# Extracorporeal Life Support (ECLS): Types of Support and Anesthetic Implications

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## Disclosures

- I, nor my spouse, have any financial disclosures related to this discussion to provide.
- Any medical equipment shown in this lecture are simply to provide examples and not to promote any specific company or product.

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## Objectives

- Discuss what ECLS or ECMO is
- Differences between veno-venous (VV) and veno-arterial (VA) ECLS
- Circuit specifics and configurations
- Management strategies for ECLS patients requiring surgery (non-cardiac)

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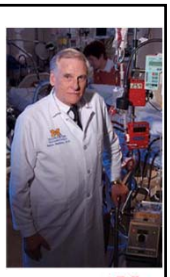
## Brief History of ECMO



- 1958 – First membrane oxygenator
- 1972 – First adult ECMO survivor
- 1976 – Bob Bartlett's first neonatal ECMO survivor "Esperanza"
- 1979 – Warren Zapol NEJM: 90% mortality in ARDS with/without ECMO
- 1979 to 2009 – the 30 year Dark Ages of adult ECMO (except Bartlett and the University of Michigan)
- 2009 – H1N1 highlights improvements in ECMO capabilities
- 2009 to present – resurgence of ECMO

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## What is Veno-Arterial (VA) ECMO?

- Mechanical circulatory support for patients with cardiogenic shock or combined cardiopulmonary shock
- Can be placed at the bedside or in the operating room
- Replaces both cardiac and pulmonary functions
- Cannulation can either be peripheral or central

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## What Is Veno-venous (VV) ECLS?

- Mechanical support system utilized for patients with severe respiratory failure not amenable to conventional therapy
- Replaces the function of the lungs temporarily in order to allow lung recovery and healing
- Can be performed rapidly at the bedside
- Differing cannulation strategies based upon needs and pathology causing respiratory dysfunction

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## Indications for VA ECMO

- Post-cardiotomy cardiac failure
- Acute congestive heart failure (CHF) following myocardial infarction
- Acute on chronic CHF with potential assist device or transplant
- Massive pulmonary embolus
- Irreversible ventricular tachycardia
- Cardiogenic shock following CPR

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## Indications for VV ECMO

- Acute Respiratory Distress Syndrome
- Pneumonia
- Bronchopleural fistula or other severe air leak pathology
- Status asthmaticus
- Mediastinal mass
- Refractory hypercapnia/hypoxia
- Bridge to lung transplantation

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## Patient Factors for ECLS


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## Do I Need VA or VV?

Hypoxia with normal heart function = VV ECMO

Hypoxia with cardiac failure = VA ECMO

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## Cannulation

- Different cannulation strategies depend on situation and timing
- Femoral/femoral cannulation most commonly employed. Can be done at the bedside.
- Femoral/Internal jugular
- Dual lumen cannula (VV only)
- Central cannulation
  - Seen typically following CPB as cannula can be placed where CPB cannulae were in place

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## Cannula Types

- Venous cannula is typically 21-25 Fr in size
- Larger sizes allow better drainage
- Arterial (return) cannula is 19-21 Fr in size
- Venous cannula (outflow) is multistage cannula and sits in IVC above the renal veins
- Return cannula sits in iliac artery for VA ECMO. For VV ECMO will be at level of the right atrium

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## Cannula Types cont.

Two site cannulae

Dual lumen cannula

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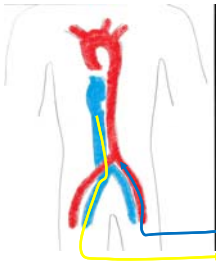
## VA ECMO Configuration



- Inflow cannula (venous) removes blood and brings to centrifugal pump and membrane (low O2, high CO2)
- Blood goes through membrane where O2 is delivered and CO2 removed
- Outflow (arterial) cannula returns blood to patient (high O2, low CO2)

ECMO Pump and Membrane

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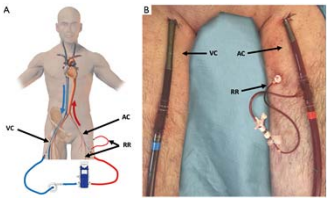
## Femoral Cannulation

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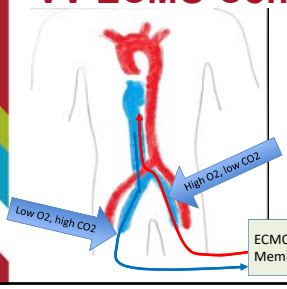
## VV ECMO Configuration




- Femoral-femoral most common
- Dual lumen catheter can allow ambulation
- Femoral-internal jugular optimal due to ease of placement

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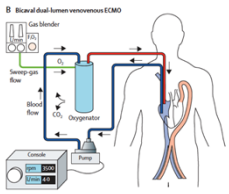
## Dual Lumen Cannula




Del Sorbo S. Lancet Resp Med. Vol. 2, No. 2, Feb. 2014

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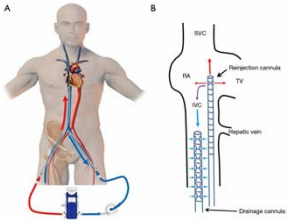
## Drainage and Return




Banfi, C; et al. J. Thor Dis. Vol 8. No. 12, 2016

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## Bedside Cannulation

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## Early ECLS

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## Pump and Membrane

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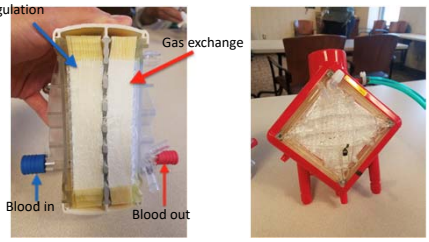
## Membrane

Temperature Regulation



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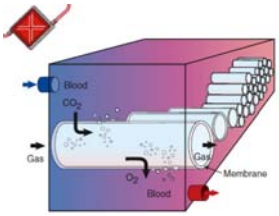
## Membrane: "Artificial Lung"




Ventetuolo & Muratore, AJRCCM, Sept. 2014

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## Circuit Controls



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## ECMO and Non-cardiac Surgery

- Mechanical support device use, including ECLS, is increasing not just in the United States but worldwide
- Many more patients will be presenting for non-cardiac surgery on VV and VA ECLS
  - Tracheostomy
  - Bronchoscopy
  - Vascular surgery
  - Thoracotomy
  - Limb amputation
  - Fasciotomy
  - Craniectomy

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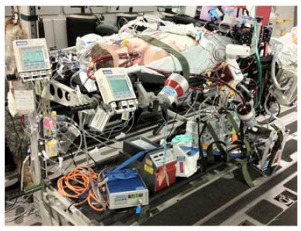
## Transport from ICU

- High risk!
- Face to face handoff
- Team approach
  - Anesthesia
  - ICU
  - Surgery
  - Respiratory
  - Perfusion



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## Management on VA and VV ECMO

- Delivery of adequate oxygen supply
- Maintenance of hemodynamics
- Lung protective mechanical ventilation
- Sedation strategies
- Weaning from ECMO
- Complications

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## Flow Settings

- VA flow needs to allow heart rest. Set flows to support hemodynamics. Typical flow should be around 60 ml/kg/min
- Need to allow for ventricular ejection
- For adults, need 50-80 ml/kg/min of flow to support fully on VV ECMO
- VV ECMO flow should allow for lung rest. Must be about equal to cardiac output
- Cannula size and diameter of tubing can be restriction to high flow rates
- Need to know rated flow of the membranes on your machine
- Most common membranes have rated flows of 5 L/min or 7 L/min
- We use membranes with 7 L/min flow

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## "Chatter" of the ECLS Circuit

- In states of hypovolemia or cannula misplacement, drainage cannula suction can cause collapse of IVC
- Will cause cannula tubing to vibrate or "chatter"
- Majority of time is due to hypovolemia
- Can resuscitate with crystalloid, colloid, or blood
- Check labs to ascertain anemia

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## VA Management

- Ideally want to limit vasoactive medicines as much as possible
- Perfusion is best ascertained by monitoring SvO2
- If > or = to 60%, then perfusion is adequate
- If SvO2 is low, then other interventions can be used
- Increase flow
- Transfusion
- May need increase in SVR

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## Pre and Post Oxygenator

| BLOOD GAS ANALYSIS | | |
|---|---|---|
| pH, Arterial | | 7.43 |
| pCO2, Arterial | | 35 |
| pO2, Arterial | | 111 |
| FIO2 | | 40 |
| HCO3 | | 23 |
| Base Excess | | |
| Base Deficit | | 0.8 |
| O2 Sat, Arterial | | 98 |
| Oxyhemoglobin Arte... | | 95 |
| pO2/FIO2, Arterial | | 278 |
| Aa Gradient, Arterial | | 119 |
| Barometric Pressure | | 731 |
| pH ECMO Post Oxygen | | 7.45 |
| pCO2 ECMO Post O2 | | 33.0 |
| pO2 ECMO Post O2 | | 344 |
| Bicarbonate ECMO/Calc | | 22.8 |
| Base Deficit ECMO | | 0.6 |
| O2 Saturation, ECMO | | 99.6 |

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## Monitoring

- Standard ASA monitors
- Central access is mandatory!
  - CVP monitoring. Not perfect, but can be helpful
  - Vasoactive medications may be needed.
  - Bleeding is a definite risk
- Arterial access is mandatory! In right upper extremity preferably
- ETCO2 likely incorrect

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## Mechanical Ventilation

- Controversial subject for patients on ECMO
- No proven best modality for patients on ECMO
- Recent meta-analysis shows lots of variability between centers across the world
- Most literature shows that low tidal volumes and elevated PEEP is best for these patients
- Find mode that allows sufficient tidal volume but minimizes plateau pressures

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## VV ECMO Management

- Name of the game is lung rest so use lung protective ventilation
  - Use predicted body weight and set TV at 4-6 ml/kg
- Maintain low plateau pressures, <30 mmHg
- More recent literature shows that driving pressure is most important variable to watch
- Calculate by Pplat - PEEP = driving pressure
- Driving pressure less than or equal to 15 associated with improved outcomes

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## Oxygen Delivery and CO2 Control

- Saturations of 88% and above are the goal
- SaO2 100% is not mandatory
- PaO2 of 50 is adequate for oxygen delivery if cardiac function is normal
- Hyperoxia can be deleterious
- FiO2 on ventilator should be 40% or below while on ECMO
- Sweep gas flow is usually equal to blood flow for proper CO2 removal
- Serial arterial blood gases to titrate

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## Check Blood Gases

- At a minimum of hourly checks in the OR
- Check immediately upon arrival to OR
- Adjust flows and sweep gas as needed
  - Avoid ventilator changes as much as possible
  - Sweep gas flow connected to OR ventilator


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## Sedation

- Pharmacokinetics greatly changed due to presence of ECMO and artificial membrane
- Drug sequestered in artificial membrane and also in tubing of the ECMO circuit
- Drug can also bind to albumin that adheres to cannula
- Increased volume of distribution
- Hemodilution very common after initiation of ECMO

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## Sedation

- Patients many times have organ dysfunction including liver and kidney injury
- This will affect metabolism and clearance of drugs even further
- Decreased albumin and increased alpha-1 glycoprotein levels
- Lipophilic medications are most affected and sequestered more readily in ECMO patients
- Fentanyl found to be 90-100% sequestered in closed circuit after 24 hours
- Propofol also found to be heavily sequestered
- Inhaled anesthetics may not be able to be used
- BIS monitor use advised

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## Anticoagulation

- Systemic anticoagulation is needed due to presence of cannula
- 50-100 mg/kg of heparin is given as a bolus upon initiation of ECMO
- Give even if coagulopathic when ECMO is begun
- Risk of thrombosis is high in ECMO and can be catastrophic

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## Anticoagulation

- Heparin infusion is typically utilized while on ECMO
- ACT is modality of monitoring heparin activity
- UNMC goal level of 150-180
- Can hold systemic anticoagulation temporarily if bleeding is excessive. Reversal should be performed if bleeding is life threatening

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## Thrombocytopenia

- Common issue in ECMO patients
- ELSO guidelines suggest keeping level above 80K
- Can watch if no bleeding ongoing to avoid potential complications from platelets
- If level less than 20K, risk of spontaneous bleeding increases greatly
- Can utilize thromboelastogram to assess coagulation status of patient
- Use of kallikrenin inhibitors including transexamic acid may be used to help with platelet dysfunction

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## Complications

- Each form of ECMO lends itself different risks of complications
- Both VA and VV ECMO have risks of bleeding
- Combination of anticoagulation and development of thrombocytopenia
- Risk of infection, hemolysis, thromboembolic events

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## VA ECMO Complications

- Distal leg ischemia
- Large cannula in femoral artery can cause poor perfusion
- Left Ventricular Overload
- Pulmonary Edema
- North-South Syndrome
- Arrhythmias

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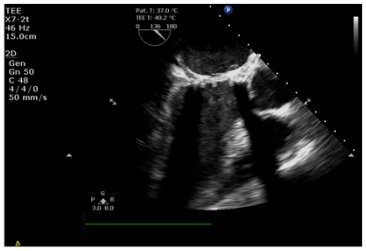
## Lack of Pulsatility

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## Loss of Pulsatility

- Lack of pulsatility on VA ECMO after high risk CABG
- Attempted increases in vasopressors without benefit
- Decreased flow on VA ECMO with improvement

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## Acute Hypoxia on ECMO

- Shouldn't happen….right?
- Few scenarios you may encounter in the OR
- Need to know cannula positions
- VA vs VV will have different causes

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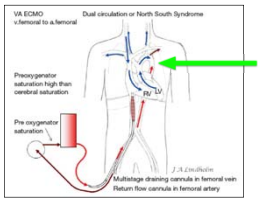
## North-South Syndrome




"mixing zone"

Journal of Thoracic Disease, Vol 10, Suppl 5 March 2018

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## Recirculation

- Issue predominantly seen in VV ECMO
- Occurs when oxygenated blood from ECMO circuit is taken back up by inflow cannula
- Can cause significant issue for patients that rely on ECMO for all oxygen delivery
- Multiple factors that can affect recirculation

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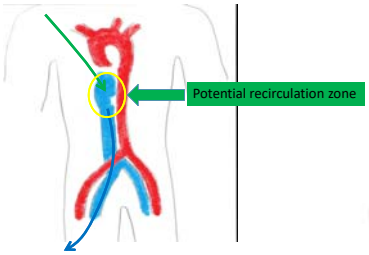
## Recirculation

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## Recirculation

- Cannula position can lead to recirculation
- In femoral/internal jugular cannulation, recirculation is common when outflow cannula is in the femoral position
- Pump speed, blood flow and cannula size can create recirculation
- Increased thoracic and/or pericardial pressure can decrease venous return and direct blood flow towards inflow cannula

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## How to Correct

- Increase flow on circuit
  - For N/S syndrome
- Anemia? Can transfuse if needed
- Cannula malposition?
- Can add second drainage cannula
- Match flow to cardiac output
  - Beta blockade may be necessary
- Can increase FiO2 on ventilator
  - Try to limit changes to ventilator as much as possible

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## Conclusions

- More patients on ECLS will be going to OR
- Lots of moving parts (literally)
- Anesthetic care can directly affect outcomes
- Maintenance of mechanical ventilation parameters in ICU is paramount
- Anesthesia and analgesia can be challenging
- High risk for complications

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