Additional Use of a 6-Fr Intra-Aortic Balloon Pump on Extracorporeal Membrane Oxygenation Was Effective in a Patient with Cardiogenic Shock with Low Pulse Pressure

Daisuke Kaneko, MD, Masao Takahashi, MD, Motoki Fukutomi, MD, Hiroshi Funayama, MD and Kazuomi Kario, MD

Summary
We report the case of a 79-year-old man with acute myocardial infarction caused by left main trunk lesion, who experienced cardiogenic shock during percutaneous coronary intervention (PCI). To reverse the cardiogenic shock, we initiated veno-arterial extra corporeal membrane oxygenation (VA-ECMO) without an intra-aortic balloon pump (IABP) due to the severe tortuosity of the left external iliac artery. Although PCI was successful, arterial pressure monitoring revealed that the pulse pressure was too low to recover from the cardiogenic shock of decreased cardiac contraction function (the left ventricular ejection fraction was 30%). Thus, we decided to use IABP from the brachial artery to improve the hemodynamics. Immediately after the deployment of a 6-Fr IABP system (Takumi) from the left brachial artery, the pulse pressure was restored and finally VA-ECMO was withdrawn from the patient without complications. Although using IABP in combination with VA-ECMO is a reasonable strategy for cardiogenic shock, the effectiveness of this combination remains controversial. In this case, IABP added to VA-ECMO clearly achieved an improvement of pulse pressure and vital signs. Based on this result, monitoring of the pulse waveform is an effective tool to determine whether the concomitant use of IABP with VA-ECMO is indicated. Moreover, when it is difficult to insert IABP from the femoral arteries, the use of a 6-Fr IABP system (Takumi) approaching from the brachial artery should be considered.

Key words: Cardiopulmonary arrest, Takumi, Brachial artery, Impella

Acutely cardiogenic shock caused by acute myocardial infarction still remains a clinical issue with high mortality rates, even though mechanical circulatory devices have been introduced in recent years.¹⁻² For the last several decades, to support the treatment of cardiogenic shock, we have used an intra-aortic balloon pump (IABP), a pressure augmentation device that produces additional cardiac output by increasing the coronary blood flow and decreasing the cardiac afterload via inflation of a balloon in diastole and active deflation in systole. Although evidence from a large randomized controlled trial and a meta-analysis did not support the routine use of IABP in patients with cardiogenic shock,³⁻⁴ IABP will continue to be used clinically in patients with cardiogenic shock or high-risk coronary artery diseases, including left main trunk (LMT) lesions and triple-vessel disease, because of a belief in a certain understanding of pathophysiology and anecdotal experience of improved clinical status.⁵⁻⁶

Veno-arterial extracorporeal membrane oxygenation (VA-ECMO) can provide full cardiopulmonary support, resulting in sufficient organ perfusion. However, VA-ECMO also increases cardiac afterload and myocardial oxygen demand because oxygenated blood is returned to the femoral or axillary artery, which competes against cardiac antegrade flow.

Theoretically, it is expected that IABP decreases cardiac afterload in patients with VA-ECMO and improves hemodynamics. However, there are many arguments both for and against the concomitant use of IABP with VA-ECMO.⁶⁻⁷ Thus, precise and detailed information on the drawbacks and benefits of the concomitant use of IABP with VA-ECMO is important in saving the lives of patients with cardiogenic shock in a clinical setting.

Here, we report a case of cardiogenic shock in which the addition of 6-Fr IABP to VA-ECMO dramatically improved the hemodynamics.

Case Report
A 79-year-old male who had a medical history of percutaneous coronary intervention (PCI) using a culotte stenting technique for the LMT lesion, presented with chest pain and dyspnea and was taken by ambulance to our hospital. His electrocardiogram showed ST elevation in the aVR lead and ST depression in the V4-V6 leads...
(Figure 1A), and his systolic blood pressure was around 100 mmHg. The decreased left ventricular contraction was observed by a transthoracic echocardiogram as severe hypokinesis from the base to the apex of the anterior and lateral wall (the left ventricular ejection fraction was 30%). The patient was diagnosed as having acute myocardial infarction and underwent emergent coronary angiography (CAG) approaching from the right radial artery. The results of CAG revealed in-stent restenosis of LMT (75% stenosis) and circumflex (LCx: 99% stenosis) (Figure 2A, B), and thereby an ad hoc PCI was planned. We tried to prepare an alternative access by a 7-Fr sheath into the right femoral artery before PCI as a safety precaution against cardiogenic shock. However, this approach failed due to the severe tortuosity of the right external iliac artery (EIA; Figure 3A-C). Although severe tortuosity of the left EIA was also observed, insertion of the 7-Fr sheath into the left femoral artery was possible (Figure 3A-C). Emergent PCI was performed using a guiding catheter with two guidewires (Heatrail BL3.5SH 7-Fr: Terumo, Tokyo; SIONblue and SION: ASAHI Intecc, Aichi, Japan). After the balloon angioplasty, drug-coated balloons (Se-
Figure 3. A-C: Severe tortuositites of the bilateral external iliac arteries were documented by three-dimensional computed tomography; the three panels show the view from the right anterior oblique, the straight view, and the view from the left anterior oblique, respectively. D: A 7-Fr sheath was inserted from the right femoral artery, but did not work due to the severe tortuosity of the right iliac artery (black arrows). A 21-Fr venous cannula was inserted from the right femoral vein (white arrowheads). E: A 12-Fr arterial cannula for VA-ECMO (white arrowheads) and a 7-Fr sheath (black arrows) were inserted from the left femoral artery.

Quent Please 3.0/20 mm and 3.0/17 mm; B. Braun Melsungen AG, Berlin, Germany) were dilated simultaneously (i.e., the kissing balloon technique was used and the balloon inflation time was 5 seconds per an inflation; Figure 2C). However, the patient experienced ventricular fibrillation with cardiogenic shock during the PCI (Figure 1B). VA-ECMO was immediately induced with a 12-Fr arterial cannula from the left femoral artery and a 21-Fr venous cannula from the right femoral vein while performing the resuscitation (including defibrillation) and tracheal intubation (Figure 3D, E). Although the arterial cannula did not reach far from the upper edge of the common femoral artery due to tortuosity of the left EIA, VA-ECMO was stably induced. We considered the placement of an IABP due to the low pulsatile flow (arterial pressure: 90/80 mmHg). However, the severe tortuosity of the bilateral EIA did not allow us to place an IABP. After the successful PCI (Figure 2D, E), the patient was treated with VA-ECMO and noradrenaline. However, the peripheral arterial pressure was 60 mmHg as a steady waveform without an obvious aortic valve opening (Figure 4A). His low cardiac output could not overcome the retrograde blood flow from the VA-ECMO, and therefore IABP was considered necessary to reduce the afterload and improve hemodynamics. In an emergent setting, the brachial artery is one of the alternative approach sites for the insertion of IABP; we therefore inserted a 6-Fr IABP system (Takumi; Zeon Medical, Tokyo) from the left brachial artery and fixed it at the descending aorta. Immediately after inducing the IABP, we observed the reappearance of pulse pressure with aortic valve opening and an increased mean pressure of more than 100 mmHg (Figure 4B). We succeeded in withdrawing the VA-ECMO 4 days after its placement without major complications. His hemodynamics had been maintained after withdrawal of the IABP.

Discussion

The present case evidenced the effectiveness of the concomitant use of IABP with VA-ECMO, based on the recording of the waveform change after IABP placement and the concomitant change of the hemodynamics. When the pulse pressure is low (or an aortic valve does not open fully) and IABP insertion from the femoral artery is difficult due to severe tortuosity of the approach artery under VA-ECMO, insertion of a 6-Fr IABP system (Takumi) from the brachial artery should be considered to improve the hemodynamics.

Although VA-ECMO can support the blood flow to organs, it increases cardiac afterload and myocardial oxygen demand, which may lead to pulmonary edema.9) When low pulse pressure due to decreased cardiac output is recognized, withdrawal of VA-ECMO is difficult due to the excessive afterload from VA-ECMO itself. In this situation, the concomitant use of IABP dramatically improves the hemodynamics, as in our present case. Two mechanisms may be considered for low pulse pressure in patients with cardiogenic shock under using VA-ECMO. The first is low left ventricular function and the second is aortic stenosis. Although the detailed criteria for the effectiveness of IABP are not clear, a state where a flat waveform is changed to a sufficient pulse waveform by IABP may be considered effective evidence.

As described above, there are some arguments both for and against the concomitant use of IABP with VA-ECMO. An observational study that assessed the concomitant use of IABP with VA-ECMO compared to VA-ECMO alone for the treatment of cardiogenic shock showed no
IABP FOR SHOCK WITH LOW PULSE PRESSURE

Figure 4. A: Waveform of arterial pressure before and after IABP insertion. The steady waveform of peripheral arterial pressure changed to a pulsatile flow by the induction of the IABP from the left brachial artery. B: Peripheral arterial pressure before and after IABP insertion. Induction of the IABP restored the pulse pressure. The red triangles indicate the measured values of arterial pressure. Blue circles indicate the heart rate of the patient.

difference in overall mortality. On the other hand, some studies have suggested that the concomitant use of IABP with VA-ECMO is associated with decreased hospital mortality and allows the early withdrawal of VA-ECMO. One of the reasons that IABP has not been clearly proven effective for improving the survival rate in combination with VA-ECMO may be that the increase in cardiac flow achieved by IABP, which has been estimated as 0.3-0.5 L/min, is insufficient. Moreover, some reports showed no increase in coronary blood flow distal to a critical stenosis on IABP use, whereas others have revealed an enhancement of distal coronary blood flow. Although a randomized controlled study showed that elective IABP insertion did not reduce the incidence of cardiac events following high-risk PCI at 28 days, after a median follow-up of 51 months, the mortality was lower among those who received an IABP. These discrepancies may provide evidence of an insufficient augmentation of cardiac flow by IABP. However, whether or not supplemental cardiac flow from IABP is low, it is important that IABP competes with retrograde blood flow from VA-ECMO and can change the blood flow to antegrade. Therefore, IABP combined with VA-ECMO would seem to be the theoretically acceptable strategy for cardiogenic shock treatment.

Another cause of the discrepancy may be complications due to the presence of multiple mechanical devices. Generally, the more the devices, the greater the increase in complications such as bleeding, device-related blood infection, device-related limb ischemia, and stroke. Despite the hemodynamics stabilization by mechanical devices, complications may cancel the improvement of hemodynamics and increase the mortality. In this regard, a 6-Fr low-profile IABP system, such as Takumi, may be a reasonable choice to reduce complications.

Newer antegrade flow devices, such as Impella (Abiomed, Danvers, MA, USA), produce superior cardiac flow, resulting in greater hemodynamics stability than IABP. The left ventricular unloading and the augmentation of coronary flow by Impella are superior to those by IABP, although Impella requires a femoral artery of at least 13-Fr width and a relatively straight aortic artery to allow the approach from a femoral artery. Thus, patients with cardiogenic shock with severe tortuosity or severe stenosis in the approaching artery are not suitable for Impella use, but would still be candidates for Takumi, which requires only a 6-Fr size artery for the approaching site. Although the smaller size of IABP tends to result in fewer complications and may resolve the limitations of access site, disadvantages are also known, such as the limited balloon volume and the resulting increase in longitudinal balloon length. As the incremental cardiac output supplied by IABP depends on the balloon volume, the limited balloon volume is a critical issue. However, in our case, the use of a 6-Fr IABP system (with a balloon volume of 30 mL) recovered the antegrade cardiac flow and maintained the hemodynamics sufficiently. In consideration of all the previous reports, the routine use of IABP should be avoided according to the guidelines. However, our present case suggested that lower pulse pressure due to low cardiac output and VA-ECMO-induced cardiac afterload is one of the clear indications for IABP, despite the smaller balloon size. Another limitation of the 6-Fr IABP is that it is impossible to monitor arterial pressure through the wire lumen, and therefore another arterial access route is required to monitor the pressure.

In conclusion, monitoring the pulse waveform is an effective tool to determine whether the concomitant use of IABP with VA-ECMO is indicated. If the pulse pressure is low and the insertion of IABP from the femoral artery is not possible in patients with VA-ECMO, a 6-Fr IABP system (Takumi) approaching from the brachial artery should
be considered without hesitation to improve the hemodynamics.

**Disclosure**

**Conflicts of interest:** The authors declare that they have no conflicts of interest.

**References**

1. Werdan K, Gielen S, Ebelt H, Hochman JS. Mechanical circulatory support in cardiogenic shock. Eur Heart J 2014; 35: 156-67.
2. Kunadian V, Qiu W, Ludman P, et al. Outcomes in patients with cardiogenic shock following percutaneous coronary intervention in the contemporary era: an analysis from the BCIS database (British Cardiovascular Intervention Society). JACC Cardiovasc Interv 2014; 7: 1374-85.
3. Thiele H, Zeymer U, Neumann FI, et al. Intraaortic balloon support for myocardial infarction with cardiogenic shock. N Engl J Med 2012; 367: 1287-96.
4. Sjauw KD, Engström AE, Vis MM, et al. A systematic review and meta-analysis of intra-aortic balloon pump therapy in ST-elevation myocardial infarction: should we change the guidelines? Eur Heart J 2009; 30: 459-68.
5. Shiraishi J, Shoji K, Yanaguchi T, et al. Rotational atherectomy followed by drug-coated balloon dilation for left main in-stent restenosis in the setting of acute coronary syndrome complicated with right coronary chronic total occlusion. Int Heart J 2017; 58: 806-11.
6. Cheng R, Hachamovitch R, Makkar R, et al. Lack of survival benefit found with use of intraaortic balloon pump in extracorporeal membrane oxygenation: A pooled experience of 1517 patients. J Invas Cardiol 2015; 27: 453-8.
7. Ma P, Zhang Z, Song T, et al. Combining ECMO with IABP for the treatment of critically Ill adult heart failure patients. Heart Lung Circ 2014; 23: 363-8.
8. Aso S, Matsui H, Fushimi K, Yasunaga H. The effect of intraaortic balloon pumping under venoarterial extracorporeal membrane oxygenation on mortality of cardiogenic patients: an analysis using a Nationwide Inpatient Database. Crit Care Med 2016; 44: 1974-9.
9. Burkhoff D, Sayer G, Doshi D, Uriel N. Hemodynamics of mechanical circulatory support. J Am Coll Cardiol 2015; 66: 2663-74.
10. Atkinson TM, Ohman EM, O’Neill WW, Rab T, Cigarroa JE, Interventional Scientific Council of the American College of Cardiology. A practical approach to mechanical circulatory support in patients undergoing percutaneous coronary intervention: an interventional perspective. JACC Cardiovasc Interv 2016; 9: 871-83.
11. Kimura A, Toyota E, Lu S, et al. Effects of intraaortic balloon pumping on septal arterial blood flow velocity waveform during severe left main coronary artery stenosis. J Am Coll Cardiol 1996; 27: 810-6.
12. Yoshitani H, Akasaka T, Kaji S, et al. Effects of intra-aortic balloon counterpulsation on coronary pressure in patients with stenotic coronary arteries. Am Heart J 2007; 154: 725-31.
13. Takeuchi M, Nohtomi Y, Yoshitani H, Miyazaki C, Sakamoto K, Yoshikawa J. Enhanced coronary flow velocity during intraaortic balloon pumping assessed by transthoracic Doppler echocardiography. J Am Coll Cardiol 2004; 43: 368-76.
14. Kern MJ, Aguirre FV, Tatini eni S, et al. Enhanced coronary blood flow velocity during intraaortic balloon counterpulsation in critically ill patients. J Am Coll Cardiol 1993; 21: 359-68.
15. Perera D, Stables R, Thomas M, et al. Elective intra-aortic balloon counterpulsation during high-risk percutaneous coronary intervention: a randomized controlled trial. JAMA 2010; 304: 867-74.
16. Perera D, Stables R, Clayton T, et al. Long-term mortality data from the balloon pump-assisted coronary intervention study (BCIS-1): a randomized, controlled trial of elective balloon counterpulsation during high-risk percutaneous coronary intervention. Circulation 2013; 127: 207-12.
17. Ponikowski P, Voors AA, Anker SD, et al. 2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure: the Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC) Developed with the special contribution of the Heart Failure Association (HFA) of the ESC. Eur Heart J 2016; 37: 2129-200.