibility of recirculation could become higher, we repositioned the drainage cannula at a higher level until SVC to maintain ECMO flow. Before positioning the drainage cannula, the recirculation rate was 26%. The first step of the repositioning procedure involved advancing the return cannula 2 cm, which increased the recirculation rate to 30%. Then, after advancing the return cannula 1cm additionally, a recirculation rate decreased to 24%, and the VV-ECMO flow was maintained stable. The next day, a recirculation rate was 14% after VV-ECMO flow was decreased from 4.4 to 4.0 LPM (Fig. 2). After 12 hospital days on VV-ECMO support, lung transplantation was performed successfully and the patient recovered well.

DISCUSSION

An important consideration of VV-ECMO cannulation is the minimization of recirculation. Dual-site VV-ECMO, the femoral to internal jugular VV-ECMO configuration is usually used in many centers.[1-3] 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. In a previous study, it was recommended that the use of a multistage cannula and cannula position adjustment be used to minimize recirculation.[5] 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, 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.[6]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 (Fig. 3).[7]

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.[8] Hori D. et al introduced that the double venous drainage system, which is jugular and femoral veinous drainage, provided better oxygenation than femoral venous drainage alone system.[9] This system could supply sufficient venous drainage from both SVC and IVC, but there are complications, such as vessel injury, bleeding and infection related to an additional cannula. In addition, the patient's management becomes more difficult.

This alternative position has a number of limitations. First, it could increase the risk of cannula-related infection. Cannula sites in our center were kept sealed with antimicrobial iodophor-impregnated incision drapes (3M Ioban; 3M Health Care, St. Paul, Minn). The cannula-related infection has not occurred in our ECMO cases when the sealed dressing of cannula sites was well maintained with the sterile procedure. Second, the drainage cannula could move into the RA appendage, not into SVC. The fluoroscopy-guided repositioning could be helped in this case. Last, this technique can not apply for tall patients because of the limitation of cannula length. In tall patients, inserting an additional cannula at SVC is needed for maintaining full ECMO support. However, it is able to predict that the drainage cannula could be repositioned to SVC by measuring the length between SVC and the tip of the drainage cannula in a chest x-ray.

Without cannula modification and additional cannulation, this alternative position of cannulae in VV-ECMO can provide sufficient full support in a patient even with a low intravascular volume or high intrathoracic/intraabdominal pressure. The highlight of this position technique is that position of the lowest recirculation rate has to identify using dilution ultrasound monitoring.

CONCLUSION

Without cannula modification and additional cannulation, this alternative position of cannulae in VV-ECMO can provide sufficient full support in a patient even with a low intravascular volume or high intrathoracic/intraabdominal pressure. The highlight of this position technique is that position of the lowest recirculation rate has to identify using dilution ultrasound monitoring.

Conflicts of interest ; no conflict of interest to declare.

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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 and black dot arrow; return and drainage cannula)

Figure 2. Alternative position of cannulae (2A) and ELSA monitor during changing a position of cannulae (2B).

Overlap distance was 8.75cm between a return (yellow arrow) and a drainage cannula (black dot arrow) Before repositioning procedure, a recirculation rate was 26%. After advancing the drainage until superior vena cava, and return cannula 2cm, a recirculation rate increased 30%. After advancing the return cannula

1cm additionally, a recirculation rate was 24%. The next day, a recirculation rate was 14% after VV-ECMO flow was decreased.

Figure 3. The schematic figure for the alternative position of cannulae.

This alternative position of cannulae in VV-ECMO can drain from superior and inferior vena cava (blue arrow) but develop the recirculation (violet arrow). The optimal position of the return cannula is determined by dilution ultrasound monitoring, which position may make oxygenated blood (red arrow) flow to the right ventricle.

List of abbreviations;

ECMO: Extracorporeal membrane oxygenation; ELSA: Extracorporeal life support assurance; LPM: Liter per minute; RA: Right atrium; SVC: Superior vena cava; VV: Venovenous.

Declare

Ethics approval and consent to participate ; The case report was approved by the institutional ethics committee/Institutional Review Board of the Gil Medical Center (No: GDIRB2020-111). The requirement for informed consent was waived because of the retrospective nature of the study.

Authors' contributions ; UW Ko: conception and design, analyses of data, drafting the manuscript. CH Choi: collect and analyses of data. CH Park: drafting the manuscript and final approval. SI Lee

: analyses of data, drafting the manuscript and final approval. All authors read and approved the final manuscripts.

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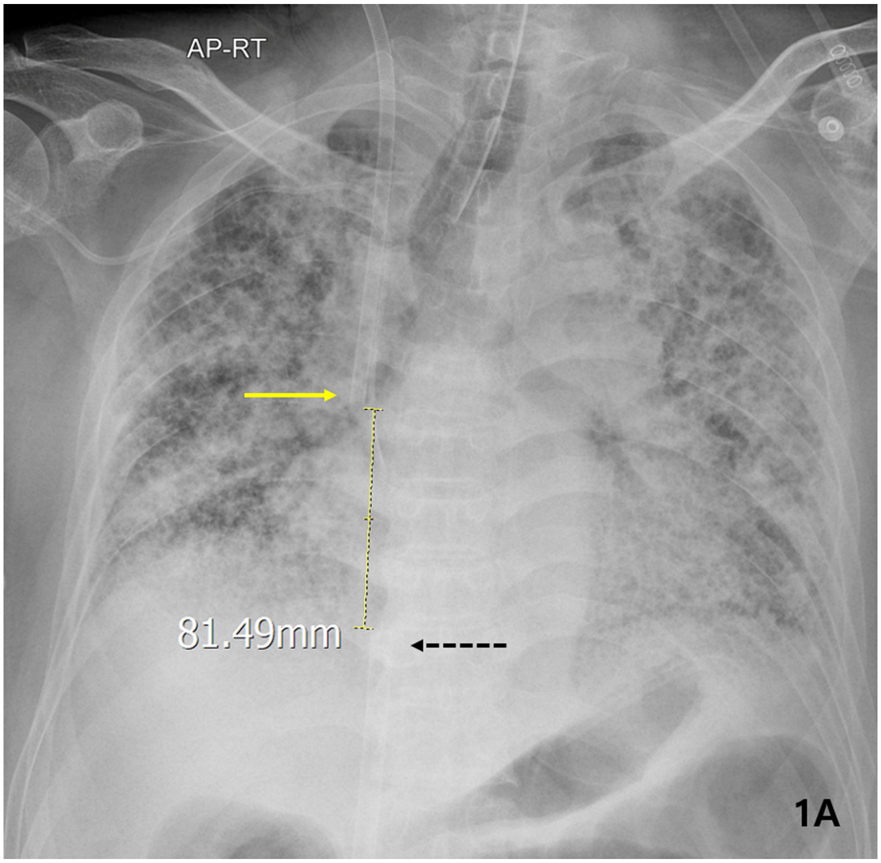
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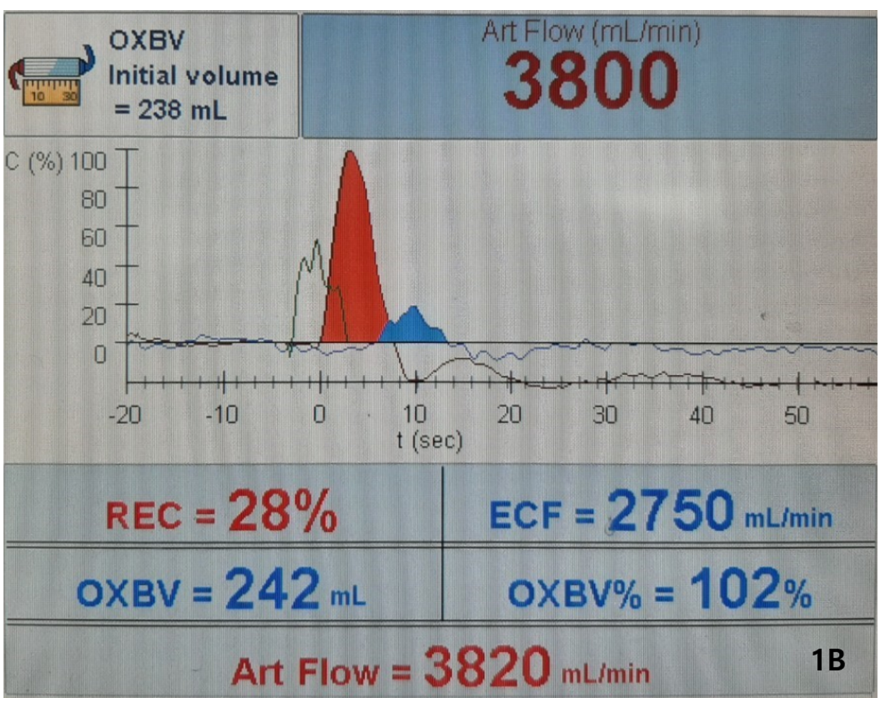
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Art Flow (mL/min)
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C (%) 100
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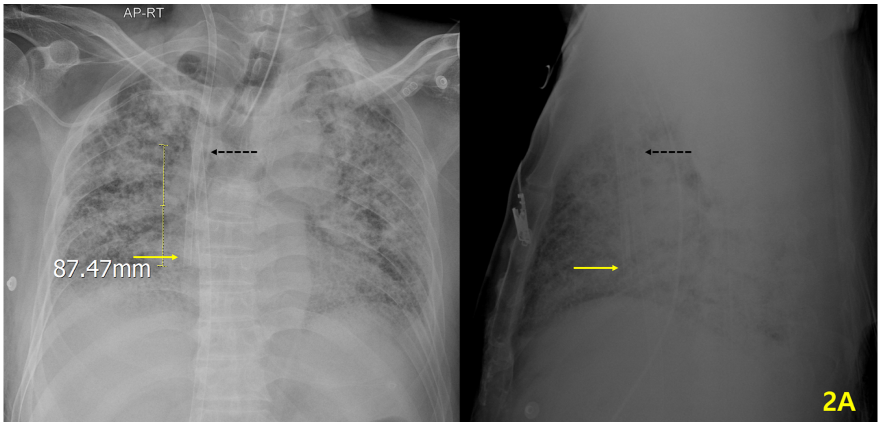
60
40
20
0
-20
-10
0
10
20
30
40
50
t (sec)
REC = 28%
ECF = 2750 mL/min
OXBV = 242 mL
OXBV% = 102%
Art Flow = 3820 mL/min
1B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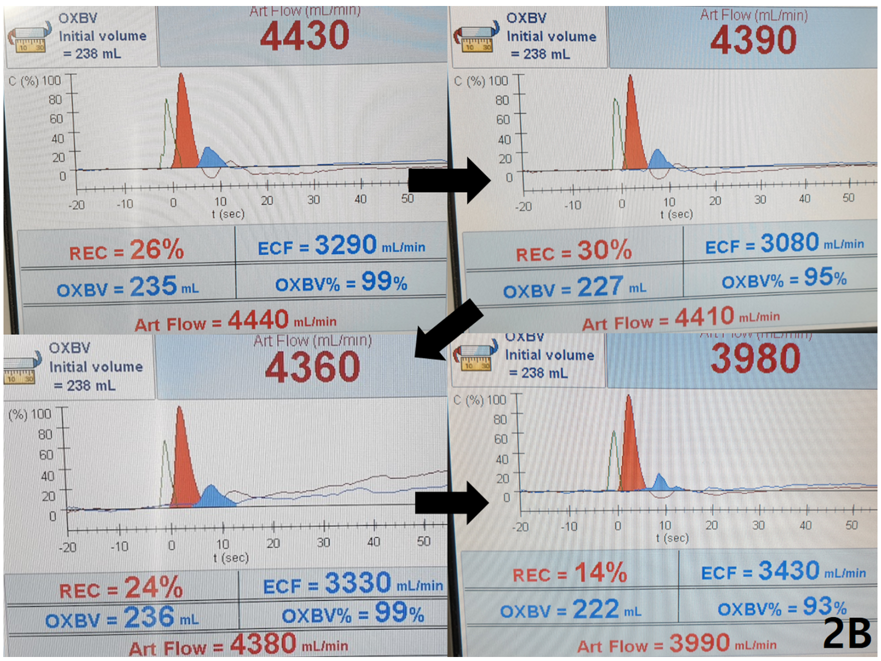
OXBV
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Art Flow (mL/min)
4430
C (%) 100
t (sec)
REC = 26%
ECF = 3290 mL/min
OXBV = 235 mL
OXBV% = 99%
Art Flow = 4440 mL/min
OXBV
Initial volume
= 238 mL
Art Flow (mL/min)
4390
REC = 30%
ECF = 3080 mL/min
OXBV = 227 mL
OXBV% = 95%
Art Flow = 4410 mL/min
OXBV
Initial volume
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Art Flow (mL/min)
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REC = 24%
ECF = 3330 mL/min
OXBV = 236 mL
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Art Flow = 4380 mL/min
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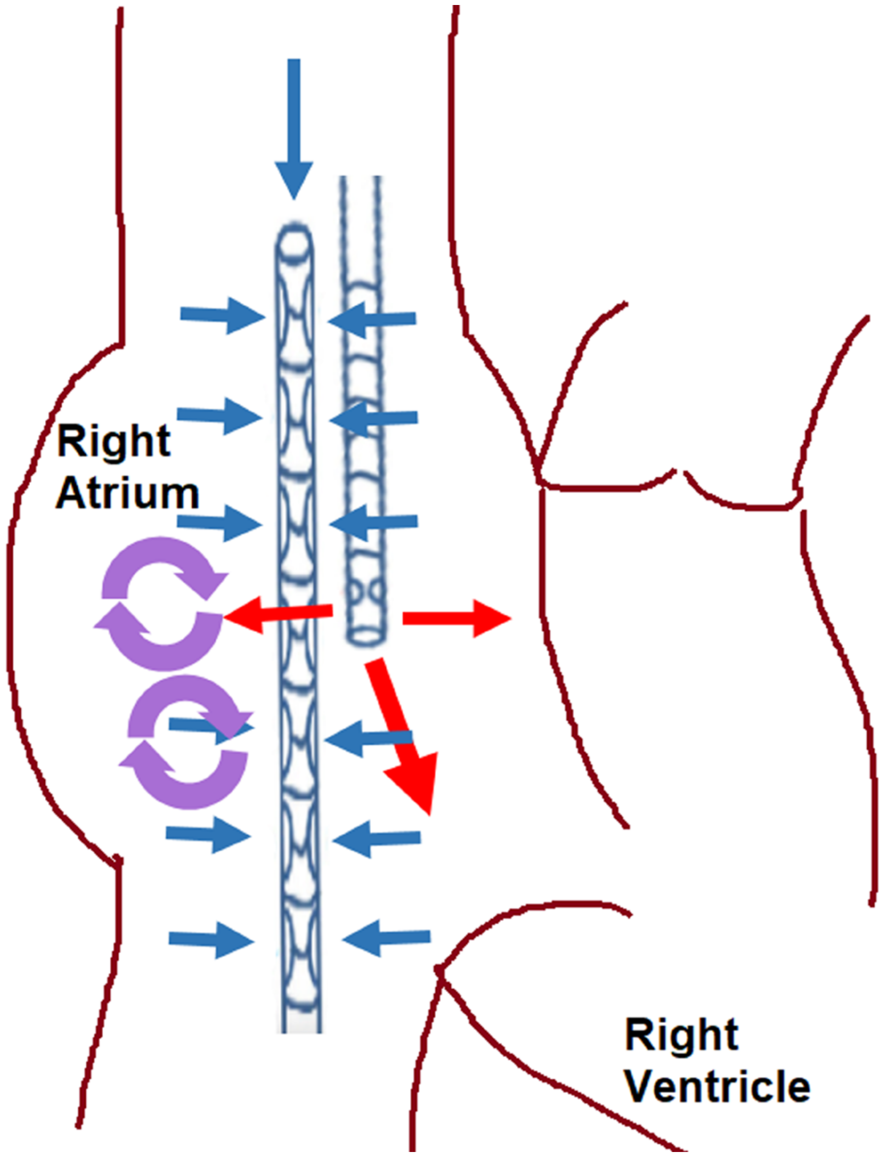
2B


Right
Atrium
Right
Ventricle