ARTIGO ORIGINAL ORIGINAL ARTICLE

ARTERIAL VASCULAR COMPLICATIONS IN PERIPHERAL VENOARTERIAL EXTRACORPOREAL MEMBRANE OXYGENATION SUPPORT

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Abstract

Introduction: *Extracorporeal membrane oxygenation (ECMO) has evolved as a life-saving measure for patients requiring emergent support of respiratory and cardiac function. The femoral artery is the standard site for vascular access when initiating adult venoarterial (VA) ECMO. Cannulation-related complications are a known source of morbidity and it has been speculated that patients undergoing ECMO via femoral arterial cannulation are more likely to develop peripheral vascular complications (up to 70%).*

Methods: *Retrospective institutional review of patients requiring ECMO (January 2011-August 2017). The primary outcome of this study was to investigate the prevalence of cannulation-related complications on VA ECMO and to determine its effect on patient morbimortality.*

Results: *Eighty-two patients underwent ECMO during the period of study, 56,1% were male with a mean age of 55,8 years. The VA mode was used in 61 patients, 56 with peripheral cannulation. Femoral arterial access was established in 52 patients (73% percutaneously). Vascular complications were observed in 28,6% of the VA femoral ECMOs: 12 acute limb ischemias and 3 major hemorrhages. At the time of femoral cannulation, distal peripheral catheter (DPC) was placed in 5 patients and none developed limb ischemia. For those who developed limb ischemia, several interventions were performed: DPC placement in 9 cases, fasciotomy in 4 and 2 major amputations. Thirty patients underwent arterial cannulas open surgical removal: 8 underwent balloon catheter trombectomy and 5 needed femoral reconstruction. There was an association between PAD (p=0,03) and ischemic cardiopathy (p=0,02;OR 4,5) with the present of vascular complications after ECMO implantation.*

Conclusions: *Cannulation of femoral vessels remains associated with considerable rates of vascular events (28.6%). PAD and ischemic cardiopathy are associated with vascular complications in this form of cannulation.*

INTRODUCTION

Extracorporeal membrane oxygenation (ECMO) has evolved as a life-saving measure for patients requiring emergent support of respiratory and cardiac function.[1]

Although ECMO has been in existence since the 1970s, early application of this technology was difficult due to high complication rates, with no established survival advantage over conventional management.[2] However, major recent advances in extracorporeal technology have favorably altered its risk-benefit profile allowing the increase of indications and the use of novel strategies.[2]

This type of extracorporeal life support technique involves an extracorporeal circuit that directly oxygenates and removes carbon dioxide from the blood using an oxygenator. Deoxygenated blood is withdrawn through a drainage cannula by an external pump, passes through the oxygenator and returns to the patient through a reinfusion cannula. When blood is drained from a central vein and returned to a central vein, a process known as venovenous (VV) ECMO, the device is providing only gas exchange. When blood is drained from the venous system and pumped into an artery, a process known as venoarterial (VA) ECMO, the circuit provides both respiratory and circulatory support.[2,3]

ECMO cannulation has traditionally been performed in the operating room.[4] The percutaneous approach has been the most performed technique nowadays, recurring to Seldinger technique.[3] However, the approach to cannulation should be individualized and based on the specific clinical scenario in which the need for ECMO arises.[5]

The femoral artery is the standard site for immediate arterial vascular access when initiating adult VA ECMO because of its size and accessibility.[6] Major complications of ECMO can include neurologic, cardiac, pulmonary, hemorrhagic, and vascular issues that may lead to serious consequences.[7] However, vascular complications related to femoral cannulation are one of the most common, being a known source of morbidity.[7] It has been speculated that patients undergoing ECMO via femoral arterial cannulation are more likely to develop peripheral vascular complications [6]. Cannulation-related complications have been reported to affect between 20 and 30% of patients supported on VA ECMO and remain a considerable source of morbidity in this critically ill patient population.[7] Specifically, some series described that the combination of hemodynamic instability and obstruction of arterial flow by the indwelling arterial cannula may result in limb ischemia in 10% to 70% of cases.[8,9] Ischemia can be caused by vascular occlusion from the cannula, thromboembolization or dissection of the artery. Bleeding and hematoma are usually caused by vascular injury (laceration, perforation, dissection).[7]

In patients with severe peripheral arterial disease (PAD), these risks are even higher and its presence may be considered a relative contraindication for femoral artery cannulation.[10]

The primary outcome of this study was to investigate the prevalence of cannulation-related complications on VA ECMO and to determine its effect on patient morbimortality. The authors also discuss some techniques that may help preventing ischemic complications that might affect patient survival and impact in the quality of life.

METHODS

The authors performed a retrospective institutional review of consecutive patients requiring ECMO between January 2011-August 2017.

They evaluated demographics and co-morbidities data. Patients were divided into two groups (complications present vs. not present) and statistical analysis was performed to determine the impact of different variables such as co-morbidities, cannulation strategy and time on ECMO in each group. Operative reports were reviewed to analyze the surgical procedures implied for treating vascular complications.

Categorical variables are presented as frequencies and percentages and continuous variables as means and standard deviations, or medians and interquartile ranges for variables with skewed distribution. Normal distribution was checked using Shapiro- Wilk test or skewness and kurtosis. All reported P values are two-tailed, with P value of 0.05 indicating statistical significance. Analyses were performed with the use of SPSS software, version 22.

RESULTS

Eighty-two patients (46 males and 36 females) underwent ECMO therapy during the period of the study at Centro Hospitalar de Vila Nova de Gaia/ Espinho, with a mean age of 55.8 years (range of 20 to 65; 13.1 years - standard deviation) – Table 1.

Table 1 **Patient demographics**

	n (%)
Age	58 (mean) 13 (sd)
Gender ♀	27 (44.3)
♂	34 (55.7)
Median time on ECMO	5.5 days (IQR 8 days)
Risk factors	
Hypertention	38 (62.3)
Dyslipidemia	34 (55.7)
Smoking	24 (39.3)
Diabetes	19 (31.1)
Chronic Heart Failure	18 (29.5)
Coronary Arterial Disease	15 (24.6)
Chronic Kidney Disease	7 (11.5)
Peripheral Arterial Disease (PAD)	4 (6.6)

The median time on the ECMO device was 5.5 days with an interquartile range of 8 days. The VA mode was used in 61 patients, 56 with peripheral cannulation. Relevant demographic characteristics and comorbid medical conditions in this group of patients are listed in Table 1.

It is notable that patients had high incidence of cardiovascular risk factors, reaching a prevalence of 62.3% for arterial hypertension and 55.7% for dyslipidemia. Peripheral arterial disease was previously diagnosed in 6.6% of the patients.

The majority of patients – 73% – were placed on support for cardiac arrest/cardiogenic shock as summarized in Table 2.

Sixty-one patients underwent cannulation for ECMO VA. Five patients were submitted to central cannulation during the cardiac surgery that involved sternotomy and direct surgical cannulation of the right atrium and aorta. Fifty-six were submitted to peripheral cannulation - femoral arterial access was established in 52 patients (73% percutaneously) and 4 peripheral cannulations were performed in upper limbs through axillar access – ECMO cannulation strategies in the study patients are summarized in Figure 1.

Table 2 **Indications for ECMO support**

Cardiopulmonar failure due to	n (%)
Low cardiac output syndrome, after cardiac surgery	22 (26,8)
Cardiopathy	38 (46,3%)
H1N1 influenza virus infection	19 (23,2)
Other [a]	3 (2,7)

[a] amyloidosis, shock due to colitis, shock due to pyelonephritis.

In 27% of cases, the peripheral cannulation was executed by open surgery with direct exposure of femoral vessels, in cardiothoracic operative room, in patients who presented cardiac dysfunction that needed surgical intervention.

Complications were defined as situation in which patients required surgical interventions (fasciotomy or amputation) or medical procedures in unstable conditions. Therefore, vascular complications were observed in 28.6% of the VA femoral ECMOs: 12 acute limb ischemia and 3 major hemorrhage.

At the time of femoral cannulation a distal perfusion catheters (DPC) was placed in 5 patients - prophylactic superficial femoral artery (SFA) cannulation - and none developed subsequent limb ischemia. For those who developed limb ischemia, several interventions were performed: DPC placement in 9 cases, fasciotomy in 4 and 2 major amputations.

Twenty patients died on VA femoral ECMO, in consequence there are no data related with the placement/removal of the arterial cannula.

Thirty patients underwent arterial cannulas open surgical removal: 17 underwent direct suture of femoral artery, 8 needed balloon catheter trombectomy and 5 required femoral reconstruction with Dacron patch angioplasty. In 2 cases, the arterial cannula was placed in profunda femoral artery - one of these associated with clinical ischemia -, and in 3 cases, the arterial cannula was placed in SFA femoral artery.

In two cases, after the decannulation, the artery was closed with Perclose Proglide® (Abbott Vascular, CA, USA), device previously placed, with no complications related.

Concerning the data collected, arterial cannula size was individually selected according to the body surface to achieve an effective blood flow and varied between 15-21 Fr. Vein cannula size was between 21 Fr and 25 Fr. In the population of the study, there was no difference between the group of patients who presented vascular complications compared with the group with no complications regarding the size of arterial cannula (p=0.64).

Several determinants of vascular complications considered in the literature were evaluated: age, gender, dyslipidemia, smoking, arterial hypertension, diabetes, chronic heart failure, coronary artery disease (CAD), chronic kidney disease, PAD, time on ECMO, type of ECMOs insertion (percutaneous/surgical) and the use of vasopressors drugs.

There was an association between PAD (p=0,03) and CAD (p=0.02; OR 4.5) and the presence of vascular complications after ECMO implantation. No statistically significant association with the presence of vascular complications was found with the other considered factors.

The global 30-day mortality rate at this group reached 66%.

VA femoral ECMO overall mortality was 69.2% (n=36). In this study, vascular complications after ECMO support were not associated with higher mortality rates (p>0.05) – Figure 2.

DISCUSSION

ECMO indications and usage has strikingly progressed over the last decades and it has been accepted as an established treatment for patients in cardiopulmonary failure.[11,12]

However, the benefits of VA ECMO should be evaluated against its inherent risks.

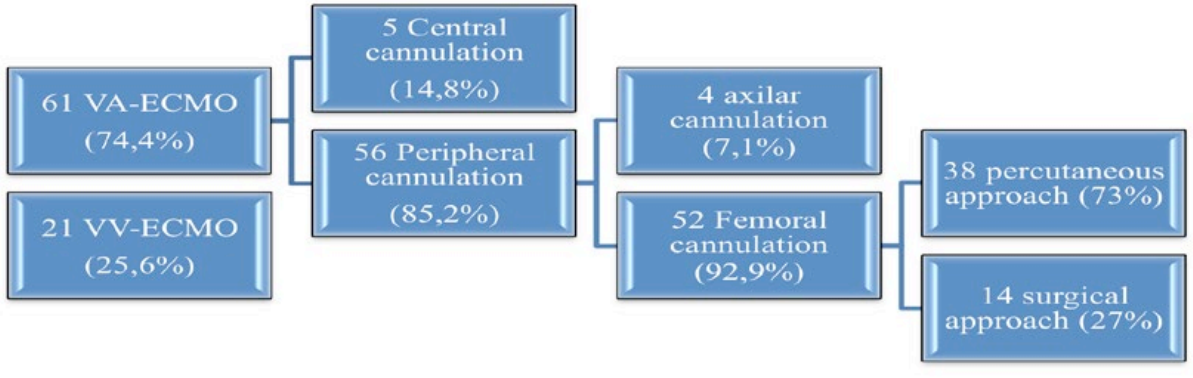

Figure 1 *ECMO cannulation strategies.*

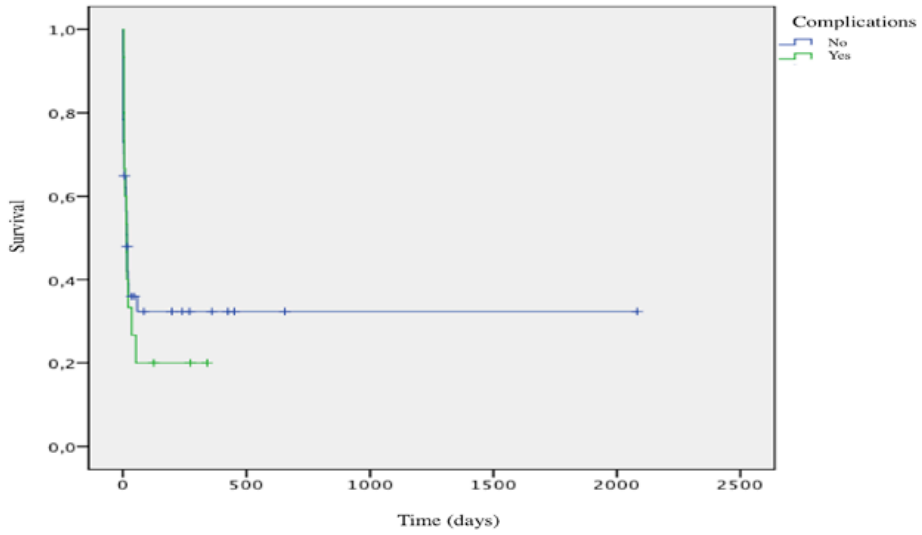

Figure 2 *Kaplan-Meier survival analysis (according to the existence of vascular complications).*

In a meta-analysis incorporating 1,866 patients from 20 studies of ECMO for cardiogenic shock or cardiac arrest between 2000 and 2012, complication rates were reported as follows: lower extremity ischemia, 16.9%; fasciotomy or compartment syndrome, 10.3%; lower extremity amputation, 4.7%; stroke, 5.9%; major or significant bleeding, 40.8%; rethoracotomy for post-cardiotomy bleeding or tamponade, 41.9%; and significant infection, 30.4%.[13]

In another revision, Roussel et al[5] reported arterial complication rates of 28% related to peripheral vessel cannulation (femoral or axillary).

These complications can vary according to the cannulation strategy and are, in most cases, directly related to the cannulation technique used. When present, they can be generally classified into hemorrhagic or ischemic categories.[7]

The majority of VA ECMOs in this study was performed by percutaneous femoral cannulation. Tanaka et al[7] described a lower incidence of infection and bleeding after percutaneous cannulation compared with open cannulation.

In the present study, the prevalence of arterial complications in patients under femoral VA ECMO was 28.6%.

The author's series demonstrated clinically significant arterial compromise leading to limb ischemia in 12 patients – none of these received prophylactic ipsilateral limb adjuncts to perfusion. Two of these patients required an amputation.

Tanaka et al[7] demonstrated that ischemic complications had a greater impact on mortality than bleeding or hematoma, which suggested that the pathophysiology of the injury was more significant with ischemia.

Techniques to perfuse the ipsilateral limb during ECMO have been described. These include the use of a right-angle high-flow femoral arterial cannula, separate antegrade cannulation of the SFA with branching of the ECMO circuit to provide flow, and suturing a prosthetic graft to the common femoral artery (CFA) in an end-to--side fashion with subsequent cannulation of the graft instead of the native artery.[8,14,15,16] Another strategy to reduce the risk of limb ischemia after ECMO cannulation have included placement of an antegrade DPC into the proximal SFA.[8,16,17,18] This is the most commonly accepted technique to limit the development of ischemia and can be placed percutaneously. Routine placement of DPCs was not performed in patients of the present study. The authors observed that there were no cases of limb ischemia in patients who had prophylactic DPC placement. That is consistent with the results from Foley et al study,[9] where none of the 10 patients who underwent prophylactic DPC placement developed this complication. Additionally, Tanaka et al.[7], describe the absence of a DPC as a predictor of a vascular complication. Therefore, prophylactic antegrade SFA cannulation to prevent ipsilateral limb ischemia may be considered or even become the standard of care at some centers.

Other aspect to consider is the proper placement of the arterial cannula in the CFA, which assumes vital importance to minimize the risk of ipsilateral limb ischemia. Inappropriate cannulation of the SFA can lead to a significant flow limitation, if not complete occlusion, due to the smaller size of this artery.[14] The authors found 3 cases of cannulation of SFA in the series, during the removal of the device.

In authors' opinion, early routine use of duplex ultrasonography to assess arterial flow and to support vascular access may help to identify the best arterial place to do the cannulation, to minimize the risk of limb ischemia.

Monitoring of lower extremity perfusion is very important in the prevention and early recognition of ischemic complications.

The authors found that there was an association between PAD (p=0.03) and CAD (p=0.02;OR 4.5) with the

present of vascular complications after ECMO implantation. Studies on the prevalence of CAD in patients with PAD show a prevalence of 40% to 60% of such patients and the prevalence of PAD in patients with CAD varies in different series from around 10% to 30%.[19] Accordingly, the authors observed these two variables associated with vascular complications. There were a small number of patients with PAD in the study (6.6%). Considering that the majority of patients with PAD are asymptomatic, the incidence might have been under reported in patient's population. Atherosclerotic vessels are vulnerable and the placement of the ECMO cannula might dislocate some plaques. Therefore, some authors recommend the measurement of ankle-brachial index before ECMO implantation by routine.[10] In case of absent ankle pulses, the flow profile in the common femoral artery should be observed to exclude hemodynamically relevant stenosis of the iliac axis. Evidently, in an urgent situation such an evaluation is impossible and the risk of vascular complications cannot be minimized.[10] Particularly, in patients presenting with peripheral arterial disease, a vascular surgeon should preferably be involved at an early stage, and both cannulation and removal should be performed as open procedures with direct artery view.[10]

According to literature, peripheral vascular disease, young age (presumably owing to a paucity of collateral circulation), large size of cannula, dialysis during VA ECMO and long-term ECMO (>7 days) are underlying risk factors associated with development of ischemia.[9,10,15] Therefore, older age and elevated body mass index tended to decrease the risk of vascular complication and the cause of this apparent effect is unknown.[7]

Alternative cannulation sites such as central aortic cannulation (after median sternotomy in cardiac surgery) and axillary or subclavian artery cannulation should be considered in selected patients.[10]

Moazami et al.[20], presented axillary artery cannulation as a safe and alternative method of arterial cannulation in patients with extensive peripheral arterial disease. However it has several complications such as brachial plexus injury, pericardial effusion and axillary artery thrombosis which is why it is not recommended as the first option.[21]

The authors did not observe association of vascular complications after ECMO support with higher mortality rate. In the literature the studies are discrepant concerning this issue. Bisdas et al.[10], in a serie of 143 patients, concluded that there was no significant difference in mortality between patients with and without vascular complications. In contrast, Tanaka et al.[7], in a study of 84 patients on VA ECMO, reported an independent association between major vascular complications and mortality in patients with femoral arterial cannulation.

CONCLUSIONS

Cannulation of femoral vessels for the implantation of an ECMO remains associated with considerable rates of vascular events (28.6%).

Peripheral arterial disease and ischemic cardiopathy are associated with vascular complications in this kind of cannulation and according to authors opinion, physical examination and the assessment of ankle-brachial index before ECMO implantation is recommended. DPCs may be considered to be routinely used to augment the limb perfusion, especially in the presence of cardiovascular risk factors. The use of duplex ultrasonography to assess arterial flow and to support vascular access may help to identify the best arterial place to do the cannulation, to minimize the risk of limb ischemia.

Improved efforts at preventing these complications need to be developed to avoid additional morbidity in an already critical patient population. Early involvement of vascular surgeons for open vessel exposure or alternative access sites (subclavian or axillary artery) should be considered for selected patients.

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