PEDIATRIC GRAND ROUNDS JUNE 4TH, 2010

PEDIATRIC ECMO: OLD DOG OR NEW TRICK?

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Pediatric ECMO Director
CHRISTUS Santa Rosa ECMO Program

Disclosures

• I have NO financial relationships with commercial interest to disclose
• I WILL be discussing off label use of FDA approved equipment
• I WILL BRIEFLY introduce equipment NOT FDA approved and will acknowledge when doing so

Learning Objectives

1. Describe the basics of ECMO, basic contraindications to ECMO, and the theory behind which ECMO can be used to treat disease.
2. Describe briefly the early applications of ECMO on neonatal and adult patients and how these patient populations have changed throughout the years.

Learning Objectives

3. Describe the cost of ECMO as it compares to other therapies such as organ transplantation and bone marrow transplantation.
4. Describe briefly some of the future applications of ECMO and its technologies including resuscitation, transport, prematurity and organ transplantation and how these advances alter future patient selection.

Pediatric ECMO

Diseases desperate grown
By desperate appliance are relieved,
Or not at all.

-Claudius, King of Denmark
In Hamlet Act IV Scene 3
W. Shakespeare

Borrowed from Jim Fortenberry, MD.
Children’s Healthcare of Atlanta at Egleston

Desperate but Reasonable?

Borrowed from Jim Fortenberry, MD.
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Pediatric ECMO Outline

• History
• Basic Principles/ Mechanics
• 3 Types of ECMO
  – Respiratory ECMO
  – Cardiac ECMO
  – “Rescue” ECMO

Pediatric ECMO Outline

• Future evolution and applications
• “Cost” of ECMO
• CSRCH ECMO program
• Success Story

What is ECMO?

• Stands for: Extra-Corporeal 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

ECMO History

• Technology is not “new”
• Reports of first patients supported in 1972
• First Study 1972 in Adults:
  – Lots of new centers performing ECMO
  – Showed no benefit
  – Conventional therapy better than Bad ECMO!

ECMO History

• Bartlett et al, Esperanza first neonatal case 1976
• Bartlett et al 1982 45 newborns, 90% predicted mortality >50% survival
• O’Rourke 1989 randomized neonatal trial: Stopped early due to ECMO benefit

ECMO Mechanics

Figure 1
Basic ECMO Circuit

Blood Return
Heparin
Hepworth
ECMO Basics

• 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 Contraindications

• ONLY Absolute:
  — Do Not Resuscitate?

“Relative” Contraindications

— Past Contraindications
— Neurological compromise
— “Recent” surgery/trauma
— “Recent” neurosurgical procedures
— Acute multi-organ failure
— Chronic organ insufficiency
— Chronic respiratory insufficiency
— Immunosuppression

Pediatric ECMO

• “Limited” evidence
  — **No randomized control trial in pediatric patients**
• “Battle” between benefit and risk
All who drink of this treatment recover within a short time, except in those who do not.

Therefore, it fails only in incurable cases.

-Galen

Borrowed from Jim Fortenberry, MD.
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Problems In Study of ECMO

- Small populations
- Often selecting the sickest patients—nonresponders
- Loss of equipoise before demonstration of effect
- Difficulties in RCTs—hard to randomize within a center
- “Can’t we use the machine?”

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Neonatal ECMO

Pediatric ECMO

Overall Patient Outcomes

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Surv ECLS</th>
<th>Surv to DC</th>
</tr>
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<tbody>
<tr>
<td>Neonatal</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Respiratory</td>
<td>23,558</td>
<td>19,964</td>
<td>85%</td>
</tr>
<tr>
<td>Cardiac</td>
<td>3,909</td>
<td>2,338</td>
<td>60%</td>
</tr>
<tr>
<td>ECPR</td>
<td>537</td>
<td>340</td>
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<tr>
<td>Pediatric</td>
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<td></td>
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<tr>
<td>Respiratory</td>
<td>4,376</td>
<td>2,831</td>
<td>65%</td>
</tr>
<tr>
<td>Cardiac</td>
<td>4,776</td>
<td>2,995</td>
<td>63%</td>
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<tr>
<td>ECPR</td>
<td>1,003</td>
<td>528</td>
<td>53%</td>
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<tr>
<td>Adult</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>1,860</td>
<td>1,140</td>
<td>61%</td>
</tr>
<tr>
<td>Cardiac</td>
<td>1,131</td>
<td>541</td>
<td>48%</td>
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<tr>
<td>ECPR</td>
<td>408</td>
<td>147</td>
<td>36%</td>
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<tr>
<td>Total</td>
<td>41,558</td>
<td>30,824</td>
<td>74%</td>
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ELSO Registry, 2010.
3 Types of ECMO

• Respiratory ECMO
• Cardiac ECMO
• “Rescue” ECMO

Pediatric Respiratory ECMO

• Remember:
  — Acute
  — Severe
  — Potentially reversible

• All mechanical ventilation causes acute lung injury (pressure, volume, jet, APRV, HFOV)
  — Earlier is better! (before irreversible lung injury)

ECMO Selection Criteria for Pediatric Respiratory Failure

• OI > 40 unresponsive to maximal ventilatory and medical management.
• Static lung compliance < 0.5cc/kg/cmH2O.
• P/F ratio < 200.
• Barotrauma: persistent air leak on maximal ventilator support.
• Hypercarbic respiratory failure: uncorrectable hypercarbia with pH < 7.0 despite maximal medical management.

Children’s Healthcare of Atlanta ECMO Selection Guidelines.

Pediatric Cases by Diagnosis

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<thead>
<tr>
<th>Diagnosis</th>
<th>Runs</th>
<th>% Surv</th>
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</thead>
<tbody>
<tr>
<td>Viral Pneumonia</td>
<td>938</td>
<td>63</td>
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<tr>
<td>Bacterial Pneumonia</td>
<td>500</td>
<td>57</td>
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<tr>
<td>Aspiration</td>
<td>200</td>
<td>66</td>
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<tr>
<td>ARDS</td>
<td>493</td>
<td>55</td>
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<tr>
<td>Acute Resp Failure, Non-ARDS</td>
<td>786</td>
<td>51</td>
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<tr>
<td>Other</td>
<td>1,557</td>
<td>51</td>
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</table>
Cardiac ECLS by Diagnosis

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Runs</th>
<th>% Survived</th>
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</thead>
<tbody>
<tr>
<td>Congenital Defect</td>
<td>6,703</td>
<td>40</td>
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<tr>
<td>Cardiac Arrest</td>
<td>193</td>
<td>37</td>
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<tr>
<td>Cardiogenic Shock</td>
<td>149</td>
<td>42</td>
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<tr>
<td>Myocardiopathy</td>
<td>574</td>
<td>59</td>
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<tr>
<td>Myocarditis</td>
<td>284</td>
<td>65</td>
</tr>
<tr>
<td>Other</td>
<td>1,127</td>
<td>47</td>
</tr>
</tbody>
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Cardiomyopathy/Myocarditis

- 2 categories of non-surgical cardiac failure increasingly supported by ECLS
- Review of 15 pediatric viral myocarditis
  - Overall survival was 80%
  - 60% recovered function to be weaned off with normal follow up function
  - Recovery for non-surgical patient may occur after prolonged cardiac support!
  - Median duration of cardiomyopathy support was 140 hrs!


ECPR: fastest growing group for ECMO

ECPR Cases

<table>
<thead>
<tr>
<th>Cases</th>
<th>1003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neonatal</td>
<td>408</td>
</tr>
<tr>
<td>Pediatric</td>
<td>537</td>
</tr>
<tr>
<td>Adult</td>
<td>1003</td>
</tr>
</tbody>
</table>

ELSOS Registry, 2010.

Why E-CPR?

- Survival to DC in Pediatric Code blue events
  - 92% for Respiratory
  - 43% respiratory to cardiac
  - Only 24% for cardiac arrest!
- 0 to 5% survival from patients with >30 min CPR
- Is there something better?
- Cardiac arrest comprises 25% of all indications for ECMO in pediatric patients

Current CPR Guidelines

- Coronary Perfusion Pressure (CPP) is Key to successful resuscitation
- Importance of minimally interrupted high quality chest compressions
  - Push hard!
  - Push fast!
- Hyperventilation is harmful!

E-CPR

- AKA Rapid deployment ECMO, Resuscitation or R-ECMO, Extracorporeal Cardiopulmonary Resuscitation
- Use of ECMO from failed CPR
- Goal of cannulation in 30 min or less
- Limited to witnessed inpatient arrest (ICU, cath lab, floor)
- Required a tremendous amount or resources and high state of readiness (Children’s Hospital?)
E-CPR

- Surgical availability
  - Level I trauma center?
- Pre-primed circuit
  - ECMO specialist able to prime 24 hrs/day on site
- Blood bank
- ICU physician, nursing staff
- Early ECMO consideration and initiation
  - <5 min into CPR

ECPR: better than conventional CPR

“Atypical” ECMO uses

- Post-traumatic respiratory failure
  - bleeding from trauma injuries is “manageable”
- Burns
  - culture positive patients with 43% ECMO survival
- Immunosuppressed
  - higher risk of infection
  - patients with wbc < 1.5 with 32% survival
- Sepsis
  - Direct cardiac cannulation?

The “Future” of Pediatric ECMO

Slide Courtesy of Robert Bartlett
Ambulatory Lung Assist with PA-LA implantation
5 weeks, bridging to transplant
Regensberg, 2007

AALA bridge to XP: Hoopes, 2009

Extubated, ambulatory VV ECMO for H1N1
University of Iowa, 2009

ECLS Research: Artificial Placenta

Slide Courtesy of Robert Bartlett

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.
Children's Healthcare of Atlanta at Egleston

ECLS Can Be Cost-Effective

Vats et al., Crit Care Med 1998
CHRISTUS Santa Rosa ECMO Program

- Neonatal Program began in 1989
  - >100 pts
- In 2008 began a comprehensive pediatric program in conjunction with Wilford Hall
- Last year CSRCH supported 18 ECMO patients
- >100 ECMO days in the pediatric ICU last year
- Program continues to grow

Recent Success

9 month old female with MSSA pneumonia/air leak cannulated in Temple Texas (150 miles north of San Antonio). Transported back and underwent 43 days of VA ECMO, including air leak on rest settings

Recent Success

Happy Second Birthday!

Conclusions

- Pediatric ECMO is established for diseases:
  - Severe
  - Acute
  - Potentially reversible
- ECMO has evolved from neonates to all age groups
- Only absolute contraindication is a DNR
- “Relative” contraindications
Conclusions

• ECMO can be cost effective
• ECMO, ECMO equipment and applications of ECMO continue to evolve
  – Resuscitation
  – Transport
  – “Bridge” to transplant
  – Prematurity

  Plenty of new tricks!

But remember!

With great thanks...

• Entire ECMO team...
  – Coordinators
  – Primers
  – Specialists
• CSRCH Neonatal Team
• UTHSCSA Perfusion Group
• Wilford Hall ECMO Program

Questions?

With great thanks...

• Jim Fortenberry
• Robert Bartlett

Hopefully I have not led you astray...

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