Intraoperative Transesophageal Echocardiography–Guided Placement of Bicaval Dual-Lumen Extracorporeal Membrane Oxygenation Cannula

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INTRODUCTION

Live imaging with intraoperative transesophageal echocardiography (TEE) is frequently used to guide placement for interventional cardiothoracic procedures. The Avalon Bi-Caval Dual Lumen Catheter (Avalon Laboratories, Rancho Dominguez, CA) can establish venovenous (VV) extracorporeal membrane oxygenation (ECMO) with single cannulation via the right internal jugular vein. The Avalon Bi-Caval Dual Lumen Catheter is a single-cannula VV ECMO system used in patients with isolated severe respiratory failure and preserved cardiac function. Historically, VV ECMO has been achieved using dual cannulation via the jugular and femoral veins.[1] Advantages of single-site VV ECMO include increased patient mobility, less site infection, and decreased chance of accidental dislodgement.[2]

The Avalon cannula has proximal and distal inflow orifices in the superior vena cava and inferior vena cava (IVC) to drain deoxygenated blood (Figure 1). The outflow port is aimed toward the tricuspid valve to deliver oxygenated blood through the valve and into the right ventricle. TEE is used to guide placement of the cannula as well as evaluate the final position and directionality of outflow once VV ECMO has been initiated. Malposition of the cannula may cause low ECMO flow or hypoxia because of recirculation. Despite proper placement, cannula migration into the hepatic vein or right ventricle is possible postoperatively.[4] The following case describes the use of TEE to optimize the position of the cannula tip using two-dimensional echocardiography and ensure laminar outflow through the tricuspid valve using color flow Doppler.

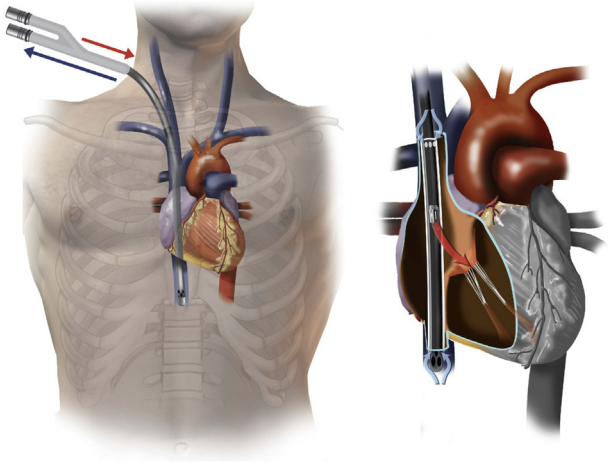

Figure 1 Illustration of Avalon Bi-Caval Dual Lumen cannula in correct position. Reproduced with permission from Hirose *et al*.[3]

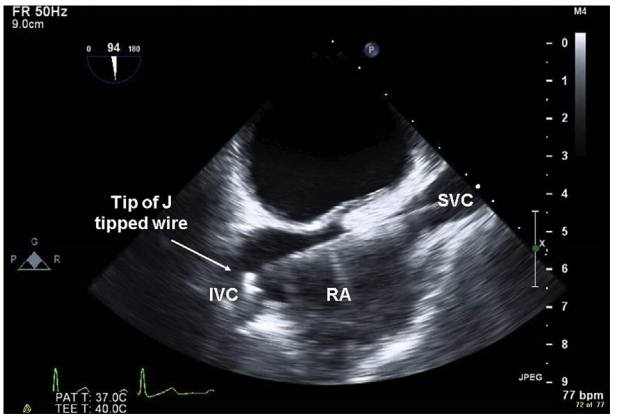

Figure 2 Midesophageal bicaval view showing termination of J-tipped wire in the IVC. *RA*, Right atrium; *SVC*, superior vena cava.

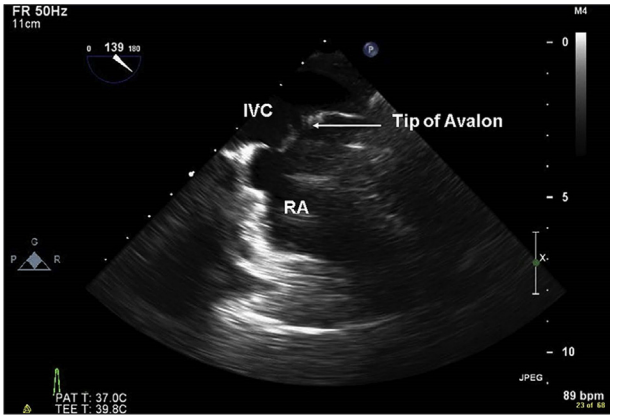

Figure 3 Midesophageal modified bicaval view demonstrating the tip of the Avalon catheter at the cavoatrial junction. *RA*, Right atrium.

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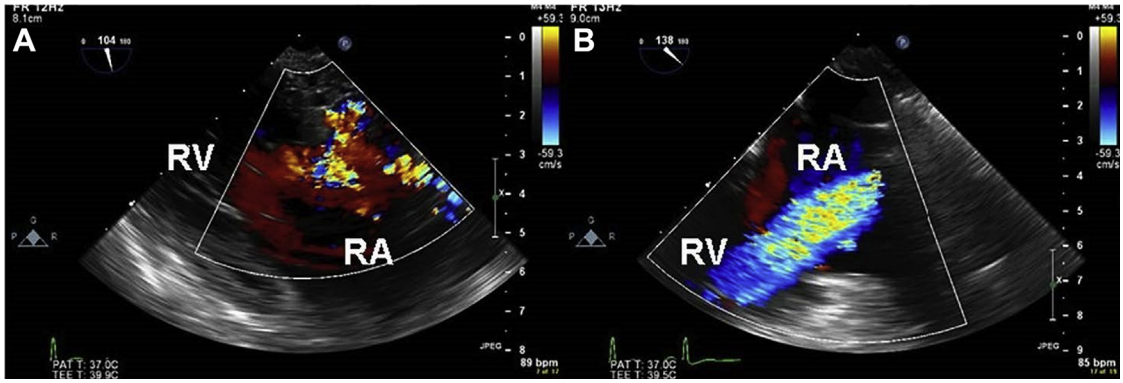

Figure 4 **(A)** Transgastric RV inflow (*left*) demonstrates turbulent outflow from the Avalon catheter, directed at the posterior leaflet. **(B)** After repositioning, the midesophageal modified bicaval view (*right*) best shows improvement of laminar flow directed through the tricuspid valve. *RA*, Right atrium; *RV*, right ventricle.

Table 1 Transesophageal echocardiographic views for Avalon VV ECMO cannulation

View	Modality	Key echocardiographic findings
Midesophageal RV inflow-outflow	2D, CFD	Laminar vs turbulent outflow across tricuspid valve
Midesophageal bicaval	2D	Visualize the tip of the catheter just distal to cavoatrial junction
Midesophageal modified bicaval	CFD	Laminar vs turbulent outflow across tricuspid valve
Transgastric RV inflow	CFD	Look for laminar vs turbulent outflow across tricuspid valve

CFD, Color flow Doppler; *RV*, right ventricular; *2D*, two-dimensional.

CASE PRESENTATION

We present the case of a 30-year-old man with a medical history of polysubstance abuse who developed severe respiratory failure secondary to inhalation injury. He remained hypoxic despite maximum mechanical ventilator support and was brought to the operating room for placement of bicaval double-lumen VV ECMO under fluoroscopy. Intraoperative TEE and fluoroscopy were used to confirm wire placement from the right internal jugular vein into the IVC. The midesophageal bicaval view was used to show progression of the wire from the superior vena cava to the right atrium to termination of the J-tipped wire in the IVC (Figure 2). After serial dilation with the Seldinger technique, a 31-Fr Avalon cannula was placed without complication. Figure 3 shows the tip of the Avalon cannula as it was advanced through the right atrium. TEE revealed posteriorly directed outflow, with turbulent flow through the tricuspid valve (Figure 4A, Video 1). Oxygen saturation improved from 82% to 90%. Because of only partially improved oxygenation and the findings on TEE, the cannula was pulled back 4 cm so that the tip of the catheter was 2 cm distal to the cavoatrial junction. Color flow Doppler revealed a laminar flow jet directed through the tricuspid valve into the right ventricle (Figure 4B, Video 2). Oxygenation saturation improved immediately, from 90% to 98%, and the cannula was sutured in place and sterile dressing applied.

DISCUSSION

VV ECMO has historically required dual cannulation. The development of newer devices, such as the Avalon Bi-Caval Dual Lumen Catheter, enable single-cannulation VV ECMO via the right internal jugular vein.[5] When the femoral vein is spared, patients are more mobile and more able to participate in physical therapy. The infection rate may also be lower when the femoral vein is spared from cannulation.[5]

Complications of Avalon placement include superior vena cava injury during serial dilation, migration, right ventricular injury, and tamponade.[4-6] To properly position an Avalon catheter, the tip of the cannula is advanced under transesophageal echocardiographic guidance until it is past the IVC–right atrium junction and outflow is directed through the tricuspid valve on color flow Doppler. If flow is directed toward the wall of the right atrium or toward a leaflet of the tricuspid valve, turbulent flow would be visualized. It is best to advance and withdraw the cannula under transesophageal echocardiographic guidance until flow is laminar and directed through the center of the tricuspid valve. Optimal position to avoid migration into the right ventricle or hepatic vein is to ensure that the tip is past the junction of the IVC and right atrium but not so deep that flow is directed toward the posterior tricuspid valve leaflet or the inferior wall of the right atrium. A malpositioned cannula will cause recirculation, as the outflow of oxygenated blood from the cannula is drained into the inflow cannula of the ECMO circuit immediately, before first being circulated systematically.[2] If the outflow is not laminar and directed through the center of the tricuspid valve, this will increase the amount of oxygenated blood that is recirculated.

Avoidance of recirculation is best achieved using both fluoroscopy and intraoperative TEE. Boucourt and Teichgraber[5] reported a case series of safe placement of Avalon catheters in the interventional radiology suite using fluoroscopy and contrast. If a patient is thought to be unstable for transport, successful placement may be achieved using chest radiography in place of fluoroscopy in the intensive care unit. Table 1 shows the key transesophageal echocardiographic views for guidance of cannula placement. TEE allows the provider to visualize the wire and cannula placement and to ensure correct direction of flow with color flow Doppler.

CONCLUSION

TEE is essential to guide placement of the newer single-cannula VV ECMO Avalon catheter. Correct positioning is imperative to ensure adequate ECMO flows and avoidance of recirculation leading to hypoxia. Key views are the midesophageal right ventricular inflow-outflow, midesophageal bicaval, and transgastric right ventricular inflow. Communication between the surgeon and echocardiographer is important for successful positioning.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.case.2017.04.002.

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