Nauka praktyce / Science for medical practice

OPIS PRZYPADKU / CASE STUDY
Otrzymano/Submitted: 29.11.2023 • Zaakceptowano/Accepted: 19.02.2024

Use of a left ventricular percutaneous assist device (Impella) and veno-arterial extracorporeal oxygenation (VA-ECMO) in severe ischemic cardiogenic shock – a case study

Wojciech J. Górski[1], Maksymilian Sikorski[1], Miłosz Jankowski[2], Tomasz Pawłowski[3], Piotr Suwalski[4], Konstanty Szułdrzyński[2]

[1] Studenckie Koło Naukowe Anestezjologii i Intensywnej Terapii, Wydział Medyczny. *Collegium Medicum*, Uniwersytet Kardynała Stefana Wyszyńskiego w Warszawie
[2] Klinika Anestezjologii i Intensywnej Terapii
[3] Klinika Kardiologii
[4] Klinika Kardiochirurgii, Państwowy Instytut Medyczny Ministerstwa Spraw Wewnętrznych i Administracji w Warszawie

Abstract

Cardiogenic shock is a life-threatening condition characterized by a significant morbidity and mortality. It occurs as a result of a decrease in cardiac output caused by severe dysfunction of the heart. Despite conventional treatment approaches, there are extreme cases that remain refractory to therapy, necessitating alternative interventions such as extracorporeal support techniques to assist the failing heart. These techniques not only help maintain proper tissue oxygenation and perfusion but also relieve the left ventricle and increase cardiac output. This article presents a case study of a patient experiencing severe cardiogenic shock due to acute coronary syndrome after thoracic trauma with pneumothorax. The authors highlight the value of simultaneous utilization of two treatment modalities: veno-arterial extracorporeal membrane oxygenation (VA-ECMO) and the Impella CP microaxial pump. By sharing this case, the authors underscore the importance of comprehensive and innovative approaches in managing critical cases of cardiogenic shock. *Anestezjologia i Ratownictwo 2024; 18: 18-23. doi:10.53139/AIR.20241803*

Keywords: cardiogenic shock, Impella CP, VA-ECMO, extracorporeal life support, left ventricle venting

Introduction

Cardiogenic shock is a severe form of myocardial insufficiency, where the decrease of cardiac output (CO) is below 2.2 l/min/m2, leading to generalized tissue hypoperfusion. It results in metabolic acidosis and eventually multiple organ failure. Unlike other types of shock caused by peripheral vascular dysfunction or insufficient circulating blood volume, cardiogenic shock arises from the dysfunction of the heart as a pump. Thus, diagnosis of this type of shock involves observing the decrease in cardiac output, peripheral hypoperfusion, systolic blood pressure below 80 mmHg without pharmacological and mechanical support, and normovolemic status indicated by pulmonary capillary wedge pressure above 15 mmHg [1,2].

Early identification and treatment of the underlying cause are crucial in managing cardiogenic shock. Cardiac echocardiography plays a vital role in assessing heart contractility, valve function, and overall myocardium condition. Additionally, coronary angiography is obligatory when myocardial infarction is suspected as the cause of the shock, as it allows to evaluate vascular perfusion and guides potential interventions such as angioplasty or even coronary artery bypass grafting [3,4].

During the conventional treatment of cardiogenic shock, patients struggle with the core components of shock, which is hypotension and tissue hypoperfusion, as well as respiratory failure. Hospitalization in an intensive care unit is necessary, along with cardiovascular pharmacotherapy and mechanical ventilation. In severe and refractory cases where pharmacotherapy alone becomes insufficient to maintain adequate blood pressure and organ perfusion, extracorporeal mechanical solutions, such as an extracorporeal veno-arterial mebrane oxygenation (VA-ECMO) and Impella microaxial pump, may be an effective continuation of therapy [5].

VA-ECMO is a temporary circulatory support technique that provides complete and immediate replacement of lung and heart function in cases of cardiac arrest or refractory cardiogenic shock. It involves collecting venous blood through a drain inserted into the inferior vena cava, then oxygenating it and removing carbon dioxide in a membrane oxygenator, and finally delivering it to the descending aorta through an arterial cannula. This mechanism allows to maintain sufficient blood pressure and partial pressures of respiratory gases, which is necessary to maintain the function of the patient's organs. VA-ECMO is used in refractory cardiogenic shock due to the reduction of myocardial workload while providing respiratory and hemodynamic support [6].

Impella is a microaxial centrifugal pump inserted percutaneously into the ventricle of the heart. There are two types of the device that support the function of the left (Impella CP) or right ventricle (Impella RP), respectively [7,8]. The combination of Impella CP and VA-ECMO is known as ECpella (or ECMELLA). It provides simultaneously proper tissue perfusion and left ventricle unloading, which has been associated with reduced mortality in patients with cardiogenic shock.[9]

This article presents a case of a 66-year-old male patient who underwent a complex and prolonged extracorporeal support involving the use of an Impella CP microaxial pump and VA-ECMO as part of the management of cardiogenic shock.

Case report

A 66-year-old male patient, employed as a construction worker by profession, following a fall from a height of approximately 7 meters, was transferred from the trauma and orthopedic surgery department of the district hospital to the Department of Anaesthesiology and Intensive Therapy, The National Institute of Medicine The Ministry of Interior and Administration in Warsaw, due to his deteriorating condition.

Upon admission, the patient was conscious (15 points in Glasgow Coma Scale), in contact and exhibited no neurological deficits. The Simplified Acute Physiology Score (SAPS II) was calculated to be 26 points, The Sequential Organ Failure Assessment (SOFA) score was 3 points and the Acute Physiology and Chronic Health Evaluation (APACHE II) score was 13 points. The patient reported shortness of breath, leading to the administration of passive oxygen therapy (flow at 3 l/min). A chest X-ray was performed, revealing signs of pneumothorax despite the pleural drainage established in the previous center. An additional drain was placed above the existing one.

On the second day of hospitalization in the intensive care unit, the patient reported worsening dyspnoea and angina pain. An electrocardiogram raised suspicion of acute coronary syndrome, and echocardiography showed a reduction of left ventricle ejection fraction (LVEF) to 15%. Coronary angiography revealed two critical stenoses of left main coronary artery (LMCA): 90% and 95% of lumen diameter proximally, and in the distal part, respectively. In addition, significant stenoses of the circumflex artery and its marginal branch were shown (both 70% of the lumen diameter), and right coronary artery (RCA) was fully obstructed in proximal part, but distally well supplied by collateral circulation from left coronary artery. The patient was then deemed eligible for coronary artery bypass grafting.

On the third day of stay, the patient experienced sudden cardiac arrest due to ventricular fibrillation. Resuscitation efforts were initiated, successfully restoring a hemodynamically effective heart rhythm. Subsequently, the patient developed cardiogenic shock, necessitating intubation and further mechanical ventilation. Given the high severity of the shock and the heightened risk of recurrence of the cardiac event, percutaneous microaxial pump supporting the left ventricle (Impella CP, Abiomed Inc.) was implanted, followed by percutaneous coronary angioplasty with the placement of a stent eluting sirolimus in LMCA. The lumen of the vessel was restored and TIMI III flow was obtained. After 24 hours LVEF increased to 30-35%.

By the fourth day of hospitalization, the patient exhibited signs of renal failure, including anuria, leading to the initiation of continuous veno-venous hemodialysis (CVVHD).

Despite high doses of vasopressors and dobutamine (Chart A), the patient's condition continued to deteriorate. Consequently, on the sixth day of hospitalization, extracorporeal membrane blood oxygenation in the venous-arterial system (VA-ECMO, Getinge) was initiated. Drainage and return cannulae were inserted via right common femoral vein and left common femoral artery, respectively; distal perfusion cannula was placed downstream through left superficial femoral artery. Due to anemia, the patient required multiple transfusions of blood products. In addition, stress ulcer prophylaxis was continued. The patient was fed both through the gastrointestinal tract and parenterally. Throughout the course of extracorporeal therapy, renal failure persisted, and indices of hepatic insufficiency progressed.

The simultaneous use of the Impella and VA-ECMO significantly improved the patient's cardiogenic shock by unloading the left ventricle and increasing cardiac output. LVEF increased to 48-50%. That is why, by observing the stabilization of the patient's circulatory system on the 20th day of hospitalization (Chart B), the decision was made to remove the VA-ECMO cannulas. Then, on day 22, the Impella device was removed under the guidance of transesophageal echocardiography (Chart C). In the following days of hospitalization, the patient regained consciousness and several attempts were made to liberate him from the ventilator, but mechanical ventilation and catecholamines were only temporarily discontinued. Tracheostomy was performed, pressure support ventilation and CVVHD were continued. Recurrent respiratory, urinary and bloodstream infections, and rectal bleeding were treated. Unfortunately, multiple organ (cardiovascular, respiratory, renal, and hepatic) failure persisted leading finally to the patient's death on the 64th day of hospitalization.

Discussion

We presented a case of prolonged mechanical circulatory support using VA-ECMO and microaxial pump Impella CP in the patient with cardiogenic shock caused by acute coronary syndrome following thoracic trauma. In our patient Impella implantation preceded the use of VA-ECMO, the latter was initiated, when the former turned out to be ineffective, but these techniques may be also instituted in reverse order. The use of VA-ECMO as a last-resort measure (the rescue treatment) in refractory cardiogenic shock is in line with results of recent randomized control trials [10,11] and metanalysis [12], which shown lack of benefit associated with earlier VA-ECMO application as compared to usual care. In addition, recent metanalysis suggests that the use of Impella in patients with cardiogenic shock is associated with lower rates of in-hospital mortality, bleeding, and stroke than ECMO [13].

Importantly, flow of oxygenated blood returning from VA-ECMO circuit to arterial circulation may increase the afterload and cause retrograde arterial flow. This can result in the reduction of the contractility of the left ventricle, impairment of natural cardiac output (CO), an increase in left ventricular end-diastolic pressure, and finally stagnation of blood in the left ventricle, closure of the aortic valve, and high risk of thrombotic events [14,15]. To address this issue VA-ECMO pump rotations may be lowered to reduce blood flow. If this is ineffective, left ventricle unloading techniques (also called venting), such as intra-aortic balloon pump, transseptal left atrial cannula, or Impella pump, are employed [15,16]. They have been shown to reduce pulmonary capillary wedge pressure, pulmonary artery pressure, and vascular resistance. It is also suggested that they may allow for effective regeneration of the myocardium and reversal of its remodeling. [15] Comparisons between Impella and more invasive surgical unloading techniques suggest certain advantages of Impella in terms of mortality and myocardial regeneration, particularly in patients over 65 years of age who have not undergone cardiopulmonary resuscitation [16].

Of note, the response to VA-ECMO may vary among patients with heart failure of different etiologies. The group of patients with acute cardiogenic shock and elevated left atrial pressure tend to benefit the most from left ventricle unloading. In addition, patients with biventricular shock, in which the right ventricle recovers faster than the left ventricle, can also benefit. In such cases, the right ventricle provides increased pulmonary flow, thereby increasing left ventricular preload despite extracorporeal support. However, it is important to consider that increasing preload and afterload may elevate left ventricle oxygen consumption, highlighting the need for an Impella centrifugal pump unloading strategy [17-18].

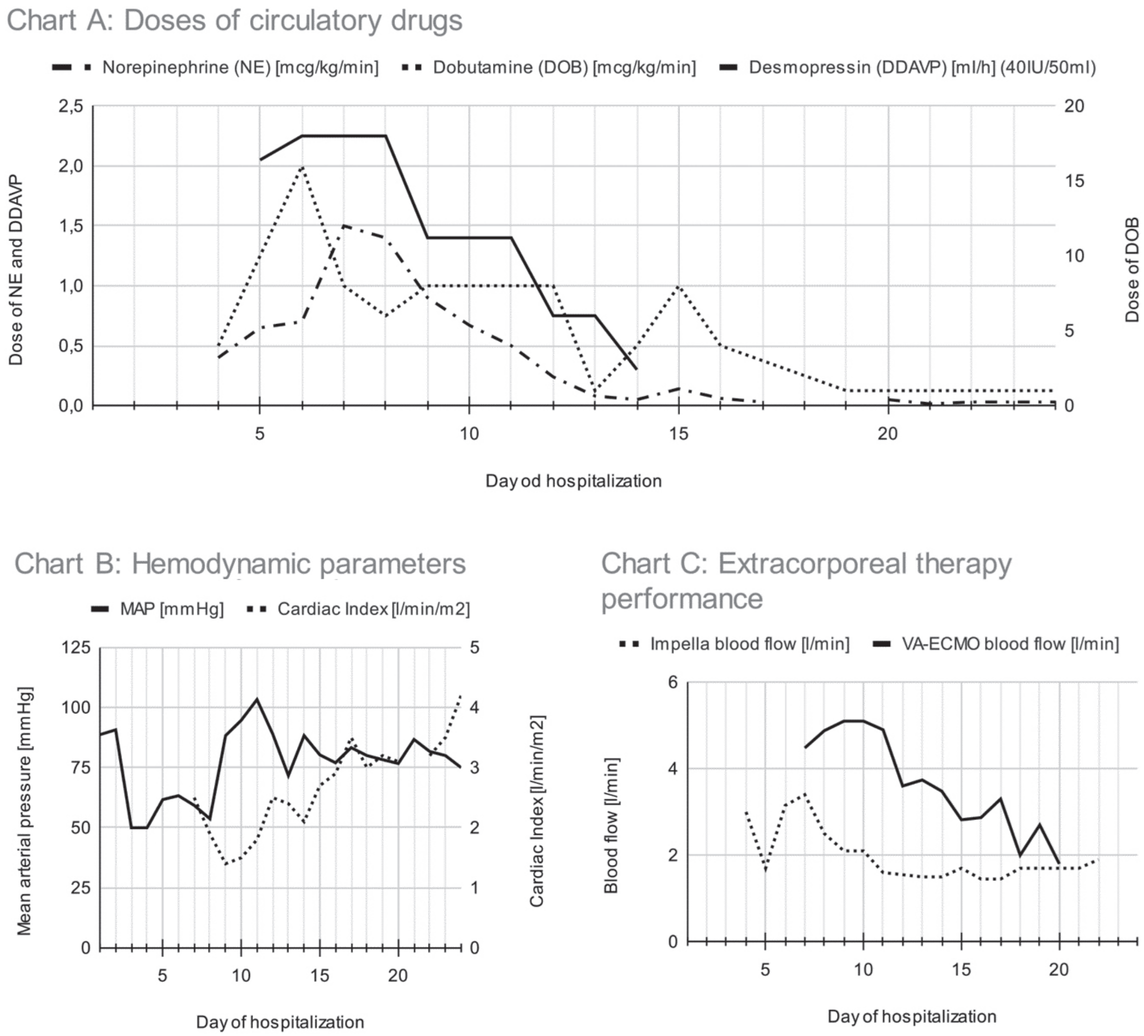

Figure 1. Characteristics of the patient's state and treatment

It should be underlined, that techniques of mechanical circulatory support are not free from the risk of complications, such as bleeding, thrombosis, hemolysis, acute kidney injury (AKI) and proinflammatory response related to the contact of blood with artificial surfaces of extracorporeal circuit [14,18]. In the case of our patient, continuous renal replacement technique (CRRT) was required prior to initiating VA-ECMO, a day after Impella implantation. It should be noted that the use of Impella may be associated with an increased risk of hemolysis and the need for CRRT [18], but in our patient AKI was rather related to hypoperfusion caused by cardiogenic shock. Of note, despite the heightened risk of complications we decided on "off-label" prolonged (more than 5-day) use of Impella CP, because it was initiated before VA ECMO support and thereafter served as left ventricle unloading technique. Otherwise, more invasive Impella 5.5 had to be surgically implanted, as it is certified for up to 30-day use.

In addition, both VA ECMO and Impella support circulation by linear (non-pulsatile) flow, which is not natural for perfused organs and tissues and might negatively impact their function [19,20]. However, comparison of pulsatile and non-pulsatile blood flow, especially in long term mechanical cardiac support remains unclear. That is why further research is needed.

It is crucial to consider all aforementioned factors when selecting the appropriate mechanical circulatory support strategy for patients with cardiogenic shock, tailoring the treatment to individual patient characteristics and optimizing outcomes. Importantly, it was reported that 20-65% of patients weaned from VA-ECMO after myocardial recovery did not survive to hospital discharge [21]. Our patient regained consciousness but despite weaning of Impella and VA-ECMO at very low doses of dobutamine and noradrenaline, the long-term sequelae of critical illness [22], and most probably tissue hypoperfusion and hypoxia during the first days of cardiogenic shock, led to persistent multiorgan failure and unfavorable outcome.

Conclusions

Simultaneous use of VA-ECMO and Impella microaxial pump provides a promising approach to overcome cardiogenic shock. Combination of these two methods diminishes the risk of so-called retrograde arterial flow, reduces afterload, and improves the left ventricular ejection fraction. These factors may contribute to a higher likelihood of myocardial regeneration following an acute coronary syndrome event. The chance of success of the Bridge to Transplant Therapy (BTT) and the heart transplant itself also increases [18].

The success of this treatment approach relies on timely and accurate patient qualification by a qualified medical team. Tissue hypoxia associated with cardiogenic shock, and subsequent multi-organ failure, significantly diminishes the patient's chances of survival. This case shows that short term success in extracorporeal therapy does not guarantee a patient's long-term survival and good quality of life [21,22].

Further research and studies are needed to better understand the optimal timing, patient selection criteria, and determinants of long-term outcomes associated with the use of VA-ECMO and Impella microaxial pump in the management of cardiogenic shock.

Konflikt interesów / Conflict of interest
Brak / None

Adres do korespondencji / Correspondence address
Wojciech J. Górski
Studenckie Koło Naukowe Anestezjologii i Intensywnej Terapii UKSW
ul. Wóycickiego 1/3 bud. 19, 01-938 Warszawa
☎ (+48) 780 754 002
kontakt@sknaiituksw.edu.pl

Piśmiennictwo/References

1. McDonagh TA, Metra M, Adamo M, et al. 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. Eur Heart J. 2021 Sep 21;42(36):3599-726. doi: 10.1093/eurheartj/ehab368.
2. van Diepen S, Katz JN, Albert NM, et al. Contemporary management of cardiogenic shock: a scientific statement from the american heart association. Circulation. 2017; 136:e232-8. doi: 10.1161/cir.0000000000000525.
3. Standl T, Annecke T, Cascorbi I, et al. The Nomenclature, Definition and Distinction of Types of Shock. Dtsch Arztebl Int. 2018;115(45):757-68. doi: 10.3238/arztebl.2018.0757.
4. Thiele H, de Waha-Thiele S, Freund A, et al. Fitzgerald S. Management of cardiogenic shock. EuroIntervention. 2021 Aug 27;17(6):451-65. doi: 10.4244/EIJ-D-20-01296.
5. Tsangaris A, Alexy T, Kalra R, et al. Overview of Veno-Arterial Extracorporeal Membrane Oxygenation (VA-ECMO) Support for the Management of Cardiogenic Shock. Front Cardiovasc Med. 2021;8:686558. doi: 10.3389/fcvm.2021.686558.
6. Le Gall A, Follin A, Cholley B, et al. Veno-arterial-ECMO in the intensive care unit: From technical aspects to clinical practice. Anaesth Crit Care Pain Med. 2018;37:259-68. doi: 10.1016/j.accpm.2017.08.007.
7. Burzotta F, Russo G, Previ L, et al. Impella: pumps overview and access site management. Minerva Cardioangiol. 2018;66:606-11. doi: 10.23736/S0026-4725.18.04703-5.
8. Montisci A, Sala S, Maj G, et al. Comprehensive evaluation of Impella RP® in right ventricular failure. Future Cardiol. 2022;18:285-98. doi: 10.2217/fca-2021-0075.
9. Meani P, Lorusso R, Pappalardo F. ECPella: Concept, Physiology and Clinical Applications. J Cardiothorac Vasc Anesth. 2022;36:557-66. doi: 10.1053/j.jvca.2021.01.056.
10. Thiele H, Zeymer U, Akin I, et. al. Extracorporeal Life Support in Infarct-Related Cardiogenic Shock. N Engl J Med. 2023. doi: 10.1056/NEJMoa2307227.

11. Ostadal P, Rokyta R, Karasek J, et al. Extracorporeal Membrane Oxygenation in the Therapy of Cardiogenic Shock: Results of the ECMO-CS Randomized Clinical Trial. Circulation. 2023;147(6):454-64. doi: 10.1161/CIRCULATIONAHA.122.062949.
12. Zeymer U, Freund A, Hochadel M, et al. Venoarterial extracorporeal membrane oxygenation in patients with infarct-related cardiogenic shock: an individual patient data meta-analysis of randomised trials. Lancet. 2023;25:S0140-6736(23)01607-0. doi: 10.1016/S0140-6736(23)01607-0.
13. Abusnina W, Ismayl M, Al-Abdouh A, et al. Impella versus extracorporeal membrane oxygenation in cardiogenic shock: a systematic review and meta-analysis. Shock. 20221;58(5):349-57. doi: 10.1097/SHK.0000000000001996.
14. Lorusso R, Shekar K, MacLaren G, et al. ELSO Interim Guidelines for Venoarterial Extracorporeal Membrane Oxygenation in Adult Cardiac Patients. ASAIO J. 2021;67:827-44.
15. Fiorelli F, Panoulas V. Impella as unloading strategy during VA-ECMO: systematic review and meta-analysis. Rev Cardiovasc Med. 2021;22(4):1503-11. doi: 10.31083/j.rcm2204154.
16. Radakovic D, Zittermann A, Knezevic A, et al. Left ventricular unloading during extracorporeal life support for myocardial infarction with cardiogenic shock: surgical venting versus Impella device. Interact Cardiovasc Thorac Surg. 2022;34:137-44. doi: 10.1093/icvts/ivab230.
17. Belohlavek J, Hunziker P, Donker DW. Left ventricular unloading and the role of ECpella. Eur Heart J Suppl. 2021;23:A27-A34. doi: 10.1093/eurheartj/suab006.
18. Bhatia K, Jain V, Hendrickson MJ, et al. A Meta-Analysis Comparing Venoarterial Extracorporeal Membrane Oxygenation With or Without Impella in Patients With Cardiogenic Shock. Am J Cardiol. 2022;181:94-101. doi: 10.1016/j.amjcard.2022.06.059.
19. Vašků J, Wotke J, Dobšák P, et al. Acute and Chronic Consequences of Non-Pulsatile Blood Flow Pattern in Long-Term Total Artificial Heart Experiment. Pathophysiology 2007;14:87-95. doi: 10.1016/j.pathophys.2007.06.002
20. Veraar CM, Rinösl H, Kühn K, et al. Non-pulsatile blood flow is associated with enhanced cerebrovascular carbon dioxide reactivity and an attenuated relationship between cerebral blood flow and regional brain oxygenation. Crit Care. 2019;23(1):426. doi:10.1186/s13054-019-2671-7.
21. Aissaoui N, El-Banayosy A, Combes A. How to wean a patient from venoarterioal extracorporeal membrane oxygenation. Intensive Care Med. 2015;41:902-5. DOI 10.1007/s00134-015-3663-y.
22. Herridge MS, Azoulay É. Outcomes after Critical Illness. N Engl J Med. 2023;388(10):913-24. doi: 10.1056/NEJMra2104669. PMID: 36884324.