Impact of Impella on Coronary Flow Assessed by Transthoracic Doppler Echocardiography

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Abstract
A 66-year-old man presented with anterior ST-elevated myocardial infarction and cardiogenic shock. After placement of the Impella device, he successfully underwent percutaneous coronary intervention for lesions in the left anterior descending artery (LAD) and left circumflex artery. Coronary flow in LAD according to the support setting was evaluated using transthoracic Doppler echocardiography during Impella weaning.

Introduction
Impella device is a percutaneous micro-axial continuous-flow pump that is used for the patients with cardiogenic shock and left ventricular unloading [1]. Impella-assisted forward blood flow may increase the coronary blood flow, however few studies investigated in vivo coronary flow with Impella support. We present a case with myocardial infarction and subsequent cardiogenic shock whose coronary flow in left anterior descending artery (LAD) according to the support setting was evaluated using transthoracic Doppler echocardiography during Impella weaning.

Case Presentation
A 66-year-old man with a history of hypertension and dyslipidemia complained sudden-onset chest pain when sleeping, and he visited our emergency department. The electrocardiography showed ST segment elevation in II, III, aVF and V2-6. Echocardiography showed diffuse left ventricular wall hypokinesis (ejection fraction 30%) with severe hypokinesis in the anterior wall. He was transferred to the catheterization laboratory for primary percutaneous coronary intervention (PCI) with a diagnosis of anterior ST-elevation myocardial infarction. His blood pressure was 71/42 mmHg under catecholamine support when the angiography started. Coronary angiography revealed the presence of total occlusions in the mid LAD and proximal right coronary artery, and another 90% stenosis in the proximal left circumflex artery (LCx) (Figure 1).
Coronary angiography showed totally occlusive lesions in the LAD and RCA, and another 90% stenosis in the proximal LCx. Ultimaster 3.5 × 33 mm was deployed in LAD, Combo 2.5 × 18 mm was implanted in the LCx with Impella support.

LAD: Left anterior descending artery, LCx: Left Circumflex artery, RCA: Right coronary artery

He showed signs of cardiogenic shock, and the Impella CP Smart Assist system (Abiomed, Danvers, Massachusetts) was placed via his right common femoral artery before the high-risk PCI. The PCI was performed for the culprit LAD lesion and the non-culprit LCx lesion. Under Impella support, a guidewire was crossed distal to the LAD lesion, and pre-dilatation was performed with a 2.5 mm semi-compliance balloon. A third-generation drug-eluting stent (DES) (Ultimaster Nagomi 3.5 × 33 mm, Terumo Interventional Systems, Tokyo, Japan) was deployed with intravascular ultrasound (IVUS) imaging guidance. Post-dilatation was performed with a 3.25 mm non-compliance balloon for the mid-distal lesion, and a 4.0 mm non-compliance balloon for the proximal segment. IVUS showed acceptable stent expansion and apposition. For the lesion in the LCx, after pre-dilatation with a 2.5 mm semi-compliance balloon, a third-generation DES (Combo plus2.5 × 18 mm, OrbusNeich Medical, Florida, USA) was implanted. Angiography showed thrombolysis in myocardial infarction grade 3 flow both in LAD and LCx.

After successful PCI for LAD and LCx lesions, coronary flow velocity assessment of LAD with transthoracic Doppler echocardiography was performed in the weaning phase of Impella.

Investigations

Our study was approved by the institutional ethics committee (reference no. 2023FY42/Tsuchiura; June 5, 2023) and conducted in compliance with the tenets of the Declaration of Helsinki for investigation in human beings. The patient provided written informed consent for this study and the use of the data in future analyses.

Echocardiographic studies were conducted according to the American Society of Echocardiography guidelines using a commercially available digital ultrasound system (GE Vivid E95; GE Vingmed Ultrasound, Horten, Norway) with a multifrequency transducer and second-harmonic technology [2]. After a standard examination, the coronary flow in the mid-distal portion of the LAD was assessed using a modified three-chamber view. For color flow mapping, the velocity range was set as 16–24 cm/sec. A sample volume (3–5 mm wide) was positioned on the distal LAD to measure blood flow velocity. Basal diastolic peak coronary flow velocity was first measured in the condition (bDPV) on Impella support by P8, then under P4 and P2, respectively. After removal of the Impella, the diastolic peak velocity (DPV) under maximal hyperemia (hDPV) was measured, which was induced by intravenous adenosine (140 μg/kg per min through a central vein). All studies were digitally stored for offline review and measurements. Regarding the stress data, three optimal flow signal profiles at rest and during hyperemia were obtained offline from the recorded data. Coronary flow velocity reserve (CFVR) was calculated as the ratio of hyperemic to basal peak diastolic flow velocities using the software package of the ultrasound system. The averaged values obtained by the two
observers were used for the final analysis.

bDPV was 0.69 m/s at P8 (5.7 l/min), 0.52 m/s at P4 (2.7 l/min), 0.35 m/s at P2 (2.3 l/min) (Figure 2)

**FIGURE 2: Coronary flow of LAD during Impella support**

Coronary flow in the mid-distal portion of the LAD was assessed using a modified three-chamber view. A sample volume (3–5 mm wide) was positioned on the distal LAD to measure blood flow velocity.

bDPV was 0.35 m/s at P2, 0.52 m/s at P4, 0.69 m/s at P8. The peak LAD flow velocity gradually decreased with the decrease in the level of Impella support.

LAD: left anterior descending artery, bDPV: basal Diastolic peak velocity

On day 13, bDPV and hDPV after Impella removal were assessed. The bDPV was 43 cm/s and hDPV was 55 cm/s. The CFVR was 1.28 (Figure 3)
FIGURE 3: Basal and hyperemic coronary flow after Impella removal

After Impella removal, basal and hyperemic DPV of the LAD were assessed. The bDPV was 43 cm/s and hDPV was 55 cm/s. the CFVR was 1.28.

LAD: left anterior descending artery, bDPV: basal diastolic peak velocity, hDPV: hyperemic diastolic peak velocity.

Management

On day 1, peak CK was 11669 U/l at 3 hours after primary PCI. The Impella was removed on day 2, considering the hemodynamic stability of the patient. Extubation was performed on day 3. He was treated with guideline-directed medical therapy including double antiplatelet, statin, angiotensin angiotensin-converting enzyme inhibitor, diuretics, and low dose β blocker. Cardiac rehabilitation was started and he showed good clinical course with no adverse event. He was discharged on day 14.

Discussion
The Impella device is a percutaneous transvalvular microaxial flow pump that is currently used for cardiogenic shock and high-risk PCI to aid left ventricular unloading [1,3]. It has been shown to provide superior hemodynamic support compared to intraaortic balloon pumping [4,5]. However, the coronary flow during Impella support and the change in coronary flow according to the Impella support level were not well elucidated. This is the first report which described the coronary flow velocity using transthoracic Doppler echocardiography in a patient with cardiogenic shock caused by myocardial infarction during Impella support and its weaning phases, as well as after Impella removal.

Conclusions
This case demonstrated that the Impella provided favorable effects on coronary microcirculation in accordance with a change in support flow without significant changes in systemic blood pressure. LV unloading by the Impella support may decrease LV end-diastolic pressure, and potentially reduce subendocardial pressure, which might increase the epicardial coronary flow observed in this case without significant changes in the systemic blood pressure and heart rate according to the reduction of microcirculatory resistance. Our case illustrates the potential impact of the Impella not only on LV unloading with the reduction of LV myocardial oxygen demand, but also on an increase in oxygen supply by increasing coronary flow through the effect on coronary microcirculation.

Additional Information

Disclosures
Human subjects: Consent was obtained or waived by all participants in this study. Tsuchiura Kyodo General Hospital institutional review board issued approval 2023FY42. Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: Payment/services info: All authors have declared that no financial support was received from any organization for the submitted work. Financial relationships: All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. Other relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

References