

Care and Management of the Cardiac Patient on Venous-Arterial Extracorporeal Membrane Oxygenation (VA-ECMO)

What the Critical Care Nurse Needs to Know

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Introduction:

Extracorporeal life support (ECLS) is a mechanical circulatory support modality for prolonged, though temporary cardiopulmonary support for severe cardiac or respiratory failure refractory to conventional therapies. The Extracorporeal life Support organization (ELSO) registry reports considerable variability in survival related to differences in anatomic diagnosis, surgical procedure, and ECMO indication among institutions using ECMO. This variability in outcomes reflects differences in patient selection, timing of ECMO cannulation and ECMO management.

Critical thinking points for initiation of VA-ECMO:

- General indications:
 - Respiratory failure
 - Myocardial failure
 - Support initiated during cardiopulmonary resuscitation (CPR) or ECPR
 - Short-term procedural support
 - Bridge to ventricular assist device (VAD) support, heart or lung transplantation or decision
- Contraindications:
 - Poor prognosis from primary illness
 - Irreversible disease
 - Advanced multisystem failure
 - Hemorrhage
 - Severe neurological insult
 - Prematurity (<34 weeks gestation)
 - Extremes in size and weight
- Indications for initiation
 - Progressive cardiac or respiratory failure despite escalation of cardiac and/or respiratory support
 - Inadequate oxygen delivery
 - Progressive acidosis and rising serum lactate levels
 - Signs of end-organ dysfunction including inadequate urine output

- Impending cardiovascular collapse or cardiac arrest unresponsive to resuscitation

Preparation for elective cannulation

- Secure venous access (central if possible) for medications & volume administration with infusion line extending beyond sterile field
- Secure endotracheal tube (ETT) to avoid dislodgement
- Ensure access to arterial line for blood drawing if possible during procedure if possible
- Ensure equipment readily available:
 - Mediastinal cart
 - Primed ECMO circuit with appropriate sized venous and arterial catheters
 - Cautery with pads attached to patient
 - External pacemaker attached to wires and accessible from sterile field
 - Defibrillator and pads (+/- internal paddles for central cannulation)
 - Surgical head lights as indicated
- Fluid and blood products available at the bedside
- Emergency cart accessible with emergency medications readily available
- Heparin bolus available for cannulation (50-100 units/kg, maximum 5000 units)
- Inotropic infusions in line, ready for use as indicated (dopamine, epinephrine)
- Position patient for cannulation as appropriate and prepare for sterile procedure utilizing maximal sterile barriers
- CPR board under patient as indicated
- Appropriate personnel and support
 - Cardiac surgeon (and OR support staff if available)
 - ECMO perfusionist
 - CICU medical staff
 - CICU nursing staff
 - Respiratory therapist
 - Blood bank
- Ensure safety with cannulation & consider “time-out” for attachment of venous and arterial cannula

ECMO CPR (ECPR)

- Witnessed arrest with good prognosis from primary disease
- Prompt decision making to cannulate with no response to conventional CPR
- Prompt notification and accessibility of the appropriate personnel (as above)
- Consider mild hypothermia for neurological protection

- Effective CPR with adequate chest compressions and minimal interruptions to compressions
- Minimize time to cannulation and once cannulated, ensure adequate ECMO flow and end organ perfusion
- Clear primed circuit if blood products not readily available

Anticoagulation and Hemostasis

- *Bleeding* and *thrombosis* (patient or circuit) events are very common
 - Bleeding can arise from viscera or cannulation sites
 - Thrombosis can be caused by contact activation of the coagulation cascade during blood-prosthetic surface interaction
 - Hematology/Coagulation consultation if indicated in certain cases
 - Age related differences in coagulation should be considered (See Pediatric Anticoagulation Guideline)
- Unfractionated heparin (UFH) is most commonly used for anticoagulation
 - Inadequate antithrombin (AT) III can minimize heparin effect despite therapeutic doses
 - Normal AT levels vary by age (neonates have lower AT levels) but in general should be maintained around 80-120%
 - Replace as indicated per institutional guideline with Thrombate III, Recombinant AT or fresh frozen plasma (FFP)
 - Bolus heparin 50-100 unit/kg (maximum 5000 units) for cannulation as indicated
 - Patients who are bleeding may require a smaller dose
 - Titrate heparin infusion to maintain desired range as per institutional guidelines and per institutional specific assay for maintaining anticoagulation (10-50 units/kg/hr)
- Common anticoagulation assays/levels used based on institutional protocols
 - Activated Clotting Time (ACT)
 - Assessment of whole blood clotting
 - Normal Values: 80-160 sec
 - ECMO Values: 180-240 seconds
 - Activated Partial Thromboplastin Time (aPTT)
 - Assessment of intrinsic pathway
 - Normal Values: 30-40sec
 - ECMO Values: 1.5x normal
 - Anti-Xa level
 - Assessment of clotting activity

- ECMO Values: 0.35-0.71 units/ml
 - Thromboelastography (TEG)
 - Assessment of whole blood clotting, fibrinolysis and platelet activity
- Strategies to prevent thrombosis
 - Monitor circuit for early signs of thrombus especially in febrile states
 - Optimize anticoagulation
 - Increase anticoagulation during low flow states (e.g. weaning)
- Strategies to treat bleeding on ECMO
 - Administer blood products as indicated based on institutional protocol
 - Platelets for level < 100K
 - Packed red blood cells for hematocrit < 35%
 - Cryoprecipitate for fibrinogen level < 100-150 mg/dl
 - FFP for Prothrombin Time > 17 seconds
 - Consider antifibrinolytic agents
 - For patients with fibrinolysis or surgical bleeding
 - Rapid access to a new ECMO circuit should be available for patients stopping therapeutic anticoagulation and receiving pro-coagulant or thrombostatic agents due the high incidence of clot induced circuit failure
 - Administer as per institutional protocol
 - Epsilon Amino Caproic Acid (Amicar) (adjust for renal dysfunction)
 - Tranexemic Acid (adjust for renal dysfunction)
 - Factor VIIa (high risk of circuit failure)

Post-cannulation stabilization

- Ensure adequate ECMO flow (usually ~ 100 ml/kg/min)
- Adjust hemodynamic support as indicated
- Adjust mechanical ventilator support as indicated
- Evaluate for tissue perfusion & end organ dysfunction
 - Assess vital signs & hemodynamics
 - Assess laboratory studies:
 - ABG
 - Lactate
 - SaO₂
 - Hepatic function
 - Renal function
 - Hematologic studies (CBC, platelet, PT, PTT, fibrinogen, AT III)

- Obtain CXR to evaluate cannula position
- Physical exam
- Assess neurological status
- Assess limb perfusion with femoral cannulation
- Correct abnormal hematological values & administer blood products as indicated
 - Monitor & treat bleeding
 - Assess for cardiac tamponade as indicated for open sternotomy cannulation
- Evaluate for left atrial (LA) hypertension & left ventricle (LV) decompression
 - Echocardiogram as indicated
 - Management of LA hypertension if indicated
 - Placement of LA vent for open sternotomy cannulation
 - Intra-atrial shunt via transcatheter approach
- Fluid management & initiation of ultrafiltration prn
- Assess for reversible causes of decompensation as indicated
 - Echocardiography
 - Laboratory studies
 - Chest exploration as indicated
 - Cardiac catheterization &/or surgical intervention as indicated

Routine Management

- Neurological
 - Monitor pupil size and equality as well as pupillary response to light.
 - Monitor level of consciousness (LOC) using Glasgow coma scale
 - For neonates and infant monitor anterior fontanel for size and fullness
 - Observe for any signs of seizure, electroencephalogram (EEG) monitoring if indicated
 - Monitor temperature of patient
 - Avoid significant hypothermia to prevent derangement of coagulation system & increased systemic vascular resistance (SVR)
 - Avoid hyperthermia
 - Head ultrasound (HUS) for infants prior to cannulation if possible, routine HUS based on institutional protocol
 - Early neurology consultation & follow-up based in institutional protocol
- Cardiovascular
 - Continuous cardiac monitoring and frequent assessment of electrocardiogram (ECG), rhythm, heart tones, capillary refill time, peripheral pulses, central and peripheral color, signs of edema

- Assess peripheral perfusion with femoral cannulation and need for distal perfusion graft if indicated
- Monitor mean arterial blood pressure since waveforms are usually dampened on full flow
 - Assess for LV clots with absence of pulsatility
 - Evaluate for return of pulsatility as flow rate is decreased & with increased myocardial contractility
- Maintain adequate cardiac preload with volume readily accessible
- Avoid increased SVR associated with hypothermia, excessive inotropic agents, tamponade, circuit issues and stress
 - Provide afterload reducing medications as needed
 - Judicious use of inotropic agents to promote cardiac contractility if indicated
- Cerebral / splenic saturations may be monitored with use of Near infrared Spectroscopy (NIRS) which can be helpful in trending changes in oxygen consumption and delivery
- Pulmonary
 - Decrease ventilator settings to allow lung rest (this may include decreased IMV, PIP, PEEP & FiO2 settings as appropriate based on patient indication)
 - Maintain functional residual capacity (FRC) to facilitate oxygenation of pulmonary blood flow without over-ventilating the lungs
 - Perform respiratory assessment every hour and prn including evaluation of breath sounds, aeration, work of breathing, chest movement, presence of cyanosis, & secretions – endotracheal tube (ETT), oral / nasal secretions.
 - Gentle pulmonary toilette to avoid bleeding
 - Avoid muscle relaxants if possible to promote intrinsic patient respiratory effort
- Gastrointestinal
 - Measure abdominal girth as indicated, and assess for presence of bowel sounds, abdominal distention, and any tenderness or firmness to palpation.
 - Assess gastric drainage & stool output, and monitor for bleeding
 - H2 blocking medications such as ranitidine as indicated
 - Provide parenteral nutrition as indicated and promote early enteral feeding
- Fluid & Nutrition
 - Assess hourly urine output and monitor routine renal function tests & electrolytes

- Oliguria and acute tubular necrosis (ATN) are common during the first 24 to 48 hours associated with capillary leak and intravascular volume depletion related to an acute inflammatory reaction from ECMO
- Diuretic phase usually begins within 48 hours and is one of the earliest signs of recovery.
- Diuretics & renal range dopamine to promote patient diuresis as appropriate
- Hemofiltration or hemodialysis may be added to ECMO circuit if renal failure does not improve
- Infection
 - Usual indicators of sepsis are unreliable on ECMO since platelets are routinely destroyed by the circuit & temperature is controlled by the heat exchanger
 - Assess for signs and symptoms of infection including, but not limited to: glucose instability, peripheral vasodilation or vasoconstriction, signs of incisional and/or central access site infection
 - Routine monitoring of CBC with differential
 - Antibiotics and fungal prophylaxis per institutional protocol
 - Surveillance cultures as indicated based on institutional protocol
- Pain and Sedation
 - Avoid excessive movement which may result in cannula dislodgement or bleeding at the cannula site.
 - Provide analgesia and sedation as appropriate to promote comfort & minimize stress (morphine, benzodiazepines)
 - Minimize use of pharmacological muscle relaxants to assess neurological status and promote spontaneous respiratory effort
- Family Education
 - Assess family's level of education, readiness to learn and provide information as appropriate
 - Utilize resources for support including social work, child life, psychiatry and chaplaincy as appropriate
- Integument & Immobility
 - Gentle change in position every 2 hours & prn as tolerated
 - Utilize pressure reducing surfaces as indicated (ie. gel pads under infant's head) & monitor for pressure ulcers
 - Utilize appropriate resources to manage cannulas and circuit during patient position changes
 - Maintain body alignment as indicated (and avoid neuropathy with femoral cannulation)

Complications

- Bleeding
- Thrombo-embolic events
- Neurological injury
- Infection
- Renal dysfunction

Special Considerations

- ECMO & Single Ventricle (SV) physiology
 - ECMO support for Norwood with modified Blalock Taussig Shunt (mBTS)
 - Manage Qp:Qs - Potential aortic run-off via BTS to pulmonary bed causing pulmonary over-circulation and inadequate systemic perfusion; manage by
 - Maintain adequate systemic flow
 - Minimize SVR
 - Avoid excessive hypothermia
 - Minimize high dose inotrope vasoconstricting agents
 - Increase ECMO flow (>150 ml/kg/hour) as indicated
 - Restriction of flow via mBTS with surgical clip(s) to mBTS as indicated
 - ECMO support for Norwood with RV-PA conduit (“Sano” modification)
 - Maintain adequate systemic flow
 - Adequate decompression of ventricle
 - Monitor for conduit patency (?thrombus or ischemia)
 - ECMO support for cavopulmonary shunted patients
 - Risk factors for poor outcomes
 - Compromised ventricular function
 - Inadequate systemic venous blood return
 - Chronic systemic venous hypertension in presence of low cardiac output
 - Inadequate brain perfusion
 - Inadequate systemic perfusion
 - Bidirectional Glenn (BDG)
 - 2 venous cannulas required to maintain adequate flow & venous decompression

- Superior vena cava (SVC) decompression to avoid prolonged cerebral venous hypertension
 - Inferior vena cava (IVC) decompression to avoid systemic venous hypertension
 - Higher ECMO flow as indicated in presence of aorta-pulmonary collaterals (APCs)
 - Fontan
 - May require SVC & IVC cannulation for adequate flow and decompression of venous system
 - Higher ECMO flow as indicated in presence of APCs
- Venovenous (VV)-ECMO
 - VV-ECMO circulation
 - VV-ECMO removes blood from a large vein and returns oxygenated blood back to the right atrium
 - Infants- a double-lumen single cannula is placed in the right internal jugular vein where the blood is drawn and returns to the right atrium
 - Older Patients- two venous cannulas may be placed, internal jugular vein and femoral vein, blood returns to central venous circulation
 - Pulmonary support only
 - Delivers highly oxygenated and saturated blood to venous side of heart
 - High concentration of oxygen to lungs
 - Improved coronary arteries oxygenation-improved LV function
 - Native cardiac function must be adequate
 - Most common cause of myocardial dysfunction in neonates is respiratory failure
 - Achieves lower PaO₂ than VA-ECMO
 - Requires higher flow rates
 - Elevated mixed venous pO₂
 - Advantages
 - Spares carotid artery
 - Pulsatile flow maintained
 - Maintains normal pulmonary flow
 - Less potential for neurological injury since clots are trapped by pulmonary vasculature
 - No cardiac “stun”

- Disadvantages
 - No cardiac support
 - Cannula repositioning be may required
 - Potential need for inotropic support, CPR & conversion to VA ECMO support for cardiovascular decompensation
 - Prolonged cannulation time may be required
 - Groin wounds, potential leg swelling/ complications
- Respiratory Insufficiency after Cardiac Surgery
 - Respiratory failure attributed to
 - Anesthesia
 - Hypothermia
 - Cardiopulmonary bypass, systemic inflammation, lung ischemia, reperfusion injury
 - Medications, adverse protamine reaction
 - Lung impairment leads to increased permeability
 - Pulmonary hypertension
 - Non-cardiogenic pulmonary edema
 - Impaired oxygenation
 - Acute respiratory distress syndrome (ARDS)
 - Proper timing of VV-ECMO initiation
- VV-ECMO prevents damage to diseased lungs
 - Pulmonary rest
 - Oxygenation primarily by gentle native lung ventilation, CO₂ clearance by ECMO circuit
- VV-ECMO complications
 - Essentially same as VA-ECMO
 - Third spacing, edema
 - Thrombocytopenia
 - Coagulopathy
 - Hemolysis
 - Hemorrhage, seizure, clots
 - Infection
 - Inadequate venous drainage, inadequate flow from hypovolemia
 - Pneumothorax, hemothorax, cardiac rupture

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