Short-Term Circulatory and Right Ventricle Support in Cardiogenic Shock

Extracorporeal Membrane Oxygenation, Tandem Heart, CentriMag, and Impella

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KEYWORDS

• Right ventricular failure • Heart failure • Cardiac surgery • Mechanical circulatory support

KEY POINTS

- Right ventricular (RV) failure can lead to significant in-hospital mortality.
- Some patients with acute RV dysfunction may require mechanical circulatory support.
- Mechanical circulatory support in the short term can rest and recover the right ventricle.

INTRODUCTION

Severe right ventricular (RV) failure is seen in 4% to 5% of patients following cardiac surgery. A lesser degree of RV dysfunction can be seen in up to 20% of patients. Severe RV failure is a significant cause of morbidity and mortality, with an in-hospital mortality rate of up to 70% to 75%.[1–3] Medical management is employed and is successful for most of these patients. However, a small percentage of patients will continue to have persistent RV failure, for which mechanical support is used for management.

Despite the clinical impact of RV failure, the right ventricle has generally been considered a mere bystander, a victim of pathologic processes affecting the cardiovascular system. Consequently, most mechanical circulatory devices have been discovered and utilized for the right ventricle, prior to their implementation for the right ventricle. As such, not all mechanical circulatory devices can be used for the right ventricle but some have been used quite successfully.

PATHOPHYSIOLOGY

Unlike the left ventricle, the right ventricle has the distinct advantage of pumping blood into a low-compliance pulmonary vasculature. This allows the right ventricle to maintain low systolic pressure, and any change in the afterload can cause RV dysfunction to a variable degree. Acute RV failure can be a consequence of impaired pump function, acute pulmonary hypertensive crises, or right-sided valvular pathology. Impaired pump function can be a consequence of an RV infarct or inadequate myocardial protection when seen

Disclosure: The authors have nothing to disclose.

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Heart Failure Clin 14 (2018) 579–583
https://doi.org/10.1016/j.hfc.2018.06.014
1551-7136/18/

heartfailure.theclinics.com

in the postcardiotomy setting. Acute pulmonary hypertensive crises can be a consequence of a large pulmonary embolus, hypoxia or as a consequence of an LV dysfunction causing increased filling pressures. All of these factors can increase the work load on the right ventricle, thereby causing dysfunction.

MEDICAL MANAGEMENT OF RIGHT VENTRICULAR FAILURE

A pulmonary artery catheter, right heart catheterization, or an echocardiogram can all provide means for the diagnosis of acute RV failure. Gated computed tomography CT angiograms can also do the same with reproducibility. The medical management of acute RV dysfunction is directed toward treating the reversible cause. This may include thrombolysis or embolectomy in the setting of a pulmonary embolus, percutaneous coronary intervention (PCI) in the setting of an RV infarct or aggressive diuresis in the setting of a dilated dysfunctional right ventricle. Treating hypoxia in a patient with respiratory distress may also help alleviate increasing pulmonary artery pressures, thus helping with RV afterload. Filling pressure can help guide subsequent management after initial therapy. Patients may benefit from atrial pacing, particularly if bradycardic, as the atrial kick in patients with RV dysfunction can be beneficial. The details of each therapeutic measure are beyond the scope of this article.

MECHANICAL SUPPORT FOR RIGHT VENTRICULAR FAILURE

Mechanical circulatory support (MCS) for the RV can be instrumental in stabilizing patients with cardiogenic shock while allowing the right ventricle to recover. Both percutaneous and open surgical options are available, which allow the heart failure team to choose the appropriate therapy for each patient depending on cause of RV dysfunction and associated comorbidities.[4–6]

PERCUTANEOUS MECHANICAL CIRCULATORY SUPPORT DEVICES

Extracorporeal Membrane Oxygenation

Extracorporeal membrane oxygenation (ECMO) is one of the most widely used mechanical circulatory support (MCS) options because of ease of availability for patients with acute RV failure. ECMO can be initiated both percutaneously and via open surgical access. ECMO is typically employed in patients with biventricular failure. A venous or drainage cannula is placed in the right atrium, most commonly via the femoral vein, and an arterial cannula is placed via the femoral artery in absence of peripheral arterial disease. Because of the large size cannulas (18–20 French) that are placed in the common femoral artery, this may cause distal leg ischemia, and a distal perfusion cannula is typically placed in the superficial femoral artery or the posterior tibial artery. The axillary artery can also be used for in-flow in patients with peripheral arterial disease. ECMO is not a direct therapy targeted for the right ventricle, but rather best suited in the setting of biventricular function. ECMO decreases RV preload by draining the right atrium and passing blood through an oxygenator before circulating through the arterial system. This can further increase left ventricular (LV) afterload, and in cases of significantly impaired LV function, can increase LV end diastolic and pulmonary artery (PA) pressures. This can be addressed with an intra-aortic balloon pump (IABP), a decompressive vent across the left ventricle via the right superior pulmonary vein, or an Impella (Abiomed, Danvers, Massachusetts) device that can be placed via the femoral artery across the aortic valve. The LV vent would be connected to the ECMO circuit and be part of the venous drainage, in which the Impella would be independent; both methods have their advantages and disadvantages.[6–8]

Intra-aortic Balloon Pump

IABPs are most commonly employed in the setting of LV failure as a result of a myocardial infarction or in the acute setting of cardiomyopathy. IABPs mainly serve 2 purposes in this setting. During diastole, IABP inflation causes increased pressure and thus flow in the sinuses of Valsalva, increasing coronary perfusion. During systole, the deflated pump creates a low pressure system in the descending thoracic aorta, which then allows for increasing LV ejection, increasing mean arterial pressure while reducing LV afterload. In the setting of acute RV failure, IABP may be helpful by unloading the LV and eventually reducing right-sided filling pressures. Additionally, it can be helpful by increasing right coronary perfusion. Both these effects on the right ventricle are indirect and may not be solely helpful in ameliorating acute RV failure. Studies have shown that IABP has a limited effect in RV failure and has not been consistent in improving measured cardiac output. The advantage of using an IABP is that this can be placed via a small-bore femoral arterial sheath (6 French) or without a sheath if so desired. When placed appropriately, the vascular access complication rate can be negligible.