Postcardiotomy Shock ECMO: peripheral or central?

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Central Message
Based on available evidence, peripheral cannulation should be considered if there is no clear reason for central cannulation, but multi-institutional, prospective data are needed to strengthen this recommendation.

Central Figure Legend
Flowchart show summarizing key advantages to peripheral and central ECMO for PCS.

Background
Post-cardiotomy shock (PCS) is poorly defined in the literature, but is broadly understood to mean circulatory failure after cardiac surgery necessitating mechanical circulatory support and high dose inotropes. PCS occurs in 0.5-1.5% of all cardiac surgeries and is important to better understand because it has an in-hospital mortality rate greater than 50% [1], [2].

In the past there were a limited of ways to support a patient in such profound cardiogenic shock, but today there are multiple mechanical circulatory support devices available. These include extracorporeal membrane oxygenation (ECMO), and several distinct technologies that fall into the category of ventricular assist device (VAD). VADs can be further classified by whether they provide short-term or long-term support, and percutaneous versus open insertion [2].

ECMO has become the most widely used support system for PCS [3]. Relative ease of ECMO cannulation and ability to deploy ECMO quickly in an emergency likely contribute to widespread use. Over the past two decades there has been a large increase in use of ECMO for all underlying etiologies, and a 5-fold increase in the use of ECMO specifically for PCS. Unfortunately, the increase in use has not been paralleled by improved survival for patients in which it is used [3], [4]. The percentage of PCS patients treated with ECMO that survive to hospital discharge varies based on source, but ranges from roughly 30-60% [4]–[6].

Several retrospective analyses have attempted to identify patient-specific characteristics associated with mortality in PCS patients [3], [6], [7]. A variety of factors have been identified in at least one study including age greater than 70, pre-operative renal insufficiency, obesity, female gender, and type of cardiac surgery among others [1], [3], [6]. A recent analysis compared patients in two five-year time periods (2007-2012 and 2013-2018). Patients from 2013-2018 had lower in-hospital mortality and were more likely to be cannulated intraoperatively and earlier in their hospital course suggesting timing of support may be crucial to survival [7]. Multiple studies support better survival when patients are cannulated at lower serum lactate with cutoffs ranging from 4-6mmol/L [1], [3], [6], [7].
There are many questions about the use of ECMO in PCS patients including ideal patient selection, and timing of deployment; however, perhaps the most frequently debated topic is whether cannulation strategy affects patient outcomes. Here, we review central and peripheral cannulation and discuss advantages/disadvantages of each method.

**Central ECMO**

Central ECMO cannulation refers to an arterial cannula entering the aorta (either directly or via a graft) and a venous drainage cannula placed in the right atrium. Central cannulation can be used for patients with an open chest, or with chest closure and tunneling of the cannulae out subxiphoid or along the path of the jugular [3]. For PCS patients, the cannulae may be the same as those used for CPB, connected to the ECMO circuit rather than the bypass machine. Alternatively, the cannulae may be exchanged or replaced if the patient was previously decannulated.

The are several benefits of central cannulation. First, some patients may not be able to tolerate chest closure due to significant edema. The direct cannulation of the ascending aorta allows antegrade flow and avoids concerns with dual circulation (also known as North-South or Harlequin syndrome) [8], [9]. Dual circulation is a phenomenon whereby inadequately oxygenated blood from the heart feeds the head vessels rather than oxygenated blood from the ECMO circuit [10]. Another advantage to central cannulation is that if the chest is already open in the operating room than central cannulation may be faster than peripheral cannulation. Finally, if the patient requires one or more return trips to the operating room, the surgery can be performed without the need to re-open the chest. When the patient is ready for chest closure the cannulation can be revised and switched to peripheral.

Two studies published in 2020 favor central cannulation. Radakovic et al. reviewed 158 patients requiring ECMO for PCS at their center between 2010 and 2019 and found that 30-day survival was higher for centrally cannulated patients as compared to those that were peripherally cannulated [8]. They also found that the peripherally cannulated group was more likely to require surgical cannulation revision due to either limb hyperperfusion or dual circulation. In this study, length of ICU stay, need for reoperation, and transfusion requirements were all similar between groups [8]. The authors concluded that central cannulation appeared to be beneficial. A second study reviewed 31 patients requiring ECMO cannulation within 72 hours of a cardiac operation and found that centrally cannulated patients were more likely to wean from ECMO and more likely to survive the hospitalization [11].

**Peripheral ECMO**

Peripheral ECMO is used more frequently than central ECMO and consists of cannulation via the femoral vein and femoral artery or femoral vein and axillary artery. Cannulation can be achieved via surgical cutdown or percutaneously. The venous
cannulae usually range in size from 19F to 25F and arterial cannulae are typically 15F to 24F. Larger cannulae support higher flows, but are associated with a greater risk of bleeding and limb ischemia [10].

There are several advantages to a peripheral strategy: percutaneous access can more easily be performed bedside in the ICU in an emergency, it is less invasive than central cannulation, and it does not require an open chest or chest re-opening for decannulation.

Historically, peripheral ECMO was thought to be associated with more vascular complications at the access site, but this is changing with the routine use of ultrasound guidance for percutaneous access and placement of distal perfusion catheters (see dedicated section). Recent literature does not show limb ischemia to be a common complication of peripheral cannulation, but it should be noted that not all patients will have adequate peripheral vascular access [9]. Another potential disadvantage to peripheral cannulation is the delivery of retrograde flow, which increases the afterload on the left ventricle and thus increases risk of LV dilation. However, this risk can be avoided by placement of an LV vent as discussed in detail below.

Multiple studies show a benefit to peripheral cannulation rather than central cannulation. Mariscalco et al. published a large registry study examining 781 patients who required ECMO for PCS between 2010 and 2018. They found that central cannulation was associated with greater in-hospital mortality, reoperation for bleeding, and transfusion of greater than 9 units of packed red blood cells [9]. They proceeded to perform a meta-analysis of available literature and compared peripheral to central cannulation among 2490 patients requiring ECMO for PCS; they again found that peripherally cannulated patients have a lower in-hospital mortality rate. Djordjevic et al. reviewed 156 patients at their institution who underwent ECMO cannulation following cardiac surgery and also found that centrally cannulated patients were more likely to undergo an additional operation for mediastinal bleeding [12]. However, in this study, there was no statistically significant difference in 30-day mortality or length of hospital stay between centrally and peripherally cannulated patients.

Finally, Raffa and colleagues performed a meta-analysis of existing studies and reviewed a total of 1791 patients. This analysis showed no difference in all-cause mortality between peripheral and central cannulation, and no statistically significant difference in limb complications by cannulation style [13]. However, this paper did find a significant reduction in risk of bleeding and need for CRRT in peripherally cannulated patients.

Complications of Extracorporeal Membrane Oxygenation

Given the illness severity of patients placed on VA ECMO and the invasive nature of the treatment modality, it is unsurprising that ECMO patients suffer from a variety of complications. Sequelae of ECMO include acute kidney injury (AKI), bleeding, infection, stroke, intracranial hemorrhage, lower extremity ischemia, and LV distension. AKI
occurs frequently, and roughly 45% of ECMO patients require renal replacement therapy [14]. Bleeding also occurs commonly in ECMO patients, and some papers report reoperation for bleeding in up to 60% of patients [13], [14]. Neurologic complications including both stroke and intracranial hemorrhage are seen in 13-17% of patients depending on the study [13], [14]. Distal limb ischemia and LV distension are discussed below along with accompanying therapies.

**Distal Perfusion**

A common complication of peripheral VA ECMO is lower extremity ischemia caused by the femoral artery cannula preventing blood flow to the distal extremity. One meta-analysis found that some form of lower extremity ischemia occurred in 12-22% of patients. In the extreme case, lower extremity compartment syndrome requiring fasciotomy and/or amputation can occur though this is less common [10], [14].

Several techniques have arisen to prevent limb ischemia. Most frequently, a 6-8 French perfusion cannula is placed distal to the femoral arterial cannula in either the superficial femoral artery or common femoral artery [10]. The introducer can be connected to the side port of the ECMO cannula to provide antegrade flow to the leg. Alternative techniques to provide retrograde flow via either the posterior tibial artery or dorsalis pedis artery have also been described [15], [16].

**Left Ventricular Venting**

Patients on VA ECMO for cardiogenic shock due to any etiology are at risk for complications of poor LV unloading. PCS patients need venting to allow recovery, and choice of vent is less important than the presence of a vent at all.

Consequences of limited to no flow out of the LV include LV dilation and arrhythmias, LA dilation and pulmonary edema, and LV thrombus [17]. Placement of an LV vent mitigates these risks by either directly removing blood from the left ventricle (impella, percutaneous VAD, surgical vent in LV or right superior pulmonary vein) or by decreasing the barrier to LV ejection (Intra-aortic Balloon Pump or IABP).

As mentioned above, there are a variety of different choices for LV vents. Surgically, a vent can be placed directly into the LV or inserted into the right superior pulmonary vein (this may have already been placed during the case). Impella is a rotary pump that sits in the LV and moves blood from the LV to the ascending aorta. The device can be implanted surgically via graft to the ascending aorta or percutaneously (most commonly via the femoral artery) [18]. An IABP is inserted percutaneously via the femoral or axillary artery. An IABP does not cross the aortic valve and so does not directly unload the LV, but encourages forward flow out of the LV via counterpulsation.

In retrospective reviews and a meta-analysis each of the above types of vents have been associated with improved survival to hospital discharge [17], [19]–[21]. The RECOVER I trial explicitly examined the use of Impella alone in PCS patients and among the 16 patients studied found a 94% survival rate at 30 days (RECOVER 1).
However, this trial had a low sample size and very specific criteria for inclusion, notably excluding patients with a cardiac index of less than 1.3, renal failure, or RV failure among other criteria.

Discussion

Post-cardiotomy shock remains a rare, but often fatal complication of cardiac surgery. With a variety of technologies available to help these patients, it is important to make sure that we are optimizing their chances of survival. While there are papers that examine the association between cannulation style and outcomes in PCS patients, they have conflicting conclusions and significant limitations. The papers that support a benefit to central cannulation have low sample sizes [8], [11]. The studies that show improved outcomes with peripheral cannulation include more patients, and include a meta-analysis, but are still retrospective [9], [12], [13]. Mariscalco et al. published the largest study (apart from meta-analyses) and found that peripherally cannulated patients had a lower in-hospital mortality. Based on the available evidence we believe the choice of cannulation style must be decided based on the individual patient; however, in the absence of a compelling reason to cannulate centrally, peripheral cannulation should be considered.

The largest limitation of all the papers is that they are retrospective reviews or meta-analyses. While the authors have adjusted for many measured clinical variables, these studies are limited by the fact that peripherally and centrally cannulated patients are fundamentally incomparable. If the chest cannot be closed due to edema and the surgeon suspects multiple reoperations for bleeding, the patient will likely be cannulated centrally. This patient cannot be compared to a patient with a closed chest and adequate peripheral access who the surgeon suspects will not be taken back for bleeding. Cannulation choice can always be revised and ultimately is likely less important than allowing the heart to recover via venting and appropriate weaning from support.

Given the limited evidence available, we should focus on designing a study that will allow us to better determine if there is a benefit to cannulation style. Randomization is not a realistic goal in this critically ill population, but our data can be improved by prospectively collecting multi-institutional data. Overcoming the limitations of prior studies will require coordination between institutions.

Conclusion

Given the evidence available, there is no clear choice of cannulation style for all PCS cases, and cannulation strategy must be decided for each individual patient. The largest studies suggest peripheral cannulation is associated with improved outcomes, so it should be considered if the patient is not in clear need of central cannulation. Future work in this area should focus on prospectively collecting data from multiple institutions to increase sample size and generalizability.
References


ECMO for PCS

Inadequate perfusion despite inotropes

Central Cannulation
- Faster if chest already open
- No dual circulation
- Easier to take back for chest washouts

Peripheral Cannulation
- Easier to perform bedside in ICU
- Can close chest easily
- Better evidence that peripheral strategy associated with improved outcomes