Limb ischemia during femoral cannulation for cardiopulmonary support

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Objectives: Extracorporeal membrane oxygenation and extracorporeal cardiopulmonary support (ECMO/CPS) are potentially life-saving techniques for patients with cardiopulmonary collapse. Complications include lower extremity ischemia from femoral artery cannulation. We examined the outcomes of patients placed on ECMO/CPS, including the rate of limb ischemia.

Methods: All instances of ECMO/CPS over a 3-year period (2006-2009) at a single university hospital were examined retrospectively for cannulation strategy, perfusion strategy, mortality, and limb ischemia. Potential predictors of limb ischemia with femoral artery cannulation were age, gender, body surface area (BSA), body mass index (BMI), and arterial cannula size.

Results: Fifty-eight patients were placed on ECMO/CPS. Of these, 43 patients (74%) had femoral arterial cannulation. In 10 patients, the superficial femoral artery (SFA) was cannulated prophylactically (without antecedent limb ischemia) and perfused in the antegrade direction from a branch of the ECMO/CPS circuit. In 7 of the remaining 33 patients (21%), limb ischemia developed requiring decannulation with fasciotomy (n = 4) or additional cannulation of the SFA with branching of the ECMO/CPS circuit (n = 3). One patient with ipsilateral leg ischemia required eventual amputation. Patients with limb ischemia were significantly younger than those who did not develop limb ischemia (P = .001). BSA, BMI, and cannula size did not predict limb ischemia. Overall 30-day mortality following the initiation of ECMO/CPS was 79%. There was no correlation between limb ischemia and mortality.

Conclusions: Younger patients may be at increased risk for lower extremity arterial insufficiency with femoral cannulation for ECMO/CPS. Prophylactic or expectant SFA cannulation are reasonable approaches. (J Vasc Surg 2010;52:850-3.)

Extracorporeal membrane oxygenation (ECMO) and extracorporeal cardiopulmonary support (CPS) can be utilized as potential life-saving measures in certain critically ill patients with cardiac (CPS) or pulmonary (ECMO) collapse. Percutaneous cannulation of the femoral artery and vein allows for rapid initiation of support; however, the femoral arterial cannula may be occlusive, or nearly so, thereby causing distal limb ischemia. Devastating limb loss can result. Several techniques have been described to perfuse the ipsilateral lower extremity to decrease the rate of limb ischemia.1-5 However, it is not known whether there are specific patient or clinical characteristics that increase the risk of or predict the development of limb ischemia. If one could predict the onset of limb ischemia, adjunctive measures could be accomplished early and in a rational selective manner.

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Competition of interest: none.


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METHODS

All patients in whom ECMO/CPS was utilized at the Hospital of the University of Pennsylvania between January 2006 and April 2009 were identified. Medical records were retrospectively examined for the following: indication for support, age, gender, body surface area (BSA), body mass index (BMI), cannulation site, size of the arterial cannula (French), development of limb ischemia, and 30-day mortality. Further intervention on patients who developed limb ischemia was recorded. In particular, any instances where the ECMO/CPS circuit was branched (prophylactically, or in response to limb ischemia) with separate cannulation of the superficial femoral artery (SFA) were noted. Logistic regression was used to examine potential predictors of limb ischemia (age, gender, BSA, BMI, and arterial cannula size); subsequently, post hoc univariate analyses were performed using Student’s t-tests and Fisher’s exact tests. Student’s t-test was used to assess for correlation between mortality and limb ischemia. All quantities are reported as mean ± standard deviation unless otherwise indicated.

ECMO/CPS was initiated percutaneously using a modified Seldinger technique, under emergent circumstances. Duplex guidance is not typically used in our practice to obtain access to the common femoral artery (CFA). While sewing a graft onto the CFA is possible and may be helpful, all cannulation was accomplished either percutaneously or via Seldinger cannulation of the CFA under direct vision (in the case of prophylactic SFA cannulation). Decannulation was performed under direct visualization after performing a cutdown on the groin. The artery was suture-
repaired primarily or with a patch angioplasty as necessary. The groin was then closed in layers.

RESULTS

Over 40 months, 58 patients were placed on ECMO/CPS at the Hospital of the University of Pennsylvania. Of these, 42 (72%) were male. The patients ranged in age from 19 to 83 years old (mean, 49 ± 17 years). The majority of patients were placed on support for cardiac arrest/cardiogenic shock (n = 50; 86.2%), as summarized in Table I. None of the patients presented initially with pneumonia. Overall 30-day mortality following the initiation of ECMO/CPS was 79%.

Femoral arterial cannulation was utilized in 43 patients (74%). Of the other 15 patients, two underwent venous cannulation and ECMO. The remaining 13 required maintenance of cardiopulmonary support via cannulae placed intraoperatively in the right atrium and aorta. In 10 patients with femoral arterial cannulation (23%), the SFA was cannulated in an antegrade fashion via a groin or thigh cutdown at the time support was initiated, without antecedent limb ischemia, and flow was obtained from a branch of the ECMO/CPS circuit (Fig 1). There were no instances of limb ischemia in the group of patients with prophylactic SFA cannulation; seven of these patients (70%) died within 30 days of initiating support. Of the remaining 33 patients undergoing common femoral arterial cannulation, limb ischemia developed in seven (21%), and mortality was 81% (27/33). There was no significant difference in 30-day mortality between patients who developed limb ischemia and those who did not (P = .09), nor between those who underwent prophylactic SFA cannulation and those who did not (P = .66).

In the seven patients who developed limb ischemia, treatment included decannulation and fasciotomy (n = 4) or additional cannulation of the SFA with branching of the ECMO/CPS circuit (n = 3). Only one of the three patients who underwent additional SFA cannulation survived. In all patients (n = 3) undergoing antegrade SFA cannulation in response to ipsilateral limb ischemia, the retrograde cannulae were confirmed to be in the CFA. One patient with ipsilateral leg ischemia, managed with decannulation and fasciotomy, required eventual amputation (Fig 2).

Logistic regression identified only age as a predictor of ipsilateral limb ischemia: patients who developed limb ischemia were significantly younger than those who did not (36 ± 18 years vs 58 ± 14 years; P = .048 by logistic regression; P = .001 by t-test). Of those patients who did not develop limb ischemia, 58% (15/26) were greater than 60 years old. No patient over 60 years of age developed limb ischemia. As summarized in Table II, arterial cannula size, BSA, and BMI did not correlate with the development of limb ischemia.

DISCUSSION

The use of ECMO/CPS as a life-saving technique has broadened to include not only patients with cardiac arrest and cardiogenic shock but also those with pulmonary insufficiency and profound hypothermia. In a series of 569 patients undergoing CPS, femoral artery occlusion related to the cannula was observed in approximately 2% of cases, with femoral vessel morbidity occurring in 11%.7 Our series demonstrated clinically significant arterial compromise leading to limb ischemia in 21% of patients who did not receive prophylactic ipsilateral limb adjuncts to perfusion. One of these patients eventually required an amputation.

Table I. Indications for extracorporeal membrane oxygenation and extracorporeal cardiopulmonary support

<table>
<thead>
<tr>
<th>Indications</th>
<th>Number (n = 58)</th>
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<tbody>
<tr>
<td>Cardiac arrest/cardiogenic shock</td>
<td>50 (86.2%)</td>
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<tr>
<td>Traumatic lung injury</td>
<td>3 (5.2%)</td>
</tr>
<tr>
<td>Massive pulmonary embolus</td>
<td>2 (3.4%)</td>
</tr>
<tr>
<td>Hypothermia</td>
<td>1 (1.7%)</td>
</tr>
<tr>
<td>Miscellaneous (traumatic inferior vena cava injury; hypoxia following arrest)</td>
<td>2 (3.4%)</td>
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Fig 1. Antegrade perfusion of the ipsilateral SFA from a branch of the CPS circuit.

Fig 2. Outcomes of patients undergoing femoral artery cannulation.
There was no reported limb ischemia or vascular injury in any of the patients who underwent prophylactic antegrade perfusion of the ipsilateral SFA.

Patients who developed limb ischemia were significantly younger than those patients without limb ischemia. This may be due to the size of the arterial cannula used in relation to the femoral artery diameter in younger patients. CFA diameter increases with age and is also related to BSA and gender,\textsuperscript{8} with larger diameters found in males and patients with larger BSA. However, the data presented here found no correlation between the rate of limb ischemia and BSA, BMI, or cannula size.

Proper placement of the arterial cannula in the CFA is of vital importance to minimize the risk of ipsilateral limb ischemia. Inappropriate retrograde cannulation of the SFA (ie, sticking too low) can lead to a significant flow limitation, if not complete occlusion. We did not find any instances of inappropriate retrograde cannulation of the SFA in our series as a cause for limb ischemia. Techniques to perfuse the ipsilateral limb during ECMO/CPS 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/CPS circuit to provide flow, and suturing a prosthetic graft to the CFA in an end-to-side fashion with subsequent cannulation of the graft instead of the native artery.\textsuperscript{1, 5}

The additional time required to perform a vascular anastomosis, coupled with a higher risk of infection associated with the use of prosthetic graft material, makes the last technique less popular. A novel arterial cannula with side holes to allow for distal limb perfusion has also been described.\textsuperscript{9}

Prophylactic antegrade SFA cannulation to prevent ipsilateral limb ischemia may be considered or even become the standard of care at some centers. However, this technique, at least in our institution, is felt to mandate surgical cutdown and cannula placement in patients who are often not fit for transport, much less a visit to the operating room. Huang and colleagues reported a small series of patients in whom they performed direct pressure measurements of the SFA after initiating ECMO to determine the need for antegrade perfusion.\textsuperscript{10} Early routine use of duplex ultrasonography to assess arterial flow in the limb distal to the cannula may help to identify which patients should undergo antegrade limb perfusion techniques upon initiation of ECMO/CPS.

Because this study is retrospective, and two different management strategies were implemented in a nonrandomized fashion, its conclusions are limited. Nevertheless, it seems reasonable that younger patients should have higher rates of distal limb ischemia on femoral arterial ECMO/CPS, both because their arteries are smaller in diameter and because they have less collateralization of the lower extremity arterial circulation. It is fairly evident that those patients over 60 years of age will not require directed SFA perfusion adjuncts if retrograde common femoral arterial cannulation alone is used.

With respect to management strategy, the authors are of the opinion that antegrade SFA perfusion adjuncts may be reasonably undertaken prophylactically or expectantly; there was no difference with respect to mortality or limb loss in comparing the two approaches. Furthermore, since no correlation was found between the development of limb ischemia and mortality, patients on ECMO/CPS who develop limb ischemia should undergo adjunctive procedures in an attempt to accomplish limb salvage. One potential shortcoming of this study, again related to its retrospective nature, is that prophylactic antegrade SFA cannulations might have been performed less frequently in sicker patients because, in dire situations, the time and opportunity for SFA cutdown might not exist. However, antegrade SFA cannulation can be, and frequently is at our institution, performed at the bedside in the ICU; thus, it less likely that there is a bias for prophylactic antegrade SFA cannulation in less severely ill patients. Furthermore, no significantly better survival was evidenced in those patients undergoing prophylactic SFA cannulation, suggesting that these patients were just as critically ill as the remaining patients.

Current data indicating the benefits of ECMO in acute respiratory insufficiency syndromes combined with anticipated demand from the H1N1 subtype influenza type-A pandemic, have generated enthusiasm for and predictions of vastly increased implementation of ECMO.\textsuperscript{11, 12} Some predict that disproportionate numbers of children and young adults will be stricken with this syndrome; this is exactly the population that the current data would suggest suffers a higher rate of femoral cannula-related limb ischemia. Therefore, early recognition of ipsilateral limb ischemia.
emia, and expeditious adjunctive procedures to ameliorate the threat to the leg, will continue to be important.

CONCLUSION

Younger patients are at increased risk for lower extremity arterial insufficiency with retrograde femoral arterial cannulation for ECMO/CPS. Prophylactic or expectant SFA cannulation are reasonable approaches and should be instituted liberally. Prophylactic antegrade SFA cannulation may be unnecessary in those patients greater than 60 years old. Routine use of duplex ultrasonography or direct pressure measurements within the SFA upon initiation of ECMO/CPS may allow for standardization of this technique to prevent limb ischemia.

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AUTHOR CONTRIBUTIONS

Conception and design: PF, BJ
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Writing the article: PF, BJ
Critical revision of the article: PF, RM, EW, MA, GW, RF, BJ
Final approval of the article: PF, RM, EW, MA, GW, RF, BJ
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Overall responsibility: BJ

REFERENCES


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