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.

Dylan Addis[1], Bo Wang[1], Shane Prejean[2], T. Watts[2], Navin C. Nanda[3], and Mustafa Ahmed[2]

[1]UAB
[2]University of Alabama at Birmingham
[3]Affiliation not available

August 6, 2020

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 the distal orifice and side ports were located within the left atrium and the proximal set of side ports at the cavoatrial junction. Three-dimensional transesophageal echocardiography demonstrated utility in guiding cannula placement and appropriate positioning within the left atrium.

KEYWORDS

Three-dimensional echocardiography, ECMO, transseptal, cannulation, venting, decompression, three-dimensional transesophageal echocardiography

INTRODUCTION

A 53 year-old male 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.

CASE REPORT

Arterial and venous femoral sheaths were placed, general anesthesia was induced, the patient intubated, and a transesophageal echocardiography (TEE) probe placed (**Movie 1)** . 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 (3.8cm) with mild insufficiency. A 6F, 24cm 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, Minnesota, USA) was employed for transseptal puncture (**Movie 2**) and a ProTrack Pigtail Wire (Baylis Medical, Texas, USA) was inserted. Atrial septostomy was performed with a 6mm x 40mm peripheral balloon (**Movie 3**) and the venous tract was dilated to accommodate the venous cannula. A 23F Medtronic Bio-Medicus NextGen Multistage Venous Cannula (Medtronic, Minnesota, USA) was placed and guided in real-time across the IAS using a combination of live 2D and 3D TEE imaging (**Movies 4 and 6**). 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 2-4)** (**Movies 6 and 7**). Specifically, 3D imaging was integral to visualizing 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 7**). 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, Illinois, 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**). 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.

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 recovery[4] 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 were particularly useful. Furthermore, offline demonstration of workflow used to align three planes for cannula measurement are presented.

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.

REFERENCES

1. Whiteside HL, Hillerson D, Coots RD, et al. Safety and Efficacy of Left Atrial Veno-Arterial (LAVA) Extracorporeal Membrane Oxygenation for the Management of Cardiogenic Shock. Poster presented at: The Society for Cardiovascular Angiography and Interventions (SCAI) 2020 Scientific Sessions; March 14-16, 2020; Virtual Conference

2. Dulnuan K, Guglin M, Zwischenberger J, et al. Left atrial veno-arterial extracorporeal membrane oxygenation: percutaneous bi-atrial drainage to avoid pulmonary edema in patients with left ventricular systolic dysfunction. *Journal of the American College of Cardiology.* 2018;71(11 Supplement):A1358.

3. Cevasco M, Takayama H, Ando M, et al. Left ventricular distension and venting strategies for patients on venoarterial extracorporeal membrane oxygenation. *J Thorac Dis.*2019;11(4):1676-1683.

4. Truby LK, Takeda K, Mauro C, et al. Incidence and Implications of Left Ventricular Distention During Venoarterial Extracorporeal Membrane Oxygenation Support. *ASAIO J.* 2017;63(3):257-265.

5. Al-Fares AA, Randhawa VK, Englesakis M, et al. Optimal Strategy and Timing of Left Ventricular Venting During Veno-Arterial Extracorporeal Life Support for Adults in Cardiogenic Shock: A Systematic Review and Meta-Analysis. *Circ Heart Fail.* 2019;12(11):e006486.

6. Kowalewski M, Malvindi PG, Zielinski K, et al. Left Ventricle Unloading with Veno-Arterial Extracorporeal Membrane Oxygenation for Cardiogenic Shock. Systematic Review and Meta-Analysis. *J Clin Med.* 2020;9(4).

7. Xie A, Forrest P, Loforte A. Left ventricular decompression in veno-arterial extracorporeal membrane oxygenation. *Ann Cardiothorac Surg.* 2019;8(1):9-18.

FIGURE LEGENDS

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; 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 (43mm) 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 lab at the time of cannulation (see Figure 5). .Other abbreviations as in previous figures.

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. Abbreviations as in previous figures.

Figure 5. Multiplanar reconstruction of a 3-D dataset (Figure 2 demonstrates original 3-D capture) demonstrating plane alignment on the venous cannula used to accurately measure the distance the cannula tip projected into the LA. Abbreviations as in previous figures.

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. Abbreviations as in previous figures.

SUPPLEMENTAL INFORMATION

Movies 1-7

MOVIE LEGENDS

Movie 1. Modified mid-esophageal 4-chamber two-dimensional TEE view obtained prior to cannulation demonstrating severe left ventricular (LV) dilation, increased LV sphericity, and severe LV dysfunction. Spontaneous echo contrast consistent with low flow state is visualized within the LV. MV: mitral valve, RV: right ventricle; TEE: transesophageal echocardiography.

Movie 2. Modified aortic valve short-axis image with the TEE probe retracted slightly and rotated clockwise to center the desired transseptal puncture site in the two-dimensional image. A BRK transseptal puncture needle (St. Jude Medical, Minnesota, USA) is visualized at the center of the image tenting the interatrial septum (IAS). This image is essential to ensure appropriate orientation of the transseptal puncture needle in the anterior and posterior planes. Device leads are seen within the right atrium. TEE: transesophageal echocardiography

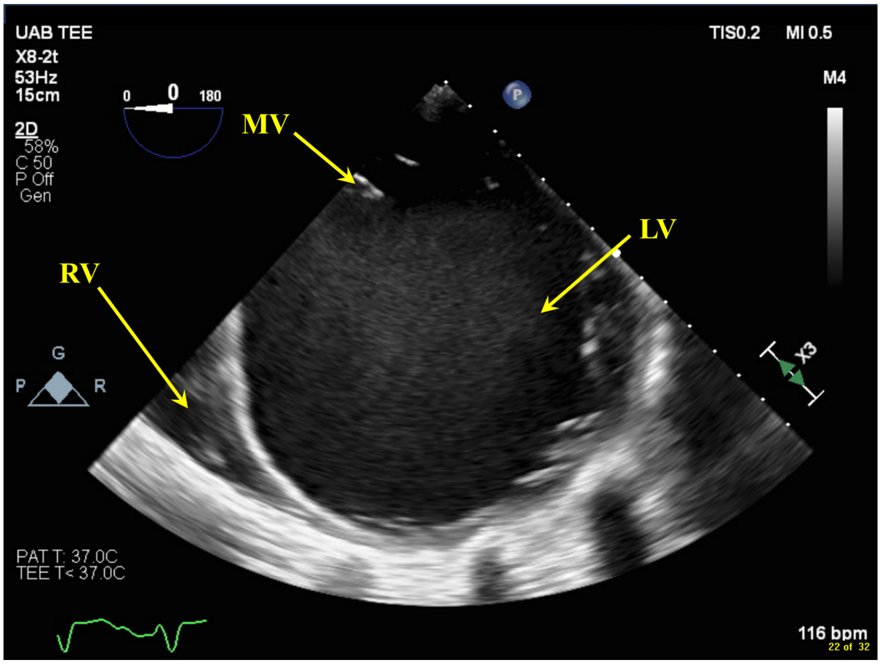
Movie 3. Nonstandard two-dimensional TEE window displaying a 6mm x 40mm peripheral balloon in long axis during atrial septostomy. After transseptal puncture and wire placement in the left atrium (LA), the location of the transseptal puncture site should be confirmed and the balloon position should be visualized in long axis to allow the imager and proceduralist to confirm location and vector prior to balloon septostomy. TEE: transesophageal echocardiography

Movie 4. Nonstandard two-dimensional TEE window demonstrating the advancement of a 23F Medtronic Bio-Medicus NextGen Multistage Venous Cannula (Medtronic, Minnesota, USA) under direct TEE visualization in long-axis. IAS: interatrial septum; TEE: transesophageal echocardiography

Movie 5. Nonstandard two-dimensional TEE window demonstrating positioning of a 23F Medtronic Bio-Medicus NextGen Multistage Venous Cannula (Medtronic, Minnesota, USA) under direct TEE visualization in long-axis after guidewire removal. IAS: interatrial septum; TEE: transesophageal echocardiography

Movie 6. Live three-dimensional (3D) TEE image used to guide and adjust position of the venous cannula and side ports within the left atrium. After satisfactory positioning of the distal and side ports in relation to intracardiac structures and the interatrial septum (IAS) this 3-D dataset was obtained and employed for intraprocedural multiplanar reconstruction to accurately measure the distance across the IAS. MV: mitral valve; TEE: transesophageal echocardiography.

Movie 7. Live 3D TEE dataset oriented to display a view of the heart from a basal to apical projection oriented anatomically to demonstrate final cannula position. 3-D: three-dimensional; AV: aortic valve; MV: mitral valve; TEE: transesophageal echocardiography; TV: tricuspid valve.



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MV
LV
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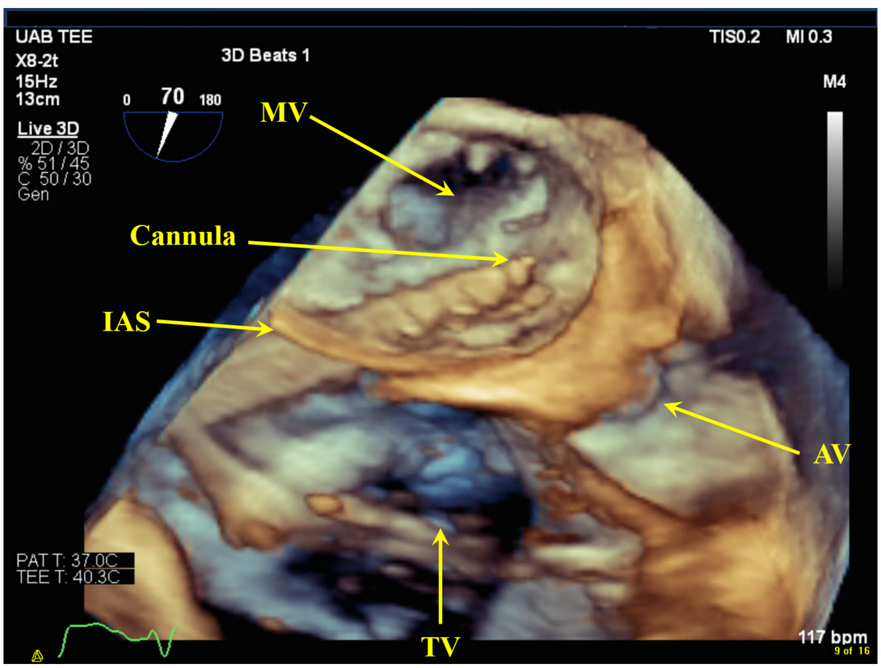
PAT T: 37.0C
TEE T< 37.0C
116 bpm
22 of 32



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15Hz
13cm
Live 3D
2D / 3D
% 51 / 45
C 50 / 30
Gen
3D Beats 1
TIS0.2 MI 0.3
M4
MV
Cannula
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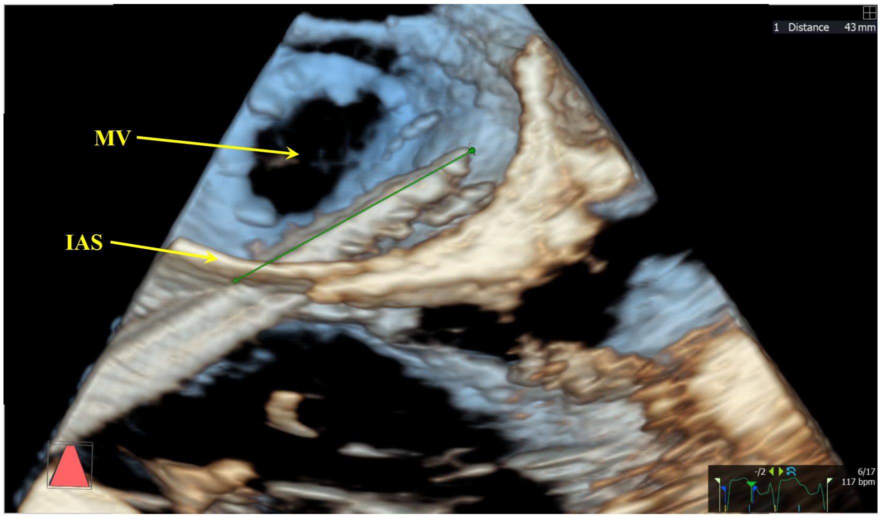
9 of 16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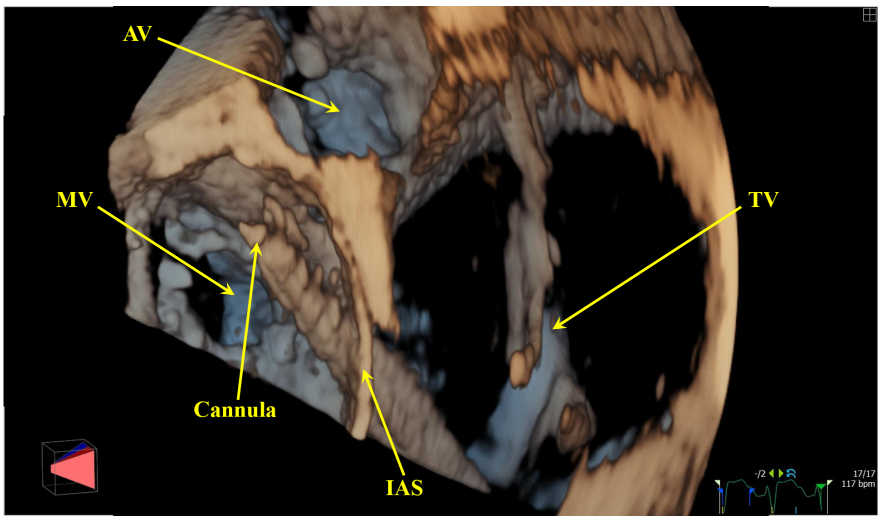
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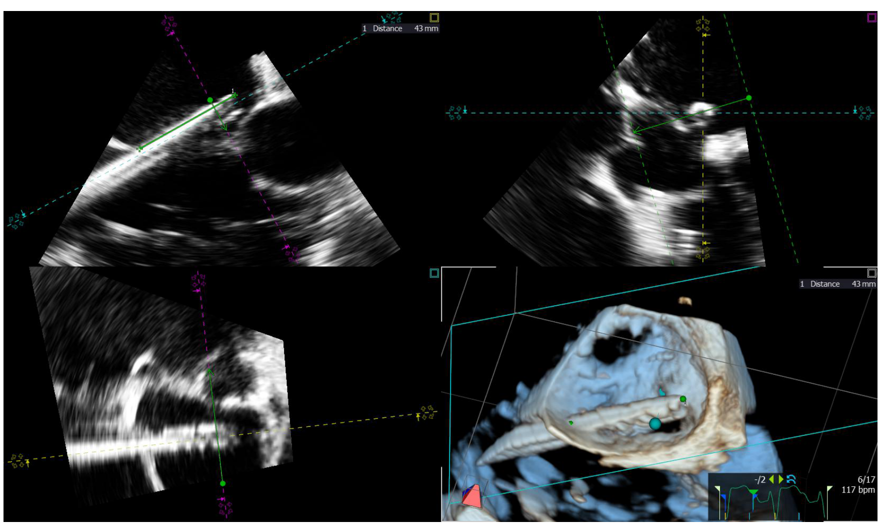
1 Distance 43 mm
1 Distance 43 mm
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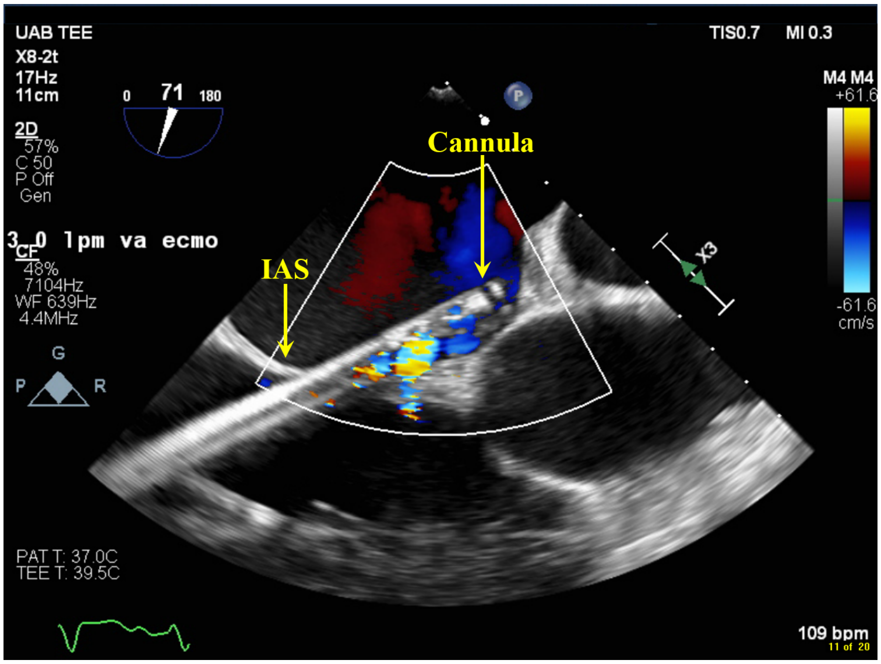
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109 bpm
11 of 20