Echocardiography in Extracorporeal Membrane Oxygenation

Introduction

In this era of using imaging as a diagnostic modality for a better prognosis, a lifesaving procedure such as extracorporeal membrane oxygenation (ECMO), too needs good imaging modality for success. The placement of cannulas and the right patient selection for ECMO, all requires echocardiography. Combes *et al*.,[1] Douflé *et al*.,[2] and Platts *et al*.[3] have all in recent literature elaborated on the judicious advantages of echocardiography for a successful ECMO run, particularly in a busy emergency department where ECMO is put following an arrest with chest compression on and cannula placement is a problem! Suresh Rao *et al*.[4] in this issue reiterate the importance of imaging during ECMO in their paper entitled "Demonstration of blood flow by color Doppler in the femoral artery distal to arterial cannula during peripheral VA-ECMO."

Echocardiography plays a fundamental role in the management of patients supported with ECMO.[5] It is particularly useful for the detection of cardiac complications that may arise during ECMO. It helps in many ways during the ECMO run, as shown in Table 1.

Types of Extracorporeal Membrane Oxygenation

ECMO is a rescue therapy used to provide cardiac and/or respiratory support for critically ill patients in whom maximal conventional medical management has failed. There are two types of ECMO – the veno-venous ECMO (VV-ECMO) and veno-arterial ECMO (VA-ECMO). VV ECMO provides adequate oxygenation and carbon dioxide removal in isolated refractory respiratory failure. VA-ECMO is preferred when support is required for cardiac and/or respiratory failure.

Role of Echocardiography

Echocardiography helps in identifying or excluding new reversible pathology, which could be the actual cause of patient hemodynamic deterioration (cardiac tamponade/undiagnosed valvular lesions and left ventricle [LV] dysfunction); thus avoiding the need for ECMO support. It also helps in providing information regarding contraindications, for example, ECMO is not to be put for an aortic dissection. Identification of significant aortic regurgitation (AR) is a relative contraindication in VA-ECMO, in which the LV afterload is increased, leading to further increase in the AR. It also provides information as regards to aortic atherosclerosis, thus guiding the intensivist in deciding the cannulation sites (central vs. peripheral) or the technique (surgical vs. percutaneous). Echocardiography also helps in evaluating the right heart morphology for any structural abnormality, which could impede the positioning of venous cannula for VV-ECMO or VA-ECMO. Chest X-ray is the most common modality used, so far during ECMO run to observe the positions of the return and access cannulas [Figure 1].

Table 1: Echocardiographic monitoring on extracorporeal membrane oxygenation

Patient selection
Monitoring during support
Insertion and correct placement of cannulas
Detecting complications
Decision making: Cardiac recovery, weaning, bridge to extracorporeal membrane oxygenation

Cannulation Sites in Extracorporeal Membrane Oxygenation

The venous cannula is placed in the common femoral vein and positioned through the inferior vena cava (IVC) into the right atrium (RA). A cannula migration is common and can lead to perforation of the RA leading to cardiac tamponade, perforation of the interatrial septum, or obstruction of the venous cannula, leading to thrombus formation. A guidewire should be seen first in any transesophageal echocardiography (TEE) view in the IVC and the aorta.

In this special Annals of Cardiac Anaesthesia issue on ECMO, Jayaraman *et al*.[6] describe in this supplement issue the use of newer dual lumen VV-ECMO cannula to facilitate extubation and mobilization. A lower esophageal hepatic vein or a bicaval view at 60°–90° is ideal for the same [Figure 2a and b].

Echocardiography has a crucial role during ECMO cannulation as it guides the correct placement of the

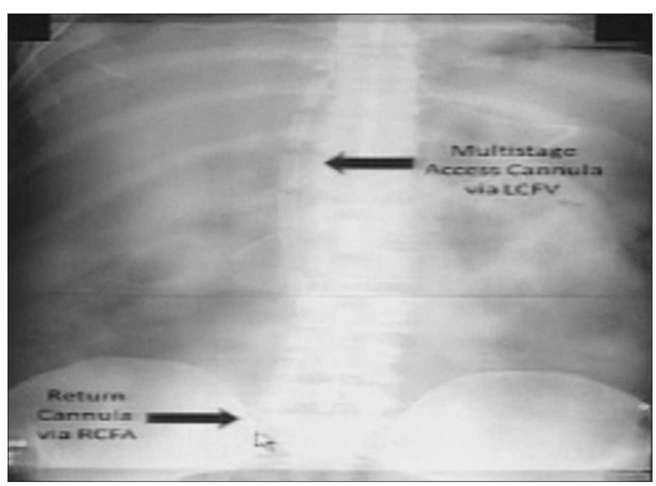

Figure 1: Chest X-ray on day 2 of extracorporeal membrane oxygenation run

ECMO cannulas. TTE may not have the adequate spatial resolution to guide ECMO cannulation, and therefore TEE is essential. There should be a direct communication between the operator and the echocardiologist as to the site of the indented cannula insertion. For example, in VV-ECMO, when one cannula is used for access and one to return the blood, this position of the access cannula tip is in the proximal IVC, just before the entry into the RA. On the other hand, the optimal position for the return cannula is in the mid–RA, but well clear from the interatrial septum and the tricuspid valve; this is apparent.

Monitoring ECMO using echocardiography is especially important for hemodynamics and fluid status monitoring during ECMO. In cases of severe LV dysfunction associated with severe mitral regurgitation, the LV becomes more enlarged, and the aortic valve may not open because of markedly reduced cardiac output. This can lead to stasis and thrombosis in the ascending aorta, the LV cavity, and pulmonary veins. In this situation, a left venting procedure or percutaneous balloon atrial septostomy has been found to be useful. TEE is an ideal procedure for guiding the septostomy catheter and balloon inflation. This is shown in Figure 3.

Failure of the aortic valve to open during peripheral VA-ECMO support poses a critical problem. To tide over this situation, anticoagulation is increased, and afterload is decreased; while native LV output is optimized using inodilators to facilitate aortic valve opening. In this setting, changing the ECMO circuit to ventricular assist device should be considered.

The hemodynamics in VV-ECMO are less complicated and more beneficial to the patient. In this mode, blood is taken from and return to the right heart with no significant change to the right ventricular (RV) preload and no adverse effects on left heart hemodynamics. VV-ECMO also increases mixed venous oxygen saturation, and this leads to decrease pulmonary vascular resistance and thus a lower RV afterload. The increase oxygenation of the LV indirectly improves the LV function and increase oxygen delivery to the coronary artery circulation.

Echocardiography AIDS in Diagnosing Complications during Extracorporeal Membrane Oxygenation

The diagnosis of upper limb hyperperfusion during ECMO relies heavily on clinical features, with imaging utilized more to determine etiology. Transthoracic echocardiography (TTE) may add incremental value in the diagnosis of arterial upper limb hyperperfusion during ECMO support with a maxillary artery anastomosis, and that it can be easily and quickly performed at the bedside.[2]

Echocardiography is critical in the detection and management of specific complication that may arise during ECMO support. Because of the limited special resolution with TTE, TEE is usually required to detect these complications. Echocardiography enables rapid assessment of cannula positioning, cardiac filling, cardiac function, and evidence of chamber compression from tamponade [Figure 4]. Detection of cardiac tamponade and assessment of significance of pericardial effusion or collection can be difficult in patients supported on ECMO as the heart is in a partially bypassed state [Figure 5].

Complications of any part of the ECMO circuit can be well seen on echocardiography as also thrombosis with two-dimensional (2D) or 3D echocardiography [Figure 6].

In a systematic review and meta-analysis in the main Jan-March 2017, special ECMO issue, Shashvat *et al*.[7] describe

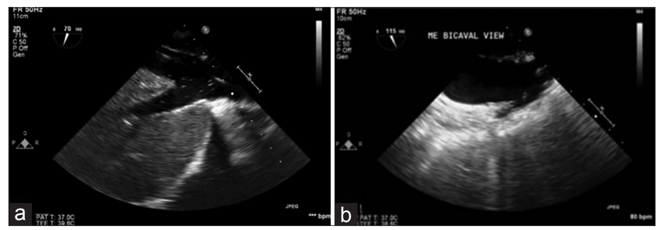

Figure 2: (a and b) A lower esophageal hepatic vein or a bicaval view

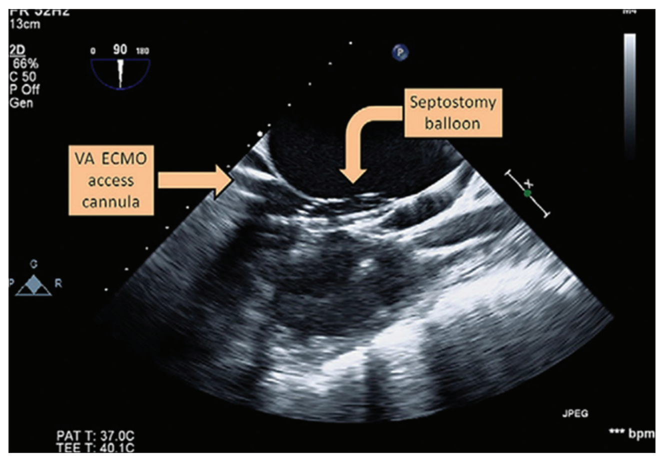

Figure 3: Transesophageal echocardiography is an ideal procedure for guiding the septostomy catheter and balloon inflation

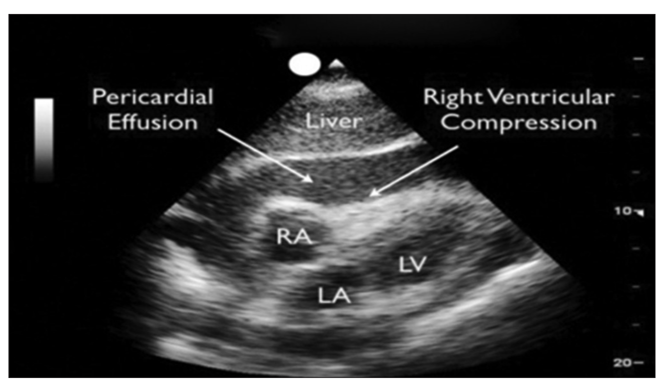

Figure 4: Pericardial tamponade

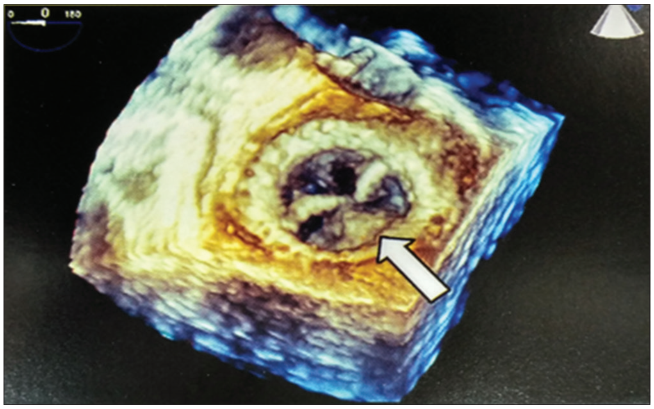

Figure 5: Three-dimensional transesophageal echocardiography of mitral valve replacement from the left atrial aspect

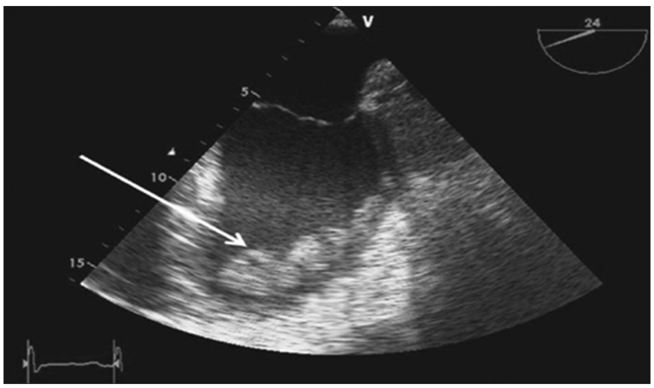

Figure 6: Thrombosis on inner aspect of left ventricle with severe left ventricle dysfunction

the use of ECMO therapy as an adjunct or salvage therapy for severe H1N1 pneumonia with respiratory failure, emphasizing like Balasubramanian *et al.*,[8] the need for echocardiography before and after VV-ECMO placement for a detailed change in LV function before and after ECMO using LV fractional shortening, ejection fraction, or peak aortic velocity. In acute respiratory distress syndrome as well as in sepsis, there is increased pulmonary vascular resistance and decreased RV function due to significant hypoxemia echocardiography is useful in documenting the effects of improved oxygenation and acid-base status on the adequacy of RV function when VV-ECMO is used.

Conclusion

Echocardiography is mandatory during initiation of ECMO, cannula insertion, hemodynamic monitoring, and detecting complications during weaning and should be an essential monitoring for a successful ECMO run.

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