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Utility of three-dimensional transesophageal echocardiography to guide transseptal positioning of a single multistage venous cannula to provide both venous drainage and indirect left ventricular venting in veno-arterial extracorporeal membrane oxygenation

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Abstract

A patient with heart failure due to dilated ischemic cardiomyopathy presented in cardiogenic shock for institution of veno-arterial extracorporeal membrane oxygenation as a bridge to cardiac transplantation. To provide adequate venous drainage and simultaneous decompression of the left atrium (indirect left ventricular venting), a single venous cannula was placed across the interatrial septum so that the distal orifice and side ports were located within the left atrium and the proximal set of side ports were positioned at the cavoatrial junction. Three-dimensional transesophageal echocardiography demonstrated utility in guiding cannula placement and appropriate positioning within the left atrium.

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CONFLICT OF INTEREST

Drs. Addis, Wang, Watts, Nanda, and Prejean have no financial disclosures to declare. Dr Ahmed serves as a consultant and proctor for Abbott, Edwards, and Medtronic.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

Keywords

cannulation; decompression; ECMO; three-dimensional echocardiography; three-dimensional transesophageal echocardiography; transseptal; venting

1 | INTRODUCTION

A 53-year-old male patient with chronic combined heart failure (HF) due to dilated ischemic cardiomyopathy presented in cardiogenic shock to the hybrid catheterization lab for institution of veno-arterial extracorporeal membrane oxygenation (VA-ECMO) as a bridge to cardiac transplantation. To provide adequate drainage and decompression of both right and left atria, the decision was made to place a single venous cannula across the interatrial septum (IAS) with the goal of positioning the distal orifice and side ports within the left atrium (LA) and the proximal set of side ports within the right atrium (RA) or inferior vena cava (IVC) for left atrial veno-arterial (LAVA)-ECMO.^{1,2} Three-dimensional (3D) transesophageal echocardiography (TEE) was employed to guide cannula placement and positioning.

2 | CASE REPORT

Arterial and venous femoral sheaths were placed, general anesthesia was induced, the patient intubated, and a TEE probe placed (Movie S1). TEE revealed biventricular dysfunction with a severely dilated left ventricle (LV) (12.1 cm at end-diastole) (Figure 1), a LV ejection fraction of <10%, spontaneous echo contrast in all chambers but no thrombus appreciated, severe mitral and tricuspid regurgitation, a mitral annuloplasty ring, mild central aortic insufficiency (AI), and a dilated pulmonary valve annulus (3.8 cm) with mild insufficiency. A 6F, 24 cm sheath was placed in the superficial femoral artery for antegrade perfusion of the extremity. Under direct, continuous TEE guidance, a BRK needle (St. Jude Medical) was employed for transseptal puncture (Movie S2) and a ProTrack Pigtail Wire (Baylis Medical) was inserted. Atrial septostomy was performed with a 6 mm × 40 mm peripheral balloon (Movie S3), and the venous tract was dilated to accommodate the venous cannula. A 23F Medtronic Bio-Medicus NextGen multistage venous cannula (Medtronic) was placed and guided in real time across the IAS using a combination of live 2D and 3D TEE imaging (Movies S4 and S6). Positioning of the venous cannula was achieved using 3D imaging to optimize distance across the IAS, ensure location of distal orifice and side ports in relation to the IAS, and avoid damage or interaction with intracardiac structures (Figures 2,3,4) (Movies S6 and S7). Specifically, 3D imaging was integral to visualize the relationship of the distal tip of the cannula and side ports to the aorta, the IAS, and the mitral valve. An orientation of the image to project a view from the perspective of the base of the heart was particularly useful (Figure 4, Movie S7). Measurements were obtained “online” at the time of positioning utilizing 3D multiplanar reconstruction (3DQ QLAB, Philips Medical Systems, Best, Netherlands) with offline demonstration of workflow used to align three planes for cannula measurement presented in Figure 5 (4D CARDIOVIEW (v 2.30), TOMTEC Corporation USA).

LAVA-ECMO was initiated and flows adjusted to balance chamber decompression and to allow for continued opening of the aortic valve with each cardiac cycle. Color Doppler inflow was noted through the distal tip and side ports of the cannula within the LA (Figure 6, Movie S8). The patient was extubated uneventfully and returned to the cardiothoracic intensive care unit. The patient demonstrated symptomatic improvement and was able to ambulate in the hallways of the unit with assistance. Two days after initiation of VA-ECMO, the patient underwent orthotopic heart transplantation. He is currently doing well.

3 | DISCUSSION

VA-ECMO can serve as a bridge to cardiac transplantation in patients with cardiogenic shock. In peripheral VA-ECMO, the arterial cannula provides retrograde flow toward the aortic valve which increases the afterload. Blood continues to fill the LV through normal myocardial blood drainage (Thebesian veins), any systemic venous return that flows past the ECMO cannula without being entrained, and in some patients through AI.³ When this LV volume cannot be fully ejected against the increased afterload, it leads to progressive LV distention, increased wall stress, and ultimately myocardial oxygen utilization. In patients with an incompetent mitral valve (as in our case), this pressure is transmitted into the LA leading to increases in LA pressure and potentially precipitating the development or worsening of cardiogenic pulmonary edema. LV distention in patients on VA-ECMO is associated with impaired myocardial recovery⁴, and LV decompression appears to decrease mortality and improve the likelihood of successful eventual weaning.^{5,6} For these reasons, multiple LV venting strategies have been developed, though there are no guidelines regarding patient selection for and timing of LV venting in VA ECMO. In our patient, this decision was driven by the presence of several factors recognized as indications for LV venting including; severe, persistent LV dysfunction, markedly dilated left ventricular chamber with elevated pressures refractory to optimal medical therapy, and a concern that the observed AI severity could substantially worsen with the increased afterload of peripheral VA-ECMO.⁷ Recently, bi-atrial drainage through a single venous cannula for LAVA-ECMO has been described.^{1,2} The decision to place a single venous cannula for LAVA-ECMO was based upon a desire to avoid placement of an additional femoral cannula that would have further interfered with patient ambulation, and avoidance of the need to incorporate an additional drainage cannula into the ECMO circuit with the need for additional tubing, a flow probe, and a flow-regulating clamp. We describe the first report of 3D TEE to guide placement of a single LAVA-ECMO venous cannula. In our case, 3D TEE including live 3D imaging along with “online” measurements obtained at the time of positioning utilizing 3D multiplanar reconstruction was particularly useful. There are several important complications that can arise during transseptal ECMO cannulation including cardiac tamponade due to inadvertent puncture of the right atrial or left atrial walls, damage to the aortic root or proximal ascending aorta, and mal-positioning of distal side ports. 3D imaging provided real time visualization of the cannula and side ports, the IAS, chamber walls, and the aortic root during positioning that aided in avoidance of complications. Furthermore, offline demonstration of workflow used to align three planes for cannula measurement is presented.

4 | CONCLUSION

3D TEE demonstrates utility in the placement and positioning of a single femoral venous cannula across the IAS to provide drainage of both left and right atria for initiation of LAVA-ECMO. This approach is feasible in appropriate patients and may provide both adequate venous drainage as well as indirect left ventricular venting. 3D TEE adds increased confidence in the positioning of the distal and proximal ports required for bi-atrial drainage.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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FIGURE 1.

Modified mid-esophageal 4-chamber two-dimensional TEE view obtained prior to cannulation demonstrating severe left ventricular dilation and increased sphericity. LV = left ventricle; MV = mitral valve; RV = right ventricle; TEE = transesophageal echocardiography

FIGURE 2.

Live three-dimensional (3D) TEE image obtained during positioning of the venous cannula across the interatrial septum (IAS) used for guidance and as the source image to perform multiplanar reconstruction to measure the distance the cannula tip extended across the IAS. AV = aortic valve; MV = mitral valve; TEE = transesophageal echocardiography; TV = tricuspid valve

FIGURE 3.

Live 3D TEE image of the final cannula tip position within the left atrium (LA). The green line displays the measured distance of the cannula across the IAS (43 mm) projected onto three-dimensional space. This measurement was obtained using multiplanar reconstruction for optimal plane alignment just as performed on the ultrasound system in the catheterization laboratory at the time of cannulation (see Figure 5). IAS = interatrial septum; MV = mitral valve; TEE = transesophageal echocardiography

FIGURE 4.

Live 3D TEE image projected to demonstrate a basal view of the heart aligned in anatomical position to demonstrate the course of the venous cannula across the IAS. AV = aortic valve; IAS = interatrial septum; MV = mitral valve; TEE = transesophageal echocardiography; TV = tricuspid valve

FIGURE 5. Multiplanar reconstruction of a 3D dataset (Figure 2 demonstrates original 3D capture) demonstrating plane alignment on the venous cannula used to accurately measure the distance the cannula tip projected into the left atrium

FIGURE 6.

Nonstandard TEE window demonstrating final position of a 23F multistage venous cannula with color Doppler flow noted at the distal tip and side ports after initiation of left atrial veno-arterial (LAVA)-ECMO. IAS = interatrial septum; TEE = transesophageal echocardiography