Open Access Maced J Med Sci **electronic publication ahead of print, published on June 15, 2019 as https://doi.org/10.3889/oamjms.2019.547**

ID Design Press, Skopje, Republic of Macedonia
Open Access Macedonian Journal of Medical Sciences.
https://doi.org/10.3889/oamjms.2019.547
eISSN: 1857-9655
Clinical Science

The usefulness of Veno-Arterial Extracorporeal Membranous Oxygenation in Patients with Cardiogenic Shock

Mohamed Abouelwafa*, Waheed Radwan, Alia Abdelfattah, Akram Abdelbary, Mohamed Khaled, Wael Samy, Mohamed Yousry, Ahmed Saeed, Mahmood Saad

Critical Care Department, Cairo University Hospitals, Cairo, Egypt

Citation: Abouelwafa M, Radwan W, Abdelfattah A, Abdelbary A, Khaled M, Samy W, Yousry M, Saeed A, Saad M. The Usefulness of Veno-Arterial Extracorporeal Membranous Oxygenation in Patients with Cardiogenic Shock. Open Access Maced J Med Sci. https://doi.org/10.3889/oamjms.2019.547

Keywords: VA ECMO; Cardiogenic shock; Myocardial infarction; Lactate: Hemodynamics

***Correspondence:** Mohamed Abouelwafa. Critical Care Department, Cairo University Hospitals, Cairo, Egypt. E-mail: dr_abouelwafa2005@hotmail.com

Received: 17-Apr-2019; **Revised:** 09-Jun-2019; **Accepted:** 10-Jun-2019; **Online first:** 15-Jun-2019

Funding: This research did not receive any financial support

Competing Interests: The authors have declared that no competing interests exist

Abstract

BACKGROUND: Venoarterial extracorporeal membranous oxygenation is a form of temporary mechanical circulatory support that gets as a salvage technique in patients with cardiogenic shock, we intended to evaluate the effect of (VA ECMO) support on hemodynamics and lactate levels in patients with cardiogenic shock.

AIM: The aim of our study is to detect the ability to introduce veno-arterial extracorporeal membranous oxygenation (VA ECMO) as a temporary extracorporeal life support system (ECLS) in our unit, demonstrate the role of ECMO in cardiogenic shock patients regarding improving hemodynamics and microcirculation, and demonstrate the complications and drawbacks in our first center experience regarding VA ECMO.

MATERIAL AND METHODS: This was a single-centre observational study that included 10 patients admitted with cardiogenic shock for which VA ECMO was used as mechanical circulatory support.

RESULTS: The MAP increased after initiation of the support. It was 41.8 ± 9.3 mmHg and 59.5 ± 6.8 mmHg (P = 0.005). The use of VA ECMO support was associated with a statistically significant decrease in the base deficit (-10.6 ± 4.2 and -6.3 ± 7.4, P = 0.038). The serum lactate declined from 5.9 ± 3.5 mmoL/L to 0.6 ± 4.4 mmoL/L by the use of VA ECMO; a statistically significant change (P = 0.005).

CONCLUSIONS: We concluded that VA ECMO as mechanical support for patients with cardiogenic shock might improve mean arterial blood pressure, base deficit and lactate clearance.

Introduction

Cardiogenic shock is a physiologic state where end-organ tissue hypoperfusion is a result of cardiac dysfunction. Despite many advances in the management of cardiogenic shock, mortality rates are still high [1].

Coronary revascularisation is the mainstay of therapy for cardiogenic shock caused by myocardial infarction. However, after reperfusion, areas of the myocardium may have myocardial stunning that persists despite the restoration of normal blood flow. These areas may improve with revascularisation, providing a strong rationale for supporting hemodynamics in cardiogenic shock [2].

The initial therapy of cardiogenic shock involves careful infusion of fluids. If the shock is persistent, then pharmacologic therapy with inotropic and vasopressor agents is started. The use of inotropes and vasopressors in cardiogenic shock treatment increases myocardial oxygen demand. However, studies have not necessarily demonstrated that their use decreases mortality rates [2].

Mortality in cardiogenic shock patients occurs mainly in the first three days, so mechanical circulatory support devices should be considered as soon as possible. The results of studies on such devices are promising in improving microcirculation and microcirculation. Also, these devices are recommended for patients in persistent shock after inotropic and vasopressor therapy [3].

While the intra-aortic balloon counterpulsation (IABP) use is limited in complicated myocardial infarction cases, other mechanical circulatory support devices such as extracorporeal membrane oxygenation (ECMO) can be used in other causes of cardiogenic shock such as pulmonary embolism. However, there are still no randomised controlled studies on the use of VA ECMO in patients with cardiogenic shock.

The aim of our study is to detect the ability to introduce veno-arterial extracorporeal membranous oxygenation (VA ECMO) as a temporary extracorporeal life support system (ECLS) in our unit, demonstrate the role of ECMO in cardiogenic shock patients regarding improving hemodynamics and microcirculation, and demonstrate the complications and drawbacks in our first center experience regarding VA ECMO. Our centre is the first centre in Egypt to be recognised as an ECMO centre by the Extracorporeal Life Support Organization.

Patients and Methods

This study is a prospective observational study on patients admitted to the Critical Care Department, Cairo University Hospitals with cardiogenic shock from January 2015 to April 2017.

The present study included patients with cardiogenic shock within 6 hours of shock development, either upon admission to the intensive care unit (ICU) or during ICU stay. The excluded patients from the study are those with irreversible cause for cardiogenic shock or those with cardiogenic shock after 6 hours duration with signs of neurologic damage, prolonged multiorgan dysfunction, or futility.

The patients enrolled in our study were subjected to full medical history and thorough clinical examination (general and cardiac). Hemodynamics and vital signs such as mean arterial pressure (MAP), heart rate (HR), respiratory rate (RR), and temperature were obtained at the time of support initiation (hemodynamics 0) and 24 hours after initiation (hemodynamics 1). All patients were subjected to routine laboratory investigations including complete blood picture, coagulation profile, renal functions, liver functions, blood gases, and lactate level. Two readings were obtained at the time of support initiation (laboratory 0) and 24 hours after initiation (laboratory 1).

Chest X-ray, 12-lead ECG, and transthoracic echocardiography (aortic velocity time integral (VTI)) was done to all patients before mechanical support initiation (echocardiography 0), 24 hours after initiation (echocardiography 1), and whenever needed after that.

Acute physiological and chronic health evaluation (APACHE II) scoring system, sequential organ failure assessment score (SOFA score), and vasoactive-inotropic score (VIS) were obtained at the time of support initiation (score 0) and 24 hours after initiation (score 1).

Cardiohelp maquet console (HLS ECMO circuit) was used in 7 patients, while Rotaflow maquet (PLS ECMO circuit) was used in 3 patients.

The HLS ECMO circuit integrates a gas exchanger (equipped with a diffusion membrane), highly efficient heat exchanger, and a centrifugal pump. Also, the integrated measuring cell is used to measure the important blood parameters of venous oxygen saturation (SVO2), hematocrit (Hct), haemoglobin (Hb), and venous temperature (Tven).

Unlike the Cardiohelp, the Rotaflow console is not portable and only has a sensor to detect the flow. The console, oxygenator, and pump are separated. The PLS ECMO set is bio line-coated.

This study was approved by the Ethical Committee Review Board of the Faculty of Medicine, Cairo University. Informed written consent was acquired from patients or relatives before their enrollment in the study.

Statistical Methods

Numerical variables were described as Mean ± standard deviation (SD). Categorical variables were described as proportions. Student ‘t’ test was used for comparisons of numerical data, with Levene test for equality of variance and paired ‘t’ test for paired comparisons. Chi-square test 2*2 was applied with Ficher exact test for comparison between categorical data. McNemar test was applied for a total less than 40 or any of observed events less than 5. P value was considered significant if ≤ 0.05. Delta change, i.e. the per cent of change, was calculated as the difference between the second and first reading divided by the first reading. Statistics were calculated using SPSS 21 package.

Results

We initially recruited 15 patients who were admitted with cardiogenic shock. Five patients were excluded because 3 of them had septic shock, and the rest (2 patients) were futile without any sign of neurological recovery.

Our study included 10 patients (7 males and 3 females with an average age of 43.4 ± 17.2 years) who were in cardiogenic shock and was supported by VA ECMO.

Patients enrolled in our study were admitted to the Critical Care Medicine Department, Cairo University Hospitals during the period from January 2015 to April 2017. Six patients had a myocardial infarction, 1 patient during CPR and another patient after CPR, two patients had a pulmonary embolism, and two patients had stress-induced cardiomyopathy.

Hemodynamic monitoring

Paired comparisons were made to show the effect of VA ECMO support on hemodynamics. These comparisons showed a significant difference between MAP (0) and MAP (1) [41.8 ± 9.3 and 59.5 ± 6.8, P value = 0.005] and another significant difference between RR (0) and RR (1) [38.0 ± 11.8 and 28.0 ± 12.2, P value = 0.006].

Table 1: Comparison between hemodynamics (0) and hemodynamics (1)

	Hemodynamics(0)	Hemodynamics(1)	P value
Temperature	37.4 ± 0.8	37.5 ± 0.7	.730
MAP	41.8 ± 9.3	59.5 ± 6.8	.005
HR	134.3 ± 15.1	113.4 ± 19.7	.076
RR	38.0 ± 11.8	28.0 ± 12.2	.006

MAP: Mean arterial pressure; HR: Heart rate; RR: Respiratory rate.

Blood gases

The paired comparisons done to show the effect of VA ECMO on blood gases showed a statistically significant difference between HCO_3 (0) and HCO_3 (1) [14.7 ± 2.3 and 18.3 ± 5.5, P value= 0.042] and another statistically significant difference between base deficit (0) and base deficit (1) [-10.6 ± 4.2 and -6.3 ± 7.4, P value = 0.038].

Table 2: Comparison between blood gases (0) and blood gases (1)

	Blood gases (0)	Blood gases (1)	P value
PH	7.2 ± 0.1	7.3 ± 0.2	.155
HCO_3	14.7 ± 2.3	18.3 ± 5.5	.042
Base deficit	-10.6 ± 4.2	-6.3 ± 7.4	.038
PaO_2	52.7 ± 19.7	58.1 ± 18.8	.009

Laboratory values

Paired comparisons were done to show the effect of VA ECMO on laboratory values where they showed a statistically significant difference between platelet (0) and platelet (1) [197.3 ± 81.9 and 146.7 ± 72.5, P value = 0.005] and another statistically significant difference between lactate (0) and lactate (1) [5.9 ± 3.5 and 4.6 ± 4.4, P value = 0.005].

Table 3: Comparison between Laboratory (0) and Laboratory (1)

	Laboratory (0)	Laboratory (1)	P value
Sodium	140.1±4.7	141.4±4.4	.362
Potassium	4.0±1.1	3.9±0.4	.788
Creatinine	2.3±1.8	2.5±1.5	.757
Bilirubin	1.0±0.8	1.8±1.5	.138
Hematocrit	30.1±9.4	29.2±5.4	.793
White blood cell	28.6±18.1	25.7±15.0	.304
Platelets	197.3±81.9	146.7±72.5	.005
Lactate	5.9±3.5	4.6±4.4	.005

Clinical severity scores

Comparison between clinical scores (0) and clinical scores (1) in group 2 are shown in Table 4.

Table 4: Comparison between clinical scores (0) and clinical scores (1) in group 2

	clinical scores (0)	clinical scores (1)	P value
GCS	12.3 ± 3.6	9.9 ± 4.6	.120
APACHE II	25.3 ± 6.8	20.9 ± 9.8	.092
SOFA	11.9 ± 2.9	11.1 ± 2.9	.140
Vasoactive inotropic score	89.3 ± 62.1	36.7 ± 28.6	.073

GCS: Glasgow coma scale.

Echocardiographic examination

Echocardiographic examination was done to measure LVEF, aortic VTI and PASP. No significant differences were demonstrated when comparing the values of these parameters pre and post-mechanical support.

Table 5: Comparison between echocardiography (0) and echocardiography (1) in group 2

	Echocardiography (0)	Echocardiography (1)	P value
LVEF	40.3 ± 25.1	39.3 ± 20.9	.806
Aortic VTI	12.9 ± 8.6	12.9 ± 7.7	1.000
PASP	44.3 ± 20.6	40.4 ± 16.4	.058

The outcome of VA ECMO

The duration of support was 4.3 ± 3.1 days with average ICU stay 12.4 ± 12.7. In our 10 patients who received VA ECMO, 5 patients experienced complications, 2 patients suffered thrombocytopenia, 2 patients suffered cerebrovascular accidents, and 1 patient suffered limb ischemia.

Four patients were weaned off the mechanical support, but only one patient survived to hospital discharge.

Discussion

Percutaneous hemodynamic support has historically been limited to the IABP counterpulsation. Although the IABP is widely available, its limitations include little hemodynamic support and myocardial protection, while VA ECMO can provide full hemodynamic support, but it is limited by complexity, multiple complications, high cost, and need for perfusion expertise [3].

The benefits of mechanical circulatory support include the ability to maintain organ perfusion which, accordingly, prevents systemic shock syndrome, reducing the intracardiac filling pressures, right and leaves ventricular volumes, wall stress as well as myocardial oxygen consumption, augmenting coronary perfusion, and supporting the circulation

during complex interventional procedures [3].

In our centre, the mechanical support with VA-ECMO is recently used for cardiogenic shock management. We used VA ECMO as mechanical circulatory support for a total of 10 cardiogenic shock patients with an increase in mean arterial pressure after the support initiation. The improvement of hemodynamics and oxygenation occurred after VA ECMO support initiation led to a significant reduction in the base deficit and lactate level.

There is a contradiction about the benefit of combined IABP and VA-ECMO support in patients with cardiogenic shock. In our study, we combined the use of VA ECMO and IABP in 3 patients to decrease the afterload. This combination led to weaning one patient from the ECMO support 48 hours after implementation of IABP.

A study was done by Petroni et al., [4] which included 12 patients on VA ECMO concluded that in cardiogenic shock patients with little or no residual left ventricular ejection implanted by peripheral VA ECMO, the use of intra-aortic balloon pump was associated with smaller left ventricular dimensions and lower pulmonary artery pressures due to the restoration of pulsatility and decrease of left ventricular afterload. A study conducted by Sattler et al., [5] on 24 patients with STEMI and NSTEMI, in which 12 patients were supported by VA ECMO and the other 12 patients were supported by IABP, showed that the percentage of 30-day survival was 67% in VA ECMO-supported patients vs 33% in IABP-supported patients.

A retrospective cohort study, including 1,650 cardiogenic shock adult patients concluded that IABP, combined with VA-ECMO support, was associated with reduced mortality and successful weaning from VA-ECMO [6]. In another study done on 529 patients who received peripheral VA ECMO, where a group of them received combined ECMO and IABP treatment while the other group received ECMO support only, the researchers found that the mortality rate at 2 weeks was not different between the two groups. Moreover, more patients in the combined group received limb fasciotomy operations due to vascular complications [7].

ECMO-CPR was instituted in 2 of our study patients; however, they were deceased. A study by Shin et al., [8] suggested that patients who receive extracorporeal cardiopulmonary resuscitation (CPR) for longer than 10 minutes following in-hospital arrest have a greater chance of survival when compared to those who receive conventional CPR. The survival discharge rate with minimal neurologic impairment in the extracorporeal CPR group was significantly higher than that in the conventional CPR group.

In our study, we used VA ECMO in two patients with pulmonary embolism. In a study of 10years period (2005-2015) that included 17 patients with confirmed or suspected pulmonary embolism, Fifteen patients (82%) suffered pre-ECMO cardiac arrest, with seven (41%) of them cannulated during cardiopulmonary resuscitation, 10 (59%) patients were weaned off ECMO and 8 patients (47%) were discharged. The study concluded that VA ECMO could be a lifesaving rescue therapy to rapidly restore the hemodynamic status when thrombolytic therapy fails or when the patient is deemed too sick to benefit from medical or surgical treatments [9].

In our study, none of the analysed variables was of help in predicting successful weaning from ECMO or heart function recovery. However, other studies have correlated echocardiographic [10] and clinical parameters as well as laboratory tests results [11] to the prediction of weaning. The lack of results in our series may be due to the limited number of patients involved in addition to the study design, which was not intended to examine this aspect.

In our study, 40% of patients could be weaned from mechanical support**.** This agrees with Muller et al., [12] study that was conducted on 108 patients with acute myocardial infarction supported by VA ECMO, where 35.5% of patients demonstrated successful weaning.

Echocardiography plays an important role in the management of VA ECMO patients. It is useful in-patient assessment, cannulation, and detecting complications during ECMO run as well as the possibility of weaning from ECMO support [5].

In our study, a trial of ECMO removal was done on four patients based on the improvement of MAP, oxygenation, laboratory findings, EF, and aortic VTI. This is in agreement with the study done by Aissaoui, N et al., [10] which concluded that whenever the patient is under minimal ECMO support, LVEF of ≥ 20–25%, and aortic VTI of ≥ 12 cm, ECMO removal should be considered.

In our study, 4 patients were weaned from ECMO support after decreasing serum lactate; this is in agreement with Li et al., [13] who demonstrated that the initial lactate level and early lactate clearance in the 12 h following ECMO initiation were independent predictors of successful ECMO weaning.

In our study, we gave levosimendan to 1patient to facilitate weaning. After levosimendan treatment, the patient showed improvement in EF (20% before levosimendan treatment vs 30% 24 hours after levosimendan treatment). This agrees with a study conducted on 6 patients by Affronti et al., who suggested that the treatment with levosimendan reduced the need for high-dose inotropes and facilitated weaning [14].

In femoral (VA -ECMO), vascular injuries and limb ischemia, unfortunately, occur as a result of the decrease of blood supply. In patients with a history of peripheral vascular disease, femoral cannulation should be avoided.

The present study demonstrated 1 patient who suffered from lower limb ischemia; however, reperfusion cannula was not inserted in this patient.

It was noted that vascular complications were associated with unsuccessful weaning from ECMO and that leg ischemia is an independent risk factor for in-hospital death [15]. To minimise such complications, a distal perfusion cannula is placed in the superficial femoral artery [16].

Some studies have shown that neurologic complications are rather common among patients receiving ECMO. These complications are generally related to thrombosis with infarction or cerebral haemorrhage [17]. In our study, 2 patients suffered from intracerebral haemorrhage without surgical intervention.

In a series of 87 adult patients, Matteen et al. found that 50% of the patients in their series suffered neurologic complications defined as stroke, intracerebral haemorrhage, seizure, encephalopathy, brain death, or coma. Moreover, they found that the increasing age was associated with higher rates of death and neurologic morbidity [17].

Lan et al., [18] found that stroke affected 7% of the patients and was associated with significantly higher odds of death. In a meta-analysis of 1,866 adult patients with cardiogenic shock, Cheng et al., [19] found that stroke occurred in approximately 6% of the patients.

In our study, 4 patients were successfully removed from ECMO support, but 3 patients were complicated by a secondary bacterial infection, and septic shock then died.

A study conducted by Aubron et al., [20] on 138 patients who received ECMO support showed that 36 patients had a total of 46 infections. These patients included 24 cases of bloodstream infection (BSI), 6 of these cases were secondary to ventilator-associated pneumonia (VAP), 23 cases of VAP, and 5 cases of catheter-associated urinary tract infection (CAUTI). The most frequent pathogens were Enterobacteriaceae (found in 16 of 46 cases), and Candida was the most common cause of BSI (in 9 of 24 cases). The SOFA score before ECMO initiation and the number of days of support were independently associated with a risk of BSI.

The lower incidence of weaning from VA ECMO and high mortality rate in our study could be attributed to severe comorbidities of the patients in our study where 3 patients had ARDS, 2 patients had post-CPR, and 1patient had a multivessel disease where CABG was done.

Limitations: This study represents the first Egyptian VA ECMO experience that had an impact on a small sample of patients. The financial constraints had an impact on the number of patients included in the study because of the high cost of VA ECMO run. Accordingly, the study was a single-centre study.

References

1. Aissaoui N, Puymirat E, Juilliere Y, Jourdain P, Blanchard D, Schiele F, et al. Fifteen-year trends in the management of cardiogenic shock and associated 1-year mortality in elderly patients with acute myocardial infarction: the FAST-MI programme. European journal of heart failure. 2016; 18(9):1144-52. https://doi.org/10.1002/ejhf.585 PMid:27594176

2. Van Herck JL, Claeys MJ, De Paep R, Van Herck PL, Vrints CJ, Jorens PG. Management of cardiogenic shock complicating acute myocardial infarction. European heart journal Acute cardiovascular care. 2015; 4(3):278-97. https://doi.org/10.1177/2048872614568294 PMid:25624526

3. Rihal CS, Naidu SS, Givertz MM, Szeto WY, Burke JA, Kapur NK, et al. 2015 SCAI/ACC/HFSA/STS Clinical Expert Consensus Statement on the Use of Percutaneous Mechanical Circulatory Support Devices in Cardiovascular Care: Endorsed by the American Heart Assocation, the Cardiological Society of India, and Sociedad Latino Americana de Cardiologia Intervencion; Affirmation of Value by the Canadian Association of Interventional Cardiology-Association Canadienne de Cardiologie d'intervention. Journal of the American College of Cardiology. 2015; 65(19):e7-e26. https://doi.org/10.1016/j.cardfail.2015.03.002 PMid:26036425

4. Petroni T, Harrois A, Amour J, Lebreton G, Brechot N, Tanaka S, et al. Intra-aortic balloon pump effects on macrocirculation and microcirculation in cardiogenic shock patients supported by venoarterial extracorporeal membrane oxygenation. Critical care medicine. 2014; 42(9):2075-82. https://doi.org/10.1097/CCM.0000000000000410 PMid:24810530

5. Sattler S, Khaladj N, Zaruba MM, Fischer M, Hausleiter J, Mehilli J, et al. Extracorporal life support (ECLS) in acute ischaemic cardiogenic shock. International journal of clinical practice. 2014; 68(4):529-31. https://doi.org/10.1111/ijcp.12380 PMid:24674706

6. Aso S, Matsui H, Fushimi K, Yasunaga H. The Effect of Intraaortic Balloon Pumping Under Venoarterial Extracorporeal Membrane Oxygenation on Mortality of Cardiogenic Patients: An Analysis Using a Nationwide Inpatient Database. Critical care medicine. 2016; 44(11):1974-9. https://doi.org/10.1097/CCM.0000000000001828 PMid:27322361

7. Lin LY, Liao CW, Wang CH, Chi NH, Yu HY, Chou NK, et al. Effects of Additional Intra-aortic Balloon Counter-Pulsation Therapy to Cardiogenic Shock Patients Supported by Extra-corporeal Membranous Oxygenation. Scientific reports. 2016; 6:23838. https://doi.org/10.1038/srep23838 PMid:27032984 PMCid:PMC4817114

8. Shin TG, Choi JH, Jo IJ, Sim MS, Song HG, Jeong YK, et al. Extracorporeal cardiopulmonary resuscitation in patients with inhospital cardiac arrest: A comparison with conventional cardiopulmonary resuscitation. Critical care medicine. 2011; 39(1):1-7. https://doi.org/10.1097/CCM.0b013e3181feb339 PMid:21057309

9. Corsi F, Lebreton G, Brechot N, Hekimian G, Nieszkowska A, Trouillet JL, et al. Life-threatening massive pulmonary embolism rescued by venoarterial-extracorporeal membrane oxygenation. Crit Care. 2017; 21(1):76. https://doi.org/10.1186/s13054-017-1655-8 PMid:28347320 PMCid:PMC5369216

10. Aissaoui N, El-Banayosy A, Combes A. How to wean a patient from veno-arterial extracorporeal membrane oxygenation. Intensive care medicine. 2015; 41(5):902-5. https://doi.org/10.1007/s00134-015-3663-y PMid:25619488

11. Luyt CE, Landivier A, Leprince P, Bernard M, Pavie A, Chastre J, et al. Usefulness of cardiac biomarkers to predict cardiac recovery in patients on extracorporeal membrane oxygenation support for refractory cardiogenic shock. Journal of critical care.

2012; 27(5):524 e7-14. https://doi.org/10.1016/j.jcrc.2011.12.009 PMid:22386227

12. Muller G, Flecher E, Lebreton G, Luyt CE, Trouillet JL, Brechot N, et al. The ENCOURAGE mortality risk score and analysis of long-term outcomes after VA-ECMO for acute myocardial infarction with cardiogenic shock. Intensive care medicine. 2016; 42(3):370-8. https://doi.org/10.1007/s00134-016-4223-9 PMid:26825953

13. Li CL, Wang H, Jia M, Ma N, Meng X, Hou XT. The early dynamic behavior of lactate is linked to mortality in postcardiotomy patients with extracorporeal membrane oxygenation support: A retrospective observational study. The Journal of thoracic and cardiovascular surgery. 2015; 149(5):1445-50. https://doi.org/10.1016/j.jtcvs.2014.11.052 PMid:25534305

14. Affronti A, di Bella I, Carino D, Ragni T. Levosimendan may improve weaning outcomes in venoarterial ECMO patients. ASAIO J. 2013; 59(6):554-7. https://doi.org/10.1097/MAT.0b013e3182a4b32e PMid:24172260

15. Aziz F, Brehm CE, El-Banyosy A, Han DC, Atnip RG, Reed AB. Arterial complications in patients undergoing extracorporeal membrane oxygenation via femoral cannulation. Annals of vascular surgery. 2014; 28(1):178-83. https://doi.org/10.1016/j.avsg.2013.03.011 PMid:24064046

16. Rao AS, Pellegrini RV, Speziali G, Marone LK. A novel percutaneous solution to limb ischemia due to arterial occlusion from a femoral artery ECMO cannula. Journal of endovascular therapy : an official journal of the International Society of Endovascular Specialists. 2010; 17(1):51-4. https://doi.org/10.1583/09-2845.1 PMid:20199267

17. Mateen FJ, Muralidharan R, Shinohara RT, Parisi JE, Schears GJ, Wijdicks EF. Neurological injury in adults treated with extracorporeal membrane oxygenation. Archives of neurology. 2011; 68(12):1543-9. https://doi.org/10.1001/archneurol.2011.209 PMid:21825216

18. Lan C, Tsai PR, Chen YS, Ko WJ. Prognostic factors for adult patients receiving extracorporeal membrane oxygenation as mechanical circulatory support--a 14-year experience at a medical center. Artificial organs. 2010; 34(2):E59-64. https://doi.org/10.1111/j.1525-1594.2009.00909.x PMid:20420591

19. Cheng R, Hachamovitch R, Kittleson M, Patel J, Arabia F, Moriguchi J, et al. Complications of extracorporeal membrane oxygenation for treatment of cardiogenic shock and cardiac arrest: a meta-analysis of 1,866 adult patients. The Annals of thoracic surgery. 2014; 97(2):610-6. https://doi.org/10.1016/j.athoracsur.2013.09.008 PMid:24210621

20. Aubron C, Cheng AC, Pilcher D, Leong T, Magrin G, Cooper DJ, et al. Infections acquired by adults who receive extracorporeal membrane oxygenation: risk factors and outcome. Infection control and hospital epidemiology. 2013; 34(1):24-30. https://doi.org/10.1086/668439 PMid:23221189