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Extracorporeal membrane oxygenation in acute myocardial infarction complicated with acute heart failure

Extracorporeal membrane oxygenation is used in acute heart failure that is resistant to drug therapy and intra-aortic balloon counterpulsation. Colleagues from America practice the use of ECMO with a cardiac index above 2.0 l/min. In our case, the application of ECMO at a cardiac index of 1.3 l/min with the discharge of the patient from the hospital with a satisfactory result of treatment is described. This article represent a clinical case of ECMO application in refractory acute heart failure and a multidisciplinary approach to the treatment of complicated myocardial infarction.

Key words: myocardial infarction, extracorporeal membrane oxygenation, intra-aortic balloon contrapulsation, coronary angiography.

Ischemic heart disease ranks first among the causes of mortality in Ukraine. According to the State Statistics Service of Ukraine, 616,835 cases of death were registered in 2020. Among these cases, 408,721 (66 %) were due to diseases of the cardiovascular system, among them 70 % – due to the coronary artery disease [1].

According to the Center for Medical Statistics, 40,000 cases of acute myocardial infarction (AMI) are diagnosed in Ukraine every year [2]. Clinically, the diagnosis of myocardial infarction is established due to the patient's symptoms and ECG changes, it is confirmed by increase of cardiac biomarkers and imaging results [3].

In recent years, the in-hospital mortality of myocardial infarction has decreased sharply due to the development of reperfusion centers and was 3 % in 2020 [4, 5, 18]. However, pre-hospital mortality, which reaches 19.5 %, remains a big problem [6].

Prognostically, infarction of the anterior wall of the left ventricle (LV) is more unfavorable, as it is associated with an increase in the frequency of acute heart failure, ventricular fibrillation, and death [7, 8]. In some studies the mortality within 30 days after onset of the disease complicated by acute heart failure was 11 % [9].

The use of extracorporeal membrane oxygenation (ECMO) in acute heart failure (HF) allows not only to restore a native heart function, but also provides time for implantation of auxiliary devices of the left ventricle (LV), heart transplantation, or drug therapy. ECMO in severe cases of HF makes possible to restore and initiate systemic circulation for all age groups [10]. ECMO is a long-term cardiopulmonary support. The effectiveness of the method depends on the patient's choice, treatment and weaning strategy [11].

Clinical case

Patient R., 69 years old, was hospitalized with a diagnosis of coronary heart disease: acute transmural myocardial infarction of the anterior-septal-apical-lateral wall of the left ventricle. Coronary atherosclerosis (total occlusion of the mouth of the anterior interventricular branch of the left coronary artery (LAD), moderate stenosis at the mouth of the posterior interventricular branch (PDA) and the

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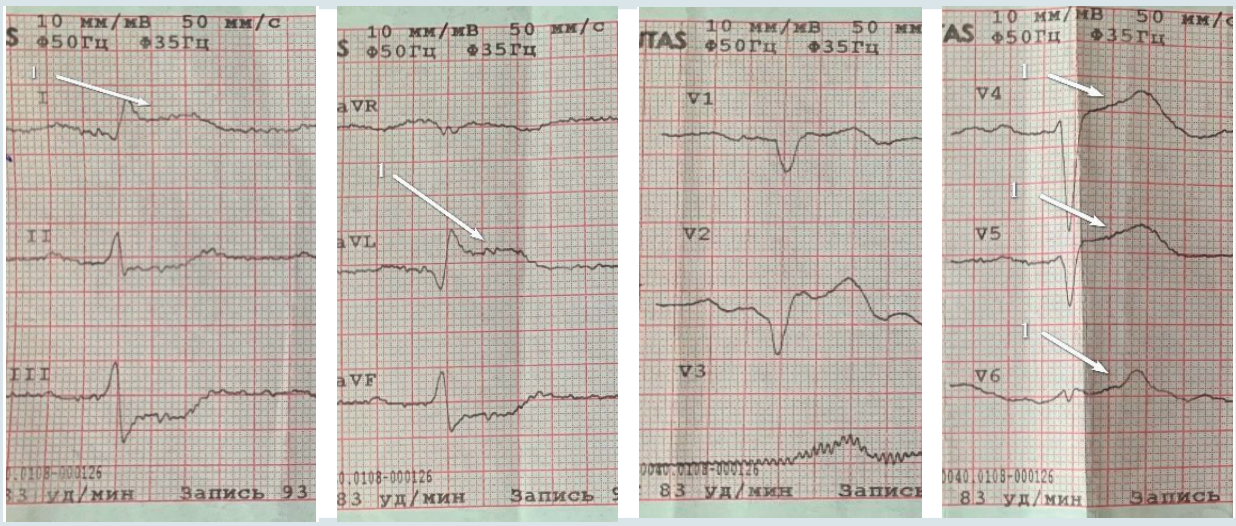

Fig. 1. **12 channel ECG: acute anterior and lateral ST-elevation MI**

posterior-lateral branch of the right coronary artery. Acute heart failure: Killip III. A slight insufficiency of the mitral valve. Mild insufficiency of the tricuspid valve. Hypertensive disease stage III, degree 3, risk 4. HF stage C with reduced LV ejection fraction (32 %).

According to the patient, chest pain occurred for the first time and did not stop with nitroglycerin.

At objective examination, the patient's condition was serious. The skin was pale, moist. Some focal rales were heard by lung auscultation. Heart sounds are muffled, rhythmic with heart rate 103 beats per min, blood pressure 100/70 mm Hg. SaO_2 was 86 %.

The following diagnostic results were obtained *(Fig. 1)*.

According to the ECG registered 2 hours after the onset of the pain syndrome: regular sinus rhythm with heart rate (HR) of 88 beats/min. ST elevation in leads reflecting anterior-septal-apical-lateral wall of the LV.

Echocardiography (Echo): End-diastolic volume (EDV): 127 ml. Ejection fraction (EF): 32 %. Mitral valve: mild regurgitation. Tricuspid valve: mild regurgitation. Aortic valve: tricuspid, maximum pressure gradient 7 mm Hg. A- and hypokinesia of the apex of the LV with transition to the interventricular membrane and antero-lateral wall of the LV. A small amount of fluid in the pericardial cavity and in both pleural cavities.

Urgent coronary angiography was performed, the results of which revealed total occlusion of the mouth of the anterior interventricular branch of the left coronary artery, stenosis of the posterior interventricular branch and posterior-lateral branch of the right coronary artery in the mouth of 50 %. Stenting of the infarct-dependent vessel – anterior interventricular branch of the left coronary artery was performed, a Xience Xpedition 3.0 × 38 stent was implanted.

The patient was transferred to the artificial lung ventilation due to respiratory and cardiovascular failure 6 hours after stenting.

The patient's condition remained serious, heart failure progressed. On the 2nd day of the heart attack, an intra-aortic balloon counterpulsation (IABP) was installed to maintain hemodynamics *(Fig. 2)*.

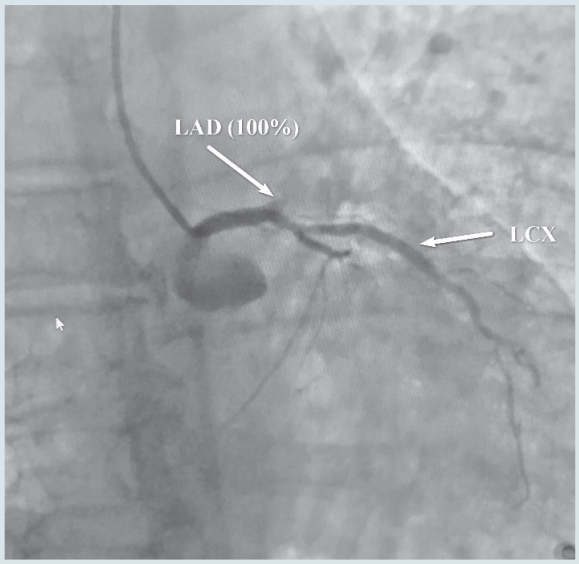

Fig. 2. **Coronary angiography**

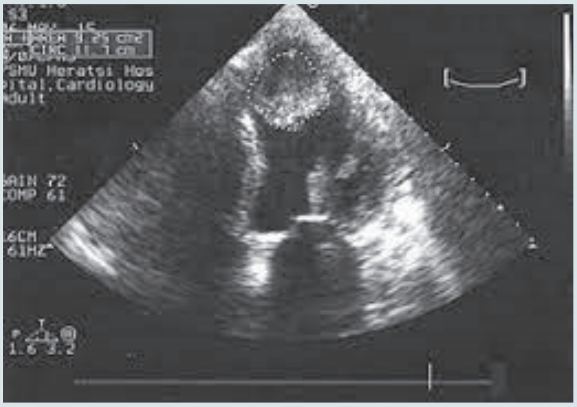

Fig. 3. **LV apex thrombus**

Against the background of IABP work, the condition stabilized, hemodynamics was supported by medium doses of sympathomimetics. On the 7th day, IABP was disconnected.

According to the data of echocardiography after disconnection of IABP and extubation: EDV: 141 ml. EF: 39 % *(Fig. 3)*. A mural thrombus measuring 3.5x1.5 cm was visualized in the LV apex. Systolic pressure in the right ventricle was 46 mm Hg. A small amount of fluid in the pericardial cavity.

On the 14th day after the onset of myocardial infarction, a persistent paroxysm of ventricular tachycardia occurred *(Fig. 4)* with a heart rate of 160/min. Its duration was 3 minutes, it was combined with signs of acute heart failure (HF).

A paroxysm of ventricular tachycardia was terminated by electrical cardioversion. Urgent echocardiography: EDV 144 ml, EF 20 %, TV – reverse flow ++, MV – reverse flow +++, cardiac index 1.3 l/min. Urgent coronary angiography: the stented segment of the LDA was passable, there was no restenosis and thrombosis. Electromechanical dissociation was noted according to the ECG data. The patient was connected to the ECMO machine. Life was maintained with the help of an extracorporeal membrane oxygenation device for 4 days. Veno-arterial ECMO was used. The right femoral vein and left femoral artery were used for cannulation. The following volumetric velocities were used – 70–80 cc/kg/min. The ECMO machine took over the pumping function of the heart, allowing it to recover its strength in the «rest» mode.

During this period, the patient received heparin, clopidogrel, aspirin, linezolid, tobramycin, meropenem, dobutamine, norepinephrine, amiodarone, furosemide, mannitol, euphylline, metoprolol, and lidocaine. Before stopping ECMO, tests were performed to confirm adequate heart and lung function. On the 4th day, the cannulas of the apparatus were removed. After ECMO, the patient's condition is severe with positive dynamics.

According to the echocardiography: EDV: 133 ml. EF: 33 %. Mitral valve: reverse flow +(+). Tricuspid valve: reverse flow +. Systolic pressure in the right ventricle: 44 mm Hg. In the area of the apex of the LV wall, there are slow-moving

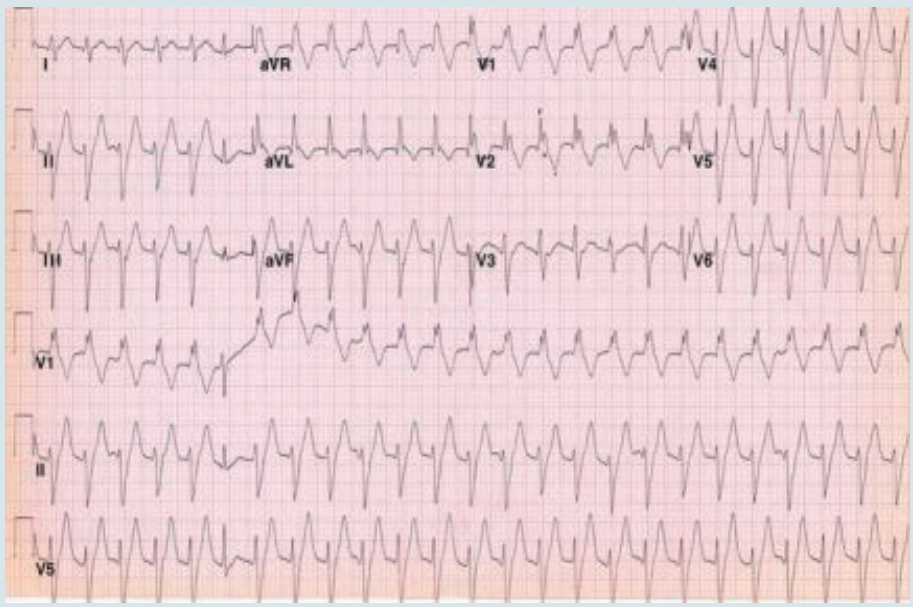

Fig. 4. **Paroxysm of ventricular tachycardia**

thrombotic layers with a thickness of 9 mm. In the pericardium, fluid is visualized along the posterior-lateral wall of the LV of 0.8–1.0 cm. The minimum amount of fluid is in the right pleural sinus.

Due to the unstable hemodynamics and heart failure, an intra-aortic balloon contrapulsor was re-connected, which helped maintain hemodynamics for 5 days. After the end of the work of IABP, echocardiography revealed: EDV: 133 ml. EF: 37 %.

Holter ECG monitoring was performed, two paroxysms of ventricular tachycardia were revealed, their total duration was 2 minutes.

In order to reduce the risk of sudden cardiac death, a two-chamber automatic cardioverter-defibrillator Medtronic Mirro MRI DR SureScan eDDME3D4 DF-4 with a primary endocardial system was implanted. The patient continued conservative treatment within the inpatient department.

On the 49th day, the patient was discharged in a stable clinical condition for further rehabilitation.

Discussion

The development of acute myocardial infarction (MI) is a frequent cause of patient disability and mortality. Timely revascularization of coronary arteries reduces the risk of MI complications, such as arrhythmias, rupture of the heart walls, heart failure, formation of blood clots in the heart cavity, development of left ventricular aneurysm, sudden cardiac arrest, and others.

A decrease in LVEF is an important independent prognostic factor in patients with coronary artery disease, including after revascularization. In particular, in the register study Keelan et al. (n = 1158) the in-hospital mortality of patients after percutaneous coronary interventions was 3 % with LVEF < 40 %, 1.6 % – with LVEF 41–49 % and 0.1 % – with LVEF ≥ 50 % ($p < 0.001$) [12].

One of the complications of MI is acute heart failure (HF). HF occurs in 4–5 % of cases at the pre-hospital stage of the development of acute MI, and the mortality rate in the development of such a complication reaches 9.9 %.

The primary treatment of acute left ventricular failure is a conservative therapy. In addition, to increase the efficiency of the heart, IABP is used, which improves coronary blood flow and blood supply to the myocardium, which allows restoring the hemodynamic stability of the patient.

Extracorporeal membrane oxygenation is not mentioned in current recommendations for the treatment of acute myocardial infarction, but it is used in medically refractory cardiogenic shock. Reversible cardiogenic shock often occurs with myocardial injury resulting from arrhythmia, myocardial ischemia, prolonged cardiotomy, significant pulmonary edema, or acute pulmonary hypertension. Myocardial damage is sometimes referred to as «stunned myocardium», referring to the reversibility of the state of low cardiac output. With the advent of IABP, approximately 75 % to 85 % of these patients achieved stable cardiac output after being placed on IABP. It has been shown that survival to discharge from the hospital was increased to 55 % [13].

Despite maximum inotropic support and IABP, some patients have persistent cardiopulmonary dysfunction. Several institutions have published their experience with ECMO to support a patient population resistant to drug therapy and IABP [13–17]. Doll and others [15] published the largest series of patients on ECMO support with duration and clear inclusion criteria. Between 1997 and 2002, they recruited 219 patients from 18,150 adult cardiovascular surgeries (coronary bypass grafts, valve replacements, pulmonary embolectomy, aortic aneurysm repair, pericardectomies, and heart transplants). ECMO was considered if cardiac index remained below 2.0 L/min despite optimal use of inotropes and IABP.

ECMO was started intraoperatively in 89 % of cases and the rest were cannulated in the intensive care unit. A total of 61 % of patients were successfully weaned from ECMO, but only 39 % were successfully discharged. The most common cause of death was a persistently low cardiac output, meaning that myocardial damage was irreversible in 71 % of cases. It is not clear whether survival would have been higher if ECMO had been initiated in all patients with a cardiac index < 2 or how long they had been at this index before starting ECMO.

Other institutions have a 30-day hospital survival from the 20th to the 80th percentile [13, 14, 16–21]. The inconsistency of the result is multifactorial: experience of the ECMO program, differences in institutional algorithms for ECMO initiation intraoperatively or in the postoperative period, for example. Despite the disparities, Doll et al have created an objective parameter for initiating consideration of ECMO [15].

Leading US clinics consider connecting ECMO when the cardiac index is greater than 2 L/min·m^2. Our patient's cardiac index was 1.3 L/min·m^2. Despite this, the patient's condition stabilized after using ECMO and we managed to discharge the patient for rehabilitation in a satisfactory condition.

Conclusions

Extracorporeal membrane oxygenation is a method of choice in the treatment of acute heart failure refractory to drug therapy and IABP. ECMO provides time and opportunity to restore the the myocardial function. When connecting a patient to ECMO, consideration of the cardiac index is a mandatory condition. This clinical case is unique, as US clinics consider the use of ECMO with a cardiac index of greater than 2 L/min·m^2. In this case, ECMO connection occurred when the index dropped sharply to 1.3 L/min·m^2. Despite this, the result of the treatment is the discharge of the patient from the hospital with a positive result. Therefore, despite the risks of ECMO, this treatment method increases the chances of survival for patients with HF.

The authors declare no conflict of interest.

Participation of authors: project of work – B.T., O.Z.; article writing, article review of the material – M.T., L.S., I.S.

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Застосування екстракорпоральної мембранної оксигенації в пацієнтів із гострою серцевою недостатністю на тлі гострого інфаркту міокарда

Екстракорпоральну мембранну оксигенацію застосовують при гострій серцевій недостатності, резистентній до медикаментозної терапії та внутрішньоаортальної балонної контрапульсації. Колеги з Америки практикують застосування ЕКМО при серцевому індексі вище ніж 2,0 л/хв. У нашому випадку описано застосування ЕКМО при серцевому індексі 1,3 л/хв із виписуванням хворого зі стаціонару із задовільним результатом лікування. У статті представлено клінічний випадок застосування ЕКМО при рефрактерній гострій серцевій недостатності та мультидисциплінарний підхід до лікування ускладненого інфаркту міокарда.

Ключові слова: інфаркт міокарда, екстракорпоральна мембранна оксигенація, внутрішньоаортальний балонний контрапульсатор, коронарографія.