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Veno-arterial extracorporeal membrane oxygenation as cardiogenic shock therapy support in adult patients after heart surgery

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Abstract

Introduction: The authors present their personal experience in qualifying and treating adult patients using veno-arterial (VA) extracorporeal membrane oxygenation (ECMO) in postcardiotomy cardiogenic shock.

Aim: The aim of this study was to analyze the results of VA ECMO in patients with postcardiotomy cardiogenic shock. An analysis of the risk factors of postoperative mortality was also performed.

Material and methods: We analyzed the perioperative results of survivors and non-survivors of treatment using VA ECMO. We compared the number of days on VA ECMO therapy, types of cardiac surgical procedures, and the frequency of VA ECMO complications such as coagulation disorders, lower limb ischemia, cardiac tamponade, and renal replacement therapy.

Results: There were 27 patients treated with VA ECMO during the study period. The mean patient age was 45 ±16 years. The hospital mortality rate of patients treated with VA ECMO therapy was 70% (19/27). There were no significant differences between the groups of survivors and non-survivors regarding age, gender, admission type and coexisting diseases. Type of cardiac surgical procedure had no influence on mortality or complications of therapy using VA ECMO.

Conclusions: The VA ECMO can be an effective form of therapy in some patients in postcardiotomy cardiogenic shock.

Key words: postcardiotomy cardiogenic shock, extracorporeal membrane oxygenation.

Streszczenie

Wstęp: Autorzy przedstawiają doświadczenia własne w kwalifikowaniu i prowadzeniu terapii dorosłych pacjentów we wstrząsie kardiogennym po operacjach serca, u których zastosowano membranowe natlenianie pozaustrojowe (ECMO) w konfiguracji żylno-tętniczej.

Cel: Głównym celem badania było przeprowadzenie analizy wyników leczenia pacjentów w ciężkim wstrząsie kardiogennym po operacjach kardiochirurgicznych leczonych z użyciem VA ECMO. Autorzy dokonali analizy czynników mających wpływ na przeżycie pacjentów leczonych VA ECMO.

Materiał i metody: Przeanalizowano przebieg leczenia z użyciem VA ECMO u pacjentów w pokardiotomijnym wstrząsie kardiogennym poprzez porównanie grupy pacjentów, u których leczenie zakończyło się pomyślnie, z grupą osób, które zmarły pomimo zastosowania VA ECMO. Analizie poddano liczbę dni terapii z użyciem VA ECMO, rodzaj operacji kardiochirurgicznej, a także częstość wystąpienia powikłań VA ECMO, takich jak zaburzenia krzepnięcia, niedokrwienie kończyn dolnych, tamponada serca i terapia nerkozastępcza. Do badania włączono wszystkich kolejnych chorych leczonych w naszym ośrodku, znajdujących się w pokardiotomijnym wstrząsie kardiogennym, u których zastosowano VA ECMO.

Wyniki: W badaniu wzięło udział 27 pacjentów poddanych terapii VA ECMO. Średni wiek chorych wynosił 45 ±16 lat, a śmiertelność szpitalna – 70% (19/27). W badaniu nie stwierdzono znaczących różnic pomiędzy grupą zmarłych pacjentów a grupą osób, u których leczenie zakończyło się pomyślnie, w zakresie wieku, płci, trybu przyjęcia oraz chorób towarzyszących. Rodzaj procedury chirurgicznej nie miał istotnego wpływu na śmiertelność i powikłania terapii z użyciem VA ECMO.

Wnioski: Membranowe natlenianie pozaustrojowe w konfiguracji żylno-tętniczej jest skuteczną formą leczenia niektórych pacjentów w ciężkim wstrząsie kardiogennym po operacjach kardiochirurgicznych.

Słowa kluczowe: pokardiotomijny wstrząs kardiogenny, membranowe natlenianie pozaustrojowe.

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Introduction

Extracorporeal membrane oxygenation (ECMO), is a modified form of extracorporeal circulation used during heart surgery. Depending on the configuration (veno-venous or veno-arterial), ECMO enables prolonged support for a patient's respiratory or cardiovascular system while in an intensive care unit, or provides complete replacement of the respiratory system. It is reported that 0.2–6.0% of adult patients subjected to cardiac surgery procedures suffer from postcardiotomy cardiogenic shock (PCCS) [1, 2]. This occurs in patients with either low or acceptable ejection fraction from the left ventricle and who are qualified for heart surgery operations. The PCCS occurs not only in patients who cannot be weaned from cardiopulmonary bypass while in the operating room but also in those who show "low cardiac output syndrome" (LCOS) in the early postoperative period. Despite maximum inotropic stimulation, persistent hemodynamic instability necessitates consideration of the use of direct mechanical support.

Conducting a complete surgical procedure is a prerequisite in this situation. Support systems, such as ECMO, ensure maintenance of flow in the systemic and/or pulmonary circulation systems while unburdening the heart. The decision to cease further increase of pharmacological stimulation and use mechanical devices should be taken prior to hypoperfusion of individual organs caused by prolonged low cardiac output, which leads to irreversible changes [3]. Extracorporeal life support (ECLS) such as ECMO may constitute an efficient method of therapy for patients with severe cardiogenic shock, and can be used as a bridge for treatment, transplantation, or long-term cardiac support therapies [4].

Not every patient can be subjected to ECMO treatment. The exclusion group includes those who have experienced irreversible changes causing cardiovascular or cardiopulmonary failure, have an active hemorrhage or have contraindications for chronic heparinization. In some centers exclusion criteria include terminal treatment, uncontrolled malignant tumor growth, severe neurological damage, age above 80, and any other severe medical problem preventing the patient's recovery and constituting absolute contraindications for the use of ECMO [5]. Technical contraindications include aortic dissection and severe aortic regurgitation [6].

Aim

The objective of this study was to analyze the results of VA ECMO therapy in patients with postcardiotomy cardiogenic shock. An analysis of postoperative mortality risk factors was also performed.

Material and methods

Study group

The study was conducted in accordance with the Declaration of Helsinki. A registered study without collection of personal data of patients and without an influence on the therapeutic process does not require an application and acceptance of the local Ethics Committees. Permission for preparation of the present manuscript was obtained from the management of the local hospital. This retrospective observational study included consecutive patients with PCCS treated at the Unit of Anesthesiology and Intensive Care of the Department of Cardiovascular Surgery and Transplantology of the Jagiellonian University in Krakow, for whom VA ECMO was used as a support system for the lungs and heart. A group of 25 patients treated with VA ECMO for accidental hypothermia and 16 patients treated with VA ECMO for cardiogenic shock where the etiology of the cardiogenic shock was different than acute heart failure after cardiac surgery were excluded from our study.

The final analysis involved a group of 27 patients treated from February 2009, when ECMO therapy was first used at our clinic, to June 2016. The analysis covered demographic data, type of hospital admission, primary reason for inception of the ECMO therapy, coexisting diseases, left ventricle ejection fraction at admission, hospital stay, intensive care stay time, ECMO therapy stay, mortality, and complications during ECMO therapy.

Hospital mortality was defined as death that occurred due to any cause within 30 days after the introduction of ECMO therapy or that occurred in a period longer than 30 days, but during the same hospitalization period [7]. Renal insufficiency was diagnosed if the creatinine level exceeded 177 µmol/l [8].

Therapy rules

The femoral vessels (vein and artery) were cannulated with 22–24 F outflow cannulae and 19–21 F inflow cannulae (Bioline Coating Maquet, Germany). The vital function support system included Rotaflow Control Console REF 706037 (Maquet, Germany), Heater Unit HU 35 (Maquet, Germany), and a set of cannulae with the oxygenator Permanent Life Support Set "Bioline Coating" (Maquet, Germany). The support was initiated with a flow rate of 65 ml/kg/min. The flow was then regulated to obtain oxygenation of the mixed venous blood with mixed venous oxygen saturation (SvO_2) at a level of 60–70%. Fraction of inspired oxygen (FiO_2) was carried out at a level of 40–60 ml to obtain oxygen pressure in arterial blood (pO_2) within a range of 150–200 mm Hg, and carbon dioxide pressure (pCO_2) of 35–45 mm Hg. Activated coagulation time (ACT) was maintained for 160–200 s with continuous heparin infusion. Average blood pressure was maintained at 60 mm Hg.

Control echocardiographic examinations were performed during the immediate postoperative period to evaluate the left ventricle ejection fraction (LVEF). Hemoglobin level was maintained at 8 mg/dl. To achieve this, transfusion of blood products was carried out. Platelet count was maintained > 80,000. A constant infusion of fentanyl with midazolam was used for analgosedation with concomitant use of controlled lung protective ventilation (tidal volume 6 ml/kg of standard weight, ventilation rate 10/min, positive end-expiratory pressure (PEEP) 4 cm H_2O). Antibiotic treatment was carried out in cooperation with the hospital infection team.

Tab. I. Patients' demographics and preoperative characteristics

Parameter	Patients who died	Patients who survived	*P*-value
Sex (M/F)	14/5	5/3	0.658
Age [years]	45.3 ±15.7	43.9 ±16.8	0.825
AH (1/0)	12/7	5/3	0.651
DM t2 (1/0)	4/15	2/6	0.594
MI (1/0)	4/15	1/7	0.528
PCI (1/0)	3/16	1/8	0.532
Urgent admission (1/0)	9/10	3/5	0.696
LVEF at admission (median)	35.6 ±20.5 (50)	27.1 ±26.6 (45)	0.245

AH – arterial hypertension, DM t2 – diabetes mellitus type 2, MI – myocardial infarction, PCI – percutaneous coronary interventions, LVEF – left ventricular ejection fraction.

Tab. II. Type of cardiac surgery procedures

Procedure	Number of cases	Frequency (%)
Aortic valve replacement	7	26
Ascending aortic aneurysm operation	7	26
Mitral valve replacement	6	22
Heart transplantation	2	7
Pulmonary valve replacement	2	7
Left ventricular aneurysm operation	1	4
Aortic and mitral valve replacement	1	4
Pulmonary embolism	1	4

Tab. III. Logistic regression analysis of demographic variables influencing death of patient subjected to VA ECMO therapy

Parameter	OR	95% CI	*P*-value
Sex	1.68	0.3–10.7	0.563
Age	1.01	0.1–1.1	0.825
Number of days on ECMO therapy	0.9	0.9–0.8	0.065

OR – odds ratio, 95% CI – 95% confidence interval.

Tab. IV. Logistic regression analysis of risk factors influencing death of patient subjected to VA ECMO therapy (independent variables in the model were types of surgical procedures)

Variable	OR	95% CI	*P*-value
MvR	0.3	0.1–2.3	0.228
AvR	0.4	0.1–3.0	0.379
AAAsc	3.2	0.3–36.5	0.319
Pulmonary valve repl.	0.0	0.2–1.1	0.998

MvR – mitral valve replacement, AvR – aortic valve replacement, AAAsc – aneurysm ascendancing aorta, OR – odds ratio, 95% CI – 95% confidence interval.

Statistical analysis

Categorical variables were expressed as counts and percentages. A logistic regression model was used for the analysis of the relationship between qualitative and continuous variables with mortality. We constructed an analysis of the variance model. The groups studied were too small to perform multivariable analysis of variances. For each significant factor, the individual odds ratio was calculated with its 95% confidence interval. Wherever it was impossible to use the logistic regression model, the χ^2 statistic was calculated. A *p*-value less than 0.05 was considered an indication of a statistically significant result. Student's *t*-test was used for the comparison of two samples and the non-parametric Mann-Whitney *U* test in the case of lack of normality. All statistical analyses were performed using Statistica 10 PL software.

Results

The population studied included 27 PCCS patients treated with VA ECMO therapy. The average patient age was 45 ±16 years; 19 (70%) patients were male and 8 (30%), were female. The hospital mortality rate was 70% (19 patients).

An analysis of the factors influencing the survival of patients treated with VA ECMO was conducted. The survival rate was 30% (8 patients) from the group of patients treated with VA ECMO therapy. Patients' demographic data and preoperative characteristics are presented in Table I.

The reason for the introduction of ECMO therapy in VA configuration was severe PCCS and lack of possibility to stop extracorporeal circulation after heart surgery. The types of cardiac surgery resulting in PCCS are presented in Table II.

There was no differences between the group of deceased and the group of survivors with reference to age, sex, height, admission type, coexisting diseases, or left ventricle ejection fraction level evaluated during hospital admission. Using the logistic regression model to determine the relationship between qualitative and continuous variables, no significant relationship with reference to sex, age (Tab. III) or type of cardiac surgery procedure (Tab. IV) was observed. The hospital and Intensive Care Unit length of stay and VA ECMO therapy were all considerably longer in the group of survivors.

Using Student's *t*-test and the nonparametric Mann-Whitney *U* test in the case of lack of normality, the group of surviving patients was compared with the group of deceased patients (Tab. V). The number of days of VA ECMO therapy, hospitalization time, and intensive care unit length of stay were also analyzed. Also here, the group of surviving patients was characterized by a considerably longer intensive care unit stay ($p = 0.002$), hospital stay ($p = 0.001$), and number of days of ECMO therapy ($p = 0.035$).

In both groups, the introduction of the VA ECMO system was not without complications (Tab. VI). In the groups tested the following conditions were observed: coagulation disorders and the need for blood product transfusion in 59% (16 patients), acute renal failure and the need to use continuous renal replacement therapies in 44% (12 patients), and lower limb ischemia in 26% (7 patients). In 12 (44%) patients heart tamponade occurred. Surgical revision (rethoracotomy) due to tamponade or bleeding was performed in 56% (15 patients). Endocavitary electrode was needed in 37% (10 patients). There was no significant relationship between death and the complications presented above (Tab. VII).

Discussion

The primary message of our study is that VA ECMO was an effective therapy for 30% of our patients with severe PCCS. The hospital mortality rate of patients treated with VA ECMO therapy in our study was 70%. In all patients, the reason for the decision to introduce VA ECMO therapy was the lack of possibility to stop extracorporeal circulation after completion of the cardiosurgical procedure, despite optimum inotropic support.

For our patients, the VA ECMO therapy was implanted in the immediate postoperative period, prior to the transfer of patients to the intensive care unit. The decision to introduce ECMO therapy was taken when the doses of pressor drugs approached the following levels: epinephrine: 0.3–0.5 µg/kg/min, norepinephrine: 0.3–0.4 µg/kg/min, dobutamine: 5–10 µg/kg/min. In 2 patients, the therapy was introduced on days 1 and 2 following intensive care unit admission, after ineffective attempts of hemodynamic stabilization with inotropic support and after the application of an intra-aortic balloon pump. In both cases, the decision to start ECMO therapy was triggered by a dynamic drop of heart ejection fraction to a value of 5–10% and elevated pressor amines demand.

Mechanical cardiac supports (MCS) is intended to bridge the patient to recover, or if not possible, as a bridge to transplantation or evaluation of alternative strategies. Different types of MCS systems are currently available to treat PCCS [9–13]. They include centrifugal pumps implanted as left ventricular assist systems [14, 15] and complex and expensive ventricular assist devices (VAD) [5]. The results of experiences with these different devices are not comparable as the data are usually limited, monocentric, and retrospectively collected [15].

Our survival results were consistent with the results of published literature. Collective data from the ELSO register demonstrate that survival of adult patients with cardiogenic shock is 39% [16]. Similar results were reported by Ko *et al.* [17] and Aissaoui *et al.* [18]. Hsu *et al.* and Rastan *et al.* reported that the successful weaning rate of ECMO for PCCS ranges from 31% to 60%, but the in-hospital mortality rate was 59–84% [2, 19].

The ECMO is also associated with various important morbidities. Severe hemorrhage is a frequent and challenging complication leading to the need for reoperation and necessity of massive transfusion of blood products. In our study, massive bleeding and the need for blood product transfusions occurred in 59% of the patients. Lower limb ischemia on the side of the cannulated femoral artery is described as a complication and was found in 20% of the patients [20]. However, due to the concerns of infection and hemorrhage complications of the mediastinum, peripheral VA ECMO is preferred at our center. According to our observations, lower limb ischemia occurred in a slightly higher percentage of patients (26%).

There are several extracorporeal circulation support systems for patients with PCCS; however, ECMO can function based on access to peripheral vessels and relatively liberal requirements for anticoagulation. The system is mobile and can be used for a longer period of time and can even be moved with the patient. It ensures good control and fluency of supporting respiratory and circulatory parameters [4]. The VA ECMO can successfully be used for PCCS treatment when conventional therapy proves ineffective.

Tab. V. Length of ECMO therapy, intensive care unit and length of hospital stay for surviving and deceased groups

Parameter	Patients who died	Patients who survived	*P*-value
Length of ECMO therapy [days] (median)	7.16 ±6.04 (6)	13.00 ±7.37 (12.5)	0.035
Intensive care length of stay [days] (median)	11.58 ±13.64 (6)	35.13 ±15.91 (30)	0.002
Hospital length of stay [days] (median)	14.42 ±14.59 (9)	48.25 ±19.02 (48.5)	0.001

Tab. VI. Perioperative complications

Complication	Number of cases	Frequency (%)
Coagulation disorders	16	59
Lower limb ischemia	7	26
Rethoracotomy	15	56
Heart tamponade	12	44
Epicardial electrode	10	37
CVVHD	12	44

CVVHD – continuous veno-venous hemodialysis.

Tab. VII. Logistic regression analysis of mortality risk factors. Complications of the ECMO therapy are independent variables in the model

Variable	OR	95% CI	*P*-value
Coagulation disorders	1.7	0.3–9.9	0.527
Lower limb ischemia	1.1	0.1–7.9	0.943
Rethoracotomy	0.7	0.1–3.9	0.638
Heart tamponade	0.7	0.1–4.2	0.707
Epicardial electrode	1.0	0.2–5.9	0.974
CVVHD	0.7	0.1–4.2	0.707

CVVHD – continuous veno-venous hemodialysis, OR – odds ratio, 95% CI – 95% confidence interval.

Limitations of the study

Firstly, it was a retrospective study. The data were obtained from medical documentation. Secondly, the small size of the study group constitutes a significant limitation, and thus conclusions of statistical significance should be drawn with care. However, in spite of the small group of patients examined, certain useful, clinical trends can be observed from the study.

Conclusions

The VA ECMO can be an effective form of therapy for some patients in postcardiotomy cardiogenic shock. How-

ever, mortality in this group of patients still remains high even with this sophisticated form of therapy.

Disclosure

Authors report no conflict of interest.

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