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Left Atrial Venoarterial Extracorporeal Membrane Oxygenation for Patients in Cardiogenic Shock and Acute Aortic Regurgitation

Pedro A. Villablanca
Henry Ford Health, PVillab1@hfhs.org

Waleed Al-Darzi
Henry Ford Health, waldarz1@hfhs.org

Andrew Boshara
Henry Ford Health, aboshar1@hfhs.org

Aeman Hana
Henry Ford Health, ahana1@hfhs.org

Mir B. Basir
Henry Ford Health, mbasir1@hfhs.org

See next page for additional authors

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Authors

Pedro A. Villablanca, Waleed Al-Darzi, Andrew Boshara, Aeman Hana, Mir B. Basir, Brian P. O'Neill, Tiberio Frisoli, James Lee, Dee Dee Wang, and William W. O'Neill

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than the 10% rate of bacteremia observed in a surgical CICU.[1] The previously described unique characteristics of a CICU population and the relatively controlled setting of ECMO deployment in a postoperative setting dominantly dictated by postcardiotomy syndrome may account for this finding. The rates of BSI were noted to be higher in patients on VA ECMO than for those supported by Impella alone. The emergent nature and imperfect sterile conditions during cannulation along with a significantly increased likelihood of antecedent cardiac arrest in patients on ECMO probably contributed to this increased prevalence of BSI in this population. We also observed that gram-positive organisms contribute to the bulk of the infections, thus signifying the importance of practicing strict sterile techniques when inserting emergent large-bore intravenous catheters and reassessing the need for indwelling lines on a daily basis. Interestingly, the presence of bacteremia in CS patients on MCS did not translate to worse in-hospital or 30-day mortality. This suggests that the determinants of survival are driven by the primary cardiogenic insult rather than a subsequent downstream complication.

Our study has certain limitations. Blood cultures were performed only when bacterial sepsis was clinically suspected. This may underestimate the true incidence of BSI in this population. Only a minority of our patients developed a fever, the need for vasopressors was near-universal, and elevation of leucocyte count has already proven to be insensitive in this setting, thus making such a diagnosis difficult. Though routine blood cultures in this population have been proposed, this has been associated with false-positive results due to skin contamination and subsequently results in inappropriate antimicrobial therapy.[2]

In conclusion, 1 in 5 patients with CS on MCS is at risk of developing BSI. Although overall mortality remains high, the presence of BSI did not adversely impact 30-day survival. Although there is a need for further research, an emphasis and scrutiny on sterile line insertion practices, appropriate handling and maintenance of vascular access sites, and minimizing the duration of access are warranted.

Raunak M. Nair, MD
Sachin Kumar, MD
Talha Saleem, MD
Sanchit Chawla, MD
Adil Vural, MD
Bahaa Abdelghaffar, MD
Ran Lee, MD
Andrew Higgins, MD
Paul Cremer, MD
Penelope Rampersad, MD
***Venu Menon, MD**

*Department of Cardiovascular Medicine
Heart, Vascular and Thoracic Institute
Cleveland Clinic
9500 Euclid Avenue
Cleveland, Ohio 44195, USA
E-mail: menonv@ccf.org
Twitter: @venumenon10, RaunakNairMD

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The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

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RESEARCH CORRESPONDENCE

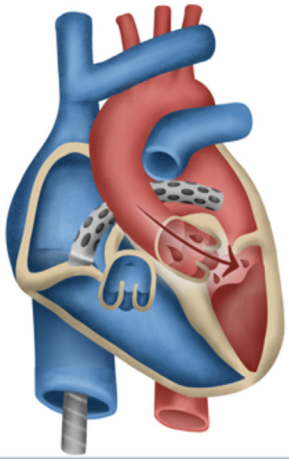
Left Atrial Venoarterial Extracorporeal Membrane Oxygenation for Patients in Cardiogenic Shock and Acute Aortic Regurgitation

Venoarterial (VA) extracorporeal membrane oxygenation (ECMO) is commonly used in cardiogenic shock (CS).[1] However, the use of VA ECMO is contraindicated in patients with severe aortic insufficiency (AI),[2] as retrograde flow can cause severe left ventricular (LV) distension and pulmonary edema.[3] VA ECMO may even lead to LV distension in patients with moderate aortic regurgitation.[4] Left atrial VA (LAVA) ECMO has emerged as a potentially ideal mechanical circulatory support (MCS) device in such cases, as it allows direct drainage of the left and right atria.[5]

We retrospectively analyzed 9 patients treated with LAVA ECMO for CS with severe AI at our institution between July 2020 and December 2021. Patient

FIGURE 1 Schematic of Left Atrial Venoarterial Extracorporeal Membrane Oxygenation Circuit and Hemodynamics

A



B

Hemodynamic Variable	Pre LAVA-ECMO Implantation, Mean (SD*)	Post LAVA-ECMO Implantation, Mean (SD)	P-value
Right Atrial Pressure (mmHg)	16.5 (5.3)	7.4 (4.4)	0.007
Mean Pulmonary Arterial Pressure (mmHg)	48.2 (5.8)	26.0 (8.2)	0.02
Left Atrial Pressure (mmHg)	30.6 (6.7)	14.5 (3.0)	0.003
Left Ventricular End-Diastolic Pressure (mmHg)	32.0 (12.7)	12.7 (2.5)	0.05
Heart Rate (beats per minute)	108.8 (36.7)	86.2 (21.9)	0.3
Mean Arterial Pressure (mmHg)	67.5 (11.8)	72.8 (12.3)	0.3
Pulmonary Artery Pulsatility Index	2.4 (0.9)	5.3 (4.7)	0.2
Cardiac Index (L/min/m^2)	1.82 (0.37)	3.24 (1.20)	0.03
Cardiac Power Output (Watts)	0.48 (0.16)	1.18 (0.29)	0.009

*SD: Standard Deviation

(A) Left atrial venoarterial (LAVA) extracorporeal membrane oxygenation (ECMO) using a multifenestrated cannula to drain both the left and right atria. **(B)** Pre- and post–LAVA ECMO hemodynamic parameters.

characteristics, procedural data, and outcomes were analyzed. Statistical analysis was performed using paired Student's *t*-test. The study was approved by the Institutional Review Board. Right and left heart catheterization was performed prior to the insertion of MCS. LAVA ECMO cannulas were implanted percutaneously using ultrasound and fluoroscopic guidance. Intracardiac echocardiography was used to guide trans-septal puncture in a mid-mid location of the fossa ovale. A 0.35-mm stiff wire was advanced into the left upper pulmonary vein to facilitate balloon septostomy using an 8 × 40 mm peripheral balloon, with subsequent delivery of a 24-F multifenestrated VFEM024 cannula (Edwards Lifesciences) into the proximal portion of the left superior pulmonary vein or left atrium just before the ostium of the left atrial appendage when pulmonary vein cannulation was not possible. Patients were fully anticoagulated with heparin as a standard part of ECMO. Invasive hemodynamic status was obtained 30 minutes postimplantation. The LAVA cannula is a 65-cm-long venous cannula with multiple 3-mm orifices along the distal 15 cm of the cannula.

Patients' mean age was 65.7 ± 15.6 years, 78% were men (7 of 9), and the mean body mass index was 32.8 ± 6.3 kg/m^2. Acute kidney injury was present in all patients, and average lactate on presentation was 4.6 mm/L. Echocardiographic findings demonstrated a mean baseline LV ejection fraction of 34% ± 18%, with right ventricular dysfunction noted in 78% of patients (7 of 9). Society of Cardiovascular Angiography and Interventions stage D CS was present in 78% of patients (7 of 9); the etiology was nonischemic CS with acute heart failure in 7 of 9 from predominant AI and acute on chronic with ongoing ischemia in 22% of the patients, and 55% of the cases were done using ad hoc transcaval access. LAVA ECMO was used for a mean of 3.7 ± 1.5 days; an additional MCS device (Impella CP) was used in only 1 case as a weaning process from LAVA ECMO after right ventricular recovery. In-hospital complications included 11% risk for stroke (1 of 9), 11% access-site hematoma (1 of 9), and 11% non-access site bleeding (1 of 9). Eighty-nine percent of patients (8 of 9) were successfully decannulated, 78% (7 of 9) were bridged to percutaneous or surgical valvular intervention including surgical and transcatheter aortic valve replacement, and all patients survived to discharge. One patient who was decannulated opted for hospice, and no intervention was performed. Two patients requiring revascularization had this done successfully with percutaneous coronary intervention. There was clinically meaningful biventricular support in all cases (Figure 1). No evidence of thrombosis was found in the cannulas, left atrium, or right atrium. Iatrogenic atrial septal defects were left open in all cases except in 1 patient who underwent surgical LV assist device implantation to prevent right-to-left shunt and hypoxemia. Lactate normalized in all patients as well as acute kidney injury.

This case series illustrates the efficacy of LAVA ECMO in providing biventricular support in patients with severe AI and CS with active unloading of the left atrium and ventricle. Although other modalities of mechanical circulatory support, such as the TandemHeart (LivaNova) can provide unloading of the left atrium, in our case series the majority of patients had right ventricular failure requiring biventricular support that the TandemHeart cannot provide. Also, LAVA ECMO and ECMO provide more flow and can also avoid the risk for hypoxia with right-to-left shunt if the cannula migrates. Finally, although the TandemHeart has been used in patients with CS, there are no available data in the setting of severe AI and the effects on hemodynamic status as described here. Larger studies are needed to confirm our findings.

***Pedro A. Villablanca, MD, MSc**
Waleed Al-Darzi, MBBCh
Andrew Boshara, MD
Aeman Hana, DO
Mir Basir, DO
Brian O'Neill, MD
Tiberio Frisoli, MD
James Lee, MD
Dee Dee Wang, MD
William W. O'Neill, MD

*Henry Ford Hospital
Centre for Structural Heart Disease
CFP 4th Floor
2799 West Grand Boulevard
Detroit, Michigan 48202, USA
E-mail: pvillab1@hfhs.org

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Dr Villablanca is a consultant for Edwards Lifesciences and Teleflex. Dr Frisoli is a proctor for Edwards Lifesciences, Abbott, Boston Scientific, and Medtronic. Dr W. O'Neill has served as a consultant for Abiomed, Edwards Lifesciences, Medtronic, Boston Scientific, Abbott Vascular, and St. Jude Medical; and serves on the Board of Directors of Neovasc. Dr Wang is a consultant to Edwards Lifesciences, Abbott, NeoChord, and Boston Scientific; and has received research grant support from Boston Scientific (assigned to the Henry Ford Health System). Dr B. O'Neill is a consultant to and has received research support from Edwards Lifesciences. Dr Basir is a consultant for Abbott Vascular, Abiomed, Cardiovascular Systems, Chiesi, Saranas, and Zoll. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

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