Mechanical Ventilation during ECMO
How, Why, Future Studies

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Disclosures/COI

• No relevant financial relationships with any commercial interests
VENTILATION WITH LOWER TIDAL VOLUMES AS COMPARED WITH TRADITIONAL TIDAL VOLUMES FOR ACUTE LUNG INJURY AND THE ACUTE RESPIRATORY DISTRESS SYNDROME

THE ACUTE RESPIRATORY DISTRESS SYNDROME NETWORK*

Low Stretch (Intervention)                  High Stretch (Control)
- $V_T$: 6.2 mL/kg                           - $V_T$: 11.8
- $P_{PLAT}$: 25 cmH$_2$O                  - $P_{PLAT}$: 32-34
- RR: 29                                    - RR: 18
- $V_{MIN}$: 13 L/min                      - $V_{MIN}$: 13
- PEEP: 9 cmH$_2$O                          - PEEP: 8

P=0.005

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

From a physiological perspective the “baby lung” helps to understand ventilator-induced lung injury. In this context, the mechanical ventilation strategy should include reducing the tidal volume ($V_T$/“baby lung” ratio. The practical message is straightforward: the smaller the “baby lung,” the greater is the potential for unsafe mechanical ventilation.
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.
• VV ECMO provides gas exchange support only
  – Blood drained from venous system and returned to venous system (e.g., jugular and femoral veins)
ECMO and Lung Rest – Limit VALI

• Subgroup of severe ARDS patients in which maintaining modest physiologic goals with lung protective MV is not possible
  – Extracorporeal gas exchange may facilitate lung rest and prevent the need for injurious MV
  – Complete apnea to spontaneous breathing

THE BEST WAY TO TREAT THE “BABY LUNG” GENTLY?
 reductions in ECCO$_2$R group
- $V_T$ from 6.3 to 4.2 mL/kg PBW
- $P_{plat}$ from 29.1 to 25.0 cmH$_2$O
- ECCO$_2$R normalized PaCO$_2$ (50.4 mmHg) and pH (7.32) despite lower $V_T$
- After 72 hrs of ventilation and ECCO$_2$R
  - Significant improvement in morphological markers of lung protection and pulmonary cytokines
- No patient-related complications observed
Combining “open-lung” ventilation and arteriovenous extracorporeal lung assist: Influence of different tidal volumes on gas exchange in experimental lung failure

How much should we “rest” the lung in patients with severe ARDS on ECMO?
Lung Rest Ventilation During ECMO

• Appropriate MV settings for severe ARDS patients on ECMO are unknown
  – Optimal tidal volume?
  – Optimal PEEP?

• Various strategies to achieve lung rest have been described
  – Effects on inflammatory markers/outcomes have not been compared
  – Role of spontaneous ventilation/extubation?

Efficacy and economic assessment of conventional ventilatory support versus extracorporeal membrane oxygenation for severe adult respiratory failure (CESAR): a multicentre randomised controlled trial

Giles J Peek, Miranda Mugford, Ravindranath Tiruvoipati, Andrew Wilson, Elizabeth Allen, Mariamma M Thalanany, Clare L Hibbert, Ann Truesdale, Felicity Clemens, Nicola Cooper, Richard K Firmin, Diana Elbourne, for the CESAR trial collaboration

Ventilation was in pressure control mode with Siemens Servo 300 ventilators (Solma, Sweden); lung rest settings were peak inspiratory pressure 20–25, positive end-expiratory pressure 10–15, rate 10, and FiO\textsubscript{2} 0.3. ECMO was continued until lung recovery, or until apparently irreversible multiorgan failure.

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<th>Patients at risk</th>
<th>Conventional management</th>
<th>ECMO*</th>
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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.

EOLIA

ECMO to rescue Lung Injury in severe ARDS

PI: Prof. Alain Combes
Randomization

Experimental Treatment Arm
- Venovenous ECMO will be started as rapidly as possible
- Mechanical ventilation settings: volume-assist control mode, $\text{FiO}_2$ 30–60%, PEEP $\geq$ 10 cm H$_2$O, $V_T$ lowered to obtain a plateau pressure $\leq$ 20 cm H$_2$O, RR 10–30/minute or APRV mode with high pressure level $\leq$ 20 cm H$_2$O an low pressure level $\geq$ 10 cm H$_2$O
- ECMO weaning according to protocol

Control Conventional Treatment Arm
- Conventional management of ARDS
- Ventilatory settings: volume-assist control mode, $V_T$ 6 ml/kg of ideal body weight and PEEP adapted so as not to exceed plateau pressure of 28–30 cm H$_2$O
- In the case of refractory hypoxemia, the usual adjunctive therapeutics can be used: NO, prone position, HFO ventilation, almitrine infusion
- Cross-over option to ECMO possible if refractory hypoxemia defined as SaO2 < 80% for >6 hours, despite mandatory use of recruitment maneuvers, and inhaled NO/prostacyclin and if technically possible a test of prone position.
To Open, or Not to Open?

• Recruited lung
  – Less likely to develop pneumonia
  – Better surfactant function
  – Less VALI?
  – Improved outcomes?

• And if so, how to recruit, and at what cost?
  – Potential for recruitment? “Inert” atelectasis?
  – Overdistention/inhomogeneity – more VALI?
“We had arbitrarily chosen 5 cmH₂O pressure to keep the lungs inflated above FRC. We do not know at this time whether this represents the optimal requirement or whether pressure is desirable or even necessary for optimal performance....

This study was not undertaken to extend the safe period of apnea during electroconvulsive therapy, bronchoscopy....Rather we feel the concept of long-term (as opposed to short-term) apnea with extracorporeal carbon dioxide removal can affect present practice of mechanical pulmonary ventilation in especially difficult cases.”
Low-Frequency Positive Pressure Ventilation with Extracorporeal Carbon Dioxide Removal (LFPPV-ECCO$_2$R): An Experimental Study

Luciano Gattinoni, MD; Antonio Pesenti, MD; Daniele Mascheroni, MD; Roberto Marcolin, MD; Roberto Fumagalli, MD; Francesca Rossi, MD; Gaetano Iapichino, MD; Giuliano Romagnoli, MD; Lji Uziel, MD; Angelo Agostoni, MD; Theodor Kolobow, MD; Giorgio Damia, MD

Extracorporeal Membrane Oxygenation in Awake Patients as Bridge to Lung Transplantation

Thomas Fuehner¹, Christian Kuehn², Johannes Hadem³, Olaf Wiesner¹, Jens Gottlieb¹, Igor Tudorache², Karen M. Olsson¹, Mark Greer¹, Wiebke Sommer², Tobias Welte¹, Axel Haverich², Marius M. Hoeper¹, and Gregor Warnecke²

¹Department of Respiratory Medicine, ²Department of Cardiothoracic, Transplant and Vascular Surgery, and ³Department of Gastroenterology, Hepatology and Endocrinology, Hannover Medical School, Hannover, Germany

A

Awake ECMO to LuTx group (n=26)

Secondary intubation (n=7)

Died before LuTx (n=10)

Died on ECMO (n=6)

Successful bridging to LuTx (n=4)

Discharged from hospital (n=3)

Not intubated (n=19)

Successful bridging to LuTx without intubation (n=16)

Died after LuTx on ICU (n=3)

Died after LuTx on ICU (n=14)

Discharged from hospital (n=13)

B

Intubation to LuTx group (n=34)

Died before LuTx (n=10)

Successful bridging to LuTx (n=24)

Died after LuTx on ICU (n=14)

Secondary ECMO (n=4)

Discharged from hospital (n=12)

Fuehner T et al., Am J Respir Crit Care Med 2012;185:763-768.
The SOLVE ARDS Study

Strategies for Optimal Lung Ventilation in ECMO for ARDS

A Goffi, K Mandelzweig, M Meineri, L Del Sorbo, E Goligher, S Abrahamson, N Ferguson, A Slutsky, E Fan
Questions?

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