

Postcardiotomy shock extracorporeal membrane oxygenation: Peripheral or central?



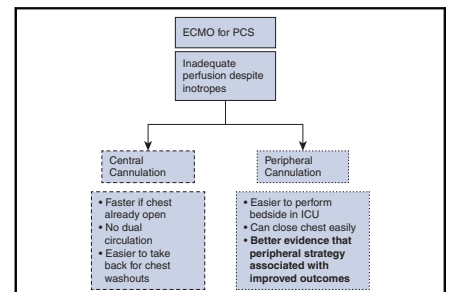
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Postcardiotomy shock (PCS) is poorly defined in the literature, but is broadly understood to mean circulatory failure after cardiac surgery necessitating mechanical circulatory support and high-dose inotropes. PCS occurs in 0.5% to 1.5% of all cardiac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

In the past there were a limited number 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 2 decades there has been a large increase in use of ECMO for all underlying etiologies, and a fivefold increase in the use of ECMO specifically for PCS. Unfortunately, the increase in use has not been paralleled by improved survival for patients in whom it is used.^{3,4} The percentage of PCS patients treated with ECMO who survive to hospital discharge varies on the basis of source, but ranges from approximately 30% to 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 1 study including age older than 70 years, preoperative renal insufficiency, obesity, female sex, and type of cardiac surgery among others.^{1,3,6} In a recent analysis patients in two 5-year time periods (2007-2012 and 2013-



Flow chart show summarizing key advantages to peripheral and central ECMO for PCS.

CENTRAL MESSAGE

On the basis of 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.

2018) were compared. Patients from 2013 through 2018 had lower in-hospital mortality and were more likely to be cannulated intraoperatively and earlier in their hospital course suggesting timing of support might be crucial to survival.⁷ Multiple studies support better survival when patients are cannulated at lower serum lactate levels with cutoffs ranging from 4 to 6 mmol/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. Herein, we review central and peripheral cannulation and discuss advantages and 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

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cannulae may be the same as those used for cardiopulmonary bypass, connected to the ECMO circuit rather than the bypass machine. Alternatively, the cannulae may be exchanged or replaced if the patient was previously decannulated.

There are several benefits of central cannulation. First, some patients might not be able to tolerate chest closure because of 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 in which inadequately oxygenated blood from the heart rather than oxygenated blood from the ECMO circuit feeds the head vessels.¹⁰ Another advantage to central cannulation is that if the chest is already open in the operating room central cannulation might 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 reopen 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 and colleagues⁸ reviewed 158 patients who required ECMO for PCS at their center between 2010 and 2019 and reported that 30-day survival was higher for centrally cannulated patients compared with those who were peripherally cannulated. They also reported that the peripherally cannulated group was more likely to require surgical cannulation revision because of either limb hyperperfusion or dual circulation. In this study, length of intensive care unit stay, need for reoperation, and transfusion requirements were all similar between groups. The authors concluded that central cannulation appeared to be beneficial. In a second study data on 31 patients requiring ECMO cannulation within 72 hours of a cardiac operation were reviewed and the authors showed 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 19 to 25 French and arterial cannulae are typically 15 to 24 French. 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 intensive care unit in an emergency, it is less invasive than central cannulation, and it does not require an open chest or chest reopening 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 the section, *Distal Perfusion*). 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 left ventricular (LV) dilation. However, this risk can be avoided by placement of an LV vent as discussed in detail in the section, *LV Venting*.

Multiple studies show a benefit to peripheral cannulation rather than central cannulation. Mariscalco and colleagues⁹ published a large registry study on 781 patients who required ECMO for PCS between 2010 and 2018. They reported that central cannulation was associated with greater in-hospital mortality, reoperation for bleeding, and transfusion of >9 units of packed red blood cells. They proceeded to perform a meta-analysis of available literature and compared peripheral with central cannulation among 2490 patients who required ECMO for PCS; they again showed that peripherally cannulated patients have a lower in-hospital mortality rate. Djordjevic and colleagues¹² reviewed data on 156 patients at their institution who underwent ECMO cannulation after cardiac surgery and also showed that centrally cannulated patients were more likely to undergo an additional operation for mediastinal bleeding. However, in this study, there was no statistically significant difference in 30-day mortality or length of hospital stay for centrally or peripherally cannulated patients.

Finally, Raffa and colleagues¹³ 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 according to cannulation style. However, this study did show a significant reduction in risk of bleeding and need for continuous renal replacement therapy in peripherally cannulated patients.

COMPLICATIONS OF ECMO

Considering the illness severity of patients given venoarterial (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, bleeding, infection, stroke, intracranial hemorrhage, lower extremity ischemia, and LV distension. Acute kidney injury occurs frequently, and approximately 45% of ECMO patients require renal replacement therapy.¹⁴ Bleeding also occurs commonly in ECMO patients, and some authors report reoperation for bleeding in up to 60% of patients.^{13,14} Neurologic complications including

stroke and intracranial hemorrhage are seen in 13% to 17% of patients depending on the study.^{13,14} Distal limb ischemia and LV distension are discussed in the following section 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 showed that some form of lower extremity ischemia occurred in 12% to 22% of patients. In the extreme case, lower extremity compartment syndrome requiring fasciotomy and/or amputation can occur although this is less common.^{10,14}

Several techniques have arisen to prevent limb ischemia. Most frequently, a 6- to 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}

LV VENTING

Patients receiving VA ECMO for cardiogenic shock because of 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 left ventricle include LV dilation and arrhythmias, left atrial 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 [Abiomed], percutaneous VAD, surgical vent in the left ventricle, or right superior pulmonary vein) or by decreasing the barrier to LV ejection (intra-aortic balloon pump [IABP]).

As mentioned previously, there are a variety of different choices for LV vents. Surgically, a vent can be placed directly into the left ventricle or inserted into the right superior pulmonary vein (this might have already been placed during the procedure). Impella is a rotary pump that sits in the left ventricle and moves blood from the left ventricle 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 left ventricle, but encourages forward flow out of the left ventricle via counterpulsation.

In retrospective reviews and a meta-analysis each of the previously described types of vents have been associated with improved survival to hospital discharge.^{17,19-21} In

RECOVER I the use of Impella alone was explicitly examined in PCS patients, and among the 16 patients studied a 94% survival rate at 30 days was reported. However, this trial had a low sample size and very specific criteria for inclusion, notably patients with a cardiac index of <1.3, renal failure, or right ventricular failure, among other criteria, were excluded.

DISCUSSION

PCS 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. Although there are reports on the association of cannulation style and outcomes in PCS patients, they have conflicting conclusions and significant limitations. The reports 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 and colleagues⁹ published the largest study (apart from meta-analyses) and showed that peripherally cannulated patients had a lower in-hospital mortality. On the basis of the available evidence we believe the choice of cannulation style must be decided on the basis of the individual patient; however, in the absence of a compelling reason to cannulate centrally, peripheral cannulation should be considered.

The largest limitation of all of the reports is that they are retrospective reviews or meta-analyses. Although the authors 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 because of edema and the surgeon suspects multiple reoperations for bleeding, the patient will likely be cannulated centrally. This patient cannot be compared with 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.

Considering the limited available evidence, 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 previous studies will require coordination between institutions.

CONCLUSIONS

Considering the available evidence, 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.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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