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Limb ischemia after common femoral artery cannulation for venoarterial extracorporeal membrane oxygenation: an unresolved problem[☆]

Jeffrey W. Gander^{*}, Jason C. Fisher, Ari R. Reichstein, Erica R. Gross, Gudrun Aspelund, William Middlesworth, and Charles J. Stolar

Department of Surgery, Division of Pediatric Surgery, Columbia University College of Physicians and Surgeons and Morgan Stanley Children's Hospital of New York-Presbyterian, New York, NY 10032, USA

Abstract

Purpose—Extracorporeal Life Support Organization Registry data confirm that the number of pediatric patients being supported by extracorporeal membrane oxygenation (ECMO) is increasing. To minimize the potential neurologic effects of carotid artery ligation, the common femoral artery (CFA) is frequently being used for arterial cannulation. The cannula has the potential for obstructing flow to the lower limb, thus increasing ischemia and possible limb loss. We present a single institution's experience with CFA cannulation for venoarterial (VA) ECMO and ask whether any precannulation variables correlate with the development of significant limb ischemia.

Methods—We reviewed all pediatric patients who were supported by VA ECMO via CFA cannulation from January 2000 to February 2010. Limb ischemia was the primary variable. The ischemia group was defined as the patients requiring an intervention because of the development of lower extremity ischemia. The patients in the no-ischemia group did not develop significant ischemia. Continuous variables were reported as medians with interquartile ranges and compared using Mann-Whitney *U* tests. Differences in categorical variables were assessed using χ^2 testing (Fisher's Exact). Statistical significance was assumed at $P < .05$.

Results—Twenty-one patients (age, 2–22 years) were cannulated via the CFA for VA ECMO. Significant ischemia requiring intervention (ischemia group) occurred in 11 (52%) of 21. In comparing the 2 groups (ischemia vs no ischemia), no clinical variables predicted the development of ischemia (Table 1). In the ischemia group, 9 (81%) of 11 had a distal perfusion catheter (DPC) placed. Complications of DPC placement included one case of compartment syndrome requiring a fasciotomy and one patient requiring interval toe amputation. Of the 2 patients in the ischemia group who did not have a DPC placed, 1 required a vascular reconstruction of an injured superficial femoral artery and 1 underwent a below-the-knee amputation. Mortality was lower in the ischemia group (27% vs 60%).

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^{*}Corresponding author. Tel.: +1 212 342 8586; fax: +1 212 305 9270. jwg2107@columbia.edu (J.W. Gander).

Conclusions—Limb ischemia remains a significant problem, as more than half of our patients developed it. The true incidence may not be known as a 60% mortality in the no-ischemia group could mask subsequent ischemia. Although children are at risk for developing limb ischemia/loss, no variable was predictive of the development of significant limb ischemia in our series. Because of the inability to predict who will develop limb ischemia, early routine placement of a DPC at the time of cannulation may be warranted. However, DPCs do not completely resolve issues around tissue loss and morbidity. Prevention of limb ischemia/loss because of CFA cannulation for VA ECMO continues to be a problem that could benefit from new strategies.

Keywords

Limb ischemia; Common femoral artery cannulation; ECMO

1. Introduction

Extracorporeal Life Support Organization (ELSO) Registry data confirm that the annual number of pediatric patients, 1 to 18 years old, being supported by extracorporeal membrane oxygenation (ECMO) is increasing [1]. This is true for both respiratory and cardiac indications. Most of these patients are being supported via venoarterial (VA) ECMO. According to recent data, more than 50% of patients are placed onto VA ECMO for refractory respiratory failure. This number increases to nearly 100% of patients supported for cardiac indications.

Venoarterial ECMO requires cannulation of a large artery to deliver oxygenated blood to the patient. Traditionally, the carotid artery is used as the site of insertion for the arterial cannula. However, this technique requires distal ligation of the carotid artery, which interrupts blood flow to the areas of the brain supplied by that vessel. If collateral circulation is not sufficient, the patient may be placed at risk for an immediate or future stroke. Studies of neonatal ECMO survivors have shown a comparable incidence of major neurologic disability after carotid ligation to critically ill neonates not requiring ECMO [2]. However, it is not clear at what age the brain loses its ability to adapt to ligation of the carotid artery. Pediatric aged patients may be at a higher risk of neurologic injury if the carotid artery is used.

To minimize the potential neurologic effects of carotid artery ligation, the common femoral artery (CFA) has been used as the site of arterial cannulation for ECMO. The annual incidence of pediatric patients supported on VA ECMO via the CFA is increasing as well [1]. Although this decreases the neurologic complications of arterial cannula placement, it presents its own unique risks. The arterial cannula may obstruct forward flow to the limb, placing it at risk for ischemia and possible limb loss [3]. The exact incidence of limb ischemia is not known because it is not routinely recorded in the ELSO Registry. In 2 small series, the incidence of ischemia associated with VA ECMO via the CFA ranged from 30% to 50% [4,5].

To relieve limb ischemia, distal perfusion catheters (DPCs), endovascular therapy, and femoral-to-femoral bypass grafts have been proposed [3,6,7]. However, many of these techniques are instituted after the development of ischemia. A delay in initiation of therapy

may lead to an irreversibly injured limb. This led us to inquire if there were any precannulation variables that could accurately predict the development of significant limb ischemia. We present a single institution's experience with CFA cannulation for VA ECMO and examine precannulation variables that were associated with limb ischemia.

2. Methods

We reviewed all pediatric patients who were supported by VA ECMO via CFA cannulation from January 2000 to February 2010 at Morgan Stanley Children's Hospital of New York-Presbyterian, New York, NY. Study approval was granted by the Columbia University Institutional Review Board (IRB-AAAF0896) (New York, NY).

Cannula size was determined by selecting the smallest arterial cannula that could deliver the maximal required flow. The maximal flow for each patient was determined by multiplying the body surface area (BSA) by a cardiac index of 2.4. Cannulas were placed into the CFA either percutaneously or via open technique. In the percutaneous cases, anatomical landmarks were used to determine the site of the CFA. In selected percutaneous cases, fluoroscopy was used in the cardiac catheterization lab to determine site of CFA. A heparin bolus of 100 U/kg was given before placement of cannulas in all cases. A heparin drip was then instituted, and the activated clotting time was measured hourly with a goal of 180 to 220.

Limb ischemia was the primary variable. The ischemia group was defined as the patients requiring an intervention because of the development of lower extremity ischemia. The patients in the no-ischemia group did not develop significant ischemia. Variables selected for analysis between the 2 groups were age, sex, height, weight, site of cannulation (right vs left CFA), cannula size, BSA and cannula size-to-BSA ratio. In addition, we calculated the vasopressor score for each patient immediately before ECMO cannulation, as previously described [8].

Continuous variables were reported as medians with interquartile ranges and compared using Mann-Whitney *U* tests. Differences in categorical variables were assessed using χ^2 testing (Fisher's Exact). Statistical significance was assumed at $P < .05$. Data analyses were performed by using the Statistical Package for the Social Sciences (SPSS 15.0; SPSS, Chicago, Ill).

3. Results

During our study period, we identified 21 patients who were cannulated via the common femoral artery for VA ECMO. The age of the patients ranged from 2 to 22 years. Of the 21 patients cannulated via the common femoral artery, 19 were placed percutaneously and 2 via open cut down. In 6 percutaneous cases, placement occurred in the cardiac catheterization laboratory using fluoroscopy as these patients required a further cardiac intervention. In the remaining 13 cases, anatomical landmarks for the common femoral artery were used. Significant ischemia requiring intervention (ischemia group) occurred in 11 (52%) of 21.

In comparing the 2 groups (ischemia vs no ischemia), no clinical variables were predictive of the development of limb ischemia (Table 1). There was no significant difference in age, sex, weight, height, and cannula site between the 2 groups. In addition, there was no difference between the ischemia group and the no-ischemia group in BSA or cannula size (BSA, 1.41 vs 1.17; $P = .76$; cannula size, 17F vs 15F; $P = .86$). The BSA-to-cannula ratio was not significantly different between the ischemia group and no-ischemia group (12.1 vs 13; $P = .56$). To assess the contribution of vasopressors to ischemia, we calculated the vasopressor score of each patient before cannulation. Again, there was no significant difference in the vasopressor score before cannulation for each group (13.5 [ischemia group] vs 28 [no ischemia group]; $P = .25$).

Of the 11 patients who developed ischemia that required an intervention, 1 patient had a below-knee amputation. An additional patient underwent a vascular reconstruction of an injured superficial femoral artery. These 2 patients were early in our study period. The remaining 9 patients in the ischemia group had a DPC placed. However, the DPC did have some associated morbidity. In the patients it was placed, the first developed compartment syndrome requiring a fasciotomy and a second developed necrotic toes that required an interval amputation.

Mortality was lower in the ischemia group (27% vs 60%). The low survival rate, 40%, in the no-ischemia group can be directly attributed to the patient's underlying disease and complications from ECMO itself. Median time on ECMO for the no-ischemia patients who died was 245 hours. Although it is not known if these patients were going to eventually develop ischemia, comparing the 2 groups is valid. The median time to development of limb ischemia was only 11 hours after placement onto ECMO. Median follow-up was 7 months in the ischemia group and 5.75 months in the no-ischemia group ($P = .71$).

4. Discussion

Limb ischemia is a significant problem as there was a 52% incidence in our study. The true incidence may be underrepresented as there was a 60% mortality in the no-ischemia group. It is possible that these patients may have gone on to develop ischemia during their ECMO course.

The overall incidence of ischemia is not known. This is because the ELSO Registry does not routinely record limb ischemia as a complication. Currently, most of published studies discussing limb ischemia after VA ECMO are case reports [3,7,9,10]. There are 2 small series in the literature that reports limb ischemia as a complication of VA ECMO [4,5]. In 4 patients supported on ECMO for H1N1 respiratory failure, there was a 50% incidence of ischemia [5]. Jaski et al [4] described 10 patients placed on ECMO after an acute myocardial infarction. Three patients developed limb ischemia. According to the ELSO registry, 5 patients have undergone a lower limb amputation after CFA cannulation [1]. This may underrepresent the true incidence. Buckley et al [5] and Jaski et al [4] both reported one patient in their series who went on to require an above-the-knee amputation. In the current series, one patient had a below-knee amputation performed because of a severe ischemic injury.

Because ischemia can ultimately result in limb loss, identification of the patients who may be prone to it is crucial. This led us to inquire about which precannulation variables were associated with developing limb ischemia. In our series, no variable was predictive of the development of limb ischemia. We initially looked at age, sex, weight, height, and cannula site (left vs right CFA) to characterize any differences between the patients in the 2 groups. However, there was no significant difference in any of these variables. Body surface area and cannula size were similar in both groups as well. We hypothesized that a larger cannula size-to-BSA ratio may more accurately predict which patients will develop ischemia. This seems logical in that patients who have a larger diameter cannula with a smaller BSA would be more prone for limb ischemia. However, there was no difference in each of the 2 groups. Finally, it seems reasonable to assume that patients who were supported on a higher dose of vasopressors may be more susceptible to limb ischemia once their ECMO cannula was placed. Again, there was no statistical difference in the 2 groups. We recognize that our sample size was small, with the possibility of type II error, but with more patients, it is possible that we may see a variable that predicts who will develop ischemia.

The use of DPCs to relieve limb ischemia during cardiopulmonary bypass or ECMO in adults was first published in 1995 [11]. This technique has been expanded to children as well [3]. In pediatric patients, the catheter is typically 5F and placed either percutaneously or via a cut-down technique. The catheter is connected to arterial tubing that is then attached to an access port from the arterial cannula. Flow is directed antegrade to perfuse the ischemic limb (Fig. 1). In the literature, outcomes have generally been good with the use of DPCs [5,10,12]. However, some of these patients died, so it is not known if they would have had a complication from the DPC or limb loss. In our study, the DPC did have some associated morbidity. In the 9 patients it was placed, the first developed compartment syndrome requiring a fasciotomy and a second developed necrotic toes that required amputation. It is possible that the catheter did not completely relieve ischemia in this patient.

Once placed onto bypass, some authors have attempted to develop criteria to identify which patients will need a DPC. Huang et al [13] measured the mean arterial pressure of the superficial femoral artery by puncturing the vessel distal to the ECMO cannula with a 23-gauge needle. If the pressure was below 50 mm Hg, a DPC was placed. There was no incidence of limb ischemia in their cohort. Another study used near-infrared spectroscopy (NIRS) to evaluate ischemia [14]. The NIRS values dropped to 38 from a baseline of 61 when a femoral bypass catheter was placed. After placing a DPC, the NIRS value rose back to baseline. Although these technologies hold promise, they have not been studied in children.

To minimize the risks of ischemia, some ECMO centers use a smaller sized arterial cannula in the femoral artery for support of the blood pressure. The oxygenated side of the circuit is then spliced into an additional cannula that is placed through the internal jugular vein with its tip resting in the right atrium. Forward flow is directed across the tricuspid valve delivering oxygenated blood to the heart and brain. In theory, this would provide a higher level of oxygenated blood to the coronary arteries and brain because the arterial cannula in the femoral artery has to deliver blood against the native pressure of the left ventricle. In our experience, the main limiting factor in delivery of adequate flow is enough venous drainage.

The above technique limits the central veins to be used for drainage of deoxygenated blood. Other techniques that have been reported are an angiographically placed flush catheter from the contralateral artery and a femoral-to-femoral bypass graft [6,7].

With the increasing use of the CFA for VA ECMO in pediatric patients, the incidence of limb ischemia may increase. Because we currently cannot predict who will develop ischemia, early, routine placement of a DPC may be warranted. However, the catheter does not completely resolve tissue loss and morbidity. Prevention of limb ischemia and loss continues to be a problem that may benefit from new strategies. Adding a field for limb ischemia onto the ELSO Registry would improve data capture that may lead to future studies that could improve patient outcomes.

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Fig. 1.
Example of distal perfusion cannula during common femoral artery cannulation for VA ECMO.

Table 1

Patient and ECMO-related variables in children who did not and did develop limb ischemia

	No ischemia (n = 10)	Ischemia (n = 11)	P
Age, y	14 (6.3–17.5)	12 (6.0–17.0)	.97
Male-female	3:7	2:9	.64
Weight, kg	45.9 (23.3–63.5)	32.5 (22.0–58.0)	.65
Height, cm	153 (119–161)	151 (130–153)	.61
BSA, m ²	1.41 (0.87–1.66)	1.17 (0.85–1.48)	.76
Arterial cannula size, F	17 (12–17)	15 (14–17)	.86
Left CFA-right CFA	3:7	6:5	.39
Cannula-BSA ratio	12.1 (10.3–16.6)	13.0 (11.5–17.6)	.56
Vasopressor score ^a	13.5 (6.9–44.4)	28 (9.0–80.0)	.25
Mortality	60%	27%	.20
Follow-up, mo	5.75 (0.5–31.25)	7 (0.5–28)	.71

Continuous variables are reported as medians and interquartile ranges and compared using Mann-Whitney *U* test; categorical variables are compared by using Fisher's Exact test.

y, years; kg, kilograms; cm, centimeters; m², meters squared; F, French; CFA, common femoral artery; BSA, body surface area; mo, months.

^a (Dopamine [$\mu\text{g/kg/min}$] $\times$ 1) + (dobutamine [$\mu\text{g/kg/min}$] $\times$ 1) + (epinephrine [$\mu\text{g/kg/min}$] $\times$ 100) + (norepinephrine [$\mu\text{g/kg/min}$] $\times$ 100) + (phenylephrine [$\mu\text{g/kg/min}$] $\times$ 100).