INTRODUCTION

Left ventricular (LV) myocardial infarction complicated by papillary muscle rupture and resultant cardiogenic shock is associated with significant morbidity and mortality. We present a case to illustrate the use of extracorporeal membrane oxygenation (ECMO) and Impella (Abiomed) as bridge to surgery through transesophageal echocardiographic (TEE) imaging for cardiogenic shock due to acute severe mitral regurgitation (MR) resulting from a myocardial infarction–related ruptured papillary muscle.

CASE PRESENTATION

A 75-year-old man presented late with an inferior ST elevation myocardial infarction (STEMI) complicated by cardiac arrest and cardiogenic shock. Following return of spontaneous circulation, bedside point-of-care ultrasound revealed LV inferior wall akinesis and MR with suspected papillary muscle rupture. Diagnostic coronary angiography revealed significant three-vessel coronary artery disease. Transesophageal echocardiography confirmed a ruptured posteromedial papillary muscle with severe MR (Figures 1 and 2; Videos 1-5), with a proximal isovelocity surface area radius of 1.1 cm (aliasing velocity = 0.6 m/sec), effective regurgitant orifice area of 1.4 cm², and regurgitant volume of 72 mL. There was LV dilation (end-systolic diameter = 4.5 cm), with mild-moderate systolic dysfunction (LV ejection fraction = 45%), mild right ventricular dilation with moderate-severe systolic dysfunction, and mild left atrial dilatation.

Staged surgical intervention was the chosen strategy over emergent surgery, as neurological status was uncertain following a prolonged period of cardiac arrest. Hemodynamic support with peripheral (femoral) venoarterial ECMO (VA-ECMO) was commenced within hours of hospital presentation, as a bridge to surgery. VA-ECMO was initially chosen over isolated left-sided mechanical support (Impella) given the presence of right ventricular systolic dysfunction.

Video 1: Two-dimensional TEE, midesophageal long-axis view with biplane imaging demonstrating complete posteromedial papillary muscle rupture and flail mitral valve leaflet.

Video 2: Two-dimensional TEE midesophageal long-axis view with color Doppler demonstrating severe, eccentric, posteriorly directed MR.

Video 3: Three-dimensional TEE zoom acquisition demonstrating the surgeon’s view of the mitral valve from the left atrial perspective, showing A3 segment flail and ruptured posteromedial papillary muscle.

Video 4: Three-dimensional TEE color Doppler of the mitral valve as viewed from the surgeon’s perspective, showing severe MR.

Video 5: Three-dimensional TEE transillumination of the mitral valve apparatus, demonstrating the posteromedial papillary muscle rupture as seen from the left atrial (left) and LV (right) perspective.

Video 6: Two-dimensional TEE midesophageal long-axis view following commencement of VA-ECMO, demonstrating minimal aortic valve opening and significant stasis of blood flow in the aortic root and ascending aorta.

Video 7: Two-dimensional TEE midesophageal long-axis view with color Doppler following VA-ECMO commencement. The MR remains severe but was less than before VA-ECMO. The dense spontaneous echo contrast is still seen in the aortic root and intermittently regurgitates into the left ventricle (mild AR).

Video 8: Two-dimensional TEE midesophageal long-axis view with biplane imaging, following placement of an Impella device, demonstrating significant reduction in stasis of flow within the aortic root/ascending aorta.

Video 9: Two-dimensional TEE mitral commissural view with biplane imaging, showing no interaction of the ventricular component of the Impella device with the mitral valve and subvalvular apparatus.

Video 10: Two-dimensional TEE midesophageal long-axis (46°) view with color Doppler showing reduction in MR severity following placement of the Impella device.
With increasing ECMO flow, and subsequent increase in aortic pressure, LV volume increase, and reduction in stroke volume, with the last one being particularly reduced due to severe MR, LV stasis developed within 15 minutes of initiating VA-ECMO. Transesophageal echocardiography demonstrated minimal aortic valve leaflet opening and significant stasis of blood flow at the aortic root and ascending aorta, despite the administration of systemic therapeutic anticoagulation (Figure 3, Videos 6 and 7). Transient reduction in ECMO flow, and thus LV loading, resulted in improved aortic valve opening and reduction in stasis at the aortic root/ascending aorta; however, this was associated with hypotension and systemic hypoperfusion. In light of developing aortic stasis, an Impella device was placed (Figure 4), enabling LV unloading, antegrade flow support, aortic root washing, and resolution of the aortic stasis (Videos 8-10). The patient’s hemodynamic status stabilized; serial echocardiography demonstrated stable LV end-diastolic dimensions indicating no worsening LV distension and no elevation in right ventricular systolic pressures. The patient subsequently underwent surgery 48 hours later.

**DISCUSSION**

Papillary muscle rupture is a rare but lethal complication of STEMI and is associated with a 65% risk of presenting as cardiogenic shock and often requires mechanical circulatory support device(s) for hemodynamic support. The goal of hemodynamic support in this setting is to reduce afterload and improve systemic blood pressure and blood flow.
flow to critical organs, while concurrently reducing LV end-diastolic pressure and pulmonary capillary wedge pressure (PCWP). VA-ECMO in the setting of acute severe MR may result in a rightward shift of the pressure-volume loop, increase in afterload, and subsequent rise in end-diastolic and end-systolic volumes and elevation in the PCWP. Echocardiography may be useful in identifying the importance of early LV unloading through monitoring of Doppler-derived left heart pressures, worsening aortic or MR, or increasing right ventricular systolic pressures suggestive of rising PCWP from pulmonary edema and elevated LV filling pressures. Left ventricular distension is of concern following commencement of VA-ECMO, which may worsen in the setting of acute severe MR.

Figure 2 Three-dimensional TEE, zoomed volume acquisition, oriented to the surgeon’s view of the mitral valve. (A) The left atrial perspective demonstrates a flail A3 segment with a ruptured posteromedial papillary muscle (arrow) (Video 3). (B) Three-dimensional color Doppler demonstrates severe MR (Video 4). (C, D) Three-dimensional transillumination; left atrial (left) and LV (right) perspective demonstrated. This technique was used to highlight the blood pool–tissue interface. The degree of transparency was adjusted to maximize the border definition between the ruptured posteromedial papillary muscle and blood pool and more clearly demonstrate the ruptured posteromedial papillary muscle (dashed arrow) (Video 5).
Effective hemodynamic support in the setting of acute severe MR requires VA-ECMO with concurrent Impella support for afterload reduction. However, the degree of Impella support is less than what would be required if used as isolated LV support.

CONCLUSION

Clinicians should be aware of the risk of VA-ECMO-related significant aortic stasis, which may develop in the setting of increasing afterload and reduction in stroke volume, the latter particularly occurring in the situation of acute severe MR. Echocardiography may be used to identify the importance of implementing an LV unloading strategy to reduce afterload and provide more effective hemodynamic support in this clinical context.

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SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.case.2022.03.003.