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Advanced Perioperative Echocardiography in Venoarterial Extracorporeal Membrane Oxygenation Weaning Trial-Off

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Introduction

The timing of extracorporeal membrane oxygenation (ECMO) weaning and removal is crucial in the treatment of patients with cardiocirculatory failure, with direct impacts on outcomes and resource utilization. Although pulmonary recovery for patients receiving venovenous ECMO is dictated by intrinsic gas exchange, lung compliance, and mechanical ventilator settings, criteria for ventricular function recoverability in patients receiving venoarterial (VA) ECMO is more complex. For this reason, a methodical approach to weaning and removal is required for patients on VA ECMO.

Current Opportunities

Extracorporeal membrane oxygenation weaning is performed without specific guidelines in most institutions. This is generally because of a scarcity of data related to this crucial aspect of ECMO support. Historical metrics include a left ventricular ejection fraction (LVEF) greater than 20% to 25%, left ventricular outflow tract (LVOT) velocity time integral (VTI) greater than 10 cm, or the absence of left ventricular dilation with progressively decreasing ECMO flows.[1,2] However, several protocols for VA ECMO weaning have been published in the last 5 years.[3-6] The authors propose a multiphase and multiparameter sequence that includes biochemical, hemodynamic, and echocardiographic parameters 48 to 72 hours following VA ECMO commencement. This bedside approach is described in Figure 1.

Recent Developments

Weaning of ECMO should be attempted as soon as there is evidence of ventricular recovery, depending on the etiology (eg, 48-72 hours for postcardiotomy shock), because the duration of ECMO support, in addition to bleeding complications, is the most important predictor of poor prognosis.[7,8] Successful ECMO removal is defined as device explant with no further mechanical circulatory support required for recurring cardiogenic shock within 30 days. Unfortunately, 57% of patients successfully weaned from VA ECMO after appropriate myocardial recovery die in the hospital after experiencing multiorgan failure or severe anoxic brain injury.[7]

The first phase in trial-off VA ECMO should be confirming an etiology for cardiac failure that is compatible with myocardial recovery. This criterion is more easily defined in patients with unexpected postcardiotomy low cardiac output syndrome. In this patient population, a pulsatile arterial waveform should be assessed in the first

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24 hours after VA ECMO implantation. For other etiologies, such as severe myocarditis or post–acute myocardial infarction, the evaluation must be individualized.[8] Once a pulsatile waveform is continuously present for more than 24 hours, the following biochemical, hemodynamic, imaging, and echocardiographic parameters facilitate readiness for VA ECMO weaning:

1) Biochemical: Partial thromboplastin time goal (60-70 seconds), lack of acidemia in arterial blood gas, a ratio of partial pressure of oxygen to fraction of inspired oxygen greater than 150, and lack of hyperlactatemia.

2) Hemodynamic: Pulsatile arterial waveform for 24 hours, mean arterial blood pressure greater than 60 mm Hg while receiving low dosage of vasopressor or inotropic support, and reassuring pulmonary artery pulsatility index higher than 2 (calculated from the ratio of the pulmonary artery pulse pressure to right atrial pressure), and a central venous pressure lower than 15 mm Hg.

3) Imaging: Lung ultrasonography and/or chest radiograph showing improvement of pulmonary edema.

Abbreviations and Acronyms

ECMO	extracorporeal membrane oxygenation
FoCUS	focused cardiac ultrasonography
LVEF	left ventricular ejection fraction
LVOT	left ventricular outflow tract
VA	venoarterial
VTI	velocity time integral

4) Focused cardiac ultrasonography (FoCUS): Shows improved biventricular function.

If the patient demonstrates an initial favorable evaluation on this multiparameter approach, we proceed to weaning VA ECMO, starting with a decrease in ECMO flow by 0.5 L/min every 5 minutes until reaching an ECMO flow of 1 L/min.[7] Maintaining adequate anticoagulation is important. Consideration should even be given to the use of additional doses of anticoagulant given low flows and variation in flows. If FoCUS reassessment and hemodynamic stability are favorable, the

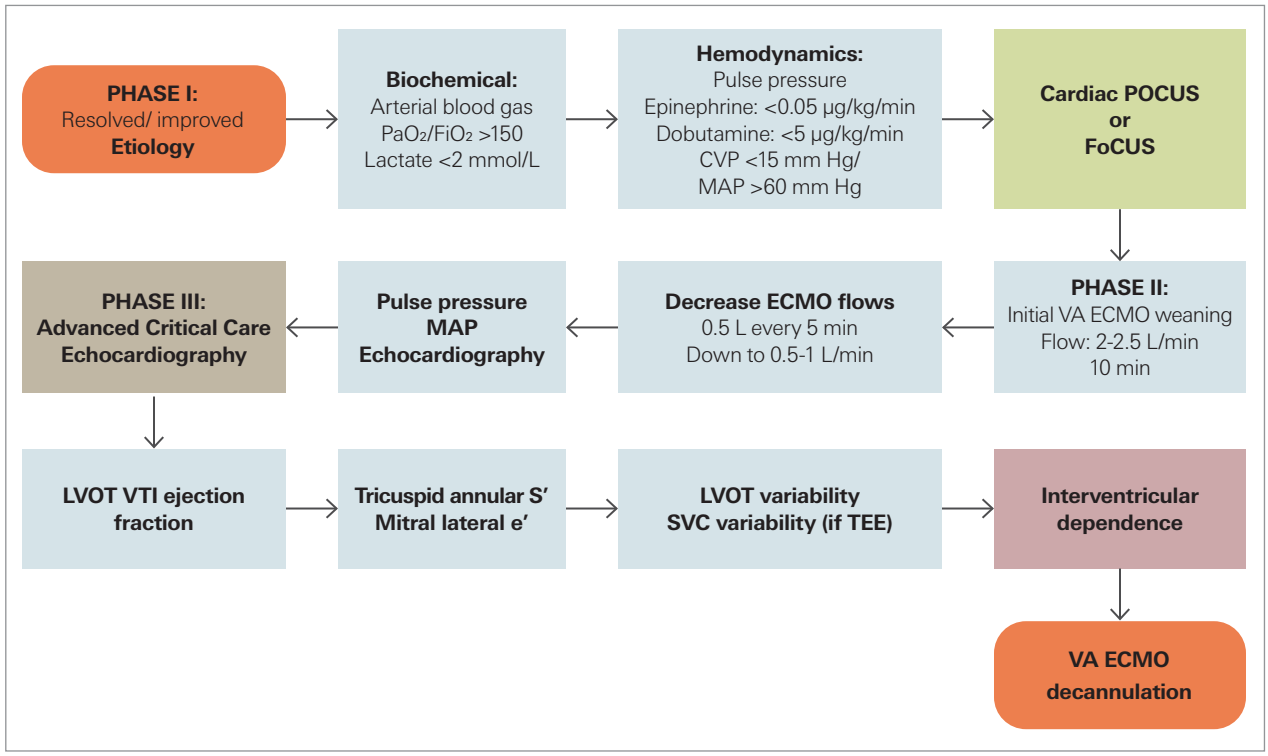

Fig. 1 Multiphase and multiparameter approach to weaning of VA ECMO support.

CVP, central venous pressure; FiO_2, fraction of inspired oxygen; FoCUS, focused cardiac ultrasonography; LVOT, left ventricular outflow tract; MAP, mean arterial pressure; PaO_2, partial pressure of oxygen; POCUS, point-of-care ultrasonography; SVC, superior vena cava; TEE, transesophageal echocardiography; VA ECMO, venoarterial extracorporeal membrane oxygenation; VTI, velocity time integral.

final phase of ECMO weaning should be initiated. Kim et al[9] found that successful weaning from VA ECMO (compared with unsuccessful weaning) was associated with echocardiographic parameters that included improvements in e′ (any amount of increase), tricuspid S′ (>10% increase), LVOT VTI (>20% at minimal flow), and right ventricular fractional area change increase during flow study. Tissue Doppler is particularly useful as a preload and afterload independent parameter.

The final phase of ECMO weaning involves decreasing ECMO flow to a minimum with concomitant quantitative echocardiographic assessment.[10] We selected echocardiography parameter values close to those published for easy recall, which we call the 6-12-24 criteria: estimation of lateral mitral e′ greater than 6 cm/s, LVOT VTI greater than 12 cm (or 20% increase), and LVEF greater than 24%. Additionally, right-to left interventricular dependence appeared to be a predictor of successful weaning.[11] Indeed, Aissaoui et al[1] showed that patients with a lateral mitral annulus peak systolic velocity greater than 6 cm/s, VTI greater than 10 cm, and LVEF greater than 20% to 25% with minimal ECMO flow were all successfully weaned. Of note, 40% of this patient cohort receiving ECMO for medical, postcardiotomy, or posttransplantation cardiogenic shock was successfully weaned from VA ECMO support.

Close monitoring after ECMO removal is mandatory. Patients who present signs of organ failure and refractory shock should be evaluated for reinsertion of VA ECMO only if they can be candidates for heart transplant or a durable left ventricular assist device.[7]

Future Directions

The evidence for both qualitative and quantitative echocardiographic assessment of ECMO weaning trials needs further validation. Still, Doppler echocardiography for quantitative assessment appears to provide robust prediction of ECMO weaning success. Furthermore, the increasing simplicity of ultrasonography systems (fewer unnecessary buttons and faster imaging), alongside the incorporation of vector flow imaging and artificial intelligence, holds promise for enhancing the predictability of VA ECMO weaning trials.

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