



Extracorporeal Life Support Organization (ELSO)

Guidelines for Pediatric Cardiac Failure

Introduction

This pediatric cardiac failure guideline is a supplement to ELSO's "General Guidelines for all ECLS Cases" which describes prolonged extracorporeal life support (ECLS, ECMO). This supplement addresses specific discussion for pediatric cardiac failure.

This guideline describes prolonged extracorporeal life support (ECLS, ECMO). This guideline describes useful and safe practice, but these are not necessarily consensus recommendations. These guidelines are not intended as a standard of care, and are revised at regular intervals as new information, devices, medications, and techniques become available.

The background, rationale, and references for these guidelines are found in "ECMO: Extracorporeal Cardiopulmonary Support in Intensive Care (The Red Book)" published by ELSO. These guidelines address technology and patient management during ECLS. Equally important issues such as personnel, training, credentialing, resources, follow up, reporting, and quality assurance are addressed in other ELSO documents or are center-specific.

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Pediatric cardiac cases

I Patient condition

A. Indications

1. Early postoperative cardiac failure in the operating room (unable to come off bypass).
2. In the ICU: the severity defined by pressor and inotropic requirement, metabolic acidosis, decreased urine output for 6 hours.
3. Cardiac arrest from any cause: with response to CPR but still unstable and no response to CPR direct massage underway for 5 minutes.
4. Myocardial failure unrelated to operation: myocarditis, cardiomyopathy, toxic drug overdose.
5. 5. Elective support through high risk catheter procedures

B. Contraindications:

1. Age and size: in general any infant considered old and large enough to undergo a cardiac operation is an appropriate candidate for ECLS.
2. Futility: the likelihood of a normal child resulting from the treatment is small
3. CPR ongoing > 5 minutes (see above)

C. Special patient considerations:

1. Untreatable underlying diseases and congenital malformations
2. Consider whether the patient is a candidate for heart transplantation on the first day of ECLS. The answer will set the goals and the time limitations for ECLS or other support systems.
3. Converting to and from cardiopulmonary bypass in the operating room is a special consideration discussed in VI

II Extracorporeal Circuit: general protocol

A heat exchanger will be required for management of these patients.

III Vascular Access

- A. All cardiac support requires venoarterial access

B. Chest cannulation is usually used when the patient cannot be weaned from cardiopulmonary bypass in the operating room. The right atrial and aortic catheters are used for ECMO access. The aortic access catheter may be too small for arterial access under prolonged conditions of normothermia and higher flows and hematocrit than during CPB. This will be indicated by high pressures in the blood return line and possibly by hemolysis.

C. Neck cannulation: VA access through the jugular and carotid is used for children < 10 Kg because of the very small size of the femoral vessels in children who are not walking.

D. Femoral vessels: the femoral or iliac vessels are usually large enough to permit appropriate vascular access in children over 10-15 Kg of weight. Both the artery and vein will be occluded by the catheter so provision must be made for perfusion of the distal leg. Venous collateral is usually adequate to avoid excessive edema and venous congestion.

IV Management during ECLS

A. Circuit related: General Protocol

1. Traveling to the cath lab or the operating room or the CT scanner is often required for pediatric cardiac cases, so the access tubing and circuit must be planned with that in mind (elevators, battery power, monitors outside of the ICU, etc.).

B. Patient related

1. Hemodynamics: Blood flow is managed to maintain the venous saturation 70-80%.

2. Ventilator: Patients may begin with pulmonary edema but this often clears early in management. The patient can be extubated during most of ECLS run. If the patient remains intubated, the ventilator should be managed at very safe levels ($FiO_2 < 40\%$, plateau pressure < 20 cm/H₂O).

3. Anticoagulation and bleeding: Standard anticoagulation is used for all patients, but bleeding is expected if the patient has undergone a recent operation under cardiopulmonary bypass. Whole blood activated clotting time should be maintained at 1.5 times normal for the ACT device. If the ACT is significantly prolonged despite a wide range of heparin dosage, consider the fact that antithrombin 3 levels may be severely decreased. This can be treated empirically with fresh frozen plasma. If intrathoracic bleeding occurs in a patient cannulated through the neck with a closed sternum, there should be a low threshold for opening the chest in the ICU, reexploring the operative sites, evacuating clot, and controlling bleeding as much as possible. Once the chest has been opened (or if the patient is taken directly from the operating room with the chest open) the chest should be left open, suction drains placed and the entire wound covered with a sealed plastic drape adherent to the skin. This will allow direct examination for subsequent bleeding and maintain a very low threshold for reexploration if bleeding persists, particularly if tamponade physiology occurs. The use blood aspiration and return (autotransfusion.) makes special measures for excessive bleeding in open chest patients.

V Weaning

The standard protocol describes weaning under conditions of recovering cardiac and pulmonary function. In these patients, futility relates to whether or not the patient is to be listed for cardiac transplantation. If transplant is possible, then appropriate measurements for matching should be made early in the course and conversion to ventricular assist device considered as soon as patient condition permits. If transplant is not an option, ECLS is used as a bridge to recovery. A ventricular assist device should not be used (under 2007 conditions), and a time limit should be established for recovery of the heart, or discontinuation of ECLS if the heart is not recovered in a defined time (typically 10-14 days).

VI Patient specific issues

A. Patient unable to come off cardiopulmonary bypass in the operating room. Once it is clear that a patient cannot be weaned from CPB despite appropriate pharmacologic measures, the decision to go to the ICU with ECMO support should be made sooner rather than later. The longer the patient is on CPB and high dose pressors the greater the fluid overload, thrombocytopenia, metabolic acidosis, and risk of organ injury. Once the decision for ECLS has been made the patient should be converted to the ECLS circuit and moved to the ICU (without prolonged attempts to stem bleeding in the operating room). The ECLS circuit is attached directly to the intracardiac cannulas after infusing most of the blood in the reservoir into the patient. Once on ECLS, blood in the CPB system should be transferred to blood bags for transfusion in the ICU. The chest is left open with enough suction drains to prevent blood overflow, and the chest is covered with an adhesive plastic drape. The patient will be systemically heparinized with the prolonged ACT. When ACT has reached a level of twice normal a low dose of heparin infusion is done with the goal of maintaining ACT at 1.5 times normal. The bleeding is generally due to thrombocytopenia, thromboctopathia, and fibrinolysis rather than heparinization per se, so reversing heparin with protamine is rarely helpful. The patient is warmed with the heat exchanger to 37° to enhance coagulation and platelet function. Platelets are transfused to maintain a level greater than 80,000. The use of aminocaproic acid is indicated. Despite these maneuvers bleeding will persist for several hours, treated by appropriate transfusion of red cells, platelets and fresh frozen plasma. Factor VII should be considered, but only after normothermia is obtained and the other coagulation factors and platelets are as normal as possible (because of the high cost of Factor VII). If mediastinal sheds blood is collected in a sterile fashion it can be reinfused although it is best to wash shed blood and reinfuse only the red cells. 24-48 Hours after CPB the heart has often recovered from myocardial stun and ECLS can be discontinued. If the heart has not recovered within that time the decision regarding possible transplantation should be made, and the remaining course identified as bridge to VAD to transplant or bridge to recovery as discussed in section V.

B. Myocarditis and Myocardiopathy. The prognosis in these conditions is generally good. The threshold for going on ECLS should be quite low because intractable arrhythmias or

diastolic arrest can occur without warning. Cannulation is via the neck vessels up to age 2-3, beyond age 3 their neck or femoral vessels can be used.

C. ECPR in children. ECLS is a valuable adjunct to CPR if it is instituted early (see I). Although CPR > 5 minutes is a general rule for a contraindication (because of the high likelihood of brain damage), if CPR is done successfully with evidence of good perfusion longer periods of arrest may be considered an indication. This is particularly true in situations like the cath lab where successful CPR can be carried on for an hour or more.

D. Echocardiography. Following ventricular function by echocardiography is an essential adjunct to ECLS management for cardiac failure. During high flow VA ECLS the heart will be relatively empty, so it is necessary to turn the flow down until the atria are appropriately filled in order to evaluate ventricular function. ECHO is the most valuable method to determine the extent of myocardial recovery. In addition ECHO can help to identify the position of intravascular catheter, the status of valve and conduit function, and the presence of clot in the cardiac chambers.

E. Non functioning ventricles, left side venting, inotropes, pulsatility and clots in the heart. If the left ventricle function is inadequate to open the aortic valve, left ventricular diastolic pressure and left atrial pressure will gradually increase during VA support, as the left side of the heart fills with bronchial venous flow, thebesian flow and any blood passing from the right side to the left. This will cause a gradual increase in left atrial pressure. When the left atrial pressure reaches 25-30 pulmonary edema will ensue. This process takes 4-8 hours in most cases. If the left ventricle is not emptying through the aortic valve the left side of the heart must be vented into the venous drainage of the ECLS circuit within a few hours. If the chest is open this can be done simply by placing a catheter in the left atrium directly. If the chest is closed this is best done by creating an atrial septal defect with a balloon septostomy in the cardiac catheterization lab. If a cardiologist experienced in this procedure is not available direct atrial venting should be done by a thoracotomy. To avoid the need for left sided venting it is worthwhile to attempt inotropic drugs to improve left ventricular contractility and vasodilator drugs to decrease systemic vascular resistance. Aside from avoiding left sided pressure, pulmonary edema and the need for venting, maintaining continuous blood flow through both sides of the heart is important to prevent clotting in the pulmonary vessels or myocardial chambers. Even with coagulopathy and systemic heparinization stagnant blood will gradually clot, most commonly in the left atrium and left ventricle. This is detected by echocardiography. If there are clots on the left side of the heart there is a risk of systemic embolism if and when myocardial function returns, creating a management dilemma. The best approach is to realize that native myocardial recovery will not occur. If the patient is a transplant candidate inotropes should be discontinued and a search for a donor emphasized. If there are clots in the heart and the patient is not a potential transplant candidate this is a sign of futility and an indication to discontinue ECLS.

F. Pulsatile flow. For the reasons discussed in E above it is important to maintain left ventricular function which will result in some systemic pulsatile flow (approximately 10 mm/Hg pulse pressure). If the native heart does not provide any pulse pressure, is there any advantage to using a pulsatile pump to maintain pulsatility for systemic organs? The answer is that pulsatility during VA perfusion is not important as long as the total perfusion is adequate (3 L/m²/min or

higher, venous saturation > 75%). In addition to being unnecessary, maintaining pulsatile flow may be deleterious because the arterial infusion catheter is usually quite small, and the intermittent high flow rates during the systolic phase of pulsation may lead to high pressure in the perfusion circuit and hemolysis.

G. Cath Lab trips. Cardiac function can be effectively followed by echocardiography, but there should be a low threshold for repeat cardiac catheterization during ECLS to measure pressures, flows, saturations etc.

VII Expected results

Series in the literature and ELSO registry data.