DISCLOSURES

• None

• I will discuss off-label use of ECLS components
• Neonatal and Pediatric Experience


  • UK Collaborative ECMO Trial Group. UK collaborative randomized trial of neonatal extracorporeal membrane oxygenation. The Lancet Vol 348, No. 9020, Jul 1996

• Early Adult


**CESAR - CONVENTIONAL VENTILATION OR ECMO FOR SEVERE ADULT RESPIRATORY FAILURE**

  - Inclusion: pH < 7.2 or Murray score > 3. (P/F, PEEP, compliance, cxr)
  - Exclusion: PIP > 30cm H2O, 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
NUMBER NEEDED TO TREAT

- **Statins - combined**: 107 – all cause mortality
- **HPS**: 59 – all cause mortality
- **COMET**: 59 – one year mortality
- **Beta Blockers p MI**: 51 – all cause mortality
- **HOPE**: 50 – all cause mortality
- **Aspirin**: 25 – MI or mortality
- **MADIT II**: 9 – all cause mortality

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>

Weaning and Decannulation Outcomes Management Cannulation Patient Selection Clinical Trials
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, postOp
• 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
  • Severe airway leaks
  • Ventilator > 7 days
  • 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 ILRI and The Department of Intensive Care at The Alfred Hospital, Melbourne. It is designed to assist in 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 a substitute for clinical assessment.


The patient's RESP Score is 3

- Age (years):
  - 18-49 ☑
  - 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 ☑
  - Traumelum ☐
  - Aspiration pneumonitis ☑
  - 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 ☑

- Extracorporeal carbon dioxide removal before ECMO ☑

- Cardiac arrest before ECMO ☐

- PaCO₂ ≥75 mmHg / 10kpa ☐

- Peak inspiratory pressure ≥20cm H2O ☐

- RespScore.com
The Murray score was used in the CESAR trial to characterize the severity of the lung injury.

http://cesar.lshtm.ac.uk/murrayscorecalculator.htm
CANNULATION

- 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

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

Weaning and Decannulation

Clinical Trials
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/drywt/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/others
  - Extubate or
  - Early percutaneous tracheostomy – 3-5 days
IMMEDIATE MANAGEMENT

• Regulate PaCO2
  • Controlled by sweep gas – target based on patient needs (~35)
  • 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
IMMEDIATE MANAGEMENT

- 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
LONGER TERM MANAGEMENT

• Assess neurologic status
  • Encephalopathy common

• 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
LONG TERM MANAGEMENT

• 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**
  • Acceptable ABG

• Remove cannula
OUTCOMES – US SUMMARY

Annual Respiratory Adult Runs

(c) 2017 Extracorporeal Life Support Organization
### 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.

(c) 2017 Extracorporeal Life Support Organization
## US SUMMARY

### Weaning and Decannulation Outcomes

#### Management

#### Cannulation

#### Patient Selection

#### Clinical Trials

### 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

(c) 2017 Extracorporeal Life Support Organization
ADULT RESPIRATORY RUNS

Other

ARDS, Not postOp/trauma

Asp PNA

ARDS, postOp/trauma

Bact PNA

Viral PNA

ARF- nonARDS

ARDS, Not postOp/trauma

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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</td>
<td>1,087</td>
<td>15.9%</td>
<td>512</td>
<td>47%</td>
</tr>
</tbody>
</table>

(c) 2017 Extracorporeal Life Support Organization
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
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.