ECMO BASICS

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DISCLOSURES

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OBJECTIVES

• Define ECMO/ECLS and be able to identify the main types

• Become familiar with the basic physiology of ECMO

• Recognize indications and contraindications for ECMO
  • Identify appropriate patients

• Learn some of the complications of ECMO

• Become familiar with current research
WHAT IS IT?
ECMO/ECLS

- Extra Corporeal Membrane Oxygenation
- Extra Corporeal Life Support
WHAT IS IT?

• Extension of heart-lung bypass

• Artificial circuit which removes venous blood from a patient and passes it through an oxygenator for gas exchange (enriching with O2 and removing CO2) before returning to the patient
HISTORY

• 1950s – development of oxygenator
• 1972 – First adult survivor
• 1975 – “Esperanza” case, abandoned neonate is first neonatal survivor
• 70s-80s - ARDS trials with poor outcomes (fell out of favor)
• 90s – success and became a standard of care in pediatrics
• 2000s – new adult trials with new equipment
• 2009 – H1N1 epidemic (widespread “salvage” use)
• 2009 – CESAR trial (Lancet, single center trial started late 90s)
  • Outcome mixed, transfer to ECMO center, ALONE, improved mortality
ECMO THERAPY

• TEMPORARY and BRIDGING therapy

• Generally used as salvage when conventional treatments fail

• Used to optimize oxygenation and tissue perfusion in the absence of adequate heart and lung function
ECMO THERAPY

• BRIDGING therapy

• Must be used as a bridge to
  • Recovery (buy time)
  • Decision (allow temporary support until next step decided)
  • Destination therapy (transplant or VAD)
HOW DOES IT WORK?
ECMO PRINCIPLES

• Blood leaves the patient from the venous system and is passed through an oxygenator to allow gas exchange

• Centrifugal pump or patient cardiac output drives the blood flow
ECLS System: ECMO

Pump

Membrane

O₂ & Air

CO₂

Return of oxygenated blood

Drainage of blood to remove CO₂

Patient
ECMO CONFIGURATIONS

• Cannulation sites define the mode

• Central

• Peripheral veno-venous (VV)

• Peripheral veno-arterial (VA)
VA ECMO

• Drainage from venous system
• Return to arterial system
• Cardiac and respiratory support
• Peripheral and central cannulation sites
VA – PERIPHERAL CANNULATION
VA – CENTRAL CANNULATION
VV ECMO

- Drainage from venous system
- Return to venous system
- Only respiratory support
- Requires intact cardiac output
VV – DOUBLE FEMORO-FEMORAL CANNULATION
VV – CLASSIC DOUBLE CANNULATION (FEMORO-JUGULAR)
VV – DUAL LUMEN BICAVAAL CANNULATION
CIRCUIT COMPONENTS

- Cannulas
- Tubing
- Pump
- Oxygenator
- Heat exchanger
CANNULAS

• Drainage
  • Blood from patient to ECMO circuit
  • Single stage vs multi-stage (tip only vs multiple fenestrations)

• Return
  • Return blood to patient
  • ALWAYS single stage (blood only expelled from tip)

• Double Lumen
  • Drainage and return cannulas in same cannula with small partition to separate

• Length and Size
  • 15-55cm depending on location of placement
  • 13-31 F
CIRCUIT COMPONENTS

- Cannulas
- **Tubing**
- Pump
- Oxygenator
- Heat exchanger
TUBING

• Connects the components of the circuit
• Transparent to allow inspection of blood and look for clot
• Shortest feasible length
  • Minimizes volume loss and heat loss
  • Limits patient mobility
• Often heparin coated
• Conventional ID 3/8”
CIRCUIT COMPONENTS

- Cannulas
- Tubing
- **Pump**
- Oxygenator
- Heat exchanger
ECMO PUMP

• Centrifugal
• Fluid vortex
  •Entrains blood from patient
• Preload dependent
• Afterload sensitive
• Pump can spin but not move blood (occlusion before pump) or spin and increase pressure without flow (occlusion after pump)
ECMO PUMP

- RPM adjusted to flow
- VV – 50-75% of patient’s CO
- VA – CI 2.1-2.5 L/min/m2
- Line pressures <300mmHg
CIRCUIT COMPONENTS

- Cannulas
- Tubing
- Pump
- **Oxygenator**
- Heat exchanger
OXYGENATOR
GAS EXCHANGE

• Membrane oxygenation
  • Multiple channels between hollow fibers (large surface area for gas exchange)

• Sweep gas flows in the hollow fibers
  • Blender flow and FiO2

• Blood flows past/around fibers

• CO2 elimination based on gradient (highly efficient)
  • Flow rate to patient CO determines clearance of CO2 (increased sweep clears more CO2)
CIRCUIT FLOW

- Drainage via vein
- Tubing
- Pump
  - Centrifugal (fluid vortex due to impeller) negative pressure, entrains blood
  - Preload dependent, afterload sensitive
- Tubing
- Oxygenator
- Tubing
- Return via vein (VV) or artery (VA)
WHEN DO WE USE IT?
He's only mostly dead. There's a big difference between mostly dead and all dead. Mostly dead is slightly alive.
INDICATIONS

• ELSO (Extra Corporeal Life Support Organization) Guidelines

• Acute severe CV or respiratory failure
  • High mortality risk
  • Reversible condition
  • Non-responsive to optimal conventional therapy

• Consider at >50% mortality
INDICATIONS – CARDIAC FAILURE (VA)

• Post Cardiotomy
• Post heart transplant
• Acute decompensated CV failure
  • CHF
  • ACS with cardiogenic shock
  • Profound distributive shock (sepsis/OD/etc)
INDICATIONS – RESPIRATORY FAILURE

• ARDS
• Severe Asthma
• Acute pneumonitis (chemical)
• Near Drowning
• Trauma
• Vasculitis
• Lung transplantation
  • Bridge to transplant (CF, IPF, COPD, etc)
  • Graft failure
INDICATIONS – RESPIRATORY FAILURE

• PaO2/FiO2 ratio <150 on FiO2 >90% and Murray score >2
• PaO2/FiO2 ratio <100 on FiO2 >90% Murray score >3
• CO2 retention despite Pplat >30

• Murray score is devised from combo of P/F ratio, PEEP, CXR findings, and Compliance
FACTORS IN PATIENT SELECTION

• Recovery potential
• Malignancy
• Advanced age
• Encephalopathy or brain injury
• Prolonged CV arrest
• Technical issues
  • Body habitus or cannulation issues
• Anticoagulation
CENTRAL ILLUSTRATION: VA-ECMO Is a Bridge

Cardiogenic Shock
- Acute myocardial infarction
- Acute or chronic heart failure due to left ventricle or biventricular
  - Myocarditis
  - Chronic cardiomyopathy
  - Septic cardiomyopathy
  - Graft failure after heart transplantation
- Chronic right ventricle (RV) failure
- Pulmonary embolism with RV failure
- Postcardiotomy syndrome

Cardiac Arrest

VA-ECMO

Heart or Heart/Lung Transplantation

Recovery

Refractory Ventricular Arrhythmia

Durable Mechanical Circulatory Support

Decision

MONITORING

• Oxygenation and end organ perfusion
  • SaO2 >90% (VA)
  • SaO2 >75% (VV)
  • SvO2 70-80% (VA)
• Adequate tissue perfusion
  • Renal function, lactate, BP, SVO2
MONITORING

• Typical monitoring (HR, BP, telemetry, sats, temp)

• Pressures
  • MAP, Pre pump, pre oxygenator, post oxygenator

• Flow rates (60-150mL/kg)

• Neuro status

• Vascular perfusion
  • Dopplers

• Cannula placement
  • Dedicated observation with moving

• Circuit function

• Labs
  • Anticoagulation, blood counts, lytes, perfusion, ABG
  • Routine cultures

• Echo

• Daily CXR
CRITICAL CARE MANAGEMENT

- Continue standards of care
- Nutrition
- Skin/turning
- GI/Stress ulcer PPx
- Safety checks
- HOB elevation
INOTROPES AND CHRONOTROPES

- Not needed with appropriate VA ECMO
- Adjusted on VV to meet perfusion needs
- Can transition VV to VA if cardiac failure advances
VENTILATION IN ECMO

• Gas exchange performed in the circuit
• Lung protective ventilator strategy
• Vt <6mL/kg IBW and rate 10
• PEEP 8-12 cm H2O
• Peak airway pressure <25 cm H2O (definitely <30 cm H2O)
• FiO2 <50% (sump effect)
• Driving pressure <15 cm H2O (Pplat – PEEP)
COMPLICATIONS

- Bleeding/Thromboembolism
- Technical failure
- Neurologic complications
- Vascular complications
  - Ischemia
  - Dissection
- Infection
BLEEDING

• 30-40%
• Coagulopathy
  • Continuous activation of the contact and fibrinolytic systems (foreign tubing)
  • Consumption of coagulation factors
• Hemolysis
• Anticoagulation
• Thrombocytopenia
  • Clumping, filter segregation
• Pulmonary hemorrhage
  • Incomplete LV emptying
THROMBOEMBOLISM

• Circuit clot
  • Up to 16%

• Worse in VA (systemic circulation)

• VV leads to cardiac thrombus or PE
TECHNICAL/MECHANICAL COMPLICATIONS

- Pump failure
- Cannula kinking, malposition, or failure
- Vessel perforation or dissection
- Tubing rupture
- Air embolism
- Limb ischemia
  - VA
  - Distal perfusion catheter
- Recirculation
  - VV
  - Oxygenated blood pulled into drainage cannula before circulating
- Harlequin syndrome
  - North/South
NEUROLOGIC COMPLICATIONS

• Bleeding

• Perfusion
  • VA perfusion of lower structures due to cannula placement/return
  • Monitoring from RUE

• Overall occurrence ~10%

• 50% in E-CPR patients
INFECTION

- Altered immunity
- Foreign body/large cannulas
- Blood products
CV ARREST

• VV
  • CPR
  • Treat reversible causes
  • Transition to VA

• VA
  • Establish adequate flow
  • Treat reversible causes
  • No CPR unless flow/pump compromised
WHAT’S THE DATA?
WHY DON'T WE TAKE THE BLOOD AND OXYGENATE IT SOMEWHERE ELSE
ECMO DATA

- Mixed at best
- Minimal RCTs (difficult to blind, lots of crossover)
- Pediatric data >>> Adult data
- Ongoing research
ECMO STUDIES

• Limited by control groups
  • Variable disease severity
  • Variable ventilation strategies
  • High cross over rates
Conventional Ventilation or ECMO for Severe Adult Respiratory Failure
CESAR

• Conventional ventilator support vs ECMO for Severe Acute Respiratory failure
• Single center UK study
• 180 patients
• Survival without disability 63% ECMO vs 47% control
• 25% of patients transferred for ECMO did not require the treatment
• Conclusion: Ship to higher level of care facilities with capability when P/F ratio low and Murray score high
EOLIA

• ECMO to rescue lung injury in severe ARDS

• 249 patients with severe ARDS (P/F ratio <50 for 3 hours or <80 for 6 hours)
  • Early VV ECMO vs conventional Low Vt/Low pressure ventilation

• Improved oxygenation, renal failure free days, and fewer CVA with ECMO

• Trend to improved 60 day mortality (did not meet statistical significance)

• Subgroup analysis showed improved outcome in early therapy vs “rescue” crossover therapy

• Conclusion: ARDS patients who fail conventional therapy should transition to ECMO sooner rather than later
Mortality

ECMO: 35
Control: 46

P=0.087 n=249
Number of days free from failure from Inclusion to Day 60

- **ECMO**
- **Control**
- **Difference**

<table>
<thead>
<tr>
<th>Condition</th>
<th>ECMO</th>
<th>Control</th>
<th>Difference</th>
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<td>Organ Failure</td>
<td>22</td>
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<td>Renal Failure</td>
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<td>Cardiac Failure</td>
<td>48</td>
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<td>Respiratory Failure</td>
<td>31</td>
<td>13</td>
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2009 H1N1 DATA

• Matched pair analysis
  • 85% of patients transferred for ECMO received the therapy
  • Lower in hospital mortality in patients sent to ECMO centers (23.7% vs 52.5%)

• UK H1N1 (JAMA) showed ECMO survival improved (76% vs 49%)

• Retrospective cohort
  • Overall lower mortality for Influenza A ARDS and no statistically significant difference between conventional ventilation group and ECMO group mortality
META ANALYSIS

• 2 RCT and 3 observational studies

• Data heterogeneity

• 60 day mortality lower in VV ECMO than conventional ventilator strategy (34% vs 47%)
  • RR 0.73 (~25% risk reduction)

• Increased risk of complications/adverse events (19% or more)
VA ECMO DATA

• Observational and case series – 20-50% survival in CV arrest, severe CV shock, or failure to wean from bypass patients
• 2 observational studies showing improved survival over CPR/ACLS
• No good RCT because not ethical/justified to have a control group
• ECLO registry >41% survival to hospital discharge
SUMMARY

• ECMO is a salvage option for severe and life threatening cardiac or pulmonary failure that has failed conventional therapy

• ECMO can be in VV or VA configurations

• Patient selection vital due to high risk and complication rate

• Outcomes data shows improvement of survival in severely critically ill patients, but it is unclear that ECMO itself is the reason why
Pre, Post, Sweep, Flow...huh?

got ecmo?