https://doi.org/10.23873/2074-0506-2025-17-3-318-328

Air transport evacuation of a patient with end-stage heart failure using full peripheral veno-arterial extracorporeal membrane oxygenation

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Abstract

Background. *Veno-arterial extracorporeal membrane oxygenation (VA-ECMO) is critical in the life support of patients with severe cardiovascular insufficiency, especially when traditional methods are not effective enough. There is no data on the full peripheral ECMO application during air transportation of patients with terminal heart failure in the Russian literature.*

Objective. *To demonstrate the features of air medical transportation of a patient with terminal heart failure using VA-ECMO.*

Material and methods. *Patient I., 41 years old with congenital heart disease (bicuspid aortic valve), aortic stenosis, acute heart failure with a left ventricular ejection fraction (LVEF) of 3% after the valve replacement operation. He underwent a surgery to replace the aortic valve with a mechanical prosthesis combined with aortic root reconstruction, which required VA-ECMO connection during the surgery and further medical evacuation by specialized flight IL-76 from Kaliningrad to Moscow for heart transplantation.*

Results. *During the evacuation, the patient's condition remained extremely severe, but could be corrected by a team of intensive care specialists. In transportation, the following interventions were performed: full peripheral VA-ECMO with a blood flow of 6.6-6.81 L/min and an oxygen flow of 3 L/min, mechanical lung ventilation (MLV) 20 (FiO_2 of 0.4; PEEP 6; Ps 20; respiratory rate of 14/min; respiratory volume 540 ml, respiratory minute volume 7.8 L/min), drug-induced depression of the central nervous system, temporary electrocardiostimulation, fluid and antibacterial therapy, vasopressor support with titration of inotropic drug infusion rate, monitoring of vital functions. The patient tolerated transportation satisfactorily and was*

transferred to the Intensive Care Unit of the Academician V.I. Shumakov National Medical Research Center of Transplantology and Artificial Organs in a stable severe condition for assessing the chances of heart transplantation.

Conclusions. *The present clinical case confirms that air transport evacuation using ECMO is a promising strategy for patients with end-stage heart failure. The success depends on the arrangement of medical evacuation, pre–transport treatment, the medical staff qualifications and skills of working with mobile life support equipment. The use of air ambulance and mobile ECMO teams, especially in remote regions, can be a step towards creating a nationwide system of emergency medical care for patients with critical life support disorders.*

Keywords: extracorporeal membrane oxygenation, veno-arterial extracorporeal membrane oxygenation, air ambulance, emergency transportation, congenital aortic valve stenosis

Conflict of interests Authors declare no conflict of interest

Financing The study was performed without external funding

Acknowledgments. The authors express their gratitude to Doctor Andrey S. Rybalko and Doctor Aleksey Yu. Belov, the Intensivists of the Transmedavia Emergency Medicine and Air Ambulance Service, LLC.

For citation: Zhuravel SV, Talyzin AM, Savostyanov MYu, Kalashnikova YuS, Kvartirkin VE, Igrunkova AV. Air evacuation of a patient with end-stage heart failure using full peripheral veno-arterial extracorporeal membrane oxygenation. *Transplantologiya. The Russian Journal of Transplantation.* 2025;17(3):318–328. (In Russ.). https://doi.org/10.23873/2074-0506-2025-17-3-318-328

ECMO, extracorporeal membrane oxygenation
LVEF, left ventricular ejection fraction
MLV, mechanical lung ventilation
RMV, respiratory minute volume
RR, respiratory rate
TV, tidal volume
TPM, temporary pacemaker
VA-ECMO, veno-arterial extracorporeal membrane oxygenation

Introduction

End-stage heart failure accompanied by low cardiac output syndrome remains one of the most complex problems of present day cardiology, which requires heart transplantation. According to the World Health Organization, annually more than 1 million patients worldwide need this operation, but an access to this procedure is limited due to a shortage of donor organs and the lack of specialized centers in some regions [1]. Extracorporeal membrane oxygenation (ECMO) is a critically important modality that temporarily provides blood circulation and tissue oxygenation, which allows maintaining the vital signs of patients before high-tech interventions [2, 3].

Transportation of patients on total veno-arterial extracorporeal membrane oxygenation (VA-ECMO) is particularly challenging, as it requires not only specialized equipment, but also the coordinated work of multidisciplinary teams [3]. In Russia, the first experience of air patient transportation using veno-venous ECMO performed on a patient with severe respiratory failure dates back to 2015 [4]. Over the next 10 years, a number of studies were published demonstrating the efficacy of using this method in air transport evacuation of children and adults with respiratory failure [5, 6].

In Russian literature, there are no case reports on air transportation of patients with end-stage heart failure under conditions of complete peripheral veno-arterial ECMO.

Our **objective** was to demonstrate the peculiarities of air medical transportation of a patient with end-stage heart failure, using complete peripheral VA-ECMO.

The presented clinical case report contributes to the development of emergency medical evacuation protocols, demonstrating that even patients with extremely low ejection fraction and signs of multiple organ

failure can be safely transported to specialized centers, provided that a multidisciplinary approach and innovative technologies are used.

Material and methods

Patient I., 41 years old, with congenital heart disease (bicuspid aortic valve), aortic stenosis, with developed acute heart failure with a left ventricular ejection fraction (LVEF) of 3% after surgery for aortic valve replacement with a mechanical prosthesis in combination with aortic root reconstruction, who was placed on peripheral VA-ECMO. ECMO was initiated in an "open" manner. The femoral vein and common femoral artery were cannulated, and the isolated perfusion of the lower limb was established through an 8 Fr arterial cannula to prevent lower limb ischemia. Additionally, a drainage cannula was placed directly into the LV cavity through the right atrium and interatrial septum. Blood was collected from the inferior vena cava (via the femoral vein (5–5.5 L/min) and drainage cannula (1–1.5 L/min), and returned to the femoral artery. The effective blood flow was 7 L/min. The futility of a subsequent treatment prompted the initiation of patient transportation to a specialized heart transplant center.

Organizing the transportation: the patient was transported by a specialized IL-76 flight (Aviastar-SP, Russia) of the Russian Ministry for Emergency Situations. Medical support was provided by the Transmedavia Emergency Medicine and Air Transportation Service team, which consisted of qualified doctors, nurses, and ECMO specialists from the N.V. Sklifosovsky Research Institute for Emergency Medicine. Teleconsulting, the placement on the emergency waiting list for heart transplantation and subsequent coordination of the transfer were performed together with specialists from the Academician V.I. Shumakov

National Medical Research Center of Transplantology and Artificial Organs.

In the Intensive Care Unit, the ECMO circuit replacement procedure and switching to the Cardiohelp-i transport device (Maquet AG, Germany) were performed under aseptic conditions. After evaluating the vital functions, checking the operation of the Biotronic record D temporary pacemaker (TPM) (Biotrinic AG, Germany), fixation of drainage, ensuring the vascular access, placing the nasogastric tube for enteral nutrition, the decision was made on the possibility of the patient air transportation. The patient was reconnected to the Hamilton-T1 ventilator (Hamilton Medical AG, Switzerland), and delivered to Volkswagen Class C ambulance Crafter (Volkswagen, Germany) by using Pensi 2000 MA Multifunction Strecher, Pensi Tilt and Load Base, and Pensi Hydraulic Lifter (Pensi Rescue Oy, Finland) for ambulances (Fig. 1, Fig. 2).

Fig. 1. Delivery of the patient to the ambulance

Fig. 2. Air transportation of a patient on veno-arterial extracorporeal membrane oxygenation

Results

The severity of patient I. condition, 41 years old, was predetermined by postcardiotomy heart failure, previous blood loss, and multiple organ failure (vascular and hepatic), and thrombocytopenia. At the moment of examination, the SOFA score was 8 (0 for central nervous system, kidneys, oxygenation, each; 2 points for liver; 3 points for cardiovascular system; 3 points for coagulation).

Before transportation, VA-ECMO had been performed for 3 days using the ADULT ALONE device (Eurosets, Italy) ensuring a blood flow of 8 L/min and an oxygen flow of 3 L/min. After reconnection to the Cardiohelp device, monitoring of pO_2, pCO_2, and hemodynamic parameters aimed at their optimization, the blood flow in ECMO was reduced to 5.5 L/min.

Respiratory support was provided using mechanical lung ventilation (MLV) in the mode of Pressure control +20 (FiO_2 0.4; PEEP 6; Ps 20; respiratory rate (RR) 14 per minute; tidal volume (TV) 540 ml,

respiratory minute volume (RMV) 7.8 L/min) under drug sedation (propofol 70 mg/hour, dexmedetomidine hydrochloride 0.4 mcg/kg/hour) and relaxation (pipecuronium bromide up to 48 mcg/day), analgesia with fentanyl (0.5 mg/hour). When sedation was turned off and the patient awakened, the consciousness was clear.

Also antibacterial therapy was administered with meropenem at a dose of 6 g/day, vancomycin at a dose of 2 g/day, and polymyxin at a dose of 200 mg/day. The cardiac rhythm was maintained by an endocardially installed temporary pacemaker (TPM); at an attempt to turn it off, an electromechanical dissociation occurred. Electrocardiography could not determine the myocardial contractility; according to echocardiography (EchoCG), spontaneous echo contrast in the LV persisted in the patient throughout his stay in the Intensive Care Unit; LV EF during EchoCG was 3%. Diuresis was 3500 mL over the previous 24 hours, with a mean rate of 0.7–1.5 mL/kg/hour; nutrition through a nasogastric tube was completely absorbed, peristalsis could be auscultated; no stool was available through a Flexi-Seal colostomy bag (ConvaTec, USA) at the time of inspection.

A control X-ray of the lungs revealed no signs of pneumonia.

Small doses of norepinephrine 0.13 mcg/kg/min were required to maintain normal blood pressure.

The dynamics of laboratory parameters are presented in Table 1.

Table. Changes of patient's laboratory parameters in the period from 05.12.24 to 07.12.24

Parameter	05.12.2024	07.12.2024
Neutrophils	$11x10^9$/L	$13x10^9$/L
Platelets	$70x10^9$/L	$50x10^9$/L
D-dimer	13,000 ng/mL	20,000 ng/mL
Hemoglobin	90 g/L	90 g/L

Results of the acid-base balance analysis: lactate <1.5 mmol/L, PaO_2 200 mmHg, $PaCO_2$ 38 mmHg. Procalcitonin was 3 ng/mL; a decrease was noted from 5 ng /mL, C-reactive protein concentration was 238 mg/L.

The postoperative wound was bandaged, vascular accesses were replaced. The patient was transfused with two therapeutic doses of universal platelets compatible with the ABO and Rh systems, anticoagulant therapy with heparin was continued with a target activated clotting time of 150–160 seconds.

Intercity evacuation was undertaken by air on board of IL-76 aircraft. An important advantage of the heavy military transport aircraft was the patient staying in a specialized ambulance vehicle at all stages of his evacuation: from transportation from the hospital to the departure airport and then from the destination airport to the destination hospital (Fig. 2).

The medical evacuation time from the moment of the circuit and the ECMO device replacement to the patient delivery to a specialized hospital was 8 hours at night. During the evacuation, the patient remained in extremely severe condition, while no serious adverse events were registered. Monitoring of vital functions included invasive and non-invasive monitoring of blood pressure, heart rate, measuring arterial blood oxygen saturation, monitoring the diuresis rate. VA-ECMO maintained a stable condition of the patient. In this case, the blood flow during takeoff was increased to 6.5 L/min, the oxygen flow remained at the same level, 3 L/min. Minor decreases in blood flow were noted during takeoff and landing, while saturation did not drop below 95%. It should be emphasized that oxygen was supplied from cylinders throughout the entire transportation, and its consumption was 1440 L, the required

reserve was calculated in advance. Medicinal sedation was continued (propofol 5 mg/kg/hour).

Respiratory support on board of the aircraft was performed via the mechanical ventilation with the following parameters: FiO_2 0.4; PEEP 6; Ps 20; RR 14 per minute; TV 540 mL, RMV 7.8 L/min.

The cardiac rhythm was imposed by TPM with a rate of 110 beats/min; hemodynamic parameters were maintained with norepinephrine at a dose of 0.1 μg/kg/min. We should note that transportation required neither an increase in the vasopressor dose nor administering any additional cardiotonic drugs. The fluid therapy was performed with balanced crystalloid solutions at a rate of 400 mL/hour. Heparin was administered through a dispenser at a dose of 750 units/hour, activated blood clotting time was monitored at the beginning of evacuation. Antibacterial therapy that had been given in the hospital before transportation was continued. No critical disruption episodes in vital functions were noted at any stages of transportation; the patient was safely delivered to the Intensive Care Unit of the Academician V.I. Shumakov National Medical Research Center of Transplantology and Artificial Organs in a stable severe condition to await a heart transplant to be performed, which was successfully performed within the next 24 hours.

Discussion

Until recently, using ECMO in the patient treatment was limited to specialized cardiac centers [7]. The ECMO technology development, improved approaches to the professional training of medical personnel, gaining practical experience and identifying new application for the technique have expanded the indications for the procedure, allowed using ECMO not only in cardiac intensive care units, but also in other intensive

care units, and also opened up the possibility of using it during medical evacuation [2, 3, 8, 9].

VA-ECMO plays a key role in stabilizing patients with severe cardiovascular failure, when traditional treatment methods do not provide optimal results [10, 11]. This clinical case report confirms the efficacy of ECMO technology in maintaining stable hemodynamics of the patient during his stay in an intensive care unit and during transportation, despite an extremely low LVEF (3%). Despite the patient's severe condition, he was successfully transported over a long distance for a long time and by several modes of transport (car transportation and air travel). Meantime, on the one hand, the organizational component was of great importance, both in carrying out the evacuation and in establishing communication between hospitals. On the other hand, highly qualified assistance was required at all stages: from preparations in the referral medical institution, the transportation, and delivery to a specialized medical facility.

Experience with interhospital transportation of patients using ECMO abroad indicates a low risk of complications when using standardized protocols and an experienced team [8, 12]. This emphasizes the importance of integrating various medical services, including air ambulances, anesthesiologists, cardiac surgeons, and transplant surgeons [13].

The difficulties of implementing ECMO technology for medical transportation are primarily due to the high requirements for personnel qualifications. In addition to general profound interdisciplinary knowledge, such specialists must be skilled in percutaneous cannulation of the main vessels, maintaining the operability of the ECMO system, and also include experience in transporting seriously ill patients and providing the necessary care [3, 13]. Meanwhile, the minimum personnel requirements for a mobile ECMO team are not provided in any of the available Guidelines. Each center has its own optimized concept and,

depending on legal and organizational requirements, the team composition may vary. Various publications contain evidence of the participation of therapists, surgeons, anesthesiologists-intensivists, emergency medicine specialists, nurses and perfusionists in medical support of a patient on ECMO [11, 14, 15]. The patient transportation described in this paper involved a team consisting of anesthesiologists-intensivists, nurses, and ECMO specialists. It is important to note that these specialists are not members of the staffed team and were involved in undertaking the medical evacuation of a specific patient. Moreover, specialists from different medical organizations took part in this medical transportation, which emphasizes the importance of well-planned organizational measures and the doctors' mastery of professional communication skills.

Air transportation always carries additional risk for the patient as it can have a significant adverse impact on vital parameters including the heart rate, blood pressure, and intracranial pressure [16]. In a study by Wothe and colleagues, patients on ECMO were shown to require inotropic support more frequently during air flight than patients transported by ground transport. However, when comparing the total time on ECMO, no statistically significant differences were obtained in the incidence of complications (thrombosis, bleeding, cardiorespiratory complications) and mortality in patients transported using ECMO by land (n=35) and by air (n=23), which indicates the feasibility of using both methods of transporting such patients [12].

Thus, an air transport evacuation using ECMO is a promising strategy that can be used for patients with end-stage heart failure. Despite the high cost of transportation, it is justified when delivering a patient to a specialized center for highly qualified care that gives the patient a chance for recovery, a heart transplant a heart transplant in this clinical case;

other examples of saving patients with acute heart failure are transportation to regional vascular centers. Further studies should be aimed at optimizing the criteria for selecting patients for such transportation, logistics, as well as reducing risks and assessing long-term outcomes. Increasing the availability of air ambulances and mobile ECMO teams, especially in remote regions, can be a step towards creating a nationwide system of emergency medical care for patients with critical vital function disorders.

Conclusion

The clinical case demonstrates the key role of extracorporeal membrane oxygenation in patient life support during complex medical transportation. The presented case report is unique in giving the description of successful air transport evacuation of a patient with end-stage heart failure (left ventricular ejection fraction 3%), which expands the understanding of the extracorporeal membrane oxygenation capabilities. The use of complete peripheral veno-arterial extracorporeal membrane oxygenation with left ventricular drainage in combination with a multidisciplinary approach allows stabilizing a critical condition even in the presence of multiple organ failure caused by postcardiotomy heart failure with total loss of cardiac muscle contractility.

Based on the results of the above presented case report, we have made the following conclusions:

1. Successful air transport evacuation of a patient with end-stage heart failure was made possible by the coordinated work of a multidisciplinary team, including intensivists, cardiac surgeons, and air ambulance personnel. The key factors were a prompt decision-making, the coordination of actions when using extracorporeal membrane

oxygenation, artificial ventilation, and vasopressor support, as well as a close interaction between medical centers.

2. The stabilization of hemodynamics, anticoagulant therapy, switching to mobile life support systems (Cardiohelp-i, Hamilton-T1) minimized the risks of complications during the flight.

3. The use of mobile extracorporeal membrane oxygenation and artificial lung ventilation systems provided the continuous respiratory and circulatory support. Monitoring of vital functions allowed a timely adjustment of therapy during the patient transportation. The absence of complications during the flight demonstrated that currently available mobile systems are capable of supporting life even in patients with a left ventricular ejection fraction of 3% and multiple organ failure.

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The article was received on March 12, 2025;
Approved after reviewing on April 10, 2025;
Accepted for publication on June 25, 2025