—**Case Reports**—

Circulatory Management with Impella Assistance during Off-Pump Coronary Artery Bypass Grafting for Cardiogenic Shock: A Report of Two Cases

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The combination of initial Impella therapy, Impella-supported coronary artery bypass grafting (ISCAB), and postoperative Impella therapy providing antegrade perfusion in myocardial infarction can prove effective. We investigated strategies for Impella stabilization in ISCAB, particularly during peripheral circumflex branch anastomosis. Case 1 was a 70-year-old man treated with an Impella 2.5, followed by urgent ISCAB on the day of hospitalization, for a left main trunk lesion. Use of an apical suction device to position the heart to expose an obtuse marginal branch caused Impella obstruction by applying suction to the left ventricular wall, interrupting revascularization; however, one revascularization was achieved. Case 2 was a 79-year-old man treated with an Impella CP for a three-vessel lesion until ISCAB 4 days later. The Impella was stabilized with appropriate positioning by adjusting the bed angle, minimal heart compression with a deep pericardial stitch without pulling on the cardiac apex, and sufficient preload, even during posterolateral branch anastomosis. Four revascularizations were eventually achieved. Multiple innovations to prevent Impella contact with the left ventricle as described herein improve ISCAB safety, particularly during peripheral circumflex branch anastomosis.

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Key words: cardiac surgery, cardiogenic shock, Impella, coronary artery bypass grafting, myocardial infarction

Introduction

Cardiogenic shock (CS) is associated with a mortality rate of 50-60%, with acute myocardial infarction (AMI) being the most common cause of CS[1]. The risk of cardiovascular complications in percutaneous coronary intervention increases in patients with three-vessel lesions, left main trunk (LMT) lesions, lesions at the entrance of the left anterior descending artery (LAD), or low ejection fraction[2]. Predictors of conversion to on-pump coronary artery bypass grafting (CABG) from off-pump CABG include low ejection fraction, congestive heart failure, Canadian Cardiovascular Society class 3/4 angina, and emergency surgery[3]. Use of a circulatory assist device such as the Impella (Abiomed Japan, Tokyo, Japan) can be beneficial before coronary intervention in CS cases[4]. The Impella is a pump catheter-type device that provides antegrade perfusion, reducing the risk of subendocardial ischemia due to AMI[5].

Various reports have described the effectiveness of Impella-supported CABG (ISCAB) and additional perioperative Impella therapy[6,7]. However, ISCAB has the major disadvantage of destabilizing the Impella during peripheral circumflex branch anastomosis. We report on some difficulties with successful Impella stabilization during ISCAB.

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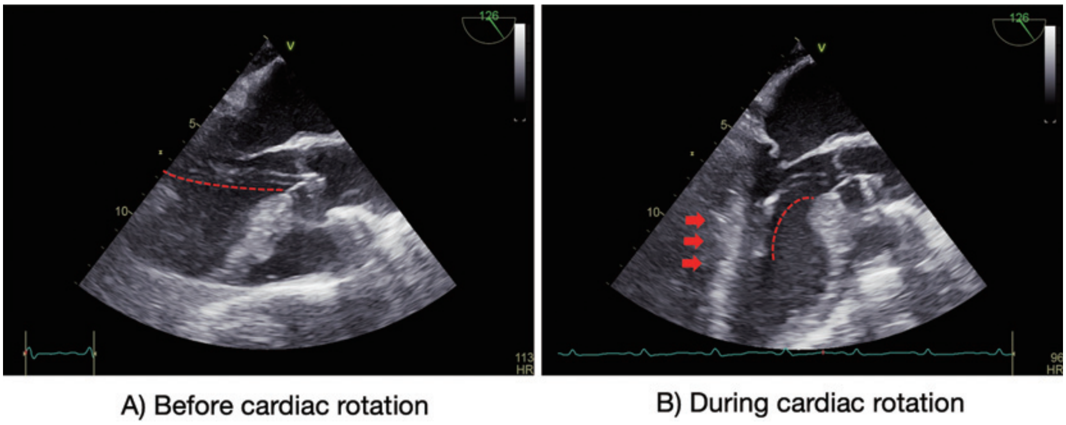

Fig. 1 Transthoracic echocardiography of Impella positioning in Case 1
A) Before heart positioning, the Impella 2.5 was not bent (dashed line) and was working normally. B) Immediately after heart positioning to obtain a view of the obtuse marginal area, the Impella 2.5 showed significant bending along the dashed line, touching the left ventricle, as indicated by the arrows, and becoming obstructed.

Case Report

Ethics approval and consent to participate

In our institution, publication of case reports is exempted from ethics committee approval.

Consent for publication

Written informed consent was obtained from both patients for publication of this case report and accompanying images.

Case 1

A 70-year-old man with a history of hypertension and diabetes presented with sudden respiratory distress that woke him from sleep. Congestive heart failure was identified, and ST-segment elevation myocardial infarction was diagnosed based on ST-segment elevation of the precordial leads (V1-3). Mechanical ventilation and administration of norepinephrine 0.2 μg/kg/min were started for CS. An LMT lesion (#5: 90%) was responsible, with no significant stenosis in the right coronary artery. Extensive calcification in wide areas of the aorta and occlusion of the left common iliac artery and stenotic right femoral artery interfered with insertion of an intra-aortic balloon pump and introduction of veno-arterial extracorporeal membrane oxygenation. An Impella 2.5 (maximum flow rate, 2.5 L/min; canula diameter, 12 Fr) was therefore introduced. Stenotic calcification of the LMT lesion was too severe to address with percutaneous coronary intervention. Because of the severe calcification in the ascending aorta, the cardiovascular surgeon suggested urgent ISCAB without cardiopulmonary bypass. The initial goal was LAD revascularization, and the obtuse marginal branch was scheduled for additional treatment. On entry to the operating room, heart rate was 125 beats/min and mean atrial pressure was 95 mm Hg. Oxygen saturation of the central vein ($ScvO_2$) with the Impella (2.5 L/min) in place was 79%. Transesophageal echocardiography (TEE) revealed an ejection fraction of 35% with no significant valvular disease. Anesthesia was induced with 0.5% sevoflurane and 50 mg of rocuronium, and the concentration was adjusted according to the hemodynamics with sevoflurane up to 1.5% and additional fentanyl. During aorta-saphenous vein graft (SvG)-LAD anastomosis, the Impella achieved stable conditions with a heart rate of 90-100 beats/min, mean atrial pressure >65 mm Hg and regional oxygen saturation (rSO_2) >70% using dobutamine 3 μg/kg/min. However, use of an apical suction device to position the heart to expose an obtuse marginal branch area caused Impella obstruction. TEE examination showed the Impella touching and applying suction to the wall of the elongated and twisted left ventricle (LV) (**Fig. 1**). Mean arterial pressure dropped sharply to <50 mm Hg and heart positioning was abandoned. After three attempts and interruptions of heart positioning, $ScvO_2$ dropped to 59%. Revascularization of the obtuse marginal branch was canceled, and revascularization of the LAD alone was finally achieved with onlay-patch grafting. The duration of surgery was 5 h 34 min, the duration of anesthesia was 7 h 21 min, the amount of crystalloid fluid administered was 8,750 mL, the volume of collected and returned blood was 900 mL, the amount of red blood cells transfused was 1,680 mL, the amount of fresh frozen plasma transfused was 720 mL, urine output was 650 mL, and water balance was 8,430 mL. Impella therapy was continued postoperatively. On postoperative day 1, peripheral ischemia

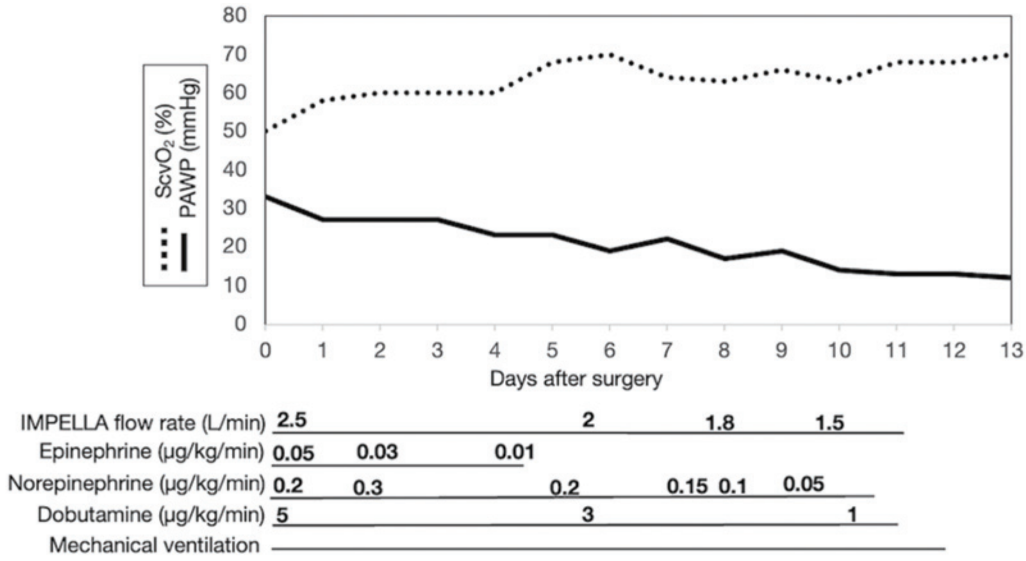

Fig. 2 Postoperative course in Case 1

The solid line shows pulmonary artery wedge pressure, expressed in millimeters of mercury. The dashed line shows oxygen saturation of the central veins ($ScvO_2$) sampled from the central venous catheter, expressed as a percentage.

caused by Impella insertion required a bypass from the Impella circuit. Pulmonary artery wedge pressure (PCWP) gradually improved with stabilized $ScvO_2$ during Impella therapy (**Fig. 2**). Impella therapy was withdrawn 11 days postoperatively and the tracheal tube was removed 12 days postoperatively. The patient was finally able to walk independently and was discharged 53 days after surgery.

Case 2

A 79-year-old man with a history of hypertension, hyperuricemia, and pulmonary emphysema complained of worsening chest pain from 2 days before hospitalization. He presented with congestive heart failure and was diagnosed with ST-segment elevation myocardial infarction in the inferior leads after transfer to our hospital. Mechanical ventilation and administration of norepinephrine were started, after which Impella CP (maximum flow rate, 3.7 L/min; canula diameter, 14 Fr) was introduced for CS with an $ScvO_2$ of 42% and a PaO_2/FiO_2 ratio of 60. The three-vessel lesion (#1: 50%; #2: 90%; #4 posterior descending branch: 90%; #6: 90%; #7: 99%; second diagonal branch: 99%; #11: 99%; #13: 99%; #12: 90%) with a SYNTAX score of 41 required CABG, although coronary perfusion had already resumed[8]. Taking Impella therapy for control of heart failure as a "bridge to therapy" and considering that ISCAB would be preferable to CABG using cardiopulmonary bypass as a means of reducing blood loss, the cardiovascular surgeon determined that optimal timing for surgery was the fourth day after hospitalization, when the patient had recovered from CS. Preoperative Impella therapy with a flow rate of 3.4 L/min improved mean PCWP from 28 mm Hg to 9 mm Hg, improved $ScvO_2$ from 42% to 60%, and reduced the dose of norepinephrine required from 0.13 μg/kg/min to 0.03 μg/kg/min on the day of operation. On entering the operating room, heart rate was 75 beats/min, mean atrial pressure was 85 mm Hg, and rSO_2 was 58%. Anesthesia was induced with 1.3% sevoflurane, 100 μg of fentanyl, and 50 mg of rocuronium and maintained with 1% sevoflurane, remifentanil 0.1-0.25 μg/kg/min, and fentanyl 25 μg/h. TEE revealed an ejection fraction of 40% and moderate mitral valve regurgitation. The Impella was stable with a flow rate of 3.9 L/min, a heart rate of 70-80 beats/min, and mean atrial pressure >65 mm Hg during left internal thoracic artery-LAD anastomosis. We attempted to stabilize the Impella during anastomosis, given our previous experience with Case 1. During the aorta-SvG-first diagonal branch-posterolateral branch-right posterior descending branch anastomosis, the surgical bed was kept in a head-down position with fine adjustment to right-down inclination to facilitate vascular anastomosis. Heart positioning was performed using a deep pericardial stitch with minimal compression and no pulling on the cardiac apex. The shape of the LV and Impella were kept unbent by providing sufficient preload (**Fig. 3**). The Impella remained stable throughout all anastomosis procedures, with no drop in mean atrial pressure from >60 mm Hg, $ScvO_2$, or rSO_2 using norepinephrine at

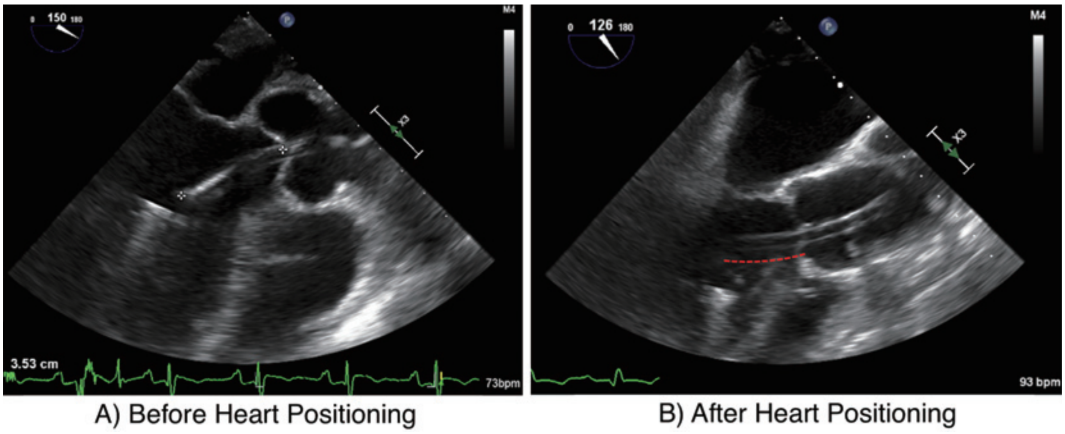

Fig. 3 Transthoracic echocardiography of Impella positioning in Case 2
A) Before heart positioning, the Impella CP was not bent and was working normally. The two asterisks were left on the display for distance measurement. B) After heart positioning to obtain a view of the circumflex area, the Impella CP showed no significant bending (along the dashed line) and was stabilized.

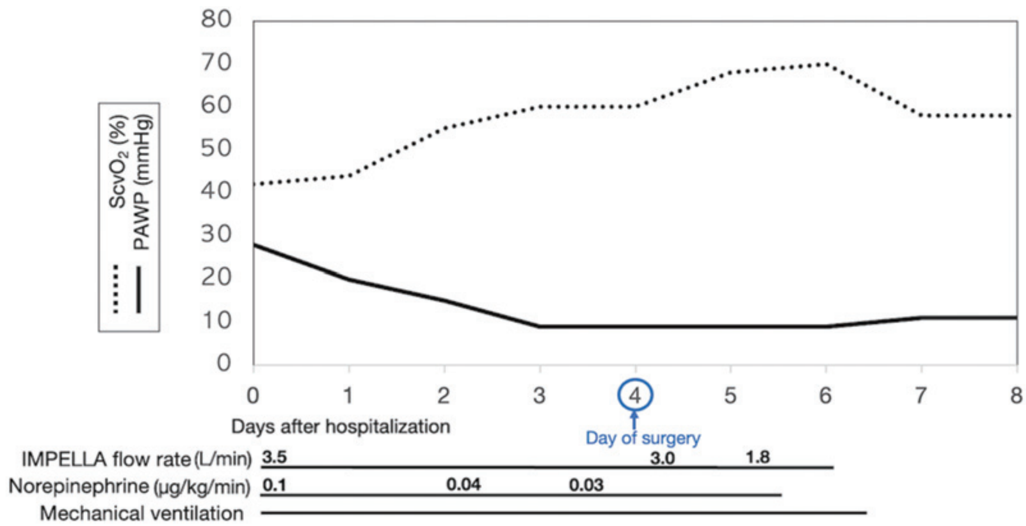

Fig. 4 Postoperative course in Case 2
The solid line shows pulmonary artery wedge pressure, expressed in millimeters of mercury. The dashed line shows oxygen saturation of the central veins ($ScvO_2$) sampled from the central venous catheter, expressed as a percentage.

a maximum dose of 0.08 μg/kg/min. Reduction of Impella flow was required only when punching out the aorta. The duration of surgery was 5 h 55 min, the duration of anesthesia was 7 h 30 min, the volume of crystalloid fluid was 8,450 mL, the amount of blood collected and returned was 647 mL, the amount of red blood cells transfused was 2,240 mL, the amount of fresh frozen plasma transfused was 1,680 mL, urine output was 1,200 mL, and water balance was 6,985 mL. Impella therapy was withdrawn on postoperative day 2. The tracheal tube was removed on postoperative day 4 (**Fig. 4**). However, aspiration pneumonia required respiratory support on postoperative day 39. Patient status improved with tracheostomy and additional antibiotic therapy. The patient was ultimately weaned from respiratory support with closure of the tracheal port. He was able to walk independently and discharged 96 days after surgery.

Discussion

In these cases, ISCAB was performed for CS in patients who underwent additional perioperative Impella therapy as a bridge to therapy, followed by postoperative Impella therapy as a bridge to recovery. In Case 1, the Impella could not be stabilized in circumflex branch anastomosis. ISCAB surgery has been reported in which right coronary artery and ramus intermedius revascularization were achieved with transfemoral Impella CP, which would not require heart positioning to exposure a posterolateral area[7]. In another case, ISCAB including aorta-SvG-posterolateral branch anastomosis was attempted, but Impella obstruction required a reduction in flow rate through the Impella[9]. A method of managing ISCAB, especially during heart positioning to expose a posterolateral circumflex branch, has not been established. In CS cases, reducing Impella support during heart positioning for revascularization requires extreme caution. Strategies for Impella stabilization in ISCAB during peripheral circumflex anastomosis have not been reported previously.

For Impella stabilization in ISCAB, the Impella must be kept in an appropriate position. During heart positioning, the wall of the elongated and narrowed LV can come into contact with the Impella, which is immediately detectable on TEE monitoring. Our experience with Case 1 suggests that the following measures may have been useful in stabilizing the Impella. First, adequate head-down positioning of the bed could have helped maintain sufficient preload, and right-down inclination of the bed could have prevented excessive folding of the LV. Second, the apical suction device used for heart positioning may have pulled excessively on the cardiac apex, causing LV elongation, rigidity, and narrowing, especially during circumflex branch anastomosis[10]. Third, sufficient preload is required to avoid LV narrowing. In off-pump CABG, preload during anastomosis is generally limited, and stable cardiac output is maintained using cardiovascular agonists instead. However, sufficient preload can provide a sufficient flow rate in ISCAB, allowing the heart to "rest" under minimal cardiovascular agonists. These innovations enabled Impella stabilization during anastomosis, including to the farthest area supplied by the circumflex branch, in Case 2. If they were not effective, it may have become necessary to reduce the flow rate of Impella to avoid the need for suction of the LV, as has been reported[9]. However, since stroke volume and ejection fraction significantly decrease during heart positioning to expose a circumflex branch, conversion to on-pump surgery may be considered at that time, especially for CS cases[10]. Moreover, the possibility that Impella use may increase bleeding during anastomosis should be considered. It should be noted that obstruction of the right ventricular outflow tract could result in the Impella accelerating the collapse of the LV and exacerbating enlargement of the right ventricle, with a sudden jump in central venous pressure. Acute right heart failure or right coronary ischemia during snare may also disable ISCAB in a similar manner. In such cases, temporary pacing, inotropic agents, and preparation for conversion to on-pump surgery are required.

Selection of ISCAB for CS cases requires careful consideration of the potential advantages over conventional CABG. Cardiopulmonary bypass carries risks such as hemodilution requiring additional transfusion, stroke, postoperative atrial fibrillation, and aortic injury[11–14]. Moreover, Impella treatment with a single insertion throughout the perioperative period can avoid the need for device replacement, thus reducing the duration of myocardial ischemia and medical costs. However, the size of the Impella device needs to be determined based on the required amount of cardiac support. In the present cases we selected the Impella 2.5 and Impella CP, which could be inserted without artificial blood vessels; however, an Impella 5.0 (maximum flow rate, 5.0 L/min) could have made ISCAB easier, as reported previously[15].

In conclusion, preoperative Impella therapy followed by ISCAB and postoperative Impella therapy may be beneficial for CS cases, although further innovations in Impella stabilization and strict monitoring are required. Incorrect positioning of the Impella during heart positioning can accelerate hemodynamic collapse by interfering with the LV. TEE monitoring and quick correction of any mispositioning are therefore warranted.

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