

## Biventricular Circulatory Support Using 2 Axial Flow Catheters for Cardiogenic Shock Without the Need for Surgical Vascular Access

Nima Aghili, MD; Yousef Bader, MD; Amanda R. Vest, MD; Michael S. Kiernan, MD; Carey Kimmelstiel, MD; David DeNofrio, MD; Navin K. Kapur, MD

**B**iventricular failure in cardiogenic shock remains a major clinical problem. Use of percutaneously delivered, acute circulatory support devices for cardiogenic shock has grown exponentially due in large part to increasing global familiarity and clinical experience demonstrating hemodynamic efficacy of these devices.<sup>1</sup> Until recently, percutaneous support options for biventricular failure have been limited to venoarterial extracorporeal membrane oxygenation or biventricular centrifugal flow pumps. We recently reported the first use of biventricular axial flow catheters with the Impella 5.0 and RP (Abiomed Inc) systems, which required surgical vascular access for the 5.0 implant.<sup>2</sup> We now report the first patient with cardiogenic shock receiving biventricular support using the Impella CP and RP catheters (BiPella) without the need for surgical vascular access.

A 30-year-old woman presented with hypotension and dyspnea after 1 week of a fever and lethargy. Within 24 hours of admission, hemodynamics demonstrated biventricular failure and an echocardiogram showed a left ventricular ejection fraction of 10% and severely dilated right ventricle (RV), despite treatment with an intra-aortic balloon pump, dobutamine, and norepinephrine (Table; Movie I in the Data Supplement). Endomyocardial biopsy confirmed the diagnosis of fulminant lymphocytic myocarditis, and pulse steroids were initiated without hemodynamic improvement. A multidisciplinary discussion determined that the patient was a potential candidate for orthotopic heart transplantation if myocardial recovery was not achieved. Durable mechanical circulatory support was deferred because of clinical instability with impaired end-organ function and uncertainty about committing the patient to surgical biventricular devices. Nondurable mechanical circulatory support using venoarterial extracorporeal membrane oxygenation was considered; however, her oxygenation status was stable, and this strategy would limit our ability to independently assess RV or left ventricle recovery and de-escalate support in a stepwise manner. We elected to proceed with simultaneous biventricular axial

flow catheter support using the Impella CP and Impella RP (Abiomed Inc, Danvers, MA) devices.

The Impella CP device was deployed into the left ventricle via a 14Fr sheath in the right femoral artery, maximally activated at P8, and achieved 3.4 L/min of flow. Within minutes of device activation, mean right atrial (RA) pressure increased from 25 to 45 mmHg, whereas mean pulmonary artery pressure remained unchanged (Figure 1A). An echocardiogram confirmed RV overload and moderate to severe tricuspid regurgitation. We then rapidly deployed the Impella RP into the RV via a 23Fr sheath in the right femoral vein. Flow through the RP device was titrated to P6, which matched CP flows at 3.4 L/min. Within minutes of activation, mean RA pressure was reduced to 18 mmHg and aortic pressure improved (Figure 1B). The intra-aortic balloon pump was removed after RP activation. Within 3 hours after BiPella support, cardiac index improved to 2.5 and levophed was weaned off. After 72 hours of BiPella support, indices of RV failure including RA pressure, RA:pulmonary capillary wedge pressure ratio (RA:PCWP), and the pulmonary artery pulsatility index (PAPi) had normalized.<sup>3</sup> The RP was explanted at the bedside with manual compression, followed by removal of the CP device 6 hours later once stability of hemodynamic parameters was confirmed. The patient was ambulatory within 24 hours after BiPella explantation and was discharged from hospital on day 8. At 6 months of follow-up, her left ventricular ejection fraction was 50% with normal RV size and function (Movie II in the Data Supplement).

### Discussion

Percutaneously delivered biventricular support has evolved considerably during the past 5 years and until now has required one of the following: (1) a trans-septal puncture for biventricular TandemHeart support, (2) surgical vascular access for insertion of an Impella 5.0 combined with either a TandemHeart RV support device<sup>4</sup> or Impella RP,<sup>2</sup> or (3) use of an oxygenator with venoarterial extracorporeal membrane oxygenation. We now report the first case of biventricular failure supported with the Impella CP and RP axial-flow catheters

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**Table. Hemodynamic and Metabolic Parameters**

Hemodynamic and Metabolic Parameters	IABP+Dobutamine+Levophed	3 h on BiPella+Dobutamine	72 h on BiPella
RA pressure, mm Hg	23	18	6
PA pressure, mm Hg	33/23	40/28	28/12
PCWP, mm Hg	19	20	10
Cardiac index, L/min per m <sup>2</sup>	1.3	2.5	2.8
PA saturation, %	39	63	69
FA saturation, %	99	99	99
MAP, mm Hg	58	72	68
RA:PCWP ratio	1.2	0.9	0.6
PAPi	0.4	0.7	2.7
Creatinine, mg/dL	0.8	3.39	1.9
Lactate, mEq/dL	4.2	7	1.5
AST, IU/L	1871	11 282	841
Total bilirubin, IU/L	0.9	2.7	1.1
Lactate dehydrogenase, IU/dL	3439	114755	2100
Troponin-I, ng/mL	13	n/a	n/a

AST indicates aspartate aminotransferase; FA, femoral artery; IABP, intra-aortic balloon pump; MAP, mean arterial pressure; PA, pulmonary artery; PAPi, pulmonary artery pulsatility index; PCWP, pulmonary capillary wedge pressure ratio; and RA, right artery.

without the need for surgical vascular access or trans-septal puncture (Figure 2). This case demonstrates that: (1) non-surgical, implantation, and removal of percutaneous biventricular axial-flow catheters is feasible; (2) Bipella improve hemodynamic indices in the setting of cardiogenic shock; (3) close monitoring of intraprocedural hemodynamics using 3 transducers (RA, pulmonary artery, and aortic pressures) may identify when RV support is required; and (4) biventricular support combined with immunosuppressive therapy may lead to myocardial recovery in the setting of myocarditis. Major advantages of the Bi-Pella approach include the ability to explant one device at a time in a step-wise manner to monitor the need for ongoing univentricular or biventricular support and early ambulation after BiPella removal. These findings suggest that Bipella is a feasible nonsurgical approach for biventricular failure, especially among patients who are poor or unclear candidates for durable mechanical circulatory support.

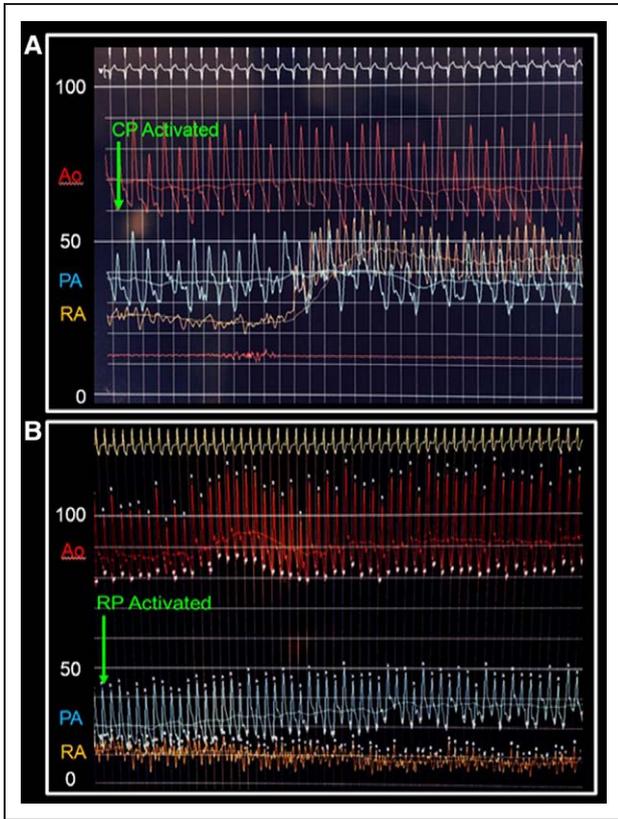
### Disclosures

Dr Kapur receives research support and speaker honoraria from Abiomed and Maquet. Dr Kiernan receives consulting fees and speaker honoraria from Heartware and Thoratec. The other authors report no conflicts.

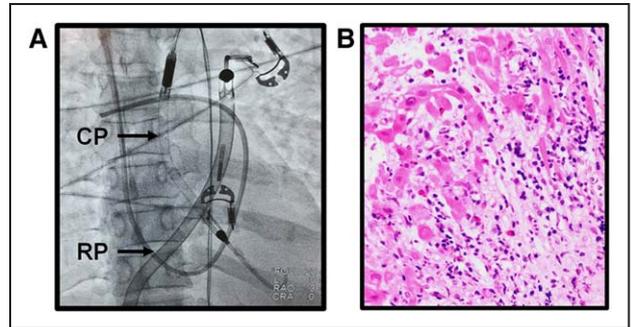
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KEY WORDS: cardiogenic shock ■ circulation ■ hemodynamics ■ intervention ■ mechanical circulatory support



**Figure 1.** Hemodynamic tracings of right atrial (RA), pulmonary artery (PA), and aortic (Ao) pressures. **A**, Activation of the Impella CP device increases RA pressure without changing PA or Ao pressures. **B**, Activation of the Impella RP device with ongoing CP support reduces RA pressure, narrows the PA pulse pressure, and increases mean Ao pressure.



**Figure 2.** **A**, A fluoroscopic image showing the Bipella configuration using an Impella CP and Impella RP axial flow catheters. **B**, Histological slide showing fulminant lymphocytic myocarditis.

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