ECMO UPDATE for Respiratory Failure

Bhavesh Patel, MD, FRCP(C), RDMS
Assistant Professor of Anesthesiology, Medicine and Neurology,
Mayo Clinic College of Medicine
Consultant, Department of Critical Care Medicine
Medical Director, Department of Respiratory Care

No financial disclosures
I will be speaking about off label uses of products
ECMO vs ECLS

- Respiratory Failure
- Circulatory Failure
- CO₂ Retention
- Combined Cardiac/Respiratory Failure
- Cardiac Arrest

ECLS WILL BE IN YOUR ICU

- Annual patient volume vs year
- 1989 to 2013
- neonatal, pediatric, adult

Gaffney AM et al. BMJ 2010
Barbano RP et al. AJRCM 2003
Adult Respiratory Cases

ELSO Registry January 2017

CESAR trial
Quadrox D oxygenator
Avalon DLVV cannula
H1N1 pandemic

Cumulative Runs

Annual Runs

Cumulative Runs

0 500 1000 1500 2000 2500
81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97

CESAR

Table 3: Primary Outcome

<table>
<thead>
<tr>
<th>Outcome</th>
<th>ECMO</th>
<th>Conventional</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death or severe disability at 6 months</td>
<td>57</td>
<td>41</td>
<td>0.001</td>
</tr>
<tr>
<td>Yes</td>
<td>35</td>
<td>48</td>
<td>0.15</td>
</tr>
<tr>
<td>No information about severe disability at 6 months</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Died within 6 months or died before discharge</td>
<td>57</td>
<td>45</td>
<td>0.001</td>
</tr>
<tr>
<td>Yes</td>
<td>31</td>
<td>45</td>
<td>0.15</td>
</tr>
</tbody>
</table>

63% vs 47% survival at 6 months

ANZICS database 2009
H1N1 70% survival to discharge
<table>
<thead>
<tr>
<th>Country</th>
<th>Duration</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japanese</td>
<td>9 days</td>
<td>Extracorporeal membrane oxygenation for 2009 influenza A(H1N1) severe respiratory failure in Japan. J Anesthesia 2012</td>
</tr>
<tr>
<td>Australian/New Zealand</td>
<td>10 days</td>
<td>Extracorporeal Membrane Oxygenation for 2009 Influenza A(H1N1) Acute Respiratory Distress Syndrome. JAMA. 2009 Nov 4;302(17):1888</td>
</tr>
<tr>
<td>Canadian</td>
<td>15 days</td>
<td>Extracorporeal lung support for patients who had severe respiratory failure secondary to influenza A (H1N1) 2009 infection in Canada. Can J Anesthesia 2010 Mar;57(3):240-7</td>
</tr>
<tr>
<td>Chinese</td>
<td>18 days</td>
<td>Extracorporeal Membrane Oxygenation for Critically Ill Patients With 2009 Influenza A (H1N1)-Related Acute Respiratory Distress Syndrome: Preliminary Experience From a Single Center. Artif Organs. 2012 Sep;36(9):780-8</td>
</tr>
<tr>
<td>Legacy/Emanuel</td>
<td>8 days</td>
<td>Extracorporeal lung support for patients who had severe respiratory failure secondary to influenza A (H1N1) 2009 infection in Canada. Can J Anesthesia 2010 Mar;57(3):240-7</td>
</tr>
</tbody>
</table>

### Additional Information

ELSO
Adult Respiratory Survival by Diagnosis and Year

- **Viral Pneum**
- **Bact Pneum**
- **Aspir**
- **ARDS**
- **ARF**
- **Others**

Adult Cardiac Cases By Year

- **Cumulative cases**
- **Annual cases**

ELSO Registry January 2017
Adult Cardiac Survival by Diagnosis and Year

LUNG PROTECTIVE VENTILATION

Slutsky AS, Ranieri VM. (2014)
RIGHT VENTRICLE PROTECTIVE VENTILATION

AVOID
High airway pressure
Hypercarbia
Hypoxia

ADJUNCTIVE THERAPY
- Nitric Oxide (NO)
- Partial Liquid Ventilation (PLV)
- Prone Position Ventilation
- Surfactant Therapy

ARDS

GENTLE VENTILATION
- Pressure Limited Ventilation (PLV) with Permissive Hypercapnia
- Inverse Ratio Ventilation (IRV)
- High Frequency Ventilation
- jet ventilation
- oscillatory ventilation
- Intrathoracic Pulmonary Ventilation (ITPV)

MECHANICAL VENTILATION
- Volume Controlled
EXTRAPULMONARY SUPPORT

TOTAL O₂ AND CO₂ EXCHANGE

- VV ECLS
- AV-ECCO₂R

TOTAL CO₂ EXCHANGE

- VV-ECCO₂R
- VA ECLS

PARTIAL CO₂ EXCHANGE

- IVOX

EXTRAPULMONARY GAS EXCHANGE

TOTAL O₂ and CO₂ EXCHANGE and CIRCULATORY SUPPORT

PARTIAL CO₂ EXCHANGE

EXTRAPULMONARY SUPPORT

CO₂ removal Oxygenation

Low-flow ECCO₂R

High-flow V-V ECMO

ARDS

MILD

MODERATE

SEVERE

200mmHg < PaO₂/FIO₂ ≤ 300mmHg with PEEP or CPAP ≥ 5cmH₂O

100mmHg < PaO₂/FIO₂ ≤ 200mmHg with PEEP ≥ 5cmH₂O

PaO₂/FIO₂ ≤ 100mmHg with PEEP ≥ 5cmH₂O
GOALS OF VV ECMO

TEMPORARILY

Improve O₂ saturation and CO₂ Removal

TO

UNTIL

RECOVERY OF ORGAN FUNCTION

While minimizing complications from ECLS therapy

BRIDGE TO DEFINITIVE TREATMENT

Treat disturbance
Rest injured lungs
Avoid / minimize injurious therapy
Maintain stability of end-organ function

GOALS OF VA ECMO

TEMPORARILY

Improve Circulation O₂ sat and CO₂ Removal

TO

UNTIL

RECOVERY OF ORGAN FUNCTION

While minimizing complications from ECLS therapy

BRIDGE TO DEFINITIVE TREATMENT

Treat disturbance
Rest injured heart/lungs
Avoid / minimize injurious therapy
Maintain stability of end-organ function
DO₂ normally 4-5 times that of VO₂

\[ \text{DO}_2 \text{ (mL/min)} = \text{CO} \text{ (L/min)} \times \text{CaO}_2 \text{ (mL O}_2 \text{/L blood)} [1.34 \cdot \text{Hgb} \cdot \text{SaO}_2] + [0.003 \cdot \text{PaO}_2] \]

DO₂ normally 4-5 times that of VO₂

\[ \text{OER} = \frac{\text{VO}_2}{\text{DO}_2} \text{ [Normal-25%]} \]

Mechanical Ventilator

\[ \text{VO}_2 \text{ (mL/min)} \times \text{CaO}_2 - \text{CvO}_2 \text{ (mL O}_2 \text{/L blood)} = \text{VO}_2 \text{ (mL/min)} \]

determined by tissue metabolic rate
ECMO CIRCUIT

- **Back-up Hand Crank**
- **Blender**
  - O2 / AIR
  - High Pressure
- **Pressure Monitoring**
  - Integrated
- **Monitoring Interface**
- **Motor**
- **Heat Exchanger**
- **Drainage**
  - Inlet - V
- **Flow Sensor**
- **Pump**
  - Inlet - V
- **Return**
  - Outlet – A or V

**Electrolyte Discharge Bag**
- Lowers voltage potential in the blood fluid path to reduce injury to cardiac muscles

**Blood Leak Detector**
- Monitor for presence of red blood cells

**Suction Control Panel**
- Up and down buttons to control suction levels

**Suction Holder**
- Holder for suction wand

**Access Pressure Pad**
- Pressure sensor that measures pressure required to pull blood from the patient

**Effluent Bag**
- Waste removal bag containing all blood

**The Blood Pump Bag**
- Replacement pre-dilution fluid that is administered to the patient and then returns to the patient

**Oscillate Bag**
- Replacement post-dilution fluid that is administered on the outside of the filter and directly enters the effluent bag

**Effluent Pressure Port**
- Pressure sensor that measures pressure required to push blood back to the patient

**Return Pressure Port**
- Pressure sensor that measures pressure required to push blood back to the patient

**Decondition Chamber**
- Removes air in the filter system prior to returning it to the patient

**Air Bubble Detector**
- Monitor for air bubbles within the system

**Return Line Clamp**
- Clamps line if air bubbles detected to prevent air from returning to the patient

**Filter Pressure Port**
- Pressure sensor that measures pressure required to push blood through the filter

**Replacement Bag**
- Replacement/post-dilution fluid that is administered via the blood and then returns to the patient

**Integrated Monitoring**
- High pressure monitoring

**Gas Mixture**
- Membrane Oxygenator
**Extra-Corporeal Membrane Oxygenation?**

**ECMO vs ECLS**

Respiratory OR Cardiopulmonary Support

**PUMP-DRIVEN FLOW**
Centrifugal

**DRAINAGE**
Inlet - V

**GAS EXCHANGE**
O₂ & CO₂

**RETURN**
Outlet – A or V

[Link to ECLS explanation](http://edecmo.org/get-started/what-is-ecls-ecmo/)

---

**VV ECBF**

DETERMINANTS AND LIMITATIONS

• Cannula size & position
• Venous capacitance, compression or collapse
• Tubing
• Pump function (i.e. thrombosis)
• Oxygenator resistance

[Diagram of VV ECMO system]
19% increase in radius with double the flow volume

ECMO CANNULA
→ blood protective flow

Biggest, shortest cannula = least resistance to flow
Aim for pressure drop < 100mmHg across cannula
ECMO CIRCUIT

Pump

CENTRIFUGAL PUMP

- Non-occlusive pump
- Pre-load sensitive
- Afterload dependent (must overcome positive resistance)

![Impeller design](image)

NO Direct relationship between RPM and Flow
- Flowmeter is necessary

---

ECMO CIRCUIT

Oxygenator

MICROPOUROUS HOLLOW FIBER

- Gas inside fibers, blood on outside
- Very small 'nano' pore size
  - 'plasma-tight'
  - High gas permeability
- Low pressure drop across membrane
ECMO CIRCUIT → Gas Blender

Connected to oxygenator
Mixes air and oxygen

O2
• Dial for FiO2 (21-100%)
• Connects to 30-70PSI inlet

Air
• Gas flow = ‘Sweep’
• 2 dials
• 0-10 LPM
**A**

Physiology of CO₂ removal during ECMO

- \( V_{CO2} \) = 200 ml/min
- \( CaCO_2 = 480 \) ml/L
- \( PaCO_2 = 40 \) mmHg

**Low-flow ECCO₂R**

- \( BF \) < 1 L/min
- \( Swgas = 10 \times BF \)

**CO₂ Removal** (of at least 250 ml/min)

**B**

Physiology of O₂ delivery during ECMO

- \( DO2 \) = 600 ml/min/m²
- \( VO2 \) = 120 ml/min/m²

**High-flow V-V ECMO**

- \( BF \) ≥ 4 L/min
- \( Swgas = BF \)

\( DO_2 = (C_{outO2} - C_{inO2}) \times BF \)

---

**To Cannulate?**

**SELECTION CRITERIA**

**Table 1. Indications and Contraindications for ECMO in Severe Cases of ARDS.**

<table>
<thead>
<tr>
<th>Indications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe hypoxemia (e.g., ratio of ( P_{aO2} ) to ( Fio2 ) &lt; 80, despite the application of high levels of PEEP [typically 15–20 cm of water]) for at least 6 hr in patients with potentially reversible respiratory failure)</td>
</tr>
<tr>
<td>Uncompensated hypercapnia with acidemia (pH &lt; 7.15) despite the best accepted standard of care for management with a ventilator</td>
</tr>
<tr>
<td>Excessively high end-inspiratory plateau pressure (&gt;35–45 cm of water, according to the patient’s body size) despite the best accepted standard of care for management with a ventilator</td>
</tr>
</tbody>
</table>

---

Brodie - NEJM 2011
To Cannulate?
PRE-ECMO PREDICTORS

RESP Score

ECMOnet Score

Pre-ECMO SOFA Score

?helpful

PRESERVE Score

SAVE Score

Recirculation on VV ECMO

<table>
<thead>
<tr>
<th>Method of estimating % recirculation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVL&lt;sup&gt;13,14&lt;/sup&gt;</td>
<td>Formula: (S&lt;sub&gt;pO2&lt;/sub&gt; - SvO&lt;sub&gt;2&lt;/sub&gt;) / (S&lt;sub&gt;pO2&lt;/sub&gt; - StO&lt;sub&gt;2&lt;/sub&gt;) x 100 SvO&lt;sub&gt;2&lt;/sub&gt; estimated by measuring venous saturation of blood from SVC or IVC via central venous catheter</td>
</tr>
<tr>
<td>SvO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;13,14&lt;/sup&gt;</td>
<td>Formula: (S&lt;sub&gt;pO2&lt;/sub&gt; - SvO&lt;sub&gt;2&lt;/sub&gt;) / (S&lt;sub&gt;pO2&lt;/sub&gt; - StO&lt;sub&gt;2&lt;/sub&gt;) x 100 SvO&lt;sub&gt;2&lt;/sub&gt; = SpO&lt;sub&gt;2&lt;/sub&gt; when sweep gas turned off and ventilator used to achieve an equivalent SaO&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>Ultrasound dilution&lt;sup&gt;915&lt;/sup&gt;</td>
<td>Saline injected into reinfusion limb; ultrasound camera detects differences in dilution between drainage and reinfusion limb</td>
</tr>
<tr>
<td>Thermodilution&lt;sup&gt;96&lt;/sup&gt;</td>
<td>Cold saline injected into reinfusion limb; thermistor-tipped catheter detects changes in temperature in drainage limb</td>
</tr>
<tr>
<td>Trending S&lt;sub&gt;pO2&lt;/sub&gt;&lt;sup&gt;913,14&lt;/sup&gt;</td>
<td>Observation of changes in SpO&lt;sub&gt;2&lt;/sub&gt; and SaO&lt;sub&gt;2&lt;/sub&gt; over time; increasing SpO&lt;sub&gt;2&lt;/sub&gt; and decreasing SaO&lt;sub&gt;2&lt;/sub&gt; suggest clinically relevant recirculation</td>
</tr>
</tbody>
</table>

Table 1. Methods of estimating the amount of recirculation

Last updated: May 2015
This document is scheduled to expire by May 2018. After this date, users are encouraged to contact the ELSO Guidelines Editorial Board to confirm that this document remains relevant to current practice.
Recirculation

CAUSES

1. Cannula Positioning
2. Venous Chamber Compliance
3. High RPM
4. Low CO

COMPLICATIONS

Whole Circuit
- foreign surface → adhesion & activation
- hemodilution on cannulation

Oxygenator
- consumption of platelets & plasma proteins

Positive pressure

Pump
- altered shear
- WSS dysfunction
- platelet activation
- reduced EUGMPS13

Low Flow Zones and Connectors
(e.g., cannula to circuit connectors, back perfusion cannula)
- turbulence & increased shear
- platelet activation

Systemic

Underlying Disease
- microthrombosis due to trauma
- infection/sepsis
- post resuscitation
- trauma

Drugs
- heparin → bleeding / HT
- antithrombin agents

Liver
- synthetic function
- procoagulant and anticoagulants
- immunosuppression

Systemic Inflammatory Response
- macrophage release
- leukocyte activation and NETs
- DIC
- disseminated intravascular coagulation
**COMPLICATIONS**

![Graph showing complications](image)

**COMPLICATIONS**

<table>
<thead>
<tr>
<th>VV</th>
<th>VA</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Complication</th>
<th>Survived (%)</th>
<th>Survived (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical O/E impermeable</td>
<td>9.3</td>
<td>42</td>
</tr>
<tr>
<td>Mechanical O/E bridge</td>
<td>6.0</td>
<td>36</td>
</tr>
<tr>
<td>Mechanical O/E bladder</td>
<td>0.3</td>
<td>47</td>
</tr>
<tr>
<td>Mechanical O/E hemofilter</td>
<td>3.3</td>
<td>46</td>
</tr>
<tr>
<td>Mechanical O/E other</td>
<td>0.7</td>
<td>46</td>
</tr>
<tr>
<td>Hemorrhagic GI hemorrhage</td>
<td>0.4</td>
<td>35</td>
</tr>
<tr>
<td>Hemorrhagic CNS hemorrhage</td>
<td>1.0</td>
<td>35</td>
</tr>
<tr>
<td>Hemorrhagic CT scan bleed</td>
<td>0.2</td>
<td>35</td>
</tr>
<tr>
<td>Hemorrhagic stroke</td>
<td>1.3</td>
<td>35</td>
</tr>
<tr>
<td>Neurologic O/E hemorrhage</td>
<td>1.7</td>
<td>35</td>
</tr>
<tr>
<td>Neurologic O/E hemorrhage by US/CT</td>
<td>5.1</td>
<td>33</td>
</tr>
<tr>
<td>Pulmonary: Pneumonia hemorrhage</td>
<td>3.1</td>
<td>36</td>
</tr>
<tr>
<td>Pulmonary: Pulmonary embolus</td>
<td>3.7</td>
<td>33</td>
</tr>
<tr>
<td>Pulmonary: Pulmonary embolus by US/CT</td>
<td>3.7</td>
<td>33</td>
</tr>
<tr>
<td>Pulmonary: Respiratory failure</td>
<td>0.9</td>
<td>35</td>
</tr>
</tbody>
</table>

---

4/6/2017
### COMPLICATIONS

Table 2  Microorganisms Associated With Various Nosocomial Infections in 142 Extracorporeal Membrane Oxygenation Patients

<table>
<thead>
<tr>
<th>Organism</th>
<th>Ventilator-Associated Pneumonia, n=162</th>
<th>Cerebrospinal Infection, n=219</th>
<th>Poststernotomy Mediastinitis, n=239</th>
<th>Bloodstream Infection, n=473</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. (%)</td>
<td>No. (%)</td>
<td>No. (%)</td>
<td>No. (%)</td>
</tr>
<tr>
<td><em>Pseudomonas aeruginosa</em></td>
<td>43 (26)</td>
<td>5 (24)</td>
<td>8 (36)</td>
<td>10 (21)</td>
</tr>
<tr>
<td><em>Staphylococcus aurous</em></td>
<td>16 (16)</td>
<td>4 (19)</td>
<td>7 (30)</td>
<td>7 (15)</td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td>16 (10)</td>
<td>3 (14)</td>
<td>2 (9)</td>
<td>6 (13)</td>
</tr>
<tr>
<td><em>Neisseria spp.</em></td>
<td>10 (6)</td>
<td>1 (6)</td>
<td>1 (4)</td>
<td>3 (6)</td>
</tr>
<tr>
<td><em>Proteus mirabilis</em></td>
<td>5 (3)</td>
<td>1 (6)</td>
<td>1 (4)</td>
<td>2 (4)</td>
</tr>
<tr>
<td><em>Enterococcus spp.</em></td>
<td>5 (3)</td>
<td>1 (6)</td>
<td>1 (4)</td>
<td>2 (4)</td>
</tr>
<tr>
<td><em>Citrobacter spp.</em></td>
<td>2 (1)</td>
<td>2 (1)</td>
<td>2 (1)</td>
<td>1 (2)</td>
</tr>
<tr>
<td><em>Enterococcus spp.</em></td>
<td>2 (1)</td>
<td>2 (1)</td>
<td>2 (1)</td>
<td>1 (2)</td>
</tr>
<tr>
<td><em>Acinetobacter baumannii</em></td>
<td>1 (1)</td>
<td>1 (1)</td>
<td>1 (1)</td>
<td>1 (2)</td>
</tr>
<tr>
<td><em>Anaerobes</em></td>
<td>1 (1)</td>
<td>1 (1)</td>
<td>1 (1)</td>
<td>1 (2)</td>
</tr>
</tbody>
</table>

*Note:* Numbers in parentheses represent percentages.
CONSIDERATIONS

Non ICU Support Services
Medical-surgical staff with emergency access (<30 min)
Cardiovascular or thoracic surgery
Acute renal surgery
Esophagogastrroduodenal endoscopic interventions
Interventional radiology including specific competencies in vascular embolization
Medical-surgical staff needed 24 h/d
Cardiology, with transthoracic and transesophageal echocardiography
Anesthesiology
Pulmonology
Neurology
Nephrology
Gastroenterology
Ear nose throat surgery
Obstetrics
General radiology for emergency ultrasound and CT scanning
Pharmacy
Laboratory staff needed 24 h/d
Blood gas laboratory
Blood chemistry and hematologic test laboratory
Blood coagulation testing laboratory
Blood bank with rapid blood product delivery capacity
Microbiology laboratory

ECMO – VENTILATOR INTERACTION

PATIENT

ECMO – VENTILATOR INTERACTION

GAS EXCHANGE

FiO2 PEEP RR V, PIP

ECMO – VENTILATOR INTERACTION

ECMO

VO2 CaO2

CO

PATIENT

ECMO

FiO2 PEEP RR V, PIP

CANNULAS TUBING PUMP

RPM FLOWS PRESSURE

OXYGENATOR

ECMO – VENTILATOR INTERACTION

IMAGING MEDS LABS

PHYSICAL EXAM

SaO2 RR HR BP CVP

PATIENT – VENTILATOR INTERACTION

PATIENT – VENTILATOR INTERACTION

PATIENT – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION

ECMO – VENTILATOR INTERACTION
International ECMO network - ECMOnet

- EOLIA – ECMO to rescue Lung Injury in severe ARDS - RCT
- The REST Trial – pRotective vEntilation with veno-venous lung assist in respiratory failure
- The SOLVE ARDS Study Program – Strategies for Optimal Lung Ventilation in ECMO for ARDS
- The SUPERNOVA Trial – Strategy of UltraProtective lung ventilation with Extracorporeal CO₂ Removal for New Onset moderate to severe ARDS
- ASAP ECMO – Antibiotic, Sedative and Analgesic Pharmacokinetics during ECMO
- LIFEGARDS Study – ventilation management of patients with Extracorporeal membrane oxygenation for Acute Respiratory Distress Syndrome
- HELP ECMO – HEparin Low-dose Protocol in ECMO patients – RCT

ECMO vs ECLS

ASAP ECMO
LIFEGARDS Study
HELP ECMO

EOLIA
SOLVE ARDS

Respiratory Failure
Circulatory Failure
Combined Cardiac/Respiratory Failure
Cardiac Arrest

Prague OHCA (Hyperinvasive)
The Vienna Project
Review Article

Adult venovenous extracorporeal membrane oxygenation for severe respiratory failure: Current status and future perspectives

Ayan Sen, Hannes L. Callisen, Cory M. Alwardt, Joel S. Larson, Amelia A. Lowell, Stacy L. Librizzi, Prithvi Tarwade, Bhavesh M. Patel, Harish Ramakrishnan

Department of Critical Care Medicine, Mayo Clinic Arizona. Division of Cardiothoracic Surgery, Mayo Clinic Arizona.

QUESTIONS

Mayo Clinic's Current Concepts in the Management of the Adult ECMO Patient

October 27-28, 2017
SIM 4

**Rationale for ECMO**

→ Improve Cellular Oxygenation

- DO2 normally 4-5 times that of VO2

\[ \text{OER} = \frac{\text{VO2}}{\text{DO2}} \text{ [Normal~25%]} \]

If DO2:VO2 is < 2:1

→ Anaerobic Metabolism

\[ \text{SvO2} < 50-60\% \]
VV ECMO → Configuration

NO cardiac support
NO ↓ in pulmonary blood flow

Usually PARTIAL pulmonary support
→ Based on EBF : CO Ratio

VV perfusate mixes with 'mixed' venous blood return, bypassed by ECMO
→ Venous Admixture

Venous Return 'mixed'

SaO2

For Best Ratio:

↑ Effective EBF
↓ Recirculation
↓ CO

SaO2

membrane oxygenated blood

ventilator settings
Regional Perfusion During Venoarterial Extracorporeal Membrane Oxygenation: A Case Report and Educational Modules on the Concept of Dual Circulations

Cory M. Alwardt, PhD, CCP,* Bhavesh M. Patel, MD,* Amelia Lowell, RT,* Jeff Dobberpuhl, MS, RN, CP,* Jeffrey B. Riley, MHPE, CCT, CCP;† Patrick A. DeValeria, MD,*

*Mayo Clinic Hospital, Phoenix, Arizona and the †Mayo Clinic, Rochester, Minnesota

*ECT, 2013;45:187–194
The Journal of ExtraCorporeal Technology