https://doi.org/10.23873/2074-0506-2025-17-1-31-40

Using mechanical support methods in patients with acute myocardial infarction

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Abstract

Objective. *To evaluate the efficacy of mechanical support (extracorporeal membrane oxygenation + intra-aortic balloon pump) in patients with acute myocardial infarction complicated by heart failure.*

Results. *The timely use of the venoarterial extracorporeal membrane oxygenation system in combination with intra-aortic balloon counterpulsation in left ventricular failure in patients with acute myocardial infarction developing as a result of volume overload is an effective, easily available, cost-effective method actively implemented in clinical practice. A rational use of venoarterial extracorporeal membrane oxygenation + intra-aortic balloon counterpulsation leads to a decrease in the intensive care unit length of stay and decrease in mortality in patients with complicated acute myocardial infarction.*

Conclusion. *The use of extracorporeal membrane oxygenation in combination with intra-aortic balloon counterpulsation is an easily available and effective method for the prevention and relief of the left*

ventricular failure developing due to the volume overload in the course of peripheral venoarterial extracorporeal membrane oxygenation in patients with acute myocardial infarction

Keywords: acute myocardial infarction, pulmonary edema, cardiogenic shock, extracorporeal membrane oxygenation, intra-aortic balloon counterpulsation

Conflict of interests Authors declare no conflict of interest

Financing The study was performed without external funding

For citation: Kuzmina IM, Muradyan NA, Gvindzhiliya TR, Zhuravel SV, Kosolapov DA, Khubutiya MSh. Using mechanical support methods in patients with acute myocardial infarction. *Transplantologiya. The Russian Journal of Transplantation.* 2025;17(1):31–40. (In Russ.). https://doi.org/10.23873/2074-0506-2025-17-1-31-40

Abbreviations

ACS, acute coronary syndrome
AMI, acute myocardial infarction
BP, blood pressure
CS, cardiogenic shock
ECG, electrocardiogram
EchoCG, echocardiography
ECMO, extracorporeal membrane oxygenation
EF, ejection fraction
HDF, hemodiafiltration
HR, heart rate
IABC, intra-aortic balloon counterpulsation/
LV, left ventricle
MI, myocardial infarction
PASP, pulmonary artery systolic pressure
PCI, percutaneous coronary intervention
RCA, right coronary artery
VA ECMO, venoarterial ECMO

Introduction

According to statistics, cardiovascular mortality is the leading cause of death. Currently, myocardial infarction (MI) continues to be one of the most important problems of modern healthcare in terms of prevalence and social significance, as it entails a long-term loss of ability to work and disability in the population. And in the recent 20-25 years, a higher incidence of MI in men of working age has been noted when compared to previous years [1]. Over the recent decade, as a result of establishing the system of vascular centers in Moscow and rendering high-tech around-the-clock care to patients with acute coronary syndrome (ACS), the mortality rate for MI in Moscow has decreased from 12% to 7.5%.

It is known that death from myocardial infarction occurs as a result of complications. Complications such as an acute heart failure and/or cardiogenic shock (CS) are of particular concern, as they are the main cause of fatal MI**.** Currently, modern mechanical circulatory support devices have become more widely used in the treatment of heart failure in patients with acute MI (AMI), but mortality in this category of patients still remains at a fairly high level and accounts for 40-50% of the total number of fatal outcomes. Over the recent decades, three large randomized controlled trials have been conducted with adequate statistics and the use of new recommendations. The first study demonstrated that immediate revascularization had a better outcome than a conservative therapy of the patient until his/her hemodynamic stabilization [2]. The second one proved that percutaneous coronary interventions (PCIs) only on the symptom-affected artery alone are more effective and safer in multivessel coronary lesions [3]. The IABP-SHOCK11 study did not confirm a significant effect of a routine use of intra-aortic balloon counterpulsation (IABC) on survival in patients with cardiogenic shock (CS) [4–7]. However, the use of extracorporeal membrane oxygenation (ECMO) is gaining popularity, despite the lack of convincing evidence of its favorable effect in terms of mortality decrease [1–3, 8–10].

Material and methods

The most common method of mechanical support is the IABC. This method has been known since the 1960s. An intra-aortic balloon is installed in the thoracic descending aorta in different modes in accordance with hemodynamic parameters recorded using a fiberoptic sensor. Depending on the data, indications for decreasing or increasing the IABC operating mode are determined.

The mechanism of the IABC is as follows: after each cardiac output, the balloon is inflated and before the next systole, it is deflated. When the balloon is inflated, the blood moves in the proximal direction (i.e., towards the heart), which leads to an increase in perfusion pressure in the coronary arteries and an increase in diastolic pressure in the aorta.

The balloon deflation during the systole causes a decrease in the end-diastolic pressure in the left ventricle (LV) and the afterload on it (Fig. 1).

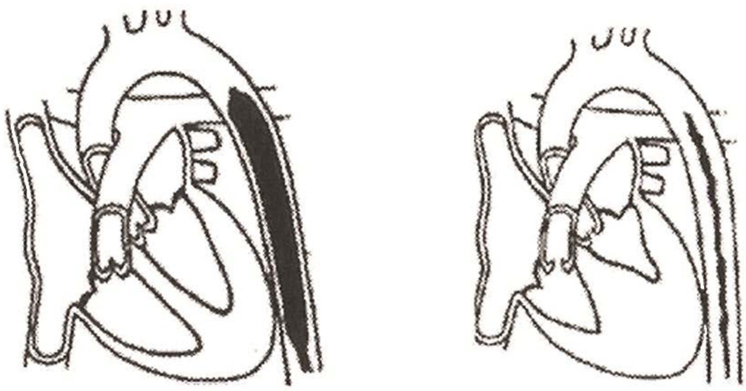

Fig. 1. The principle of intra-aortic balloon counterpulsation [11]

Reducing the afterload on the LV is the essence of the IABC. As a result of the IABC functioning, the myocardial perfusion improves, the blood flow in the coronary artery supplying blood to the infarction zone is maintained, and the patient's hemodynamics is stabilized.

Also, with IABC, a 15% increase in the LV pumping function was noted (Fig. 2).

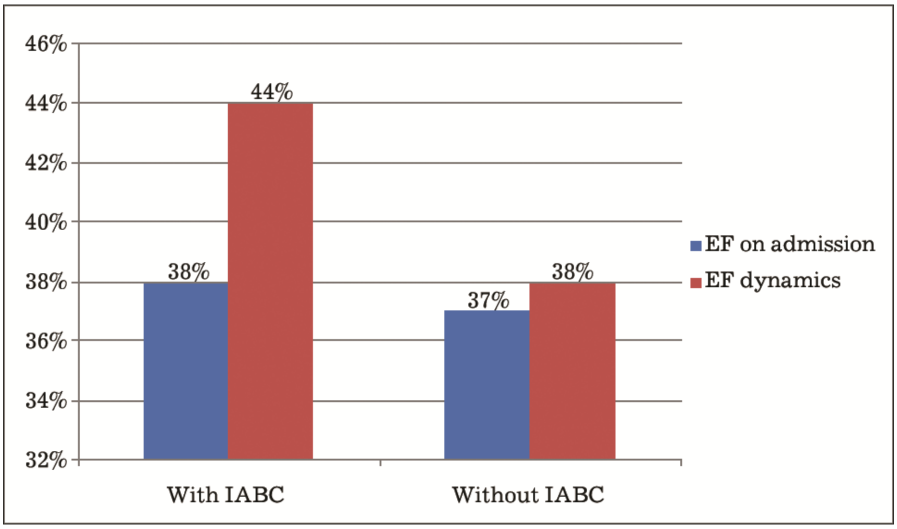

Fig. 2. Dynamics of improvement in the left ventricular myocardium contractile function in the setting of intra-aortic balloon counterpulsation

In our study, IABC was performed using the DATASCOPE SYSTEM CS 300 Intra-Aortic Balloon Pump (IABP).

Indications for the use of intra-aortic balloon counterpulsation:

– AMI complicated by left ventricular failure (Killip 2–3) and reduced LV ejection fraction (EF);

– PCI performed on a symptom-affected artery (including the left main coronary artery) in patients with a high risk of complications;

– a tendency towards hypotension (systolic pressure lower 90 mm Hg) and absent adequate hemodynamic response to therapeutic doses of sympathomimetics; oliguria (up to signs of organ hypoperfusion and CS).

In our Department, IABC was used mainly as an aid in performing PCI in patients with a high risk of developing complications prior to the signs of hypoperfusion and CS.

In patients in condition of CS, with aortic insufficiency, and signs of aortic dissection, IABC was not used.

In recent years, the ECMO system as a mechanical circulatory support has become more preferably used. ECMO is a method of temporary replacement of the gas exchange and/or blood circulation function in patients with acute heart failure, who are in critical condition and resistant to traditional intensive care methods. The main principle of this method is to improve oxygen delivery and carbon dioxide removal using cardio-pulmonary bypass pump and membrane oxygenator.

For patients with cardiovascular failure refractory to inotropic therapy and IABC, peripheral venoarterial ECMO (VA ECMO) is more often used in CS to maintain blood circulation and gas exchange. The principle of VA ECMO is that blood is taken from either a large vein or the right atrium, being pumped through an oxygenator, it is returned to the arterial bed, thus replacing the pumping function of the heart (Fig. 3).

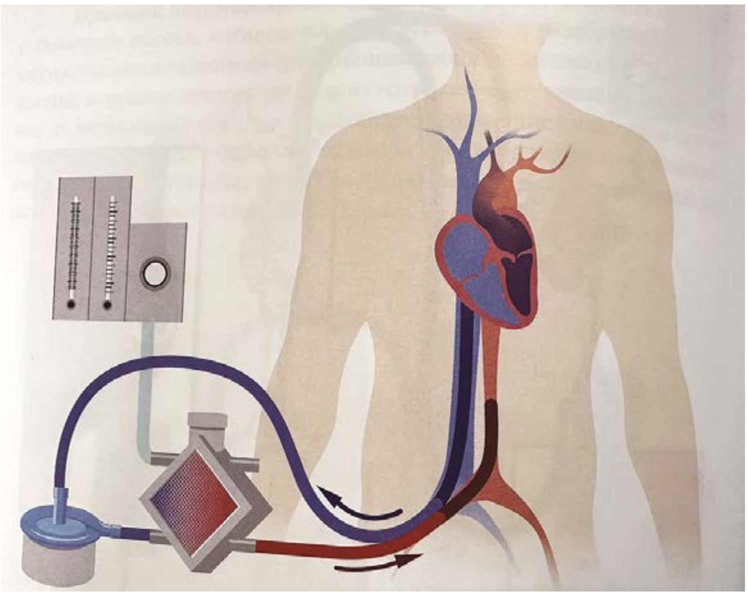

Fig. 3. The principle of venoarterial extracorporeal membrane oxygenation [12]

The main indications for the use of venoarterial extracorporeal membrane oxygenation:

— AMI complicated by CS, papillary muscle rupture and myocardial rupture;

— AMI complicated by heart failure refractory to traditional therapy, as a “bridge” to further heart transplantation and/or implantation of ventricle assist devices to maintain the pumping function of the heart ventricles.

The indication for establishing the peripheral VA ECMO system in patients with AMI was the progressive heart failure confirmed by the clinical and laboratory data, such as a tendency to hypotension with blood pressure (BP) below 90 mm Hg, which was accompanied by the need to increase the inotropic support with dopamine (dobutamine) more than 7-8 μg/kg/min in combination with epinephrine; oliguria and/or anuria; an increase in the content of nitrogenous wastes in blood, creatinine level above 140 μmol/L, urea above 12 mmol/L, blood lactate above 4-5 mmol/L, as well as persistent dyspnea, a decrease in the LV myocardium contractility below 40%, life-threatening rhythm and conduction disturbances, and effective resuscitation measures.

The use of mechanical circulatory support methods is considered as a means to prevent the deterioration of patient's condition and the risk of the circulatory arrest development.

However, it is known from the literature that in 20–25% of cases with extensive infarction and a large area of myocardial damage, there is a lack of adequate LV unloading in the course of VA ECMO. In the process of VA ECMO this may be accompanied by the development of blood stagnation in the pulmonary circulation, being manifested clinically and radiologically by pulmonary edema. Today, the literature sources have described several methods of unloading the LV volume by using peripheral VA ECMO.

In our Department, we used IABC in the 1:1, 1:2 mode in order to effectively unload the LV volume during peripheral VA ECMO. The reason for setting IABC during VA ECMO was the presence of clinical and instrumental manifestations of congestion in the pulmonary circulation, pulmonary edema, despite the adequate volumetric velocity of extracorporeal blood flow, patient complaints of increased dyspnea, auscultatory and radiological signs of pulmonary edema, decreased oxygenation, the need for mechanical lung ventilation, and the following echocardiographic (Echo-CG) signs in dynamics: a decreased LV myocardium contractile function, increased volumetric characteristics of the LV, such as the end-diastolic dimensions and end-diastolic volume (EDV).

Case Report

Patient H., 56 years old, was admitted at the Intensive Care Unit of the Regional Vascular Center of the N.V. Sklifosovsky Research Institute for Emergency Medicine and was diagnosed with ACS with ST segment elevation of the LV lower wall on the 4^{th} day from the onset of the disease with complaints of retrosternal pressing pain and weakness.

From the medical history: the patient had never suffered from heart attacks or strokes. He did not take regular medications. The first retrosternal pain of a wave-like nature appeared 4 days before; he did not seek for medical help. Later, weakness, sweating appeared, and the chest pains recurred. He called an ambulance and was admitted at the hospital.

On admission the patient's condition was severe. The skin was pale and moist. In the lungs, breathing was conducted in all sections, isolated wheezing was noted in the lower sections. Heart sounds were clear with systolic murmur being at the apex. BP was 115/65 mm Hg. The abdomen was soft, painless. The liver protruded by 1 cm from under the edge of the costal arch. There was no edema.

At examination: the electrocardiogram (ECG) showed sinus rhythm, the pattern of acute MI of the LV inferolateral and posterior wall (Fig. 4).

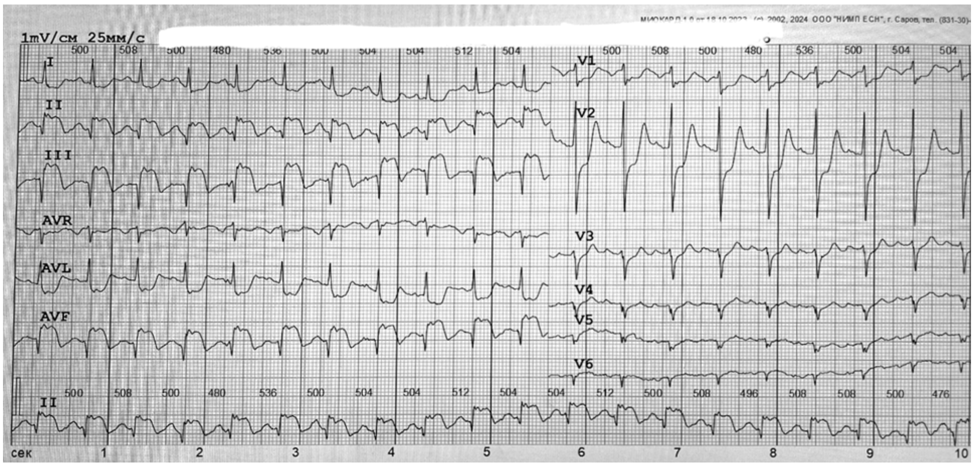

Fig. 4. Electrocardiogram of patient H., 56 years old, on admission. The pattern of the left ventricle inferior wall myocardial infarction

Taking into account the clinical presentation and the ECG data, the patient was delivered to the X-ray Room 15 minutes after admission to have the coronary angiography performed, the coronary bed assessment and PCI performance.

Coronary angiography showed 50% stenosis in the proximal third of the anterior interventricular artery, systolic component in the middle third with the lumen stenosis of up to 90%; 75% stenosis in the proximal third of the right coronary artery (RCA), occlusion in the middle third, the distal bed was slightly filled through intersystem collaterals, the remaining coronary arteries were without hemodynamically significant stenosis (Fig. 5).

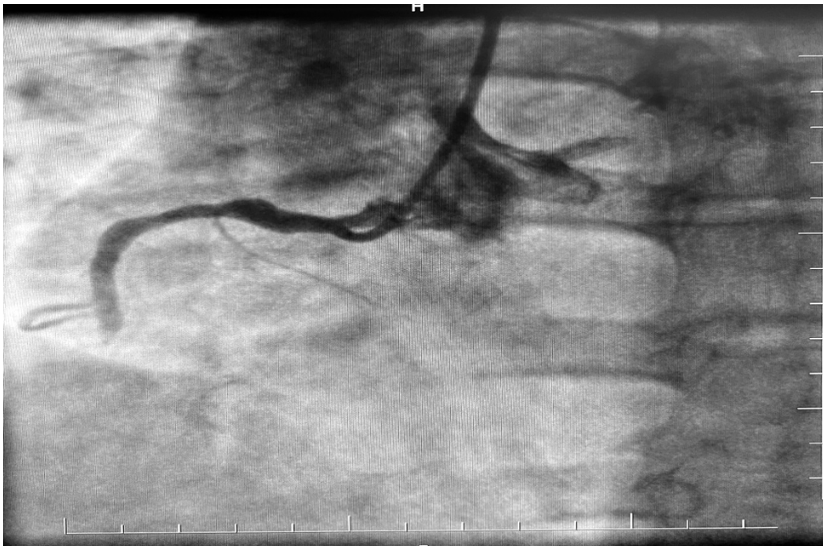

Fig. 5. Patient H., 56 years old. The right coronary artery occlusion before the percutaneous coronary intervention

PCI was performed in the following volume: mechanical recanalization, transluminal balloon angioplasty with RCA stenting (Fig. 6).

Fig. 6. Patient H., 56 years old. The right coronary artery after the percutaneous coronary intervention

Echocardiography (EchoCG) showed the following: left atrium dilation; local systolic function of the left ventricle being impaired: akinesis of the posterior wall, hypoakinesis of the basal and middle segments of the inferior wall, hypokinesis of the apical segment of the inferior wall; minor hypertrophy of the LV myocardium; signs of detachment of the papillary muscle head; total mitral valve insufficiency; Grade 2 tricuspid valve insufficiency; signs of moderate pulmonary hypertension; pulmonary artery systolic pressure (PASP) being 53 mm Hg (Fig. 7).

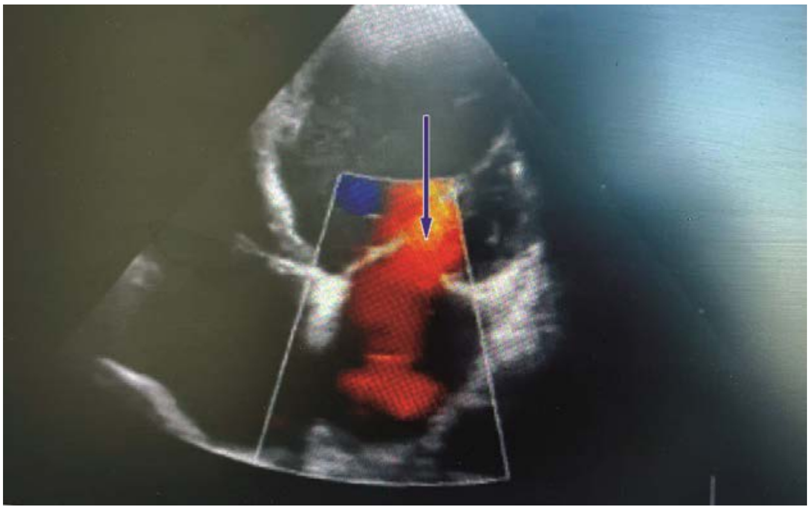

Fig. 7. Patient H., 56 years old. Mitral valve regurgitation, grade 3

Subsequently, the patient's hemodynamics remained unstable with a tendency to hypotension and tachycardia (BP 85/60 mm Hg, heart rate (HR) 110–120 beats/min). Vasopressor support with norepinephrine at a dose of 300 ng/kg /min was started.

Given the ineffectiveness of drug therapy, progression of multiple organ failure according to clinical and laboratory studies (systolic blood pressure being below 90 mm Hg, mean arterial pressure below 60 mm Hg, oliguria (less than 1.0 ml/kg/h over the last 6 hours), blood creatinine level above 120 μmol/L, urea above 12 mmol/L, total bilirubin above 30 μmol/L, increasing general weakness, the presence of acrocyanosis, shortness of breath at rest), a multidisciplinary team made a decision on the necessity to use mechanical circulatory support.

The patient was set up with the VA ECMO system: flow 3.7 L/min, 7300 rpm. The VA ECMO system was set up within 40 minutes from the moment of admission.

In the course of VA ECMO, hemodynamics was maintained with vasoinotropic drugs Sol. Noradrenalini, 350 ng/kg/min, and Sol. Dobutamini, 9 mcg/kg/min.

Despite the therapy, the patient continued to have shortness of breath, moderate hypotension (BP: 90/60 mm Hg), and sinus tachycardia (HR 110–120 beats/min).

Chest radiographs showed signs of interstitial pulmonary edema.

Given the tolerance to therapy and persistent signs of the left ventricular failure, in order to reduce the afterload, a decision was made to install an IABC in the patient in 1:1 ratio. Also given the increase in biochemical blood parameters (hyperkalemia, hyperazotemia, creatine kinase level, and renal function markers), the hemodiafiltration (HDF) was started.

With the combination of mechanical circulatory support methods (ECMO/IABC), extracorporeal detoxification and dehydration, some improvement in the patient's condition was observed. At 12–15 hours of the circulatory support system operation, some stabilization of hemodynamics was noted, which made it possible to reduce the productivity of the ECMO system (IABP ECMO (flow 2.5 l/min) in combination with IABP in 1:1 mode and vasoinotropic support with Sol. Noradrenalini, 300 ng/kg/min, Sol. Dobutamini, 7 mcg/kg/min). According to echocardiography (EF 41% (up to Simpson), PASP 37 mm Hg, EDV 130 ml, rupture of the posterior papillary muscle head, Grade 3-4 mitral reurgitation), no increase was observed in the cardiac chamber dimensions in dynamics. Signs of moderate pulmonary hypertension were noted with PASP being 63 mm Hg. The cardiac monitor showed sinus rhythm with a heart rate of 90-92 beats/min. Maintenance HDF was continued for the purpose of dehydration and detoxification.

However, despite some stabilization of the patient's condition, an attempt to further reduce the VA ECMO/IABC regimen and vasopressor support was unsuccessful.

On the 6th day, acute myocardial infarction of the LV lower lateral wall complicated by the tear of the posterior papillary muscle head from the mitral valve, total mitral insufficiency despite the intensive therapy, including the assisted circulatory support (ECMO/IABC for 48 hours), the extracorporeal detoxification and dehydration, and the signs of acute heart failure decompensation persisted.

Due to the futility of further conservative therapy, the patient underwent mitral valve replacement with a 29 mm MedInzh mechanical prosthesis under conditions of cardiopulmonary bypass, and intraoperative removal of the peripheral VA ECMO system for vital indications, despite the early stages of complicated MI.

The early postoperative period against the background of IABP proceeded quite smoothly. Subsequently, positive dynamics were observed in the patient's condition, which made it possible to reduce vasopressor and inotropic support up to its complete cancellation, and then disconnect the patient from the IABP.

EchoCG after surgery showed EF 37%, impaired LV myocardial contractility with hypoakinesis of the inferior and posterior walls, asynergistic movement of the interventricular septum. The mean gradient on the mitral valve was 3.7 mm Hg; transprosthetic regurgitation, grade 0-1 in the projection of the mitral valve; tricuspid regurgitation up to grade 2, PASP 28 mm Hg.

The postoperative period was uneventful, and the patient was discharged from hospital with recommendations for outpatient follow-up.

Discussion

One of the problems with the use of peripheral VA ECMO is the LV volume overload against an adequate volumetric velocity of the extracorporeal perfusion in patients with AMI. This is manifested by the clinical signs of the left ventricular failure with pulmonary edema.

This phenomenon is mainly observed in patients with AMI with aortic valve insufficiency and/or with a progressive decrease in the LV contractility and an increase in the LV afterload.

To prevent the volume overload of the LV, it is primarily necessary to achieve volemia, in which there would be no overfilling of the left heart chambers with an adequate rate of extracorporeal blood flow. This requires the control of the fluid therapy volume, adequate dehydration therapy, and, if necessary, the use of renal replacement therapy and inotropic support. It is important to remember that LV volume overload and slow blood circulation in it are often accompanied by coagulopathy and various thromboembolic complications.

In order to correct the development of volumetric LV overload against the background of VA ECMO, several methods are considered: transseptal drainage of the left atrium, transapical LV cannulation, the placement of a drainage cannula in the pulmonary artery and installation of the Impella system. In order to unload the LV and reduce the afterload while using the VA ECMO in patients with AMI, a minimally invasive, more affordable and safe method was successfully used, namely IABC in the 1:1–1:2 mode.

Conclusion

In myocardial infarction complicated by heart failure and/or cardiogenic shock, today, along with percutaneous coronary intervention on symptom-affected arteries, the methods of mechanical circulatory support are widely used, including the intra-aortic balloon counterpulsation and venoarterial extracorporeal membrane oxygenation of blood. In peripheral venoarterial extracorporeal membrane oxygenation in patients with acute myocardial infarction complicated by heart failure, the intra-aortic balloon counterpulsation is an effective, safer, and more cost-effective method that reduces afterload, prevents the occurrence of the left heart volume overload and helps relieving the pulmonary edema. A rational combination of venoarterial extracorporeal membrane oxygenation and intra-aortic balloon counterpulsation methods is highly effective, which provides time for patient stabilization and determination of further treatment tactics.

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The article was received on October 7, 2024;

Approved after reviewing on November 15, 2024;

Accepted for publication on December 25, 2024