Translated by A.P. Strelkova

Case Report
https://doi.org/10.23934/2223-9022-2023-12-4-690-696

Venovenous Extracorporeal Membrane Oxygenation in Severe Polytrauma

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BACKGROUND Road transport injuries (RTI) are the leading cause of death among the working-age population at present. Often, severe combined trauma is accompanied by significant damage to the chest with the development of severe respiratory disorders. Standard methods of intensive therapy for respiratory failure are often ineffective. The use of extracorporeal membrane oxygenation (ECMO) can be an effective method of reducing mortality in this category of patients, even in conditions where it is impossible to use systemic anticoagulation.

AIM OF THE STUDY Consider the use of ECMO in patients with serious polytrauma trauma and a high risk of hemorrhagic complications.

MATERIAL AND METHODS Patient R., 43 years old, got a severe combined injury in a traffic accident; due to progressive acute respiratory failure, veno-venous ECMO (VV-ECMO) was performed for 11 days.

RESULTS This report reviews a clinical observation of the successful use of VV-ECMO in a patient with severe acute respiratory distress syndrome as a result of polytrauma in a road accident. Due to the high risk of hemorrhagic complications, the procedure was performed without the use of systemic anticoagulation, which is a rather rare case in modern intensive care. On the 11th day, the VV-ECMO procedure was stopped. On the 7th day of VV-ECMO, an intense hemorrhagic syndrome developed as a complication, which was successfully treated. On the 13th day after weaning, the patient was transferred from the intensive care unit to the rehabilitation center.

CONCLUSIONS The venovenous extracorporeal membrane oxygenation method can be considered as part of the treatment of severe acute respiratory distress syndrome as a result of severe chest trauma when standard methods of respiratory support are ineffective. With a high risk of hemorrhagic complications, which is often observed in patients in this category, it is possible to use venovenous extracorporeal membrane oxygenation without systemic anticoagulation.

Keywords: Severe combined trauma, ARDS, venovenous ECMO, systemic anticoagulation
For citation Vlasov PA, Kudryashova EA, Melnichenko PI, Nikiforov IS, Petrushin MA. Venovenous Extracorporeal Membrane Oxygenation in Severe Polytrauma. Russian Sklifosovsky Journal of Emergency Medical Care. 2023;12(4):690–696. https://doi.org/10.23934/2223-9022-2023-12-4-690-696 (in Russ.)
Conflict of interest Authors declare lack of the conflicts of interests
Acknowledgments, sponsorship The study has no sponsorship

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ARDS – acute respiratory distress syndrome
AVL – artificial ventilation of the lungs
ECMO – extracorporeal membrane oxygenation
EMS – emergency medical services
FAST – Focused Assessment with Sonography for Trauma
FiO_2 – fraction of oxygen in the inhaled mixture
PaO_2/FiO_2 – oxygenation index
Pdrive – driving pressure (difference between Pplat and PEEP)
PEEP – positive end expiratory pressure
pO_2 – partial pressure of oxygen
Ppeak – peak pressure of inspiratory flow
Pplat – plateau pressure
RTA – road-traffic accident
RTT – road traffic trauma
SpO_2 – saturation, blood saturation with oxygen
VV-ECMO – venovenous extracorporeal membrane oxygenation
VPL – ventilator-induced lung injury

INTRODUCTION

In patients with severe concomitant trauma, chest injury is observed in almost half of the cases [1]. Chest trauma is the third most common cause of death in patients with multiple injuries, after abdominal and head injuries [2]. In more than 50% of cases of chest trauma, the development of acute respiratory distress syndrome (ARDS) is observed [3]. Treatment of ARDS remains challenging. The suggested concept of protective artificial pulmonary ventilation (ALV) is not always effective. In cases of developed hypoxemia that is resistant to treatment, the use of extracorporeal membrane oxygenation (ECMO) can improve the survival of this category of patients [4, 5].

The first experience with the use of ECMO in the treatment of ARDS as a result of severe concomitant trauma was described in 1971 [6]. Since then, the ECMO technique has undergone intensive development. For a long time, it was believed that the place of ECMO was limited to cardiac surgery practice. Further development of technology has made it possible to reconsider the place of the ECMO technique in the treatment of critically ill patients. The greatest interest in ECMO as a method of treating life-threatening respiratory failure arose during the H1N1 influenza virus pandemic in 2009 and the SARS-CoV-2 COVID-19 virus pandemic in 2019, when ECMO was used in the treatment of ARDS against the background of viral pneumonia. There are frequent reports of the use of ECMO in the treatment of ARDS in patients with severe concomitant trauma.

The need to use systemic anticoagulation in patients with severe associated trauma remains controversial. The accumulated experience is often limited to the description of individual clinical cases.

Particular concern is given to patients in whom the use of systemic anticoagulant therapy may provoke further bleeding. Patients with parenchymal organ damage, previous surgery and chest trauma are an unresolved problem in clinical practice [7]. If life-threatening acute respiratory failure develops in this category of patients, the choice of therapy may be the use of ECMO without systemic anticoagulation.

Aim of study: to consider the possibility of using ECMO in patients with severe concomitant trauma and a high risk of hemorrhagic complications using the example of clinical observation.

MATERIAL AND METHODS

Patient R., 43 years old, was delivered by an ambulance team to the trauma center 30 minutes after a road traffic accident (RTA) with the diagnosis: "Polytrauma in a road accident. Closed chest injury. Displaced sternum fracture. Multiple rib fractures. Pneumothorax on the right. Lung contusion. Heart contusion. Closed abdominal trauma. Liver rupture. Splenic rupture. Retroperitoneal hematoma. Fracture of the body of the ilium with transition to the acetabulum. Fracture of the transverse processes L 1, L 5 on the left. Abrasions of the soft tissues of the head. Incised wound in the area of the right elbow joint, the upper third of the right forearm, and the second finger of the right hand. Multiple abrasions of the upper and lower extremities."

After performing an ultrasound examination using the FAST protocol, the patient was taken to the operating room. Emergency drainage of the right pleural cavity, laparotomy, suturing of the liver rupture, splenectomy, sanitation and drainage of the abdominal cavity were performed. In the postoperative period, he was transferred to the intensive care unit and mechanical ventilation was continued. On the 2nd day, percutaneous puncture dilatation tracheostomy was performed. Severe respiratory failure was noted against the background of severe skeletal trauma to the chest and bilateral pulmonary contusion (Fig. 1). On the 3rd day after the injury, a significant decrease in oxygenation was revealed: SpO_2 78%, arterial blood pO_2 46 mm Hg, PaO_2/FiO_2 46 mm Hg at FiO_2 100% and PEEP 20 cm water column. Considering the development of life-threatening acute respiratory failure against the background of severe ARDS, resistant to mechanical ventilation beyond the protective parameters, the medical council decided to use venovenous extracorporeal membrane oxygenation (VV-ECMO).

The visiting team performed cannulation of the right femoral vein (cannula for ECMO 27 Fr.) and the right internal jugular vein (cannula for ECMO 19 Fr.). VV-ECMO was started with parameters: flow 2500 ml/min, motor speed 4800 rpm, oxygen flow 5.0 l/min. Ventilation parameters adjusted: PEEP 8 cmH2O, FiO_2 50%, Ppeak 19 cmH2O, Pplat 9 cmH2O. After 15 minutes from the start of VV-ECMO, positive dynamics were achieved: SpO_2 96%, arterial blood pO_2 58 mm Hg; index PaO_2/FiO_2 116 mm Hg.

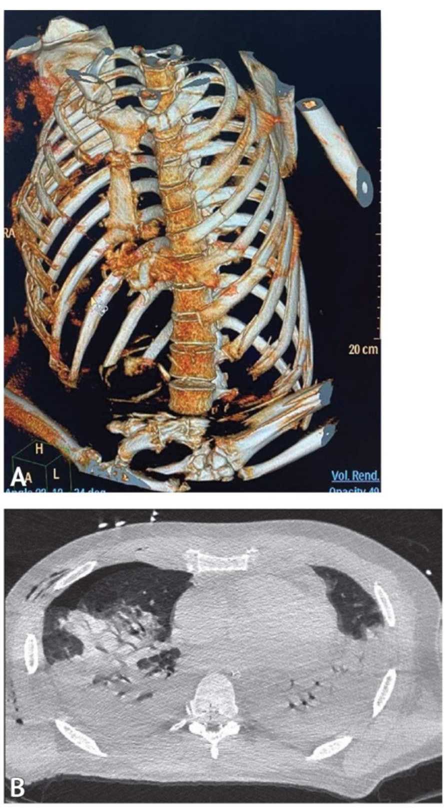

Fig. 1. CT scan of the chest before initiation of venovenous extracorporeal membrane oxygenation. A — 3D visualization of the chest skeleton: multiple bilateral rib fractures, sternum fractures; B — bilateral massive contusions of the lungs, right-sided pneumothorax

The patient was transported to the regional hospital. Mechanical ventilation was continued within the protective parameters (tidal volume 6 ml/kg, PEEP 8 cmH2O, FiO_2 30%) under conditions of total myoplegia and drug sedation. Laboratory examination revealed thrombocytopenia of the 2nd degree (77×10^9/l), during rotational thromboelastometry, an extension of the CT INTEM interval to 418 seconds was revealed). Taking into account laboratory data, traumatic liver injury and previous surgery, a decision was made to perform the ECMO procedure without systemic anticoagulation due to the high risk of hemorrhagic complications. To reduce potential thrombotic complications, such as thrombosis of the ECMO circuit or oxygenator, a higher blood flow rate (3,500 ml/min) was used. On the 4th day of ECMO, myoplegia and medical sedation were discontinued; in the subsequent period, the patient was conscious under conditions of mechanical ventilation in an auxiliary mode. Positive dynamics were noted in the respiratory status in the form of a gradual increase in the arterial blood pO_2 value and the PaO_2/FiO_2 (Fig. 2).

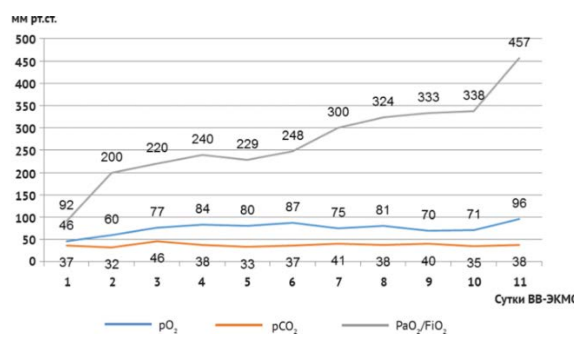

Fig. 2. The dynamics of changes in arterial blood gas composition and oxygenation index

Note: VV-ECMO – venovenous extracorporeal membrane oxygenation

On the 8th day, gradual weaning from ECMO was initiated; on the 11th day, the procedure was terminated, decannulation was performed without complications. The repeated computed tomography of the chest organs revealed a decrease in infiltration in areas of pulmonary tissue contusions (Fig. 3).

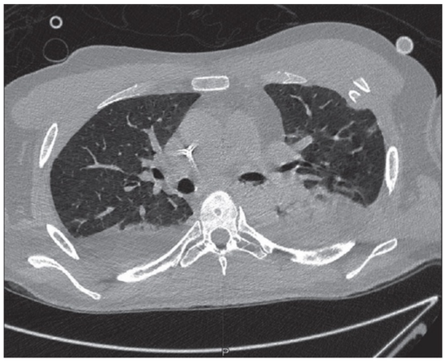

Fig. 3. CT scan of the chest on the 8th day of venovenous extracorporeal membrane oxygenation: reduction of areas of pulmonary contusions, resolution of pneumothorax

During the VV-ECMO procedure, standard monitoring of laboratory parameters was carried out, the target blood hemoglobin level was maintained at 80–100 g/l in order to ensure adequate gas transport function of the blood, the target platelet level was 80–100×10^9/l (Fig. 4). Routine monitoring of standard coagulogram parameters was carried out, the target level of fibrinogen was maintained at 2–2.5 g/l, as well as rotational thromboelastometry monitoring - the value of the CT INTEM segment was assessed as an assessment indicator of the concentration of plasma coagulation factors (Fig. 5, 6).

On the 7th day of VV-ECMO, hemorrhagic syndrome developed: bleeding from the sites of vascular catheterization, tracheostomy defect, sites of abdominal drainage, and serous-hemorrhagic discharge along the drainage was observed. Laboratory tests revealed a decrease in fibrinogen concentration to 1.22 g/l; rotational thromboelastometry revealed a deficiency of plasma

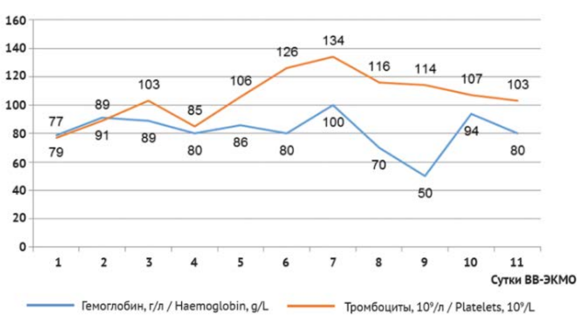

Fig. 4. The dynamics of changes in hemoglobin and platelet levels
Note: VV-ECMO – venovenous extracorporeal membrane oxygenation

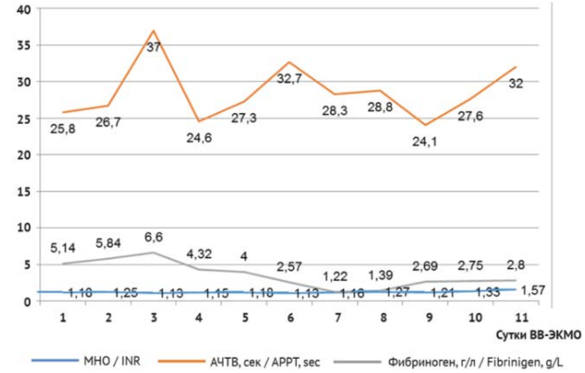

Fig. 5. The dynamics of changes in international normalized ratio (INR), activated partial thromboplastin time (APTT) and fibrinogen
Note: VV-ECMO - venovenous extracorporeal membrane oxygenation

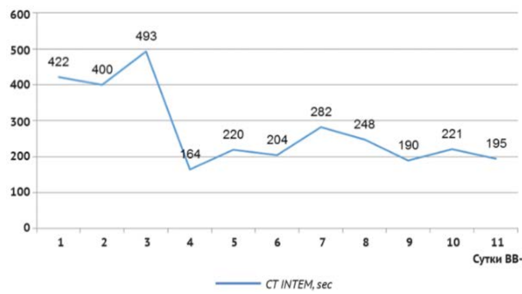

Fig. 6. The dynamics of changes in the CT INTEM segment
Note: VV-ECMO - venovenous extracorporeal membrane oxygenation

coagulation factors (increase in the CT INTEM segment to 282 seconds). In order to restore the concentration of procoagulant factors, transfusions of cryoprecipitate were performed at the rate of 2 doses per 10 kg of the patient's body weight, transfusions of fresh frozen plasma at the rate of 10–15 ml per 1 kg of the patient's body weight. On the 9th day of VV-ECMO, the manifestations of hemorrhagic syndrome were completely relieved.

After weaning the patient from VV-ECMO, mechanical ventilation was continued as part of the treatment of multiple bilateral rib fractures with phenomena of flotation of the segment, the center of which was the sternum. In parallel with mechanical ventilation and drug therapy, rehabilitation measures were carried out. On the 22nd day from the moment of injury, the patient was weaned from mechanical ventilation. On the 24th day from the moment of injury, the patient was transferred from the intensive care unit to the rehabilitation center.

RESULTS

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DISCUSSION

According to the World Health Organization, road traffic injuries are the leading cause of death among the working population. According to statistics, the mortality rate of patients with damage to the chest organs as a result of severe combined trauma ranges from 5 to 25%, and severe lung contusions with the development of life-threatening respiratory failure have a significant impact on the negative prognosis [8].

With the development of severe respiratory failure against the background of ARDS, the leading goal of therapy is to ensure adequate oxygenation by escalating methods of respiratory support with increasing their invasiveness, up to mechanical ventilation. It is important to remember that the use of mechanical ventilation in the vast majority of cases is associated with a high risk of developing ventilator-induced lung injury (VILI) [9].

The leading factor in the development of VILI is damage to the cells of the alveolar wall as a result of overextension, increased pressure, cyclic closure and opening of the alveoli, and, as a consequence, the release of cytokines as a result of damage to the cells of the alveolar wall with the development of systemic inflammation [10]. One of the methods for preventing VILI is to perform mechanical ventilation in a protective mode: setting the tidal volume to 6–8 ml/kg of the patient's body weight, limiting Ppeak to less than 25 cm of water column, limiting PEEP to 5–10 cm, maintaining Pdrive less than 15 cm, setting the respiratory rate and oxygen fraction in the inhaled mixture at the minimum possible level to maintain normoxemia and normocapnia.

Often, the use of protective modes of mechanical ventilation in the treatment of severe respiratory failure due to chest trauma is ineffective, and a change in parameters towards "hard" ones inevitably leads to the development of VILI. In such cases, the method of choice for ensuring adequate oxygenation may be the use of ECMO.

The use of ECMO in patients with ARDS secondary to severe chest trauma, according to various sources, ensures patient survival from 44 to 74.1% [11]. Early use of ECMO in this group of patients is associated with an increased risk of complications. Damage to parenchymal organs, recent surgical interventions, and previous bleeding often lead to the development of coagulopathy, which determines a high risk of recurrent bleeding and a high frequency of deaths [12, 13].

For this cohort of patients, one possible option is the use of ECMO without systemic anticoagulant therapy. Advances in the field of ECMO over the past few years have made it possible to use this type of therapy, heparin coating of ECMO circuits, the use of new types of centrifugal pumps, the use of oxygenators made of polymethylpentene. All these technologies make it possible to use ECMO in the treatment of patients with severe hemostatic disorders [14]. The experience of using ECMO without systemic anticoagulant therapy in this category of patients is limited to the description of individual clinical cases [15, 16].

Undoubtedly, ECMO is a very aggressive invasive procedure associated with both damage to the intima of the cannulated vessels and inevitable damage to blood cells during perfusion and adsorption of plasma coagulation factors in the ECMO circuit. These factors lead to an imbalance between the pro- and anticoagulant components of the hemostatic system, which causes the development of hemorrhagic and thrombogenic complications typical for ECMO. Based on the foregoing, each case of ECMO use requires clearly defined monitoring of coagulation parameters.

In our observation, the patient initially had a high risk of hemorrhagic complications as a result of trauma to the abdominal organs, previous bleeding and surgical interventions, which influenced the decision to perform ECMO without systemic anticoagulant therapy. Considering the data from scientific publications on complications associated with the use of the ECMO technique, we expected a greater likelihood of developing thrombotic complications, given the gradual normalization of our patient's hemostatic factors and the increase in the titer of D-dimer, which is the most sensitive factor in thrombus formation (Fig. 7).

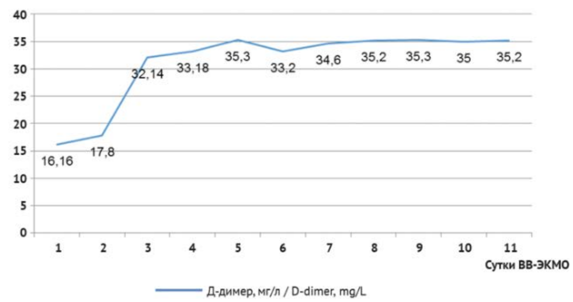

Fig. 7. The dynamics of changes in the concentration of D-dimer
Note: VV-ECMO - venovenous extracorporeal membrane oxygenation

Most likely, the use of higher blood flow on ECMO allowed these types of complications to be avioded. However, on the contrary, we had a complication with the development of hemorrhagic syndrome, not associated with the use of anticoagulants. The rapid diagnosis and timely correction of the causes of hemorrhagic syndrome ensured relief of hemorrhagic syndrome before the development of more serious consequences, such as severe anemia with impaired gas transport function of the blood, hemorrhagic shock.

CONCLUSION

The use of extracorporeal membrane oxygenation may be considered as a treatment option for patients with traumatic lung injury and life-threatening respiratory failure refractory to standard respiratory support. The extracorporeal membrane oxygenation method is associated with a high incidence of complications, so its use requires a careful assessment of the likely risks and constant monitoring of coagulation parameters. If there is a high risk of hemorrhagic complications in patients with severe concomitant trauma, it is necessary to consider the use of extracorporeal membrane oxygenation without systemic anticoagulation.

FINDING

1. Extracorporeal membrane oxygenation may be the method of choice for the treatment of life-threatening acute respiratory distress syndrome due to chest trauma.
2. If there is a potentially high risk of hemorrhagic complications, it is possible to use extracorporeal membrane oxygenation without systemic anticoagulation.
3. With careful monitoring of coagulation factors, extracorporeal membrane oxygenation is a safe and effective treatment method.

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Received on 10/14/2022
Review completed on 09/25/2023
Accepted on 09/26/2023