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EDITORIAL COMMENT

Mechanical Support in Cardiogenic Shock

The Delicate Balance Between Patient and Machine*

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The development of effective cardiac mechanical support devices has allowed us to give a fighting chance to the sickest of patients. The growing use of and experience with extracorporeal membrane oxygenation (ECMO) has resulted in improved outcomes for this patient population. However, successfully troubleshooting ECMO-patient interactions is a huge challenge and a paradigmatic example of the importance of teamwork.

In this issue of *JACC: Case Reports*, Hollowed and Nsair (1) present a complex case of short-term mechanical support for fulminant myocarditis in a very objective and engaging manner. The team's dynamic management and methodical approach to complications (**Figure 1**) was key to the successful outcome.

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The indication for venoarterial (VA)-ECMO was clear: a young, previously healthy patient in profound cardiogenic shock due to a potentially reversible cause (2). Myocarditis is a well-known complication of influenza infection. In a recent review (3), myocarditis was reported in 0.4% to 13% of influenza infections, mainly related to H1N1. Among patients with influenza-associated myocarditis, 62% required advanced cardiac support therapies, and the mortality rate was 33%. In this case, the immediate presentation, with profound cardiogenic shock leading to arrest, set the stage for the difficulties ahead.

The first challenge was low ECMO flow. After excluding thrombus, the team tried changing to a hybrid configuration. Hybrid ECMO refers to different cannulation strategies that are sometimes necessary to improve flow, oxygenation, or left ventricular (LV) unloading (4). It is currently used in 2% of ECMO patients (4,5).

In this case, a venovenous-arterial ECMO configuration was used by adding a new drainage cannula. The dual drainage via both right femoral and jugular veins augmented venous flow through the ECMO pump and decreased the volume of blood getting to the LV via pulmonary circulation, thus also contributing to reduce left filling pressures. The ECMO flow improved, but hemodynamic instability persisted, and the pericardial effusion was increasing.

Ascertaining the need and timing for pericardiocentesis in ECMO patients is difficult because the mechanics of tamponade are altered, and we cannot rely on either blood pressure, heart rate, or typical echocardiographic findings. In this instance, given the persistent hemodynamic instability and the aggravating effusion, attempting drainage seemed wise, because the external compression could have contributed to LV dysfunction.

Despite the team's best efforts, the patient's aggressive influenza infection got worse, causing rhabdomyolysis, severe lung injury, and myocardial edema with near cardiac standstill.

The combination of a failing LV with the inherent increase in afterload, caused by the ECMO retrograde aortic flow, augments end-diastolic pressures, leading to lung edema and LV distension. The reduced flow to the coronary arteries contributes to ischemia and further impairs recovery. Also, there is a high risk of blood stagnation and thrombus formation in the LV.

Currently employed strategies for LV unloading involve "actively" venting and improving stroke volume. LV venting can be done either surgically or percutaneously by a transaortic or trans-septal approach. Indirect LV venting can be achieved via

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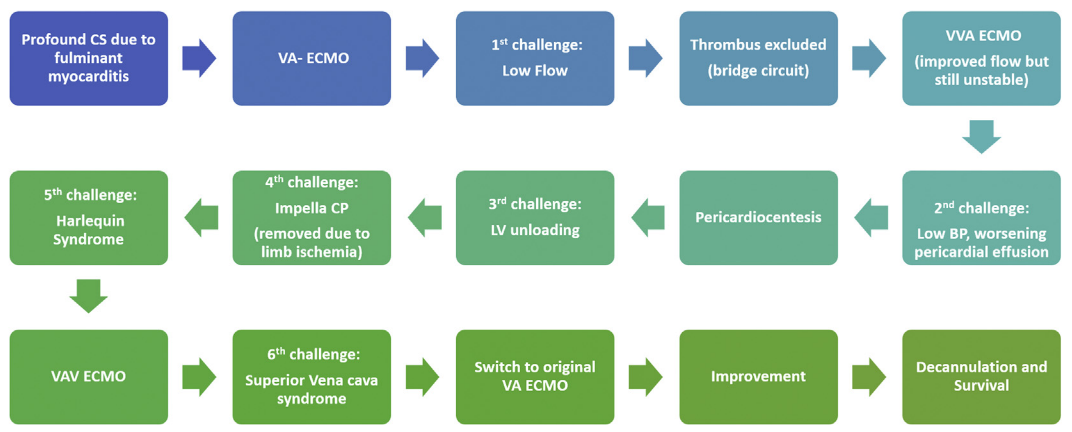
FIGURE 1 **Sequence of Events**



BP = blood pressure; CS = cardiogenic shock; ECMO = extracorporeal membranous oxygenation; LV = left ventricular; VA = venoarterial; VAV = venoarterial-venous; VVA = venovenous-arterial.

atrial septostomy and direct LV venting via surgical approaches. Augmenting stroke volume is achieved through inotropes or percutaneous pump devices (6), such as the intra-aortic balloon pump or the Impella heart pump (Abiomed, Danvers, Massachusetts). In a meta-analysis of observational studies, LV unloading correlated with increased survival in adult patients with cardiogenic shock (7), although the routine use of unloading techniques remains controversial (6).

The choice of an Impella device here, as stated by the investigators, was based on recent reports proving its utility in similar cases. However, the combination of an additional arterial access with severe rhabdomyolysis from the H2N3 infection further compromised distal limb perfusion, leading to severe ischemia and need for bilateral fasciotomies. This complication is described in 1.5% of VA-ECMO patients in the latest EuroELSO report (5).

After a few days, the patient cardiac function began improving, but the lungs were still badly damaged. When this occurred the LV started ejecting poorly oxygenated blood coming from the pulmonary circulation. The blood mix in the aorta moved distally to the heart, hampering delivery of oxygen to vital organs and causing differential hypoxemia, also known as the North-South or the Harlequin syndrome (2). Serial blood gas samples taken from the right side of the body are critical to monitor for the occurrence of this complication. The change to a venoarterial-venous configuration meant using the jugular vein cannula to redirect part of the arterial return flow to the right atrium. The oxygenated blood can then reach the LV and correct differential hypoxemia (4).

Despite the success of venoarterial-venous ECMO in improving oxygenation, the delivery of high-pressure arterial blood to a vein significantly increases afterload. Given the compliance of venous system, this can manifest as dilation and subsequent compression of the surrounding structures.

Hollowed and Nsair (1) have detailed an heroic approach to the care of a critically ill patient, which involved teamwork, active surveillance for complications, and troubleshooting of the different scenarios as they arose. The complications were both machine- and patient-related and required ongoing vigilance of the team in order to achieve this successful outcome for a young, previously healthy patient. Appropriate patient selection for this extraordinary level of mechanical support and intervention is crucial to replicate this outcome with similar strategies.

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