**V V ECMO: THE FUTURE IS HERE (almost)**

Susan C. Seatter MD  
Abbott Northwestern Hospital Intensivists  
Advanced Circulatory Support for the Critically Ill Adult  
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**10 Things To Know About VV ECMO**

<table>
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<th>1 Consider ECMO Early</th>
<th>6a ECMO Wean: Not Too Early and Not Too Late</th>
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<td>2 Don’t Use The Lungs</td>
<td>6b Futility</td>
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<td>7 It Takes A Village</td>
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<td>10 Partner With ELSO</td>
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**ARDS + Ventilator Induced Lung Injury = EVIL**

- Barotrauma and volutrauma  
- Biotrauma: IL-8, ILGF2 are markers/targets (?)  
- Endothelium: fluid and leukocyte leak  
- Epithelium: decreased alveolar fluid clearance  
- Alveolar stretch and collapse: necrosis and apoptosis  
- Lung protective vent strategy (LPVS) = limitation of end-inspiratory stretch  
- Negative fluid balance, prone position, chemical paralysis  
- Severe ARDS mortality 45%

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**3a Know Your Circuit**

- Membrane oxygenator is analogous to the alveolar unit  
- Oxygen delivery capability is determined by blood flow, hemoglobin concentration, inlet hemoglobin saturation and oxygenator properties.  
- Use sweep to clear CO2: sweep flow is analogous to alveolar ventilation  
- Carbon dioxide removal always exceeds oxygen delivery when the circuit is planned for full support.  
- The oxygenator and blood flow should be capable of oxygen delivery and CO2 removal at least equal to the normal metabolism of the patient.

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**Extracorporeal Cardiopulmonary Support in Critical Care 4th Edition pg 149**

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**3a Know Your Circuit**

Extracorporeal Cardiopulmonary Support in Critical Care 4th Edition pg 149
3b Know Your Cannula: Dual Lumen: Right IJ

Bi-Caval: Right IJ/Femoral

• Single cannula
• Improved mobility
• Less recirculation
• Less drainage (?)
• ECHO, fluoroscopy for placement
• Migration

Bi-Caval: Right IJ/Femoral

• Two access sites
• Improved drainage
• Decreased mobility
• More recirculation
• Fluoroscopy
• No imaging (?)

Infusion blood mixes with systemic venous return blood. At typical blood flow the ratio of infusion blood to de-oxygenated right atrial blood is around 3:1. This results in a pO2 40-50, O2 sat 80-90% in the pulmonary artery. If there is no native lung function, this will be the composition of the gases in the arterial blood.

Systemic arterial saturation around 80% is typical during VV support.

As long as the hematocrit is over 40% and cardiac function is good, systemic oxygen delivery will be adequate at this level of hypoxemia.

Extracorporeal Cardiopulmonary Support in Critical Care 4th Edition pg 132

4 Things to Know About VV ECMO

4 Understand Oxygen Delivery

• Infusion blood mixes with systemic venous return blood. At typical blood flow the ratio of infusion blood to de-oxygenated right atrial blood is around 3:1. This results in a pO2 40-50, O2 sat 80-90% in the pulmonary artery. If there is no native lung function, this will be the composition of the gases in the arterial blood.
• Systemic arterial saturation around 80% is typical during VV support.

5 Minimize Sedation

• Stabilize with necessary sedation and then minimize benzodiazepine
• Propofol through peripheral IV
• Dexmedetomidine
• Dose increase for circuit adsorption
• Fentanyl at high dose: change to hydromorphone
• Stop paralytic

Walking, talking, breathing VV ECMO?

Why do we breathe when our blood gas is normal?

• To keep the lungs open.
• Is there harm (or gain) in trying to open the lungs if they can’t open?
• Is lung collapse (complete, partial) an unavoidable consequence of lung rest?
• Does the size of a spontaneous tidal volume matter?
• Does it matter more on CMV than PS?
How do we breathe (best) when our lungs are abnormal?
- NAVA: neutrally adjusted vent assist
- VentQuest.ca
- Strategies for Optimal Lung Ventilation in ECMO for ARDS: The SOLVE ARDS Study Program
- To assess if a CPAP strategy that minimizes end-tidal pulmonary stress/strain mitigates VILI in comparison to current MV using tidal ventilation in severe ARDS patients on VV ECMO
- Tracheostomy: yes or no?

10 Things To Know About VV ECMO
6a. Not Too Early and Not Too Late
- Weaning algorithm
- Monitor native lung: compliance, plateau pressure, ETCO2
- Decreasing sweep, pump flow
- Circuit FiO2 1.0
- Trial off: decrease sweep and circuit FiO2 or turn sweep off
- Blood gas is a mix up of oxygen delivered both from the ECMO and from the native lung. SvO2 DOES NOT reflect supply/demand but if SaO2 > SvO2 then there must be some lung function

6b. Futility
- Define goals of care before initiating ECMO and update as clinical condition changes
- Family and staff updates: daily rounds but also weekly team meetings
- Duration of support (?)

The PRESERVE Mortality Risk Score

ECLS and cardiogenic shock...
Deployment of ECLS technologies in the context of medical futility generally results in futile deployment of technology. It is rarely “the device”
ECMO technology generally restores physiology but may not alter survival depending upon the specifics of deployment
ECMO can support patients awaiting good clinical decision making. It is ineffective in supporting bad clinical decisions

ST5 Symposium Charles Hasples MD University of Kentucky 2013

10 Things To Know About Deployment of ECMO technologies in the context of medical futility generally results in futile deployment of technology. It is rarely “the device”
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Two types of ECMO/ECLS programs... clinical goals define infrastructure (technology and personnel)
- Acute stabilization and short term transfer
- “Transplant” program (in-house... cath lab, ED, OR)
- Duration of support < 72 hrs, limited infrastructure
- Rapid deployment technology (non-durable technologies)
- Integrated programs (ICU and/or transplant)
- “Recovery” and “bridge to transplant” (referral based)
- Duration of support > 72 hrs, extended infrastructure (MCS)
- Durable technologies (“ambulatory ECMO”)
- Institutional culture and hospital structure impact an ECLS program design

7 Review Your Work: ANW 2015

7a. Not Too Early and Not Too Late
- Weaning algorithm
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7 Review Your Work: 2015

- 10 patients; 11 runs
- Viral pneumonia: 1 (100%)
- Bacterial pneumonia: 2 (20%); MOF
- Aspiration pneumonia: 1 (100%)
- ARDS, post-op or trauma: 1 (100%); fluid overload/TRALI
- ARDS, not post-op or trauma: 4 (65%); 1 sepsis, 2 possibly inhalational, 1 pulmonary fibrosis
- Acute resp failure, non-ARDS: 2 (0%); PE; pulmonary hemorrhage
- Survival to de-cannulation: 64%
- Survival to discharge or transfer: 54%
  - 1 VV (100%), 8 DL (50%), 1 DL + V (100%), 1 VA + V (0%)

7 Review Your Work: International

<table>
<thead>
<tr>
<th>Year</th>
<th>Adult Respiratory Runs by Year</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>2012</td>
<td>952</td>
<td>5,442</td>
<td>204</td>
<td>6,246</td>
<td>344</td>
<td>57%</td>
</tr>
<tr>
<td>2013</td>
<td>1,422</td>
<td>5,864</td>
<td>280</td>
<td>6,745</td>
<td>367</td>
<td>60%</td>
</tr>
<tr>
<td>2014</td>
<td>1,899</td>
<td>7,763</td>
<td>290</td>
<td>3,288</td>
<td>1,164</td>
<td>61%</td>
</tr>
<tr>
<td>2015</td>
<td>1,689</td>
<td>6,301</td>
<td>263</td>
<td>4,272</td>
<td>866</td>
<td>56%</td>
</tr>
</tbody>
</table>

<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>751</td>
<td>321</td>
<td>3288</td>
<td>485</td>
<td>66%</td>
</tr>
<tr>
<td>Bacterial pneumonia</td>
<td>1,239</td>
<td>287</td>
<td>3288</td>
<td>786</td>
<td>61%</td>
</tr>
<tr>
<td>Aspiration pneumonia</td>
<td>190</td>
<td>238</td>
<td>2834</td>
<td>122</td>
<td>64%</td>
</tr>
<tr>
<td>ARDS, postop/posttrauma</td>
<td>440</td>
<td>253</td>
<td>1950</td>
<td>235</td>
<td>56%</td>
</tr>
<tr>
<td>ARDS, not postop/posttrauma</td>
<td>778</td>
<td>311</td>
<td>4248</td>
<td>420</td>
<td>54%</td>
</tr>
<tr>
<td>Acute resp failure, non-ARDS</td>
<td>1,587</td>
<td>269</td>
<td>4127</td>
<td>987</td>
<td>56%</td>
</tr>
<tr>
<td>Other</td>
<td>4,331</td>
<td>228</td>
<td>6745</td>
<td>2,407</td>
<td>50%</td>
</tr>
</tbody>
</table>

Hospital day #4

A Tale of Two Patients

<table>
<thead>
<tr>
<th>Admission</th>
<th>Pneumonia (no organism): VA ECMO, transfer, VVECMO (bi-caval cannulation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influenza A H1N1: LPVS + paralytic + prone</td>
<td>Pneumonia (no organism): VA ECMO</td>
</tr>
<tr>
<td>Influenza A H1N1: LPVS + paralytic + prone</td>
<td>Pneumonia (no organism): VV ECMO</td>
</tr>
<tr>
<td>- CMV</td>
<td>- CMV</td>
</tr>
<tr>
<td>- RR 28</td>
<td>- RR 12</td>
</tr>
<tr>
<td>- Tidal volume 300 cc (6cc/kg)</td>
<td>- Tidal volume 250 cc (5cc/kg)</td>
</tr>
<tr>
<td>- PEEP 14</td>
<td>- PEEP 8</td>
</tr>
<tr>
<td>- FiO2 0.6</td>
<td>- FiO2 0.3</td>
</tr>
<tr>
<td>- PaO2/FiCO2 140; O2 sat &gt; 92%</td>
<td>- Pump flow 4.75 LPM; O2 sat &gt; 92%</td>
</tr>
<tr>
<td>- Paco2 60 mm Hg</td>
<td>- Sweep flow 4 LPM; pCO2 40</td>
</tr>
<tr>
<td>- Plateau pressure 26 mm Hg</td>
<td>- Peak pressure 20</td>
</tr>
<tr>
<td>- Cisatracurium, fentanyl, Propofol, midazolam</td>
<td>- Propofol, fentanyl, steroid</td>
</tr>
</tbody>
</table>
**A Tale of Two Patients**

**Hospital day #18**

**Influenza A H1N1: LPVS + paralytic + prone**

- Tracheostomy vent day #14
- CMV
- Tidal volume 400 cc
- FiO2 0.55
- RR 40
- Delirium
- Concern for VAP (on antibiotic)
- D/C to LTAC HD #26

**Pneumonia (no organism): VV ECMO**

- De-cannulated VV ECMO Day #12
- Extubated vent day #14
- Intermittent CPAP
- Room air
- RR 18
- Weakness
- Right LE fasciotomy incisions and popliteal DVT
- Transfer to floor HD #18

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**VV ECMO is a Rescue (Therapy) for Severe ARDS but Can Lung Rest Help Heal the Lungs?**

- Mortality for severe ARDS is 45%
- High risk (patient bleeds, circuit clots), low volume (1600 last year) with 66% survival
- ECMO run: long periods of boredom marked by moments of terror
- Goal is lung rest in order to mitigate further lung damage
- Goal is improved gas exchange: increase oxygen supply and clear CO2 (normalize pH)
- But it may be true that lung rest itself is therapeutic
- Is 4 cc/kg/IBW better than 6 cc/kg/IBW?
- Partial or total extracorporeal support techniques

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**Extracorporeal Membrane Oxygenation for Severe Acute Respiratory Distress Syndrome (EOLIA)**

- ECMO to rescue Lung Injury in severe ARDS
- PaO2/FiO2 < 50 mm Hg with FiO2 ≥ 80% for > 3 hours
- PaO2/FiO2 < 80 mm Hg with FiO2 ≥ 80% for > 6 hours
- pH < 7.25 for > 6 hours
- ECMO will be initiated as rapidly as possible by venovenous access.
- Enrollment began 2011
- Adjuncts: prone, inhaled epoprostenol, paralytic
- Improve ARDS morbidity, mortality?

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**Strategy of UltraProtective Lung Ventilation With Extracorporeal CO2 Removal for New Onset Moderate to Severe ARDS (SUPERNOVA)**

- Lung hyperinflation still occurs in approximately 30% of ARDS patients even though they are being ventilated using the ARDSNet strategy
- Mortality decreased as Pplat declined from high to low levels at all levels of Pplat
- VT reduction to <6 ml/kg to achieve very low Pplat may induce severe hypercapnia and may cause elevated intracranial pressure, pulmonary hypertension, decreased myocardial contractility, decreased renal blood flow, and the release of endogenous catecholamines
- Primary outcome measure: Achievement of VT reduction to 4 ml/kg while maintaining pH and PaCO2 to ± 20% of baseline values obtained at VT of 6 ml/kg.

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9 Celebrate Success and Share What You Have Learned

- "Truisms" about ECLS/ECMO...
  - ECMO resuscitates the moribund … it cannot resuscitate the dead …
  - question of patient viability or myocardial recovery
  - ECMO remains a non-durable technology …
  - ECLS is a simple procedure, extracorporeal technologies are a complex management paradigm
  - ECLS accomplishes nothing (it is non-therapeutic), but facilitates everything

STS Symposium, Charles Hoopes MD, University of Kentucky 2013
Principles of VV ECMO

- Appropriate patient selection: who can we help?
- Define ARDS: "other indications" not so easy
- Develop an algorithm for hypoxemic respiratory failure and follow it
- Got ECMO?
- Process of initiation (inclusion, exclusion), cannulation, daily management, weaning
- Care of the post-ECMO patient defined
- Primary purpose of ECLS/ECMO is to provide blood oxygenation
- ECMO allows lung rest
- Maintain oxygen delivery > oxygen consumption
- Mitigation of risk requires a highly skilled team: you have to understand the circuit, the patient and how they interact
- Clarity of goals
- Review and improve

9 Celebrate Success and Share What You Have Learned

- ECMO Conference
- ECMO M&M
- Twin Cities ECMO Consortium
- ANW and affiliates, HCMC, UMN

“Steve Austin — astronaut. A man barely alive. We can rebuild him. We have the technology. We can make him better than he was. Better…stronger…faster.”

VV ECMO Algorithm for Referring Hospitals:
Call 612-863-1715

References

- Morrison KA, Jorde UP, Garan AR, Takayama H, Nakai Y, Uriel N. Acquired von Willebrand disease during CentriMag support is associated with high prevalence of bleeding during support and after transition to heart replacement therapy. ASAIO J. 2014;60:241–242
References


International ECMO Network: Clinical Trials

- ASAP ECMO: pharmacokinetics
- HELP ECMO: low dose heparin
- LIFEGUARDS: mechanical ventilation
- REST: VV-CO2 removal

Adult Respiratory Distress Syndrome

- ARDS is a type of acute diffuse lung injury associated with a predisposing risk factor characterized by inflammation leading to increased pulmonary vascular permeability and alveolar collapse.
- Hypoxemia and bilateral radiographic infiltrates, increased pulmonary right-to-left venous admixture, increased physiological dead space, and decreased respiratory system compliance are the hallmarks of the syndrome.
- Diffuse alveolar damage (lung edema, inflammation, hyaline membrane, and alveolar hemorrhage) is the characteristic morphological finding.
- Berlin definition allows us to identify and stratify patients with ARDS.