Peer-Reviewed Case Report

Left Atrial Veno-Arterial Extracorporeal Membrane Oxygenation (LAVA-ECMO): Percutaneous Bi-Atrial Drainage to Avoid Pulmonary Edema in a Patient with Left Ventricular Systolic Dysfunction

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Abstract

Veno-arterial extracorporeal membrane oxygenation (V-A ECMO) is used in patients with severe cardiogenic shock refractory to medical therapy. During V-A ECMO, retrograde flow in the aorta towards the left ventricle (LV) causes increased left-sided filling pressures, which may lead to pulmonary edema. Different strategies have been proposed to decompress the left heart, including placement of an intraaortic balloon pump (IABP), Impella® (Abiomed), or TandemHeart® (Cardiac Assist).[1-3] Percutaneous decompression of the left atrium via placement of a transseptal cannula incorporated into the existing venous limb had also been previously done.[4] We describe the use of the VFEM venous femoral cannula (Edwards Lifesciences) placed transseptally in a left atrial, veno-arterial (LAVA) configuration to provide simultaneous bi-atrial drainage in a patient on V-A ECMO due to cardiogenic shock.

Background

Veno-arterial extracorporeal membrane oxygenation (V-A ECMO) is used in patients with severe cardiogenic shock refractory to medical therapy. During V-A ECMO, retrograde flow in the aorta towards the left ventricle (LV) causes increased left-sided filling pressures, which may lead to pulmonary edema. Different strategies have been proposed to decompress the left heart, including placement of an intraaortic balloon pump (IABP), Impella® (Abiomed), or TandemHeart® (Cardiac Assist).[1-3] Percutaneous decompression of the left atrium via placement of a transseptal cannula incorporated into the existing venous limb had also been previously done.[4] We describe the use of the VFEM venous femoral cannula (Edwards Lifesciences) placed transseptally in a left atrial, veno-arterial (LAVA) configuration to provide simultaneous bi-atrial drainage in a patient on V-A ECMO due to cardiogenic shock.

Case Report

A 63-year-old Caucasian male with a history of coronary artery disease, chronic systolic heart failure due to ischemic cardiomyopathy, and paroxysmal ventricular tachycardia was admitted to an outside hospital. Previous interventions included coronary artery bypass grafting surgery, an ablation, and the placement of an automated implantable cardioverter-defibrillator (AICD). He presented with generalized malaise, dyspnea, and lower extremity edema. He was in atrial fibrillation, and his chest x-ray (CXR) showed mild pulmonary edema. He was admitted to undergo a transesophageal echocardiogram and direct current cardioversion. However, before the planned procedure, the patient acutely decompensated and became hypotensive. He went into respiratory distress and was subsequently intubated. He was initially started on norepinephrine, but dobutamine was added soon after due to worsening hypotension. A repeat CXR showed severe pulmonary edema. The patient was then transferred to our institution for advanced management. The patient's inotropic and oxygen requirements increased; thus, V-A ECMO support was initiated. First, we performed right heart catheterization with the placement of a Swan-Ganz catheter, and the following hemodynamic pressure measurements (in mm Hg) were obtained: right atrium (RA) of 18, right ventricle of 69/11, pulmonary artery of 72/43 with a mean of 51, and pulmonary capillary wedge (PCWP) of 35. The SVO_2 was 32%. We then proceeded with cannulation for V-A ECMO.

We obtained antegrade access to the right superficial femoral artery (SFA) using a micropuncture needle under ultrasound guidance and placed a short 6-French Arrow-Flex® sheath (Teleflex). In a similar fashion, we obtained left femoral vein access and placed an 11-French long sheath for intracardiac echocardiography (ICE). We performed a transseptal puncture on the right femoral vein under ICE guidance using an SL1™ sheath (Abbott) and a Brockenbrough™ needle (Medtronic). Next, we advanced the SL1 sheath across the septum to the left upper pulmonary vein (LUPV) and removed the sheath over an Amplatz Super Stiff™ Guidewire (Boston Scientific). The left atrial pressure was transduced to be 35 mmHg. We then serially dilated the arteriotomy site and placed an 18-French cannula in the right femoral artery. Using a heat gun, the tip of a 24-French VFEM venous femoral cannula (Edwards Lifesciences) was shaped to have a 45-degree angulation (Figure 1). The venous access was subsequently serially dilated, and the pre-shaped venous cannula was advanced over the wire across the septum (Video 1). Both cannulas were connected to the perfusion circuit using wet-to-wet connection; the resultant flows averaged above 4.0 L/min upon activation of ECMO. Immediately after the initiation of flow across the circuit, the RA and PCW pressures decreased to 8 and 19 mm Hg, respectively. The cannulas were sutured into place, and the SFA perfusion catheter was connected to the inflow cannula. The ICE catheter and the 11-French sheath were removed from the left femoral vein, and a purse-string suture was placed for hemostasis.

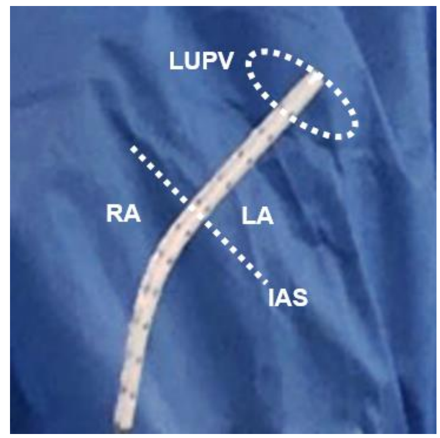

Figure 1. *A 24-French VFEM venous femoral cannula (Edwards Lifesciences) was shaped with a heat gun to have a 45-degree angulation. Its intended position relative to anatomic structures is shown. Abbreviations: RA-right atrium; LA-left atrium; LUPV-left upper pulmonary vein; IAS-interatrial septum.*

The patient's inotropic support was weaned over six days, and his pulmonary edema significantly improved (Figure 2). He then underwent placement of a left ventricular assist device (LVAD) and decannulation

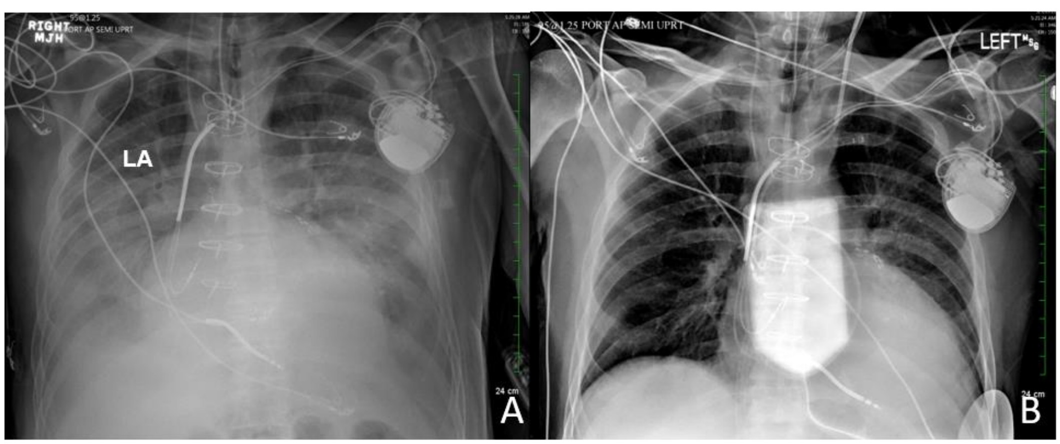

Figure 2. *Chest radiographs of the patient were taken A) before and B) five days after initiation of veno-arterial extracorporeal membrane oxygenation.*

Discussion

During VA-ECMO, retrograde flow from the arterial cannula results in increased afterload on the failing heart, leading to rising LV end-diastolic and left atrial pressures. Without successful unloading of the ventricle, pulmonary edema or hemorrhage is common. Ventricular recovery is unlikely because of the increase in mechanical work and the reduction in diastolic coronary flow.[4] Although there is no consensus as to the indication of LV unloading in adult patients on V-A ECMO, it should be considered in those at high risk for pulmonary edema, such as patients with aortic valve insufficiency, increased afterload states, complete failure of the heart with no remaining ejection fraction, and inadequate venous drainage.[5]

There are several strategies to unload the left heart; percutaneous placement of an IABP or an Impella is commonly used. Transseptal venting has also been performed. In a case series involving five pediatric and two young adult patients, Aiyagari et al. first described the placement of a transseptal sheath, with sizes ranging from 8-French to 15-French, to unload the left atrium during V-A ECMO.[6] The authors suggested that using a larger cannula was associated with more effective decompression. Kang et al. subsequently described the case of a 28-year-old man with cardiogenic shock who underwent transseptal placement of a 28-French venous cannula 34 hours after initiating V-A ECMO.[7] The patient's pulmonary edema improved considerably within hours, and he was discharged alive.

Aiyagari and Kang describe placing the transseptal cannula to decompress the left atrium and an existing venous catheter draining the right atrium. In contrast, we described the transseptal placement of a 24-French VFEM venous cannula that served as the sole inflow limb of the ECMO circuit in a LAVA configuration. A similar technique was described in manuscripts by Singh-Kucukarslan[8] and Chiang.[9] By reshaping this catheter with a heat gun, we carefully directed the tip towards the LUPV, thereby avoiding free wall contact with the left atrium (Figure 3). The presence of perforations at the distal end of the catheter allowed simultaneous drainage of both atria. We speculate that the catheter acted as a self-balancing conduit, which preferentially drained the left atrium when there was a significant volume or pressure difference between both atria. The immediate drop of 19 mm Hg in PCWP demonstrated the significant unloading provided by the LAVA-ECMO configuration to our patient. Also noteworthy was that the circuit could generate flows above 4.0 L/min for a patient with a BSA of 1.8 m^2.

There are several advantages of using LAVA-ECMO as an unloading strategy. First, it is completely percutaneous and employs the conventional pump-oxygenator circuit and a commonly used venous catheter. Unlike the placement of an IABP or an Impella, which operate on a separate mechanical circuit, LAVA-ECMO mitigates the need for additional arterial cannulation. As such, the risk of limb ischemia is reduced. Another advantage of this configuration is that LAVA-ECMO allows left-sided decompression at the onset of ECMO initiation. In patients with cardiogenic shock, as in the case we presented, pulmonary edema is a common finding, and early unloading may prevent progression to "white lungs" during V-AECMO. An early left atrial decompression strategy is associated with better LV recovery and an improved likelihood of weaning from ECMO.[10]

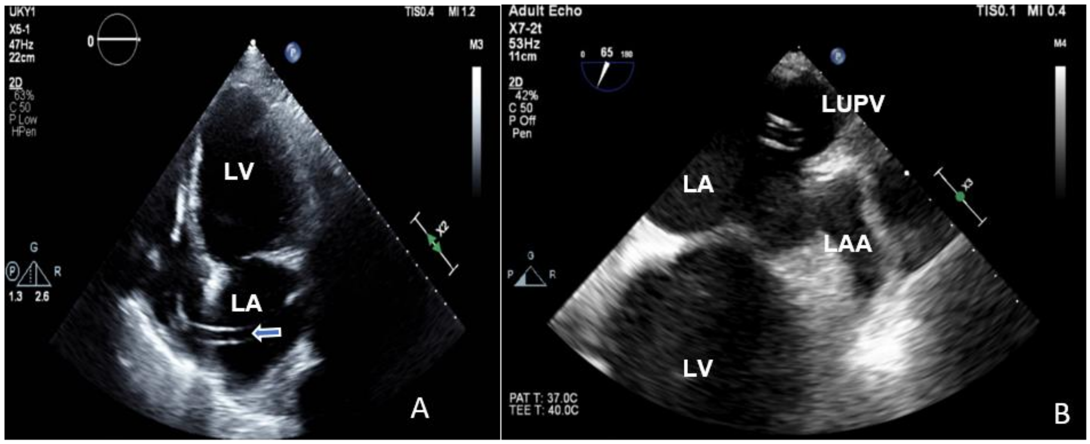

Figure 3. *A) Transthoracic apical 4-chamber view and B) transesophageal echocardiogram before decannulation from extracorporeal membrane oxygenation. The arrow points to the transseptal cannula. LA, left atrium; LAA, left atrial appendage; LV, left ventricle; LUPV, left upper pulmonary vein*

LAVA-ECMO requires transseptal puncture—a skill with a significant operator learning curve.[11] As with any procedure involving transseptal catheterization, there is the potential of developing a persistent iatrogenic atrial septal defect (IASD) as a complication following this cannulation strategy. It has been shown that larger catheter sizes and more manipulation across the interatrial septum may be associated with an increased incidence of IASD.[12] The persistence of IASD following transseptal puncture following placement of MitraClip™ (Abbott), which has a catheter septal crossing diameter of 22-French, has been associated with worse clinical outcomes.[13] In the V-A ECMO population, the clinical significance of persistent IASD following transseptal venting is unknown.

Conclusion

We described LAVA-ECMO, a configuration and unloading strategy involving the transseptal placement of a VFEM venous catheter to simultaneously drain both atria in a patient with cardiogenic shock. Further studies are needed to validate the safety and efficacy of this percutaneous technique.

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