Application of V-A ECMO therapies for short-term mechanical circulatory support in patients with cardiogenic shock

Robert Musiał¹, Tomasz Darocha², Sylwester Kosiński³, Jarosław Stoliński⁴, Jerzy Sadowski⁴, Rafał Drwiła²

¹Department of Anaesthesiology and Intensive Care, John Paul II Specialist Hospital in Krakow, Poland
²Department of Anaesthesiology and Intensive Care, John Paul II Specialist Hospital in Krakow, Poland
³Department of Anaesthesiology and Intensive Care, Olgierd Sokolowski Specialist Hospital of Lung Diseases in Zakopane, Poland
⁴Department of Cardiac Surgery, Vascular Surgery and Transplantology, John Paul II Specialist Hospital, Collegium Medicum, Jagiellonian University in Krakow, Poland

Abstract

Background: The aim of the study was to present our experience with short-term mechanical circulatory support by veno-arterial extracorporeal membrane oxygenation (V-A ECMO). A series of cases is described involving patients with symptoms of severe cardiogenic shock successfully treated with V-A ECMO.

Case reports: Depending on indications, veno-venous (V-V) or veno-arterial (V-A) ECMO can be used. The patients described here presented symptoms of severe cardiogenic shock and the ECMO kit was successfully applied as an element of circulatory support. V-A ECMO was used as a bridge to recovery in a patient after pulmonary artery embolectomy and a bridge to heart transplantation in a patient with giant cell myocarditis; in the third case, ECMO was applied to the treatment of cardiogenic shock in deep hypothermia.

Conclusions: The number of cases in which ECMO has been successfully applied in patients with cardiogenic shock and in deep hypothermia is increasingly high; therefore, it seems advisable to elaborate ECMO guidelines to be used in such situations. V-A ECMO is an effective and recognized method of treatment of patients in cardiogenic shock and deep hypothermia.

Key words: cardiogenic shock, deep hypothermia, extracorporeal life support, extracorporeal membrane oxygenation

Anaesthesiology Intensive Therapy 2015, vol. 47, no 4, 324–327

The first extracorporeal membrane oxygenation (ECMO) was performed by D.J. Hill in 1972 in a patient with respiratory failure [1, 2]. Over the following years, ECMO technology was developed and improved. In 2009, during an AH1N1 flu epidemic, this form of treatment started to be used more intensively. The use of veno-venous ECMO (V-V ECMO) therapy preventing critical hypoxia enabled pharmacological treatment of the most severe infections. Since that time, the extracorporeal life support organization (ELSO) has registered over 32,000 newborns, 12,000 children and more than 9,000 adults treated with ECMO [3]. Thanks to the coupling of an oxygenator and centrifugal pump, the kit is designed for extracorporeal support of pulmonary and systemic circulation.

The aim of the report was to describe the use of ECMO therapy in three different cases.

CASE A

A 22-year-old male patient in severe cardiogenic shock with borderline lung function, conscious but with a limited contact (the GCS score — 12) was admitted to the Department of Cardiac Surgery, Vascular Surgery and Transplantology. The patient had earlier been treated for a left testicle tumour. On admission, HR 110 min⁻¹, SAP/DAP 80/50 mm Hg, ejection fraction (EF) 0.65, IT III ST right ventricular systolic pressure (RVSP) 65 mm Hg were found. A computed tomography confirmed massive pulmonary embolism and inferior vena cava thrombosis. Urgent embolectomy of the
pulmonary artery was decided, which was performed under extracorporeal circulation, deep hypothermia (24°C) and temporary total exclusion of circulation (34 min.). The total time of extracorporeal circulation was 4 h and 10 min.

During surgery, the embolic material was removed from the left branch of the pulmonary artery and the inferior vena cava was assessed using an aspirator. Since it was not possible to disconnect the extracorporeal circulation after prolonged reperfusion, and despite the institution of maximum pharmacological ionotropic support, the use of V-A ECMO was decided. Although the patient underwent cardiac surgery and sternotomy, central ECMO was not applied. Due to difficulties in maintenance of haemostasis at the surgical site, inguinal access was decided. The surgical access to both femoral vessels was provided in the region of the left groin — venous outflow through a 24F cannula and return through a 21F cannula. The support was initiated with the flow of 65 mL kg\(^{-1}\) min\(^{-1}\), which was subsequently adjusted to provide mixed venous oxygen saturation (SvO\(_2\)) of 60–70%. \(F_O2\) was 0.4–0.6 to achieve \(PaO_2\) of 150–200 mm Hg and \(PaCO_2\) of 35–45 mm Hg. The activated clotting time (ACT) was maintained within 160–200 sec. using a heparin infusion while the mean arterial pressure (MAP) was maintained at 60 mm Hg.

In the immediate postoperative period, an infusion of catecholamines (adrenalin, noradrenalin) and milrinone was applied due to myocardial akinesis and valve dysfunction. An echocardiography showed an LVEF of 0.10. Blood preparations were administered due to massive blood loss. Two re-thoracotomies were performed because of haemorrhage. Since clotting disorders were observed and effective haemostasis was not possible to be achieved, haemostatic sponges were used.

The patient was administered conventional protective lung ventilation (\(V_l, 6\) mL kg\(^{-1}\), \(f\) 13 min\(^{-1}\), PEEP 4 cm H\(_2\)O). Analgosedation was provided using an infusion of fentanyl and midazolam. Arterial blood gasometry results on treatment day 1 are listed in Table 1.

Pathomorphological testing of the embolic material revealed a malignant, mixed germinal tumour, predominantly of embryonal carcinoma texture. On day 9, the ECMO flow was decreased by 10% (to 55 mL kg\(^{-1}\) min\(^{-1}\)); LVEF was 0.15. After another two days, the ECMO flow was reduced by another 10% (to 45 mL kg\(^{-1}\) min\(^{-1}\)), and LVEF reached 0.20. Continuous renal replacement therapy was applied due to acute renal failure and a transdermal tracheostomy was performed. On day 13, the ECMO circuit was removed. On day 30, the conscious patient (GCS score 15 and cerebral performance category (CPC) 1) with efficient respiration and haemodynamically stable was transferred to the Department of Systemic and Generalised Cancers at the Centre of Oncology.

**CASE B**

A 57-year-old female patient was admitted to the intensive care unit (ICU) after implantation of a cardiac stimulator. During hospitalization, the patient developed numerous ventricular complex arrhythmias requiring multiple electrical cardioversions. Based on the clinical picture, myocarditis with electrical storm was suspected. The diagnosis was histopathologically confirmed as giant cell myocarditis. On admission, the patient was conscious with limited verbal contact, tachypnoea, SAP/DAP 100/60 mm Hg, HR 120 min\(^{-1}\). Echocardiography revealed extensive disorders of segmental myocardial contractility, EF 0.12. Since arrhythmias did not respond to pharmacological treatment and the patient developed multiple incidents of VF cardiac arrest, it was decided to use V-A ECMO as a form of mechanical circulatory support. The support was started with a flow of 60 ml kg\(^{-1}\) min\(^{-1}\), which was subsequently adjusted to maintain SvO\(_2\) within 60–70%. The results of the arterial blood gasometry are presented in Table 2.

On day 7 of ECMO therapy, ablation of the atrial-ventricular junction was performed due to repeated incidents of ventricular fibrillation and ventricular tachycardia. On day 10, the patient was qualified for an urgent heart transplant. Due to prolonged ECMO therapy and the lack of heart donor, on day 15, the ECMO circuit was replaced by a new one. After 7 days of therapy, the patient underwent orthotopic heart transplantation; the pacemaker was removed and the ECMO support maintained for 2 days. The patient’s condition improved — LVEF was 0.55. One week after transplantation, the patient was transferred to the surgical department. On day 12 after transplantation, cardiac tamponade was diagnosed, which was instantly decompressed. After another 30 days of treatment, the patient, who was conscious (GCS

### Table 1. Case A — acid-base balance parameters on treatment day 1

<table>
<thead>
<tr>
<th>Time of examination</th>
<th>pH</th>
<th>(\text{PaCO}_2) (mm Hg)</th>
<th>(\text{HCO}_3) (mmol L(^{-1}))</th>
<th>BE (mmol L(^{-1}))</th>
<th>(\text{PaO}_2) (mm Hg)</th>
<th>Concentration of lactates (mmol L(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>After admission</td>
<td>7.176</td>
<td>43.8</td>
<td>13.4</td>
<td>–11.6</td>
<td>254</td>
<td>9.8</td>
</tr>
<tr>
<td>After 24 h ECMO therapy</td>
<td>7.443</td>
<td>43.1</td>
<td>29.0</td>
<td>4.9</td>
<td>199</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Robert Musiał et al., V-A ECMO in cardiogenic shock
score 15, CPC 1), haemodynamically stable and breathing efficiently, was discharged from hospital; follow-ups at the transplant outpatient clinic were recommended.

CASE C
An 84-year-old female patient was admitted to the intensive care unit (ICU) due to accidental deep hypothermia (core body temperature 25.9°C). On admission, the patient was conscious (GCS score 6), with nodal rhythm and features of substantial circulatory instability requiring high doses of noradrenalin and dopamine. A V-A ECMO circuit was emergently implanted through the left and right femoral vessels with active circulatory support. Extracorporeal warming was initiated with the parameters set to achieve normothermia within 3 hours. Additionally, to prevent “rescue collapse”, which can complicate warming at each stage of treatment, extracorporeal therapy was planned to be continued for 24 h. When normothermia was achieved and the cardiovascular system stabilized, after 20 h of extracorporeal therapy it was decided to remove the circuit due to symptoms of ischaemia of the left lower limb. In the operating suite, the ECMO circuit was removed and a left lower limb embolectomy was performed. On treatment day 2, the patient was extubated; LVEF was 0.45. On hospitalization day 3, the conscious (GCS score 15, CPC 1) patient with stable circulation and respiration was transferred to the internal medicine ward of a local hospital. The results of arterial blood gasometry on day 1 of ECMO therapy are presented in Table 3.

DISCUSSION
In each of the cases described, the key element affecting the survival of patients was the use of the lung-heart support system. All patients had symptoms of severe cardiogenic shock and the ECMO circuit kit was successfully used as an element of circulatory support, providing a bridge to causal treatment and recovery.

A multitude of ECMO applications relies on technical and clinical features of the system. The system can function based on peripheral vascular access and relatively liberal anticoagulation requirements. Moreover, the system is portable, can be moved with the patient and used for a long time. It ensures good control and steady support of respiratory and circulatory parameters, or even thermal parameters, which is evidenced by our case C.

The use of veno-venous ECMO is not complication-free. The possible complications include haemorrhages and transfusions of blood preparations associated with them, pneumothorax, acute renal failure, as well as low cardiac output syndrome requiring catecholamines [4]. However, proper qualification of patients and strict monitoring of vital functions enable their early diagnosis and prompt effective treatment.

The third case described is an example of ECMO use for different reasons. Extracorporeal warming in deep hypothermia is the gold standard of treatment, which is successfully applied in many centres [5–8]. In recent years, the tendency to use ECMO as the treatment of choice has been observed [9–14]. It is noteworthy that depression of the circulatory system in accidental hypothermia is largely caused by marked systolic and diastolic dysfunction [14]. Moreover, warming can lead to pulmonary oedema and respiratory failure. Thus, the use of ECMO in patients in deep hypothermia has two goals — to warm the patient (causal therapy) and to treat their symptoms (circulatory-respiratory support). Accidental hypothermia is rarely recognised and its incidence is most likely underestimated. Interestingly, treatment outcomes in patients in deep hypothermia, including cardiac arrest, are unexpectedly good using extracorporeal warming techniques [8–13].

In Poland, the ECMO guidelines for treatment of acute respiratory failure are currently available [15]. Since the number of successful ECMO applications in cardiogenic

<table>
<thead>
<tr>
<th>Time of examination</th>
<th>pH</th>
<th>PaCO₂ (mm Hg)</th>
<th>HCO₃⁻ (mmol L⁻¹)</th>
<th>BE (mmol L⁻¹)</th>
<th>PaO₂ (mm Hg)</th>
<th>Concentration of lactates (mmol L⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>On admission</td>
<td>7.486</td>
<td>16.7</td>
<td>11.7</td>
<td>−11.0</td>
<td>149.0</td>
<td>0.9</td>
</tr>
<tr>
<td>After 24h ECMO therapy</td>
<td>7.419</td>
<td>40.8</td>
<td>25.9</td>
<td>1.8</td>
<td>165.0</td>
<td>0.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time of examination</th>
<th>pH</th>
<th>PaCO₂ (mm Hg)</th>
<th>HCO₃⁻ (mmol L⁻¹)</th>
<th>BE (mmol L⁻¹)</th>
<th>PaO₂ (mm Hg)</th>
<th>Concentration of lactates (mmol L⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>After ED admission</td>
<td>7.14</td>
<td>36.2</td>
<td>12.5</td>
<td>−15.2</td>
<td>105</td>
<td>3.1</td>
</tr>
<tr>
<td>After achieving normothermia</td>
<td>7.28</td>
<td>28.5</td>
<td>13.1</td>
<td>−12.10</td>
<td>163</td>
<td>0.8</td>
</tr>
</tbody>
</table>
shock and deep hypothermia is rapidly growing, it is advisable to elaborate standards of extracorporeal oxygenation coexisting with circulatory support to be used in such clinical situations.

ACKNOWLEDGEMENTS
1. The authors thank the Tatra Mountains Volunteer Rescue Service and Mountain Rescue Service personnel for cooperation.
2. The authors declare no financial disclosure.
3. The authors declare no conflict of interest.

References:

Corresponding author:
Robert Musiał
Department of Anaesthesiology and Intensive Care
John Paul II Specialist Hospital in Krakow
ul. Pądnicka 80, 31-202 Cracow, Poland
e-mail: r.musial@aclex.com.pl

Received: 23.10.2014
Accepted: 31.03.2015