Extracorporeal Life Support in Respiratory Failure (ECMO)

Jason Mohr, DO
Medical Director, Extracorporeal Life Support
Disclosures

Nothing to Disclose

Any equipment illustrated in this presentation is for educational purposes only. I do not endorse any specific brand.
Outline

- Respiratory failure
- Pathophysiology
- Secondary Injury
- When do we cannulate?
- When do we de-cannulate?
- Discussion
Outline

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Respiratory Failure that we need to worry about - ARDS

/ Severe dyspnea, tachypnea, cyanosis
/ Refractory to oxygen therapy, decreased pulmonary compliance
/ Diffuse alveolar infiltrates on chest radiograph, atelectasis, vascular congestion, hemorrhage
/ Pulmonary edema, and hyaline membranes at autopsy

Ashbaugh and colleagues, 1967 (11)
History

Four-point lung injury scoring system, specifies clinical cause of lung injury based on:

- Oxygenation
- Positive end-expiratory pressure
- Respiratory system compliance
- Chest radiograph involvement

Murray and colleagues, 1988 (20)
History

- Diffuse alveolar involvement
- Acute Onset
- No left heart failure/left atrial hypertension
- Oxygenation score
  - $\text{PaO}_2/\text{FiO}_2$ is $\leq 300$ Acute Lung Injury
  - $\text{PaO}_2/\text{FiO}_2$ is $\leq 200$ ARDS

Bernard and colleagues, 1994 (19) (American European Consensus Conference Definition)
History

- No Acute lung injury as part of definition
- Acute and persistent onset
- Radiological evidence consistent with diffuse pulmonary edema
  - 3 severities according to level of hypoxemia
  - Mild: $\text{PaO}_2/\text{FiO}_2 > 200$ and $\leq 300$
  - Moderate: $\text{PaO}_2/\text{FiO}_2 > 100$ and $\leq 200$
  - Severe: $\text{PaO}_2/\text{FiO}_2 \leq 100$

Berlin definition 2012
Current ARDS Outcomes

Within the context of extreme variability among the few population-based studies on ARDS, the incidence of ARDS has not changed substantially in Europe in the last 10 years, but it is an order of magnitude lower than the reported incidence in the USA.

Current overall mortality approximates 40–50% in all major series, although several randomized controlled trials have reported an improvement in survival in selected ARDS patients.

A risk stratification model based on a composite of respiratory, ventilatory and physiological variables might identify patients who should be the target of extraordinary measures in clinical trials aimed to decrease ARDS mortality, or identify ARDS patients in whom benefit from treatment may be limited or disproportional to the resources used.

It is expected that broad application of lung protective ventilation, appropriate setting of PEEP, restricting blood transfusion and rapid management of sepsis would decrease incidence and mortality of hospital acquired ARDS.
Outline

- Respiratory failure
- *Pathophysiology*
- Secondary Injury
- When do we cannulate?
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Causes of ARDS

- Pneumonia: 35%
- Severe Sepsis: 26%
- Aspiration: 15%
- Trauma: 11%
- Other: 13%

Other: drowning, pancreatitis, reperfusion, salicylate and narcotic OD, fat/amniotic embolism, smoke/chemical inhalation.
Pathophysiology

1. Direct or indirect injury to the alveolus causes alveolar macrophages to release pro-inflammatory cytokines

Ware et al. NEJM 2000; 342:1334
2. Cytokines attract neutrophils into the alveolus and interstitium, where they damage the alveolar-capillary membrane (ACM).
3. ACM integrity is lost, interstitial and alveolus fills with proteinaceous fluid, surfactant can no longer support alveolus.

Ware et al. NEJM 2000; 342:1334
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High stretch ventilation

Low stretch ventilation
ARDS - What are the standard treatments and intervention’s. How do we prevent secondary injury??

/ Treat the underlying cause if possible. *Example-sepsis.*

/ **Prevent** secondary injury
  - Barotrauma
  - Volutrauma
  - Atelectrauma
  - Biotrauma
  - Oxygen Toxicity
  - Secondary injury can take a single organ mortality rate of 40% and turn it into a 80-100% mortality
ARDS – What does the TEAM need to focus on?

- Prevent secondary injury which can cause extraordinary mediator release – circulating inflammatory mediators – multi organ failure and **DOUBLE** the risk mortality
- Follow the least injurious ventilator strategy possible
- Generally accepted guidelines – supported by the literature
  - Tidal Volume 6-8 ml/kg/pbw (even 4ml if Pplat >30)
  - Avoid de-recruitment with PEEP
  - Pplat < 30cm H₂O
  - Minimal FIO₂
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- A risk stratification model based on a composite of respiratory, ventilatory and physiological variables might identify patients who should be the target of extraordinary measures in clinical trials aimed to decrease ARDS mortality, or identify ARDS patients in whom benefit from treatment may be limited or disproportional to the resources used.

- It is expected that broad application of lung protective ventilation, appropriate setting of PEEP, restricting blood transfusion and rapid management of sepsis would decrease incidence and mortality of hospital acquired ARDS.
What **MAY** be the best way to prevent secondary injury caused by the ventilator?

Don’t use one!!!!

OK you still have to use one but you can make it play second fiddle
Outline

/ Respiratory failure
/ Pathophysiology
/ Secondary Injury
/ *When do we cannulate?*
/ *When do we de-cannulate?*
/ Discussion
What is ECMO

- ECLS is extracorporeal life support and is a general term that encompasses more than one technique (ECMO, ECCO₂R)
- Can support cardiac function, pulmonary function or both
- Has advanced considerably over the last few years and can be relatively easy to start and manage
- Is commonly started to support the lungs in acute respiratory failure
History

- First used in the 1970s on adult respiratory patients
- 1974 first Neonatal Respiratory ECMO for MAS (Bob Bartlett)
- NIH sponsored a study of adult respiratory failure but trial halted after only 90 patients due to less than 10% survival
- Bartlett went on to treat respiratory distress infants with a 75% survival rate
In hypoxic respiratory failure due to any cause (primary or secondary), ECLS should be considered when the risk of mortality is 50% or greater, and is indicated when the risk of mortality is 80% or greater.

- 50% mortality risk is associated with a PaO₂/FiO₂ < 150 on FiO₂ > 90% and/or Murray score 2-3.
- 80% mortality risk is associated with a PaO₂/FiO₂ < 100 on FiO₂ > 90% and/or Murray score 3-4 despite optimal care for 6 hours or more.

- CO₂ retention on mechanical ventilation despite high Pplat (>30 cm H₂O)
- Severe air leak syndromes
- Need for intubation in a patient on lung transplant list
- Immediate cardiac or respiratory collapse (PE, blocked airway, unresponsive to optimal care)
Criteria for Adult ECLS

Murray Lung Injury Score (MLIS)
- PaO2/FiO2: > 300 = 0, 225-299 = 1, 175-224 = 2, 100-174 = 3, < 100 = 4
- CXR: Normal = 0, 1 pt per quadrant infiltrated
- PEEP: <5 = 0, 6-8 = 1, 9-11 = 2, 12-14 = 3, >15 = 4
- Compliance (ml/cmH2O): >80 = 0, 60-70 = 1, 40-59 = 2, 20-39 = 3, <19 = 4

Points for each category are added together, then divided by 4 to get the MLIS #. ** a MLIS score > 3 in the hypoxic pt., is severe enough to warrant ECLS

*** Hypercapnic pt.’s may not have a high MLIS score and should be considered when their pH is < 7.2.

- Acute cardiac compromise
- PaO2/FiO2: < 80

*ECMO: Extracorporeal Cardiopulmonary Support in Critical Care 4th edition
Who gets ECMO

$$\frac{\text{PaO}_2/\text{FIO}_2}{\text{mmhg}} \div 0.50 = 100$$
Problem with PaO₂/FiO₂ Ratio

Example 1:
- **Nasal cannula 6L/min**
- PaO₂ = 80, FiO₂ = ~45%
- P/F = 182

Example 2:
- **Mechanical Ventilation AC (14) 500ml VT, FIO₂ 45%, PEEP 16**
- PaO₂ 80, FiO₂ 45%
- P/F = 182

Same P/F but clearly two entirely different patients
# Murry Lung Injury Score (MLIS)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>P/F</td>
<td>≥ 300</td>
<td>225-299</td>
<td>175-224</td>
<td>100-174</td>
<td>&lt; 100</td>
</tr>
<tr>
<td>CXR (quadrants)</td>
<td>Normal</td>
<td>1 quadrant</td>
<td>2 quadrants</td>
<td>3 quadrants</td>
<td>4 quadrants</td>
</tr>
<tr>
<td>PEEP</td>
<td>≤ 5</td>
<td>6-8</td>
<td>9-11</td>
<td>12-14</td>
<td>≥ 15</td>
</tr>
<tr>
<td>Compliance (ml/cmH2O)</td>
<td>≥ 80</td>
<td>60-79</td>
<td>40-59</td>
<td>20-39</td>
<td>≤ 19</td>
</tr>
</tbody>
</table>

Example patient with P/F 50 (4), 4 quadrant involvement (4), PEEP 12 (3), Compliance 16 (4) = 15/4 = **MLIS 3.75**

ELSO Suggests ECMO with MLIS > 3.0
Oxygenation Index

\[ \text{FiO}_2 \times \text{mPaw} \div \text{PaO}_2 \]

\[ 100 \times 25 \div 50 = 50 \]
Oxygenation Index

- Historically used in pediatric and neonatal critical care
- Inclusion criteria for ECMO - pediatrics/neonates
- Previously unclear what the utility of OI is in adults
- Uses the same indices as the P/F ratio PLUS includes level of support (Mean Airway Pressure)
- May be more sensitive for expressing severity of illness
Example 2:
- Mechanical Ventilation AC (14) 500ml VT, FiO₂ 45%, PEEP 20
- PaO₂ 80, FiO₂ 45%
- P/F = 100/100% = 100 (Mortality 39% and 49%)
- OI = 100 × 26/100 = 26 (Mortality 100% and 48%)

<table>
<thead>
<tr>
<th>Oxygen Index (OI)</th>
<th>N (575)</th>
<th>Alive (389)</th>
<th>Deceased (186)</th>
<th>Mortality (32%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 4.9</td>
<td>342</td>
<td>257</td>
<td>85</td>
<td>25%</td>
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<tr>
<td>5.0 – 9.9</td>
<td>153</td>
<td>99</td>
<td>54</td>
<td>35%</td>
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<tr>
<td>10 – 14.9</td>
<td>37</td>
<td>21</td>
<td>16</td>
<td>43%</td>
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<tr>
<td>15 – 19.9</td>
<td>24</td>
<td>14</td>
<td>10</td>
<td>42%</td>
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<tr>
<td>20 – 24.9</td>
<td>9</td>
<td>5</td>
<td>4</td>
<td>44%</td>
</tr>
<tr>
<td>≥ 25</td>
<td>10</td>
<td>0</td>
<td>10</td>
<td>100%</td>
</tr>
</tbody>
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<tbody>
<tr>
<td>P/F &gt; 300</td>
<td>217</td>
<td>179</td>
<td>38</td>
<td>18%</td>
</tr>
<tr>
<td>P/F 200 - 300</td>
<td>191</td>
<td>123</td>
<td>68</td>
<td>26%</td>
</tr>
<tr>
<td>P/F 100 - 199</td>
<td>135</td>
<td>82</td>
<td>53</td>
<td>39%</td>
</tr>
<tr>
<td>P/F &lt; 100</td>
<td>32</td>
<td>15</td>
<td>17</td>
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**Example 2:**
- *Mechanical Ventilation AC (14) 500ml VT, FiO₂ 45%, PEEP 20*
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- *P/F = 100/100% = 100 (Mortality 39% and 49%)*
- *OI = 100 X 26/100 = 26 (Mortality 100% and 48%)*

### Table 2 (ELSO Data)

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<thead>
<tr>
<th>Oxygen Index (OI)</th>
<th>N (1018)</th>
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<tbody>
<tr>
<td>0 - 4.9</td>
<td>24</td>
<td>19</td>
<td>5</td>
<td>21%</td>
</tr>
<tr>
<td>5.0 – 9.9</td>
<td>28</td>
<td>17</td>
<td>11</td>
<td>39%</td>
</tr>
<tr>
<td>10 – 14.9</td>
<td>56</td>
<td>26</td>
<td>30</td>
<td>54%</td>
</tr>
<tr>
<td>15 – 19.9</td>
<td>63</td>
<td>31</td>
<td>32</td>
<td>51%</td>
</tr>
<tr>
<td>20 – 24.9</td>
<td>88</td>
<td>58</td>
<td>29</td>
<td>33%</td>
</tr>
<tr>
<td>25 – 29.9</td>
<td>113</td>
<td>59</td>
<td>54</td>
<td>48%</td>
</tr>
<tr>
<td>30 – 34.9</td>
<td>123</td>
<td>72</td>
<td>51</td>
<td>41%</td>
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<tr>
<td>35 – 39.9</td>
<td>95</td>
<td>48</td>
<td>47</td>
<td>49%</td>
</tr>
<tr>
<td>40 - 44.9</td>
<td>91</td>
<td>45</td>
<td>46</td>
<td>51%</td>
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<tr>
<td>≥ 45</td>
<td>337</td>
<td>201</td>
<td>136</td>
<td>40%</td>
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<td>55</td>
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</tr>
<tr>
<td>P/F &lt; 100</td>
<td>866</td>
<td>488</td>
<td>378</td>
<td>44%</td>
</tr>
</tbody>
</table>
OI and P/F
Contraindications

• There are no absolute contraindications to ECLS

• There are conditions, however, that are known to be associated with a poor outcome despite ECLS

  • Mechanical ventilation at high settings (FiO₂ > .90, Pplat > 30) for 7 days or more
  • Major pharmacologic immunosuppression (absolute neutrophil count < 400/ml³)
  • CNS hemorrhage that is recent or expanding
Complications

- Hemorrhage (Pulm, GI, Surgical Site)
- Infection
- CNS Damage (bleed, infarction)
- Fluid retention and severe edema
- Seizures (Metabolic or CNS)
- Cardiac Dysrhythmias
- Heparin induced thrombocytopenia
- Thromboembolism
- Equipment malfunctions??
Bottom Line Who

/ Hi likelihood of dying
/ Reversible Condition
/ Bridge to treatment
  • Transplant
  • VAD
How does it work?

/ **veno-arterial (VA-ECMO):** allows gas exchange and hemodynamic support while blood is pumped from the venous side to the arterial side. Augments Cardiac Output/function

/ **veno-venous (VV-ECMO):** facilitates gas exchange; blood is removed from the venous side and then pumped back into it, but does not provide hemodynamic support. Maybe a little when myocardium gets more oxygen

/ **arterial-venous (AV-ECMO):** (Pumpless): Allows gas exchange by using the patients own CO to “pump” blood through compact oxygenator. Compact. Simple. Example NovaLung
Veno-Arterial ECMO

VA ECMO: Dual Cannula Circuit Model
Veno-Venous ECMO
How does it work?

- Deoxygenated blood is removed from a large central vein
- This deoxygenated blood is then pumped through a membrane oxygenator

For Veno-Venous ECMO (VV ECMO)

- Oxygenated blood is returned to a large central vein/RA
- The patient’s own heart pumps the oxygenated blood through the damaged lungs and to the body
How does it work?

For Veno-Arterial ECMO (VA ECMO)
/ Blood is returned to the aorta, thus supporting cardiac function as well, bypassing the lungs entirely

For Arterial-Venous ECMO (AV ECMO)
/ Blood is allowed to flow from arterial side to venous side via native blood pressure (ECCO$_2$R)
What effects gas exchange

/ Sweep flow regulates gas exchange as it regulates how much gas flow is introduced to the hollow fiber filled (polymethylpentene) artificial LUNG (aka Oxygenator)
/ The artificial LUNG is 100% efficient unlike the sick human lung
/ FIO$_2$ controls O$_2$
/ Sweep flow controls CO$_2$
Ventilator management

- Use least injurious strategy as possible
- Moderate PEEP (prevent atelectasis)
- Safe distending pressures (prevent vole/barotrauma)
- Now is the time to perform bronchoscopy!
Outline

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/ *When do we de-cannulate?*
/ Discussion
Weaning

Veno-arterial ECMO liberation trial

VA ECMO trials require temporary clamping of both the drainage and infusion lines, while allowing the ECMO circuit to circulate through a bridge between the arterial and venous limbs. This prevents thrombosis of stagnant blood within the ECMO circuit. In addition, the arterial and venous lines should be flushed continuously with heparinized saline or intermittently with heparinized blood from the circuit. In general, VA ECMO trials are shorter in duration than VV ECMO trials because of the higher risk of thrombus formation.
Weaning

Veno-venous ECMO liberation trial

Trials are performed by eliminating all countercurrent sweep gas through the oxygenator. Extracorporeal blood flow remains constant, but gas transfer does not occur. Patients are observed for several hours, during which the ventilator settings that are necessary to maintain adequate oxygenation and ventilation off ECMO are determined as indicated by arterial and venous blood gas results.
Monitor end-organ perfusion & delivery

- Lactate
- ScvO₂ or SvO₂
- StO₂
- Other organ function creatinine, LFT’s urine output
- INVOS NIRS for limb and cerebral ischemia
Summary

- ARDS/Respiratory failure has a across the board mortality rate of at LEAST 40% but can approach 100%
- ECLS should be initiated when there is a high risk of dying and where there is a reversible process
- Initiating ECLS too early can worsen outcomes
- Initiating ECLS too late can worsen outcomes
- Appropriate patient selection will improve outcomes
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