Transesophageal Echocardiographic Guidance of Venovenous Extracorporeal Membrane Oxygenation Cannula (Avalon Cannula) Repositioning

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INTRODUCTION

In acute respiratory distress syndrome (ARDS) with severe hypoxemia or respiratory acidosis, venovenous extracorporeal membrane oxygenation (VV-ECMO) has become an integral part of contemporary management. Suboptimal positioning of the Avalon cannula (Avalon, Rancho Dominguez, CA) is uncommon. However, it is vitally important when suboptimal positioning of the Avalon cannula occurs that it be recognized, with appropriate repositioning performed under echocardiographic guidance.

CASE PRESENTATION

A 47-year-old man was involved in a motor vehicle accident resulting in multiple rib fractures, cardiopulmonary contusion, and an anterior wall myocardial infarction secondary to dissection of the left anterior descending coronary artery. Peak serum troponin T was >50 ng/mL (normal range, 0.000–0.029 ng/mL), and creatine

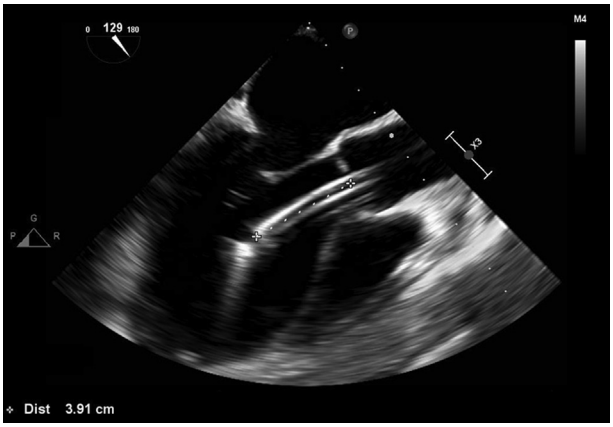

Figure 1 TEE (midesophageal long-axis view at 129°) in a patient with an Impella CP, demonstrating appropriate placement, with the distal port at about 4 cm from the annular plane. *Dist*, Distance.

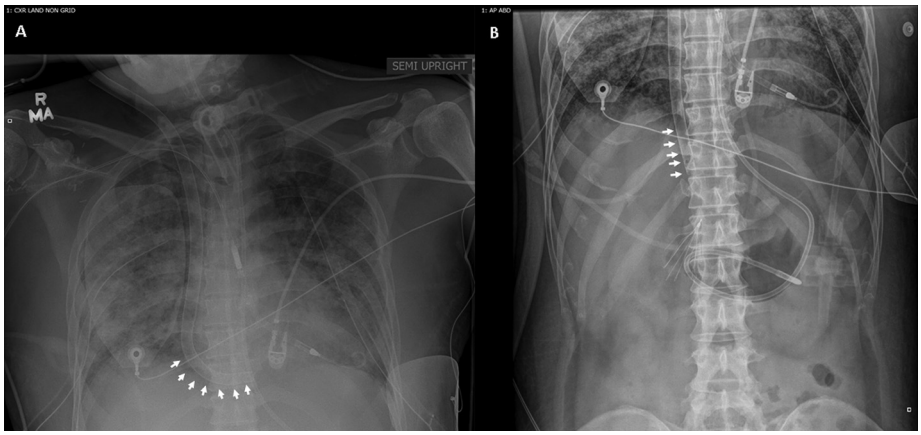

Figure 2 **(A)** Portable chest radiography demonstrating the large Avalon catheter starting at the right internal jugular vein, coursing through the superior vena cava (SVC) and into the right atrium (RA). It became coiled around the tricuspid annulus, with the distal port facing leftward (*arrows*). Additionally, the Impella CP, bilateral chest tubes, and nasogastric and tracheostomy tubes could be visualized. Note the diffuse bilateral pulmonary infiltrates secondary to ARDS. **(B)** Portable radiography demonstrating the orientation of the distal port of the Avalon catheter after TEE-guided reposition (*arrows*). Again, note the Impella CP, nasogastric and bilateral chest tubes, and IVC filter.

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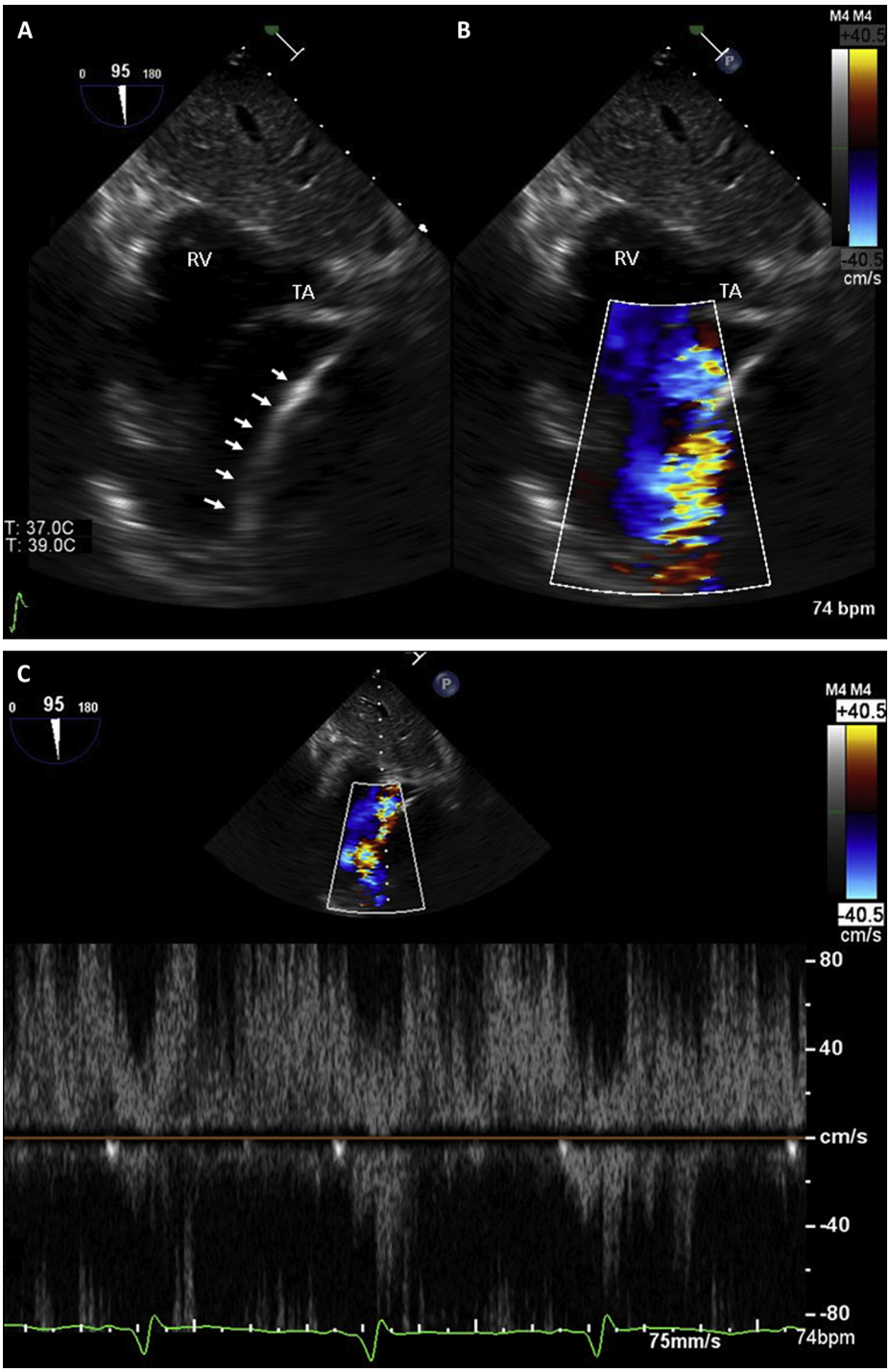

Figure 3 **(A)** TEE (deep transgastric view at 95° with clockwise rotation) to allow visualization of the right ventricle (RV) and the VV-ECMO cannula (*white arrows*), which coils over the tricuspid annulus (TA) and does not enter the IVC. **(B)** Color Doppler demonstrated continuous flow originating from the outflow port located in the suboptimal proximal position at the high right atrial level. **(C)** TEE (deep transgastric view at 95°) with continuous-wave Doppler demonstrating the continuous outflow from the most proximal port of the VV-ECMO cannula.

kinase MB was significantly elevated at >1,000 ng/mL (normal range, 0.0–2.4 ng/mL). He received multiple overlapping stents extending from the left main trunk to the distal left anterior descending coronary artery. The left circumflex coronary artery was jailed during the complex stenting procedure. Initial transthoracic echocardiography revealed a left ventricular ejection fraction of 25%, with akinesis of the entire anterior, anteroseptal, and anterolateral walls. There was also severe mitral regurgitation. The patient was supported hemodynamically by an intra-aortic balloon pump and multiple inotropes at the time of arrival to our institution. However, soon after arrival, his

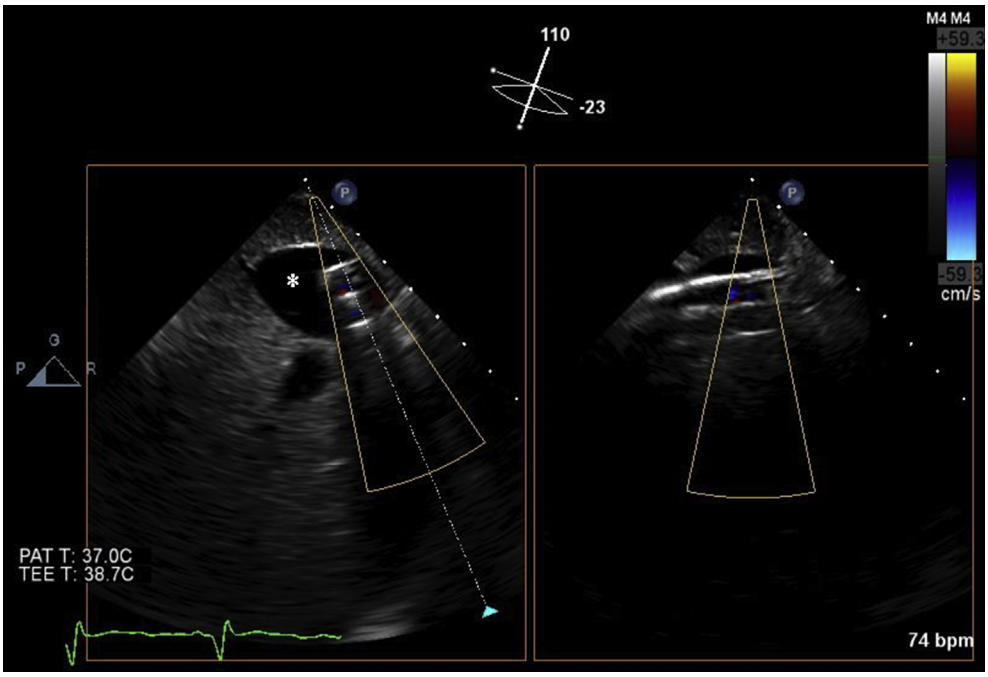

Figure 4 TEE-guided repositioning of the VV-ECMO cannula. Deep transgastric view with biplane assessment of the proximal IVC (*asterisk*), demonstrating adequate placement of the distal port of the VV-ECMO cannula. *PAT*, Patient.

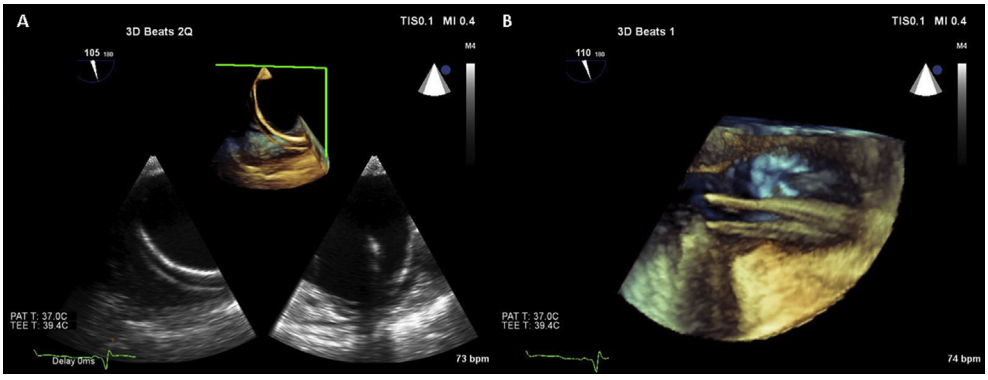

Figure 5 **(A)** TEE (three-dimensional [3D] midesophageal view) of the misplaced VV-ECMO cannula, which appeared coiled over the tricuspid annulus. **(B)** After TEE-guided repositioning, the distal end of the VV-ECMO cannula appeared straight, rather than curved and coiled, and was free within the IVC. *PAT*, Patient.

hemodynamics continued to deteriorate, resulting in the need for placement of a right axillary Impella CP (Abiomed, Danvers, MA) (Figure 1, Video 1) as a bridge to left ventricular assist device placement. Subsequently, his hospitalization course was further complicated by the development of ARDS and rapid clinical deterioration despite conventional ventilation and adjunctive supportive measures. A decision was made to institute a form of VV-ECMO with a bicaval double-lumen Avalon cannula in the right internal jugular venous position. The right internal jugular vein was accessed, and a stiff wire was placed, extending into the inferior vena cava (IVC). The right internal jugular vein was then serially dilated, and a size 31 Avalon cannula was inserted without additional echocardiographic guidance. Approximately 4 hours after insertion of the Avalon cannula, increasingly frequent episodes of nonsustained monomorphic and polymorphic ventricular tachycardia occurred, requiring multiple external defibrillations, despite continuous infusions of amiodarone (at 1 mg/min) and procainamide (at 1 mg/min). Portable chest radiography subsequently revealed suboptimal location of the distal end of the Avalon catheter (Figure 2A). The tip of the catheter appeared to coil at the tricuspid annulus without proper termination within the IVC. Transesophageal echocardiography (TEE) was performed to assist in the guidance of appropriate repositioning and placement of the distal cannula. Initially, the IVC was not optimally imaged beyond the inferior cavoatrial junction from the midesophageal bicaval view. Alternative deep transgastric views were successfully used in the subsequent assessment, resulting in guidance of optimal cannula repositioning (Figures 3-6, Videos 2-6). Despite appropriate repositioning of the Avalon cannula, the patient continued to deteriorate clinically, with his intensive care unit admission complicated by refractory ventricular tachycardias requiring ablation, failure of the right axillary Impella CP requiring replacement, and ultimately multiple-organ failure resulting in cardiac arrest. The patient died on hospital admission day 54.

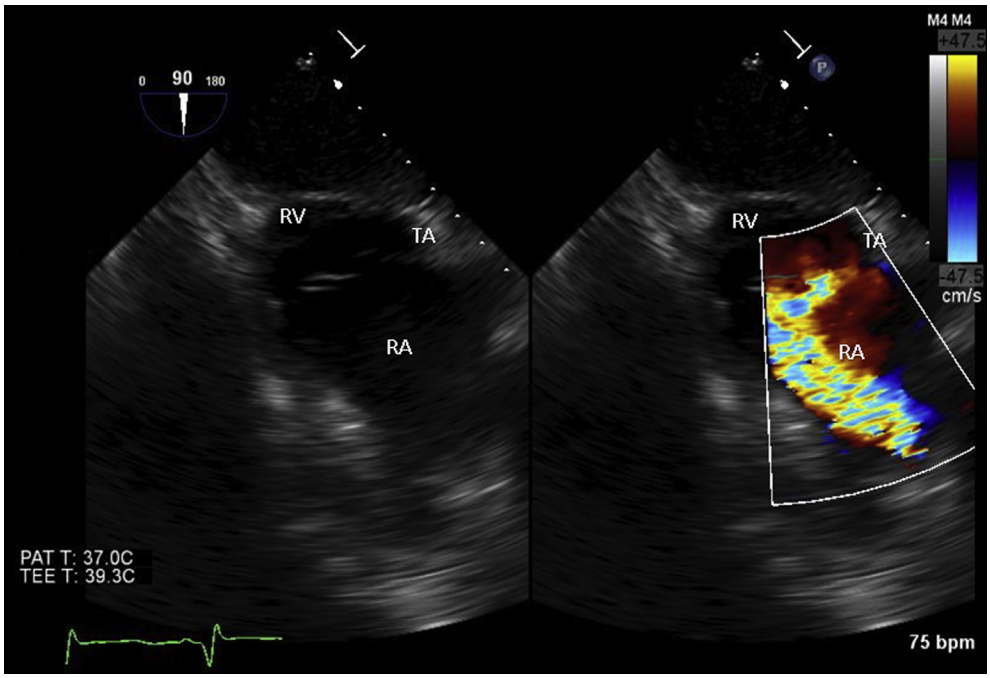

Figure 6 TEE (deep transgastric view at 90° with clockwise rotation) to allow visualization of the right ventricle (RV) and the tricuspid annulus (TA). Color Doppler following cannula repositioning demonstrated optimal jet flow directed toward the RV inflow. *PAT*, Patient; *RA*, right atrium.

DISCUSSION

In ARDS with severe hypoxemia or respiratory acidosis, VV-ECMO has become an integral part of contemporary management. Since the introduction of the Avalon cannula into clinical practice,[1,2] the dual-lumen single catheter has become the method of choice for VV-ECMO, as it establishes VV-ECMO with a single cannulation via right internal jugular venous cannulation. Although effective placement under initial fluoroscopic and/or transesophageal guidance is achieved in most patients, the need for repositioning exists. In a case series of 27 patients, one patient (4%) required repositioning.[3] Malposition of this cannula can cause inadequate ECMO flow, hypoxia, and structural injuries with potentially fatal outcomes, such as right ventricular rupture, tamponade, and unintentional cannulation of the hepatic veins and coronary sinus.[4,5] TEE and transthoracic echocardiography,[6] as well as fluoroscopy, have been reported as useful imaging techniques in the early detection and prevention of potential life-threatening complications.[4,5,7] Migration of the distal cannula into the hepatic vein and the right ventricle has been reported, with subsequent successful repositioning under transesophageal echocardiographic guidance without the use of a guidewire, fluoroscopy, discontinuation of extracorporeal membrane oxygenation, or bleeding.[8]

Appropriate positioning of the cannula is achieved when the distal drainage port is located within the IVC below the hepatic veins, while the proximal drainage port lies in the superior vena cava. This allows the outflow jet originating from the return port within the midright atrium to be directed toward the tricuspid valve and right ventricular inflow. Transesophageal echocardiographic guidance of appropriate dual-lumen VV-ECMO cannula placement was previously described in a patient with ARDS and extreme obesity.[9] From a technical point of view, in addition to standard midesophageal views, dedicated deep gastric views on TEE, allowing clear visualization of the right ventricle, tricuspid valve annulus, and IVC, are particularly important for the guidance of repositioning of the Avalon cannula.

Advanced echocardiography during VV-ECMO support is of particular interest to cardiac intensivists, as the data that can be obtained provide immediate accurate assessment, with a direct impact on the plan of care of complex patients with unpredictable hemodynamic changes and challenging transthoracic echocardiographic windows. However, the rate of utilization of advanced TEE during VV-ECMO support varies significantly from center to center.[10] This case report exemplifies the contemporary clinical value of TEE in the daily management of cardiac critical care patients.

CONCLUSION

TEE is the ideal imaging modality to guide adequate placement and repositioning of bicaval double-lumen catheters for VV-ECMO, as it combines readily portable availability with excellent accuracy in the early recognition and prevention of emergency situations.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.case.2017.04.006.

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