Buying Time: The Basics of Neonatal ECMO

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Outline
- Introduce ECMO terminology
- Neonatal ECMO history
- Indications for Neonatal ECMO
- Neonatal diseases and ECMO
- ECMO Circuit
- Complications of ECMO
- ECMO Outcomes

Terminology - Acronyms
- ECLS = Extracorporeal Cardiovascular Life Support
  - i.e. ECMO, LVAD, Berlin Heart
- ECMO = Extracorporeal Membrane Oxygenation
- ECPR = Extracorporeal Cardiopulmonary Resuscitation
  - Rapid deployment of ECMO for patients not responding to CPR
- ELSO = Extracorporeal Life Support Organization
It Takes a Village

- ECMO Specialists
- NICU Nurses
- Perfusionists
- ECMO Physicians
- Pediatric Surgeons and Cardiothoracic Surgeons

ECMO History

- Dr. John Gibbon, Jr.
  - Developed a heart-lung machine in the 1930s–40s
  - 1st successful open heart surgery using extracorporeal support (1953)

- Dr. Willem Kolff
  - Pioneer in dialysis, worked on the Jarvik Heart
  - 1st to note that oxygen could be transported across a membrane into the blood

- Dr. Theodore Kolobow
  - Silicone membrane gas exchange device (1963)
  - Primary oxygenator used for the next 40+ years

- Dr. Robert Bartlett
  - 1st Neonatal survivor of ECMO after Meconium Aspiration Syndrome (1976)
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First Adult Landmark Study
- Extracorporeal Membrane Oxygenation in Severe Acute Respiratory Failure: A Randomized Prospective Study
- NIH Study on Adults with ARDS
  - 90 patients enrolled
    - Conventional Therapy = 8.3% survival
    - ECMO = 9.5% survival
  - Enrollment terminated early due to lack of increased survival
  - Wide variation in patients, centers, care
  - Effectively ended the use of ECMO in Adults for years

Early Neonatal Success
- ELSO Data Published in 1991
  - 3528 infants treated with estimated 80% mortality without ECMO
  - Survival with ECMO was 83%

**What does ECMO Do?**
- Provides cardiorespiratory support in patients whose own cardiac and / or respiratory function is inadequate.
- Similar to what a cardiopulmonary bypass circuit provides during cardiac surgery.
- Generally reserved for patients likely to die without it
Buying Time

- ECMO itself doesn’t actually treat – heal – fix anything
  - Provides a bridge to further support
    - Heart transplant
    - EXIT to ECMO to Operative Repair
  - Provides time for an acute process to reverse
    - Pulmonary hypertension
    - Sepsis
  - Allows the body time to rest and recover with less ongoing damage
    - Inflammation
    - Mechanical ventilation injury
    - Cardiac support

ECMO Indications

- Reversible Pathological Process
  - Nature of the disease
  - Length of time already on mechanical ventilation
  - Failure of maximal conventional medical therapy

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    - Varies patient to patient
    - Varies between diseases
    - Varies center to center
ECMO In a Nutshell

- Take some of the blood out of the body
- Oxygenate it / remove carbon dioxide
- Warm it back to body temperature
- Pump it back into the body

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Cardiac Support
Neonatal Respiratory Diseases

- Meconium Aspiration Syndrome
- Persistent Pulmonary Hypertension
- Hyaline Membrane Disease
- Pneumonia
- Sepsis
- Pulmonary Air Leak
- Congenital Diaphragmatic Hernia

Cardiac Diseases

- Post-operative cardiopulmonary failure
- Post-operative cardiac transplant
- Myocarditis
- Cardiomyopathy

Diseases Not Amenable to ECMO

- Bronchopulmonary Dysplasia
  - Damage is not rapidly reversible

- Congenital Pulmonary Malformations
  - Lymphangiectasia
  - Congenital Surfactant Deficiencies
  - Alveolar Capillary Dysplasia
ECMO Contraindications
- Weight less than 2000 g
- Gestational age less than 34 weeks
- Major Intracranial Hemorrhage
- Significant Coagulopathy
- Congenital Heart Disease

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Cardiorespiratory Support Modalities
- Conventional Mechanical Ventilation
- High Frequency Ventilation
- Surfactant
- Inhaled Nitric Oxide
- Blood Pressure Support
- Antibiotics
- Sedation
Ways to Measure Failure

• A – a gradient
  • Difference between the Alveolar and arterial Oxygen Concentrations
    • Alveolar oxygen = (Barometric pressure – water pressure) * FiO2 – PCO2
    • Arterial oxygen = PaO2
    • Difference = (760 – 47)*1 – PCO2 – PaO2 (on 100% FiO2)
    • 713 – PCO2 – PaO2
  • Typically 15-35 in room air
  • 600s for 4-8 hours ~80% mortality

Ways to Measure Failure

• Oxygenation Index (OI)

\[ OI = \frac{MAP \times FiO2 \times 100}{PaO2} \]

• MAP = Mean Airway Pressure
• OI > 40 for > 4 hours ~ 80% mortality

Ways to Measure Failure

• Arterial partial pressure of oxygen (PaO2)
  • Less than 50 for 4 hours

• Cardiovascular Instability
• Failure to Improve
• Disease dependant
Before Going on ECMO

- Echocardiogram
- Head Ultrasound
- Agreement amongst the medical/surgical team that a patient qualifies
- Parental Consent

ECMO Cannulation

- VenoArterial (VA)
  - Two cannulas
    - Arterial – Right Common Carotid Artery to Aortic Arch
    - Venous – Right Internal Jugular Vein to Right atrium
  - Provides cardiac and respiratory support
  - Sacrifices the Right Carotid Artery
  - Can use femoral vessels in larger patients
ECMO Cannulation

VA ECMO Cannula Position

Two Cardiovascular Systems
ECMO Cannulation

- **VenoVeno (VV)**
  - Double lumen cannula inserted via the R Internal Jugular Vein to the RA/IVC
  - Only provides respiratory support
  - Cannula position critical
  - Spares the carotid artery
  - Less risk of arterial emboli

Hirono et al. *Journal of Cardiothoracic Surgery* 2012, 7:36

### VV ECMO Cannula Position

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ECMO Circuit - VA

ECMO Circuit - VA
Take blood out of the body

Pump it back into the body

Oxygenate it / remove carbon dioxide

Warm it back to body temperature
ECMO Oxygenators

- Silicone Membrane
  - Been in use for 40+ years
  - Very efficient gas exchange
  - Relatively high resistance

- Hollow Fiber
  - Smaller, easier to prime
  - Less clotting
  - Even better gas exchange
  - Low resistance
  - Integrated heat exchanger
Membrane Lung Gas Exchange
Related to differences in partial pressures in gases

Sweep Flow – 100% oxygen

Membrane

Mixed venous blood

\[ \text{PO}_2 = 760 \text{ mmHg}, \text{PCO}_2 = 0 \text{ mmHg} \]

\[ \text{PO}_2 = 40 \text{ mmHg}, \text{PCO}_2 = 46 \text{ mmHg} \]

Oxygen Driving Pressure (760 - 40) = 720 mmHg

CO\textsubscript{2} Driving Pressure (56 - 0) = 56 mmHg

\[ \text{PO}_2 < 760 \text{ mmHg}, \text{PCO}_2 > 0 \text{ mmHg} \]
The Ventilator

- Essentially two vent settings
  - Rest settings
    - High PEEP
    - Long IT
    - Low Rate
    - Low FiO₂
  - Emergency Settings
    - Typically pre-ECMO settings
    - Only used when there is a pump emergency or other reason to remove patient from ECMO

What to Expect while on ECMO

- Lots and lots of blood product transfusions
  - Packed Red Blood Cells
  - Platelets
  - Fresh Frozen Plasma
  - Cryoprecipitate
What to Expect while on ECMO

- Babies require continuous sedation
- Paralysis during Cannulation and Decannulation
- Pain Control
  - Fentanyl drip and boluses
- Agitation relief
  - Versed drip and boluses
- Often times develop tolerance to the sedatives
  - Slow weaning once off ECMO
  - Transition to oral sedation
  - Monitoring for narcotic withdrawal

What to expect while on ECMO

- Nutrition
  - Primarily Parenteral
    - TPN
    - Lipids
    - Maximize the intake as tolerated but limit the volume
  - Enteral feedings are attempted once patient has stabilized

Coagulation Issues

- Blood is exposed to all the tubing, connectors, oxygenator, etc
- Increases the risk for clotting
- Continuous Heparin infusion to limit the development of clots
- Increases the risk for bleeding
  - Intracranial
  - Cannula site
  - Operative sites
  - Hemothorax
- Cannot place IVs, NGs, Foley, etc after heparinized
ECMO Complications

- “ECMO is 95% sheer boredom and 5% sheer terror”

ECMO Complications

- Bleeding
- Infection
- Mechanical Failure
  - Circuit Pieces
  - Circuit Occlusion
  - Cannula
- Emboli
  - Clot
  - Air

How long is an ECMO course?

- Average run length depends on the reason for cannulation
  - Shorter for PPHN, Meconium Aspiration, HMD
    - ~5 – 7 days
  - Longer for CDH, Sepsis
    - ~7 – 14 days
- Can be on ECMO for longer
  - ECMO Circuit has more risk of failure
  - More likelihood of inability to survive without ECMO
Neonatal ECMO Outcomes

- At discharge ECMO survivors often have
  - Decreased tone, weak reflexes
  - Improves by ~4 months
  - Feeding problems
  - Poor growth
  - Oxygen requirement (15%)

Bayley exams at 2 years old
- 65% normal
- 20% suspect
- 15% delayed
  - Cognitive impairment (13%)
  - Motor disability (6%)
  - Seizure disorders (2%)
  - Sensorineural hearing loss (3%)
  - Cortical visual impairment (2%)

At 5 years old
- Mean IQ normal
- 38% with concerns for learning disability
  - Language, Visual/perceptual functioning, behavioral problems