RESPIRATORY ECLS

APACVS 2017
DISCLOSURES

• None

• I will discuss off-label use of ECLS components
AGENDA

- History
- Patient Selection
- Cannulation
- Short and Long-term Management
- Weaning and Decannulation
- Outcomes
• Early pediatric experience
• Early adult experience
• Clinical trials
• Literature support
NEONATAL AND PEDIATRIC EXPERIENCE

• First successful use in newborn: meconium aspiration respiratory failure 1975
  • 13 moribund infants (including 9 neonates), with 4 survivors (3 neonates). Successful cases included cardiac failure, infant respiratory distress syndrome, massive meconium aspiration, and persistent fetal circulation. All cases were managed with veno-arterial bypass at flow rates of 80-100 cc/Kg/min.

• 1985 Bartlett randomized trial – benefit

• 1986 Bartlett presented at ASA meeting

• 1989 O’Rourke randomized trial

• 1996 UK Collaborative trial – ECMO 32% vs 59% mortality in conventional group. Trial halted early.
  • UK Collaborative ECMO Trial Group. UK collaborative randomized trial of neonatal extracorporeal membrane oxygenation. The Lancet Vol 348, No. 9020, Jul 1996
EARLY ADULT

• First successful use of ECMO 1972 – young adult with post-traumatic ARDS

• 1979 NIH-ARDS randomized trial – survival 8.3 vs 9.5% - ns
    • VA ECMO, high anticoagulation with bleeding, high pressure ventilation, vent time > 9days

• 1986 Gattinoni ECCO2R cohort trial – 43 pts; efficacy of ECCO2R

• 1994 Morris ECCO2R randomized trial - n = 40pts; 30day surv-42 vs 33% (ns)
  • Low flow ECCO@ removal, higher pressure ventilation, PCIRV
CESAR - CONVENTIONAL VENTILATION OR ECMO FOR SEVERE ADULT RESPIRATORY FAILURE

  • Inclusion: pH < 7.2 or Murray score > 3. (P/F, EEP, compliance, cxr)
  • Exclusion: PIP > 30cm H$_2$O, FiO2 > .8 for > 7 days, ICB, limitation to recovery
  • 180 pts randomized; ECMO pts transferred to ECMO center
  • Survival at 6 months without severe disability: 63% vs 47% in ECMO vs usual care group respectively
  • NNT: 7

CESAR RESULTS

Survival

<table>
<thead>
<tr>
<th></th>
<th>28 day</th>
<th>180 day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>50</td>
<td>47</td>
</tr>
<tr>
<td>ECMO</td>
<td>76</td>
<td>63</td>
</tr>
</tbody>
</table>
EXTRACORPOREAL MEMBRANE OXYGENATION FOR 2009 INFLUENZA A(H1N1) ACUTE RESPIRATORY DISTRESS SYNDROME

- Observation of the incidence, resource utilization, and patient outcomes in patients with H1N1-associated ARDS treated with ECMO.
- Observational review of 68 patients with influenza-A ARDS treated with ECMO in 15 ICUs in New Zealand and Australia
  - 133 patients with influenza A received mechanical ventilation but no ECMO.
  - Before ECMO, patients had a median:
    - P/F ratio of 56 (48-63)
    - PEEP of 18 (15-20) cm H2O
- The median duration of ECMO support was 10 (7-15) days
- 48 of the 68 patients (71%) survived to ICU discharge
- 32 survived to hospital discharge and 16 remained hospitalized at the time of publication

VV ECMO PHYSIOLOGY

- External gas exchange that bypasses the lungs and allows reduction in barotrauma.
- Drainage of venous blood from the IVC and/or SVC and return of oxygenated blood to the right atrium.
  - Maintains lung blood flow
  - Pulsatile blood pressure
  - Oxygenated blood in aortic root
- Limits to flow
  - Cannula size and length
  - Size of vasculature
  - Volume status
INDICATIONS

• Ventilation
  • Airway obstruction
  • hypercarbia

• Respiratory
  • ARDS
  • Pneumonia
  • Aspiration
  • Contusion

• Lung transplant
  • IntrOp, bridge to transplant, graft failure
• Selection criteria
  • Hypoxic failure – Murray score* > 3
    • P/F < 150 on FiO2 > 0.90 – consider
    • P/F < 100 on FiO2 >0.90 - indicated
  • Hypercarbia
  • Bridge to lung transplant
• Relative contraindications
  • Advanced age, malignancy
  • Cardiac failure
• Absolute – condition incompatible with recovery or transplant
• Lung transplant graft dysfunction
• Ventilator > 7 days
• Severe air leaks
• MODS or CNS injury

(* - available at cesar.ishtm.ac.uk/murrayscorecalculator.htm)
PATIENT EVALUATION

- Pre-ECMO evaluation
  - ECHO – EF
  - CO – estimate flow rate
  - Vascular US – r/o DVT, malformations
- Murray score
  - P/F <150, PIP > 25, PEEP >
- RESP scoring
- APPS Score
  - Age, P/F, and plateau pressure
The RESP Score

The RESP Score has been developed by ELSO and The Department of Intensive Care at The Alfred Hospital, Melbourne. It is designed to assist prediction of survival for adult patients undergoing Extra-Corporeal Membrane Oxygenation for respiratory failure. It should not be considered for patients who are not on ECMO or as substitute for clinical assessment.

For more information see:

Available online
Works on mobile device
Estimates survival
RespScore.com

The patient’s RESP Score is 3

Age (years:)
- 16-49
- 50-59
- 60+

Immunocompromised

Mechanical ventilation prior to initiation of ECMO
- <48 hours
- 48 hours - 7 days
- >7 days

Acute Respiratory diagnosis group
- Viral pneumonia
- Bacterial pneumonia
- Asthma
- Trauma/pulm
- Acute leukaemia
- Other acute respiratory diagnosis
- Non-respiratory and chronic respiratory diagnoses

Central nervous system dysfunction

Acute associated (non-pulmonary) infection

Neuro-muscular blockade before ECMO

Nitric oxide use before ECMO

Bicarbonate infusion before ECMO

Cardiac arrest before ECMO

PaCO₂ ≥75 mmHg / 10kpa

Peak inspiratory pressure ≥20cmH₂O
The Murray score was used in the CESAR trial to characterize the severity of the lung injury.

http://cesar.lshtm.ac.uk/murrayscorecalculator.htm
• Placed in OR or at bedside (RV support?)
• Fluoroscopic or ECHO guidance (TEE) required
• Two cannula – fem/fem, fem/IJ
  • IVC drainage
  • RA return
• Double lumen cannula
  • Avalon
  • RIJ approach
  • Allows ambulation

ORIGEN BIOMEDICAL

<table>
<thead>
<tr>
<th>Product Code</th>
<th>Tip Diameter (F)</th>
<th>Inserted Length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VV13F</td>
<td>13F</td>
<td>8.2</td>
</tr>
<tr>
<td>VV16F</td>
<td>16F</td>
<td>9.5</td>
</tr>
<tr>
<td>VV19F</td>
<td>19F</td>
<td>13.7</td>
</tr>
<tr>
<td>VV23F</td>
<td>23F</td>
<td>18.2</td>
</tr>
<tr>
<td>VV28F</td>
<td>28F</td>
<td>22.5</td>
</tr>
<tr>
<td>VV32F</td>
<td>32F</td>
<td>25.0</td>
</tr>
</tbody>
</table>
AVALON ELITE AND ORIGEN FLOW
THE CIRCUIT

• Pump
• Oxygenator
  • Polymethylpentene - Q
  • Polypropylene - Medtronic
  • Silicone - Avecor
• Tubing
• Sensors
  • Bubble detector (CardioHelp)
• Gas
• Heat exchanger
PUMP TECHNOLOGY

- CardioHelp – Maquet
- Centrimag – Medtronic
- Rotaflow – Maquet
- Biomedicus -Medtronic

History
Patient Selection
Cannulation and Circuit
Management
Weaning and Decannulation
Outcomes
IMMEDIATE MANAGEMENT

- Hypoxia and flow
  - FiO2 high on circuit/low on vent
  - High flow rates often needed
    - 50-80mL/dry wt/min – high flow then titrate down
    - keep SpO2 > 75%
    - DO2I matching needs
  - Limited by venous return
  - May have increased recirculation
- Ventilatory
  - Optimal strategy unclear
  - Provide some positive pressure – gradual recruitment
    - Role for high PEEP
  - Sedate until stable – morphine, midazolam, ketamine.
    - Drug clearance altered – fentanyl/midaz
  - Extubate
  - Early percutaneous tracheostomy – 3-5 days
- Regulate PaCO2
  - Controlled by sweep gas – target based on patient needs
  - Pulmonary vasoconstriction and RV function
  - May be up to 15LPM with low blood flow rates
IMMEDIATE MANAGEMENT

• Minimize recirculation – increase in oxygenated blood through drain cannula
  • Cannula configuration, size and sites, pump flow, increased intrathoracic pressure
  • Difficult to accurately measure – trend ScVO2 and SpO2
  • Reposition cannula (ECHO)
  • Use of DL cannula – flow directed at TV
  • Add drainage cannula

• Optimize hemodynamic parameters with inotropes, pressors, vasodilators, transfusions as needed
  • ECHO or hTEE useful for following hemodynamics and adjusting interventions
  • Pulmonary artery pressures and cardiac output
  • Assess tissue perfusion and oxygenation
REDUCE
RECIRCULATION

- Reposition with ECHO guidance
LONGER TERM MANAGEMENT

• Assess neurologic status
  • Encephalopathic

• Wean/extubate
  • Wake up and out-of-bed

• Volume removal –
  • Diuresis, UF to dry weight

• Optimize O2 transport
  • Maintain Hgb and cardiac output
  • Follow markers of ischemia
  • Adjust for hypermetabolic states
LONG TERM MANAGEMENT

• Anticoagulate – yes or no
  • +/- Heparin bolus on cannulation
  • Monitor – aPTT, ACT, anti-Xa, TEG, ROTEM

• Dysrhythmias
  • Hypoxia/electrolytes/mechanical
  • Identify cause

• Hypertension
  • Increases risk of CVA or hemorrhage

• Metabolic
  • Nutrition support – avoid TPN, use gut
  • Glycemic control
LONG TERM MANAGEMENT

• Complications common and anticipated
  • Bleeding – most frequent
    • Most common at surgical site, invasive procedures, cannula site, ENT, pulmonary hemorrhage, GI - Avoid invasive procedures
    • Transfuse to maintain adequate levels
    • Correct clotting factors
    • Stop anticoagulation
    • Bronchoscopy, EGD
  • Thrombocytopenia – circuit activation
  • Hemolysis – circuit or patient issue
    • Frequent check of LDH or FH
  • Infection
    • Large central access and frequent manipulation
    • Minimize circuit access
    • CLABSI
    • Skin breakdown
  • SIRS
    • Triggered by ECMO and subsequent events – bronch..
LONG TERM MANAGEMENT

- AKI
  - ATN common – capillary leak/volume loss
  - RRT common
    - Circuit or catheter access
- Thromboembolism
  - Catheter/cannula/membrane
  - Intracardiac
  - Anticoagulation target
  - Change circuit
- CNS
  - ICB or infarction
  - Seizures
- HIT/HITTs
  - Hep AB, SRA
  - DTI use – bivalirudin, argatroban
• Lung recovery may take weeks or months
• Sweep gas wean
  • Gradual decrease and follow ABGs
• CXR improvement
  • Improvement in aeration
  • Recruitment
• Optimize ventilator
• Acceptable mechanics
• Stop sweep and maintain flow
• Remove cannula
OUTCOMES – US SUMMARY

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## Adult Respiratory Runs by Year

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual Runs</th>
<th>Cumulative Runs</th>
<th>Average Run Time</th>
<th>Longest Run Time</th>
<th>No. Survived</th>
<th>% Survived</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>261</td>
<td>1,499</td>
<td>218</td>
<td>1,487</td>
<td>128</td>
<td>49%</td>
</tr>
<tr>
<td>2011</td>
<td>360</td>
<td>1,859</td>
<td>245</td>
<td>2,245</td>
<td>190</td>
<td>52%</td>
</tr>
<tr>
<td>2012</td>
<td>435</td>
<td>2,294</td>
<td>242</td>
<td>6,248</td>
<td>219</td>
<td>50%</td>
</tr>
<tr>
<td>2013</td>
<td>788</td>
<td>3,082</td>
<td>259</td>
<td>4,527</td>
<td>474</td>
<td>60%</td>
</tr>
<tr>
<td>2014</td>
<td>1,092</td>
<td>4,174</td>
<td>301</td>
<td>3,208</td>
<td>655</td>
<td>59%</td>
</tr>
<tr>
<td>2015</td>
<td>1,239</td>
<td>5,413</td>
<td>277</td>
<td>3,146</td>
<td>710</td>
<td>57%</td>
</tr>
<tr>
<td>2016</td>
<td>1,406</td>
<td>6,819</td>
<td>294</td>
<td>5,355</td>
<td>847</td>
<td>60%</td>
</tr>
</tbody>
</table>

Run time in hours. Survived = survival to discharge or transfer based on number of runs

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## Adult Respiratory Runs by Diagnosis

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Total Runs</th>
<th>Avg Run Time</th>
<th>Longest Run Time</th>
<th>Survived</th>
<th>% Survived</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viral pneumonia</td>
<td>459</td>
<td>347</td>
<td>3,208</td>
<td>284</td>
<td>61%</td>
</tr>
<tr>
<td>Bacterial pneumonia</td>
<td>377</td>
<td>280</td>
<td>1,548</td>
<td>205</td>
<td>54%</td>
</tr>
<tr>
<td>Aspiration pneumonia</td>
<td>98</td>
<td>259</td>
<td>4,799</td>
<td>65</td>
<td>66%</td>
</tr>
<tr>
<td>ARDS, postop/trauma</td>
<td>255</td>
<td>253</td>
<td>2,205</td>
<td>125</td>
<td>49%</td>
</tr>
<tr>
<td>ARDS, not postop/trauma</td>
<td>606</td>
<td>292</td>
<td>6,248</td>
<td>344</td>
<td>56%</td>
</tr>
<tr>
<td>Acute resp failure, non-ARDS</td>
<td>1,685</td>
<td>281</td>
<td>4,527</td>
<td>944</td>
<td>56%</td>
</tr>
<tr>
<td>Other</td>
<td>3,075</td>
<td>232</td>
<td>5,355</td>
<td>1,704</td>
<td>55%</td>
</tr>
</tbody>
</table>

Run time in hours. Survived = survival to discharge or transfer based on number of runs.

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### Adult Respiratory Complications

<table>
<thead>
<tr>
<th>Condition</th>
<th>No. Reported</th>
<th>% Reported</th>
<th>No. Survived</th>
<th>% Survived</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical: Oxygenator failure</td>
<td>468</td>
<td>6.9%</td>
<td>219</td>
<td>47%</td>
</tr>
<tr>
<td>Mechanical: Clots: oxygenator</td>
<td>965</td>
<td>14.2%</td>
<td>551</td>
<td>57%</td>
</tr>
<tr>
<td>Mechanical: Cannula problems</td>
<td>399</td>
<td>5.9%</td>
<td>171</td>
<td>43%</td>
</tr>
<tr>
<td>Hemorrhagic: GI hemorrhage</td>
<td>415</td>
<td>6.1%</td>
<td>161</td>
<td>39%</td>
</tr>
<tr>
<td>Hemorrhagic: Cannulation site bleeding</td>
<td>906</td>
<td>13.3%</td>
<td>420</td>
<td>46%</td>
</tr>
<tr>
<td>Hemorrhagic: Surgical site bleeding</td>
<td>824</td>
<td>12.1%</td>
<td>361</td>
<td>44%</td>
</tr>
<tr>
<td>Hemorrhagic: Hemolysis (hgb &gt; 50 mg/dl)</td>
<td>437</td>
<td>6.4%</td>
<td>214</td>
<td>49%</td>
</tr>
<tr>
<td>Renal: Creatinine 1.5 - 3.0</td>
<td>1,479</td>
<td>21.7%</td>
<td>674</td>
<td>46%</td>
</tr>
<tr>
<td>Renal: Creatinine &gt; 3.0</td>
<td>771</td>
<td>11.3%</td>
<td>335</td>
<td>43%</td>
</tr>
<tr>
<td>Renal: Dialysis required</td>
<td>715</td>
<td>10.5%</td>
<td>295</td>
<td>41%</td>
</tr>
<tr>
<td>Renal: Hemofiltration required</td>
<td>805</td>
<td>11.8%</td>
<td>384</td>
<td>48%</td>
</tr>
<tr>
<td>Renal: CAVHD required</td>
<td>938</td>
<td>13.8%</td>
<td>392</td>
<td>42%</td>
</tr>
<tr>
<td>Cardiovascular: Inotropes on ECLS</td>
<td>2,506</td>
<td>36.8%</td>
<td>1,094</td>
<td>44%</td>
</tr>
<tr>
<td>Cardiovascular: CPR required</td>
<td>393</td>
<td>5.8%</td>
<td>78</td>
<td>20%</td>
</tr>
<tr>
<td>Cardiovascular: Cardiac arrhythmia</td>
<td>737</td>
<td>10.8%</td>
<td>253</td>
<td>34%</td>
</tr>
<tr>
<td>Cardiovascular: Hypertension requiring vasodilators</td>
<td>448</td>
<td>6.6%</td>
<td>254</td>
<td>57%</td>
</tr>
<tr>
<td>Infectious: Culture proven infection (see Infections)</td>
<td>1,087</td>
<td>15.9%</td>
<td>512</td>
<td>47%</td>
</tr>
</tbody>
</table>

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LONG-TERM SURVIVAL
ECMO CENTER KAROLINSKA IN STOCKHOLM, SWEDEN ESTABLISHED 1987

• Respiratory ECLS 1995 – 2013
• n = 255
• Age (m): 46 yr [33-58]
• Gender male: 65%
• Duration VV (m): 8 day [4-17]
• P/F ratio (mmHg): 54 [47-60]

(von Bahr et al. Long Term Survival in Adults Treated With Extracorporeal Membrane Oxygenation for Respiratory Failure and Sepsis. Crt Care Med 2017; 201745:164-170)
LONG-TERM SURVIVAL
ECMO CENTER KAROLINSKA

- Survived to discharge: 64%
- Median follow-up 4.4 years
- For those that survived > 90 days; five year survival: 87%

(von Bahr et al. Long Term Survival in Adults Treated With Extracorporeal Membrane Oxygenation for Respiratory Failure and Sepsis. Crit Care Med 2017; 201745:164-170)
FLORIDA HOSPITAL 2016

- VV – cases: 28
  - Age: 44yr (m) [19-73]
  - Gender: F-14 (50%)
  - Run (days): 16.6(m) [2-61]
    - (hrs): 392 (m) [45-1,459]
  - LOS: 32 d (m) [2-69]
FH – 2016

Diagnosis
- Flu/H1N1: 36%
- ARDS: 36%
- Other: 21%
- PE: 7%

Resp ECLS
- Expired: 39%
- Discharged Alive: 61%

Discharged alive: 17 (61%)

(Flu/H1N1 discharged alive – 60%)
Respiratory ECLS has become an established tool to allow recovery, bridge to transplant, or bridge to decision for patients with hypoxic respiratory failure.

Long term trials demonstrating the mortality benefit are ongoing.

Ideal strategies for adjunctive support i.e. anticoagulation, ventilator modes, extubation timing, and others await further delineation.