OBJECTIVES

- What is ECMO/ECLS
- Types of ECMO
- Describe indications for ECMO
- ECMO and sepsis
- Venovenous vs. Venoarterial ECMO
- Why choose Venovenous ECMO
- Venovenous ECMO in sepsis
DEFINITION

- Prolonged extracorporeal cardiopulmonary bypass in patients with acute reversible respiratory or cardiac failure
DEFINITION

- Draining venous blood
- Removing CO₂
- Adding O₂ through an artificial lung
- Returning warmed, oxygenated blood to the circulation.
- Allow normal aerobic metabolism while lung “rest” occurs
TYPES OF ECMO

2 Types:

1. Venoarterial
2. Venovenous
1. Veno-Arterial (V-A)

Drainage is through a vein.
Blood return through an artery.
Oxygenated blood to aorta and systemic circulation.
Bypasses the heart and lungs.
3. Veno-Venous (V-V)

- Drainage is through a vein.
- Blood return through a vein.
- Oxygenated blood to right side of heart.
- Bypasses lungs only, native cardiac output carries oxygenated blood to systemic circulation.
INDICATIONS

Neonatal Cardiopulmonary failure:

- Meconium Aspiration
- Primary Pulmonary Hypertension
- Respiratory Distress Syndrome
- Pneumonia
- Massive Air Leak
- Congenital Diaphragmatic Hernia
- Sepsis

Survival

> 90%

60 %
ECMO CRITERIA

Oxygenation Index (OI) = \( \frac{MAP \times FiO_2 \times 100}{PaO_2} \)

- OI \( \geq 40 \) → 80% mortality risk
- OI = 25-40 → 50% mortality risk
ECMO CRITERIA

- **AaDO₂ > 610 x 8 hr → 79% Mortality**
  \[ AaDO₂ = FiO₂ \times (760 - 47) - (PaCO₂/0.8) - PaO₂ \]

- **PaO₂ < 50 mmHg x 4 hr**

- **Acute deterioration**
  - **PaO₂ < 40 mmHg x 2 hr**
  - **pH < 7.15 x 2 hr**
SEPSIS IN CHILDREN

- Pediatric Septic Shock
  - Hypothermia or hyperthermia
  - Altered mental status
  - Peripheral vasodilation (warm shock)
  - Cool extremities (cold shock)

Clinical practice parameters for hemodynamic support of pediatric and neonatal septic shock: 2007 update from the American College of Critical Care Medicine*
PEDIATRIC RESPONSE TO SEPSIS

- Newborn: Persistent pulmonary hypertension of newborn and right ventricular failure
- Infants: Left ventricular impairment and low cardiac output
- Children to Adult: Vasoplegic or distributive shock, often with high cardiac output

Extracorporeal Membrane Oxygenation and Sepsis. Graeme MacLaren and Warwick Butt. Critical Care and resuscitation, Volume 9, Number 1, March 2007: pp76-80
Infants and Children

- Recognize decreased perfusion and hypotension.
- Begin high flow O₂, establish IV/IO access.

**Initial resuscitation:** Peak 100 ml/kg isotonic saline or colloid up to 300 ml/kg until perfusion improves or unless rales or hypotonia develop. Correct hypoglycemia & hypothermia. Begin antibiotics.

**Check not reversed?**

**Fluid refractory shock:** Begin isotone IV/IO, use amrinone/tetramisole IV/IO to obtain central access & airway if needed. Reserve cold shock by titrating central dopamine or if necessary, titrate central epinephrine. Reverse warm shock by titrating central dopamine.

**Check not reversed?**

**Catecholamine resistant shock:** Begin hydrocortisone if at risk for adrenal insufficiency.

**Check not reversed?**

**Infants and Children**

- Cold shock with normal blood pressure:
  1. Tissue fluid & epinephrine, ScrO₂ > 70%, HR < 100 bpm.
  2. If ScrO₂ still > 70%
     - Add vasopressors & inotropic support or inotropes.
     - Consider levosimendan.

- Warm shock with low blood pressure:
  1. Tissue fluid & epinephrine, ScrO₂ > 70%, HR < 100 bpm.
  2. If ScrO₂ still > 70%
     - Add vasopressors & inotropic support.
     - Consider levosimendan.

**Check not reversed?**

- Persistent catecholamine resistant shock:
  - Rule out and correct potential perfusion, pulmonary ...
  - Consider pulmonary artery, PAO₂O₂, or FADT-TCM values.
  - Consider levosimendan.

**Check not reversed?**

**Refractory shock:** ECMO

Neonates

- Recognize decreased perfusion, cyanosis, and RDS. Maintain airway and establish access according to NRP guidelines.

**Initial resuscitation:** Peak 100 ml/kg isotonic saline or colloid up to 300 ml/kg until perfusion improves or unless rales or hypotonia develop. Correct hypoglycemia & hypothermia. Begin antibiotics. Begin prophylactic natal intracranial pressure if needed.

**Check not reversed?**

**Fluid refractory shock:** Titrate dopamine 5–10 mcg/kg/min. Add dobutamine up to 10 mcg/kg/min.

**Check not reversed?**

**Catecholamine resistant shock:** Monitor CVP in NICU, attain normal MAP/CVP & ScrO₂ > 70%. SVC flow > 40 ml/kg/min or CI > 3.3 L/min/m².

**Check not reversed?**

**Infants and Children**

- Cold shock with normal blood pressure & evidence of poor LV function:
  - ScrO₂ > 70%
  - SVC flow > 40 ml/kg/min or CI > 3.3 L/min/m².
  - Add vasopressors, inotropic support.

**Check not reversed?**

**Refractory shock:** ECMO

Clinical practice parameters for hemodynamic support of pediatric and neonatal septic shock: 2007 update from the American College of Critical Care Medicine*

Joe Brierley, MD; Joseph A. Carcillo, MD; Karen Choong, MD; Tim Cornell, MD; Allan DeCaen, MD; Andreas Deymann, MD; Allan Doctor, MD; Alan Davis, MD; John Duff, MD; Marc-Andre Dugas, MD; Alan Duncan, MD; Barry Evans, MD; Jonathan Feldman, MD; Kathryn Felmet, MD; Gene Fisher, MD; Larry Frankel, MD; Howard Jeffries, MD; Bruce Greenwald, MD; Juan Gutierrez, MD; Mark Hall, MD; Yong Y. Han, MD; James Hanson, MD; Jan Hazelzet, MD; Lynn Herman, MD; Jane Kiff, MD; Niranjana Kipson, MD; Alexander Kon, MD; Jose Irazusta, MD; John Lin, MD; Angie Lorts, MD; Michael Mariscalco, MD; Renuka Mehta, MD; Simon Nade, MD; Trung Nguyen, MD; Carol Nicholson, MD; Mark Peters, MD; Regina Okhuysen-Cawley, MD; Tom Poulton, MD; Monica Relfes, MD; Agustin Rodriguez, MD; Ranna Rozenfeld, MD; Eduardo Schnitzler, MD; Tom Shanley, MD; Sara Skache, MD; Peter Skippen, MD; Adalberto Torres, MD; Bettina von Dessauer, MD; Jacki Weingarten, MD; Timothy Yeh, MD; Arno Zaritsky, MD; Bonnie Stojadinovic, MD; Jerry Zimmerman, MD; Aaron Zuckerber, MD
ECMO IN SEPSIS

- Initially, sepsis contraindication to ECMO
- 1990’s multiple studies showed ECMO effective in sepsis
- Today VA remains primary mode of ECMO
- VV reserved for hemodynamic stability
- Few reports of VV ECMO and sepsis
ECMO IN SEPSIS

1990

*Extracorporeal Membrane Oxygenation Therapy in Neonates With Septic Shock*


- Because of risks of hemorrhage and history of poor survival, a number of institutions do not consider septic neonates for ECMO therapy
- 10 Patients with shock  ➡️ All survived
- ECMO is viable alternative for neonates with septic shock
ECMO IN SEPSIS

1994

Extracorporeal Membrane Oxygenation for Refractory Septic Shock in Children


- 9 children with sepsis → 5 survived (All VA ECMO)
- Septic shock should not be contraindication to ECMO
- ECMO can support the circulation in children with refractory septic shock
Historically, sepsis considered contraindication to ECMO
VV cannulation for respiratory failure
VA cannulation for circulatory failure
Patients with sepsis can be successfully supported
ECMO IN SEPSIS

*Extracorporeal Membrane Oxygenation For Refractory Septic Shock in Children: One Institution’s Experience.*

Graeme MacLaren, Warwick Butt, Derek Best, Susan Donath, Anna Taylor. Pediatr Crit Care Med 2007, Volume 8, Number 57: pp447-451

- Reviewed records from 1998-2006
- 441 Children requiring ECMO
- 45 (10%) - Septic shock
- All placed on VA ECMO (central cannulation)
- 21 (47%) - Survived to hospital discharge
Why Choose VA ECMO over VV ECMO in Sepsis?
VA ECMO IN SEPSIS

- Provides cardiac and respiratory support
- Decreases Right ventricular preload
- No risk of recirculation
- Better oxygen delivery
VA ECMO

Why NOT choose VA ECMO?

- Increases left ventricular afterload
- Lowers pulse pressure
- Coronary oxygenation by left ventricular blood
- "Cardiac Stun"
- Decreased cerebral autoregulation
VA ECMO

- Dr. Billie Lou Short- Children’s National Medical Center
  - Multiple studies looking at VA ECMO and cerebral autoregulation
  - Used newborn lambs on VA ECMO with controls
- 1990- Neither cerebral blood flow nor oxygen metabolism changed after initiation of ECMO
- 1993- VA ECMO alters cerebral autoregulation

VA ECMO

- 2000- 2 hours of exposure to VA ECMO can impair cerebral arterial endothelial function
- 2006- VA ECMO impairs myogenic responses of cerebral arteries and causes altered endothelial function


VV ECMO IN SEPSIS

Why choose VV ECMO?

- Avoids major arterial cannulation
- Provides direct pulmonary oxygenation
- Improves coronary oxygenation
- Limits Neurological complications
- Maintains patient pulsatility and cardiac output
- Vasopressors not contraindication
Why NOT choose VV ECMO?

- May have inadequate oxygen delivery
- Does not provide direct cardiac support
- Increased incidence of recirculation
1999

Comparison of Venoarterial Versus Venovenous Access in the Cerebral Circulation of Newborns Undergoing Extracorporeal Membrane Oxygenation

Pediatr Surg Int (1999) 15: 78±84

- Compared VA vs VV in cerebral circulation of newborns
- 14 infants on VA, 19 infants on VV
- 7 (50%) VA had intracranial complications
- 18 (95%) VV had NO intracranial complications
- Concluded- Cerebral blood flow velocities, especially in patients with intracranial complications, decreased after onset of ECMO along with poor cardiac function
VV vs. VA ECMO IN SEPSIS

Which is better in sepsis VA or VV ECMO?
VV vs. VA ECMO IN SEPSIS

- Reviewed ELSO registry 1990-2008
- Children < 18 y.o.
- Primary, secondary, discharge diagnosis of sepsis
- Excluded congenital cardiac disease
- Excluded conversions and unknown mode
VV vs. VA ECMO IN SEPSIS

- Compared survival using chi squared analysis
- Differential survival by age group
  - Compared by logistic regression
- Total 6,387 ECMO runs 1990-2008
- Excluded 1,831 - cardiac, 219 - unknown mode
- Analyzed 4,337 ECMO runs for sepsis
# VV vs. VA ECMO IN SEPSIS

## Modality by Age Group (P = .007)

<table>
<thead>
<tr>
<th>AGE</th>
<th>V-A</th>
<th>V-V</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 1 m</td>
<td>2711 (74%)</td>
<td>940 (26%)</td>
<td>3651</td>
</tr>
<tr>
<td>1m – 12y</td>
<td>477 (80%)</td>
<td>118 (20%)</td>
<td>595</td>
</tr>
<tr>
<td>12y - 18y</td>
<td>71 (78%)</td>
<td>20 (22%)</td>
<td>91</td>
</tr>
<tr>
<td>TOTAL</td>
<td>3259 (75%)</td>
<td>1078 (25%)</td>
<td>4337</td>
</tr>
</tbody>
</table>
## VV vs. VA ECMO IN SEPSIS

Survival by Modality (P < .001)

<table>
<thead>
<tr>
<th>MODE</th>
<th>SURVIVED</th>
<th>DIED</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-A</td>
<td>2086 (64%)</td>
<td>1173 (36%)</td>
<td>3259</td>
</tr>
<tr>
<td>V-V</td>
<td>849 (79%)</td>
<td>229 (21%)</td>
<td>1078</td>
</tr>
</tbody>
</table>

**TOTAL**

2935 (68%) 1402 (32%) 4337
## VV vs. VA ECMO IN SEPSIS

### Survival by Age Group ($P < .001$)

<table>
<thead>
<tr>
<th>AGE</th>
<th>SURVIVED</th>
<th>DIED</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 1 m</td>
<td>2669 (73%)</td>
<td>982 (27%)</td>
<td>3651</td>
</tr>
<tr>
<td>1m – 12y</td>
<td>240 (40%)</td>
<td>355 (60%)</td>
<td>595</td>
</tr>
<tr>
<td>12y - 18y</td>
<td>26 (29%)</td>
<td>65 (71%)</td>
<td>91</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2935 (68%)</td>
<td>1402 (32%)</td>
<td>4337</td>
</tr>
</tbody>
</table>
Multivariable Odds Ratios for Mortality by Modality and Age Group (all $P < .001$)

- VA carries higher mortality
- Children and adolescents have higher mortality
CONCLUSIONS

- VV ECMO may be preferred mode in sepsis
- Decreased risk of mortality versus VA ECMO
- Most pronounced in neonatal period
CONCLUSIONS

- VV avoids arterial cannulation
- Utilizes patient pulsatility
- Preferred in high output shock, VA may be better in low output shock
- Provides better Pulmonary oxygenation and coronary oxygenation
- Better cerebral autoregulation and decreased intracranial complications
Would like to prospectively look at VV ECMO in septic patients
Hey, Any Questions?