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Operative Technique

# A multidisciplinary approach to VA ECMO cannulation in children☆

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ABSTRACT

*Purpose:* Extracorporeal membrane oxygenation (ECMO) supports gas exchange and circulation in critically ill patients. This study describes a multidisciplinary approach to ECMO cannulation using the expertise of pediatric surgery (PS) and interventional radiology (IR).
*Material and methods:* Pediatric patients (<18 years) undergoing percutaneous cannulation for peripheral veno-arterial (VA) ECMO by PS and IR from April 2017 to May 2018 were included. Cardiac patients and children cannulated by PS alone were excluded.
*Results:* Five patients were included in the series. Median age was 16 [12.5–17] years and 3 were female. Median ECMO arterial and venous catheter sizes were 19 [17–22] Fr and 25 [25–28] Fr, respectively. Both catheters were placed in the common femoral vessels. A 6Fr antegrade distal perfusion cannula (DPC) was also placed in the superficial femoral artery by IR at the time of cannulation. The median time from admission to procedure start was 10 [7–50] hours and the children were on ECMO for a median length of 3.2 [2.3–4.8] days. There were two episodes of bleeding. No patients had loss of limb circulation.
*Conclusion:* A multidisciplinary approach to peripheral VA ECMO cannulation is feasible and safe. Maintenance of limb perfusion by percutaneous placement and removal of DPC may be an advantage of this collaborative approach.
*Level of Evidence:* IV.
*Type of Research:* Case series.



## 1. Background

Extracorporeal membrane oxygenation (ECMO) supports gas exchange and circulation in critically ill patients. In peripheral veno-arterial (VA) ECMO, blood is removed from the body via a vein (femoral or internal jugular), oxygenated, and returned via an artery (common carotid or femoral) [1]. There is currently variation in practice and lack of consensus on pediatric cannulation strategies and management, including whether to use neck or groin vessels for peripheral cannulation [2].

In studies looking at cannulation site, there has been no difference in mortality between children cannulated via neck versus femoral vessels [3]. There may be, however, an increased risk of neurologic complications with neck cannulation and an increased risk of lower limb ischemia with femoral cannulation [3,4]. To help treat limb ischemia, distal perfusion catheters (DPCs) can be inserted into the superficial femoral artery either during or after common femoral artery access [5]. Some physicians advocate for the prophylactic placement of DPCs after femoral cannulation, but current studies have shown no difference in outcomes compared to placement when clinically indicated [5].

There are several techniques for peripheral VA ECMO cannulation including open cutdown, percutaneous (Seldinger), graft placement, or a combination of the three [1]. Open cutdown has been the method of choice in the past, but some now advocate for percutaneous cannulation due to its several advantages including a decreased risk of infection and fewer bleeding complications [6]. This type of cannulation in children requires a specialized skillset, one included in the repertoire of both pediatric surgeons and interventional radiologists. The literature is lacking information on collaborative approaches that can be utilized between these specialties.

☆ Declarations of Interest: None.

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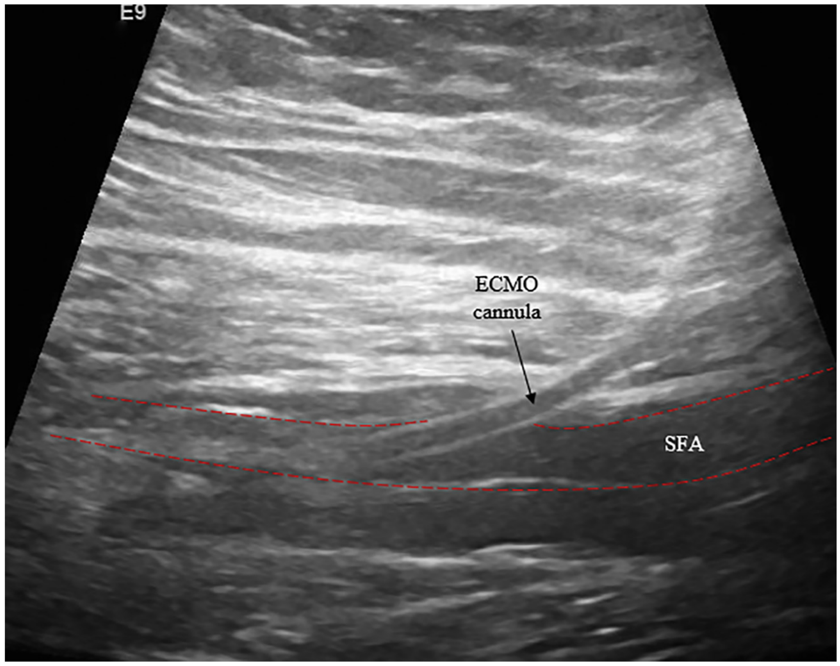


**Fig. 1.** ECMO distal perfusion cannula placement in the superficial femoral artery under ultrasound guidance. SFA- Superficial femoral artery.

The purpose of this study is to describe a multidisciplinary approach to VA ECMO cannulation using the expertise of pediatric surgery (PS) and interventional radiology (IR) with an emphasis on the placement and removal of DPCs to maintain limb perfusion. By describing the clinical course and outcomes of pediatric patients that undergo peripheral VA ECMO cannulation by IR and PS, we will highlight the complexities of ECMO and the benefits of a multidisciplinary team.

## 2. Methods

A retrospective chart review was performed using the electronic medical record system at Texas Children's Hospital, in Houston Texas. The study was approved by the Baylor College of Medicine Institutional Review Board (H-43129). Those included in the study were children <18 years who underwent percutaneous cannulation by PS and IR for peripheral VA ECMO between April, 2017 and May, 2018. Cardiac patients and patients cannulated by PS alone were excluded. From a surgical perspective, all cardiac and ECPR cannulations are performed by the congenital heart surgical service and all other cannulations are performed by pediatric surgery. Patients were candidates for a joint PS/IR approach when the optimal cannulation strategy was determined to be venoarterial and peripheral through a femoral approach. The cannulation strategy was determined collaboratively by pediatric surgery, the intensive care unit team, and the interventional radiology team. There were no specific exclusion criteria for the PS/IR collaborative approach. At Texas Children's, an on-call pediatric surgery attending is “in house” 24/7 and the interventional radiology team takes home call. Although we believe in the benefits of a multidisciplinary approach, cannulation may proceed by pediatric surgery alone if any delays are anticipated.

From a procedural perspective, all catheters were placed under ultrasound guidance using the Seldinger technique. PS placed the venous cannula in the common femoral vein and IR placed the arterial cannula retrograde in the common femoral artery. IR also placed a DPC antegrade in the superficial femoral artery on the ipsilateral side of the arterial cannula in order to perfuse the lower extremity (Fig. 1). Data collected included patient demographics, diagnosis, laboratory values, ECMO cannulation data, cannula-related complications, hospital course, and outcome. There were no missing data for each collected data point. Descriptive statistics were used. Categorical variables are reported as, number (percentage), and continuous variables are reported as, median [interquartile range]. Statistical analysis was performed using SPSS version 24, IBM®.

## 3. Results

Over the 1-year study period, five children met study criteria. The median age was 16 [12.5–17] years and 3 (60%) were female. Other patient characteristics can be seen in Table 1. Indications for ECMO included cardiogenic shock (n = 2), septic shock (n = 1), cardiac collapse (n = 1), and respiratory failure (n = 1). Four children underwent cardiopulmonary resuscitation (CPR) prior to cannulation. Of note, the total number of ECMO cases during this time period was 47; 21 (45%) were venovenous. There were 15 (4 VV, 11 VA) neonatal patients and 32 (17 VV, 15 VA) pediatric patients. Within this

**Table 1**
Patient characteristics.

| Patient | Age (years) | Weight (kg) | Gender | Race/Ethnicity | Diagnosis | Arterial cannula laterality | Venous cannula laterality | Mortality |
|---|---|---|---|---|---|---|---|---|
| A | 14 | 180 | Female | Non-Hispanic white | Drug overdose | Right | Left | Yes |
| B | 16 | 67 | Female | Hispanic white | Possible toxic shock syndrome | Right | Right | No |
| C | 11 | 98 | Male | Non-Hispanic black | Diabetic ketoacidosis with aspiration | Right | Left | Yes |
| D | 17 | 100 | Male | Unknown | Drug overdose | Right | Left | No |
| E | 17 | 141 | Female | Non-Hispanic black | Aspiration with acute respiratory distress syndrome | Left | Right | Yes |

**Table 2**
Pre-ECMO laboratory data.

| Patient | Lactate | Base excess | Hemoglobin | Platelet count | INR |
|---|---|---|---|---|---|
| A | 5.9 | −7 | 13.9 | 197 | 1.5 |
| B | 11.1 | −11 | 11.4 | 89 | 1.3 |
| C | 13.2 | −11 | 10.2 | - | 1.8 |
| D | 9.1 | +7.2 | 12.1 | 219 | 1.1 |
| E | 18.4 | −9 | 9.3 | 42 | 1.5 |

population there were 18 patients would be classified as “cardiac”. Prior to starting ECMO, laboratory derangements were common, all patients were being mechanically ventilated, and all were receiving vasopressor infusions (median of 3 [3,4]) (Table 2).

Cannulation was performed by five PS and four IR of varying experience. The time from admission to ECMO cannulation was 10.3 [7.4–50.2] hours. The arterial and venous catheter sizes were 19 [17–22] Fr and 25 [25–28] Fr, respectively. The arterial and venous catheters were placed on contralateral sides except in the case of patient B who was in a prothrombotic state resulting in occlusion of the contralateral vein. As a result the venous and arterial catheters were inserted on the same side. All DPCs were 6Fr and placed ipsilateral to the common femoral artery cannula. The median time from procedure start to initiation of ECMO flow was 1.2 [0.4–1.5] hours. At the time of cannulation, one child experienced hemorrhage with 900 ml of blood loss and another child had cardiac arrest with subsequent resuscitation.

All cannula placement occurred at the bedside in the PICU. Patient C underwent cannulation for veno-venous (VV) ECMO 13 h prior to being converted to VA ECMO. Both VV and VA cannulation took place at the bedside.

The patients received ECMO for a median of 3.2 [2.3–4.8] days. Upon ECMO catheter decannulation, multiple modalities were utilized for hemostasis. Manual compression was used at the venous cannulation site, a mechanical arterial compression device (FemoStop®) was used at the arterial cannulation site (Fig. 2.), and an arterial closure device (Mynx®) was used at the DPC site. Decannulation was performed by both PS (venous) and IR (arterial). Only three patients underwent decannulation; two children died while receiving ECMO. There was one episode of post-decannulation bleeding (350 ml blood loss) that did not require surgical intervention. No patients had loss of limb circulation. Survival to discharge was 60% (n = 3) with one child being discharged to hospice where she subsequently died.

**Fig. 2.** Mechanical arterial compression device (FemoStop®) after ECMO cannula removal.

## 4. Discussion

This case series was designed to assess the feasibility and outcomes of using a collaborative approach for percutaneous cannulation of VA ECMO in children. This approach developed over time as there was increased mutual recognition by the pediatric surgery and intensive care unit physicians of potential technical expertise and technologic advantages afforded by the interventional radiology service; particularly with respect to image guided placement of an antegrade distal perfusion catheter in the superficial femoral artery as well as percutaneous removal using image guided closure devices. Prior to this study, a survey of the American Pediatric Surgical Association (APSA) concerning VA ECMO cannulation strategies in children showed variations in care, suggesting lack of consensus among American pediatric surgeons [2]. Cannulation was usually performed by PS (88%), followed by cardiac surgery (6%). In this survey, there was no option suggesting placement by IR. Even in the adult literature, studies concerning ECMO cannulation by IR are limited [7,8]. Nevertheless, percutaneous vascular access and cannulation is a routine procedure performed by IR [9]. Also, several studies have shown comparable outcomes when percutaneous ECMO cannulation is performed by other non-surgical specialists such as intensivists [10–12]. Additionally, although difficult to assess in a small case series, multiple procedural services operating in parallel may decrease time to flow compared to sequential vascular access that may improve outcomes.

In this case series, the patient's ages ranged from 11 to 17 years, and they weighed between 67 and 141 kg. According to the APSA survey, only 22% of surgeons would perform percutaneous cannulation in a 7 year old, and 49% in children older than 12 years. Eight percent of surgeons used weight as a factor for choosing femoral cannulation [2]. Our institution does not have a weight or age cut off for femoral ECMO cannulation, but cannulation strategy is decided upon on an individual basis by the intervening surgeon.

A main concern after femoral cannulation is distal limb ischemia, especially in children whose vessel caliber may be much smaller than adults [13]. The common femoral artery cannula is placed retrograde in order to provide flow to the aorta. Because of this, flow is limited beyond the cannula to the distal limb, increasing the risk of ischemia. The rate of distal limb ischemia in children ranges from 29% to 52% [5]. One method of counteracting this ischemia is placement of a DPC. While only 59% of the APSA surgeons say they use a DPC when performing peripheral VA ECMO cannulation, all of the children in our study had a DPC placed [2]. A recent meta-analysis showed a 15.7% absolute reduction in limb ischemia in adults with DPC placement compared to without based on retrospective observational data [14]. Studies concerning limb ischemia in children after DPC placement have shown mixed results, with some showing decrease in ischemia and other showing no difference [4,5]. As seen in Fig. 3, extremity perfusion may notably improve following DPC insertion. No children in our series developed distal limb ischemia after percutaneous DPC placement performed by IR.

The most common complication encountered with VA ECMO is bleeding which has been reported to occur in 10–30% of adults [15,16]. In our group of patients, two (33%) had an episode of bleeding. One had bleeding at time of cannula placement, and the other after cannula removal. The bleeding at time of placement was complicated by inadvertent removal of the guidewire after the common femoral artery had been dilated. The bleeding after cannula removal came from the venous site and occurred about 10 h after decannulation. The patient had

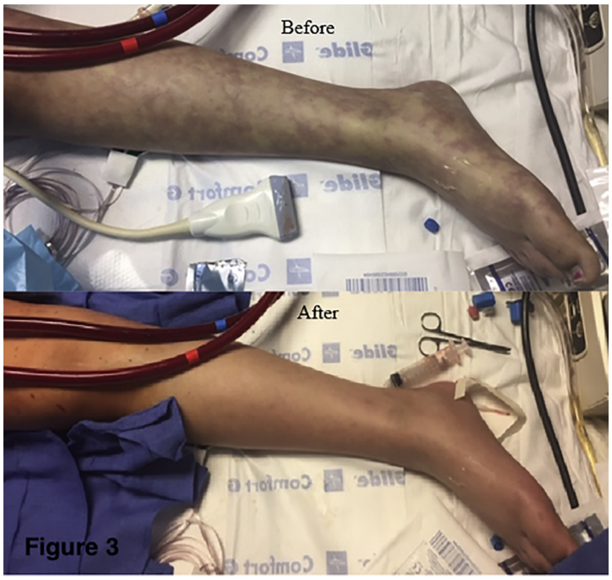


**Fig. 3.** Before and after distal perfusion cannula placement for VA-ECMO.

become agitated and began to cough and strain, resulting in the bleeding episode. Bleeding was controlled by direct pressure in both instances. In a study comparing patients that underwent percutaneous femoral ECMO cannulation to those that underwent surgical cutdown, it was interesting to find that the percutaneous patients had an increased risk of bleeding after decannulation [17].

It is of note, that four out of five patients had undergone CPR prior to ECMO, one of which had cardiac arrest at time of cannulation. Extracorporeal cardiopulmonary resuscitation (ECPR) is a type of advanced rescue therapy that uses ECMO to support circulation in patients with cardiac arrest that are refractory to conventional CPR [18]. Over the last 20 years, this form of selective resuscitation has gained traction with over 3400 pediatric cases reported to the Extracorporeal Life Support Organization (ELSO) from 1989 to 2017. Of the ELSO patients to undergo ECPR, 42% survived to discharge [19]. This is somewhat lower than the 50–60% survival for any children to undergo ECMO for cardiac and/or respiratory support. [20] Our small series of patients had similar survival with 60% overall survival to discharge and 50% survival to discharge if they underwent CPR prior to ECMO.

There are several imitations inherent to this study design. As a case series of only 5 patients, this study is unable to show cause-effect relationships or significantly meaningful data on patient outcomes. For example, procedure start to initiation of flow was 1.2 h. Unfortunately, due to the retrospective nature of the review, we are unable to comment specifically on factors that may have influenced this timeline. However, we do not feel that this is reflective of a more diverse team; but may reflect patient complexity. In order to obtain more statistically significant data, a larger study would need to be performed to analyze outcomes for ECMO patients cannulated by a multidisciplinary team in comparison to a single service such as pediatric surgery.

## 5. Conclusion

A multidisciplinary approach to peripheral VA ECMO cannulation involving pediatric surgery and interventional radiology is feasible and safe. Maintenance of limb perfusion by percutaneous placement and removal of DPC may be an advantage of this collaborative approach.

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