During the past 2 decades, the use of durable mechanical circulatory support (MCS) for advanced heart failure has grown exponentially, in large part, because of clinical trials demonstrating improved rates of survival when compared with medical therapy alone. Among patients referred for durable MCS implantation, 2 major predictors of poor survival include (1) clinical instability identified as Interagency for Mechanically Assisted Circulatory Support profiles 1 or 2 and (2) preoperative right ventricular failure. Right ventricular failure also currently prohibits the use of durable MCS as a destination therapy option. In parallel to growth in durable MCS implants, nondurable or percutaneous MCS device use has also increased since 2007. No reports have described the use of percutaneously delivered axial flow catheters to fully support both right and left ventricular (LV) functions before durable MCS implantation. We describe a case illustrating the potential use of axial flow catheters to support a patient with cardiogenic shock caused by biventricular failure (BiVF).

A 45-year-old man with stage D ischemic cardiomyopathy and a LV ejection fraction of 10%, moderate RV dysfunction, and moderate tricuspid regurgitation presents with 1 month of worsening dyspnea without chest pain. A recent coronary angiogram confirmed no revascularization option. On the basis of initial hemodynamics (Table), we initiated milrinone. Within 6 hours, the patient developed ventricular fibrillation requiring a single defibrillation without cardiopulmonary resuscitation. To improve cardiac output, an intra-aortic balloon pump was implanted and milrinone continued. Within 4 hours, he continued to decline with worsening dyspnea, hemodynamic indices, and renal function. Echocardiography confirmed severe BiVF (Movies I and II in the Data Supplement). A multidisciplinary discussion determined that the patient was a potential candidate for orthotopic heart transplantation pending completion of his transplant evaluation and improved clinical stability. Durable MCS was deferred because of clinical instability with impaired end-organ function and uncertainty about committing him to surgical biventricular devices without transplant candidacy being defined. Nondurable MCS using venoarterial extracorporeal membrane oxygenation was considered; however, his oxygenation was stable and this strategy would limit our ability to remove RV support if the RV recovered function either before or after LV assist device (LVAD) implantation. We elected to proceed with simultaneous biventricular axial flow catheter support using the Impella 5.0 LP and Impella RP (Abiomed Inc, Danvers, MA) devices. A 10-mm vascular graft was anastomosed to the right axillary artery, and the Impella 5.0 LP device was delivered into the LV. Device activation achieved 5.0 L/min of flow at power level 8 (P8) resulting in reduced LV pressures and increased mean arterial pressure (Figure 1A; Table). Central venous pressure increased after initiating LV support alone. Next, the Impella RP device was delivered via the right femoral vein into the pulmonary artery. Activation of the Impella RP at 3.4 L/min at P6 reduced the central venous pressure and increased both LV diastolic pressure and mean arterial pressure (Figure 1B; Table). Biventricular Impella (Bi-Pella) support was continued for 5 days followed by implantation of a HeartMate-II LVAD (Thoratec Inc). Estimated RP flow ranged between 3.4 and 4.2 L/min and was titrated to maintain an LP flow of 4.9 to 5.1 L/min. The Impella RP was left in place for 3 days after LVAD implantation followed by removal with manual venous compression only (Figure 2). The patient was successfully discharged to home on hospital day 15 without inotropic therapy.

BiVF remains a major clinical challenge when evaluating patients for durable MCS. Venoarterial extracorporeal membrane oxygenation can temporarily stabilize patients, but it is limited by the inability to selectively support 1 ventricle at a time before or after LVAD implantation. Biventricular support with extracorporeal centrifugal pumps require either surgical cannulation via a thoracotomy or a trans-septal puncture into the left atrium. In this report, we describe the first successful use of 2 axial flow catheters in the LV and RV to provide full biventricular support before LVAD implantation. We further show that supporting the LV alone can worsen RV hemodynamics in the setting of BiVF and that preprocedural planning...
for simultaneous biventricular support provides hemodynamic stability. Furthermore, continued use of the RV support catheter after LVAD implantation allows for ongoing RV recovery and removal of the RV device without the need for durable RV MCS. These findings suggest that Bi-Pella is a feasible percutaneous approach for BiVF, especially among patients who are poor or unclear candidates for durable MCS.

Disclosures
Drs Kapur and Pham receive research support, consulting fees, and speaker honoraria from Abiomed, Heartware, or Thoratec. Drs Kiernan and Ghuloom receive consulting fees and speaker honoraria from Heartware and Thoratec. The other authors report no conflicts.

References

Key Words: arterial pressure ■ central venous pressure ■ heart-assist devices ■ shock, cardiogenic ■ ventricular function, left

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<th>Hemodynamics</th>
<th>Milrinone</th>
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Bi-Pella indicates Biventricular Impella; HM-II, HeartMate-II; IABP, Intra-aortic balloon pump; and PA, pulmonary artery.
Figure 1. Hemodynamic tracings of left ventricular (LV) and aortic (Ao) pressures. A, †Activation of the Impella 5.0 LP device reduces LV systolic and diastolic pressures, reduces aortic pulse pressure, and increases mean aortic pressure. B, Central venous pressure (CVP) also increases and a pulsus paradoxus (arrow) consistent with right ventricular pressure overload is noted in the aortic pressure tracing after 15 min of Impella 5.0 support alone. ‡Activation of the Impella RP device restores LV preload and therefore increases LV systolic and diastolic pressures, increases mean aortic pressure, and decreases CVP. The pulsus paradoxus resolves after the patient is on Bi-Pella support (†‡) with the both Impella 5.0 LP and RP devices activated simultaneously.

Figure 2. Fluoroscopic and radiographic images showing (A) positioning of the Impella 5.0 LP and Impella RP axial flow catheters, (B) ongoing support with the Impella RP device after implantation of a HeartMate-II (HM-II) left ventricular assist device (LVAD), and (C) pre-discharge image of the HM-II LVAD alone.
First Successful Use of 2 Axial Flow Catheters for Percutaneous Biventricular Circulatory Support as a Bridge to a Durable Left Ventricular Assist Device

Navin K. Kapur, Marwan Jumean, Adel Ghuloom, Nima Aghili, Caitlin Vassallo, Michael S. Kiernan, David DeNofrio and Duc Thinh Pham

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Video 2. Echocardiogram showing severe left and right ventricular failure in the 4-chamber view.