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STATEMENT FROM THE INTERVENTIONAL COUNCIL OF THE ACC

A Practical Approach to Mechanical Circulatory Support in Patients Undergoing Percutaneous Coronary Intervention

An Interventional Perspective

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ABSTRACT

Percutaneous mechanical circulatory support has been used to stabilize patients in cardiogenic shock and provide hemodynamic support during high-risk percutaneous coronary interventions for several decades. The goal of this paper is to provide a practical approach to percutaneous mechanical circulatory support in patients undergoing percutaneous coronary intervention with cardiogenic shock and/or high risk features to aid in decision making for interventional cardiologists. (J Am Coll Cardiol Intv 2016;9:871–83) © 2016 by the American College of Cardiology Foundation.

Percutaneous mechanical circulatory support (MCS) has evolved dramatically since the first intra-aortic balloon pump (IABP) was used in humans in the 1960s (1,2). Although IABP has been the mainstay of MCS devices, recent studies have demonstrated lack of efficacy (3–5). In the setting of cardiogenic shock and high-risk percutaneous coronary intervention (HR-PCI), the introduction of newer devices coupled with data from clinical trials is challenging the role of the IABP (6–8). Mechanical circulatory support, such as Impella (Abiomed Inc., Danvers, Massachusetts), TandemHeart (CardiacAssist, Inc., Pittsburgh, Pennsylvania), and extracorporeal membrane oxygenation (ECMO), all possess an ability to provide greater hemodynamic support and may improve clinical outcomes.

MCS is used primarily in 3 populations including HR-PCI, cardiogenic shock, and cardiac arrest. As defined by the 2015 Society for Cardiovascular Angiography and Interventions/American College of Cardiology/Heart Failure Society of America/Society of Thoracic Surgeons Clinical Expert Consensus on the use of percutaneous MCS in cardiovascular care, the purpose of MCS is to reduce left ventricular stroke work and myocardial oxygen demand while maintaining systemic and coronary perfusion in the setting of cardiogenic shock or to provide hemodynamic support during complex cardiac procedures including HR-PCI and certain high-risk ventricular tachycardia electrophysiology ablation procedures (9). With multiple treatment modalities available, the challenge for the practicing interventional cardiologist is to understand which MCS offers the best use in each

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ABBREVIATIONS AND ACRONYMS

3VD = 3-vessel disease

CPR = cardiopulmonary resuscitation

ECMO = extracorporeal membrane oxygenation

HR-PCI = high-risk percutaneous coronary intervention

IABP = intra-aortic balloon pump

ICU = intensive care unit

MCS = mechanical circulatory support

ROSC = return of spontaneous circulation

VA = venoarterial

clinical scenario and to understand how patient characteristics impact this choice. The goal of this paper is to define a *practical approach* for the interventional cardiologist regarding when to use MCS, how to select MCS device type, and practical points to consider when utilizing MCS devices.

POPULATIONS REQUIRING PERCUTANEOUS MECHANICAL CIRCULATORY SUPPORT

CARDIOGENIC SHOCK. Cardiogenic shock occurs secondary to multiple etiologies including left ventricular systolic dysfunction, right ventricular systolic dysfunction, valvular heart disease, pericardial disease, and vasodilatory abnormalities. These conditions, in our patient population, most often present in patients with acute myocardial infarction, out-of-hospital cardiac arrest, and patients with a history of congestive heart failure and/or advanced valvular heart disease. While cardiogenic shock is one of the more fatal complications of acute myocardial infarction, it is relatively rare occurring in about 7% of all acute myocardial infarctions (10,11). Even with prompt reperfusion therapy with primary percutaneous coronary intervention, mortality rates still range from 30% to 50% (3). The SHOCK (SHould we emergently revascularize Occluded Coronaries for cardiogenic shocK?) trial outlined clinical and hemodynamic criteria to define cardiogenic shock (Table 1). In clinical practice, patients with cardiogenic shock represent a spectrum of disease secondary to different etiologies, which can be classified as pre/early shock, shock, and severe shock (Table 2) (12–21). Therefore, a structured approach to determine the best adjunctive MCS device in patients undergoing percutaneous coronary intervention (PCI) is required.

TABLE 1 Hemodynamic Criteria for Cardiogenic Shock

Clinical	
	SBP $<$90 mm Hg for 30 min
	Supportive measures needed to maintain SBP $>$90 mm Hg
	End-organ hypoperfusion
	Cool extremities
	UOP $<$30 ml/h
	HR $>$60 beats/min
Hemodynamic	
	Cardiac index $<$2.2 ml/min/m^2
	PCWP $>$15 mm Hg

The SHOCK trial defined cardiogenic shock according the clinical and hemodynamic criteria listed (11).

HR = heart rate; PCWP = pulmonary capillary wedge pressure; SBP = systolic blood pressure; UOP = urine output.

HR-PCI. The evolution of PCI with advances in catheter design, creation of low profile balloons, guidewire design, stent deliverability, and development of effective antiproliferative medications have increased the number of patients eligible for percutaneous revascularization. According to recent American Heart Association statistics, although both PCI and coronary artery bypass graft surgery numbers have declined, PCI is the most common revascularization modality and is applied to patients with increased lesion complexity and comorbidities with 51% of all PCI performed in patients >65 years of age (22). In addition, the advent of transcatheter techniques for the treatment of patients with valvular heart disease has resulted in older patients with severe coronary disease and left ventricular systolic dysfunction undergoing HR-PCI. Multiple variables define HR-PCI including clinical presentation, coronary anatomy, hemodynamic status, electrical instability and end organ function (Table 3) (23,24). PCI in patients with factors such as impaired left ventricular systolic function defined as ejection fraction <35%, unprotected left main disease, severe 3-vessel disease (3VD) (SYNTAX score >33), or last remaining patent vessel are associated with in-hospital mortality rates between 5% and 15% (24–30).

MCS has been used to provide stability during high-risk interventions for over 25 years. The goal of MCS during HR-PCI is to provide sufficient forward cardiac output to maintain myocardial, cerebral, mesenteric, renal, and peripheral tissue perfusion. Nellis et al. (31) have demonstrated in an animal model that a 40 mm Hg pressure gradient exists between coronary arterioles and venules. Sustained hypotension with coronary perfusion gradients <40 mm Hg can lead to profound myocardial ischemia, which quickly depresses an already impaired left ventricle and may lead to cardiovascular collapse and arrest. Clinicians must recognize this scenario and act prior to reaching this threshold to avoid this lethal spiral. Measuring a left ventricular end-diastolic pressure prior to PCI can help differentiate where the patient is on the spectrum of cardiogenic shock and determine whether MCS is needed prior to PCI. MCS should be instituted prior to PCI in an effort to avoid "crashing onto support" and to enable the most complete revascularization feasible. In the PROTECT II (Prospective, Multicenter, Randomized Controlled Trial of the IMPELLA RECOVER LP 2.5 System Versus Intra Aortic Balloon Pump [IABP] in Patients Undergoing Non Emergent High Risk PCI) trial, hypotensive events occurred less often in the Impella group (11.8% vs. 17.2%; $p < 0.001$). Patients with the lowest major adverse events at