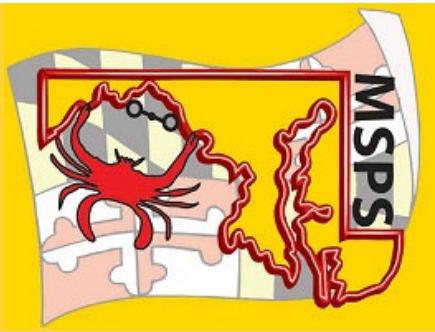
MAVES
Mid-Atlantic VAD and ECMO Symposium



Welcome to the 12th Annual MAVES

3 May 2020

MAVES
Mid-Atlantic VAD and ECMO Symposium

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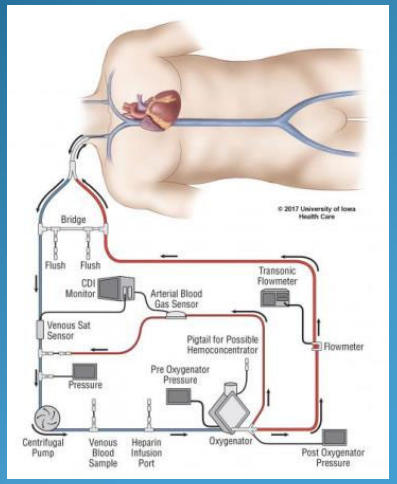
Extracorporeal Membrane Oxygenation: Just the basics

Sarah Guthrie, PA-C



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

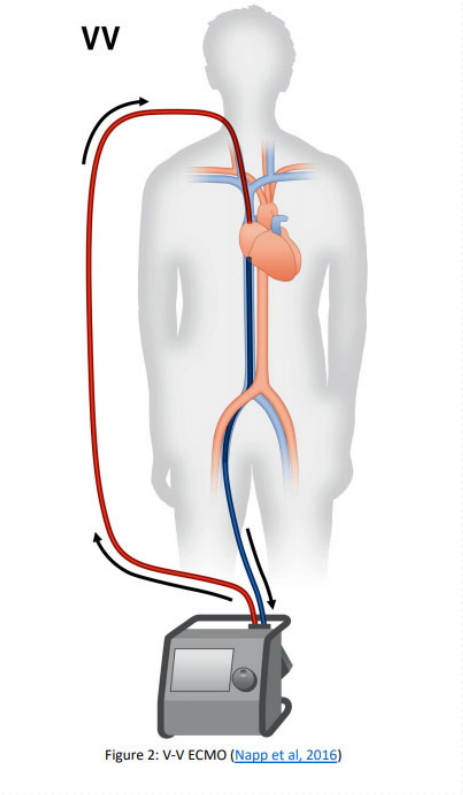


Figure 2: V-V ECMO (Napp et al, 2016)

Percutaneous V-V ECMO

Dual Cannula

- drain from distal port in IVC
- return flow into RA

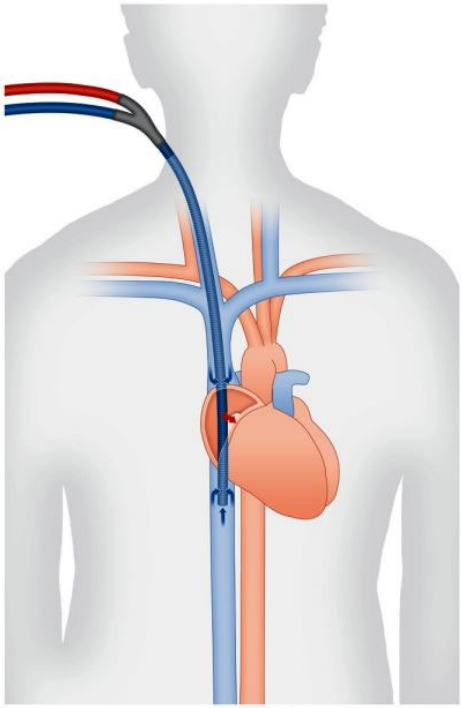


Figure 3: single cannula V-V ECMO (Napp et al, 2016)

Central V-A ECMO

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

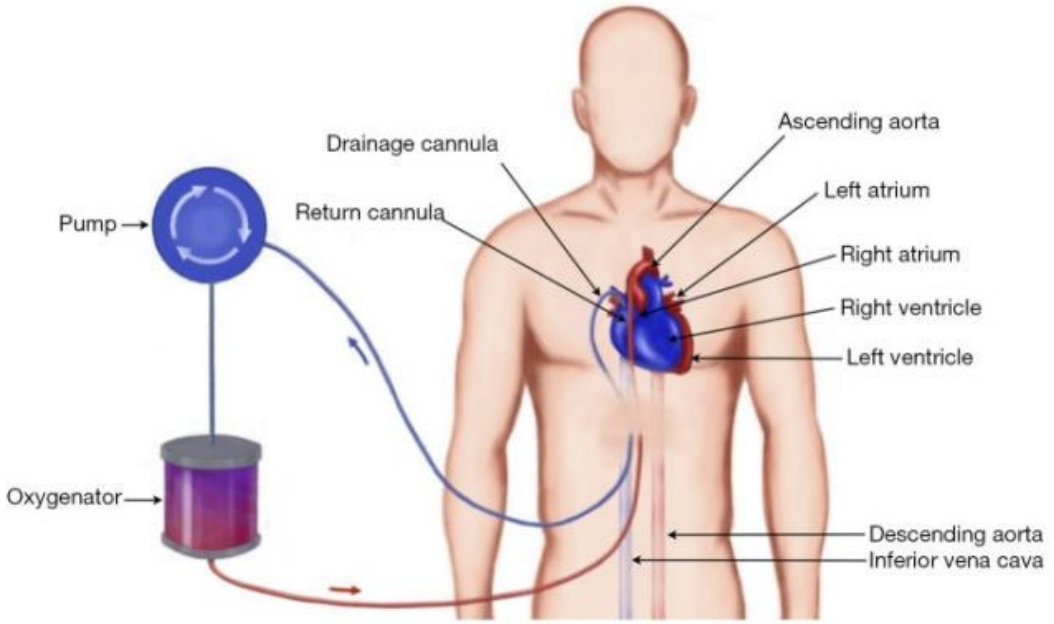


Figure 1: Central V-A ECMO (Pavlushkov et al, 2017)

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

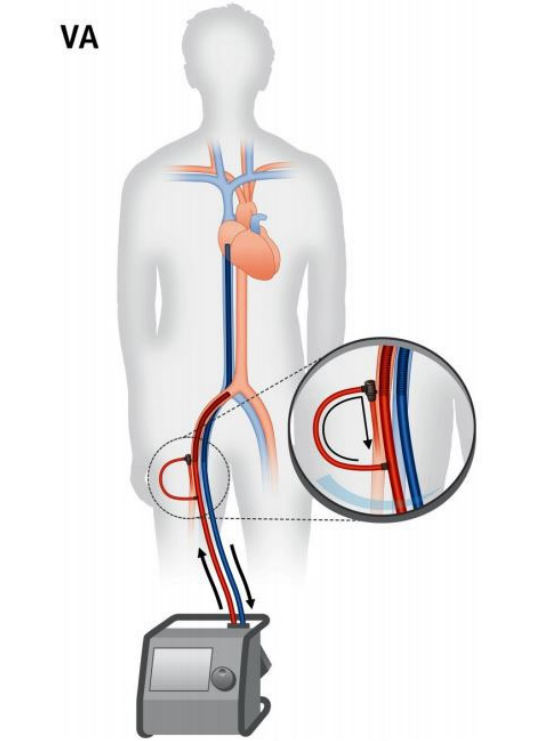


Figure 4: V-A ECMO (Napp et al, 2016)

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

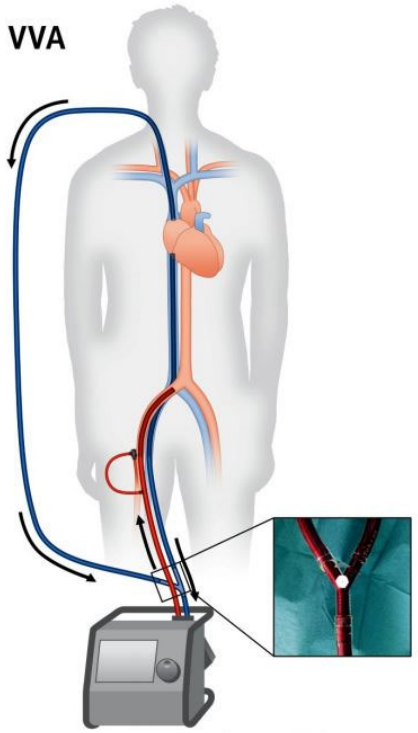


Figure 5: V-V-V ECMO (Napp et al, 2016)

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

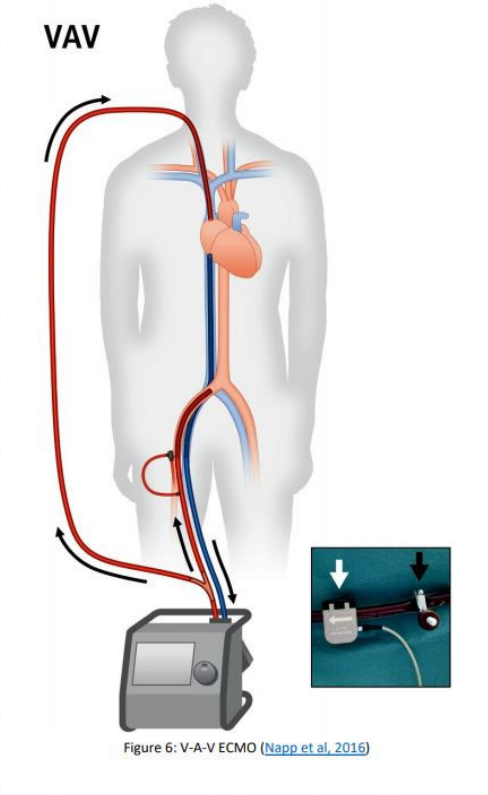


Figure 6: V-A-V ECMO (Napp et al, 2016)

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

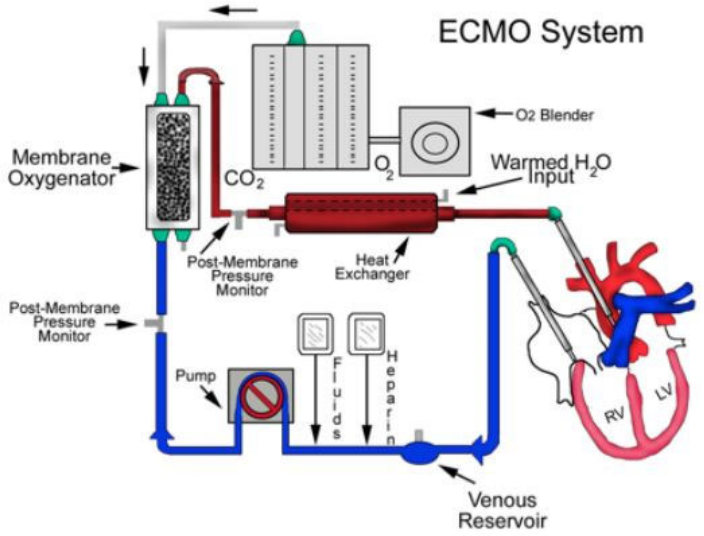


Figure 7: Circuit (emDOCs, 2018)

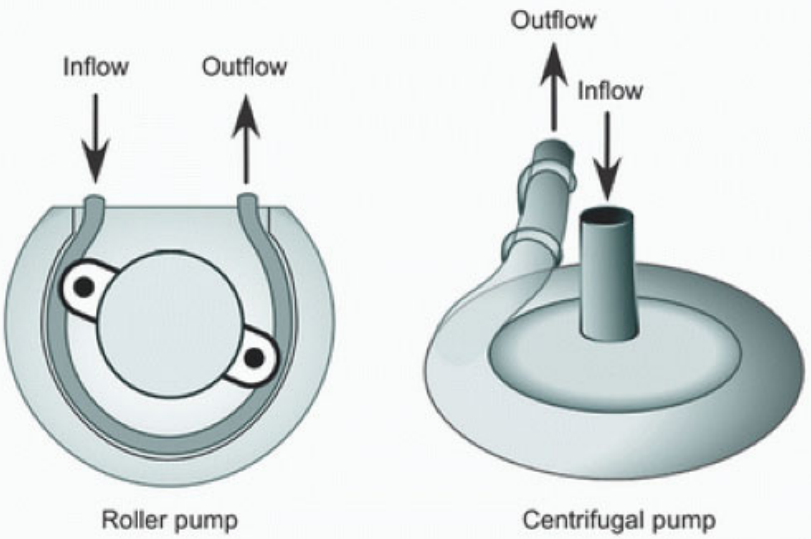
Pumps

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



https://thoracickey.com/extracorporeal-membrane-oxygenation-in-infants-and-children/

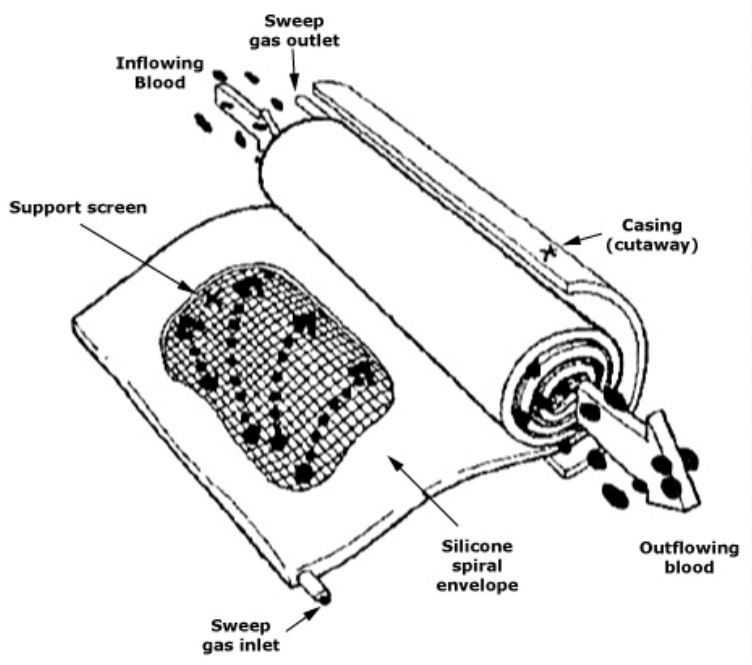
Flow

- 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.

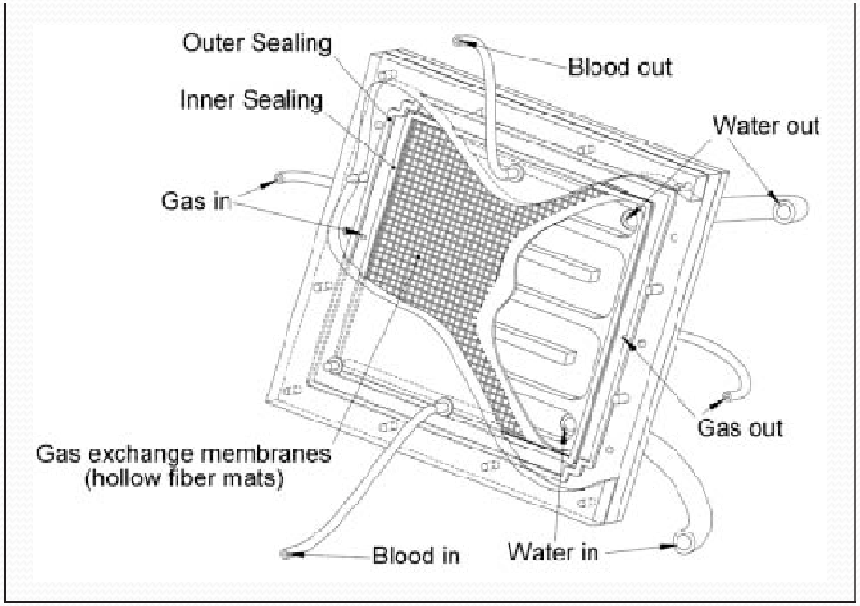
- V-V ECMO (for respiratory failure): 60-80cc/kg/min. CO_2 removal always exceeds O_2 delivery. Besides blood flow, oxygenator/membrane properties and gas sweep determine O_2 and CO_2 levels.

Membrane Oxygenator

Used to add oxygen and remove CO_2



Sweep: gas ventilated through gas exchange



Membrane Oxygenator

ABG goals on ECMO

- pH: 7.35-7.45
- pCO_2: 35-45 mmHg
- pO_2: 80-100mmHg

Titrating FiO_2:

- ↑ FiO_2 = ↑ pO_2
- ↓ FiO_2= ↓ pO_2

Titrating Sweep:

- ↑ sweep = ↑ CO_2 removal
- ↓ sweep = ↓ CO_2 removal

Delivered Oxygen

- DO_2=CO x CaO_2 (mL/min/m2)
- CaO_2=(1.34 X Hgb X SaO_2) + (0.003 X PaO_2)

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 thrombycytosis 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/INRPTT
  - Fibrinogen
  - LDH
  - Lactic Acid

To transfuse or not?

Lab evaluation	Goal
Platelets	Transfuse to maintain > 100,000 uL
INR	FFP transfusion to maintain INR < 2
Fibrinogen	Cryoprecipitate to maintain fibrinogen > 100 mg/dL
Hematocrit	PRBCs to maintain hematocrit > 25%
Antithrombin	FFP or AT3 to maintain Antithrombin > 50%

Pulsatile vs Non-pulsatile management

Pulsatile

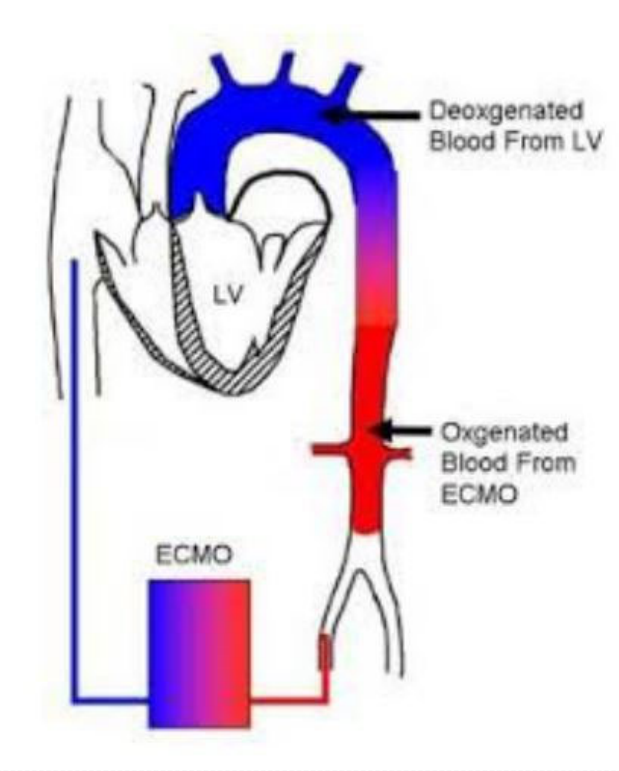
- SBP goal 100-120mmHg
- LV contracting reduces risk of developing a thrombus
- Potential for North-South Syndrome

Non-pulsatile

- MAP goal 60-80 mmHg
- May need surgical LV vent or Impella to decompress and prevent thrombus formation

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

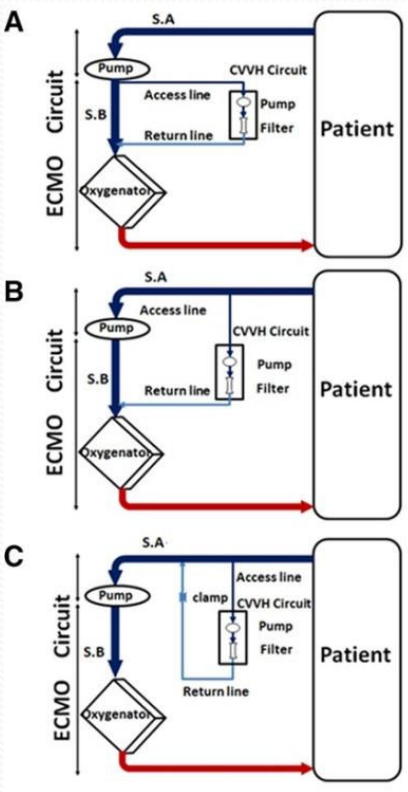
- Surgical vent – cannula placed in left atrium or ventricle or pulmonary artery
  - Axillary artery through the aortic valve to ventricle
- Intra-aortic balloon pump- decompresses by lowering afterload reduction
- Impella – effectively drains LV

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.



Option 1: Pressures in CVVH access line < +200 mmHg and in return line <+350 mmHg

Advantages :
- No risk of air embolism
- Return line connected on positive pressure
- No oxygenation membrane shunt
- No recirculation

Drawbacks:
- Access line connected on positive pressure

Option 2a: Used for high positive pressures in CVVH access line: > 200 mmHg

Advantages :
- Access line connected on negative pressure
- Return line connected on positive pressure
- No oxygenation membrane shunt
- No recirculation

Drawbacks:
- hypothetical risk of air embolism

Option 2b: Used for high positive pressures in CVVH return line: > 350 mmHg

Advantages :
- Access line connected on negative pressure
- No oxygenation membrane shunt
- No recirculation

Drawbacks:
- Theorical risk of air embolism
- Return line connected on negative pressure
  - But Clamp can mitigate negative pressure on return line in case of pressure below low pressure alarm

S.A: Segment A: ECMO segment with negative pressure
S.B: Segment B: ECMO segment with positive pressure

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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

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