Temporary Percutaneous Mechanical Circulatory Support in Advanced Heart Failure

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KEYWORDS

• Cardiogenic shock • Percutaneous mechanical circulatory support • IABP • Impella • TandemHeart • ECMO • Pressure-volume loop

KEY POINTS

- Temporary percutaneous mechanical circulatory support (MCS) devices are increasingly used for patients with cardiogenic shock as a bridge to recovery, decision, or definitive therapy.
- Temporary percutaneous MCS devices include the intra-aortic balloon pump, TandemHeart, Impella, and extracorporeal membrane oxygenation.
- The choice of MCS device is multifactorial, based on patient characteristics, operator ability, and the degree of hemodynamic support desired.
- The hemodynamic effects vary across the MCS device types and are an important consideration when evaluating a patient's response to MCS support.
- The use of temporary MCS is best approached through a care team that includes an advanced heart failure cardiologist.

Temporary percutaneous mechanical circulatory support (MCS) is part of the treatment armamentarium for high-risk percutaneous intervention (PCI) and acute myocardial infarction (AMI) complicated with cardiogenic shock.[1] Cardiogenic shock is typically defined as severe, refractory heart failure caused by significant myocardial dysfunction in the setting of adequate preload that is accompanied by systemic hypoperfusion. Specific clinical and hemodynamic criteria for cardiogenic shock caused by AMI are listed in **Box 1**.[2] Progressive end-organ dysfunction is a hallmark of persistent cardiogenic shock and necessitates intervention to overcome the altered hemodynamics and to restore end-organ perfusion. Vasopressors and positive inotropic agents act as the first lines of therapy, but often offer insufficient support. MCS devices such as durable left ventricular assist devices (LVADs) require surgical placement for which many patients are deemed too ill. Moreover, unstable patients with critical cardiogenic shock who receive a durable LVAD carry the highest postoperative mortality risk.[3]

Clinical studies that have examined cardiogenic shock have predominately focused on the high-risk PCI or AMI conditions (**Table 1**). However, shock can complicate many other conditions (**Box 2**), including chronic progressive heart failure.[12] The International Society of Heart and

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Box 1
Cardiogenic shock[a] definition used in the SHOCK trial

Clinical criteria

- Hypotension:
  - Systolic blood pressure (SBP) less than 90 mm Hg for at least 30 minutes or
  - Need for supportive measures to maintain an SBP greater than or equal to 90 mm Hg
- End-organ hypoperfusion:
  - Cool extremities or
  - Urine output less than 30 mL/h and
  - Heart rate greater than 60 beats/min

Hemodynamic criteria

- Cardiac index less than or equal to 2.2 L/min/m^2 and
- Pulmonary capillary wedge pressure greater than or equal to 15 mm Hg

[a] Early revascularization in AMI complicated by cardiogenic shock.

Adapted from Hochman JS, Sleeper LA, Webb JG, et al. Early revascularization in acute myocardial infarction complicated by cardiogenic shock. SHOCK Investigators. Should We Emergently Revascularize Occluded Coronaries for Cardiogenic Shock. N Engl J Med 1999;341:626.

Lung Transplantation (ISHLT) 2013 guidelines recommend nondurable (temporary) MCS for acute decompensated heart failure failing maximal medical therapy, multiorgan failure, sepsis, or ventilator-dependent patients to optimize hemodynamics and evaluate neurologic status (class 1 recommendation).[13] More recently, a consensus summary statement including endorsement by the American Heart Association suggested several indications for percutaneous MCS (Table 2).[14] Percutaneous MCS devices can be placed emergently to unload the left ventricle, decrease intracardiac filling pressures and left ventricle volume, and provide increased cardiac output to restore vital organ perfusion. Given the dire consequences of systemic hypoperfusion in the setting of progressive cardiac dysfunction, the use of percutaneous MCS in severe, refractory cardiogenic shock should be considered early in a patient's clinical course. The use of temporary MCS devices has increased dramatically over the last few years. As noted by Stretch and colleagues,[15] their use in the United States alone has increased by more than 1000%, with percutaneous devices showing the fastest rate of growth among all forms of MCS. These percutaneous MCS devices act as a bridge for critically ill patients, whether it is to recovery, durable mechanical support, or cardiac transplantation. Fig. 1 shows the strategic role of temporary MCS, including patient and programmatic considerations.

The choice of which MCS device to use is based on many factors, including patient characteristics, the degree of desired hemodynamic support, operator abilities, and institutional resources. Table 3 outlines the different characteristics of the available percutaneous devices. Although it offers the least amount of hemodynamic support, the intra-aortic balloon counterpulsation (intra-aortic balloon pump [IABP]) is widely available and most easily inserted during emergent bedside situations. However, several studies have shown that percutaneous MCS, including the Impella devices, TandemHeart, and veno-arterial extracorporeal membrane oxygenation (ECMO), provides greater hemodynamic support compared with IABP. This article provides an update on the types of percutaneous devices, hemodynamic effects, indications and contraindications for use, and management considerations for use in patients with cardiogenic shock.

TEMPORARY PERCUTANEOUS DEVICE TYPES AND HEMODYNAMIC EFFECTS

The device types described here are illustrated in Fig. 2. These devices can improve cardiac index, systemic blood pressure, and tissue perfusion to different degrees. In general, there is a continuum of increasing hemodynamic support from the IABP to the Impella 2.5 and CP devices to the TandemHeart and veno-arterial (VA) ECMO. This increased hemodynamic support is, in general terms, at the expense of more invasive vascular access and greater complication rates (bleeding and leg ischemia). The hemodynamic effects of percutaneous MCS in patients with cardiogenic shock are best understood through the effects of device support on the position and shape of the ventricular pressure-volume loop (PVL). As recently reviewed in the clinical consensus expert statement on percutaneous MCS[14] and by Burkhoff and colleagues,[16] many factors affect these PVLs. The anticipated patient response to percutaneous MCS also depends on the presenting clinical syndrome (ie, acute insult like myocardial infarction [MI] or acute on chronic left ventricular [LV] remodeling and/or right ventricular [RV] involvement). The response to percutaneous MCS must take into account underlying preload, afterload, LV contractility, and