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TECHNICAL FORUM

Artificial Lung / ECMO

A case of successful bedside cannulation with a bicaval dual-lumen cannula guided by transthoracic echocardiography and mobile X-ray for veno-venous extracorporeal membrane oxygenation

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Introduction

Extracorporeal membrane oxygenation (ECMO) has been widely used for refractory cardiogenic shock and respiratory failure for several decades. Veno-venous (V-V) ECMO is sometimes used in patients with severe acute respiratory distress syndrome that is refractory to conventional support.

There are two configurations of V-V ECMO. One is conventional two-site cannulation, in which the drainage and return cannulas are inserted into the femoral and internal jugular veins. The other is single-site cannulation, in which a dual-lumen cannula (DLC) is inserted into the right internal jugular vein. A bicaval DLC drains blood from the superior vena cava and inferior vena cava (IVC) and returns it to the right atrium. In Japan, the bicaval DLC was approved in 2018, but its uptake remains low and reports on its use are scarce. A DLC has some advantages during V-V ECMO, including less recirculation. However, complications such as right ventricle rupture [1] and cannula migration into the hepatic vein [2] may occur during insertion of a bicaval DLC. Therefore, it is recommended to insert the DLC under fluoroscopic guidance and/or transesophageal echocardiography (TEE) [2–4].

However, depending on the patient's condition and availability in the facility, it may be difficult to move to the fluoroscopy room and V-V ECMO may have to be introduced at the bedside, where TEE may not be available. Herein, we report a case of bedside cannulation using a bicaval DLC for V-V ECMO guided by a combination of transthoracic echocardiography (TTE) and mobile X-ray.

Brief case summary and description of the cannulation technique

A 62 year-old man was brought to a hospital by ambulance with respiratory distress and a 4 day history of fever. A reverse transcriptase polymerase chain reaction test confirmed a diagnosis of coronavirus disease 2019 (COVID-19), and the patient was transferred to our hospital. On admission, he developed respiratory failure requiring mechanical ventilation. His hypoxia gradually worsened, and after 6 days of mechanical ventilation, he required V-V ECMO.

An ultrasound prescan of the internal jugular and femoral veins revealed a right inguinal hernia; in view of the anatomical position between the left femoral vein and artery, we abandoned the plan to insert the cannula into his femoral

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vein. Instead, we decided to insert a 27 Fr AVALON Elite Bi-Caval Dual Lumen Catheter (GETINGE Group, Tokyo, Japan) into the right internal jugular vein. We were unable to use the fluoroscopy room or TEE immediately because of COVID-19 infection control measures and the patient's poor respiratory status. Therefore, we decided to insert a DLC guided by TTE and mobile X-ray at the bedside in the intensive care unit.

First, we inserted a 5 Fr short sheath into his right internal jugular vein. We then inserted a J-tipped 0.035" Radifocus guidewire (Terumo Corp., Tokyo, Japan) through the sheath and confirmed that the tip of the guidewire was inside the IVC in real time by abdominal ultrasonography. The tip of the guidewire initially migrated into the left hepatic vein (Fig. 1a) but was rapidly returned to its correct position under ultrasonographic guidance (Fig. 1b). In addition, mobile X-ray images confirmed that the guidewire was not looping in the right atrium or right ventricle and that it was advancing linearly into the IVC (Fig. 1c). We took care to confirm that there was no change in the length of the guidewire inserted during percutaneous dilation. After dilation up to 24 from 8 Fr using a vascular dilator kit (MICS Cannulae; LivaNova USA Inc., Houston, TX), we inserted a 27 Fr DLC. Insertion of the guidewire, dilation, and insertion of the DLC were performed smoothly without encountering any abnormal resistance. The DLC was adjusted so that the arm of the return cannula was pointing in the 10 o'clock direction when viewed in the short axis of the cannula. We then started the centrifugal pump and confirmed that the ECMO blood flow rate was 3.6 L/min at a drainage pressure of − 90 mmHg. Visual observation of a difference in the color of blood between the venous lumen and the return lumen confirmed that there was little recirculation. We also confirmed blood flow from the reinfusion port toward the tricuspid valve by TTE (Fig. 1d). The cannula was fixed with seven 2–0 nylon sutures.

After 43 days of ECMO, we obtained a contrast-enhanced computed tomography scan of the chest that showed spread of the contrast agent from the cannula in the right atrium toward the tricuspid valve (Fig. 1e). The patient was often shifted to a prone position or a sitting position for respiratory physical therapy until end of ECMO on day 69. However, the

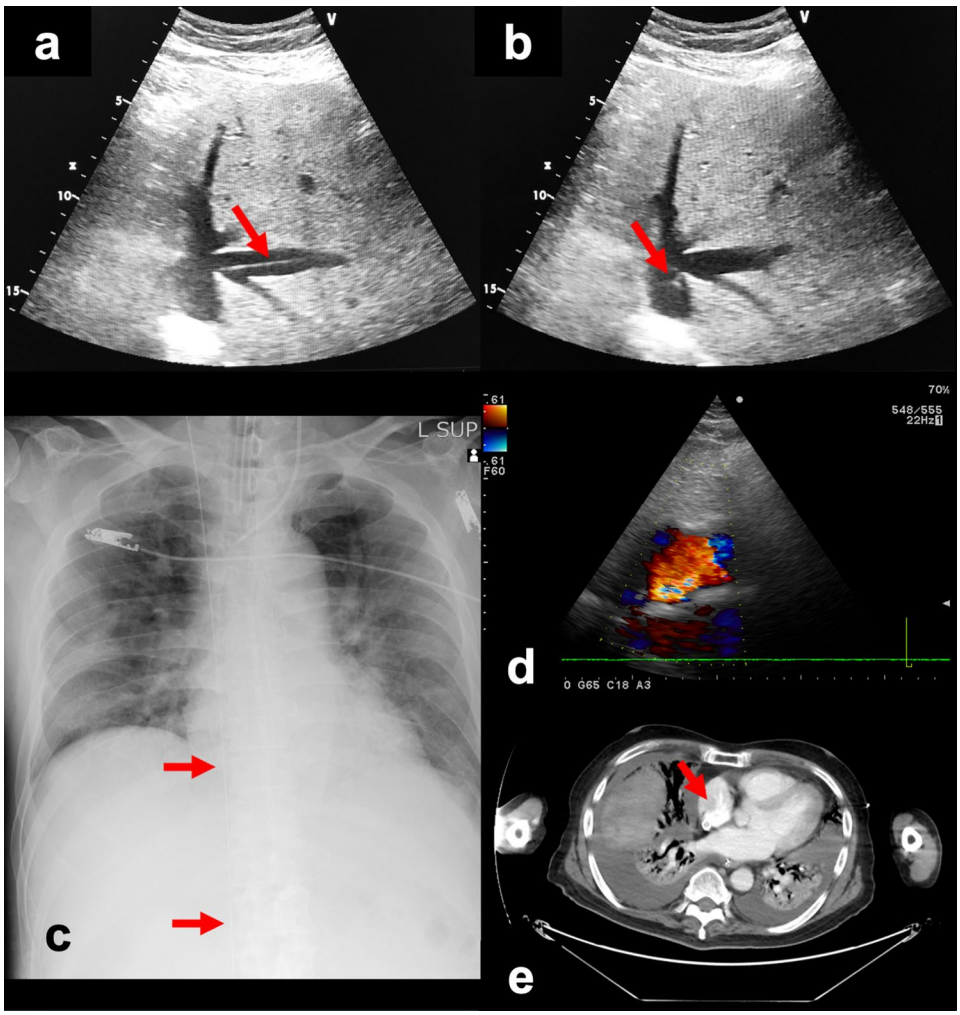

Fig. 1 Imaging findings. **a** Ultrasonographic image obtained in a subcostal view shows that the guidewire is incorrectly positioned in the left hepatic vein (red arrow). **b** A subcostal ultrasonographic view shows that the guidewire is correctly positioned in the IVC (red arrow). **c** Mobile chest X-ray image shows that the guidewire is located in the IVC in a straight line (red arrows). **d** A subcostal longitudinal view on TTE shows the inflow jet directed toward the tricuspid valve. **e** Contrast-enhanced CT scan shows the inflow jet directed toward the tricuspid valve from the reinfusion port of the DLC (red arrow). *IVC* inferior vena cava; *TTE* transthoracic echocardiography; *CT* computed tomography; *DLC* dual-lumen cannula

DLC remained in the correct position and did not have to be repositioned during the course of treatment.

Discussion of DLC insertion for V-V ECMO

We have performed cannulation at the bedside using a bicaval DLC guided by a combination of TTE and mobile X-ray. The DLC has several advantages for V-V ECMO. First, it has a single-site configuration and allows less recirculation than a cannula with two-site configuration [4]. Second, the absence of a cannula into the femoral vein is advantageous for early mobilization during V-V ECMO [4]. Third, since only one cannula is required, use of the DLC reduces the likelihood of catheter-related bloodstream infection [2].

However, DLC for V-V ECMO has some disadvantages. First, compared with the configuration of two-site cannulation, it is difficult to obtain high blood flow for V-V ECMO with a DLC owing to the short diameter of each lumen [3]. Second, DLC is more expensive than a conventional drainage or return cannula. In particular, cannulation using a DLC is more difficult than conventional two-site cannulation and is associated with complications, including rupture of the right ventricle [1], looping of the guidewire in the right ventricle [5], and malpositioning of the cannula if the DLC migrates into the hepatic vein [2]. Therefore, the Extracorporeal Life Support Organization guidelines recommend insertion of a DLC guided by fluoroscopy and/or TEE [3].

In our case, the following precautions were taken during insertion of the DLC at the bedside guided by TTE and mobile X-ray. Real-time ultrasonography was used to confirm that the tip of the guidewire was in the correct place in the IVC and not strayed into the hepatic vein and to avoid right heart injury (Fig. 1a, 1b). It was difficult to confirm that the loop of the guidewire was in the right ventricle using ultrasonography alone; therefore, we used mobile X-ray imaging to confirm that the guidewire was located in the IVC in a straight line without kinking (Fig. 1c). We proceeded with the operation, during which we confirmed that there was no change in the length of guidewire inserted or any abnormal resistance during dilation that would cause the tip of the guidewire to move from its correct position. Orientation of the reinfusion port is also important. We confirmed that the inflow jet was directed from the reinfusion port to the tricuspid valve by TTE (Fig. 1d).

Ideally, a DLC should be inserted in a fluoroscopy room. However, a bicaval DLC can be placed at the bedside in an intensive care unit using a combination of TTE and mobile X-ray and taking the following precautions:

1When inserting the guidewire, confirm that the tip of the guidewire is inside the IVC by real-time ultrasonography.
2Confirm that the guidewire is not looping in the right ventricle on mobile X-ray images.
3Ensure that no abnormal resistance is felt during insertion of the guidewire or dilation and that there is no change in the length of the guidewire inserted during dilation.
4Confirm that the inflow jet is directed toward the tricuspid valve from the reinfusion port of the DLC by TTE.

This is a technical report of only one case, and unexpected complications may occur in the future using this protocol. However, in circumstances where a fluoroscopy room or TEE is not available, such as when COVID-19 infection control measures are in place, it may be possible to insert a bicaval DLC for V-V ECMO at the bedside using the above protocol. An alternative method is to insert the DLC at the bedside guided by C-arm fluoroscopy; however, a normal bed in the intensive care unit would not be compatible with a C-arm. There may also be concern about radiation exposure in the intensive care unit. In conclusion, DLC may be inserted at the bedside guided by a combination of TTE and mobile X-ray.

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Declarations

Conflict of interest All authors declare that they have no conflict of interest.

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