ECMO for Respiratory Support

UPDATE on

Extracorporeal CO2 removal: When and how

Antonio Pesenti
University of Milano
Italy
antonio.pesenti@unimi.it
Conflict of Interests

• Received travel support
  – Maquet, Drager

• Received research support
  – Maquet, Drager, Bellco

• Consulting for
  – Maquet, Novalung, Gambro, Bellco
Adult respiratory distress syndrome (ARDS): Why did ECMO fail?

T. Kolobow, M. Solca, L. Gattinoni, A. Pesenti

The International Journal Of Artificial Organs / Vol. 4 no. 2, 1981 / p. 59
© by Wichtig Editore srl, 1981
Laboratory Report

Control of Breathing Using an Extracorporeal Membrane Lung

Theodor Kolobow, M.D.,* Luciano Gattinoni, M.D.,* Timothy A. Tomlinson, B.S.,* Joseph E. Pierce, D.V.M.†

\[ y = 3.936 + 0.9096 \times \\
\text{r} = 0.9518 
\]
Venovenous Carbon Dioxide Removal in Chronic Obstructive Pulmonary Disease

Cardenas et al ASAIO J 2009
Venovenous Carbon Dioxide Removal in Chronic Obstructive Pulmonary Disease

Cardenas et al ASAIO J 2009
Venovenous Carbon Dioxide Removal in Chronic Obstructive Pulmonary Disease

Cardenas et al ASAIO J 2009
Extracorporeal CO2 Removal
Physiological Side Effects

• Decreased $P_A O_2$: (Due to decreased QR)
• Decreased TV - Decrecruitment
  – Higher PEEP Maintain Paw
• Ineffective Coughing (?)

• Control of breathing?
ECCO2R in ARDS

Rationale

• ARDS is not Just Hypoxemia: Co2 elimination is a problem
• ARDS High PAP and RVF (dysfunction)
• Severe respiratory alkalosis of Dead Space regions
• Barotrauma Ventilator Induced Lung Injury
• VAP
• Sedation
The technique seems to prevent the pulmonary barotrauma and extrapulmonary derangements caused by conventional mechanical ventilation.

Summary
Terminal respiratory failure was reversed in three patients with a combination of extracorporeal CO$_2$ 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.
ARDS Status

• ECCO2R to:
  - go from 6 to 3ml/kg and lower

SUPERNOVA STUDY
Sponsored by ESICM
PIs: A. Combes  VM Ranieri
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

**Screening $\rightarrow$ 305 patients:**
acute respiratory failure
PaO$_2$/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
P/F ≤ 150 mmHg, n=28

P/F > 150 mmHg, n=34

Probability of successful weaning

Days

p=0.045

p=0.529
Early ARDS

- ECCO2R to:
  - prevent intubation
  - extend NIV application
ARDS Recovering

- ECCO2R to allow:
  - early spontaneous breathing
  - early extubation
  - early NIV or CPAP
Two way RM ANOVA:
P-value for GF% < 0.001
P-value for vent. mode = 0.01

A

B

Two way RM ANOVA:
P-value for GF% < 0.001
P-value for vent. mode = 0.01
**Figure 4.** Variations in tidal volume (expressed as % of control measurements) caused by different amounts of extracorporeal CO₂ removal expressed as percentage of total CO₂ production. Experimental points were grouped in three categories of extracorporeal CO₂ removal: 1–60%, 61–80%, and 81–100%. Black bars represent healthy sheep, while hatched bars represent sheep with acute respiratory distress.
Avoiding invasive mechanical ventilation by extracorporeal carbon dioxide removal in patients failing noninvasive ventilation

Kluge S Intensive Care Med (2012) 38:1632

In this study the use of extracorporeal carbon dioxide removal allowed avoiding intubation and invasive mechanical ventilation in the majority of patients with acute on chronic respiratory failure not responding to NIV
Pilot Study of Extracorporeal Carbon Dioxide Removal to Facilitate Extubation and Ambulation in Exacerbations of Chronic Obstructive Pulmonary Disease

Darryl C. Abrams¹, Keith Brenner¹, Kristin M. Burkart¹, Cara L. Agerstrand¹, Byron M. Thomashow¹, Matthew Bacchetta²*, and Daniel Brodie¹*

¹Division of Pulmonary, Allergy, and Critical Care, Department of Medicine; and ²Division of Thoracic Surgery, Department of Surgery, Columbia University College of Physicians and Surgeons/New York-Presbyterian Hospital, New York, New York
Ecco2R in COPD exacerbation
Abrams DC Annals ATS 2013

- 5 COPD pts on MV (failed NIV)
- pH 7.23 ± 0.05; PaCO2 82 ± 16 mmHg
- P/F 256 ± 58 mmHg
- Blood flow 1-1.7 l/min
- 20-23 F double lumen cannula
Fig. 2 Sequential changes in arterial partial pressure of carbon dioxide (PaCO₂), pH, and respiratory rate over time from ICU admission until 24 h after PECLA implantation. Boxplots display medians, 10th, 25th, 75th and 90th percentiles. *p < 0.001 BL vs. 21–24 h
Extracorporeal $\text{CO}_2$ Removal in Hypercapnic Patients At Risk of Noninvasive Ventilation Failure: A Matched Cohort Study With Historical Control*

Del Sorbo Crit Care Med 2015
CO2 removal blood flows

• High flow (> 2 l/min)
  – Contribute to oxygenation (if v-v)
  – Total Co2 removal

• Intermediate (0.5 < flow < 2 l/min)
  – Minor oxygenation
  – Partial to total CO2 removal

• Low flow (< 0.5 l/min)
  – Clinically irrelevant oxygenation
  – Partial (10 to 40%) CO2 removal
CRITICAL CARE MEDICINE

Regional Blood Acidification Enhances Extracorporeal Carbon Dioxide Removal

A 48-hour Animal Study

Alberto Zanella, M.D., Paolo Mangili, M.D., Sara Redaelli, M.D., Vittorio Scaravilli, M.D., Marco Giani, M.D., Daniela Ferlicca, M.D., Diletta Scaccabarozzi, Federica Pirrone, D.V.M., Ph.D., Mariangela Albertini, D.V.M., Ph.D., Nicolò Patroniti, M.D., Antonio Pesenti, M.D.

Anesthesiology 2014; 120:416-24

Some more interesting data………..
Respiratory Electrodeionlysis
A Novel, Highly Efficient Extracorporeal CO\textsubscript{2} Removal Technique

Alberto Zanella\textsuperscript{1}, Luigi Castagna\textsuperscript{1}, Domenico Salerno\textsuperscript{1}, Vittorio Scaravilli\textsuperscript{1}, Salua Abd El Aziz El Sayed Deab\textsuperscript{1}, Federico Magni\textsuperscript{1}, Marco Giani\textsuperscript{1}, Silvia Mazzola\textsuperscript{2}, Mariangela Albertini\textsuperscript{2}, Nicolò Patroniti\textsuperscript{1,3}, Francesco Mantegazza\textsuperscript{1}, and Antonio Pesenti\textsuperscript{1,3}

\textsuperscript{1}Dipartimento di Scienze della Salute, Università degli Studi di Milano Bicocca, Monza, Italy; \textsuperscript{2}Dipartimento di Scienze Veterinarie e Sanità Pubblica, Università degli Studi di Milano, Italy; and \textsuperscript{3}Dipartimento di Anestesia e Rianimazione, Ospedale San Gerardo, Monza, Italy
Respiratory electro dialysis

CO₂ removal

First Baseline
ECCO₂R
Respiratory Electrodialysis
Final Baseline

VCO₂ ml/min

*%$

NL VCO₂
ML VCO₂
Extracorporeal CO2 Removal

• It is an experimental technique
• Many things we do not know yet

• There are more things in heaven and earth, Horatio, Than are dreamt of in your philosophy.

– *Hamlet Act 1, scene 5, 159–167*