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Extracorporeal Membrane Oxygenation: Just the basics

Sarah Guthrie, PA-C

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Objectives

- Understand the basics of ECMO and its application
- Identify key components to the ECMO circuit
- Identify the role of Clinical Specialist in the care of ECMO patient
- Identify methods for anticoagulation
- Recognize additional mechanical interventions seen with ECMO
ECMO basics

- Used for management of life threatening pulmonary and/or cardiac failure when other treatment is not working
- Essentially a modification of the cardiopulmonary bypass circuit used in cardiac surgery
- Temporary support – allow for time for treatment and recovery of organs
- Used to deliver oxygen and remove carbon dioxide
- Two types:
  - Respiratory Failure requires VV (veno-venous) ECMO configuration
  - Cardiac Failure requires VA (veno-arterial) ECMO configuration
What is Extracorporeal Membrane Oxygenation?

- As defined by the Extracorporeal Life Support Organization (ELSO):

  The use of mechanical devices to support heart and/or lung function in severe heart or lung failure, unresponsive to optimal conventional care. (Brogan, 2017)
Goals of ECMO

- Bridge to decision
  - Recovery
  - Durable ventricular Assist Device
  - Transplant
  - Withdrawal
Indications for ECMO

Respiratory Failure (V-V)
- Refractory Hypoxemia
- Refractory Hypercapnia
- Ventilator Induced Lung Injury
- Acute Respiratory Distress Syndrome
- H1N1

Cardiovascular Compromise (V-A)
- Acute myocardial infarction
- Post cardiotomy
- Acute Myocarditis
- Acute Pulmonary Embolism
- Bailout post cardiac intervention
- Preoperative Support
- Acutely decompensated chronic cardiomyopathy
Exclusion criteria of ECMO

Absolute Contraindication
- Pre-existing condition incompatible with recover
  - Severe neurological injury
  - End stage malignancy

Relative Contraindication
- Very poor prognosis from primary condition
- Uncontrollable bleeding
  - Unable to tolerate anticoagulation
- Aortic insufficiency
- Aortic Dissection
Types of ECMO support access

- Percutaneous veno-venous (V-V) ECMO
- Central veno-atrial (V-A) ECMO
- Percutaneous veno-atrial (V-A) ECMO
- Percutaneous veno-venous-atrial (V-V-A) ECMO
- Percutaneous veno-atrial-venous (V-A-V) ECMO
Percutaneous V-V ECMO

Traditional cannulation placement
- Drainage cannula- right femoral vein, tip in IVC
- Right internal jugular, tip in SVC
- Can also cannulate via bilateral femoral veins
Percutaneous V-V ECMO

Dual Cannula

- drain from distal port in IVC
- return flow into RA
Central V-A ECMO

- Drainage cannula in right atrium
- Return cannula in aorta
- Requires sternum to remain open
- Difficult to transport

Figure 1: Central V-A ECMO (Pavlushkov et al. 2017)
Percutaneous V-A ECMO

- Drainage cannula in femoral vein terminating by RA
- Return cannula in femoral artery, terminating in Iliac/aorta
- Need for flow into the SFA of cannulated limb
  - Antegrade perfusion canula- Return flow cannulas to prevent limb ischemia
Percutaneous V-V-A ECMO

Reduces circulatory overload of the heart and reduces filling pressures
- Blood is drained from SVC and IVC
- Further lowers blood volume into the heart/lungs
- Effectively decreases CVP and PA pressures
Percutaneous V-A-V ECMO

Return flow is divided

- Drainage cannula in femoral vein, terminating in IVC by RA
- Return cannulas in femoral artery, terminating in iliac/aorta, and right internal vein, terminating in SVC by the RA
Equipment

- Perfusionist typically maintain the ECMO circuits and their availability
  - cannulas
  - tubing
  - pump
  - membrane oxygenator
  - heat exchanger
  - gas blender
- Each facility maintains their own set up and device that varies in size and transport capability
Basic ECMO Circuit

1. Pump
   - RPM
   - Volume
   - Flow

2. Membrane Oxygenator
   - FiO₂
   - Sweep

3. Heat Exchanger

Figure 7: Circuit (emDOCS, 2018)
Pumps

Centrifugal
- More efficient designs of pumps result in safer use than previous designs
- Magnetic driven and magnetic suspended pumps available

Roller
- Positive displacement pump generating forward flow as a function of tubing size and pump speed
- Fundamental in the conduct of CPB and ECLS
- Better for lower blood flows
Flow

- V-A ECMO (for cardiac failure): 50-60cc/kg/min. The flow is limited by vascular access, length and size of cannula, and pump properties.

- V-V ECMO (for respiratory failure): 60-80cc/kg/min. CO2 removal always exceeds O2 delivery. Besides blood flow, oxygenator/membrane properties and gas sweep determine O2 and CO2 levels.
Membrane Oxygenator

Used to add oxygen and remove CO2

Sweep: gas ventilated through gas exchange
Membrane Oxygenator

ABG goals on ECMO
- pH: 7.35-7.45
- pCO2: 35-45 mmHg
- pO2: 80-100mmHg

Titrating Sweep:
- ↑ sweep = ↑ CO2 removal
- ↓ sweep = ↓ CO2 removal

Titrating FiO2:
- ↑ FiO2 = ↑ pO2
- ↓ FiO2= ↓ pO2

Delivered Oxygen
- DO2=CO x CaO2 (mL/min/m2)
- CaO2=(1.34 X Hgb X SaO2) + (0.003 X PaO2)
Clinical Specialists

- ECMO clinical specialist (CS) is "technical specialist trained to manage the ECMO system and the clinical needs of the patient"
- CS may be perfusionists, nurses, respiratory therapists
  - Perfusionists may be ideal due to their knowledge and training of CPB and ECMO
- Defined CS help streamline and provide consistency for ECMO emergencies
- Resource for the providers, nurses, patient
Anticoagulation Strategies

- Unfractionated Heparin (UNFH) infusion
  - First line medication for ECMO thrombus prevention
  - Measured by aPTT
  - Risk to develop heparin inducted thrombocytosis and thrombosis (HITT)
  - Risk to develop heparin resistance
Anticoagulation Strategies

- Bivalirudin (Angiomax) infusion
  - DTI- direct thrombin inhibitor
  - Measured by aPTT
  - Ideal in setting of HITT, heparin resistance, or non-HIT thrombocytopenia
  - Falsely raises INR
  - Renally cleared, can be used in CRRT/HD
Anticoagulation Strategies

- Argatroban infusion
  - DTI
  - Measured by aPTT
  - Second line medication when bivalirudin is not ideal
  - Falsely raises INR
  - Contraindicated in transaminitis/shock liver
Anticoagulation Monitoring

- Activated Clotting Time (ACT)
- Activated Partial Thromboplastin Time (aPTT)
- Anti-factor Xa Assay (Anti-Xa)
- Antithrombin Level (AT)
- Lactic Dehydrogenase (LDH)
ACT: goal 160-180 seconds

Advantages
- Can be done at bedside
- Minutes to obtain
- Only a drop of blood

Disadvantages
- Multiple causes for high ACT
  - Excessive anticoagulation
  - Thrombocytopenia
  - Coagulopathy
  - Combination of all above
- Variability in the ACT even from a single sample
aPTT goal: 60-80 seconds

**Advantages**
- More accurate than ACT
- Decreased risk of hemorrhagic complications when using UNFH

**Disadvantages**
- Increased risk of circuit clots when using UNFH
- Unreliable in critical illness due to effects of acute phase reactants
  - Falsely prolonged with elevated C-reactive protein
  - Falsely decreased with elevated Factor VIII
Anti-Xa goal: 0.3-0.5 units/mL

**Advantages**
- More accurate than aPTT
- Decreased blood product use, hemorrhagic complications, and increased circuit life

**Disadvantages**
- Send out lab at most hospitals – prolonged turn around time and costs
Antithrombin [deficiency]

- Antithrombin is an Important inhibitor of coagulation
  - need it to stop coagulation
- AT deficiency occurs secondary to chest tube losses (consumption)
- Can be replaced by fresh frozen plasma or by Antithrombin III (AT3)
  - Counterintuitive– need to restore antithrombin to prevent clots
- Send out lab at most hospitals
LDH and Plasma Free Hemoglobin

Measures of hemolysis from the ECMO circuit due to:

- Sheering stress
- High ECMO flow
- Cavitation (chugging, chatter)
- Pressure changes in oxygenator

Elevated values increase risk of circuit thrombus and embolic events
Lab Draws

- How often? 4 hours? 6 hours? 12 hours?
- ABG
  - Arterial blood gas – bedside (EPOC, iStat)- quick result, less accurate, more expensive
  - Conventional – lab – accurate (gold standard), slower results
- CBC
- PT/INR/PTT
- Fibrinogen
- LDH
- Lactic Acid
To transfuse or not?

<table>
<thead>
<tr>
<th>Lab evaluation</th>
<th>Goal</th>
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<tbody>
<tr>
<td>Platelets</td>
<td>Transfuse to maintain &gt; 100,000 uL</td>
</tr>
<tr>
<td>INR</td>
<td>FFP transfusion to maintain INR &lt; 2</td>
</tr>
<tr>
<td>Fibrinogen</td>
<td>Cryoprecipitate to maintain fibrinogen &gt; 100 mg/dL</td>
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<tr>
<td>Hematocrit</td>
<td>PRBCs to maintain hematocrit &gt; 25%</td>
</tr>
<tr>
<td>Antithrombin</td>
<td>FFP or AT3 to maintain Antithrombin &gt; 50%</td>
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# Pulsatile vs Non-pulsatile management

<table>
<thead>
<tr>
<th>Pulsatile</th>
<th>Non-pulsatile</th>
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<tbody>
<tr>
<td>SBP goal 100-120mmHg</td>
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<td>LV contracting reduces risk of developing a thrombus</td>
<td></td>
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<tr>
<td>Potential for North-South Syndrome</td>
<td>MAP goal 60-80 mmHg</td>
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<td>May need surgical LV vent or Impella to decompress and prevent thrombus formation</td>
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North-South Syndrome

- Aka: Harlequin Syndrome, “Blue Head, Red Legs”
- Recovering heart prevents the retrograde flow from the ECMO circuit to perfuse the upper half of the body
- Consider V-A-V ECMO if unable to decannulate
Left Ventricle Vent

**Reasons**
- Findings of LV dysfunction with increased LV end-diastolic and systolic volumes increase myocardial wall stress
- Ex: impaired LV unloading, LV stasis, and pulmonary edema
- Is it needed?

**Methods**
- Surgical vent – cannula placed in left atrium or ventricle or pulmonary artery
  - Axillary artery through the aortic valve to ventricle
- Intra-aortic balloon pump decompresses by lowering afterload reduction
- Impella – effectively drains LV
CRRT and ECMO

A: First-line connection of CVVH to the ECMO circuit. Both lines connected between pump and oxygenator (segment B).

B: Second-line connection: Access line connected before the pump (segment A).

C: Both lines before the pump (segment A). Optional clamp adjusted on return line if pressure is below the low-pressure alarm. CVVH, continuous veno-venous hemofiltration.
Patient Management - Ventilator

- Central V-A ECMO
  - Rest settings (low VT, PEEP support)
  - Goal is to maintain lung volumes
- Percutaneous ECMO
  - Variable, modes/settings are dependent on clinical situation and the presence of North-South Syndrome
- No evidence basis for ideal strategy, from anecdotal experience
Patient Management- Vasopressors

- Epinephrine, vasopressin, norepinephrine, phenylephrine
- Extremity ischemia/compartment syndrome
Patient Management - Inotropes

- Milrinone, epinephrine, dopamine, dobutamine
- No evidence basis for idea strategy, from anecdotal experience
References

- de Tymowski, Christian; Augustin, Pascal; Houissa, Hamda; Allou, Nicolas; Montravers, Philippe; Delzongle, Alienor; Pellenc, Quentin; Desmard, Mathieu ASAIO Journal63(1):48-52, January/February 2017. doi: 10.1097/MAT.0000000000000441