ExtraCorporeal CO₂ removal Devices

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www.reamedpitie.com
Conflict of interest

- Principal Investigator: HEROICS trial
  - HVHF after complicated heart surgery
  - NCT01077349
  - Sponsored by GAMBRO
- Principal Investigator: EOLIA trial
  - VV ECMO in ARDS
  - NCT01470703
  - Sponsored MAQUET, Getinge Group
- Received honoraria from
  - MAQUET, Getinge Group
  - Gambro
The rationale...

For ARDS patients...
The goods and the bads of MV in patients with ARDS...

- **MV harms the respiratory system**
  - Ventilator-Induced Lung Injury
    - Pressure
    - Volume
  - Inactivity of the diaphragm
- **MV promotes VAP**
- **MV requires patients sedation/paralysis**
The Acute Respiratory Distress Syndrome Network, ARMA


- 6 ml/Kg PBW
- 12 ml/Kg PBW

Mortality
- 10%
- 20%
- 30%
- 40%
Tidal Volume Reduction in Patients with Acute Lung Injury When Plateau Pressures Are Not High

David N. Hager, Jerry A. Krishnan, Douglas L. Hayden, and Roy G. Brower for the ARDS Clinical Trials Network

Am J Respir Crit Care Med Vol 172 pp 1241–1245, 2005
Tidal Hyperinflation during Low Tidal Volume Ventilation in Acute Respiratory Distress Syndrome

Pier Paolo Terragni, Giulio Rosboch, Andrea Tealdi, Eleonora Corno, Eleonora Menaldo, Ottavio Davini, Giovanni Gandini, Peter Herrmann, Luciana Mascia, Michel Quintel, Arthur S. Slutsky, Luciano Gattinoni, and V. Marco Ranieri

Am J Respir Crit Care Med 2007;175:160-166.
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Am J Respir Crit Care Med Vol 172 pp 1241–1245, 2005
Lung protective mechanical ventilation and two year survival in patients with acute lung injury: prospective cohort study

Needham DM et al., BMJ 2012;344:e2124.
The evolving paradigm...

- ARDSnet strategy might not protect against tidal hyperinflation
  - When Pplat remains >28-30 cm H\textsubscript{2}O

- Further decrease of Vt
  - From 6 to 5, 4 or 3 ml/kg IBW
  - To decrease Pplat <25 cm H\textsubscript{2}O, To decrease ΔP
  - To further reduce VILI
  - With sufficient PEEP to prevent lung derecruitment

- Induced Hypercapnia controlled by extracorporeal CO\textsubscript{2} removal
  - “CO\textsubscript{2} dialysis”
  - Low-flow devices
Move the patient out of the bed...
The History of CO₂ removal in ARDS ...
### Table III. Comparative technical difficulty of haemodialysis, extracorporeal removal of carbon dioxide and extracorporeal oxygenation

<table>
<thead>
<tr>
<th></th>
<th>Renal haemodialysis</th>
<th>Extracorporeal removal of carbon dioxide</th>
<th>Extracorporeal oxygenation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extracorporeal blood flow (ml min⁻¹)</td>
<td>200–300</td>
<td>500–1000</td>
<td>2000–4000</td>
</tr>
<tr>
<td>Blood pumping</td>
<td>optional small</td>
<td>optional small A–V shunt or A–V fistula</td>
<td>required major V–A or V–V</td>
</tr>
<tr>
<td>Haemodynamic changes</td>
<td>A–V shunt or A–V fistula</td>
<td>A–V shunt or A–V fistula or V–V pumping</td>
<td></td>
</tr>
<tr>
<td>Vascular access</td>
<td>simple</td>
<td>simple</td>
<td>complex advanced large</td>
</tr>
<tr>
<td>Surgical complexity</td>
<td>simple</td>
<td>simple</td>
<td></td>
</tr>
<tr>
<td>Complexity of equipment</td>
<td>moderate small</td>
<td>moderate small</td>
<td></td>
</tr>
<tr>
<td>Requirement for heparin</td>
<td>small</td>
<td>simple</td>
<td></td>
</tr>
</tbody>
</table>
43 patients, uncontrolled study

- Low-flow veno-venous CO2 removal device
  - ECCO2-R

- To avoid lung injury from conventional MV, the lungs were kept "at rest"
  - 3-5 breaths/min
  - "Low" peak airway pressure, 35-45 cm H$_2$O

- Survival: 21/43 (48.8%) patients
- Lung function improved in 31(72.8%) patients
- **Blood loss:** 1800±850mL/day...
Randomized clinical trial of pressure-controlled inverse ratio ventilation and extracorporeal CO2 removal for adult respiratory distress syndrome

- Randomized controlled clinical trial
- 40 patients with severe ARDS
- Extracorporeal CO2 removal:
  - ECCO2R
  - Low-flow veno-venous device
- Survival at 30 days not significantly different:
  - 42% in the 19 mechanical ventilation
  - 33% in the 21 ECCO2R patients (p = 0.8)
  - All deaths occurred within 30 days of randomization
- Study stopped for futility
- >30% patients with severe hemorrhage

Morris, AH, AJRCCM, 94
Techniques of the 2000’s...
Hemodec DECAP
**Tidal Volume Lower than 6 ml/kg Enhances Lung Protection**

*Role of Extracorporeal Carbon Dioxide Removal*

Anesthesiology 2009; 111:826-35

Pier Paolo Terragni, M.D.,† Lorenzo Del Sorbo, M.D.,* Luciana Mascia, M.D., Ph.D.,* Rosario Urbino, M.D.,* Erica L. Martin, Ph.D.,* Alberto Birocco, M.D.,† Chiara Faggiano, M.D.,† Michael Quintel, M.D.,† Luciano Gattinoni, M.D.,§ V. Marco Ranieri, M.D.,||

**DIAGNOSIS of ARDS**

"ARDSNet" strategy
for 72 hrs
N = 32

25 < P_{PLAT} < 28 cmH₂O
N = 22

BAL and CT scan

28 ≤ P_{PLAT} ≤ 30 cmH₂O
N = 10

BAL and CT scan

**LOWER "ARDSNet"/CARBON DIOXIDE REMOVAL:**

"ARDSNet" strategy
for 72 hrs
N = 22

- Reduce Vₜ to achieve 25<P_{PLAT}<28 cmH₂O
- PEEP-FIO₂ combination set according to the higher PEEP arm of the ALVEOLI study
- Increase respiratory rate up to 40 b/min
- Bicarbonate infusion up to 20 mEq/h

If pH ≤ 7.25 apply CARBON DIOXIDE REMOVAL for at least 72 hrs
N = 10

BAL (N=15) and CT scan (N=12)

BAL and CT scan
N = 10
Tidal Volume Lower than 6 ml/kg Enhances Lung Protection

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V_t (ml/Kg PBW)

P_plat (cm H_2O)

PEEP (cm H_2O)

PaO_2/FiO_2

"ARDSNet" baseline T_1.5 T_24 T_48 T_72

"ARDSNet" baseline T_1.5 T_24 T_48 T_72
Tidal Volume Lower than 6 ml/kg Enhances Lung Protection

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V. Marco Ranieri, M.D.||

PaCO₂ (mm Hg)

pH

“ARDSNet” baseline T1.5 T24 T48 T72

“ARDSNet” baseline T1.5 T24 T48 T72
Novalung, ILA, Pumpless AV shunt
Novalung, ILA pumpless AV shunt
A new pumpless extracorporeal interventional lung assist in critical hypoxemia/hypercapnia*

Thomas Bein, MD; Frank Weber, MD; Alois Philipp, ECCP; Christopher Prasser, MD; Michael Pfeifer, MD; Franz-Xaver Schmid, MD; Bernhard Butz, MD; Dietrich Birnbaum, MD; Kai Taeger, MD; Hans J. Schlitt, MD

Objective: Pump-driven extracorporeal gas exchange systems have been advocated in patients suffering from severe acute respiratory distress syndrome who are at risk for life-threatening hypoxemia and/or hypercapnia. This requires extended technical and staff support.

Design: We report retrospectively our experience with a new pumpless extracorporeal interventional lung assist (iLA) establishing an arteriovenous shunt as the driving pressure.

Setting: University hospital.

Patients: Ninety patients with acute respiratory distress syndrome.

Interventions: Interventional lung assist was inserted in 90 patients with acute respiratory distress syndrome.

Measurements and Main Results: Oxygenation improvement, carbon dioxide elimination, hemodynamic variables, and the amount of vasopressor substitution were reported before, 2 hrs after, and 24 hrs after implementation of the system. Interventional lung assist led to an acute and moderate increase in arterial oxygenation (Pao₂/Fio₂ ratio 2 hrs after initiation of iLA [median and interquartile range], 82 mm Hg [64–103]) compared with pre-iLA (58 mm Hg [47–78], p < .05). Oxygenation continued to improve for 24 hrs after implementation (101 mm Hg [74–142], p < .05). Hypercapnia was promptly and markedly reversed by iLA within 2 hrs (Paco₂, 36 mm Hg [30–44]) in comparison with before (60 mm Hg [48–80], p < .05), which allowed a less aggressive ventilation. For hemodynamic stability, all patients received continuous nor-epinephrine infusion. The incidence of complications was 24.4%, mostly due to ischemia in a lower limb. Thirty-seven of 90 patients survived, creating a lower mortality rate than expected from the Sequential Organ Failure Assessment score.

Conclusions: Interventional lung assist might provide a sufficient rescue measure with easy handling properties and low cost in patients with severe acute respiratory distress syndrome and persistent hypoxia/hypercapnia. (Crit Care Med 2006; 34:1372–1377)
A new pumpless extracorporeal interventional lung assist in critical hypoxemia/hypercapnia*

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Crit Care Med 2006 Vol. 34, No. 5
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<table>
<thead>
<tr>
<th>Parameter</th>
<th>Survivors (S)</th>
<th>Nonsurvivors (NS)</th>
<th>All Patients</th>
<th>( p ) (S vs. NS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>37</td>
<td>53</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Age, yrs</td>
<td>32 (22–49)</td>
<td>49 (33–60)</td>
<td>44 (26–59)</td>
<td>.009</td>
</tr>
<tr>
<td>Female/male ratio</td>
<td>8/29</td>
<td>13/40</td>
<td>21/69</td>
<td>NS</td>
</tr>
<tr>
<td>Body mass index</td>
<td>24.1 (22.5–26.6)</td>
<td>27.7 (24.0–30.8)</td>
<td>25.4 (23.4–29.7)</td>
<td>.001</td>
</tr>
<tr>
<td>Days on ventilator before ILA</td>
<td>1 (1–8)</td>
<td>4 (1–14)</td>
<td>3 (1–10)</td>
<td>.034</td>
</tr>
<tr>
<td>SOFA score</td>
<td>10 (7–11)</td>
<td>11 (8–14)</td>
<td>11 (8–13)</td>
<td>.016</td>
</tr>
<tr>
<td>Lung injury score</td>
<td>3.7 (3.3–3.8)</td>
<td>3.5 (3.3–3.8)</td>
<td>3.5 (3.5–3.8)</td>
<td>NS</td>
</tr>
</tbody>
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<thead>
<tr>
<th></th>
<th>Pre</th>
<th>2 Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FiO₂</strong></td>
<td>1.0 (1.0–1.0)</td>
<td>0.9 (0.8–1.0)</td>
</tr>
<tr>
<td><strong>Minute ventilation, L · min⁻¹</strong></td>
<td>13.0 (10.0–16.4)</td>
<td>11.0 (8.0–14.1)</td>
</tr>
<tr>
<td><strong>Tidal volume, mL</strong></td>
<td>430 (360–540)</td>
<td>410 (330–480)</td>
</tr>
<tr>
<td><strong>Respiratory frequency, breaths/min</strong></td>
<td>27 (21–43)</td>
<td>25 (20–40)</td>
</tr>
<tr>
<td><strong>Peak inspiratory pressure, cm H₂O</strong></td>
<td>38 (35–40)</td>
<td>36 (32–39)</td>
</tr>
<tr>
<td><strong>PEEP, cm H₂O</strong></td>
<td>15 (12–17)</td>
<td>15 (13–18)</td>
</tr>
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<thead>
<tr>
<th>Complication/Side Effect</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ischemia of a lower limb after cannulation</td>
<td>9</td>
</tr>
<tr>
<td>Cannula thrombosis</td>
<td>4</td>
</tr>
<tr>
<td>Compartmental syndrome in a lower limb</td>
<td>4</td>
</tr>
<tr>
<td>Hematoma/aneurysm at cannulation site</td>
<td>2</td>
</tr>
<tr>
<td>Hemolysis</td>
<td>1</td>
</tr>
<tr>
<td>Intracerebral hemorrhage</td>
<td>1</td>
</tr>
<tr>
<td>Diffuse bleeding/shock syndrome during cannulation</td>
<td>1</td>
</tr>
<tr>
<td>All</td>
<td>22 (24.4%)</td>
</tr>
</tbody>
</table>
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<tr>
<th>Complication/Side Effect</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ischemia of a lower limb after arterial canulation</td>
<td>9</td>
</tr>
</tbody>
</table>

25% Incidence of complications and side effects
Limb ischemia due to arterial canulation +++
Need for IV norepinephrine (24.4%)
The Xtravent trial

Lower tidal volume strategy ($\approx 3$ ml/kg) combined with extracorporeal CO$_2$ removal versus ‘conventional’ protective ventilation (6 ml/kg) in severe ARDS

The prospective randomized Xtravent-study

Thomas Bein
Steffen Weber-Carstens
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Intensive Care Med
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**Screening $\rightarrow$ 305 patients:**
- acute respiratory failure
- $\text{PaO}_2/\text{FiO}_2 \leq 200$

**Stabilization over 24 hrs:**
- $V_t$ 6 ml/kg/IBW
- ARDSNet „high-PEEP“
- CVP $10 - 16$ mmHg
- MAP $\geq 70$ mmHg
- echocardiography

**103 patients:**
- no inclusion criteria fulfilled

**64 patients:**
- no inclusion due to *improvement*
- $\text{PaO}_2/\text{FiO}_2 > 200$

**50 patients:**
- no inclusion due to *deterioration*
- $\text{PaO}_2/\text{FiO}_2 < 70 \rightarrow \text{wECMO}$

**4 patients:**
- no inclusion due to death

**5 patients:**
- no informed consent

---

**randomization $\rightarrow$ 79 patients**

40 patients $\rightarrow$ avECCO$_2$-R
- $V_t$ 3 ml/kg/IBW
- ARDSNet „high-PEEP“

ventilation target:
- $\text{PaO}_2 \geq 60$ mmHg
- art. pH $\geq 7.2$

39 patients $\rightarrow$ control
- $V_t$ 6 ml/kg/IBW
- ARDSNet „high-PEEP“
Lower tidal volume strategy ($\approx 3$ ml/kg) combined with extracorporeal CO$_2$ removal versus ‘conventional’ protective ventilation (6 ml/kg) in severe ARDS

The prospective randomized Xtravent-study

Established ARDS. Methods: Seventy-nine patients were enrolled after a ‘stabilization period’ (24 h with optimized therapy and high PEEP). They were randomly assigned to receive a low $V_T$ ventilation ($\approx 3$ ml/kg) combined with extracorporeal CO$_2$ elimination, or to a ARDSNet strategy ($\approx 6$ ml/kg) without the extracorporeal device. The primary outcome was the 28-days and 60-days ventilator-free days (VFD).

Secondary outcome parameters were respiratory mechanics, gas exchange, analgesic/sedation use, complications and hospital mortality.
Lower tidal volume strategy (\(\approx 3\) ml/kg) combined with extracorporeal CO\(_2\) removal versus ‘conventional’ protective ventilation (6 ml/kg) in severe ARDS

The prospective randomized Xtravent-study

| Table 2 Ventilation parameters and gas exchange after 24-h stabilization period at randomization |
|--------------------------------------|----------|----------|----------|
|                                      | avECCO\(_2\)-R | Control | \(p\)  |
|                                      | (\(n = 40\))    | (\(n = 39\)) |        |
| PaO\(_2\)/FIO\(_2\)                 | 152 ± 37    | 168 ± 37 | 0.044  |
| PaCO\(_2\) (mmHg)                    | 57.3 ± 12   | 54.3 ± 9  | 0.352  |
| Arterial pH                          | 7.34 ± 0.07 | 7.36 ± 0.07 | 0.317 |
| \(V_T\) (ml/kg, PBW)                | 5.9 ± 1.2   | 6.0 ± 0.6 | 0.495  |
| Minute ventilation (l/min)           | 9.9 ± 1.6   | 9.8 ± 2.4 | 0.745  |
| Frequency/min                        | 22.4 ± 3    | 22.7 ± 3.5 | 0.854 |
| PEEP (cmH\(_2\)O)                   | 16.1 ± 3    | 16.0 ± 3  | 0.898  |
| Plateau pressure (cmH\(_2\)O)       | 29.0 ± 5    | 28.0 ± 7  | 0.384  |
| Delta (PEEP-Plateau) (cmH\(_2\)O)   | 12.9 ± 4    | 12.4 ± 4  | 0.475  |
| FIO\(_2\)                            | 0.62 ± 0.2  | 0.53 ± 0.1 | 0.028  |

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The prospective randomized Xtravent-study

<table>
<thead>
<tr>
<th>All patients</th>
<th>avECCO₂-R</th>
<th>Control</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilator-free-days-28</td>
<td>10.0 ± 8</td>
<td>9.3 ± 9</td>
<td>0.779</td>
</tr>
<tr>
<td>Ventilator-free-days-60</td>
<td>33.2 ± 20</td>
<td>29.2 ± 21</td>
<td>0.469</td>
</tr>
<tr>
<td>Non-pulmonary organ failure free days-60</td>
<td>21.0 ± 14</td>
<td>23.9 ± 15</td>
<td>0.447</td>
</tr>
<tr>
<td>Lung injury score on day 10</td>
<td>2.2 ± 0.6</td>
<td>2.1 ± 0.5</td>
<td>0.854</td>
</tr>
<tr>
<td>Length of stay in hospital (days)</td>
<td>46.7 ± 33</td>
<td>35.1 ± 17</td>
<td>0.113</td>
</tr>
<tr>
<td>Length of stay in ICU (days)</td>
<td>31.3 ± 23</td>
<td>22.9 ± 11</td>
<td>0.144</td>
</tr>
<tr>
<td>In-hospital mortality</td>
<td>7/40 (17.5 %)</td>
<td>6/39 (15.4 %)</td>
<td>1.000</td>
</tr>
</tbody>
</table>

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Intensive Care Med
**Lower tidal volume strategy (≈ 3 ml/kg) combined with extracorporeal CO₂ removal versus ‘conventional’ protective ventilation (6 ml/kg) in severe ARDS**

The prospective randomized Xtravent-study

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### Subgroup: PAO₂/FIO₂ <150

<table>
<thead>
<tr>
<th></th>
<th>avECCO₂-R</th>
<th>Control</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilator-free-days-28</td>
<td>11.3 ± 7.5</td>
<td>5.0 ± 6.3</td>
<td>0.033</td>
</tr>
<tr>
<td>Ventilator-free-days-60</td>
<td>40.9 ± 12.8</td>
<td>28.2 ± 16.4</td>
<td>0.033</td>
</tr>
<tr>
<td>Non-pulmonary organ failure free days-60</td>
<td>24.1 ± 7.5</td>
<td>29.0 ± 17.7</td>
<td>0.428</td>
</tr>
<tr>
<td>Lung injury score on day 10</td>
<td>2.3 ± 0.8</td>
<td>2.2 ± 0.5</td>
<td>0.601</td>
</tr>
<tr>
<td>Length of stay in hospital (days)</td>
<td>42.0 ± 16.6</td>
<td>40.3 ± 15.7</td>
<td>0.815</td>
</tr>
<tr>
<td>Length of stay in ICU (days)</td>
<td>25.9 ± 13.1</td>
<td>31.0 ± 12.7</td>
<td>0.258</td>
</tr>
<tr>
<td>In-hospital mortality</td>
<td>1/21 (4.8 %)</td>
<td>1/10 (10 %)</td>
<td>0.563</td>
</tr>
</tbody>
</table>
Lower tidal volume strategy ($\approx 3$ ml/kg) combined with extracorporeal CO$_2$ removal versus ‘conventional’ protective ventilation (6 ml/kg) in severe ARDS

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Intensive Care Med

$P/F \leq 150$ mmHg, n=28

$P/F > 150$ mmHg, n=34

$P=0.045$

$P=0.529$
Techniques of the 2010’s…
Respiratory dialysis: Reduction in dependence on mechanical ventilation by venovenous extracorporeal CO₂ removal

Andriy I. Batchinsky, MD; Bryan S. Jordan, RN, MSN; Dara Regn, MD; Corina Necsoiu, MD; William J. Federspiel, PhD; Michael J. Morris, MD; Leopoldo C. Cancio, MD

Crit Care Med 2011; 39:1382–1387
Respiratory dialysis: Reduction in dependence on mechanical ventilation by venovenous extracorporeal CO₂ removal*

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Crit Care Med 2011; 39:1382–1387

Objectives: Mechanical ventilation is injurious to the lung. Use of lung-protective strategies may complicate patient management, motivating a search for better lung-replacement approaches. We investigated the ability of a novel extracorporeal venovenous CO₂ removal device to reduce minute ventilation while maintaining normocarbia.

Design: Prospective animal study.

Setting: Government laboratory animal intensive care unit.

Subjects: Seven sedated swine.

Interventions: Tracheostomy, volume-controlled mechanical ventilation, and 72 hrs of round-the-clock intensive care unit care. A 15-F dual-lumen catheter was inserted in the external jugular vein and connected to the Hemolung, an extracorporeal pump-driven venovenous CO₂ removal device. Minute ventilation was reduced, and normocarbia (Paco₂ 35–45 mm Hg) maintained. Heparinization was maintained at an activated clotting time of 150–180 secs.

Measurements and Main Results: Minute ventilation (L/min), CO₂ removal by Hemolung (mL/min), Hemolung blood flow, O₂ consumption (mL/min), CO₂ production by the lung (mL/min), Paco₂, and plasma-free hemoglobin (g/dL) were measured at baseline (where applicable), 2 hrs after device insertion, and every 6 hrs thereafter. Minute ventilation was reduced from 5.6 L/min at baseline to 2.6 L/min 2 hrs after device insertion and was maintained at 3 L/min until the end of the study. CO₂ removal by Hemolung remained steady over 72 hrs, averaging 72 ± 1.2 mL/min at blood flows of 447 ± 5 mL/min. After insertion, O₂ consumption did not change; CO₂ production by the lung decreased by 50% and stayed at that level (p < .001). As the arterial PCO₂ rose or fell, so did CO₂ removal by Hemolung. Plasma-free hemoglobin did not change.

Conclusions: Venovenous CO₂ removal enabled a 50% reduction in minute ventilation while maintaining normocarbia and may be an effective lung-protective adjunct to mechanical ventilation. (Crit Care Med 2011; 39:1382–1387)

Key Words: lung-protective ventilation; mechanical ventilation; extracorporeal circulation; CO₂ removal; respiratory dialysis; swine
Respiratory dialysis: Reduction in dependence on mechanical ventilation by venovenous extracorporeal CO$_2$ removal*

Andriy I. Batchinsky, MD; Bryan S. Jordan, RN, MSN; Dara Regn, MD; Corina Necsoiu, MD; William J. Federspiel, PhD; Michael J. Morris, MD; Leopoldo C. Cancio, MD

Crit Care Med 2011; 39:1382–1387
PALP, MAQUET®
PrismaLung, Amplya...
More to come...
A new paradigm...
Acute Respiratory Distress Syndrome

The Berlin Definition

Increasing Intensity of Intervention

- Low Tidal Volume Ventilation
- Higher PEEP
- Prone Positioning
- Neuromuscular Blockade
- Inhaled NO
- ECMO
- HFVO
- NIV
- Low-Moderate PEEP
- Low Tidal Volume Ventilation

Mild ARDS
Moderate ARDS
Severe ARDS

PaO₂/FiO₂

The ARDS Definition Taskforce. JAMA 2012;307:2526-2533.
Acute Respiratory Distress Syndrome

The Berlin Definition

**Mild ARDS**
- Low Tidal Volume Ventilation
- Low PEEP
- Low tidal volume/PEEP + ECCO₂R?
- NIV

**Moderate ARDS**
- Low-Moderate PEEP
- Lower Tidal Volume/Pplat + ECCO₂R?

**Severe ARDS**
- Higher PEEP
- Prone Positioning
- Neuromuscular Blockade
- Higher PEEP
- ECMO
- Inhaled NO
- HFVO

The ARDS Definition Taskforce. JAMA 2012;307:2526-2533.
Conclusion

- ExtraCorporeal CO₂ Removal
  - “Respiratory dialysis”
  - Not for refractory hypoxemia: VV-ECMO
- Potential for use for moderate to severe ARDS
  - To allow further reduction of Vt/Pplat
  - To limit VILI, without major respiratory acidosis
- For COPD patients
  - Prevent intubation when NIV fails
- Should be (re)tested in large clinical trials...
  - Recent major technological improvement in devices
A **Strategy of Ultra**Protective lung ventilation
With **Extracorporeal CO\textsubscript{2} Removal for New-Onset** moderate to severe **ARDS**

The **SUPERNOVA** trial