Artificial Lung and Ambulatory ECMO

Joseph B. Zwischenberger MD
Johnston-Wright Professor
Chairman: Department of Surgery
Surgeon-in-Chief UK Healthcare
859-229-6635 (mobile)
jzwis2@uky.edu

The University of Kentucky
Lexington, Kentucky
Presenter Disclosure Information

Joseph B. Zwischenberger, M.D.

Research supported in part through

- **Competitive funding:**
  National Institutes of Health (SBIR, STTR, T-32)

- **Contracts:**
  MC3, Ann Arbor Mi
  Exotherm, Lexington Ky
  W-Z Biotek, Lexington Ky
  Maquet

  **Patent:** Avalon Elite™
Z-Bergerism #12

Innovation is never evidence-based
VENOVOUS ECMO
Single, Double Lumen Cannula
For total gas exchange alone

Kendall 1989

Zwischenberger/Drake Prototype ASAIO J 1984
The higher pump flow, the more recirculation (♦)
Effective flow (■) no longer increases as pump flow increases
VV Triple site cannulation

- Minimizes recirculation
- Maximizes venous drainage
- Improves gas exchange
Wang-Zwische DLC

Bicaval cannulation to separate flow
W-Z DLC ➔ Avalon Elite®: Key Elements

- Ultra-thin membrane reinfusion lumen
- Anti-kink stainless steel reinforced catheter with ultra-thin wall
- Reinforced reinfusion port
- Extended tip introducer
Avalon Elite® Catheter Placement: image guidance required
Flouro insertion with ECHO positioning
Newborn with Meconium Aspiration on Avalon Elite® VVDL ECMO 6 days: No Recirculation

Blue blood out → Red blood in

2009
Dual Lumen Canula (Avalon^R)

- One cannula inserted through right internal jugular vein
- Drainage from IVC and SVC → oxygenated blood returned to right atrium
- Designed for application in adults
Extracorporeal Membrane Oxygenation for 2009 Influenza A (H1N1) Acute Respiratory Distress Syndrome

- Observational study from 6/1 - 8/31 2009
- 68 adults placed on ECMO for influenza related ARDS (61 H1N1, 7 suspected H1N1)
- 54/68 survived to “off ECMO” (~80%)
- No published outcomes or follow-up

Australia and New Zealand ECMO Influenza Investigators

JAMA-EXPRESS

JAMA 2009;302:17
United Kingdom H1N1
ECMO vs Conventional care

- 69 ECMO patients in 4 centers
- Matched pairs study, 3 methods

<table>
<thead>
<tr>
<th>Method</th>
<th>ECMO</th>
<th>CC</th>
<th>survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual</td>
<td>77</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>Propensity score</td>
<td>76</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>Genmatch</td>
<td>76</td>
<td>49</td>
<td></td>
</tr>
</tbody>
</table>

Conclusion: ECMO survival 76%
Conventional Care 49%

Noah  JAMA 2011, 366:1659
Goal: Ambulatory Paracorporeal Artificial Lung

Alert 3-3-09 Chuck Hoopes (UCSF): the first Ambulatory Lung Assist patient using Avalon Cannula, Quadrox and Centrimag!!

Total gas exchange - no recirculation
Exercise at the bedside
VA ECMO
“Sport Model”

Optional V-VA
or WEAN to DLC VV

All configurations allow ambulation

Bacchetta 2012
Next Generation MAQUET ELITE-i (RA) Dual Lumen Catheter

- Catheter tip in RA (Right Atrium) NOT IVC (Inferior Vena Cava)
- Shorter length minimizes the possibility of insertion complications
- Shortened length allows insertion with or without a guidewire
- Available in 13Fr
This is ECMO?

“walking ECMO”…dual lumen Avalon VV (hypoxia, hypercarbea secondary BOS.. to redo BLTx)

“walking bypass”…RA to Ao cannulation (BiV failure, PHTN s/p PEA..to HLTx)

“ambulatory right heart bypass”…PA to LA cannulation (RV failure, hypoxia, PHTN s/p PEA..to BLTx)
Extracorporeal Membrane Oxygenation as a Bridge to Pulmonary Transplantation

19 of the last 25 were ambulatory at transplantation - all survived to 6 mo

"Pump failure" – was most common early
...... “respiratory failure” is now most common

“ECMO bridge to transplant or recovery is evolving into standard of care”

Latest: 42/49 (85%) – survival to 6 mo

Hoopes, Zwischenberger et.al. JTCVS 2013;145:862-8
Does anyone with severe respiratory failure really benefit from mechanical intubation and positive pressure ventilation?

......With ECMO......

*prevent barotrauma and activation of inflammatory mediators

*Limit end organ injury

*avoid sedation and muscle atrophy (frailty)

20/22 consecutive ambulatory ECMO adult patients are alive to 6 months
Cerebral Hypoxia
Fem-Fem VA

- Diagnosis with right radial saturations
  - Better venous drainage
    - Less LV ejection of hypoxic blood
  - V-AV support
    - Partial VA ECMO/Partial VV ECMO
Selection of ECLS Support Mode /Configuration

Hypercapnic failure → Hemodynamic stable

Hypoxic failure → Hemodynamic stable

Hemodynamic instability

- Support level A: Arterio-Venous (pumpless)
- PAH (severe RV dysfunction)
  - PA-LA (pumpless)
  - Support level C: Veno-Arterial (pump-driven)
  - Support level B: Veno-Venous (pump-driven)

Higher Volumes, Better Outcomes: The End or Just the Beginning of the Story for ECMO?

- 3 retrospective studies in neonatal/pediatric patients demonstrate higher volume programs (>30-50 cases per yr) have lower mortality

<table>
<thead>
<tr>
<th>Study, Years</th>
<th>Population</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeman and colleagues (2014)</td>
<td>Neonatal/pediatric patients, Age = 0–18 yr</td>
<td>Lower mortality in medium-volume (20–49 cases/yr) centers (adjusted OR, 0.86; 95% CI, 0.75–0.98)* and high-volume (≥50 cases/yr) centers (adjusted OR, 0.75; 95% CI, 0.63–0.89)*. The minimum annual case load most significantly associated with lower mortality was 22 (95% CI, 22–28).</td>
</tr>
<tr>
<td>Karamlou and colleagues (2013)</td>
<td>Pediatric patients, Age ≤ 20 yr, N = 3,867</td>
<td>Higher annual ECMO volume tertile was associated with reduced in-hospital mortality (P = 0.01) in nearly all risk-adjustment categories. After adjustment for congenital heart surgery category and other patient variables, lower ECMO volume remained a significant determinant of in-hospital mortality (OR, 1.75; 95% CI, 1.03–2.94).</td>
</tr>
<tr>
<td>Barbaro and colleagues (2015)</td>
<td>Neonatal/pediatric/adult patients, N = 56,222</td>
<td>Lower mortality in high-volume (&gt;30 cases/yr) centers for neonatal (adjusted OR, 0.69; 95% CI, 0.56–0.84) and adult (adjusted OR, 0.51; 95% CI, 0.48–0.79) cases.† When restricted to 2008–2013, the association only remained significant for adult high-volume centers (adjusted OR, 0.61; 95% CI, 0.46–0.80)†.</td>
</tr>
</tbody>
</table>

*Definition of abbreviations: CI = confidence interval; ECMO = extracorporeal membrane oxygenation; OR = odds ratio.
*Compared with low-volume (0–19 cases/yr) centers.
†Compared with low-volume (1–5 cases/yr) centers.

VV-ECLS improves survival in adult trauma patients with acute hypoxemic respiratory failure: a multicenter retrospective cohort study

• Retrospective study from two Level 1 trauma centers with acute hypoxemic respiratory failure aged 16-55;
• VV-ECLS (n=26) vs. mechanical vent (CONV, n=76)
• Ventilator days, ICU LOS, and hospital LOS did not differ between groups
• VV-ECLS: more blood transfusions and bleeding
CONV: more pulmonary complications.
• VV-ECLS was independently associated with survival in adult trauma patients.

Guirand et al. J Trauma Acute Care Surg 2015;76:1275-1281
Pediatric Ambulatory ECMO patient
ECMO FUTURE
Ambulatory Catheter based Technology

Neonates, Children, Adults
◆ Acute Severe Respiratory failure
◆ Acute Cardiac support

Transplantation
  – Recipient Support
    • Hypoxia/Hypercarbia from any origin
    • Pulmonary Hypertension/RV failure
  – Donor Support: EISOR
    • Bridge to Donation after Cardiac Death/DCD
  – Organ Block Support : Lung in a Box
    • Resuscitation, Reconditioning, Evaluation
AATS 2015

• Columbia: 52 pts bridge to lung transplant
  – 77% VV ECMO
  – 61% ambulated
  – 51% received lung transplant
  – 87% 1-year survival

• Toronto
  – 200 total adult ECMO patients with ~70% survival, increasingly use ambulatory ECMO
AATS 2015: 12 ECMO Presentations

- Neonates, children, and adults regarding cardiopulmonary support
- Pre, during, and post lung transplant

- AATS Guidelines: Bridge to transplant and Extracorporeal lung support (Bacchetta 2015)
Artificial Lung and Ambulatory ECMO

Joseph B. Zwischenberger MD

Johnston-Wright Professor
Chairman: Department of Surgery
Surgeon-in-Chief UK Healthcare
859-229-6635 (mobile)

jzwis2@uky.edu

The University of Kentucky
Lexington, Kentucky