‘Broken Lungs’

Cait P. Searl
Consultant Cardiothoracic Anaesthetist / Intensivist
Luhr et al, *Am J Respir Care Med* 1999; **159**:1849

**ACUTE RESPIRATORY FAILURE**  n=1231

**ALI**  n=287

**ARDS**  n=221
Does the **actual** diagnosis matter?
Exacerbations of COAD – optimal mode of ventilation?

Aim to balance

- Treatment of hypoxaemia
- Treatment of hypercapnia
- Unloading respiratory muscles
- Managing auto-PEEP
- Managing atelectasis
Normalisation of milieu

Target is normalising blood gases for that patient
Two principles of ‘conventional’ ventilation

1. Lung protection

2. Lung recruitment
- Independent lung ventilation
- Maintaining spontaneous ventilation
- High frequency ventilation
- Continuous positioning therapy
- Prone positioning
- ECMO
- iNO
- Partial liquid ventilation
- Nebulised prostacyclin
- Surfactant
- Anti-inflammatory agents
- Anti-oxidants
- iLA
- i.v. salbutamol
- Carbon monoxide
- etc
- etc
Respiration

Combination of ventilation and perfusion

Separate out the ventilation (air in and out) component usually and treat just that.
Respiratory failure

Components

1. Mechanical
2. Lack of functional lung tissue
3. Lack of blood supply
Respiratory Failure: Adjunctive treatment making ventilatory support more effective

- NO
- Inhaled epoprostenol

Improve ventilation-perfusion matching by dilating arterioles in ventilated alveoli
Respiratory Failure: Treatment recruiting functional but non-functioning lung

- Pronation
- HFOV
HFOV

• High frequency (3-15Hz) oscillation
• Ventilation (1-4 ml / kg)

Theoretically meets goals of protective ventilation and maintains constant lung recruitment.
But...

Unproven benefits
Disadvantages

OSCAR?
And...

Hypercapnia is almost inevitable.... hypoxia may not improve
There may not be recruitable lung tissue
Lung Replacement

- **Temporary**
  - NOVAlung
  - ECMO
- **Semi-permanent**
- **Permanent**
  - Transplant
  - Stem cell therapy
  - Biolung
NovaLung function

Two variables:
Sweep gas flow controls CO2 removal
Blood flow controls oxygenation
  (MAP & cannula size)

• High CO2 gradient between blood and sweep gas allows diffusion across the membrane, allowing efficient CO2 removal
• Oxygenation limited due to arterial inflow
• Low resistance to blood flow (7mmHg at 1.5l/minute) allowing the heart to be the pump for the device
• Heparin coated biocompatible surface
Searl et al, 2010

<table>
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<tr>
<th>Insertion</th>
<th>Pre pH</th>
<th>Post pH</th>
<th>Pre CO₂ kPa</th>
<th>Post CO₂ kPa</th>
<th>Pre P_{insp} cmH₂O</th>
<th>Post P_{insp} cmH₂O</th>
<th>Outcome</th>
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<tr>
<td>17 days</td>
<td>7.07</td>
<td>7.23</td>
<td>10</td>
<td>6.7</td>
<td>31/8</td>
<td>25/12</td>
<td>Dead</td>
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<tr>
<td>1 hour</td>
<td>7.10</td>
<td>7.38</td>
<td>13.4</td>
<td>6.0</td>
<td>32/10</td>
<td>24/8</td>
<td>Dead</td>
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<tr>
<td>4 hours</td>
<td>7.06</td>
<td>7.31</td>
<td>12.2</td>
<td>6.4</td>
<td>32/10</td>
<td>20/8</td>
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</tr>
<tr>
<td>10 hours</td>
<td>6.94</td>
<td>7.31</td>
<td>15</td>
<td>5.7</td>
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<tr>
<td>12 hours</td>
<td>7.04</td>
<td>7.34</td>
<td>13.3</td>
<td>6.2</td>
<td>35/12</td>
<td>18/10</td>
<td>Alive</td>
</tr>
</tbody>
</table>
Novalung as bridge to transplant

43 yrs F

- lymphangioleiomyomatosis (LAMM)
- increasing problems due to pneumothoraces
- developed hypercapnia with a progressive respiratory acidosis
Immediate improvement was produced with a correction in pH from 7.19 to 7.4 and P\textsubscript{co}\textsubscript{2} from 15 to 8.5 kPa.
Not an Oxygenator

when used as designed...
ECMO

Caesar trial etc...
Basically extended CPB

Blood drained from body
Blood circulated through an oxygenator (can be membrane diffusor or bubble)
Pumped back to body
ECMO

VV ECMO
VA ECMO
ECMO

Blood drained from body

Passed through Oxygenator

Blood pumped back to Body
In parallel

Allows oxygenation as receives deoxygenated blood
Novalung x 2 plumbed from pulmonary artery and back to Left atria
In parallel, low resistance so receives most blood

No sieving out of thrombi
In series – i.e. plugged between prox. and distal PA
Biolung

- Under development
- No long term rejection problems
- Would need long term anticaogulation (similar to mechanical heart valves)

- May take over from lung transplantation as a long term solution to chronic respiratory failure in conditions like COAD
Tissue Engineering?

Lung units consisting of pulmonary epithelium and vascular endothelium

If can build bone marrow and tracheas, why not lungs?
My approach at the moment

• Maximise protective ventilation using adjuncts if appropriate; if hypoxic try oscillator
• Elevated CO$_2$ – use NOVAlung first
• Continuing hypoxia – use VV ECMO

BUT MUST BE POTENTIALLY REVERSIBLE & NOT JUST EXTENDING DYING