

Bedside veno-venous ECMO cannulation

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Abstract

Patient selection and cannulation arguably represent the key steps for the successful implementation of Extracorporeal Membrane Oxygenation (ECMO) support. Cannulation is traditionally performed in the operating room or the catheterization laboratory for a number of reasons, including physician preference and access to real-time imaging, with the goal of minimizing complications and ensuring appropriate cannula positioning. Nonetheless, the patients' critical and unstable conditions often require emergent initiation of ECMO and preclude the safe transport of the patient to a procedural suite. Therefore, with the objective of avoiding delay with initiation of therapy and reducing the hazard of transport, we implemented a protocol for bedside ECMO cannulation. In the current pandemic, this strategy may have additional benefits for the care of patients with refractory acute respiratory distress syndrome (ARDS) due to COVID-19 decreasing risk of healthcare worker or other patients exposure to the novel SARS-CoV-2 virus occurring during patient transport, preparation, or during disinfection of the procedural suite and the transportation pathway after ECMO cannulation.

Introduction

Veno-venous (VV) ECMO has been recognized as a potentially life-saving therapy for patients with refractory ARDS secondary to pneumonia and its use in adults has increased exponentially following the influenza A (H1N1) pandemic in 2009 (1-5). The Extracorporeal Life Support Organization (ELSO) has published comprehensive guidelines defining the appropriate clinical indications for VV-ECMO use and has established detailed protocols and quality measures for to ensure appropriate implementation of therapy (6,7).

Extracorporeal circulation in VV-ECMO is traditionally obtained with the insertion of two venous cannulas either with the internal jugular-femoral or the femoro-femoral configuration (5,8,9). In recent years, a technique using a single bicaval dual-lumen catheter (Avalon Elite[®], Maquet Inc., Rastatt, Germany) with access through the right internal jugular vein (IJV) has become available as an alternative method to the traditional double venous cannulation strategy (5,10,11). The single insertion site, which may reduce the risk of bleeding and infection, the location of the insertion site in the neck, which may facilitate patients' prone positioning as needed, and possibly the more efficient oxygenation, most likely related to lesser incidence of the phenomenon of "recirculation", account for the advantages of using a single dual-lumen cannula versus a double cannulation strategy (8,9,12-14). On the other hand, the perceived technical difficulty of the internal jugular venous cannulation using a large bore cannula (27 Fr or 31 Fr, both with an insertable length of 31 cm) is seen as a potential disadvantage. For this reason, the dual lumen catheter IJV placement is traditionally performed in the operating room or the catheterization laboratory with assistance of fluoroscopy and transesophageal echocardiography (11,15,16).

In 2015, we implemented a strategy of routine bedside cannulation at Hennepin County Medical Center. An internal committee was created with the objective of designing protocols and determining the logistics of the cannulation procedure. Dry runs were simulated in the Surgical Intensive Care Unit (SICU) until the

optimal cannulation protocol was defined. A total of 89 patients required ECMO support at Hennepin County Medical Center between March 2015 and December 2019. Of these, 28 (31%) patients were cannulated for veno-venous support, all at bedside. A dual-lumen, bicaval cannula (Avalon Elite[®], Maquet Inc.) was used in 23 cases; a two cannula approach using the right internal jugular vein and femoral vein was selected in 5 cases due to patient-specific factors, such as a high native cardiac output. Of the 28 VV-ECMO cases, the average age was 40 years (range 12-66), 12 (43%) were women, and the average body surface area (BSA) was 2.04 m² (range 1.53-2.71). Cannula size selection was based on the patient's BSA. The indication for VV-ECMO was ARDS in all cases; the etiology of ARDS was pneumonia (N=10, 36%), massive aspiration (N=7, 25%), blunt trauma (N=8, 29%), and drowning (N=3, 10%). Bedside cannulation was successful in 27 of 28 cases (97%), and there was no mortality or morbidity associated with the procedure. The failed cannulation was in the case of a young woman who hanged herself. Percutaneous access to the right IJV failed due to massive subcutaneous emphysema; she was cannulated using a peripheral veno-arterial configuration via the femoral vessels. ECMO blood flow achieved was > 60% of native cardiac output in all cases. The median days of VV-ECMO support was 8 (range 1-37). Twenty of 28 patients (71%) undergoing VV-ECMO support survived to hospital discharge.

Strategy and tips for cannulation:

We designed a process of in-situ VV-ECMO cannulation based on the layout of our intensive care unit (ICU) where patients with refractory respiratory failure are routinely hospitalized (fig. 1). We utilize a portable fluoroscopy bed which is placed to the side of the ICU bed (fig. 2). After moving the patient from the ICU to the fluoroscopy bed, the medical equipment is positioned around the patient to allow convenient access to the right side of the neck as the cannula insertion site (fig. 3). The procedure is completed under sterile conditions with fluoroscopic guidance. Fluoroscopic guidance represent our preferred imaging method since it may offer the highest level of safety (9,11). However, in the absence of conditions allowing routine use of fluoroscopy at the bedside, the procedure can also be safely performed with transthoracic echocardiogram (TTE) to confirm guidewire and cannula positioning (9, 17-19). Appropriate positioning of the wire can be confirmed with subcostal views, making sure that the guidewire is advanced into the retro-hepatic inferior vena cava (IVC) (9, 18-23). Alternatively, imaging by portable chest X-ray can also be used to spot check guidewire and cannula position (16).

Cannulation best practices using our approach are listed in table 1. We always use real-time ultrasound visualization for the puncture of the IJV. The patient is maintained in slight Trendelenburg position for the entire duration of the procedure to reduce the risk of venous air-embolism. The guidewire is advanced deep into the retrohepatic IVC and its position is confirmed by imaging. We used the standard packaging of the Avalon Elite[®] venous cannula kit (0.038" x 210 cm change guidewire) in all cases (table 2). After serial dilation of the skin and soft tissue at the cannula insertion site, the IJV is cannulated with 10 Fr through 30 Fr dilators. The cannula is inserted under imaging guidance ensuring no resistance is encountered while the catheter is advanced through the right atrium into the IVC. The cannula is connected to the ECMO circuit with meticulous de-airing and is secured to the skin once final manual manipulation is made to ensure adequate extracorporeal blood flow and desired arterial oxygenation (table 1).

Discussion

In our experience, the procedure of bedside VV-ECMO cannulation was safe and effective. We had only one case of failed IJV single-cannula insertion which required veno-arterial cannulation using the common femoral artery and vein due to anatomic constraints. All procedures were performed in the ICU under fluoroscopic and echocardiographic guidance. Our set-up allowed the efficient utilization of fluoroscopy by using a mobile, x-ray compatible bed (figures 1,2)). We selected the use of a bicaval dual-lumen cannula whenever indicated to facilitate adequate ECMO flow and optimize blood oxygenation by reducing "recirculation" (5,12,24). Although there is a lack of randomized trials comparing the effectiveness of the single dual-lumen versus a double venous cannulation strategy, clinical data and experimental studies show at least comparable flow-parameters and clinical results (24, 25). Nonetheless, the location of the cannula on the side of the neck, as compared to the groin, provides more opportunity for patient mobilization and may offer significant

advantages in light of the fact that VV-ECMO support is often required for a considerable length of time.

The benefits of in-situ ECMO cannulation, not only in terms of potentially expediting the timing of initiation of therapy and decreasing the hazard of transporting the patient to the procedural location, appears of crucial importance during the COVID-19 pandemic in the extreme cases of respiratory decompensation and refractory hypoxemia which may benefit from VV-ECMO support. Avoidance of transporting the patient out of the ICU to reach the designated cannulation location reduces the risk of SARS-CoV-2 virus transmission to other patients and healthcare providers while also decreasing the risk of environmental contamination inevitably associated with the transportation process, and possibly decreasing unnecessary personal-protective-equipment (PPE) usage outside of the ICU. The use of fluoroscopic guidance has represented the standard for our protocol, however cannulation can also be safely completed using echocardiographic imaging with TTE or even using portable chest x-ray, which can be both routinely arranged at any healthcare facility. No matter of the imaging technique used, single venous cannulation with bicaval dual-lumen catheter remains a highly demanding procedure with risk of life-threatening complications, so that it should be performed by experienced operators in highly specialized centers (21,23,26).

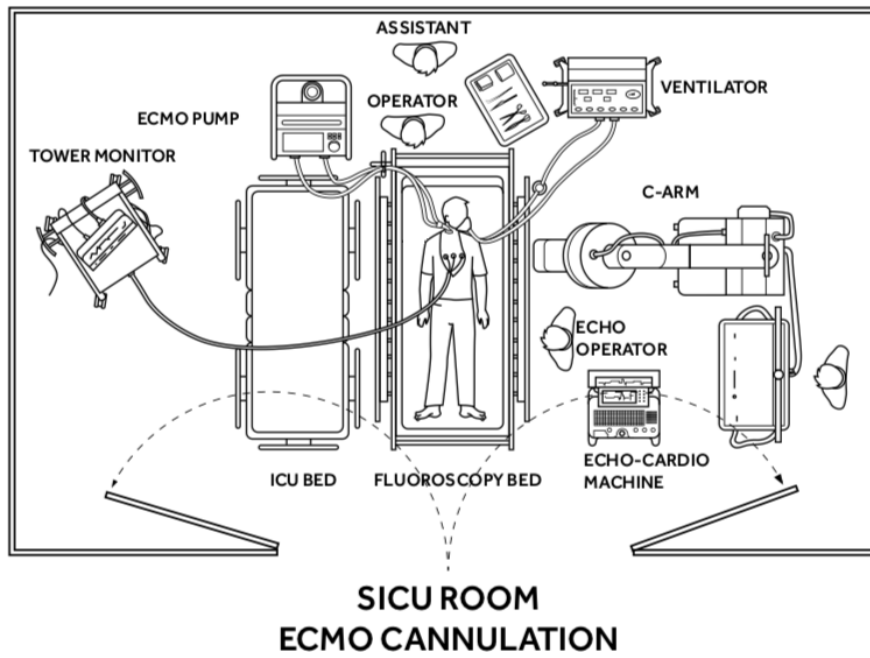
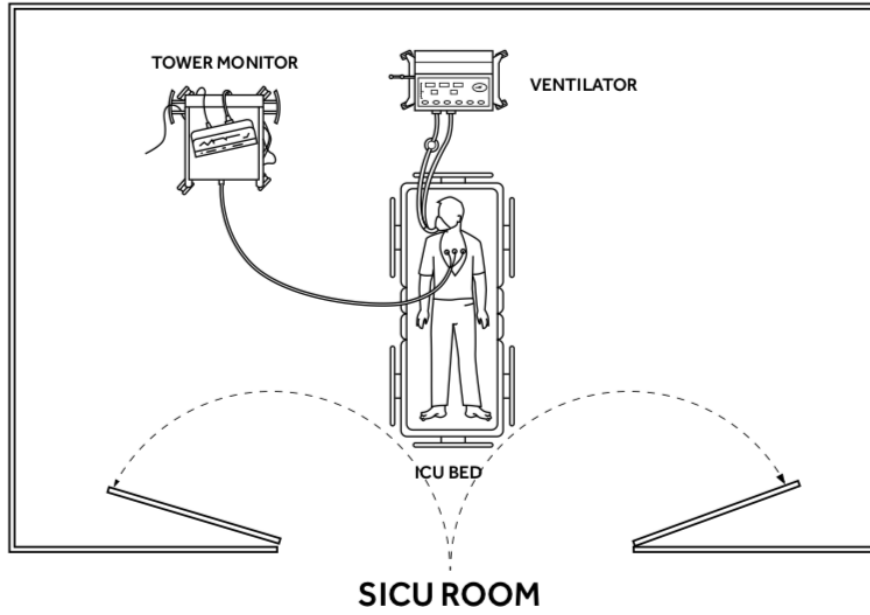
Conclusions

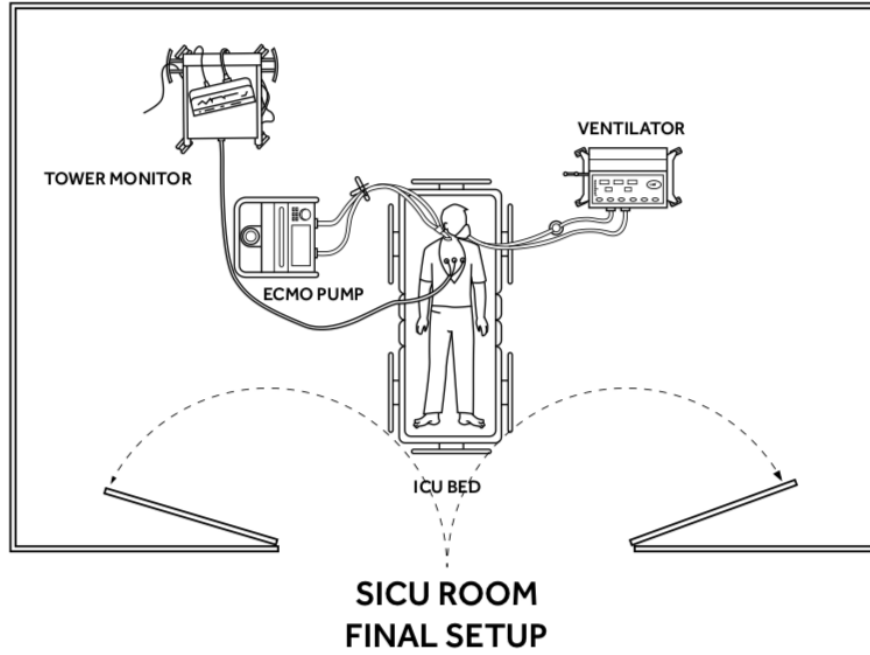
Our experience shows that adequate planning of veno-venous ECMO cannulation allows safe completion of the procedure at bedside. This strategy can be particularly useful in patients with refractory hypoxemia due to COVID-19 associated severe ARDS as bedside cannulation can minimize the inadvertent nosocomial transmission of this highly contagious disease. Veno-venous ECMO management is resource-intensive and limited to specialized referral centers but can be used as salvage therapy in patients with refractory respiratory failure who have preserved life-expectancy and few associated end-organ failures. Certainly, we acknowledge the ethical dilemma of patient selection for access to life-sustaining extracorporeal support during this pandemic. Nonetheless, the opportunity of saving even a relatively small number of patients in comparison to the large loss of lives produced by this highly lethal disease cannot be ignored.

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