Veno-venous ECMO in severe Ards

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Conflict of Interest

• Has received consultation fees, travel grants or research support from:
  – Maquet
  – Drager
  – Ge
  – Novalung
  – BellCo
ARTIFICIAL ORGANS FOR RESPIRATORY FAILURE

Ventilatory

Mechanical ventilation

Parenchimal

Membrane lung
NIH ECMO Trial

Zapol WM: *JAMA* 1979; 242: 2193-6

From Conrad SA slide on internet
Artificial Lung

From Oxygenators:
Buying time with artificial lungs
Zapol WM, Kits RJ, NEJM 1972; 286 (12)

To
Artificial lungs:
Resting the lung
Gattinoni L 1976? Personal Communication
The technique seems to prevent the pulmonary barotrauma and extrapulmonary derangements caused by conventional mechanical ventilation.

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**Summary**

Terminal respiratory failure was reversed in three patients with a combination of extracorporeal CO₂ removal through a membrane lung and oxygen diffusion into the diseased lungs between mechanical breaths induced at a frequency of 2–3/min. The technique seems to prevent the pulmonary barotrauma and extrapulmonary derangements caused by conventional mechanical ventilation.
OXYGENATION

\[ \text{FiO}_2 = 1.0 \] 250 mL min\(^{-1} \]

\[ 7000 \text{ mL min}^{-1} \] PBF

\[ \text{Sat}_a 98\% \]

\[ \text{P}_{aO_2} 110 \text{ mmHg} \]

Hb 15 g
Sat\(_v\) 82%
\[ \text{P}_{vO_2} 47 \text{ mmHg} \]
\[ \text{CO}_2 \text{ cont} 52 \text{ mL} \]
\[ \text{P}_{vCO_2} 43 \text{ mmHg} \]

CO\(_2\) REMOVAL

\[ \text{VA} 9500 \text{ mL min}^{-1} \]

\[ 1100 \text{ mL min}^{-1} \] PBF

\[ \text{CO}_2 \text{ cont} 34 \text{ mL} \]

\[ \text{P}_{aCO_2} 15 \text{ mmHg} \]

\[ \text{PBF} \]

\[ \text{VO}_2 250 \text{ mL min}^{-1} \]

\[ \text{VCO}_2 200 \text{ mL min}^{-1} \]

Gattinoni et al., International Anesthesiology Clinics, 1983; 21: 97-117
LFPPV ECCO₂R IN SEVERE ACUTE RESPIRATORY FAILURE

GATTINONI et al: JAMA 1986

ECMO CRITERIA + TSLC < 30 cmH₂O
43 patients  21 survivors (49%)

Mean by-pass length:
Survivors    5.4 ± 3.5 days
NonSurvivors 10.6 ± 6.6 days

Bleeding: 1800 ± 500 ml/day
<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds Ratio</th>
<th>95% Confidence Interval</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.03</td>
<td>1.01–1.05</td>
<td>0.01</td>
</tr>
<tr>
<td>Gender (male vs. female)</td>
<td>0.58</td>
<td>0.34–0.996</td>
<td>0.048</td>
</tr>
<tr>
<td>Pre-ECLS pH ≤7.10</td>
<td>8.40</td>
<td>1.55–45.5</td>
<td>0.01</td>
</tr>
<tr>
<td>Pre-ECLS PaO₂/FiO₂</td>
<td>0.98</td>
<td>0.96–0.998</td>
<td>0.03</td>
</tr>
<tr>
<td>Pre-ECLS ventilator days</td>
<td>1.20</td>
<td>1.09–1.31</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pre-ECLS ventilator days &gt;8</td>
<td>5.53</td>
<td>1.94–15.8</td>
<td>0.001</td>
</tr>
</tbody>
</table>
We recommend transferring of adult patients with severe but potentially reversible respiratory failure, whose Murray score exceeds 3·0 or who have a pH of less than 7·20 on optimum conventional management, to a centre with an ECMO-based management protocol to significantly improve survival without severe disability.
Figure 2: Kaplan-Meier survival estimates
ECMO=extracorporeal membrane oxygenation. *Patients were randomly allocated to consideration for treatment by ECMO, but did not necessarily receive this treatment.
A case of ARDS associated with influenza A - H1N1 infection treated with extracorporeal respiratory support

G. GRASSELLI 1, G. FOTI 1, N. PATRONITI 1, 2, A. GIUFFRIDA 1, B. CORTINOVIS 1, A. ZANELLA 2, F. PAGNI 3, M. MERGONI 4, A. PESCI 5, 6, A. PESENTI 1, 2

(Minerva Anestesiol 2009;75:741-5)
Figure 1. Flow Diagram of Patients Receiving Mechanical Ventilation for Suspected 2009 Influenza A(H1N1) Infection at ECMO Centers

- 68 Received ECMO
  - 61 Confirmed 2009 influenza A(H1N1) or influenza A not subtyped
    - 53 Confirmed 2009 influenza A(H1N1)
      - 42 Alive
      - 4 Still in ICU
      - 11 Died
    - 8 Confirmed influenza A not subtyped
      - 6 Alive
      - 1 Still in ICU
      - 2 Died

### Table 3. Patient Outcomes

<table>
<thead>
<tr>
<th>Outcome Measure</th>
<th>All Infections (N = 68)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge destination</td>
<td></td>
</tr>
<tr>
<td>Died</td>
<td>14 (21)</td>
</tr>
<tr>
<td>Home</td>
<td>22 (32)</td>
</tr>
<tr>
<td>Other hospital</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Rehabilitation facility</td>
<td>9 (13)</td>
</tr>
<tr>
<td>Cause of death&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Hemorrhage</td>
<td>4 (29)</td>
</tr>
<tr>
<td>Intracranial hemorrhage</td>
<td>6 (43)</td>
</tr>
<tr>
<td>Infection</td>
<td>1 (7)</td>
</tr>
<tr>
<td>Intractable respiratory failure</td>
<td>4 (29)</td>
</tr>
</tbody>
</table>
ECMO ANZICS  jama 2009

- Median duration of ECMO was 10 (7-15) days
- Median blood flow was 4.9 l/min
- Max 23 pts in 3 consecutive days
- Estimated use of ECMO 2.6 to 2 cases per million
14 National ECMO centers
2 Local ECMO transportation
5 National on call ECMO transportation

ECMO call center
AIM of the ECMO NETWORK

1) Early referral of all potentially severe ARDS patients to tertiary hospitals able to provide advanced treatment options including ECMO.

2) Assuring safe transportation even on ECMO if needed

3) Institution of a stable NETWORK able to face possible future respiratory and circulatory diseases (SARS, Avian Influenza, bioterrorism)
Organization of the ECMO network

Five key elements:

1) Two national clinical coordinators.
   • Connection between Health Ministry and the network participants for selection of centers and allocation of resources,
   • 24 hours available to solve non-predicted problems and complex situations.
   • Contact with Military Aeronautic Service

2) 14 ECMO centers selected according to following criteria:
   1) previous experience in treating ARDS patients;
   2) previous experience in use of ECMO technology (8 centers) or presence of a cardiosurgery team expert in ECMO technology (6 centers);
   3) Territorial distribution.

3) A national 24 hours ECMO Call Center.
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4) A three days training course for venous-venous ECMO in ARDS patients
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5) Guidelines for early patient referral
RECOMMENDATIONS FOR EARLY CENTRALIZATION

ICUs of tertiary hospitals without ECMO facility

SatO2 < 85%
or
oxygenation index > 25 for at least 6 hour after optimization of MV
0r
PaO2/FiO2 <100 with PEEP ≥ 10 cmH2O for at least 6 hour s
or
hypercapnia and respiratory acidosis with pH<7.25,
0r
SvO2< 65% in spite Ht > 30 and asoactive drugs

National ECMO Call Center
60 Total ECMO included

ARDS_{Early} (Survival 77%)

ARGS_{H1N1} (Survival 71%)

ARDS_{Other} (Survival 55%)

ARGS_{Late} (Survival 33%)

48 Days of MV before ECMO \leq 7
43 Confirmed H1N1
(survival 77%)

49 Confirmed H1N1

12 Days of MV before ECMO \leq 7
6 Confirmed H1N1
(survival 33%)
Referral to an Extracorporeal Membrane Oxygenation Center and Mortality Among Patients With Severe 2009 Influenza A(H1N1)

Table 2. Deaths Analyzed by Matching Methods

<table>
<thead>
<tr>
<th>Matching method</th>
<th>ECMO-Reflected</th>
<th>Non-ECMO-Reflected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propensity score</td>
<td>18/75 (24.0)</td>
<td>35/75 (46.7)</td>
</tr>
<tr>
<td>GenMatch</td>
<td>18/75 (24.0)</td>
<td>38/75 (50.7)</td>
</tr>
<tr>
<td>Individual</td>
<td>14/59 (23.7)</td>
<td>31/59 (52.5)</td>
</tr>
</tbody>
</table>

Noah ME et al JAMA 2011, 306, 1659
Extracorporeal Membrane Oxygenation for Pandemic Influenza A(H1N1)–induced Acute Respiratory Distress Syndrome
A Cohort Study and Propensity-matched Analysis

Tâl Pham1,2, Alain Combes3,4, Hadrien Roze5, Sylvie Chevret2,6, Alain Mercat7,8, Antoine Roch9,10, Bruno Mourvillier11,12, Claire Ara-Somohano13,14, Olivier Bastien15,16, Ellie Zoghelil17, Marc Clavel18,19, Adrien Constan1, Jean-Christophe Marie Richard20,21,22, Christian Brun-Buisson1,23,24, and Laurent Brochard20,21,22, for the REVA Research Network*
260 ARDS patients treated conventionally

Excluded:
103 Not « severe » ARDS

157 « Severe » ARDS patients*

123 ARDS patients treated with ECMO

Excluded:
20 ECMO started after the first week of MV

103 ECMO started during the first week

52 Matched pairs
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Selected for Matching (52)</th>
<th>Not Selected for Matching (51)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, yr</td>
<td>45 (13)</td>
<td>38 (13)</td>
</tr>
<tr>
<td>Male sex</td>
<td>30 (58%)</td>
<td>19 (37%)</td>
</tr>
<tr>
<td><strong>Pre-ECMO</strong></td>
<td></td>
<td></td>
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<tr>
<td>Tidal volume, ml/kg PBW</td>
<td>6.6 (1.4)</td>
<td>6.8 (1.8)</td>
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<tr>
<td>Respiratory rate, min⁻¹</td>
<td>28 (6)</td>
<td>26 (5)</td>
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<td>13 (4)</td>
<td>13 (3)</td>
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<td>( \text{Pa}_o₂/\text{Fi}_o₂ ) ratio</td>
<td>70 (26)</td>
<td>54 (13)</td>
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<td>( \text{Sa}_o₂ ), %</td>
<td>87 (9)</td>
<td>80 (11)</td>
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<td><strong>Complications and outcome</strong></td>
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<td></td>
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<tr>
<td>Nosocomial pneumonia, n</td>
<td>32 (61%)</td>
<td>22 (43%)</td>
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<tr>
<td>Length of ECMO, d</td>
<td>9 (7–18)</td>
<td>13 (9–23)</td>
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<tr>
<td>Length of MV, d</td>
<td>22 (12–35)</td>
<td>30 (15–42)</td>
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<tr>
<td>Length of ICU stay, d</td>
<td>27 (11–52)</td>
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<td>26 (50%)</td>
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Vv ECMO: INDICATIONS

1. RESCUE

1. HIGH BLOOD FLOW

2. CLINICALLY PROVEN EFFICACY
VV ECMO

- ECLS should be considered when the risk of mortality is 50% or greater, and is indicated when the risk is 80% or greater.
  - a. 50% mortality risk: PaO2/FiO2 < 150 on FiO2 > 90% and/or Murray score 2-3
  - b. 80% mortality risk: PaO2/FiO2 < 80 on FiO2 > 90% and Murray score 3-4
ECMO

- Potent effective tool in severe hypoxemia rescue.
- Invasive
- High Blood Flow
- Complex
- Specialized Expert Environment
- Targeted to avoid Hypoxic Death