Technique

Extracorporeal Life Support of Neonates with Congenital Cardiac Defects: Techniques Used During Cardiac Catheterization and Surgery

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ABSTRACT

Neonatal patients with congenital cardiac defects require proper diagnosis often by cardiac catheterization before surgical repair. In our institution, patients whose echocardiograms reveal surgically correctable lesions, but who are severely decompensated, have been placed on Extracorporeal Life Support (ECLS) prior to catheterization or surgery. Subsequent management of ECLS and cardiopulmonary bypass (CPB) are dictated by the surgical procedure. Hypothermia can be utilized while on ECLS to facilitate low-flow CPB, or circulatory arrest. Total extracorporeal circulation may be performed with the ECLS circuit, or the patient may be transferred to a conventional CPB circuit during the procedure. If required, post surgical ECLS can be facilitated through prior cannulation. We have found pre-operative institution of ECLS, in the neonate with severe congenital cardiac defects, provides immediate control of hemodynamic and respiratory problems, lowers the risk of cardiac catheterization, and reduces the usage of blood products during surgery.

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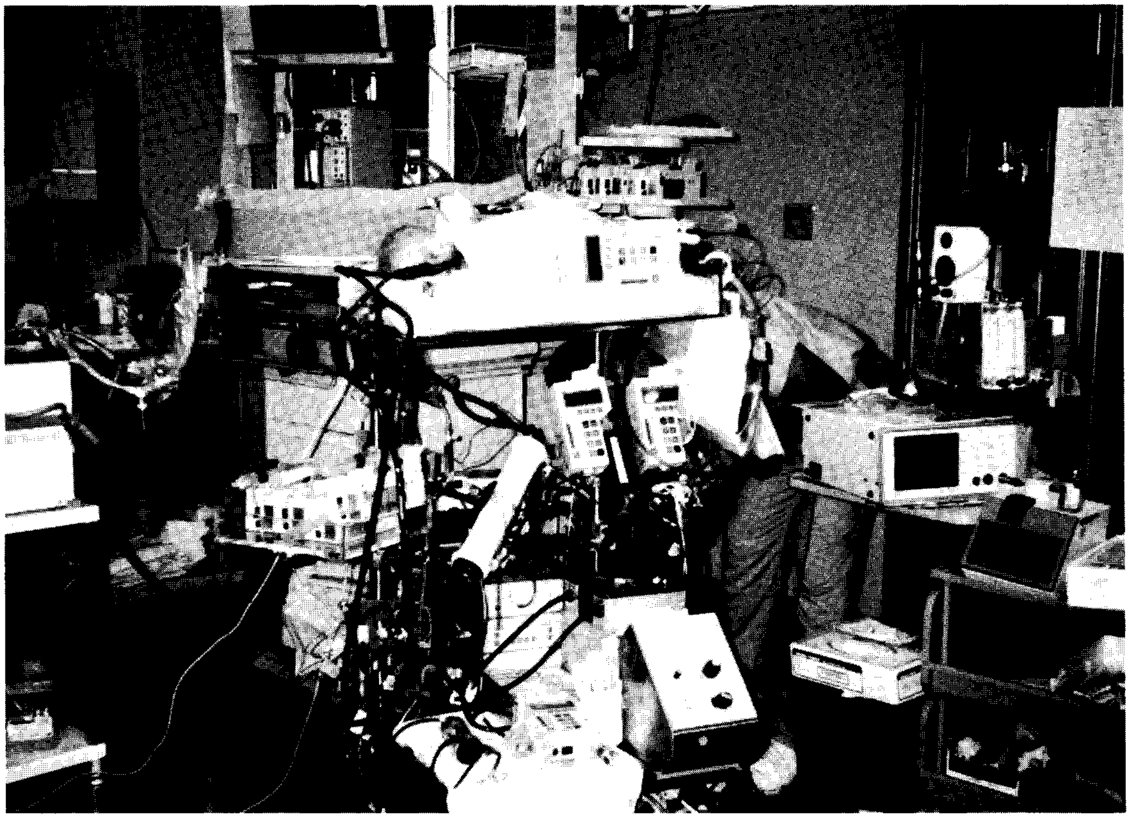


Figure 1
Neonates in transportation cradle on mobile ECLS pump. Patient has been readied for transport to the catheterization laboratory

INTRODUCTION

Although Extracorporeal Life Support (ECLS) successfully treats neonates with respiratory failure, ECLS for cardiac patients has not been as successful (1). Overall survival of the 246 neonatal cardiac patients registered with Extracorporeal Life Support Organization (ELSO) is only 49%, compared to a survival rate of approximately 80% or greater for patients with respiratory failure (2). We have recently employed ECLS to stabilize four neonates with congenital heart disease who were unresponsive to medical management. In all four infants, echocardiography revealed a potentially correctable cardiac defect despite their severe hypoxemia. All underwent cardiac catheterization while on ECLS. Techniques utilized to support infants with congenital heart defects prior to, or during, diagnostic and therapeutic procedures are reviewed.

MATERIALS AND METHODS

Methods of ECLS in the Catheterization Lab

Cannulation for ECLS is performed in the intensive care unit alleviating the risks associated with patient transport. Once the patient is stabilized by ECLS, transportation to the catheterization lab for further cardiac evaluation or to the operating room for surgical repair can proceed.

The design of the ECLS equipment allows placing the patient on a cradle attached to the top of the pump stand (Figure 1). In transport, the roller pump is converted to battery power and all infusion syringes are secured either in the cradle or on a side tray attached to the roller pump. A syringe of 5% albumin or packed red blood cells is attached to a port on the venous side of the circuit for immediate infusion should venous return become inadequate. During transport, one person is responsible for monitoring the venous reservoir since servo-regulation of the roller pump is de-activated while on battery power. Another person secures the cannulae to protect them from dislodgement. Respiratory care personnel transport the ventilator to the cath lab. If ECLS is adequate, the patient need not be ventilated during the transport.

Upon arriving in the cath lab, the pump is reconnected to an electrical outlet and servo-regulation reestablished. Other safety devices including the low level alarm, air bubble detector, and venous Doppler are reactivated. Mechanical ventilation is restarted and the cannulae are secured with "O" ring tubing clamps. Standard cardiac catheterization is then performed taking into account the patient's anticoagulated state. Communication between the cardiologist and the ECLS technician is of the utmost importance during the procedure especially during movement of the table and patient (Figure 2). The ECLS specialist continues routine monitoring and charting during the cardiac catheterization.

The cardiologist will advise the ECLS coordinator and

Figure 2
Cardiac catheterization being performed via umbilical vein while the patient remains on ECLS

specialist when cineangiography is to be performed. Depending on the site of contrast injection, removing the clamp from the bridge of the ECLS circuit may improve the quality of the cineangiogram. The patient's blood pressure will drop during this period of time but should return to its original point shortly after the clamp is replaced on the bridge.

If the patient develops ventricular fibrillation, pump flow is increased as much as possible to reduce the risk of cardiac distension. The patient often spontaneously converts to sinus rhythm by the increased pump flow. Any required anti-dysrhythmic agents are administered at a post-membrane port of the circuit. Following completion of the catheterization, the patient is returned to the intensive care unit or taken to the operating room. Routine monitoring and hourly procedures are performed until the patient is transported to the operating room.

ECLS in the Operating Room

Deep hypothermia with circulatory arrest

Similar transport procedures are utilized to transport the ECLS patient to the operating room. Patients having repair under deep hypothermia, with circulatory arrest, are cooled through the ECLS heat exchanger attached to a cooler/heater[a] using the temperature probe located post heat exchanger to record arterial blood temperature (Figure 3).

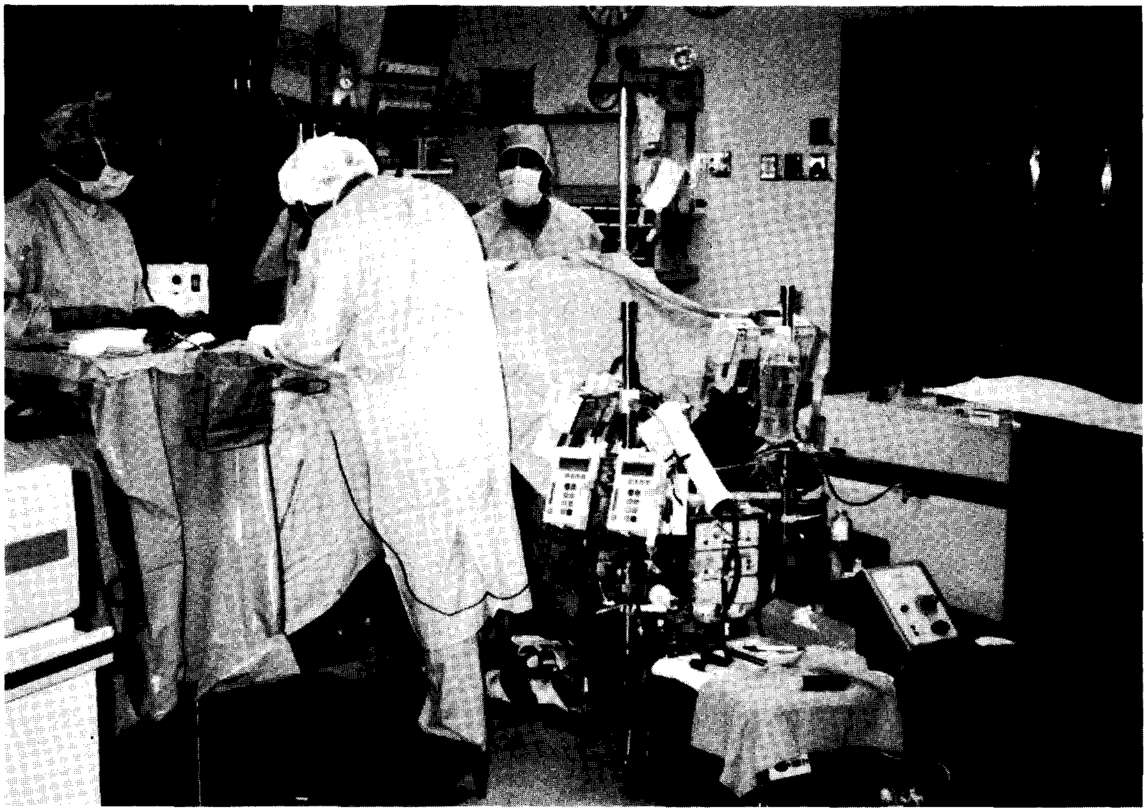
The patient's hematocrit is lowered by aspirating blood from the activated clotting time (ACT) sampling port into a sterile blood bag while simultaneously infusing crystalloid solution into the platelet port (Figure 4). During this procedure it is important to adjust the withdrawn and infused volumes so as to maintain the filling pressure of the heart and the blood pressure at the desired level. As the withdrawn blood contains heparin it is sent to the blood bank to be washed and spun for later use as packed red blood cell transfusions during rewarming. Exsanguination with volume replacement is continued until the hematocrit reaches approximately 20%.

Once the patient reaches the desired temperature, the ECLS pump is turned off, oxygen disconnected, all infusions stopped, and clamps applied to the arterial and venous lines close to the pump. A section of the venous line at the lowest point of the circuit is double clamped and prepped with provodone iodine. The tubing is cut, a 1/4 x 1/4 x 1/4 "Y" connector inserted, and a sterile blood bag is attached to a side arm (Figure 5). The venous clamp by the patient is opened and blood drained into the bag until the surgeon signals the heart is empty, at which time a clamp is applied to the blood bag. The arterial and venous circuit limbs between the patient and the circuit bridge are clamped, the other circuit clamps are removed, and the pump is restarted at a blood flow rate of 150 ml/min allowing recirculation through the circuit during surgery.

Near the end of circulatory arrest the previously washed and spun red blood cells are drawn into a syringe, connected to a transfusion set, and attached to an infusion port on the venous side of the circuit. The blood bag previously attached via a "Y" on the venous line is inverted and readied for re-infusion. The pump is shut off and the clamp on the arterial line is removed and placed on the bridge of the ECLS circuit. The roller pump is restarted at a flow rate of 50 ml/min and the clamp on the blood bag released. Once the volume in the blood bag is transfused a clamp is reapplied to the blood bag tubing. The washed packed red blood cells recovered during hemodilution are then infused into the venous line. A unit of packed red blood cells is also available if needed. Pressure in the venous reservoir is closely monitored and blood infusion rate adjusted in an attempt to maintain the pre-operative reservoir pressure. As the heart begins to fill, the clamp on the venous line is slowly removed, and ECLS flow restarted to the patient. Once the venous clamp is removed pump flow is gradually increased to 120-130 ml/kg/min. The water bath is turned on and the patient rewarmed. During rewarming mannitol (1 gm/kg) is infused post-membrane. When the patient reaches a blood temperature of 35°C, 500 mg calcium chloride is infused followed by rapid infusion of one unit of

a Cincinnati Sub-Zero, Cincinnati, OH

Figure 3
Post-operative rewarming of patient using ECLS in the operating room



reduced volume platelet pheresis into a post-membrane port. One unit of cryoprecipitate is given after the platelet infusion through the same infusion port. ACT is monitored closely and heparin boluses given as needed to maintain ACT at 200-240 seconds. Arterial blood gas tensions and pH are measured and derangements in acid/base homeostasis are corrected.

Care is taken to establish surgical hemostasis by liberal use of an electrocautery and topical thrombostatic agents. The chest incision remains open but covered with an iodized plastic adhesive drape. Once completely warmed and stable the patient is transported to the intensive care unit as previously described. In the intensive care unit a coagulation panel is completed and the patient's hematocrit adjusted to 40% utilizing diuretics, an ultrafiltration device, and infusions of packed red blood cells. Special attention is paid to maintain the filling pressures within acceptable ranges during readjustment of the hematocrit (Figure 6).

Moderate hypothermia with low blood flow

Patients that do not require deep hypothermia with circulatory arrest can have their body temperature lowered to 28-30°C while continuing support with a reduced pump flow (50 ml/kg/min). Acceptable blood pressure and filling pressures are obtained by removing blood via an infusion port on the venous or arterial side of the ECLS circuit. This blood is processed as previously described and returned to the operating room for reinfusion during rewarming.

A second ECLS pump with two roller pump heads and 1/4" tubing is used for sterile field suction. Any blood aspirated from the field is collected in a vented hard-shell reservoir. Salvaged blood is aspirated into a syringe from the reservoir and sent to the blood bank for processing. Following repair, the stabilized and rewarmed patient is transported to the intensive care unit.

Converting from ECLS to conventional CPB

Conventional CPB is always available should it become necessary. Mediastinal cannulation can be performed while maintaining ECLS. Once the chest cannulae are in place and the CPB circuit attached, standard cardiopulmonary bypass is initiated, and the ECLS circulation discontinued by placing clamps on the arterial and venous lines close to the roller pump. The sweep gas line is removed and all infusions stopped. If the bridge and cannulae are accessible the clamps are adjusted to allow recirculation of the ECLS circuit.

Once the repair is completed, the switch from conventional CPB to ECLS can be made if long-term support is needed. To start ECLS, the arterial clamp is removed, the bridge is clamped, and the venous clamp is removed. ECLS flow is increased slowly to 120-130 ml/kg/min. The patient is weaned from conventional CPB and the chest arterial and venous lines are clamped on the sterile field. Close communication between the surgeon, perfusionists, and ECLS teams is essential to avoid confusion over which circuit and team is being addressed. Should the patients require volume expansion, transfusion from the CPB circuit is possible. It is not uncommon to encounter some venous air detected by the Doppler on the venous line when reinstituting ECLS. Significant air can be easily aspirated from the venous reservoir. Once the patient is stabilized, the conventional CPB cannulae are removed. Any blood left in the CPB circuit is processed by the blood bank and reinfused as necessary into the ECLS circuit. As above, adequate surgical hemostasis is required before the patient is transported to the intensive care unit.

RESULTS

Four neonates with structural congenital heart defects have been supported on ECLS prior to catheterization or surgery at our institution. One patient was transported while on ECLS from a referring level III nursery but found at catheterization to have inoperable total anomalous pulmonary venous return. A second patient transported from a referring hospital on ECLS had transposition of the great vessels with intact ventricular septum. The patient underwent surgery and was successfully weaned from ECLS, but expired several weeks later from renal failure. The third patient demonstrated total anomalous pulmonary venous return on echocardiography with marginal distal pulmonary arteries. ECLS was instituted and the patient transported to the catheterization lab for diagnosis. Cardiac repair utilizing deep hypothermia with circulatory arrest was performed while the patient remained on ECLS. Following surgery the patient required prolonged ECLS. He was eventually weaned from ECLS but later expired from pul-

Figure 4
Lowering hematocrit by exchange transfusion with crystalloid

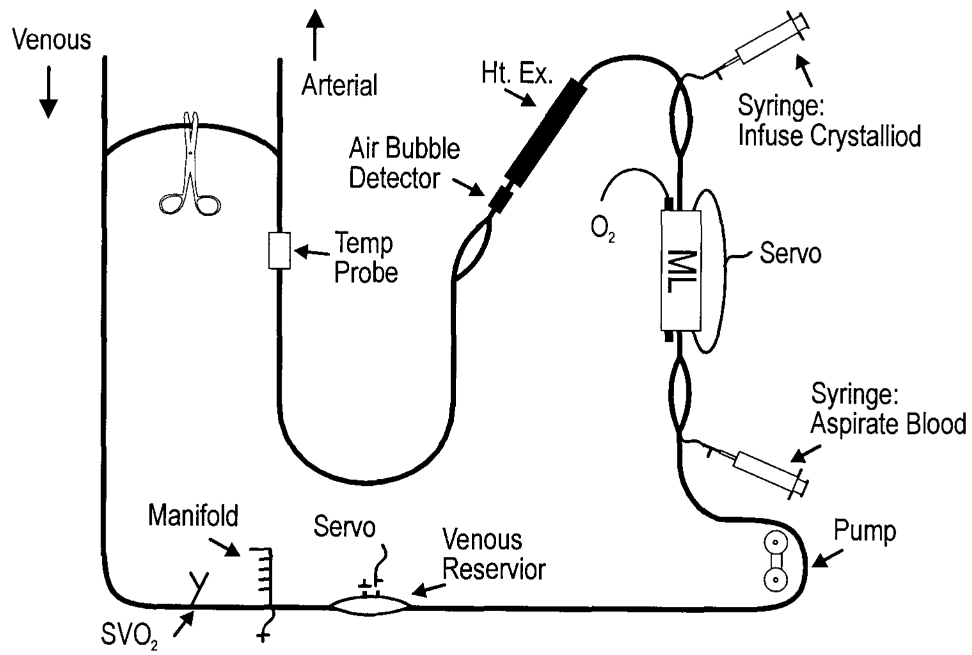
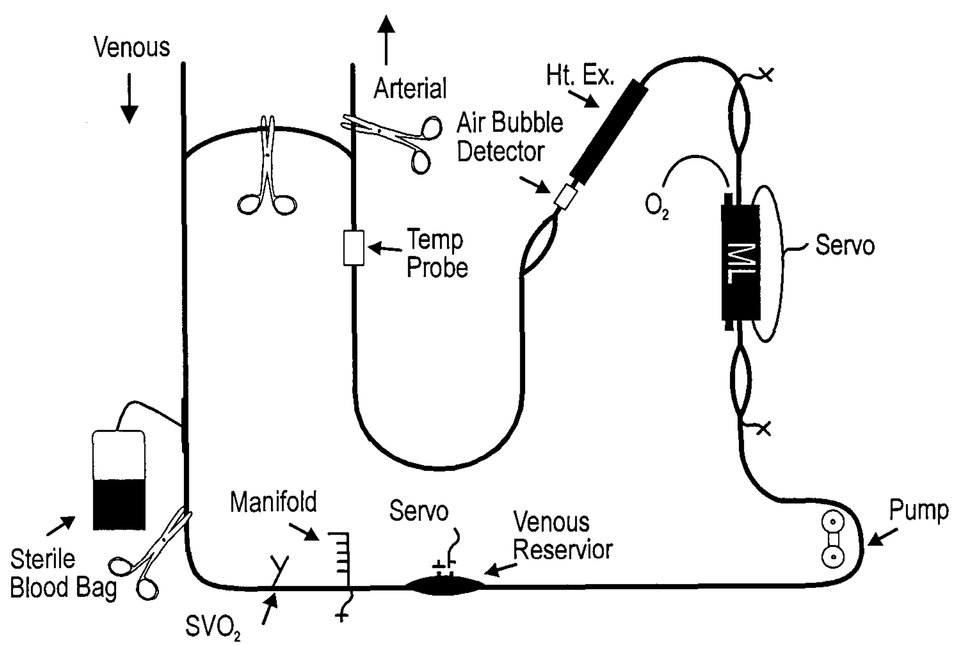


Figure 5
Draining venous line during deep hypothermia and circulatory arrest



monary arterial hypoplasia. The fourth patient had profound hypoxemia and was placed on ECLS after echocardiography demonstrated pulmonary atresia/ventricular septal defect. He underwent cardiac catherization followed by surgical repair and required continued ECLS post-operatively. The patient was successfully weaned from ECLS and was discharged home on post-operative day 22. All patients except the infant with an inoperable lesion were able to be weaned from either CPB or ECLS.

CONCLUSION

ECLS can be used to support severely compromised neonates with repairable cardiac defects. This facilitates stabilization of the patient while protecting organ function from the effects of hypotension and hypoxemia. Transportation to the catheterization laboratory or operating room can be performed safely. ECLS reduces the stress on the severely compromised patient allowing time to perform diagnostic procedures under more ideal conditions.

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Figure 6
Ports used to change vascular pressures