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Pearls in Hemodynamics

Nonpulsatile Systemic Flow During Mechanical Circulatory Support in Acute Myocardial Infarction–Related Cardiogenic Shock

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Introduction

Mechanical circulatory support (MCS) devices are increasingly being used in patients with acute myocardial infarction (MI) complicated by cardiogenic shock (CS), although their clinical advantage is still controversial.

The Impella CP (Abiomed) is a continuous-flow MCS device with a microaxial pump that decompresses the left ventricle and delivers a maximum flow of 4.0 L/min into the ascending aorta. In the setting of CS, the Impella device unloads the ventricle, reduces ventricular end-diastolic pressure, increases mean arterial pressure, and decreases myocardial oxygen consumption. In April 2016, the US Food and Drug Administration approved the Impella device for use in acute MI–related CS based on circulatory support effect, not based on improved clinical outcomes.[1,2]

In the present case, we described the role of the Impella CP device in supporting the blood circulation in a patient with CS complicating non-ST-elevation MI.

Case report

The patient was a 74-year-old woman with a non-ST-elevation MI complicated by CS. Cardiovascular risk factors included hypertension, hyperlipidemia, diabetes mellitus, and chronic kidney disease. The echocardiographic assessment performed at baseline revealed severe left ventricular (LV) dysfunction (LV ejection fraction = 20%) and preserved right ventricular function (tricuspid annular plane systolic excursion = 19 mm; fractional area change = 36%). Coronary angiography showed a critical (80%) calcified left main lesion and a critical (>70%) stenosis at the ostium of the right coronary artery. MCS was promptly provided by the Impella CP SmartAssist device (Abiomed) advanced through the right femoral artery. Due to failure in dilating the left main stenosis with the noncompliant balloon and cutting balloon, we performed bailout rotational atherectomy followed by drug-eluting stent implantation (Ultimaster Tansei 3.5 × 18 mm, Terumo Corporation). Thereafter, a 3.5 × 12 mm drug-eluting stent (Ultimaster Tansei) was implanted at the ostium of the right coronary artery. In the intensive care unit, enoximone (a phosphodiesterase inhibitor with a usual infusion dose of 2-10 μg/kg/min) was started. Approximately 1 hour following the percutaneous revascularization, a monophasic, nonpulsatile flow characterized by a low-velocity, steady, and consistent signal with minimal to no variation waveform was observed in the abdominal aorta and in peripheral arteries by pulse-wave Doppler examination (Figure 1A). During this phase, the lack of aortic valve opening was documented by 2-dimensional echocardiography. MCS by the Impella CP was maintained. Norepinephrine infusion (0.2 μg/kg/min) was started. The nonpulsatile flow persisted for approximately 10 hours. Then, a pulsatile, biphasic flow reappeared (Figure 1B). The most important clinical and hemodynamic parameters before Impella support, during the "nonpulsatile flow phase," and during the "pulsatile flow phase" are reported in the Figure 1D. Hemodynamic mechanical support was maintained for 5 days. The LV ejection fraction recovered up to 45%. The patient was discharged after 3 weeks.

Discussion

The nonpulsatile-flow pattern indicates that blood circulation was totally Impella CP–dependent. The lack of aortic valve opening is a characteristic of continuous-flow MCS.[2] In the nonpulsatile flow phase, the estimated LV systolic pressure on the Automated Impella Controller (Abiomed) was same or below the aortic pressure throughout the cardiac cycle, and the 2-dimensional echocardiogram confirmed no aortic valve opening (LV uncoupling condition). During the pulsatile flow phase, the estimated LV systolic pressure on the Automated Impella Controller exceeded the aortic pressure at the early systolic phase, and the aortic valve motion on the echocardiogram indicated that blood was ejected from the left ventricle. The observed nonpulsatile-flow pattern may reflect several physiopathological aspects[3]: 1) the severe LV dysfunction causing the lack of the systolic component of an arterial waveform, 2) the performance of the continuous-flow Impella device, and 3) treatment with the phosphodiesterase inhibitor enoximone which reduces cardiac afterload by dilating the central vessels.[3]

Keywords: acute myocardial infarction; cardiogenic shock; mechanical circulatory support.

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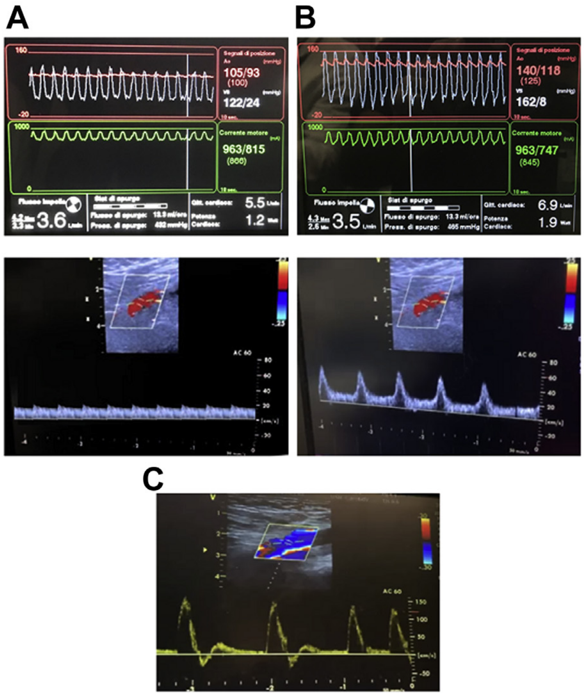

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Table

	Before Impella Support	During Impella Support Non-pulsatile Flow Phase	Pulsatile Flow Phase
Impella speed, rpm	—	46,000	46,000
Left ventricular ejection fraction, %	20	15 ± 4	22 ± 3
Heart rate, bpm	105 ± 4	108 ± 3	100 ± 2
Blood pressure, mm Hg			
Systolic	85 ± 3	98 ± 8	125 ± 4
Diastolic	50 ± 5	73 ± 5	71 ± 3
Mean	60 ± 3	81 ± 4	89 ± 5
Systemic vascular resistance, dynes * s/cm^{-5}	—	2295 ± 351	1769 ± 240
Pulmonary artery pulsatility index	—	1.7 ± 1.1	1.9 ± 1.2
Cardiac output, L/min*	—		
Total		5.5 ± 0.50	7.0 ± 0.40
Impella flow		3.5 ± 0.10	3.6 ± 0.09
Native		2.0 ± 0.12	3.4 ± 0.10
MAP*CO	—		
Total		433 ± 22	627 ± 14
Native		117 ± 9	305 ± 1
Cardiac power output, W*			
Total		0.96 ± 0.08	1.49 ± 0.10
Native		0.26 ± 0.06	0.68 ± 0.01
Urine flow rate, mL/h	—	73 ± 15	82 ± 9
pH	7.35	7.43 ± 0.06	7.48 ± 0.02
Lactate, mmol/L	2.00	2.00 ± 0.28	1.58 ± 0.31
SaO_2, %	85	92 ± 3	95 ± 2
Mental status	Confusion	Somnolence/confusion	Somnolence

*Cardiac output (CO) was measured by Fick's formula. In detail, a Swan-Ganz catheter was advanced into the pulmonary artery to assess the mixed venous O_2 saturation (SvO_2). Calculated CO is entered into the Automated Impella Controller (AIC) at the beginning. AIC automatically calculates CO and cardiac power output following entry.

Figure 1. (**A**) Nonpulsatile arterial flow pattern observed on the Automated Impella Controller (AIC) (red line; top image) and on the common left femoral artery by pulse-wave Doppler examination (bottom image). The nonpulsatile flow is characterized by a low-velocity, steady, and consistent Doppler signal with minimal to no variation waveform. The left ventricular (LV) pressure is not directly measured. Indeed the LV waveform is derived from the aortic placement signal and the motor current. The optical sensor on the Impella heart pump senses aortic pressure. The Impella motor current recognizes pressure gradients between the aorta and left ventricle during the cardiac cycle. The estimated LV end-diastolic pressure (calculated using the pressure assessed in the aorta from the optical sensor and the pressure derived from the motor; an algorithm detects ventricular contraction and identifies the pressure prior to contraction) is 24 mm Hg. (**B**) Pulsatile arterial flow pattern observed on the AIC (red line; top image) and on the common left femoral artery by pulse-wave Doppler examination (bottom image) approximately 10 hours later. The pulsatile flow comprises 2 components: 1) a rapid anterograde flow reaching a peak during systole and 2) a steady, low-velocity diastolic component. The estimated LV end-diastolic pressure is 8 mm Hg. (**C**) The normal pulsatile arterial flow comprises 3 components: 1) rapid anterograde flow reaching a peak during systole, 2) transient reversal of flow during early diastole, and 3) slow anterograde flow during late diastole. (**D**) The most important clinical and hemodynamic parameters before and during Impella support. *The cardiac output (CO) was measured by Fick's formula. In detail, a Swan-Ganz catheter was advanced into the pulmonary artery in order to assess the mixed venous O_2 saturation (SvO_2). The calculated CO is entered into the AIC at the beginning. The AIC automatically calculates the CO and cardiac power output following entry.

Pearls in Hemodynamics from editors Larry S. Dean, MD, and Morton J. Kern, MD

Pearl #1 Although uncommon, LV collapse and significant hypotension during high-risk percutaneous coronary intervention can be successfully managed with Impella.

Pearl #2 The nonpulsatile systemic pressure waveforms indicate the degree of support from the device over the native heart.

Pearl #3 Return of pulsatile waveforms indicates LV recovery.

Declaration of competing interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethics statement

The research reported has adhered to the relevant ethical guidelines.

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