Ventilators and ECLS: How to Manage the Vent?

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• I have no financial disclosures related to this presentation.
Objectives

Upon completion of this educational activity, you will be able to:

• Indicate optimal ventilatory strategy for patients who require ECLS.
• Assess the possible benefits from the use of lung ventilation strategies.
Gap-There is a significant knowledge gap in understanding the risks of mechanical ventilation (MV) during ECLS.

Need = The desired change/result in practice is to be aware of the different indications and possible complications for MV.
Expected Outcomes

• At the end of this presentation, learners will be aware of measures to minimize ventilator-induced lung injury in ECLS.
Ventilator ECMO interaction: current evidence
Issues

• Knowledge gap in understanding the benefits and risks of MV (mechanical ventilation) during ECMO.
• Native lung vs. Artificial lung
• ARDSNet protocol: does it apply to ECMO patients?
VV-ECMO goals

- Oxygenation
- CO2 clearance
- Avoid Lung Injury
- Survival
Mechanical Ventilation during Extracorporeal Membrane Oxygenation
An International Survey

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PEEP Levels in Adult vs. Pediatrics/Neonatal Patients on vvECMO

![Graph showing PEEP levels in adult vs. pediatric/neonatal patients on vvECMO. The x-axis represents PEEP (cm H2O) with categories ≤ 5, 6-10, 11-15, ≥ 16, and Other. The y-axis represents Percentage (%). The graph compares Pediatric/Neonatal (N=75) with Adult (N=38).]
## TABLE 3. Multivariate Logistic Regression and Cox Proportional Hazard Modeling With “ICU Death” as Outcome

<table>
<thead>
<tr>
<th>Variables</th>
<th>ICU Death</th>
<th></th>
<th></th>
<th>Time to ICU Death</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td>p</td>
<td>Hazard Ratio (95% CI)</td>
<td>p</td>
<td></td>
</tr>
<tr>
<td>Country (France vs Australia)</td>
<td>0.56 (0.22–1.42)</td>
<td>0.56</td>
<td>0.39 (0.19–0.81)</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Duration between ICU admission and ECMO initiation (d)</td>
<td>1.15 (1.06–1.26)</td>
<td>0.001</td>
<td>1.02 (0.97–1.07)</td>
<td>0.56</td>
<td></td>
</tr>
<tr>
<td>Plateau pressure before ECMO &gt; 30 cm H₂O</td>
<td>5.18 (1.88–14.31)</td>
<td>0.02</td>
<td>3.31 (1.53–7.15)</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>Mean positive end-expiratory pressure from day 1 to 3 on ECMO</td>
<td>0.75 (0.64–0.88)</td>
<td>0.0006</td>
<td>0.78 (0.69–0.88)</td>
<td>&lt; 0.0001</td>
<td></td>
</tr>
<tr>
<td>Lactate at day 3 (log transformed)</td>
<td>4.77 (2.12–10.73)</td>
<td>0.0002</td>
<td>3.64 (2.24–5.92)</td>
<td>&lt; 0.0001</td>
<td></td>
</tr>
</tbody>
</table>
• Decrease in driving pressure (\(\Delta P = \frac{Vt}{CRS}\)) is the factor associated to improved survival in ARDS patients, considering that CRS is closely related to the aerated lung volume, i.e., functional lung size.

• \(\Delta P\) which is calculated as Pp-PEEP (cmH2O), a decrease is associated to an improved prognosis, while an increase is associated to a poorer prognosis.
• Meta-analysis of 9 observational studies (545 patients) in adult ARDS patients receiving ECMO.

• In this series of ARDS patients receiving ECMO for refractory hypoxemia, driving pressure during ECMO was the only ventilator setting that showed an independent association with in-hospital mortality.

<table>
<thead>
<tr>
<th>Table 3 Multivariable time-dependent frailty model with in-hospital mortality as the primary outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HR (95 %CI), p</strong></td>
</tr>
<tr>
<td>Age, years</td>
</tr>
<tr>
<td>Gender, male</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
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<tr>
<td>Risk of death, %²</td>
</tr>
<tr>
<td>SOFA</td>
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<tr>
<td>Time between MV-ECMO</td>
</tr>
<tr>
<td>≤24 h</td>
</tr>
<tr>
<td>24–72 h</td>
</tr>
<tr>
<td>&gt;72 h</td>
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<tr>
<td>Indication of ECMO</td>
</tr>
<tr>
<td>Hypoxemia</td>
</tr>
<tr>
<td>Hypercapnia</td>
</tr>
<tr>
<td>Ventilatory parameters</td>
</tr>
<tr>
<td>PEEP, cmH₂O</td>
</tr>
<tr>
<td>FiO₂, %</td>
</tr>
<tr>
<td>Driving pressure, cmH₂O</td>
</tr>
<tr>
<td>Respiratory rate, bpm</td>
</tr>
<tr>
<td>Laboratory parameters</td>
</tr>
<tr>
<td>PaO₂/FiO₂, mmHg</td>
</tr>
<tr>
<td>PaCO₂, mmHg</td>
</tr>
<tr>
<td>Lactate, mg/dL</td>
</tr>
<tr>
<td>Hemodynamics (pre-ECMO)</td>
</tr>
<tr>
<td>Norepinephrine, μg/kg/min²</td>
</tr>
</tbody>
</table>

Study

• The use of high PEEP to improve alveolar recruitment, minimizing alveolar over distension, has not been shown to reduce mortality in patients with ARDS.

• But in patients treated with ECMO, the use of high PEEP (>10cmH2O) in the first three days of extracorporeal support was independently correlated to a decrease in mortality.

M. Schmidt, C. Stewart, M. Bailey, A. Nieszkowska, J. Kelly, L. Murphy
Mechanical ventilation management during extracorporeal membrane oxygenation for acute respiratory distress syndrome: A retrospective international multicenter study
• Among ARDS patients undergoing ECMO therapy, only plateau pressure is associated with hospital survival.

• Plateau pressure and PEEP are both associated with 30 day survival post hospital discharge.
How to ventilate on ECMO?
Concept of Baby-Lung
Ventilator-Induced Lung Injury (VILI)

Step 1. conventional MV for ARDS patients
(i) Pressure-control mode
(ii) PIP $\leq 35$ cmH$_2$O, $V_T \leq 8$ mL/kg, and FiO$_2 \leq 0.6$
(iii) Optimal PEEP: 10–18 cmH$_2$O
(iv) RR: 20–26/min
(v) Paralytic sedation and Rota-prone
(vi) Therapeutic target: MAP 70–90 mmHg; SaO$_2 \geq 90\%$; PaO$_2 \geq 60$ mmHg; and PaCO$_2 \leq 60$ mmHg

Poor response to MV alone
(i) PaO$_2$/FiO$_2 < 70$ mmHg or PaCO$_2 > 60$ mmHg with advanced MV setting
(ii) Pneumothorax with significant air leakage

Step 2. MV + VV-ECMO

| ECMO setting | (i) Gas FiO$_2$: 1.0  
(ii) Optimal gas and blood flow  
(iii) Postoxygenator PO$_2 \geq 200$ mmHg |
|--------------|------------------------------------------------|
| Lung protective MV | (i) Pressure-control mode  
(ii) PIP $\leq 30$ cmH$_2$O  
(iii) Optimal PEEP: 10–18 cmH$_2$O  
(iv) FiO$_2$ tapered to 0.4  
(v) RR: 10–12/min  
(vi) Paralytic sedation |
| Therapeutic targets | (i) SaO$_2 \geq 90\%$ or PaO$_2 \geq 60$ mmHg  
(ii) pH $\geq 72$ |

Step 3 weaning off after improvement
(i) ECMO blood flow $< 2$ L/min
(ii) ECMO gas flow $< 21\%$
(iii) Decannulation after 2–4 hours if therapeutic targets can be maintained by protective MV
Considerations

• MV is NOT absolutely necessary in VV-ECMO for gas exchange (also keep in mind, ECCO2R can be used for CO2 clearance which work at low flows)

• During VV-ECMO lung is perfused with oxygenated blood
The Balance

Improving Gas Exchange  Mechanical Ventilation  VILI
1. What Tidal volume?

• General consensus, use pressure and volume limiting strategies
• No agreement on how low the Vt and driving pressure should be!

• Less ventilation and less injury (Perhaps in the near future, management of ARDS will include a minimally invasive extracorporeal carbon dioxide removal circuit, and noninvasive continuous positive airway pressure.)
2. How much PEEP?

• set the PEEP which achieves the highest static compliance
• set it above the lower inflection point of the pressure volume curve (therefore avoiding cyclic atelectasis)
• use a staircase recruitment (or decruitment) maneuver to find the lowest PEEP at which the maximal oxygenation is maintained
The average PEEP needed in patient with ARDS to keep their lung open is approximately the same (approximately 16 cm H2O) independently on the fact that the amount of tissue to be kept open is as low as 3% or as high 50% of the total lung weight".
Lung recovery
Atelectrauma
Beneficial effects on CVS (RV)
Prevention of VAP
To Recruit or Not Recruit, This Is ...*

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The use of small tidal volumes (6 mL/kg ideal body weight) and low plateau pressure (< 30 cm H₂O) is the robust evidence that should guide ventilation in patients with acute respiratory distress syndrome (ARDS) (1). The need for an adequate or at least vital gas exchange may force, how-

ECMO, clinical evidences and scientific community does appear. et al (13) analyzing a multiscience did not identify any major change. ECMO over a 20-year time span rate of 10 and a mean airway reported as the most common. Hong et al (14), analyzing Extracorporeal life support registry database, reported that preferred a lung rest strategy and a PEEP between 5 and 10. FIO₂ of all ECMO patients, the of the ones proposed by the most clinicians (1). Most physicians involved that the best lung rest is achieved.
3. Spontaneous breathing during ECMO

- 23 of 48 patients were enrolled in the prospective study (9 bridged to lung transplant, 6 COPD, and 8 acute respiratory distress syndrome). The response to the carbon dioxide removal was evaluated in terms of respiratory rate and esophageal pressure swings by increasing (“relief” threshold) and decreasing (“distress” threshold) the extracorporeal membrane oxygenation gas flow, starting from baseline condition.

- Spontaneous breathing was possible in most during bridge to transplant (100%) or chronic obstructive pulmonary disease (86%) but in less than 30% of acute respiratory distress syndrome, and in half of these, dyspnea persisted despite carbon dioxide removal.
4. Inflammatory response to ECMO

- The inflammatory response to ECMO is complex and multi-faceted.
- It remains unclear whether this excess inflammation is all deleterious, or if it has potential benefits to the host.
- It arises principally due to the contact and complement systems becoming activated as a result of blood exposure to the extracorporeal circuit. The combination of a sustained innate immune response and the pro-inflammatory aspects of coagulation result in “pan-endothelial” injury, with leukocyte activation and the production of pro-inflammatory mediators.
- This ultimately ends in a systemic inflammatory response and end organ damage.
• The goal of ventilator management on ECLS is to use FiO2 <0.4, and non-damaging “lung rest settings”

• Pressure controlled ventilation at 25-15, I:E 2:1, rate 5-8, FiO2 50% FiN2 50%

• Positive pressure is continued to maintain some lung inflation, but Pp (Plateau pressure) >25 cmH2O can cause ongoing lung damage

• PEEP can be as high as tolerated (10-15 cmH2O)
What is actually happening at ECMO Centers

- There are no clinical evidence-based guidelines recommending a concrete form of mechanical ventilation in patients subjected to VV ECMO, although 77% of the centers with ECMO experience apply the “lung rest” concept and to minimize ventilator-induced lung injury (VILI)

  - low tidal volume (Vt) (4-6ml/kg ibw)
  - low respiratory frequency (RF) (less than 10-12)
  - high positive end-expiratory pressure (PEEP)
  - Pp (<25 for ultra protective, otherwise <28–30cmH2O)
• Strategies for Optimal Lung Ventilation in ECMO for ARDS: The SOLVE ARDS study