Extracorporeal Membrane Oxygenation (ECMO) in Pediatric Trauma

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Disclosures

• Curt Froehlich, MD has **NO** financial relationships with commercial interest to disclose

• I **WILL** be discussing off label use of FDA approved equipment

• I **WILL** introduce equipment **NOT** FDA approved and will acknowledge when doing so
Disclosures

• I am a believer
• I believe in improving the availability of these services
• I AM NOT:
  • Nephrologist
  • Pathologist
  • Hematologist
  • Cardiologist
  • Surgeon
Learning Objectives

A. List 3 indications for ECMO in Pediatric Trauma patients

B. Name the most common complication of ECMO in pediatric trauma patients and its management

C. Name 2 adjunctive therapies which can be offered during ECMO in pediatric trauma patients
ECMO in Pediatric Trauma

- History
- Extracorporeal Life Support Organization (ELSO)
- ECMO Basics
- ECMO and Trauma
- ECMO and Cost
- Future of ECMO
- Applied ECMO
1st Successful ECMO
Santa Barbara, CA 1971
J Donald Hill & Maury Bramson
NEJM 1972

Slide Courtesy of Daniel Brodie, MD
Photo courtesy of Robert Bartlett, MD
ECMO in 2014

Video Courtesy of Daniel Brodie, MD
ECMO in 2014

Slide Courtesy of Daniel Brodie, MD
What is ECMO?

• Stands for: ExtraCorporeal Membrane Oxygenation?
• Should it stand for Extremely Costly Midnight Operation?
• What is it?
  – A way in which the lungs or the heart and lungs can be artificially supported for prolonged periods of time
  – What is prolonged?
    • 2 weeks?
    • 3 months?
    • 9 months?
ECMO History

• Technology is not “new”
• Reports of first patients supported 1971 after development of long term “oxygenators”
• First Randomized Adult Study 1972
  – Used “new” ECMO centers
  – No “rest” settings
  – Most common complication of ECMO is bleeding (And there was lots of bleeding)
  – Showed conventional therapy better than “bad” ECMO
ECMO History

- Bartlett et al, Esperanza (Hope) first neonatal case 1976
  - “Persistent fetal circulation”
- Bartlett et al 1982 45 newborns, 90% predicted mortality >50% survival
- O’ Rourke 1989 randomized neonatal trial: Stopped early due to ECMO benefit
• Extracorporeal Life Support Organization
  – Organization of national and international centers
  – Formed by Dr. Bartlett and others in 1989
  – 223 international centers in 2014 and growing rapidly
  – Provides collaboration
  – Each patient a “data point”
ECMO Basics

- All mechanical ventilation causes acute lung injury (pressure, volume, jet, APRV, HFOV)
- ECMO provides support, it does not **FIX ANYTHING DIRECTLY!**
- Right therapy/Right Time
- ECMO support allows time to heal, optimizing fluid status and nutrition, restoration of acid/base status and normalizing oxygen delivery
ECMO Basics

• ECMO should be considered if the process is:
  – Severe
  – Acute
  – Potentially reversible

• Can be used to support adjunctive therapies
  – Renal replacement therapies
  – Plasma exchange
  – Hemoperfusion?
  – Others?
What has changed since 2010?

Efficacy and economic assessment of conventional ventilatory support versus extracorporeal membrane oxygenation for severe adult respiratory failure (CESAR): a multicentre randomised controlled trial

Giles J Peek, Miranda Mugford, Ravindranath Tiruvoipati, Andrew Wilson, Elizabeth Allen, Mariamma M Thalany, Clare L Hibbert, Ann Truesdale, Felicity Clemens, Nicola Cooper, Richard K Firmin, Diana Elbourne, for the CESAR trial collaboration
And in 2014?

Flu hitting adults hard, ECMO treatment helped save one man’s life

Posted on: 4:21 pm, January 8, 2014, by Meryl Lin McKean, updated on: 06:01am, January 9, 2014
Trauma and ECMO

Extracorporeal Life Support for Posttraumatic Acute Respiratory Distress Syndrome at a Children’s Medical Center

By James D. Fortenberry, Andreas H. Meier, Robert Pettignano, Michael Heard, C. Robert Chambliss, and Mark Wulkan
Atlanta, Georgia and Orlando, Florida

- Case series of 8 patients supported on ECMO from 1991-2001
- 5 of 8 patients received CRRT
Indications
• All met criteria for ARDS
• 3 with large pulmonary contusions
• 2 with traumatic pneumothoraces

Other potential indications
• Pulmonary embolism
• Fat emboli
• Aspiration
### Trauma and ECMO

**Table 2. ECMO Management of Posttraumatic Respiratory Failure Patients**

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Mode of Cannulation</th>
<th>Additional Venous Cannula</th>
<th>Maximal ECMO Flow-mL/kg/min (total L/M)</th>
<th>Hemorrhagic Complications</th>
<th>Hours on ECMO</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VV</td>
<td>–</td>
<td>133 (3.6)</td>
<td>Surgical site bleeding</td>
<td>921</td>
<td>Lived</td>
</tr>
<tr>
<td>2</td>
<td>VV + V</td>
<td>Cephalad</td>
<td>125 (2.5)</td>
<td>Surgical site bleeding</td>
<td>709</td>
<td>Lived</td>
</tr>
<tr>
<td>3</td>
<td>VV + V</td>
<td>Cephalad</td>
<td>121 (1.9)</td>
<td>Surgical site bleeding, bleeding from mouth/nose</td>
<td>190</td>
<td>Lived</td>
</tr>
<tr>
<td>4</td>
<td>VV + V→VA</td>
<td>Cephalad</td>
<td>61 (5.5)</td>
<td>Surgical site bleeding</td>
<td>402</td>
<td>Lived</td>
</tr>
<tr>
<td>5</td>
<td>VA(+V)</td>
<td>Cephalad</td>
<td>100 (1.5)</td>
<td>Surgical site bleeding, pulmonary hemorrhage</td>
<td>653</td>
<td>Died</td>
</tr>
<tr>
<td>6</td>
<td>VV</td>
<td>Cephalad</td>
<td>65 (4.1)</td>
<td>None</td>
<td>213</td>
<td>Lived</td>
</tr>
<tr>
<td>7</td>
<td>VV</td>
<td>Cephalad</td>
<td>95 (6.2)</td>
<td>GI hemorrhage, surgical site bleeding, DIC</td>
<td>179</td>
<td>Died</td>
</tr>
<tr>
<td>8</td>
<td>VV</td>
<td>Femoral</td>
<td>110 (5.6)</td>
<td>GI hemorrhage, surgical site bleeding, DIC</td>
<td>480</td>
<td>Lived</td>
</tr>
</tbody>
</table>

Abbreviations: +V, additional venous drainage cannula; GI, gastrointestinal; DIC-disseminated intravascular coagulopathy.

- **Keys to success**
  - Used early
  - Almost all venovenous
  - Lots of venous drainage
  - 75% survival

Trauma and ECMO: Heparin Free?

Prolonged heparin-free extracorporeal membrane oxygenation in multiple injured acute respiratory distress syndrome patients with traumatic brain injury

Ralf M. Muellenbach, MD, Markus Kredel, MD, Ekkehard Kunze, MD, Peter Kranke, MD, Julian Kuestermann, MD, Alexander Brack, MD, Armin Gorski, MD, Christian Wunder, MD, Norbert Roewer, MD, and Thomas Wurmb, MD, Würzburg, Germany

• 3 cases with ICH and run without heparin
• Bleeding is the most common complication of ECMO
• All venovenous ECMO
• All included “rest” vent settings
Trauma and ECMO: Heparin Free?

Figure 1. CT of the brain. (A) On admission, traumatic subarachnoid bleeding and a right frontal contusion were detected. (B). Follow-up CT of the brain demonstrating resolution of the frontal contusion and of the subarachnoid bleeding.

Figure 2. Thoracic CT scan. (A) Severe bilateral lung contusions with positive air bronchograms on both sides. (B) Partial resolution of the lung contusions with modest atelectasis of the lower left lung 10 days after the trauma.
Trauma and ECMO: Heparin Free?

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• All 3 survived
• One patient had thromboembolic complications
• Heparin free vs. low dose heparin?

Muellenbach et al. J Trauma Volume 72, Number 5
## Overall Patient Outcomes

<table>
<thead>
<tr>
<th>Category</th>
<th>Total</th>
<th>Surv ECLS</th>
<th>Surv to DC</th>
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</thead>
<tbody>
<tr>
<td><strong>Neonatal</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Respiratory</td>
<td>27,007</td>
<td>22,782</td>
<td>20,093</td>
</tr>
<tr>
<td>Cardiac</td>
<td>5,425</td>
<td>3,339</td>
<td>2,206</td>
</tr>
<tr>
<td>ECPR</td>
<td>980</td>
<td>626</td>
<td>388</td>
</tr>
<tr>
<td><strong>Pediatric</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>6,149</td>
<td>4,034</td>
<td>3,496</td>
</tr>
<tr>
<td>Cardiac</td>
<td>6,784</td>
<td>4,443</td>
<td>3,388</td>
</tr>
<tr>
<td>ECPR</td>
<td>2,071</td>
<td>1,123</td>
<td>840</td>
</tr>
<tr>
<td><strong>Adult</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>5,146</td>
<td>3,317</td>
<td>2,905</td>
</tr>
<tr>
<td>Cardiac</td>
<td>4,042</td>
<td>2,255</td>
<td>1,636</td>
</tr>
<tr>
<td>ECPR</td>
<td>1,238</td>
<td>476</td>
<td>355</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>58,842</td>
<td>42,395</td>
<td>35,307</td>
</tr>
<tr>
<td></td>
<td>72%</td>
<td>60%</td>
<td></td>
</tr>
</tbody>
</table>
Pediatric Respiratory Cases

Annual Runs vs Cumulative Runs for the years 1981 to 2013.
Adult Respiratory Cases

Cumulative Runs

Annual Runs

0  1000  2000  3000  4000  5000  6000

0  200  400  600  800  1000  1200
Future of ECMO?

- Past “contraindications”
  - Single ventricle
  - CPR in progress
  - Sepsis
  - Organ support
- “Acceptable” candidates are always evolving
  - HIV?
  - Malignancy?
  - Bridge to transplant?
  - Bridge to VAD?
  - Multi organ trauma?
  - Sepsis?
ECMO?
Home ECMO?

Picture Courtesy of Björn Frenckner
What about Cost?

- Financial Obligation / Institutional Responsibilities (1993 analysis)
  - Average cost of ECMO patient: $50,000
  - Assuming accepted mortality and survival rates
  - Comparisons:
    - Renal Transplant - $16,300/life year saved
    - Heart Transplant - $26,900/life year saved
    - Liver Transplant - 43,500/life year saved
    - Bone-Marrow Transplant - $62,500/life year saved

Borrowed from Jim Fortenberry, MD.
ECLS Can Be Cost-Effective

Cost/Life-year-saved:
Pediatric ECLS vs. Other Therapies

Vats et al., *Crit Care Med* 1998
ECMO and Trauma

- 17 y/o in a unrestrained low speed/high kinetic energy transfer (car vs. 1 ton truck full of equipment)
- Unable to fix abdominal bleeding via splenectomy and open exploration
- Initiated massive transfusion protocols for anemia and coagulopathy
- Liver right lobe artery embolized via endovascular coil
- Arrested 3X

Slide Courtesy of Joshua Walker B.S., CCP
ECMO and Trauma

- Acute Lung Injury
  - Modes attempted - all failed
    - APRV, PC, HFOV, INO
  - Hand bagging best results with SaO2 <50% eventually up to 90%

- Required compressions multiple times

- Re-explored open abdomen in ICU to reduce venous impedance

- Consult for ECMO
ECMO and Trauma

- Placed on VV ECMO with rest ventilator settings
  - VT- 200 ml, RR- 4, Peep- 10 mmhg, FiO2- 50%
- Patient received dialysis for acute kidney failure- intermittent 45 days
- Heparin free run
- Trip to CT to r/o neuro/cervical injury

Slide Courtesy of Joshua Walker B.S., CCP
ECMO and Trauma

- Bilateral cerebral parenchymal bleeds diagnosed via CT
  - Treated medically
- DC’d from support after 95 hours
  - Vent- VT 450 ml, RR- 24, Peep- 10, FIO2 60%
- Total ICU stay of 58 days
- Total blood transfusion of >565 units
- Discharged home
UHS Neonatal/Pediatric Extracorporeal Therapies

- Designed to maximize neonatal/pediatric experience
  - Neonatal ECMO
  - Pediatric ECMO
  - CRRT
  - Plasmapheresis (with Pathology)
  - Erythrocytapheresis (with Pathology)
  - Call (210) 358-2500 for referrals

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UT kids
UT MEDICINE SAN ANTONIO
Conclusions

• Trauma patients can be supported with ECMO
• Bleeding is the most common complication on ECMO
• ECMO can be used to support adjunctive therapies
  – CRRT
  – Plasma
  – Others?
• Application and development of extracorporeal therapies continues to evolve
Remember......

Borrowed from Peter D. Wearden, MD, PhD
With Great Thanks!

- UHS Administration
- Pathology
- Hematology
- Nephrology
- Neonatology
- Cardiology
- General Surgery
- CT Surgery
- Critical Care
- Jim Fortenberry
- Matt Paden
- Robert Bartlett
- ELSO
- Kendra
- Casey
- Perfusion (Josh and Haven)
- All of our specialists
Questions?