Pathophysiology of Gas Exchange in ARDS

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Conflict Of Interest

- Grants from Maquet, Drager
- Consultant for Maquet, Novalung Gambro
- Patents in CO2 removal technology
- Patent in respiratory monitoring
Brun-Buisson C. ALIVE study., Intensive Care Med. 2004;30:51
KING OF THE HILL

Trail is granted a rare audience with Reinhold Messner – a man who has spent 40 years achieving the impossible.

Words: Siomoe Ingram

A

gainst a backdrop of drooping paint in Kathmandu is the Rum Doodle Bar. On returning from Everest, this is where people congregate. More sober organisations may hold the statistics of who has reached the top of the Earth, but it’s the tales of Rum Doodle that hold their souls. Here in thousands of signatures, caricatures and unmentionable stories from adventurers who have enthralled their boozed relays under this roof and allowed their eyes to entertain ideas and great mountain tales.

Above the bar on a piece of wood is the largest collection of Everest autographs in the world. Among the chaos a scribble, closed letter, the loopy signature of the late Sir Hillary; swastikas; it’s a case 1955/53, just above it’s a chopper signature, atop the dates 3/5/78 and 20/6/80. Among all these, there are the three most significant autographs of Everest, first, first without oxygen; second, solo without oxygen.

The owner of the first, sadly, is no longer with us. But the man who made those second and third dates is currently sat 4,552 miles from it, in the snowy beauty of London’s Royal Geographical Society, doing Trail with a steady expression of bemusement. Moments before, amid the throngs of Community Action Nepal, a Foreign Everest Event, trail runners had received an autograph, then pushed my luck and asked for an interview. Unexpectedly, Reinhold Messner, the world’s most prolific, outspoken and enigmatic adventurer – shrouded and sliced from

Spent a few minutes digesting the ofrec Reinhold Messner and try to come up with a definition of exactly what this man is. Rock-climber, mountaineer, adventurer, politician, yak hunter, museum creator, author, yak farmer, restaurateur. He’s even got his own line of natural cosmetics. So possibly asking Messner himself would be a good place to start.
Figure 2. Changes in the Arterial Mean Partial Pressure of Oxygen, Oxygen Saturation, Hemoglobin Concentration, and Oxygen Content in Climbers on Mount Everest.
I bars denote standard deviations.
Large leftward shift of dissociation curve
Hyperventilation, bicarbonate loss, high pH

The hypoxemia forgotten cause:

- ↓ SvO$_2$
- ↓ C.O.
- ↓ Hb
- ↑ Vo$_2$
HbO2 = 75%

SvO2 = 75%

HbO2 = 100%

HbO2 = \frac{(75 + 100)}{2} = 87.5\%

PaO2 = 58
SvO from 75% to 50% (e.g.: ↓ C.O.)
Shunt stable at 50%
\[ \text{HbO}_2 = 50\% \]

\[ \text{SvO}_2 = 50\% \]

\[ \text{HbO}_2 = 100\% \]

\[ \text{HbO}_2 = \frac{50 + 100}{2} = 75\% \]

\[ \text{PaO}_2 = 40 \]
PaO2/FiO2

✓ in clinical practice substitutes $\Delta P (A - a)$
✓ Does not take PaCO2 into account
✓ normal value is $\text{PaO2/FiO2} = 480$
✓ ARDS if $\text{PaO2/FiO2} < 300$ (Berlin def)
PaO$_2$/FiO$_2$ ratio: effect of FiO$_2$

- **SHUNT = 20 %**

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- **SHUNT = 30 %**

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**PaO$_2$/FiO$_2$** vs **FiO$_2$**

**∆av (ml/100ml):**

- **PaO$_2$/FiO$_2$**
  - 0
  - 50
  - 100
  - 150
  - 200
  - 250
  - 300
  - 350
  - 400
  - 450
  - 500
  - 550
  - 600

- **FiO$_2$**
  - 0
  - 0.2
  - 0.4
  - 0.6
  - 0.8
  - 1

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Means to correct hypoxia

• Evaluate oxygenation impairment

• Increase FiO2

• Positive +more positive airway pressure

• Prevent derecruitment
Reabsorption atelectasis in ARDS patients

Santos C.: AJRCCM 2000:161:26

**TABLE 2**

<table>
<thead>
<tr>
<th>PULMONARY GAS EXCHANGE VARIABLES</th>
<th>F(_{1O2}) -100%</th>
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<tbody>
<tr>
<td></td>
<td>Baseline</td>
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<table>
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<th>Patients with ALI (n = 8)</th>
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<tbody>
<tr>
<td>F(_{1O2}), %</td>
<td>40 ± 5</td>
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<tr>
<td>Pa(_{O2}), mm Hg</td>
<td>94 ± 24</td>
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<tr>
<td>Pa(_{CO2}), mm Hg</td>
<td>41 ± 10</td>
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<tr>
<td>pHa</td>
<td>7.42 ± 0.07</td>
</tr>
<tr>
<td>P(\overline{V}_{O2}), mm Hg</td>
<td>39 ± 5</td>
</tr>
<tr>
<td>Qs/Qt, % Qt</td>
<td>20 ± 10</td>
</tr>
<tr>
<td>Shunt, % Qt</td>
<td>16 ± 10</td>
</tr>
<tr>
<td>Low V(_{A}/Q), % Qt</td>
<td>2.60 ± 2.60</td>
</tr>
</tbody>
</table>

Qs/Qt = Venous Admixture

Shunt = Va/Q<0.05
Recruitment manoeuvre and anesthesia

Post induction

Post recruitment

FiO2 0.4

FiO2 1

5’

45’
<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>DAY 1</th>
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<tr>
<td></td>
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</table>
Gas Exchange in ARDS

• ARDS is not Just Hypoxemia: Co2 elimination is a major problem
  • ARDS High PAP and RVF (dysfunction)
  • Severe respiratory alkalosis of Dead Space regions
  • Barotrauma Ventilator Induced Lung Injury
  • VAP
  • Sedation
Alveolar VD

Anatomic VD

Ideal
Gas Exchange in ARDS

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• Barotrauma Ventilator Induced Lung Injury
• VAP
• Sedation
Figure 2-Microthrombosis.

- A-Postmortem arteriogram of normal adult lung.
- B-Arteriogram of a patient with early ARDS (6 days after aspiration). There are reduced filling of small arteries and prominent, edematous interlobular septa.
Figure 1. Stratification of 60-day mortality in patients with acute lung injury by increasing transpulmonary gradient (TPG). Elevation of the TPG was associated with higher mortality (19 versus 27 versus 49%; \( P = 0.0006 \) for the trend).
ARDS: a pulmonary microvascular disease
Gas Exchange in ARDS

- 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
Massive pulmonary infarction during total cardiopulmonary bypass in unanesthetized spontaneously breathing lambs

T. Kolobow, R.G. Spragg, J.E. Pierce
Effect of inhaled CO$_2$ on hemorrhagic consolidation due to unilateral pulmonary arterial ligation

FIG. 1. Inflated left lungs of animals from group C-5 (left) and group CO$_2$-5 (right). Left lung of the CO$_2$-treated animal had only small peripheral areas of hemorrhagic consolidation.
Recruitment and PaCO2

• Recruitment of perfused alveoli at constant ventilation:
  – More Homogeneous $\text{Va/Q} = \text{decreased PaCO2}$

• Recruitment of unperfused alveoli:
  – increased dispersion of $\text{Va/Q} = \text{increased PaCO2}$
CONCLUSION

- ARDS is an hypoxemic syndrome
- Carbon Dioxide elimination is the true target of ventilation
- Vd/Vt is a global index of pulmonary function, with important prognostic value
- We ventilate our patients to eliminate CO2
- BAD CO2 ELIMINATION = VILI
Evaluation gas exchange ARDS

- Oxygenation
- Sp O2 p/F ratio, FiO2 1 tests, Qva/Qt
- SVo2 and CO
- Oxygenation improvement as a predictor of improved survival
- Shunt dx sin anatomico
- Carbon dioxide
- Dead space pulmonary hypertension VILI
- Co2 improvement as a prognostic factor therapy
- Recruitment and dead space: an odd couple
- Prone position: recruitment without airway pressure